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INTERNATIONAL SUSTAINABLE DEVELOPMENT FOUNDATION

Final Report

Environmental Improvement Projects Sustainable Development

for International Sustainable Development Foundation on behalf of Tainan City, Taiwan

November 30, 2001

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June 6, 2001

TDA Mission Statement

The U.S. Trade and Development Agency (TDA) assists in the creation of jobs for Americans by helping U.S. companies pursue overseas business opportunities. By funding feasibility studies and related support activities, TDA directly assists American firms with market entry efforts through early involvement in the planning stage of infrastructure and industrial projects in the difficult to penetrate middle-income and developing countries.

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INTERIM REPORT AND SUSTAINABLE DEVELOPMENT FRAMEWORK FOR TAINAN CITY, TAIWAN

Team Oregon, LLC

June 6, 2001

I. INTRODUCTION TO THE PROJECT

The US Trade and Development Agency (TDA) provided a grant to The International Sustainable Development Foundation (ISDF) to provide project services to Tainan City, Taiwan.

Tainan City is a rapidly growing city in southern Taiwan. In 1661, Cheng Cheng-kung, a military leader and Ming Dynasty loyalist, sailed across the Taiwan straits, expelled Dutch leaders, and established his capital at Tainan City and started developing the surrounding lands. Because of its history, Tainan City is considered the cultural capital of Taiwan with more than three hundred important temples and a rich historic milieu. The Tainan region also is an emerging metropolis of 1.6 million, with close economic ties to the nearby port city of Kaohsiung. Development of Taiwan's second national science park is now underway. The economic future of the city is strengthened by the presence of the National Cheng Kung University.

Team Oregon, LLC (TO), the contractor to ISDF for services to Tainan City, is responsible for developing a single integrated sustainable development (SD) approach, called the SD Framework, to provide guidance to three projects in Tainan City including the wastewater treatment system, Tainan Ecological School (Eco-School), and the Chai Tou Gang Shi (CTGS) cleanup and beautification. (See Appendix 1 for a summary of Team Oregon, LLC and ISDF.) The SD Framework will be applied to each of the three projects and guide the overall work of the project.

Team Oregon's work plan includes the following responsibilities:

- Develop the SD principles for Tainan City
- Apply the principles and guidelines to the projects
- Assess and rank a limited number of options
- Develop conceptual designs for the selected options
- Provide technical support and review the work of local firms
- Assist the city with tender preparations
- Submit a list of providers of products and services for the three projects under review and development

This report is a summary of the SD principles and guidelines developed by Team Oregon, in consultation with ISDF and Tainan City, a summary of how they can be applied to the three

projects under review and development, and design alternatives with preliminary cost estimates and ranking.

To accomplish its work, Team Oregon traveled to Tainan City in November, 2000 and April, 2001. During the first trip, Team Oregon met with the Mayor of Tainan City, department heads, and other officials from the city and Taiwan authorities to gather basic information on the city and the three projects under review and development, and to obtain information on the sustainable development policies of Tainan City, other cities in Taiwan, and the Taiwan authorities.

During the second trip, Team Oregon gathered more information and presented its recommended SD Framework to the Mayor and agency officials. Team Oregon also met with Taiwan authorities to review project status, and with other city officials to review the SD Framework and its application to projects in Tainan.

II. SUSTAINABLE DEVELOPMENT PRINCIPLES AND GUIDELINES

Team Oregon members met with several Taiwan authorities to gather the primary source documents and identify how they are currently being applied in Taiwan. Team Oregon found that, although Taiwan documents and research on sustainable development are exemplary, it is not clear how the vision of sustainable development is applied in practical terms to city government. Although there seems to be a general understanding of sustainable development goals, there are no readily available examples of how the research and policy recommendations can be transformed into action plans at the city level.

Although Taiwan has undertaken several efforts to identify sustainable development policies, an integrated set of sustainability principles and guidelines has not been recommended to Taiwanese cities or to Tainan City, specifically.

To date, the most important Taiwan-based documents on sustainable development include:

- *Strategic Guidelines for Sustainable Development of the Republic of Taiwan* (1998) published by the Council for Economic Planning and Development
- *Agenda 21 National Sustainable Development Strategy Guidelines* for Taiwan published by the Council for Economic Planning and Development
- *1999 Annual Report of National Sustainable Development* (1999) published by the National Council for Sustainable Development
- *Evaluation Manual for Green Building in Taiwan* (1999) published by the Ministry of the Interior

These reports were reviewed to identify the definitions of sustainable development, visions of the future, principles and guidelines recommended, and for recommendations on applying them to urban development. These primary source documents were supplemented by Team Oregon source material reviewed in Appendix 2 – Bibliography.

In developing the SD Framework, Team Oregon built on the work of Taiwan authorities. TO also reviewed the work of US cities, especially the Sustainable Portland Commission, academic research and publications in the field, and examples from other US and Pacific Rim cities.

Tainan City, through the leadership of the Mayor and departments, agreed that a clear set of examples of how an SD Framework can be applied to several practical applications is needed. Team Oregon agreed to apply the SD Framework to the projects addressed in the TDA-funded projects in Tainan City—the wastewater treatment system, Eco-School, and the Chai Tou Gang Shi cleanup and beautification.

The recommended SD Framework provided by Team Oregon includes the following six components, which are summarized in Table 1.

Definition of Sustainable Development. The common definition of sustainable development is based on *Our Common Future*, published by the 1987 Commission of Global Environment and Development of the United Nations. The definition defines the scope or the "what" of

sustainable development. The commonly accepted definition is: "development which can meet today's needs without sacrificing the ability of future generations to meet their needs." This also is the definition used commonly in Taiwanese policy documents on SD and elsewhere in the world.

Vision of a Sustainable Future. Three important visions of sustainable development were identified, based on Taiwan's *Agenda 21 National Sustainable Development Strategy Guidelines*: a sustainable ecosystem, sustainable communities and a sustainable economy. These "visions" define the primary development goals of society looking 20 to 50 years into the future. The three visions are seen as interrelated, mutually supportive, and widely shared. They can be used to define the basis for city urban development policy.

Principles of Sustainable Development. Ten sustainable development principles are included in the *Agenda 21 report on National Sustainable Development Strategy Guidelines*. These principles can be used as a decision-making checklist to help guide the development of plans, policies, programs, or projects. The principles used in the SD Framework include:

1. Consider intergenerational equity — Consider the impact of current decisions on future generations.
2. Prevent environmental overloading — Prevent pollution which causes the environment (air, water, land and ecosystems) to be overloaded to the extent that their future health is compromised.
3. Balance environment, economy and community needs — Balance the three visions of a sustainable future. Better yet, try to make decisions which benefit all three.
4. Consider impacts of decisions on human health and the environment — Develop systematic techniques such as environmental impact statements (EIS's) that consider the impacts of decisions on human health including current disease levels and causes of diseases.
5. Promote fairness and justice — Make decisions which promote the equal distribution of economic, environmental, and community costs and benefits.
6. Involve and educate the public — Use sustainable development plans, programs, and projects to involve and educate those affected.
7. Internalize costs — Include total life cycle costs in decisions on plans, programs, and projects.
8. Apply science and technology solutions to solve problems — Use new, advanced technologies to reduce and eliminate pollution and conserve and produce energy. Examples include: use of renewable energy and low energy use machinery, zero waste engineering of production facilities, etc.
9. Integrate public, private and NGO efforts — Develop cross-sector alliances for planning, programs, and projects.
10. Learn from others globally — Participate in international forums and exchanges to identify new sustainable development plans, programs, and projects from throughout the world. Of special use are the APEC Sustainable Development Network (Portland, Oregon) and the Agenda 21 Cities Network in Aalborg, Denmark.

Guidelines for Applying Sustainable Development. Guidelines on how to apply the SD Framework are included for each vision of the future—the environment, economy, and community—in Table 1. These guidelines indicate the actions necessary to achieve the visions of a sustainable environment, sustainable economy, and sustainable community. The 26 guidelines were identified from primary Taiwanese sources cited above and other Team Oregon source materials such as those in Appendix 2—Bibliography. These guidelines can be used by Tainan City and other public and private organizations to guide the developing plans, policies, projects and programs.

Urban Development Decision-Making. Team Oregon, working with Tainan City officials, Taiwan authorities, and academic leaders in Taiwan, found that most of these leaders had a good grasp of the basic concepts of sustainable development. What they lack is a way of making urban development decisions using sustainable development concepts on a systematic basis. To address this challenge, Team Oregon developed the SD Framework to provide a way to review activities at each step in the development process, including:

- Policy-making for legislation, programs, and budgets
- Plan-making for land use, functions such as transportation, and areas such as neighborhoods
- Architectural and engineering design for sites, buildings, and public facilities
- Construction of buildings and public facilities
- Facility management

Adopting the SD Framework. To achieve the full benefit of the SD Framework, Team Oregon believes Tainan City should consider the following recommendations:

- Adopt the SD Framework through executive and/or legislative action;
- Appoint a sustainable development commission or coordinating committee for Tainan City;
- Institute a training program for city employees;
- Develop an outreach program to involve citizens, academic institutions, the private sector, and non-governmental organizations; and
- Identify obstacles to the application of the SD framework and work with the Taiwan authorities to remove those barriers.

Table 1

SUSTAINABLE DEVELOPMENT FRAMEWORK

"Sustainable development is that development which meets the needs of the present without compromising the ability of future generations to meet their own needs." --Our Common Future, 1987.

VISIONS

- A Sustainable Environment is the "Basis of Life"
- A Sustainable Economy is the "Basis for Prosperity"
- Sustainable Communities are the "Basis of Happiness and Comfortable Living"

PRINCIPLES

1. Consider intergenerational equity
2. Prevent environmental overloading
3. Balance environment, economy and community needs
4. Consider impacts of decisions on human health and the environment
5. Promote fairness and justice
6. Involve and educate the public
7. Internalize costs/full cost accounting
8. Apply science and technology solutions to solve problems
9. Support public, private, academic, and NGO cooperation
10. Learn from others globally

GUIDELINES

ENVIRONMENT

- Support clean atmosphere, water, land, and marine resources
- Avoid habitat destruction
- Protect and restore ecosystems
- Protect and restore biological diversity
- Assess and encourage programs to reduce negative impacts
- Develop resources consistent with prevention of natural disasters
- Reduce the output of greenhouse gases

ECONOMY

- Increase the productivity of all forms of capital
- Increase the quality and durability of goods
- Reduce, recycle and, reuse raw materials
- Substitute embodied and solar energy for produced energy
- Reduce and eliminate all forms of waste and pollution
- Apply science and technology to problems
- Develop transportation and energy supply systems consistent with SD
- Substitute non-toxic and biodegradable substances for toxic substances
- Review/revise tax, capital investment, and regulatory policies to increase SD and eliminate subsidies for non-SD
- Use life cycle cost analysis in procurement decisions

COMMUNITY

- Provide clean air, water, and food.
- Provide clean and safe shelter
- Provide a safe, clean, and beautiful community living environment
- Protect and enhance the arts and cultural and historic resources
- Provide public education on sustainable development
- Promote public involvement in decisions
- Provide collaborative, community-based decision-making with public, private, NGO participants
- Promote cooperation among levels of government and globally
- Provide access to information on decisions
- Undertake social and economic impact analysis of major decisions

INTEGRATED DECISION-MAKING

POLICY

- ✓ Leadership
- ✓ Education and information
- ✓ Tax policy
- ✓ Budget priorities
- ✓ Investment policy
- ✓ Regulation
- ✓ Procurement

PLANNING

- ✓ Strategic and visioning
- ✓ Comprehensive
- ✓ Agency
- ✓ Land Use
- ✓ Area or neighborhood
- ✓ Impact Analysis
- ✓ Metrics and Benchmarks

DESIGN AND ENGINEERING

- ✓ Qualification
- ✓ Concept Development (pre-design, programming, concepts)
- ✓ Design Process (site analysis, cost-estimating, schematic design, design development, permitting, construction documents)
- ✓ Tender
- ✓ Bidding
- ✓ Construction Administration
- ✓ Start-up and testing
- ✓ Close-out

CONSTRUCTION

- ✓ Estimation
- ✓ Qualification
- ✓ Selection
- ✓ Inspections
- ✓ Permitting
- ✓ Construction plans
- ✓ Project management
- ✓ Start-up
- ✓ Close-out

FACILITY MANAGEMENT

- ✓ Training
- ✓ O&M Plan
- ✓ Schedule
- ✓ Monitoring
- ✓ Cleaning
- ✓ Repair
- ✓ Remodel and replace
- ✓ Waste management (reduce, reuse, recycle)
- ✓ Energy management

- Applied to:
- Infrastructure
- Services (HVAC, electrical, telecom, lighting, controls)
- Fixed interior
- Supplies
- Furnishings
- Mechanical and industrial
- equipment
- Energy supply

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III. APPLICATION OF PRINCIPLES AND GUIDELINES

Using the SD Framework, three projects were reviewed and are summarized below.

Wastewater Treatment System. Team Oregon reviewed planning documents and conducted interviews with Tainan City, Taiwan authorities, and other city officials to gain a better understanding of the overall wastewater treatment system plan for the Tainan region. Team Oregon identified the major wastewater treatment system elements (treatment plants, collection and conveyance system, pumping station, etc.) and developed an understanding of how each of these elements operate and integrate with each other. Based on this understanding, Team Oregon applied the SD Framework to the development of the wastewater treatment system.

Chai Tou Gang Shi. The Chai Tou Gang Shi is a small urban watershed that is currently developed with commercial, residential and light industrial land uses. The CTGS currently holds raw sewage effluent and heavy seasonal rains. Several interrelated issues are being addressed in this clean-up and beautification project: sewage treatment, stream flow and flooding; stream-bank beautification and parklands including a possible greenbelt; bridge crossings, parking and transportation issues; and possible commercial development. Concept plans to address these issues will be developed using the SD Framework.

Tainan Ecological School. Tainan City is designing and developing a new primary school to reflect SD principles and guidelines and be a national model for a "green building." The design for the Eco-School will focus on integrating the SD Framework into the project by addressing the management of water, energy usage, indoor air quality and the toxicity of materials, resource guidelines, and related subjects. Team Oregon worked specifically with the school architect and Tainan Bureau of Education to integrate sustainable design elements into the design of the Eco-School.

IV. WASTEWATER TREATMENT SYSTEM

Untreated wastewater can affect the environment in several ways. It contains many pathogens that can cause disease; nutrients that can negatively impact surrounding environments by causing eutrophication of water bodies; and toxic substances from industrial wastes. Also, if allowed to accumulate, it can be the source of malodorous gases negatively impacting the quality of life for nearby residents. The role of wastewater treatment is to protect the environment in a way that addresses public health, economic, social, and political concerns (Metcalf & Eddy, 1991).

Through two visits—in November, 2000 and April, 2001—Team Oregon was able to review planning documents and interview Tainan City and Taiwan authorities Government officials to gain an understanding of the wastewater treatment system facilities planned for Tainan City. The City's plans call for the wastewater collection and treatment system to be completed by 2021.

The design and planning for the treatment facilities is primarily funded through the Taiwan authorities. Tainan City currently has plans to construct a wastewater collection system consisting of small pipelines, trunks, and mainlines. Some of these pipelines have already been constructed. Flow through these pipelines will be primarily by gravity and, due to the topography of the city, flows will be directed to one of six wastewater treatment plants. The treatment plants have design flows ranging from 12,000 to 181,000 cubic meters per day (CMD) or 3.2 to 47.8 million gallons per day (MGD). Currently, there are no plans for intermediate wastewater pump stations.

Of the six wastewater treatment plants, two are currently constructed—one is currently in testing, and the other is not expected on-line for approximately 18 months. The remaining four treatment facilities are in the planning stages. In addition to these facilities, Tainan County has plans for at least one wastewater treatment facility close to one of the treatment plants planned for the City.

The treatment plants are all designed for secondary treatment, and discharge to nearby water bodies. Typical wastewater treatment plant processes are planned for each of these plants. Liquid processes include screening, primary and secondary settling, aeration, and disinfection. Solid handling processes include sludge thickening, aerobic and/or anaerobic digestion, and dewatering. In addition to the large processes, monitoring and sampling equipment also will be necessary.

The review of the planned wastewater treatment system facilities shows that Tainan City has plans to systematically reduce the impact of sanitary waste on the environment. The following report describes additional features that can be considered to incorporate sustainable concepts into Tainan's wastewater treatment system.

DESIGN PRINCIPLES & GUIDELINES

Wastewater treatment facilities inherently strive to achieve some of the goals of sustainable development by cleaning wastewater and supporting clean water resources. Wastewater treatment plants (WWTP's) are designed to operate reliably, economically, and unobtrusively to meet discharge standards. In addition, the design of the facilities should address regulatory requirements, public goals, financial constraints, and incorporate appropriate technology to achieve these goals (WEF, 1998).

Integrating sustainable concepts into the wastewater treatment systems results in the list of sustainable strategies shown in Tables IV-2 through IV-4. The tables also show how the strategies are related and prioritized against the Sustainable Guidelines described in Section II of this report. Higher priorities (a score of 1) were given to strategies that have a more significant positive impact on the environment in Tainan.

DESIGN ALTERNATIVES

Several sustainable design alternatives related to wastewater treatment systems are being used in various communities throughout the United States. The alternatives or strategies that should be considered in Tainan include:

- Treatment System Alternatives
- Regional Governments
- Use of Natural Systems
- Recycle/Reuse of Waste
- Life Cycle Cost Estimation

Treatment System Alternatives

Centralized Treatment vs. Decentralized Treatment. Large centralized treatment facilities have been the norm for larger communities. Recently, a closer look at utilizing cluster systems to treat wastewater has been examined. Cluster systems are "wastewater collection and treatment systems where two or more dwellings, but less than the entire community, are served. The wastewater from several homes may be pretreated onsite by individual septic tanks or package plants before being transported through low cost, alternative technology sewers to a treatment unit that is relatively small compared to centralized systems" (USEPA, 1997).

The choice for communities without wastewater treatment systems has been whether or not to build one centralized treatment facility or to build several smaller facilities. The most cost-effective solution is based on a combination of population density, distance to sewer interceptor, topography, and availability of land. Other costs to consider include operation, maintenance, and the ability of the receiving environment to assimilate the effluent.

Typically, the choice of a decentralized system is best suited for areas with low population densities. Constructing centralized treatment facilities in these areas is often economically unfeasible because of the large distances between homes, the significant piping required to tie-in all the connections, and the inability to achieve economies of scale (i.e., a certain number of users to support system costs) (USEPA, 1997).

Alternately, in areas where population density is high (i.e., urban or suburban areas), large-scale, centralized collection and treatment of wastewater is usually most cost-effective (USEPA, 1997). In these areas the system costs can be distributed across a large number of users.

Wastewater Lift Stations. Current plans in Tainan call for six large treatment plants to treat wastewater generated within the city. The number of plants has been dictated by the relatively flat topography of the landscape. Wastewater lift stations are facilities designed to move wastewater from lower to higher elevations through pipes. This technology is particularly applicable where the elevation of the source is not sufficient for gravity flow and/or when the use of gravity conveyance will result in excessive excavation depths and high sewer construction costs (USEPA, 2000b). The incorporation of these types of facility into Tainan's collection system could reduce the number of necessary wastewater treatment plants by enabling wastewater flows to be efficiently moved from one section of the city to another.

The primary advantage of wastewater lift stations is in the reduction of capital costs for collection system construction. Pipe installation costs can be minimized if trench depths can be kept at a minimum (less than three meters or ten feet). In addition, pumping wastewater can convey the same amount of flow using a smaller pipe at a shallower depth, further reducing pipeline costs (USEPA, 2000b).

Disadvantages to pump stations include the relatively high cost to construct the pump station facility compared to the construction of conveyance systems. Additional costs for the pump station facilities include the building construction costs, a source for power and emergency power, odor and noise control, operation and maintenance, and addressing public concerns and/or negative reaction (USEPA, 2000b).

Despite the high capital and operation and maintenance costs of wastewater pump stations versus collection systems, they are by far less expensive than the construction of complete treatment plants. Savings could be realized by utilizing pump stations at various points within Tainan City to transport wastewater to fewer treatment plants. As a result of the reduced number of treatment plants, fewer discharge points into nearby water bodies would be necessary, reducing the impact on the environment.

Disinfection Alternatives. There are three main methods of disinfection being used in wastewater treatment facilities today: chlorine disinfection, ozone disinfection, and ultraviolet (UV) disinfection. Chlorine disinfection is the most widely used method of disinfecting municipal wastewater. It does, however, have certain health and safety limitations (USEPA, 1999a). Ozone disinfection has the ability to achieve a higher level of disinfection than either chlorine or UV. The capital costs and operation and maintenance costs, however, are higher for this technology (USEPA, 1999b). UV disinfection is as effective as chlorine but, being a physical

process rather than based on a chemical process, eliminates the exposure to toxic/hazardous or corrosive chemicals (USEPA, 1999c). Advantages and disadvantages for each technology are listed in Table IV-1

Disinfection processes are included in each of Tainan's planned treatment plants. Chlorine disinfection is the primary technology planned. Alternative disinfection technologies should be evaluated to determine if economic, community, or environmental benefits can be achieved.

TABLE IV-1
Advantages & Disadvantages of Disinfection Alternatives

Disinfection Alternative	Advantages	Disadvantages
Chlorine[1]	• Chlorination is a well-established technology. • Chlorine is more cost-effective than either UV or ozone disinfection. • The chlorine residual that remains in the wastewater effluent can prolong disinfection even after initial treatment and can be measured to evaluate the effectiveness. • Chlorine disinfection is reliable and effective against a wide spectrum of pathogenic organisms. • Chlorine is effective in oxidizing certain organic and inorganic compounds. • Chlorination has flexible dosing control. • Chlorine can eliminate certain noxious odors during disinfection.	• The chlorine residual, even at low concentration, is toxic to aquatic life and may require dechlorination. • All forms of chlorine are highly corrosive and toxic. Thus, storage, shipping, and handling pose a risk, requiring increased safety regulations. • Chlorine oxidizes certain types of organic matter in wastewater, creating more hazardous compounds. • The level of total dissolved solids is increased in the treated effluent. • The chlorine content of the wastewater is increased. • Chlorine residual is unstable in the presence of high concentrations of chlorine-demanding materials, thus requiring higher doses to effect adequate disinfection. • Some parasitic species have shown resistance to low doses of chlorine, including oocysts of Cryptosporidium parvum, cysts of Endamoeba histolytica, and Giardia lambila, and eggs of parasitic worms. • Long-term effects of discharging dechlorinated compounds into the environment are unknown.
Ozone[2]	• More effective than chlorine in destroying viruses and bacteria. • The ozonation process utilizes a short contact time. • No harmful residuals need to be	• Low dosage may not effectively inactivate some viruses, spores, and cysts. • Ozonation is a more complex technology than is chlorine or UV

Disinfection Alternative	Advantages	Disadvantages
	removed after ozonation because ozone decomposes rapidly. • No regrowth of microorganisms, except for those protected by the particulates in the wastewater stream. • Ozone is generated onsite, and thus, there are fewer safety problems associated with shipping and handling. • Elevates the dissolved oxygen concentration of the effluent which can eliminate the need for re-aeration and also raise the level of dissolved oxygen in the receiving stream.	disinfection, requiring complicated equipment and efficient contacting systems. • Ozone is very reactive and corrosive, thus requiring corrosion-resistant material such as stainless steel. • Ozonation is not economical for wastewater with high levels of suspended solids, biological oxygen demand, chemical oxygen demand, or total organic carbon. • Ozone is extremely irritating and possibly toxic, so off-gases from the contactor must be destroyed to prevent worker exposure. • The cost of treatment can be relatively high in capital and power intensiveness.
Ultraviolet[3]	• Effective at inactivating most viruses, spores, and cysts. • Physical process rather than a chemical disinfectant, eliminating the need to generate, handle, transport, or store toxic/hazardous or corrosive chemicals. • No residual effect that can be harmful to humans or aquatic life. • User-friendly for operators. • Has a shorter contact time when compared with other disinfectants. • Requires less space than other methods.	• Low dosage may not effectively inactivate some viruses, spores, and cysts. • Organisms can sometimes repair and reverse the destructive effects of UV through a "repair mechanism." • A preventative maintenance program is necessary to control fouling of tubes. • Turbidity and total suspended solids in the wastewater can render UV disinfection ineffective. • UV disinfection is not as cost-effective as chlorination, but costs are competitive when chlorination dechlorination is used and fire codes are met.

[1] USEPA, 1999a
[2] USEPA, 1999b
[3] USEPA, 1999c

Regional Governments

Regional governments are typically developed to deal with issues that are more efficiently addressed on a large scale or when cooperation among other government agencies is required. They also are effective where other government agencies, such as cities and counties, cannot afford the cost of large projects like sewage treatment plants. Considering multiple priorities cities and counties have for their financial resources, a regional government can relieve these economic pressures.

A regional government is a governing body that, in some cases, coordinates land use planning and services for a region. This body frequently can be is responsible for maintaining and enhancing the livability for a region. In Portland, Oregon, for example, the local regional government known as Metro is responsible for regional land use and transportation planning, and is further empowered to address any other issues of "metropolitan concern" (Metro Web site).

Metro is a directly elected regional government that serves residents in three counties and 24 cities in the Portland, Oregon metropolitan area. Its primary mission is to manage growth in the region. To that end, it provides transportation and land-use planning services and oversees regional garbage disposal and recycling waste reduction programs. Metro is governed by an executive officer (elected region-wide), and a seven-member council (elected by districts). Citizen advisory committees play an important part in this government by providing input and advice to the council, executive officer, and staff on various regional issues (Metro Web site).

Another type of regional government in the Portland area is the Unified Sewerage Agency (USA). This agency addresses water pollution problems in a local watershed, which covers portions of one county and 12 cities. USA owns, operates, and maintains or controls the sanitary sewerage collection and treatment system within its service area. It also maintains the public drainage and flood management systems and is responsible for surface water quality in the area (USA Web site).

The USA Advisory Commission is a body within the USA organization that consists of 15 members, each serving three-year terms. Their purpose is to review, discuss and make recommendations to the Board of Directors on major policy issues and programs (USA Web site).

The advantage of establishing a regional government is that region-wide issues are addressed and solutions are established for a region, thus eliminating duplicate efforts in several nearby cities and/or counties. This type of arrangement for water, wastewater, and other services between Tainan City and Tainan County may be beneficial.

Natural Systems

Natural systems used to treat wastewater are designed to emulate nature's ability to treat itself. There are many systems being used around the world today, but two seem suited to Tainan: constructed wetlands and Living Machine™ technology. The construction and operations and

maintenance costs of these systems vary widely and are dependent on size, operational procedures, and waste treated.

Constructed Wetlands. Constructed wetlands for wastewater treatment systems are engineered systems that utilize natural processes. These systems are designed to mimic a natural wetland system, utilizing wetland plants, soils and their associated microorganisms to remove contaminants from wastewater effluents. In addition, constructed wetlands provide an opportunity to create valuable wetland habitat for wildlife use and environmental enhancement (USEPA, 1993).

There are two types of constructed wetlands - subsurface flow and free water surface systems. Subsurface flow systems are designed to keep the water to be treated beneath the surface contained in a permeable membrane. The main feature of this design is to avoid the development of odors and other nuisance problems. Free water surface systems, on the other hand, are designed to simulate natural wetlands with the water flowing over the soil surface at shallow depths. Both types are typically constructed in basins or channels with a natural or constructed subsurface barrier to limit seepage (USEPA, 1993).

A free surface constructed wetland system seems well suited for Tainan. An existing fish pond could be converted into a constructed wetland to polish treatment plant effluent. In the process the system would create a natural habitat in the city for birds and other local wildlife.

Living Machines™. Living Machine™ technology is a relatively new technology first developed in the 1970's. This technology stresses using natural ecosystems to treat wastes. They are ecologically designed aquatic systems that utilize a diverse community of biological organisms, from bacteria to plants and fish, to treat water to advanced levels (Living Machines, Inc. Web site). Although this is a relatively new technology, there are several installations around the United States and globally where systems are in successful operation. Most applications are for smaller flows (up to 80,000 gallons per day), although there is work being done to evaluate this system for use with larger flow rates.

Systems typically include anaerobic and aerobic treatment areas which can contain plants, fish, snails, bacteria, and many other organisms that act together to breakdown pollutants in wastewater. The effluent from these systems can be discharged, recirculated, creating a completely closed treatment cycle, or reused for irrigation or other purposes (e.g., used for flushing toilets).

In Tainan, this technology can used to treat localized treatment flows (e.g., the Eco-school, museums, small community developments) and can provide an excellent opportunity for community education.

Recycle/Reuse Waste

Chai Tou Gang Shi Restoration. The Chai Tou Gang Shi is an urban channel that acts as the border between Tainan City and Tainan County. Currently water in this channel is very polluted and, for the most part, consists primarily of raw sewage. Flow rates in the channel

fluctuate with rainfall, and flooding occurs in places along the channel creating a health hazard for those who live nearby.

Plans to restore and revitalize this channel are underway and should include cleaning up the water. The City has plans for a wastewater treatment facility near the upstream end of this channel. Part of the restoration process for this body of water could be to collect sewage that currently flows into this channel and route it to the new treatment facility. Treated effluent could be discharged into the channel providing cleaner water and a more steady flow with which to incorporate further beautification features (see Section V).

Fuel Cell Technology. A fuel cell is an electrochemical device that uses hydrogen and oxygen to produce electricity and heat. The source of oxygen is typically obtained from the air. The source of hydrogen can be obtained from natural gas, propane, and methane (Nice, Web page). There are some fuel cells currently being used that obtain their hydrogen source from anaerobic digester gas. The methane in this gas is used to extract the necessary hydrogen to run the fuel cell.

In Portland, Oregon, the Columbia Boulevard Wastewater Treatment Plant is currently using one of these fuel cells to generate electricity for use in the facility. Their fuel cell consumes approximately 50 cubic feet of digester gas a minute to produce approximately 175 kW of power. It is estimated that they produce as much as 1.6 million kW-hr per year (Simonson, 2001).

Fuel cells range in size from 5 to 2,000 kW. Initial installation costs run approximately US$3,000-$4,000 per kW for the system, which includes the fuel cell, a hydrogen stripper, a DC to AC converter, and equipment for making use of waste heat. Cost to generate electricity runs about US$0.10-$0.15 per kWh (NRECA, 2001).

This technology installed at Tainan's treatment facilities will help minimize the amount of digester gas that must be vented into the atmosphere and will also subsidize the electricity needed to operate the plant facilities.

Microturbine Technology. Microturbines are smaller versions of a traditional fuel burning, power producing turbine. They are, however, smaller and cleaner burning. They operate using a variety of liquid and gas fuels, including natural gas or methane. Although they are not as clean burning as a fuel cell, microturbines are significantly cleaner than traditional turbines or combustion engines. In addition, the waste heat generated can be used for hot water, chilling, or direct heat.

Microturbines are less expensive than fuel cells. Installation costs are estimated to be US$1,000-$1,500 per kW. The cost to generate electricity is roughly US$0.08-$0.10 per kWh (NRECA, 2001).

Land Application of Biosolids. Biosolids are a natural, nutrient-rich by-product of municipal wastewater treatment. Recycling this by-product of wastewater treatment through land application returns a useful resource to the land. Biosolids are rich in nutrients and organic

matter that aid the growth of farm crops, gardens, forests, and parks (City of Portland Web site).

The application of biosolids must be carefully monitored. Application rates must not exceed the nutrient requirements of the vegetation to prevent excess nutrients from leaching into groundwater or impacting surface water. Maintenance of a buffer zone between application areas and surface water bodies will also help to minimize impacts to surface waters. Monitoring of the application biosolids also helps to prevent the accumulation of metals to harmful levels. Although some metals such as nickel, zinc, and copper are necessary nutrients in small amounts, their accumulation could negatively impact human health (USEPA, 2000a).

Current plans in Tainan call for the disposal the of treatment plant biosolids to a local land fill, and possibly through incineration. While these are appropriate methods of disposal, there is the opportunity to use these solids in a more beneficial manner. Plant biosolids could be used for land application on local farms or nurseries. By recycling the biosolids to land application, landfill space will be freed up, air emissions from incineration will be eliminated, and nutrients and organic matter will be returned to the soils.

Life Cycle Cost Analysis

When evaluating products or systems, the total cost of an alternative should not be limited to merely the construction and operations & maintenance costs. Life cycle cost analysis is a better indicator of cost and benefits that a system or product will provide. Life cycle cost is the "amortized annual cost of a product, including capital costs, installation costs, operating costs, maintenance costs, and disposal costs discounted over the lifetime of a product" (USEPA, 1995). By performing a life cycle cost analysis the most cost-effective approach for using available resources over the entire lifespan of the product or system can be selected. Not only financial costs, but also environmental and societal costs are taken into account when doing this type of analysis.

TABLE IV-2
Application of Sustainable Development Guidelines for the Environment

	Environment Sustainable Guidelines	Strategy	Priority
1	Support clean atmosphere, water, land, and marine resources	• Collection & treatment system.	1
2	Avoid habitat destruction	• Clean waterways—Chai Tou Gang Shi restoration.	1
3	Protect and restore ecosystems	• Use of constructed wetlands for treatment/polishing.	2
4	Protect and restore biological diversity	• Use of constructed wetlands for treatment/polishing.	2
5	Assess and encourage programs to reduce negative impacts	N/A	--
6	Develop resources consistent with prevention of natural disasters	N/A	--
7	Reduce the output of greenhouse gases	• Use methane gas produced as a power source (fuel cells, microturbines, etc.).	2

TABLE IV-3
Application of Sustainable Development Guidelines for the Economy

	Economy Sustainable Guidelines	Strategy	Priority
1	Increase the productivity of all forms of capital	• Consider establishing Regional Government for wastewater management.	3
		• Centralized vs. decentralized treatment systems.	2
		• Chai Tou Gang Shi restoration will generate economic opportunity in adjacent community.	1
		• Compost biosolids for sale to agriculture industry.	2
2	Increase the quality and durability of goods	• Evaluate and maximize life-span of products being used (pipe, equipment, materials, etc.).	2
3	Reduce, recycle and, reuse raw materials	• Use treated effluent for irrigation, influent to fish ponds, etc.	2
		• Use Living Machine™ to grow food.	3
4	Substitute embodied and solar energy for produced energy	• Use methane gas generated as power source (fuel cells, microturbines, etc.).	2
5	Reduce and eliminate all forms of waste and pollution	• Use methane as power source (fuel cells, microturbines, etc.).	2
		• Land application of sludge.	2
6	Apply science and technology to problems	• Use of constructed wetlands or Living Machine™ technology and other "state of the art" treatment systems.	3
		• Use most energy and resource efficient equipment in buildout of plan.	1
7	Develop transportation and energy supply systems consistent with SD	• Use methane gas generated as power source at treatment plant (fuel cells, microturbines, etc.).	2
8	Substitute non-toxic and biodegradable substances for toxic substances	• Use non-toxic substances in treatment processes (e.g., UV or ozone instead of chlorine).	2
9	Review/revise tax, capital investment, and regulatory policies to increase SD and eliminate subsidies for non-SD	• Review/revise government policies that promote multiple treatment plants over pump stations.	2
10	Use life cycle cost analysis in procurement decisions	• Perform life cycle cost analysis to wastewater treatment process.	2

TABLE IV-4
Application of Sustainable Development Guidelines for the Community

	Community Sustainable Guidelines	Strategy	Priority
1	Provide clean air, water, and food	• Collection & treatment system.	1
2	Provide clean and safe shelter	• Utilize green building techniques for treatment plant buildings.	2
3	Provide a safe, clean, and beautiful community living environment	• Discharge effluent from treatment plant near Chai Tou Gang Shi to Chai Tou Gang Shi removing raw sewage from channel.	1
		• Constructed wetlands as wildlife habitat.	2
4	Protect and enhance the arts and cultural and historic resources	N/A	--
5	Provide public education on sustainable development	• Use treatment plant site for educational opportunity to educate the local community.	2
		• Provide public space for meetings or other local community activities.	3
6	Promote public involvement in decisions	N/A	--
7	Provide collaborative, community-based decision-making with public, private, NGO participants	N/A	--
8	Promote cooperation among levels of government and globally	• Consider establishing Regional Government for wastewater management.	3
9	Provide access to information on decisions	N/A	--
10	Undertake social and economic impact analysis of major decisions	N/A	--

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V. CHAI TOU GANG SHI

The Chai Tou Gang Shi is a small drainage which forms the northeastern boundary of Tainan City. The west bank of the River lies in Tainan City, with the east bank in Tainan County. The Chai Tou Gang Shi currently emerges from a large culvert and flows approximately 3.9 kilometers to its confluence with the Yen Shui Shi, and from there, out to the ocean.

According to City officials, the Chai Tou Gang Shi no longer contains a natural base flow of water coming from a natural headwaters spring. Instead, the flow in the River is entirely formed by both untreated sewage and stormwater runoff coming from the County and City neighborhoods that flank it. The river channel ranges from 10 to 60 meters in width and in depth from 2.5 to 7 meters, below the top of bank. Flows in the channel vary from about .5 to 4.5 cubic meters per second.

The Chai Tou Gang Shi discharges through a primarily residential part of Tainan, with few office, commercial, or industrial uses. The character of the residential development includes very small shelters up to major apartment buildings of 6 or more stories. The land within Tainan City adjacent to the river is zoned medium to high-density residential. With undeveloped and under-developed parcels common along the river, development potential is high.

SITE INVESTIGATION

Preliminary investigation of the river, data collection, and consultation with city officials was accomplished in two separate trips to Taiwan: November 13 to 16, 2000 and April 9 to 12, 2001. Extensive site analysis and photo documentation of the river was conducted with assistance from City staff and Mr. Kai-Yao Chang, the lead engineer from Moh and Associates, a local Taiwanese Civil Engineering consulting firm.

Team Oregon also reviewed the Chai Tou Gang Shi Master Plan, prepared by Moh and Associates in September 2000. This report is very informative, with key information on the hydrology and existing conditions of the river. The task was to present ideas and concepts that could be used to enhance the Moh and Associates Plan for beautification and restoration. Specific issues addressed include: stream flow and flooding; streambank beautification and parklands, including a possible greenbelt; bridge crossings; parking and transportation issues; and possible commercial development.

During the April, 2001 visit to Tainan, TO learned that the City of Tainan wishes to move ahead in June with detailed design of a demonstration project along the Chai Tou Gang Shi. The project area is approximately 165 meters in length, located between the railway bridge and the Nan Kang Bridge.

The recommendations that follow can be implemented in both the demonstration project area and the entire reach of the Chai Tou Gang Shi. Dollar amounts noted are in US dollars, unless otherwise specified.

APPLICATION OF SUSTAINABLE DEVELOPMENT GUIDELINES

Environment

1. Support Clean Atmosphere, Water, Land, and Marine Resources

Sustainable Alternative Strategies:

a. Separate and isolate sewer effluent from storm drainage in surrounding areas. This removal of the sanitary sewage flow from the river is critical to all other improvements. This can be accomplished by constructing a single sanitary sewer main under the river channel. To avoid costly duplication, this single line could be jointly owned, used and maintained by both Tainan City and Tainan County.

b. Take sewage to new Wastewater Treatment Plant (WWTP). This could be the new plant currently completing construction on the eastern boundary of Tainan City (WWTP #3), or a new proposed plant in Tainan County, just east of the confluence of the Chai Tou Gang Shi and Yen Shui Shi.

c. Direct clean effluent from WWTP #3 to create the base flow for Chai Tou Gang Shi. This clean water would flow year-round, helping to turn the sewage channel into an attractive stream for people and wildlife.

d. Prevent soil erosion on riverbank using bioengineered bank treatments, geotechnical stabilization fabrics, terracing and extensive vegetation to prevent increasing the turbidity of the water in the channel.

(Cost: $1,500-2,500/linear meter)

e. Capture and treat stormwater runoff before it enters the river with biological filtration swales and underground filter systems. It is important that stormwater runoff be intercepted prior to entering the channel. Swales and systems such as "storm-ceptors" allow sediments and pollution to be filtered out of runoff, allowing clean water to enter the river.

(Cost: $5,000-25,000, depending on size, capacity & land ownership)

d. Encourage walking instead of scooters with a beautiful riverwalk connecting key areas. Much of the pollution which is carried into the rivers comes from the poor air quality of Tainan. By encouraging alternative methods of transportation such as walking, biking and mass transit, scooters—which account for the vast majority of air pollution in Tainan—would be reduced.

(No direct additional cost)

2. Protect and Restore Ecosystems

Sustainable Alternative Strategies:

a. Recreate native riparian (streamside) plant community along the river. Tainan is a subtropical area that supports a broad diversity of plant species. To provide the most beneficial habitat possible, the greatest likelihood of success and the least amount of ongoing maintenance required, only native plants should be used.

(Cost: $75-200/tree installed)

The following trees are native to Taiwan, suitable for the Chai Tou Gang Shi project in Tainan, and are generally commercially available.

Botanical Name	Common Name
Acacia confusa	
Acer serrulatum	
Alnus formosana or Alnus japonica	*Formosan Alder*
Alstonia sholaris	
Ampelopsis brevipedunculata	
Bischofia javanica	*Autumn Maple Tree*
Casuarina equistifolia	
Cinnamomum camphora	*Camphor Tree*
Ficus fistulosa	*Common Yellow-Stem Fig*
Ficus stipulosa	
Garcinia subelliptica	*Common Garcinia*
Idesia polycarpa	*Many Seed Idesia*
Machilus kusanoi	
Machilus zuihoensis var. zuihoensis	
Planchonella obovata	*Pouteria*
Pongamia pinnata	
Prunus phaeosticta	*Dark-Spotted Cherry*
Sapium discolor	*Taiwan Tallow-Tree*
Trema orientalis	*Indiacharcal Trema*
Viburnum luzonicum	
Viburnum odortissimum	

b. Protect and preserve undeveloped lowland floodplains. These areas are critical to help reduce flooding during infrequent floods and are a source of extremely valuable open space for residents and habitat for wildlife.

(No direct cost unless land must be purchased)

c. Preserve and maintain meandering character of stream course. Straightening a stream channel and making the banks "smooth" was once thought to decrease the

likelihood of flooding by moving water quickly through an area. However, research has shown that to recharge aquifers below the surface and to minimize the damage to downstream riverbanks that high velocity flows cause, a natural meandering stream channel is preferable.[1] This creates large flood storage areas, excellent habitat, and open space.

(Cost: significantly less per linear meter than a straight, concrete-lined channel)

d. Strive to develop a greenbelt that extends 20-25 meters beyond top of bank. There is a real potential to make the Chai Tou Gang Shi a major ecological corridor, connecting people and wildlife. However, to benefit both, the "greening" of the river can not end at the top of bank. It should be extended into the urban fabric by use of a parkway or linear park. This civic amenity will have the collateral benefit of increasing property values along the River frontage.

(Cost: $1,500-2,500/linear meter)

3. Protect and Restore Biological Diversity

Sustainable Alternative Strategies:

a. Utilize only plants that are native to the Tainan area, as these plants are the most likely to support indigenous fauna. With assistance from leading scientists, develop a list of the plant species that are most valuable for local and migratory wildlife. Create a plant nursery industry that can supply these plants for restoration projects in the area.

(No additional cost for native plants)

b. Install bird boxes and other artificial habitat structures to attract native and migratory bird species.

(Cost: $50-$100/box for construction and installation)

c. Create a dense and diverse forest overstory of trees with understory shrubs and groundcover. These plants should be grouped according to their natural hydrologic associations, with differing plant communities at the bottom, midslope and top of the Chai Tou Gang Shi riverbank.

(Cost: $20-30 per square meter)

d. Prohibit use of toxic herbicides and pesticides along the corridor.

(No direct additional cost)

[1] *Cities and Natural Processes*, by Michael Hough, Routledge Publishing, New York, NY, 1995.

4. **Develop Resources Consistent with Prevention of Natural Disasters**

Sustainable Alternative Strategies:

a. Ensure all improvements below the 100-year-storm-event elevation can withstand periodic flooding. Improvements appropriate in the lower channel area include the Greenbelt trail, water access points, overlooks and planted areas. All these improvements should be designed to withstand inundation.

(No direct additional cost)

b. Ensure floors of all buildings are above the 100-year flood elevation. This will prevent the economic and personal catastrophes that occur when residential areas are flooded. Structures can be designed with parking and storage areas under the 100-year elevation, with occupied floors above.

(No direct additional cost)

c. Create a dense and diverse forest overstory of trees with understory shrubs and groundcover. These plants should be grouped according to their natural hydrologic associations, with differing plant communities at the bottom, midslope and top of the Chai Tou Gang Shi riverbank.

(Cost included in 3c, above)

5. **Reduce Output of Greenhouse Gases**

Sustainable Alternative Strategies:

a. Save intact areas of significant native vegetation, and augment with an aggressive "greening" of the Chai Tou Gang Shi corridor.

(No direct additional cost)

b. Reduce energy inputs by using materials containing recycled content and locally available, indigenous materials. Avoid extensive use of petroleum-based products.

(Cost not ascertainable)

APPLICATION OF SUSTAINABLE DEVELOPMENT GUIDELINES

Economy

1. **Increase the Productivity of all Forms of Capital**

Sustainable Alternative Strategies:

a. Convert the Chai Tou Gang Shi to a beautiful civic amenity, dramatically increasing the value of all properties in the area. This enhancement of the River will spur a

major economic redevelopment along the corridor, with new residential, commercial and office uses finding the river to be a desirable location.

(Cost: $750 to 1,000/linear meter)

b. Develop restoration-based industries as key contributors to the local economy. Examples include native plant nurseries, recycling collection, sorting and processing facilities, and restoration contractors.

(Cost not ascertainable)

2. Increase the Quality and Durability of Goods

Sustainable Alternative Strategies:

a. Utilize long-lasting materials such as stone, concrete, ceramic tile, brick, and metal for structures along the Greenbelt. Utilize renewable material such as wood in places where it can be replaced easily every 10 to 20 years.

(Cost not ascertainable)

3. Reduce, Recycle and Reuse Raw Materials

Sustainable Alternative Strategies:

a. Use indigenous Taiwanese construction materials such as stone, brick, wood, and block which is grown or manufactured locally. Establish a preference for renewable materials such as sustainably harvested wood.

(No direct additional cost)

b. Use construction materials that either contain recycled content, are being reused with minor processing, or can themselves be recycled in the future. Examples include reprocessed concrete or asphalt for paving or retaining wall systems, steel for structural members and railings that contain at least 50% recycled content, and wood members that have been salvaged from construction sites.

(Cost not ascertainable)

4. Reduce and Eliminate all Forms of Waste and Pollution

Sustainable Alternative Strategies:

a. Create and follow a construction waste management plan. Plans for construction should strive to eliminate waste through use of standardized building material dimensions. During construction, measures should be implemented to educate construction contractors, eliminate off-site erosion, rigorously control use and disposal of hazardous materials, and sort construction waste for reprocessing. The

plan should be monitored carefully by an on-site construction manager, preferably a city employee.

(No direct additional cost)

5. **Apply Science and Technology to Problems**

Sustainable Alternative Strategies:

a. Intercept surface stormwater runoff before it enters the Chai Tou Gang Shi. Use inground stormwater filtration systems that remove sediments, petrochemicals, and other compounds that degrade water quality.

(No direct additional cost)

b. Utilize latest innovations in bio-engineering design and construction materials to provide stable riverbanks that can support native riparian forest on the banks. These materials include geotechnical fabrics, modular retaining wall systems, reusable modular paving systems, and erosion control materials.

(Cost: $1,500-2,500/linear meter)

6. **Develop Transportation and Energy Supply Systems Consistent with Sustainable Development Guidelines**

Sustainable Alternative Strategies:

a. By creating a greenbelt trail system, encourage pedestrian and bicycle circulation along the river as an alternative to vehicles. By encouraging a diversity of development along the corridor, including commercial, office and residential development, the greenbelt will function as an important circulation corridor.

(No direct additional cost)

APPLICATION OF SUSTAINABLE DEVELOPMENT GUIDELINES

Community

1. **Provide Clean Air, Water and Food**

Sustainable Alternative Strategies:

a. Establish Chai Tou Gang Shi Greenbelt with dense broadleaf trees to assist in CO_2 abatement.

(Cost: $75-200/tree installed)

b. Create a network of public "community gardens" in floodplain areas along the CTGS corridor for residents to grow vegetables and fruit in individual plots for their own consumption.

(Cost: $250/plot for city to administer and mark)

2. **Provide a Safe, Clean and Beautiful Community Living Environment**

Sustainable Alternative Strategies:

a. Create a unified Park District for the CTGS Greenbelt, supported by Tainan City and County for the ongoing operations and maintenance of the park.

(No direct additional cost)

b. Create a maintenance and management plan for the CTGS Greenbelt. This cooperative venture between Tainan City and County will form the basis for the Greenbelt to be recognized as a community park for the surrounding neighborhoods.

(Cost: $1500 for city & county administrative time)

c. Ensure there are access/egress points along the Greenbelt trail at least every 100 meters. This will ensure that neighborhoods are linked physically with the trail and River, and will build a citizen constituency for the future.

(Cost not ascertainable)

d. Select plant materials that provide for seasonal variation in flower, fruit and foliage color.

(No direct additional cost)

3. **Protect and Enhance the Arts, Cultural and Historic Resources**

Sustainable Alternative Strategies:

a. Integrate public art into the Greenbelt trail. Art can be used as landmarks along the trail, serve to provide visual interest, and will form an important civic and tourist attraction as an "art walk" that displays significant works of art of Tainan City as the cultural center of Taiwan.

(Cost: allocate 1% of construction costs to public art installations)

b. Identify and interpret significant cultural and historical sites along the Chai Tou Gang Shi. Maps of the surrounding neighborhood could be very useful in helping trail users orient to their location and the attractions that are nearby.

(Cost: $5,000/porcelain enamel map design, fabrication and installation)

4. **Provide Public Education on Sustainable Development**

Sustainable Alternative Strategies:

a. Create environmental education and interpretive exhibits along the trail that explain ecological processes in the Chai Tou Gang Shi. These should discuss the plants, wildlife, and hydrology of the Chai Tou Gang Shi watershed.

(Cost: $5,000/porcelain enamel interpretive sign design, fabrication and installation)

b. Create "before" and "after" interpretive exhibits so people can see and appreciate the investment and changes along the Chai Tou Gang Shi.

(Cost: $5,000/porcelain enamel interpretive sign design, fabrication and installation)

5. **Promote Cooperation Among Levels of Government and Globally**

Sustainable Alternative Strategies:

a. Tainan City and County create a memorandum of Agreement to jointly fund the design, construction and maintenance of CTGS and sanitary sewer improvements.

(Cost: $1,500 for city & county administrative time)

TABLE V-1
CHAI TOU GANG SHI
Application of Sustainable Development Guidelines

	Environment	Strategies	Sustain-ability Priority
1	Support clean atmosphere, water, land, and marine resources	a. Separate and isolate sewer from storm drainage in surrounding areas	1
		b. Take sewage to new Waste Water Treatment Plant	2
		c. Direct clean effluent from WWTP #3 to create the base flow for Chai Tou Gang Shi	1
		d. Prevent soil erosion on riverbank	2
		e. Capture and treat stormwater runoff before it enters CTGS with biofiltration swales and underground filter systems	1
		f. Encourage walking instead of scooters with beautiful riverwalk connecting key areas	3
2	Avoid habitat destruction	N/A	
3	Protect and restore ecosystems	a. Recreate native riparian (streamside) plant community along CTGS	2
		b. Protect and preserve undeveloped lowland floodplain areas	1
		c. Preserve and maintain meandering character of stream course	1
		d. Strive to develop a greenbelt that extends 20-25 meters beyond top of bank	3
4	Protect and restore biological diversity	a. Utilize only plants that are native to the Tainan area	2
		b. Install bird boxes along Greenbelt for native species	3
		c. Create a dense and diverse forest overstory with understory shrubs and groundcover	1
		d. Prohibit use of herbicides and pesticides along the CTGS	3
5	Manage environment programs	N/A	
6	Develop resources consistent with prevention of natural disasters	a. Ensure all improvements below 100-year flood elevation can withstand periodic flooding	2
		b. Ensure floors of all buildings are higher than 100-year flood elevation	2
7	Reduce output of greenhouse gases	a. Save native ecosystems	2
		b. Reduce energy inputs	3

	Economy	Strategies	Sustain-ability Priority
1	Increase the productivity of all forms of capital	a. Convert CTGS to beautiful civic amenity, increasing value of all properties in the area b. Develop restoration-based industries as key contributors to the local economy	2 2
2	Increase the quality and durability of goods	a. Use long-lasting materials such as stone, concrete and metal	2
3	Reduce, recycle and, reuse raw materials	a. Use indigenous Taiwanese construction material b. Use recycled construction materials	2 2
4	Substitute embodied and solar energy for produced energy	N/A	1
5	Reduce and eliminate all forms of waste and pollution	a. Create and follow a construction waste management plan	1
6	Apply science and technology to problems	a. Use in-ground stormwater filtration systems b. Use bio-engineered riverbank solutions	1 1
7	Develop transportation and energy supply systems consistent with SD	a. By creating Greenbelt trail system, encourage pedestrian and bicycle circulation along CTGS as alternative to vehicles	2
8	Substitute non-toxic and biodegradable substances for toxic substances	N/A	
9	Review/revise tax, capital investment, and regulatory policies to increase SD and eliminate subsidies for non-SD	N/A	
10	Use life cycle cost analysis in procurement decisions	N/A	

	Community	Strategies	Sustain-ability Priority
1	Provide clean air, water, and food	a. Establish Greenbelt with dense broadleaf trees to assist in CO_2 abatement b. Create a network of public "community gardens" in floodplain areas	1 2
2	Provide clean & safe shelter	N/A	
3	Provide a safe, clean, and beautiful community living environment	a. Create a unified CTGS Greenbelt park district, supported by Tainan City and County for operation and maintenance b. Create a maintenance and management plan for CTGS Greenbelt c. Ensure access/egress points along Greenbelt trail at least every 100 meters d. Select plant materials that provide for seasonal variation in flower, foliage color, etc.	1 2 2 1
4	Protect and enhance the arts and cultural and historic resources	a. Integrate public art into the Greenbelt trail b. Identify and interpret significant cultural and historical sites along the CTGS	2 2
5	Provide public education on sustainable development	a. Create environmental education and interpretive exhibits that explain ecological processes in CTGS b. Create "before" and "after" interpretive signs so people can see and appreciate the change	1 1
6	Promote public involvement in decisions	N/A	
7	Provide collaborative, community-based decision-making with public, private, NGO participants	N/A	
8	Promote cooperation among levels of government and globally	a. Tainan County and City create a Memorandum of Agreement to jointly fund the design, construction and maintenance of CTGS sanitary sewer improvements	1
9	Provide access to information on decisions	N/A	
10	Undertake social and economic impact analysis of major decisions	N/A	

VI. TAINAN ECOLOGICAL SCHOOL

The Tainan Ecological School (Eco School) is currently in design development by the office of Marshal Liu, architect, selected through a competition among Taiwan architects. The site is located on a full block of 3 hectares just east of the Yi Tsai Ching Cheng (Eternal Castle) in the Anping District. The overall school use area is approximately 12,200 sq. meters plus outdoor pools, gardens, play areas, running track and tennis courts. There are additional public spaces for community meetings and lectures.

There are several general educational design goals for the school, which were described to Team Oregon by the architect during workshop discussions:

1. Innovative open classroom areas will support a group of four traditionally organized classrooms.
2. Green architectural features will be integrated to demonstrate sustainable principles to all users.
3. The school will foster interactive learning through the use of the entire site as a place of teaching.
4. Classrooms will use team teaching with diverse curricula and materials.

This school is a radical departure from traditional teaching methods in Taiwan. It will implement creative, new educational processes with a focus on the environment and sustainability. The building, therefore, is meant to educate and inform the occupants of its relationship and response to the environment.

In November, 2000, during the first trip to Tainan (Task 1), Team Oregon visited the site and met briefly with the architect. They also visited two other relatively new schools in the area to establish a baseline for typical construction methods and detailing. From that visit, the Team outlined a list of questions and additional information that would be required to complete Tasks 2 and 3.

Team Oregon's role is to review the design development process to date with the school architect, discuss alternatives, and choose the desired alternatives for further development and refinement. This portion of the interim report summarizes a single integrated sustainable development approach based on the SD Framework, design alternatives, ranking and preliminary general costs that apply to the Eco School. Also, the school architect and his team have expressed an interest in new technologies and products. Team Oregon brought to Taiwan many examples of US materials and technologies that are considered "green" building products.

During the March, 2001 visit, Team Oregon met with the architect, his design team, city officials, and school board representatives. Over a two-day period, the group established goals for five basic subject areas of green building design: sites, water, energy, materials, and facilities management. Within each category, specific strategies and measurable criteria were identified to reach these goals.

Workshop Day 1. Team Oregon held a one-day workshop on April 11 with the Eco School architects and their electrical consultants. In the afternoon the subjects of Sites and Water were covered. After dinner, the discussion continued with Energy and Materials. The final agenda topic was to have been Facilities Management but the meeting had to adjourn. This category is included in the Design Alternative Assessment and rankings.

Workshop Day 2. The school architect, Mr. Liu and the Director of the Bureau of Education, Mr. Cheng, joined the presentation to the Mayor and staff. Sirs Cheng and Liu indicated that the construction schedule for the first phase had to be completed by the end of December, 2001 to accommodate 435 students. This was deemed by the Mayor and staff to be too aggressive for the amount of work in Phase 1, which includes the parking garage and electrical vault plus three of the six classroom blocks located on the south and east corner of the property. Team Oregon members suggested that the three classrooms at the north-east side of the site could be constructed first, leaving more time to complete the parking.

On another evening, one member of the Team, Logan Cravens, joined some of the architect's staff at their office to continue discussion of specific detailing of design features regarding natural ventilation, water features, building placement, and green roofs.

GUIDELINES AND STRATEGIES

Sustainable Development Framework Guidelines

There are three categories of guidelines that define sustainable development: Environmental, Economic, and Community. Within each of these categories, specific guidelines outline the basic decisions that should be addressed for any project. Resulting from the two-day workshop on the Eco School, specific design strategies were established as possible alternatives for Team Oregon to study further. Each of these strategies responds to one <u>or more</u> of the guidelines. In fact, the more guidelines any given strategy can address, the higher priority it gains in future tasks. The tables at the end of this report section summarize the guidelines and strategies for the Eco School.

Environmental Design Strategies

Five basic areas of investigation address the sustainable design goals for the Eco School: Sites, Water Quality, Energy Savings and Conservation, Materials Conservation and Quality, and Facilities Management. Each of these has a number of strategies that are to be measured by an agreed benchmark of performance. As a point of reference, Team Oregon used many of the measurements from *The Evaluation Manual for Green Building in Taiwan* published by the Architectural Building Research Institute (ABRI Manual).

Sites

The existing site is in a developing neighborhood. To the east it is zoned for high rise residential (five stories or more). To the south, west and north, mid-rise residential and mixed-

use is planned (five stories or less). The current architectural concept refers to two forts that are currently visible from the site. An Ping Fort to the north inspired the design of the new entry tower. The Eternal Fortress to the south and west of the site determined the rotation in orientation of the buildings.

Primary questions regarding the site design are: How much open space is preserved by minimizing the building footprint? Is there extensive landscaping, designed to require minimal maintenance and water? Is erosion controlled and stormwater collected for on-site uses? Are impervious surfaces minimized? The answers to these questions have significant impacts on the site. In an urban condition, these impacts extend to the neighborhood.

1. Open Space and Reduced Heat Island Effect

The coverage by building and pervious paving in the current plan is about one-third of the site. This is a good ratio if the remainder of the site is landscaped for maximum shading. The ratio may be improved by adding green roofs.

Sustainable Alternative Strategies:

a. Increase plantings and place to shade 85% of any impervious paving and at least 50% of open areas.

Cost: $10,000-20,000

b. Add green roofs to the Administrative Wing, Gym and Lecture Room.

Cost: $53-86/sq. meter

2. CO_2 Absorption

Currently there is no accounting of how much CO_2 is tied up in the landscape design for the project. This can be easily determined by the formula and charts provided by the ABRI Manual. Once this is done, it can be confirmed if the minimum average standard of 600 kg/m^2 of $C0_2$ absorption is achieved.

Sustainable Alternative Strategies:

a. Increase planting of trees and shrubs to achieve an average of 800 kg/m^2 of $C0_2$ absorption. This is to be considered the average over the entire 3-hectare site.

Cost: $10,000-20,000

b. Suggested Strategy and Criteria: As an offset to embodied CO_2 in all construction, establish and maintain a program of neighborhood tree-planting and regular tree planting field trips in the region. This can become an important precedent for all city projects.

Cost: $1/tree

3. Reduced Parking

A major cost of this project is in the parking structure, which is underground. While this is a very good strategy to reduce the heat island effect, it may be possible to reduce the number of required parking spaces (currently 100 cars, 100 motor scooters), thereby reducing the structural mass overall. Since concrete is itself a large contributor to CO_2 emissions and water pollution, reduction in its use serves multiple purposes.

Sustainable Alternative Strategies:

a. Reduce area for parking by at least 25%. Reduce building mass and replace with pervious materials and landscaping.

Net savings per contractor's unit costs

b. Provide connection to city bus system for employees.

Cost: coordinate cost estimate with Tainan transit system

ENERGY SAVINGS AND CONSERVATION

Air conditioning will be used only in certain areas during the hottest summer days. Therefore the simplest move towards energy efficiency is in natural ventilation, building orientation and properly sized sunscreens. Another key consideration for the future is the sources of energy. As energy prices continue to rise, alternative low-impact technologies become more cost-effective. Solar-based sources are closer to "free" energy than nuclear or fossil fuel-based technologies.

The Eco School is designed for 100 kw/hour peak demand. At least a 20% reduction of this amount would be feasible and desirable. While most of the classrooms are daylit, there are lights and mechanical systems which may be considered in the reduction concept. Photo-voltaics and small wind turbines are of primary interest to the architect. Fuel cells could also be considered if they would prove cost-effective and fuel-ready. All of these technologies can be consolidated into one system that effectively produces more energy than is consumed by the facility, rating it a 0% energy consumer.

1. Natural Ventilation

Sustainable Alternative Strategies:

a. The classrooms are designed in a traditional style of architecture. Their roof tiles are installed over a concrete structural roof. A detail was recommended to allow air circulation between the tile and the concrete and still maintain the traditional ridge detailing. This detail should be reviewed with code officials for fire safety; however, as it is over a concrete frame, there does not appear to be any problem with smoke or flame development.

Cost: Double-skin roof system $9.67/sq. meter

b. Various stair wells can be used as 'heat chimneys' to enhance vertical stacking of ventilation air in the community use and administrative buildings. Those floors that require air conditioning could still be closed off at the stairwell, but the intent would be to eliminate the need for air conditioning as much as possible.

Cost: Thermal chimneys $800-1,200/stairwell

c. The Lecture Hall has several opportunities for improved natural ventilation. On the roof are three gabled-roof air monitors. The gables themselves, facing south, may be used for air vents. However, the amount of free air is limited. An alternative design would be to provide an asymmetrical cross-section to the roof monitor with the roof shape simulating a wing. The vents should then be oriented to the east or "lee" side of the roof monitors thereby creating negative pressure to pull air up and out of the hall. This could be coupled with supply vents in the risers of the seating platforms.

Cost: Lecture Hall natural ventilation $50,000-75,000

2. Reduced Lighting Loads

Sustainable Alternative Strategy:

a. Other than people, the primary source of heat in buildings is the lighting. Reduction of lighting reduces both heat and energy requirements. Combined with daylight and lighting controls, this measure will significantly reduce the energy requirements of the building. The architect for the Eco School reports that these strategies are to be included. However, a goal of percent reduction has not been set.

Reduce lighting loads by at least 20% with the following actions:

- Incorporate T-5 (16mm) fluorescent tubes
- Separate zones for lighting adjacent to windows
- Use task lighting whenever possible
- Lay out electrical circuitry to allow users flexible control of lights

Cost savings is determined by power/unit cost

3. Sun Screens

Sustainable Alternative Strategy:

a. The original architectural concept presented by the architect mixes two styles—modern and traditional. The classrooms reside in the traditionally detailed structures, which use deep overhangs and arcades to moderate the bright sunlight. The community spaces and the gymnasium occupy the modern architecture that has minimal shading of windows and walks. This can be modified to accept sun screens and still maintain the modern 'language' of architecture. The workshop

discussion focused on the Gymnasium, which in the original plan and model faced west. Team Oregon suggested rotating the long axis and adding sun screens on the south facade, along with a green roof to reduce heat gains on the envelope. In fact, the architect had already begun a re-study of the 'modern' buildings on the site, including a rotation of the gymnasium. However, sun screens and roof overhangs are still minimal.

Cost: Sun screens at all south-facing elevations, over windows, along exterior walkways $328/lineal meter; vertical broad-leaf deciduous trees for west building facades $500/tree installed

4. Photo-Voltaics (P-V)

Sustainable Alternative Strategies:

a. Team Oregon is investigating various sources of photo-voltaic systems. If they are to be used, the school should seek private funding as a market test case. Taiwan authorities have financing through the Environmental Protection Agency to fund up to 50% of renewable energy systems. Their application can be applied readily to individual landscape lighting on a stand-alone basis. Pumps for the pools and constructed streams can also be run as stand-alone systems for low cost.

b. More extensive roof-applied systems should be sized for specific task areas, such as cafeteria or gymnasium lighting. If such a system is depended upon for night time power, an area for battery storage would have to be found in the garage. An additional benefit, if allowed by the local utility, is that any unused electricity may be returned to the grid for a credit to the school. Care must be taken in the placement of photo-voltaic panels considering shade from trees.

5. Ground Source Heat Pump

Sustainable Alternative Strategy:

a. This system acts just like any heat pump. Operating in one direction, it removes heat from the air and puts it in the ground acting as an air conditioner. Operating in the other direction, it can draw heat from the ground to provide heat for water or other purposes. Tainan climate dictates cooling over most of the year, but the heat drawn from the air may be used to preheat water before it is dispersed into the ground. The system has some costs involved with its installation; however, its efficiency provides a quick pay-back.

Cost: Ground source hydronic heat pump system $125,000

6. **Fuel Cells**

Sustainable Alternative Strategy:

a. Fuel cell technology, in its optimal state, runs on hydrogen. The only by-products are pure water or steam and heat. Current technologies include another piece of hardware to convert fossil fuels and biomass into hydrogen, thus producing some pollutants at a much lower level than combustion engines. Fuel cells could be retrofitted at any time to the school's electrical system as cheap sources of hydrogen become available. Like the photo-voltaic systems, they may be used to generate more electricity than is needed by the facility, which could be sold back to the utility.

Cost: Commercial 250 kw fuel cell system or multiple residential-size systems
$375,000 for 250 kw fuel cell over the next 10 years

7. **Wind Turbines**

Sustainable Alternative Strategy:

a. Either ground-mounted or roof-mounted, wind turbines of the appropriate scale can supply electricity for a portion of the Eco-school's demand. This sort of technology can also be taught in the schools. By integrating it with other systems, wind turbines can supplement the amount of energy being sold to the power utility.

Cost: Wind turbines to provide 20% of the school energy demand approx. $4,000-1,800/kw

WATER QUALITY

The Eco School can be a model of good water management. A sustainable goal is to use no more water than is received from rainfall. To understand the impacts, Team Oregon did a brief analysis of the water budget:

- Annual rainfall: approximately 250 cm per year
- Roof area—approximately 5,670 square meters
- Amount of collected rainwater from roofs alone: 14,175,000 liters per year
- Estimated water use (handwash, wash basins, wastewater): 3,465,000 liters per year

Clearly, the estimated uses for handwashing, toilet flushing, and wash basins can be provided by the annual rainfall. The question is raised as to how much savings are possible. There is currently a Taiwanese program that subsidizes Green Building water savings if it is at least 20% more. The Eco School may reach this level by employing two-section toilet fixtures, faucet aerators, motion-sensor water taps and motion sensors at urinals. All of these should pass the "water savings proof" of the Water Resources Bureau, Ministry of Economic Affairs. Beyond that effort, there are three areas for improvement.

1. Stormwater Filtration

Sustainable Alternative Strategy:

a. Use bio-filtration swales and storm water filtration systems to filter all stormwater leaving the site, with a standard for oil and particulate levels of less than 10 mg per liter of total suspended solids. Not all stormwater may be used by the facility, especially during a storm. The quality of runoff into the city system is a factor in the quality of water flowing into the rivers and the water treatment plants. Any filtration of water leaving the site is desirable; however, the architect cannot establish an acceptable level of sediment and chemicals without seeing costs of systems designed to remove these. Team Oregon will recommend several systems at different cost levels for the school board and architect to assess. Levels of water quality are usually set by the Environmental Protection Agency.

Cost: $10,000

2. Reduce Toilet Water Requirements

The flushing of toilets accounts for 35% of the water used in Taiwan (ABRI Manual, chapters 2 to 3) A system that recaptures "gray" wastewater from hand washing and other light uses can be filtered for toilet flushing and irrigation. The use of waterless urinals can save as much as 151,400 liters per fixture, per year.

Sustainable Alternative Strategies:

a. Reduce water consumption levels of fixtures as follows:

Toilets:	4.2 liters/flush
Urinals:	2.7 liters/flush
Faucets*:	6.8 liters/minute

*based on 4.63 kg/cm^2 water pressure

Cost: neutral

b. Install composting toilets that use little or no water. They do require maintenance and servicing that are not common. Larger units may require lower level access to the system.

Cost: varies per system

c. Waterless urinals require no water supply and connect to the same waste line as traditional urinals. They require regular cleaning maintenance and replacement of filters is required on a regular basis. They can save up to 151,400 liters annually in high-use facilities.

Cost: $400/fixture installed

3. **Living Machine™**

Sustainable Alternative Strategy:

a. Treat water to tertiary level with the removal of organics, solids and nutrients as well as biological or chemical polishing, generally to effluent levels of 10 mg/BOD_5 and 10 mg/liter Total Suspended Solids with the use of a living machine. A living machine is a combination of human knowledge, technology and biological processes that works as a sewage treatment plant. Tertiary levels of water treatment can be reached. This would be suitable for uses such as flushing toilets or irrigation systems—any use without human contact. Once the system is established it maintains itself if no major deviations occur in the makeup of water sources. Costs will vary depending on capacity and complexity. Living machines allow for the re-use of water that typically goes straight to the rivers or sewage treatment plant.

Cost: varies because it replaces the cost of sewer charges and services

MATERIALS CONSERVATION AND QUALITY

The efficient use of resources and the health impacts to building occupants are two primary concerns with the use of materials. All materials should be non-toxic and procured through sustainable processes. Certain materials embody significant environmental impacts such as concrete, plastics, and synthetic adhesives. Specifications should be reviewed to eliminate toxic substances in materials and increase recycled content.

1. **Reduce, Reuse, Recycle**

The three guidelines of materials are reduce, reuse, and recycle. Reduction of materials and finishes saves money and time. In some cases finishes are required to maintain durability and quality, but in other cases additional materials are used for ornamentation and decoration and should be reconsidered for utility and necessity.

Reuse of building materials ranges from construction processes to building equipment and furnishings. Wood and metal concrete forms can be reused and eventually recycled. Some suppliers of building products are now taking back their product in order to refurbish and reuse or recycle.

Recycling in Tainan is dependent upon existing facilities that provide a market for the basic materials of wood, plastics, metal, glass, paper and cardboard. While steel and aluminum are recycled at a rate of 80% in Taiwan, other materials are at very low levels. The city of Tainan should support such industries as a network of small businesses or integrated into city services. This will give contractors incentive to recycle on the job.

Sustainable Alternative Strategies:

a. Minimize construction waste and materials:

- Specify minimal packaging for products delivered to the site
- Require suppliers to remove and recycle any packaging associated with their tasks
- Require reusable concrete forms
- Require contractor to prepare a waste management plan, including recycling bins for wood, metal, glass, cardboard, paper, plastic, and cementitious product

Cost: neutral where contract already includes waste management.

b. Recycle the following materials at a rate of 80% or better:

- Metals, including steel and aluminum
- Glass
- Paper
- Tile and grout
- Concrete
- Wood
- Plastics, including sheet wraps and containers

Cost: Determined by recycle service to pick up materials

2. CO_2 Reduction in Construction

Reinforced concrete construction is the primary mode of construction in Taiwan. Concrete contributes substantially to CO_2 gases and water quality degradation. Even though its CO_2 contribution per kilogram is less than steel, it must be used in greater quantities to achieve safe structural performance. Thus, lighter steel frame construction is an improvement over concrete. Also, recycled steel produces half the CO_2 of new production steel.

Energy used in the transportation of products to the construction is based on fossil fuels, therefore contributes a sizeable portion of CO_2 to the atmosphere.

Sustainable Alternative Strategies:

a. Consider lightweight steel construction for 30% of the structures. The 'modern' style buildings that serve community functions may be good examples of this type of construction. Proper attention must be paid to insulation in walls and ceilings as well as seismic requirements.

Cost: Verify with contractor as alternate to concrete system; should be a net savings of 10-20%

b. Use up to 50% flyash content in concrete to replace Portland cement. Approximately one ton of CO_2 is generated in one ton of Portland cement through the burning of lime. Flyash replaces the cement. This requires careful concrete mix designs. Using less water reduces the cure time. The low workability is offset by the plasticizing effect of high flyash content.

Cost: Savings depends on local availability of flyash from coal-burning industrial processes

3. **Kitchen Waste Recycling**

Sustainable Alternative Strategy:

a. Compost 100% kitchen food waste on site. Use compost bins and worm boxes coupled with classroom gardens. Part of the goal of the Eco School is that the building will teach ecological principles. The organic food wastes from the kitchen can be used as compost for classroom gardens. This would reduce the load on solid waste as well as sewage.

Cost: $80/compost bin

4. **Eliminate Toxic Materials**

Sustainable Alternative Strategy:

a. Have architect prepare a new specification section listing levels of environmental performance required of various products. Include % recycled content, allowable maximums for Volatile Organic Compounds (VOC's), and a list of banned substances. Many materials contain toxic substances in their manufacture. These escape from the material over time as VOC's, leachates or particulates. Careful consideration must be taken in the preparation of specifications to ensure that the contractor understands the requirements for the project as well as the available products. Each section of the specification must be reviewed by the architect for known toxic and hazardous materials.

Cost: 8-40 FTE hours

FACILITIES MANAGEMENT

The operations and maintenance of buildings accounts for costs many times higher than the cost to build the facility. Building commissioning, energy management systems, good training manuals and scheduled maintenance will ensure the Eco School has a long life. Cleaning products should contain no toxic substances. Paints should comply with the original specification. Replacement materials should have the same or better environmental standard as the original product.

1. **Eliminate Toxic Cleaning Materials**

Sustainable Alternative Strategy:

a. Choose 100% low toxic, biodegradable cleaning agents. The choice of materials and finishes in the design phase will partially dictate the types of materials used for cleaning and maintenance.

Cost: neutral

2. **Maintain Energy Performance of Building Systems**

Schedule regular maintenance. Replace system components before they fail. Measure and record performance of systems using energy and water.

Sustainable Alternative Strategies:

a. Install energy management system with reporting capabilities.

Cost: $2,000 - $4,000

b. Establish schedules of maintenance for all major mechanical, electrical and plumbing systems.

Cost neutral

c. Monitor and display building energy performance or energy production of specific system such as P-V arrays.

Cost: $200-400

3. **Landscape Maintenance**

Sustainable Alternative Strategy:

a. Eliminate pesticides and fertilizers. Implement a pest management program and use compost from cafeteria. Fertilizer and pesticide use involved with landscaping affects water quality negatively.

Cost: 0-low

4. **Building Life-Cycle**

Sustainable Alternative Strategy:

a. Allow for expansion, change of use, de-construction, de-mountability, and/or recycling of buildings. Over the life of the building, the structure and systems will have to be changed, adjusted, replaced and modified. Therefore, threaded fasteners are preferable to permanent connections.

Cost: 0-low

5. **Building Waste Reuse and Recycling**

a. Establish and monitor a waste recycling program. Collection of waste materials should be designed into the building and a program established to set what materials will be recycled. The program should be maintained and monitored by a designated director. Reliable sources for recycling must be identified if this program is to be successful. Community action and cooperation could make this a popular program beyond the school itself.

Cost: 0-low

TABLE VI-1
ECO SCHOOL
Sustainable Development Guidelines for Economy

	Economy	Strategy	Priority
1	Increase the productivity of all forms of capital	a. Increase plantings and place to shade 85% of the pervious paving and at least 50% of open areas	2
		b. Increase planting of trees and shrubs to achieve an average of 800 kg/m² CO_2 absorption	1
		c. As an offset to embodied CO_2 in all construction, establish and maintain a program of neighborhood tree planting	1
2	Increase the quality and durability of goods	a. Eliminate toxic materials	1
		b. Eliminate toxic cleaning materials	1
3	Reduce, recycle and, reuse raw materials	a. Recycle common use materials at a rate of 80% or better	2
4	Substitute embodied and solar energy for produced energy	a. Photo-voltaic water pumps for pools and constructed stream	3
		b. Photo-voltaic landscape lighting	3
		c. Ground source hydronic heat pump system for air conditioning and water heating	2
		d. Wind Turbines to provide 20% of the school energy demand.	1
5	Reduce and eliminate all forms of waste and pollution	a. Minimize construction waste and materials	1
		b. Eliminate toxic materials	1
		c. Eliminate toxic cleaning materials	1
6	Apply science and technology to problems	a. Add green roofs to the Administrative Wing, Gym and Lecture Room.	3
		b. Natural ventilation	1
		c. Reduced lighting loads	1
		d. Living Machine	3

	Economy	Strategy	Priority
7	Develop transportation and energy supply systems consistent with SD	a. Fuel Cells b. Wind Turbines	3 3
8	Substitute non-toxic and biodegradable substances for toxic substances	a. Eliminate Toxic Materials b. Eliminate Toxic Cleaning Materials	1 1
9	Review/revise tax, capital investment, and regulatory policies to increase SD and eliminate subsidies for non-SD	Not applicable	N/A
10	Use life-cycle cost analysis in procurement decisions	N/A	N/A

TABLE VI-2
ECO SCHOOL
Sustainable Development Guidelines for Economy

Community		Strategy	Priority
1	Provide clean air, water, and food	a. Natural ventilation	1
		b. Increased landscaping to capture CO_2	1
		c. Green roofs	3
		d. Tree planting program	1
		e. Stormwater filtration	1
		f. Living Machine	3
		g. Eliminate toxic building materials	1
		h. Eliminate toxic cleaning materials	1
2	Provide clean and safe shelter	a. Natural ventilation	1
		b. Minimize construction waste and materials	1
		c. Eliminate toxic building materials	1
		d. Eliminate Toxic Cleaning Materials	1
		e. Day lighting	1
3	Provide a safe, clean, and beautiful community living environment	a. Open space and reduce heat island effect	1
		b. Increased landscaping to capture CO_2	2
		c. Neighborhood tree planting program	2
4	Protect and enhance the arts and cultural and historic resources	a. Basic design concept respects context of site	1
5	Provide public education on sustainable development	N/A	N/A
6	Promote public involvement in decisions	a. Several community meetings were held with architect during conceptual design phase	1

7	Provide collaborative, community-based decision-making with public, private, NGO participants	N\A	N\A
8	Promote cooperation among levels of government and globally	a. Team Oregon and TDA grant	1
9	Provide access to information on decisions	a. Team Oregon products assessments	1
10	Undertake social and economic impact analysis of major decisions	N\A	N\A

TABLE VI-3
ECO SCHOOL
Sustainable Development Guidelines for Economy

	Environment	Strategy	Priority
1	Support clean atmosphere, water, land, and marine resources	a. Increase planting of trees and shrubs to achieve an average of 800 kg/m²	1
		b. As an offset to embodied CO_2 in all construction, establish and maintain a program of neighborhood tree planting	1
		c. Living Machine	
		d. Composting Toilets that use little or no water	1
		e. Waterless urinals	1
2	Avoid habitat destruction	a. Increase planting of trees and shrubs to achieve an average of 800 kg/m²	1
3	Protect and restore ecosystems	a. As an offset to embodied CO_2 in all construction, establish and maintain a program of neighborhood tree planting	1
		b. Stormwater filtration	1
4	Protect and restore biological diversity	N\A	N\A
5	Assess and encourage programs to reduce negative impacts	N\A	N\A
6	Develop resources consistent with prevention of natural disasters	N\A	N\A
7	Reduce the output of greenhouse gases	a. As an offset to embodied CO_2 in all construction, establish and maintain a program of neighborhood tree planting	1
		b. Reduced parking	2
		c. Consider lightweight steel construction for 30% of the structures	3

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Team Oregon

Team Oregon, LLC

Team Oregon, LLC

Team Oregon, LLC is a consortium of firms organized in Portland, Oregon, USA to provide sustainable development services to public and private clients throughout the world The City of Portland and the State of Oregon are leaders in North America in sustainable development.

The key services provided by Team Oregon include public policy guidance; strategic, and land use planning; urban design and master planning; landscape architecture; architecture and interior planning; and civil and environmental engineering. Team Oregon, LLC works with multiple firms to bring clients the exact package of services required by individual projects.

Sustainable development addresses the challenges of unhealthy and unattractive cities, inefficient buildings and infrastructure, pollution, habitat reduction and the decline in bio-diversity, and resource and energy constraints.

The solution to these challenges is sustainable development, which meets today's needs without sacrificing the ability of future generations to meet their needs. Sustainable development results in clear policy vision and public commitment; protection and restoration of ecosystems; conservation, recycling, and reduction of natural resource and energy use; reduction of pollution and use of toxic substances; a stable, diverse, and fair economy; and healthy, safe and pleasant communities

Team Oregon has been selected by the US Trade and Development Agency to provide sustainable development services to Tainan City, Taiwan, R.O.C. The initial $450,000 grant will fund development of a sustainable development policy framework and feasibility studies for the design of an Eco School, sewage treatment systems, and river enhancement and beautification projects in Tainan City

Team Oregon will work with the International Sustainable Development Foundation (ISDF) in Portland, Oregon USA to provide services to Tainan City. ISDF is host to the Asia Pacific Economic Cooperation (APEC), Sustainable Development Training and Information Network and the China-US Center for Sustainable Development Team Oregon also will collaborate with the Taipei Office of the Oregon Economic and Community Development Department.

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Team Oregon

Team Oregon, LLC

BOB WISE, COGAN OWENS COGAN

Bob Wise is team leader for Team Oregon, LLC and senior associate with Cogan Owens Cogan, LLC. He advises clients in strategic planning, public policy, and sustainable development. Mr. Wise builds solutions to problems that meet multiple objectives and harmonize competing interests. He is the recipient of the Theodore Roosevelt Award for innovation in public policy from the U.S. Council of Governors' Policy Advisors/National Governors' Association. This is one of the highest honors given in State government, and has been awarded to only a few individuals in the last 25 years. Bob is the chairman of the Sustainable Portland Commission.

J. NED DEMPSEY, CENTURY WEST ENGINEERING

As president of Century West Engineering and Century Testing Laboratories, Mr. Dempsey has spearheaded the firm's growth for more than twenty years. In the two decades that he has serves at its helm, Century West has grown from a small Oregon based company to a major regional corporation, specializing in water and waste water facility design and construction management.

MIKE ABBATÉ, GREENWORKS

Mike Abbaté is the President of GreenWorks, a Landscape Architecture and Environmental Design firm in Oregon. GreenWorks is committed to integrating people and nature through creative and sustainable design. Mike brings over 16 years of professional experience to Team Oregon and has received national certification from the Council of Landscape Architects Review Board. He has received numerous awards for projects with both regional and national significance. Prior to joining GreenWorks, Mike served as Design Coordinator for the USDA Forest Service interdisciplinary design team. As an advocate of the principles of "Sustainable Design", he has contributed to facilities which reflect and protect the natural character and processes of the landscapes in which they are built.

JOHN ECHLIN, SERA ARCHITECTS

John brings more than 20 years of international experience in architecture and urban design to his role as Principal at SERA Architects. With an emphasis on civic institutions and open space design, John has taken lead design responsibility for projects in Italy, Switzerland, Germany and the United States. While a resident in Switzerland, John taught architectural design and urban planning at the Swiss Federal Institute of Technology. With a passion for green architecture, John currently directs sustainable project integration at SERA. John is a member of the Sustainable Portland Commission.

ADVISOR

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Richard Schulberg is Executive Director and Secretary of the Board of Directors for the International Sustainable Development Foundation. In that capacity, he is responsible for the overall administration and management of the ISDF including the APEC Center for Sustainable Development, the China-U.S. Center for Sustainable Development and the Zero Waste Alliance. The International Sustainable Development Foundation has the mission to accelerate the understanding and use of practices that lead to economic, social and environmental sustainability. It achieves this mission by educating and motivating organizations to take action, developing demonstration projects and disseminating information and best practices through international networks. The International Sustainable Development Foundation is a 501 (c) 3 non-profit organization.

Team Oregon

APPENDIX 2

Fact Sheet*

The State of Oregon and Sustainable Development
Team Oregon, LLC

April 27, 2001

The State of Oregon, USA, located in the Pacific Northwest, enjoys an enviable quality of life. This quality of life is based on engaged citizens, a strong economy, clean air and water, livable cities, and open access to natural surroundings for all its citizens. Sustainable development, defined as "meeting the needs of the present while providing for the needs of future generations," is a goal for Oregon government, businesses and communities.

Oregon's reputation as a sustainable development leader is an increasing magnet for new investment. In 1996, Oregon was recognized as a global leader in attracting foreign investment and promoting growth of local industries.[1] In the space of just two years, over $14 billion in investment was attracted from US, Asian and European investors.[2]

Oregon's commitment to sustainable development came about through recognition over the years that a strong economy could only be maintained if the natural environment, agricultural and forest lands and the livability of communities could be nurtured. Oregon did not always have a reputation as a leader in sustainable development. Because of the state's historical reliance on wood products and agriculture, as population grew following the Second World War, the state's rivers and airsheds became increasingly polluted. In fact, at one time, the Willamette River in western Oregon was widely considered to be one of the most polluted rivers in America. For ecological purposes, it was nearly dead. Coupled with the increasing hazards of smoke-filled valleys, the people of Oregon—both the government and business community—began to realize that the environment must be considered in expanding business.

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As a result, Oregon began a process almost sixty years ago that grew until now, when the state is viewed as one of the leaders in the United States in achieving both environmental quality and a high rate of economic development.

Oregon has provided leadership in North America on sustainable development but is now addressing new complex challenges related to non-point source pollution, ecosystem restoration, and improving the quality of urban development.

Some of the key examples of Oregon's leadership include the following:

- Oregon was the first state in the US to adopt a comprehensive statewide land use planning and development program. Known as "Land Conservation and Development", this program has allowed

[1] Coopers & Lybrand and Area Development Publications, 1996 Outstanding Economic Development Organization in North America and the Outstanding Economic Development Organization in the world.

[2] Oregon was asked to share its strategy and to make a special presentation in Geneva to the United Nations Commission on Trade and Development and the founding congress of the World Association of Investment Promotion Agencies.

for the successful integration and management of agricultural, residential, commercial and industrial developments.

- Oregon's Governor, John Kitzhaber, was the first American governor to establish a policy and program, through executive order, to make Oregon a sustainable society.
- Oregon has supported an active international network on sustainable development through the creation of the International Sustainable Development Foundation, which serves as secretariat to the Asia Pacific Economic Cooperation (APEC) Sustainable Development Network, the China-US Center for Sustainable Development, and the Zero Waste Alliance.
- Oregon was the first state government certified to directly administer air quality regulations on behalf of the US Government. Oregon had actually been ahead of the US Government in formulating higher air quality standards.
- Oregon has the first and most comprehensive system of watershed or "ecosystem" councils in the US, comprised of governments, private, and non-governmental organization (NGO) representatives to plan for, manage, and restore to health watersheds in Oregon.
- Oregon was the first state to adopt a comprehensive business-public sector program to clean up point sources of pollution on its rivers. An initial focus of this clean up was the Willamette River. The clean up was successful and the Willamette River is now a popular recreation area and fishing stream for the Pacific Northwest Salmon. Current efforts are addressing non-point source pollution and reestablishing or more natural streambanks.
- Oregon was the first state to adopt innovative recycling programs, including the "bottle bill" and curbside residential recycling, to reduce solid waste in landfills, save money, and stimulate new recycling jobs.
- Oregon was the first, and remains the only state, to preserve the marine shoreline for open access to all citizens through public ownership of beaches.
- Oregon was the first state to develop a private sector volunteer campaign to clean Oregon beaches and coastal areas. This program, known as "SOLV", Stop Oregon Litter and Vandalism, is now a national model and is being used by other US states and countries.
- Oregon was the first state and now leads the US in the establishment of standards, known as "benchmarks", to measure progress in economic and environmental areas. The Oregon Progress Board, which oversees the benchmarks, recently completed the first comprehensive and peer-reviewed State of the Environment report.
- Environmental Technology and Services was targeted as a "key industry" for Oregon's economy.
- The Northwest Environmental Business Council, headquartered in Portland, covers a five-state region representing companies engaged in environmental technology, clean-up, and sustainable development.
- Many leading edge environmental technology and design firms are located in Oregon, such as Team Oregon, CH_2M Hill, Century West Engineering, SERA Architects, and Greenworks landscape architects.
- Oregon is the center of several leading research efforts including the newly established Western US Hazardous Materials Center.
- Oregon has leading multi-disciplinary environmental studies, environmental engineering and management programs at both the undergraduate and graduate levels of higher education. Several

research institutes focus on sustainable development including the Center for Watershed and Community Health at Portland State University.

- Oregon has created the Oregon Climate Trust to buy, sell, trade, and retire carbon credits to address global warming challenges worldwide.
- Portland had the first Climate Change action plan of any city in the US.
- Portland has the only citizen-elected regional government in the US. This seven-member council, Metro, coordinates land use planning, the urban growth boundary, greenspaces, transportation, solid waste, and major cultural facilities planning.
- Portland has the first Sustainable Portland Commission, Office of Sustainable Development, and adopted sustainable development principles in the US. The Sustainable Portland Commission is expanding its coverage to include the surrounding county.
- Portland has design review, and historic and landmarks commissions to review and approve all major projects in the central city.
- Portland has a Green Building Policy and staff to guide public and private development in the city toward complete life-cycle planning for new and renewed buildings and projects. For example, construction waste is recycled as part of the demolition and building process.
- Portland has a comprehensive Urban Forestry Management Plan and Forestry Commission. The goal of the plan is to provide guidance to all sectors of the city on the types, placement, maintenance, and protection of the urban forest, parks, and street trees.
- Portland has a thriving community of almost 100 non-governmental organizations (NGO's) involved in sustainable development and environmental activism. Leading among these is the Portland City Club, a 100-year old NGO which studies and recommends public policy to the city and state. It recently completed a comprehensive study, *Building a Sustainable Future for Portland* (April 2001). Other important NGO's include Sustainable Northwest, Ecotrust, the Oregon Natural Step Network, the Northwest Earth Institute, Oregon Environmental Council, and Friends of Trees.

* This fact sheet is based, in part, on information provided by the Oregon Economic and Community Development Department and the International Sustainable Development Foundation.

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Team Oregon

APPENDIX 3

Review Draft

An Annotated Bibliography of Literature Concerning Sustainable Development

1. **Abbaté, G. Michael, *Sustainable Design on National Forests*. 1995. 11 pages. USDA Forest Service, Vancouver, Washington.**

Presented at the Urban National Forest Academy in April 1995, this paper outlines several factors to assist foresters in evaluating proposed or constructed projects in National Forests. Factors include site planning, energy, water, waste, building design, construction materials, construction technologies, and operations and maintenance. Emphasizes site context; carrying capacity; energy and water cycles; conservation of energy, water and materials; and cultural appropriateness.

2. **Abbaté, Mike, *Sustainable Landscapes and Site Design*. 2000. 12 pages. Team Oregon, LLC, Portland.**

A series of photographs and diagrams that illustrate 10 design principles for "Sustainable Landscapes, Beautiful Communities and Healthy Watersheds". These principles are: reduce stormwater runoff; improve fish and wildlife habitat; control erosion; rebuild disturbed soils; reduce use of chemicals; utilize native plants; reduce use of turf; protect streams, rivers and wetlands; support biodiversity; add beauty and art into outdoor environments.

3. ***Agenda 21: National Sustainable Development Strategy Guidelines of Taiwan R.O.C.* 20 pages. Draft, Government of Taiwan.**

Drafted in response to *Agenda 21* and the 1992 Earth Summit, presents Taiwan's strategy for implementing sustainable development. Describes specific environmental challenges Taiwan faces; defines sustainable development; presents a vision for sustainable development that includes a sustainable ecosystem, a comfortable environment, safe society, and open economy; identifies basic principles of sustainable development; outlines a nine-step integrated strategy of sustainable development; and presents strategy guidelines organized around the categories of sustainable environment, sustainable society, sustainable economy, development motivation, and promoting mechanisms.

4. **Alexander, Christopher et al., *A Pattern Language: Towns, Buildings, Construction.* 1977. 1171 pages, Oxford University Press, New York.**

A resource book that describes the detailed patterns for towns and neighborhoods, houses, gardens and rooms, this is a guide to 253 discrete 'patterns' described in detail and in application. Connections among 'patterns', from larger-scale 'independent regions', 'agricultural valleys', the 'lace of country streets', to the 'magic of the city' and 'local transport areas' to specific areas such as the 'house cluster', and the 'industrial ribbon' are explored. Specific architectural elements for pleasant and inviting design are also described—from 'wings of light' and 'positive outdoor space' to 'indoor sunlight', 'communal eating areas' and openings to the street.

5. **Anderson, Ray C., *Mid Course Correction: Toward a Sustainable Enterprise: the Interface Model.* 1998. 207 pages. Peregrinzilla Press, Atlanta.**

A study of *Interface,* a carpet-making company and its revolution toward a closed-system, zero-waste-producing business. A very practical and inspiring documentation of one man and company's efforts toward realizing an environmentally sustainable and socially responsible business. Explores crisis and the challenge of opportunity through personal and corporate experience. Defines the "prototypical company of the 21st century" – where the company and even its supply chain and customers is treated as a system codependent with the earth's lithosphere and biosphere. Presents and explains the closed-loop system using the example of one business, its consumers, inputs, transportation system, and even tax system. In closing, suggests the Power of One and challenges the reader to Love all Children for a more complete and sustainable world.

6. ***APA Policy Guide on Planning for Sustainability.* 2000. 23 pages. American Planning Association, New York.**

States APA's position on sustainability. Defines four aspects of sustainability: sustaining communities as good places to live; sustaining social values such as democracy; sustaining biodiversity; sustaining functions of natural systems. Identifies global indicators of unsustainability, including global warming, soil degradation, deforestation, species extinction, declining fisheries, and economic inequity. Also identifies indicators of unsustainability in the U.S., including suburban sprawl, segregation/unequal opportunity, loss of agricultural land and open space, depletion and degradation of water resources, loss of wetlands, traffic congestion and air pollution, and disproportionate exposure to environmental hazards. Lists factors that contribute to unsustainability, including overconsumption, population growth, dependence on non-renewable resources, pollution, environmentally and socially destructive development patterns, and inequities in resource distribution. Presents four general policy objectives: reduce dependence upon fossil fuels, extracted underground metals and minerals; reduce dependence on chemicals and other manufactured substances that can accumulate in nature; reduce dependence on activities that harm life-sustaining ecosystems; meet the hierarchy of present and future human needs fairly and efficiently. Presents 13 specific policy objectives an outlines possible planning actions toward sustainability.

7. **Architects Council of Europe, et. al. , *A Green Vitruvius.* 1999. 145 pages. James & James, London.**

Excellent overview of the architectural design-delivery process coupled with principles of sustainability. Includes examples and diagrams of strategies primarily for European climates.

8. **Architecture and Building Research Institute, *Evaluation Manual for Green Building in Taiwan.* 1999. 57 pages. Architecture and Building Research Institute, Taipei, Taiwan.**

Discusses the history and evolution of the "Green Building" concept. Presents seven evaluation indices for Green Buildings: Carbon dioxide absorption and fixation; soil water content; water conservation; energy conservation; Carbon dioxide emission; waste reduction; sewer and garbage. For each index, defines the concept, identifies the goal, describes the quantitative index and its basis; describes how the goal can be met, and presents a case study.

9. **Ashworth, William, *The Economy of Nature: Rethinking the Connections Between Ecology and Economics.* 1995. 340 pages. Houghton Mifflin Company, New York.**

Ashworth maintains in *The Economy of Nature* that we do not have to choose between ecology and economics, rather that each is good and essential for the other. Environmental destruction considered as not only morally wrong, but fiscally irresponsible. Begins with a chapter on "Only One Household" with the statement that there is nowhere on our Earth that the environmental crisis has not reached. He reminds the reader that the health of a society's economy depends on their relationship to its environment. He explores the character and role and limits of laws and regulations and nature preserves; and suggests we are operating with the wrong set of incentives and that whatever compromises the environment compromises our economy. With "thinking like a forest" thinking, Ashworth suggests we adhere to a gaia-like principle of stewardship ethics in our daily lives and all our operations. He encourages a serious consideration of our limits, the value of our resources, opportunity costs that we lose when we damage nature, our collective tendency toward selfishness, our definition of national wealth, limits to free and subsidized access to public land, true-value pricing, environmental justice and a new access to nature.

10. **Batie, Sandra S. et al., eds., *Business-led Initiatives in Environmental Management: The Next Generation of Policy?* 1997. 204 pages. American Agricultural Economics Association, Special Report (SR) 92.**

Series of papers on application of business-led initiatives in Environmental Management to agro-environmental problems. Notes that agriculture is the largest source of non point source pollution in the United States. Assesses the need for "agro-environmental" legislation and the adequacy of voluntary business initiatives such as marketing of eco-friendly products. Analyzes business and regulatory aspects of corporate environmental management, economics and effectiveness of environmental management, and implications for the food system.

11. **Benyus, Janine M., *Biomimicry: Innovation Inspired by Nature.* 1997. 308 pages. Quill William Morrow, New York.**

Holds that biomimicry defines: 1) nature as model; 2) nature as measure; and 3) nature as mentor—and that its practice is "a conscious emulation of life's genius." Includes an inspiring "canon" of nature's laws. Explores how we, as a population, are going to continue to feed ourselves functionally with our 'recent' industrial agricultural methods; how we are going to harness energy; how we will make things; how we'll heal ourselves; how we will store what we learn; how we will conduct business; and how we will go from here.

12. **Berke, Philip R. and Maria Manta Conroy, "Are We Planning for Sustainable Development? An Evaluation of 30 Comprehensive Plans," *American Planning Association Journal,* Vol. 66, No. 1, (2000): 21-33.**

Discusses the increasing effort by cities and counties in America to integrate sustainable development into their planning processes. Evaluates 30 comprehensive plans from local jurisdictions in America against six criteria: harmony with nature; livable built environments; place-based economies; equity; polluters pay; responsible regionalism. The study finds that there is not a significant difference in results between jurisdictions that have adopted policies to integrate sustainable development and those that have not. For example, Portland, Oregon, which has adopted sustainable development policies, has the second-highest rating among the 30

jurisdictions, and Jacksonville, Florida, which had not adopted sustainable development policies, is ranked the highest. It finds that many jurisdictions address one or two of the six criteria much more directly and effectively than others. Concludes that the next step is to "narrow the gap between theory and practice."

13. Botkin, Daniel B., Discordant Harmonies: A New Ecology for the Twenty-First Century. 1990. 241 pages. Oxford University Press, New York.

Argues that many current practices of managing the environment and ecosystems are based on incorrect assumptions about nature, including that nature in a state undisturbed by humans would be static and stable. Describes the conceptual paradox of viewing nature both from a rational and analytical perspective and from an emotional and intuitive one. Shows through a series of case studies how these incorrect assumptions and concepts translate into management decisions that do not reverse environmental destruction and actually harm ecosystems. Explains that environmental management in the twenty-first century will require a conceptual shift and a redefinition of humanity's relationship to nature and humanity's role in managing it.

14. Brand, Stewart, *How Buildings Learn*, 1994. 242 pages. Penguin Books, New York.

Creative, witty analysis of the way buildings change over time due to a variety of factors. Influential in thinking about the usefulness, meaning and longevity of our built environment.

15. Bryant, Steve, et al., *A Template for Local Government Sustainable Development Initiatives*. 2000. 45 pages. PSU Center for Watershed and Community Health/League of Oregon Cities.

A guidebook for local jurisdictions outlining a step-by-step process for adopting sustainable development policies, programs and practices. Focuses on five key questions around which a sustainable development initiative should be organized: What is our commitment to sustainability? How sustainable are we now? How sustainable do we want to be? How do we get there? How do we measure it? Provides numerous examples of existing endeavors by local jurisdictions around the world. Lists "start-up" ideas that a jurisdiction can take as easy first steps to begin its process of moving towards sustainability. Includes exercises to help assess past and present approaches to the five key questions and to assist with developing new programs for sustainability. Also includes the introductory document, *Context and Background for Local Government Sustainable Development Initiatives.*

16. City Club of Portland, *Building a Sustainable Future for Portland.* 2001. 86 pages. City Club of Portland, Portland.

Attempts to define the term "sustainability", particularly as it applies to the Portland metropolitan region. Explores the costs and benefits associated with sustainability. Reviews approaches that assess progress toward sustainability goals. Describes various roles of government, private business, the community, and individuals in promoting sustainability. Notes that because sustainability is such a broad and complex concept, there are not widely agreed-upon criteria to measure sustainability. Concludes that community value judgements and a widespread consensus on sustainability indicators are needed.

17. *City of Portland Green Building Policy*. 2000. 8 pages. City of Portland Web site.

Policy statement for the City's Green Building Initiative. Because buildings consume significant amounts of materials and energy, construction and maintenance of buildings represents a key opportunity for conservation. Policy statement describes integrated design strategies and life cycle analysis and explains the Leadership in Energy and Environmental Design (LEED) rating system that Portland has joined. Outlines four major policy strategies: incorporation of green building practices into all facilities and projects constructed, owned, managed or financed by the City; adoption of the LEED rating system by the Portland Development Commission; development of a rating system of public infrastructure; promotion of voluntary application of green building guidelines in the private sector. Suggests evaluation criteria for measuring architects' and engineers' knowledge of green building design.

18. City of Portland Office of Sustainable Development, *Sustainable City Principles*. 1994. 2 pages. City of Portland Web site.

Presents the overall goal of the City of Portland to promote sustainable development and outlines ten principles to guide elected officials and staff. Principles address the connection between the environment and economy; recognizing cumulative and long term impacts; equity and environmental justice; linking environmental quality to decision making in other sectors; reducing demand for natural resources; pollution prevention; acting locally to help solve global environmental problems; choice of products to purchase; educating and involving the public; and annual reporting.

19. Cogan Owens Cogan, for the Oregon Department of Environmental Quality, *Stakeholder Guidelines*. 1999. 30 pages. Portland.

Provides guidelines for developing, implementing and monitoring a successful stakeholder involvement program. Though designed for the Oregon Department of Environmental Quality's Green Permits Programs, this is also a model for stakeholder involvement. The Green Permits Program encourages facilities to achieve environmental performance that significantly exceeds legal requirements through the use of recognition and rewards. Facilities must engage the public and other stakeholders in dialogue and other forms of involvement to be eligible for the program. The document describes basic elements of stakeholder involvement including objectives, benefits and drawbacks of involvement; stakeholder identification; variety of stakeholder involvement techniques, their objectives, strengths and weaknesses; key factors for successful implementation; measures to evaluate a program's effectiveness; achievement guidelines for the three different "Tiers" of facilities; and how DEQ will evaluate and verify stakeholder involvement.

20. Crites, Ronald W., Sherwood C. Reed, and Robert K. Bastian, *Land Treatment Systems for Municipal and Industrial Wastes*. 2000. 433 pages. McGraw-Hill, New York.

This book, written by three of the field's leading experts, discusses land and other ecologically sound methods for treatment, renovation, reuse, and disposal of wastewater and biosolids.

21. Davis, Gary and Catherine Wilt, *Extended Product Responsibility: A New Principle for Product-Oriented Pollution Prevention*. 1997. 130 pages. University of Tennessee, Knoxville.

Extended Product Responsibility (EPR) is a principle for pollution prevention that focuses on all segments of the product chain, including selection of product materials, production impacts, use

and disposal of the products. Report examines EPR in the United States and explores several case studies, including the electronics industry; automotive take-back and recycling programs; recycling of nickel-cadmium batteries; EPR at the Xerox Corporation; and EPR at the Rochester-Midland Corporation.

22. Detail in Building, *Wind Towers: Battle McCarthy Consulting Engineers. 1999.* 96 pages. Academy Editions, London.

Case studies and history of wind towers as an integral element in climatic design of buildings.

23. Durning, Alan Thein and Yoram Bauman, *Tax Shift: How to Help the Economy, Improve the Environment, and Get the Tax Man off Our Backs.* 1998. 115 pages. Northwest Environment Watch, Seattle.

Describes premise that we should not be taxing things we do value, e.g., our paychecks and our businesses, but we should be taxing the things we do not want, e.g., pollution and traffic congestion. Taxing elements that erode rather than support the public good presented as a way to correct our current disconnect between private behavior and ecological sustainability. Briefly describes the "cobbled" system of taxation (including personal income tax, payroll, property, corporate income and sales tax) and offers clues as to how to identify the difference between a "good" tax and "bad." Suggests taxes that would be more in line with obtaining socially desirable results such as carbon taxes, pollution, including both point and non-point pollution. Lists property tax "evaders" (farms, automobiles, mansions, energy, timberlands) and describes the implication of that "evasion." Suggests ways to begin to press for this type of social-environmental correction.

24. EDAW, *Planning the Green Zone.* 1995. 36 pages. U.S. Government Printing Office, Washington D.C.

In the summer of 1994, eleven students converged at an elevation of 8,000 feet in the wilds of the Rocky Mountains of Colorado for a two-week charette-style workshop in order to create a model for sustainable development. Coming from very diverse backgrounds and perspectives, EDAW's summer workshop brought students and professionals together and provided the environment, resources and collaborative format to deal with the planning and design of a sustainable boundary zone between Rocky Mountain National Park and the neighboring Estes Park community. EDAW personal, experts in various fields, the National Park Service and Estes Town officials provided the factual data and direction from which this report was produced. The team brought with them open and creative minds and an ability to question and challenge the role of the NPS and the people of Estes Park in creating a prototype for sustainability which any community could use as a model.

25. Edwards, Brian, *Sustainable Architecture: European Directives & Building Design.* 1999, second ed. 277 pages. Architectural Press, Oxford.

European examples coupled with in-depth discussion of additional subjects that circle around sustainable architecture such as environmental audits, the ecology of materials, and the future of laws governing the environment.

26. Environmental Resources Management, *Sustainable Development in Hong Kong for the 21st Century, Second Stage Consultation.* 2000. 109 pages. Environmental Resources Management, Hong Kong.

The Sustainable Development for Hong Kong in the 21st Century (SUSDEV 21) study program has the goal of operationalizing the concept of sustainable development into the process of government decision making. Two key aspects of the program are to develop sustainability indicators to predict implications of policy decisions and develop a computer-based decision support tool. The "Second Stage Consultation Programme" had the dual goals of obtaining public feedback on the study and raising awareness about sustainability. This document describes SUSDEV 21's public consultation program; summarizes feedback received from the public and the study team's responses; and discusses how the feedback will be incorporated into the outputs of the study. Many of the specific comments relate to the set of indicators that will be used.

27. Frankel, Carl, *In Earth's Company.* 1998. 240 pages. New Society Publishing.

Identifies the key elements of the emerging era of corporate environmentalism. Details the many concepts and technologies for creating a sustainable future that have already been developed and are in use.

28. Gore, Albert, *Earth in the Balance: Ecology and the Human Spirit.* 1993. 407 pages. Plume.

Written by former American Vice President Al Gore, demonstrates that the quality of air, water and soil is at grave risk, not only locally or regionally, but globally. Argues that only a radical rethinking of the human relationship with nature can save the earth's ecology for future generations.

29. *Green@work.* January-February 2000.

A bi-monthly periodical focusing on business and the environment. Articles describe initiatives by major business leaders, new technological innovations, management theories and new policies.

30. Hawkins, Paul; Lovins, Amory and L. Hunter, *Nature Capitalism: Creating the Next Industrial Revolution.* 1999. 396 pages. Little, Brown and Company, Boston.

A biological and social framework to assist with the transformation of commerce to a sustainable end. A win-win situation is described in Paul Hawkins and Amory and L. Hunter's work: "...a place where the environment and humans are vital and well-being." According to the authors, increasing natural capital adds to everyone's present and future prosperity. The authors suggest a capitalistic system "... as if living systems mattered." They forecast more efficient cars and waste system(s), and new processes in corporate culture as well as design and new technologies. True cost and longer range returns show more clearly the result of "green" or conscious investment. Business/ Economic development.

31. Hillary, Ruth, ed., *ISO 14001: Case Studies and Practical Experiences.* 2000. 382 pages. Greenleaf Publishing Limited, Sheffield.

ISO 14001 is the International Organization for Standardization's most prestigious environmental management system (EMS) standard. This book presents 30 case studies from around the world of organizations that have implemented ISO 14001. Case studies discuss implementation techniques to make ISO 14001 operational, maintainable, and beneficial; explores various issues related to certification, including certifying a group of small businesses and global certification; describes tools to either streamline the ISO 14001 process or make it more intensive; discusses training and communication; presents issues related to engaging stakeholders; describes how products, design and technology can be accommodated into the EMS model; discusses environmental and economic benefits; and considers how organizations can use ISO 14001 to meet the broader needs of sustainable development.

32. Hough, Michael, *Cities and Natural Process*, 1995. 326 pages. Routledge Press, London.

Hough's thesis is that traditional design values that have shaped our cities' physical landscapes have contributed little to their environmental health, their success as civilizing, enriching places to live. He explores the concept of urban ecology, an area easily overlooked for its complexity and socio-political challenges. Traditional versus modern urban forms compared, with the division between city and countryside increasingly defined. The role of humans and human development in this context mentioned. Chapters are devoted to elements of our natural world—water (what we've done to it and some examples of restoration), plants (their loss in cities and some examples of restoration), wildlife (natural and urban processes, opportunities, including in planning and management), city farming (context and some examples are given), climate and the urban influence including temperature control, and the connection between these elements. Urban planning and ecosystems.

33. Industrial Technology Research Institute. *Strategic Guidelines for Sustainable Development of the Republic of China, Proposed by National Forum on Sustainable Development.* 1998. 80 pages. Council for Economic Planning and Development, Executive Yuan, Taiwan R.O.C.

Based on National Sustainable Development Forum (NSDF) conferences of over 240 experts in a wide variety of fields, outlines principles proposed by the NSDF to guide Taiwan in promoting sustainable development. Also outlines action plans for the economic, environmental and social sectors. Proposed principles include: promoting generational equity; maintaining a balance between the environment and economic development; internalizing external costs; adopting a precautionary approach; embedding the spirit of sustainable development in society; encouraging public participation in decision-making; emphasizing scientific and technological developments; taking action systematically and integratively; actively pursuing internationalization. Proposed lines of action include: participation of all segments of society in forming national sustainable development policy; guidance to local governments on their role in implementing sustainable development; public education; allocation of administrative resources; and redrafting of basic environmental laws. Sustainable development policy.

34. Jones, David Lloyd, *Architecture and the Environment: bioclimatic building design.* 1998. 256 pages. The Overlook Press, Woodstock, N.Y.

Balanced collection of new projects from the world, coupled with essays on green architecture and bioclimatic design. Green building/landscape design.

35. Lyle, John Tillman, *Design for Human Ecosystems: Landscape, Land Use, and Natural Resources.* 1999. 279 pages. Island Press, Washington, D.C.

This 1999 contribution to the field concerns the principles, methods and techniques for working with and 'shaping' landscape, land use and natural resources so that they operate in more sustainable ways. Beginning with a documentation of public awareness of our growing ecological crisis, a "hierarchy" of scale is described, from the geographic region, with the role of the growth of regional planning, subcontinents, and the whole earth. Plan Units and smaller landscapes also are described; various design/land use layouts also described with a focus on ecological considerations and ecological planning. Residential development projects described. Human and technological processes of design explored as well as the field of planning and modes of ecological order (structure, plants, habitats). Lyle ends by encouraging capacity for adaptive change—creative change.

36. Lyle, John Tillman. *Regenerative Design for Sustainable Development.* 1994. 338 pages. John Wiley & Sons, Inc., New York.

Regenerative Design for Sustainable Development is a practical guide to the theory, design, and construction of regenerative systems. It describes practical applications to the essential system of land development: energy flow, water flow, agriculture and land use, and building design. The book also explores the cultural, social, and economic implications of regenerative systems, and speculates on the global landscape that can result from their application. Many of the systems that Lyle describes have been incorporated into the designs for the Center for Regenerative Studies - a 16-acre on-campus site at the California State Polytechnic University in Pomona designed to integrate regenerative systems of energy, water, shelter, food productions, waste disposal, and other essential functions. A central tenet of this book is that sustainable development relies on the interaction of numerous systems working in harmony with one another.

37. Lynch, Kevin. *Site Planning,* 2nd Edition. 1974. 380 pages. The Colonial Press, Inc., Massachusetts of Technology, Boston.

This classic site planning text has been updated from the 1969 version with increased attention to ecology, psychosocial analyses, design methods, and the concept of environmental design as a continuous process involving many participants. Examples of site planning across the millennia explored—from Mach Piccu in Peru to modern urban landscapes. People in their environments is emphasized as a design tool. Lynch encourages the study of these "behavioral settings." Density and thresholds explored. Chapters include site form and ecology; social and psychological analyses (understanding how people use and value their environment); movement systems; streets and ways; earthwork and utilities; sensuous form; the problems of control; design and site management; design methods; cost; housing; and special types of site planning (shopping centers and commercial strips), industrial districts, institutions, open space and renewal.

38. McDonough, William and Michael Braungart, *The Hannover Principles Design for Sustainability.* 1992. 122 pages. William McDonough Architects, New York.

The City of Hannover, site of the 2000 World's Fair (EXPO 2000), chose "Humanity, Nature, and Technology" as the Fair's theme. The City commissioned sustainability principles to inform design competitions that were part of the Fair. These "Hannover Principles" are also intended

for a wider context, both for the City and the rest of the world. Principles include: insist on rights of humanity and nature to coexist; recognize interdependence; respect relationships between spirit and matter; accept responsibility for the consequences of design; create safe objects of long-term value; eliminate the concept of waste; rely on natural energy flows; understand the limitations of design; seek constant improvement by the sharing of knowledge. Presents a series of design guidelines organized around the concepts of earth, air, fire, water and spirit.

39. McHarg, Ian L., *Design with Nature.* 1969. 197 pages. Doubleday/Natural History Press, Garden City, New York.

One of the classic texts in the fields of environmental planning and urban design, this book contends that development must occur in harmony with the natural landscape and work with ecological functions and processes rather than against them. It discusses its theme at the philosophical, conceptual, policy and implementation levels. Explores urban development at the regional, metropolitan and watershed scales and contrasts uncontrolled growth and its consequences with planned growth.

40. Melet, Ed, *Sustainable Architecture: towards a diverse built environment* . 1999. 189 pages. NAI Publishers, Rotterdam.

Examples of current examples of world architecture built and un-built. Organized by elements of design: glazed thermal buffers, smart buildings, buildings as energy generators, and compact cities.

41. Minnesota Planning, *From Policy to Reality: Model Ordinances for Sustainable Development.* 2000. 313 pages. State of Minnesota Web site, www.mnplan.state.mn.us/SDI/ordinances.html.

This document is the result of Minnesota Statues, Section 4A.07(3) which directs Minnesota Planning to prepare a model ordinance in consultation with appropriate parties to guide sustainable development. It is a first step in pursuit of the goal of creating a package of model ordinances that Minnesota communities can use in charting their futures. This guide offers tools to help make the best choices today for the health of the community tomorrow. Communities can adapt these model ordinances to their own special circumstances as part of a citizen-based community planning process.

42. National Council for Sustainable Development, *1999 Annual Report of National Sustainable Development.* 1999. 92 pages. National Council for Sustainable Development, Taiwan.

Reports on the progress of Taiwan's National Council for Sustainable Development (NCSD). Discusses trend and current status of sustainable development promotions; reviews important NCSD tasks and their implementation status; outlines the accomplishments of the eight working groups; and discusses future work plans and prospects.

43. National Research Council, *Nature's Numbers: Expanding the National Economic Accounts to Include the Environment.* 1999. 250 pages. National Academy Press, Washington, D.C.

To more comprehensively value and evaluate the sustainability of our nation's capital, the Council recommends that the U.S. National Income and Products Account (NIPA) include "assets and production activities associated with natural resources and the environment." This is put in the context of a "...larger movement to develop broader economic indicators..." that has been growing, at least since the late 1970's. The authors suggest a three-phase work plan: an overall technological and measurement framework; extend these accounts to stocks and water resources; and lastly, to "non-market" assets such as clean water and air. History of NIPA and its application to the environment.

44. Nattrass, Brian and Mary Altomare, *The Natural Step for Business: Wealth, Ecology and the Evolutionary Corporation.* 1999. 222 pages.

Explains how The Natural Step provides a simple yet elegant framework to integrate environmental issues into the frame of business reality. Provides detailed case studies of four leading corporations—IKEA, Scandic Hotels, Interface, and Collins Pine—that are using The Natural Step as a central part of their corporate strategies.

45. The Natural Step, *The Natural Step's Four System Conditions.* The Natural Step U.S. Web site, www.naturalstep.org.

The Natural Step is an international environmental organization that works with businesses, governments and other organizations to promote sustainable development. The organization's sustainable development framework is a set of four scientifically-based principles called "system conditions". The four conditions are: In a sustainable society, nature is not subject to systematically increasing 1) concentrations of substances extracted from the earth's crust, 2) concentrations of substances produced by society, 3) degradation by physical means; and in that society, 4) human needs are met worldwide.

46. Olgyay, Victor, *Design with Climate: Bioclimatic approach to architectural regionlism.* 1963. 190 pages. Princeton University Press, Princeton, N.J.

Classic textbook on the bioclimatic approach to design. Full of diagrams and analysis of strategies regarding solar, thermal, and wind effects on the design of buildings.

47. Oregon Natural Step Construction Industry Group, *Using the Natural Step as a Framework Toward the Construction and Operation of Fully Sustainable Buildings, Draft #8.* 2000. 14 pages. Oregon Natural Step Construction Industry Group.

Applies the Natural Step Framework to constructing a commercial building. Discusses the four Natural Step system conditions. Depicts the "life cycle" of a building. Assesses current building practices using the four system conditions. Outlines criteria for materials used, energy, air, water, transportation and other factors for a building to meet the system conditions. Describes a goal or "end point" of green building design.

48. Porter, Douglas R., *The Practice of Sustainable Development.* 2000. 162 pages. Urban Land Institute, Washington D.C.

Published by the Urban Land Institute, this collection of articles begins with a brief introduction to sustainable development, its history, struggle for identity and current challenges. Porter's

'dimensions' of sustainability—social equity, economic prosperity and ecological integrity—are explored in the context of modern challenges and cultural behaviors such as consumerism, post-WWII suburban developments and the American value of privacy. Porter and his co-contributors offer a historical and contextual introduction to various perspectives on sustainable development – urban planning trends such as 'smart growth', 'new urbanism', transit-oriented developments', 'habitat conservation planning' to avoid penalties under the Endangered Species Act and 'green development'—and considers the appropriate scale for incentives to sustainability planning in the U.S. Site-specific examples in terms of urban development also given.

49. President's Council on Sustainable Development, *Eco-Efficiency: Task Force Report.* 1996. 35 pages. U.S. Government Printing Office, Washington D.C.

The premise of this Task Force Report is a self-described "belief that environmental protection and economic growth can, and must be, linked." The mission of the Task Force was to identify the means by which the United States can realize sustainable development. Eco-efficiency, used to describe corporations producing economically viable goods while continuously reducing the ecological impact of those goods, is applied to goals for a eco-efficient economy. Goals include responsibility; economic growth; sustainable resource utilization; environmental quality; government regulatory policy; and social well-being. A context statement, goal and indicators of progress are given for each. Nine policy recommendations given ranging from chemical operations, eco-industrial parks. Information, economics, regulatory, and money and management clusters described.

50. President's Council on Sustainable Development, *Sustainable America: A New Consensus for Prosperity, Opportunity and a Healthy Environment.* 1996. 186 pages. U.S. Government Printing Office, Washington D.C.

This consensus document begins with a 16-point statement of belief regarding sustainability that was collaboratively developed by its American members. National goals toward sustainable development are presented. In addition to implementation indicators, a policy framework is described, strategies to strengthen communities, encourage natural resources stewardship in forestry, fisheries, restoration and biological conservation formed. Population growth and international leadership discussed. National goals including health and the environment; economic property; equity; conservation of nature; stewardship; sustainable communities; civic engagement; population; international responsibility; and education. Specific goals, action items and indicators of progress are also given.

51. President's Council on Sustainable Development, *Toward a Sustainable America: Advancing Prosperity, Opportunity, and a Healthy Environment for the 21st Century.* 1999. 158 pages. U.S. Government Printing Office, Washington D.C.

The Vision Statement and beliefs published in *Sustainable America* are reprinted as an introduction to this collection of policy areas President Clinton asked the Council to consider. Each policy area contains an introduction and context section. Policy arenas include climate change; environmental management; metropolitan and rural strategies on sustainable communities, including economic health; and international leadership in sustainable development. Key findings summarized and action programs recommended for many policy areas.

52. Risser, Dr. Paul G., Chair, State of the Environment Science Panel et al., *Oregon State of the Environment Report 2000: Executive Summary*. 2000. 80 pages. Oregon Progress Board, Salem, Oregon.

This much-needed comprehensive evaluation of the State of Oregon's current environmental status contains broad-scale inventory information gathered to identify future risks to Oregon's economic health and lasting ecosystem vitality. Data is given in the form of background, status and key indicators regarding estuarine, forest, riparian, farmland, wetlands, rangelands urban areas, biodiversity, and other areas. Areas in Oregon described by eco-region: the coast range, the Willamette Valley, the Klamath Mountains, Eastern Cascades, Columbia Plateau, Blue Mountains, and the Northern Basin and Range. A set of findings and conclusions for each area is given, from water quality, to forests, rangelands biological diversity, agriculture, toxic emissions and data collection and management.

53. Rocky Mountain Institute, et. al., *Green Development: Integrating Ecology and Real Estate*. 1998. 522 pages. John Wiley & Sons, Inc., New York.

Covers all aspects of development , beginning with a new view of real estate and continuing through construction. Includes the benefits of marketing a green development as well as case studies. A CD is also available with supplementary information, not included in the book, for each case study.

54. Romm, Joseph, *How the Best Businesses Boost Profits and Productivity by Cutting Greenhouse Gas Emissions*. 1999. 277 pages. Island Press.

Shows how energy efficiency investments improve productivity, yield high return on investment, and mitigate climate change. Key book about the next industrial revolution.

55. Roseland, Mark, *Toward Sustainable Communities: A Resource Book for Municipal and Local Governments*. 1992. 339 pages. National Round Table on the Environment and Economy, Ottawa.

Chronicles examples of practical outcomes of the Healthy Cities, sustainable communities, and eco-cities movements. Looks at the application of sustainable development through an "ecosystem approach to human settlements management." Written for an audience of local government officials and citizens to apply the concept in their communities. Holds that many of the most pressing global environmental challenges are really rooted in local, day-to-day problems of things such as poor planning or lack of consideration of environment and long-term effect. Defines sustainable development according to the Bruntland Commission perspective as published in its 1987 report *Our Common Future*. Gives examples of initiatives in several cities—using the city as a brief case study example. Summarizes a variety of "sustainable community tools": atmospheric change and air quality; transportation planning and traffic management; land use and growth management; energy conservation and efficiency; waste reduction and recycling; water and sewer; greening the city; economic and community development; and investments and purchasing. Presents several planning and administrative tools: leadership (environmental auditing, staff training); environmental administration (operating principles, public involvement) and implementation.

56. Ryan, John C. and Alan Thein Durning, *Stuff: The Secret Lives of Everyday Things*. 1997. 86 pages. Northwest Environment Watch, Seattle.

Describes the full environmental impact of things we use or consume everyday, such as cars, coffee, newspapers, hamburgers, clothing and computers. Outlines the step-by-step production process for these goods in terms of resource inputs, water consumption, energy costs, and pollution byproducts. Explores changes we can make in our daily life, shopping and transportation to reduce our impacts on the environment.

57. Todd, Nancy Jack and John Todd, *From Eco-Cities to Living Machines: Principles of Ecological Design*. 1994. 197 pages. North Atlantic Books, Berkeley, Ca.

Living machines combine intellectual, biological and technical tools to treat water waste to tertiary levels. Includes history and theory behind the systems as well as early examples.

58. United States Department of the Interior, National Park Service. *Guiding Principles of Sustainable Design*. 1993. 117 pages. U.S Government Printing Office, Washington D.C.

Guiding Principles of Sustainable Design is intended to provide a basis for achieving sustainability in facility planning and design, emphasize the importance of biodiversity, and encourage responsible development decisions in parks and other conservation areas, particularly where related to ecotourism. This merger of sustainable development and ecotourism provides tremendous opportunities for affecting visitor perceptions of the natural and cultural world, and developing conservation-oriented values. It is a marriage that would clearly distinguish sustainable development from traditional tourist development. Sustainable principles have been developed for nine topics: interpretation, natural resources, cultural resources, site design, building design, energy management, water supply, waste prevention, and facility maintenance and operations. Although material is presented in separate sections, the interconnection of all systems and resources must be recognized; the resulting development should reflect the blending of disciplines to demonstrate respect for local, regional, and global environments.

59. U.S. Environmental Protection Agency, *Constructed Wetlands for Wastewater Treatment and Wildlife Habitat: 17 Case Studies*. 1993. 174 pages. EPA832-R-93-005, U.S. EPA.

This document provides a brief description of 17 wetland treatment systems from around the United States that are providing significant water quality benefits while demonstrating additional benefits such as wildlife habitat. The projects described include systems involving both constructed and natural wetlands, habitat creation and restoration, and the improvement of municipal effluent, urban stormwater and river water quality.

60. Vale, Brenda and Robert Vale, *Green Architecture*. 1991. 192 pages. Thames and Hudson Ltd., London.

Discusses the importance of architectural design as it affects the environment. Proposes "ground rules" for green cities. Well illustrated with examples and tables.

61. Van der Ryn, Sim and Calthorpe, Peter. *Sustainable Communities: A New Design for Cities, Suburbs, and Towns*. 1986. 238 pages. Sierra Club Books, San Francisco.

In this persuasive and evocative book, two authorities on appropriate technology have assembled a practical vision of how different types of American communities can make the transition to a

way of life that encourages sustainability, reduces resource waste, balances consumption and production, and produces a long-term social and ecological health. *Sustainable Communities* presents practical guidelines for urban and suburban renovation as well as new community planning, and offers inspiring commentaries by leading-edge thinkers in the burgeoning field of "sane" redevelopment, including John Todd on the synthesis of biology and design and Paul Hawken on the economics of sustainability.

62. Van Der Ryn and Cowan, *Ecological Design.* 1996. 201 pages. Island Press, Washington D.C.

Van Der Ryn and Cowan contend that the living world and humanity can be reunited by making ecology the basis for design. Describes two approaches as organized by David W. Orr—technological and ecological sustainability. Where technological sustainability does not demand a radical change in the way we related to our environment, ecological sustainability does. The authors contend that ecological design respects species diversity, minimizes natural resource depletion, preserves the integrity of nutrient and water cycles, maintains habitat quality, and responds to all other conditions of human and ecological health. It is described as "adaptation to and integration with nature's processes." Scale and ecological design processes described according to the following principles: solutions grow from place; ecological accounting informs design; design with nature; everyone is a designer; and making nature visible.

63. Wackernagel, Mathis and William Rees, *Our Ecological Footprint.* 1996. 160 pages. New Society Publishers, Canada.

Fascinating analysis of world's various standards of living and how they relate to amounts of natural resources used to support them. Gives perspective to other approaches to the puzzle of sustainability.

64. Wells, Malcolm, *Gentle Architecture.* 1981. 178 pages. McGraw-Hill, Inc., USA.

An early and highly personal approach to green building as seen by one of the first pioneers of sustainable design. Includes "wilderness-based" checklist for design and construction that measures performance against natural systems.

65. *Willamette Riverbank Design Notebook.* 2000. 105 pages. City of Portland.

A key tool for the City of Portland's efforts to promote recovery of endangered fish species through restoration of healthy watersheds. Provides guidance for repair and modification of the banks of the Willamette River, and is intended to be a common frame of reference for landowners, designers, land use planners, and regulators. Describes current conditions of the banks of the river within the City. Presents design objectives for the riverbanks that stem from discussions with the National Marine Fisheries Service about properly functioning conditions for the lower Willamette River. Provides analysis methods to assess conditions for a particular site, implementation measures and design references. Design guidelines oriented around three different elevation zones of the riverbank. As it is titled, it is a design notebook!

66. Williams, Katie, Elizabeth Burton and Mike Jenks, eds., *Achieving Sustainable Urban Form.* 2000. 388 pages. E & FN Spon, London.

Extensive collection of academic studies exploring the relationship between urban form and sustainability. Various studies examine compactness, density, intensification, centralization and decentralization, mixed land uses and other urban forms for their influences on travel demand, traffic congestion, accessibility, energy use, housing costs, social equity and other factors. Editors review the studies collectively to attempt to define sustainable urban form and approaches to achieve it, both at the policy level and the design level.

67. Wilson, E. O., Editor, *Biodiversity* 1988. 521 pages. National Academy Press, Washington D.C.

Developed by the Smithsonian Institute's Directorate of International Activities Board on Basic Biology, this book maintains that biological diversity "is a global resource to be understood, used and preserved." Written in the context of rapid population growth; increasing understanding of and interest in the value of diverse plants and species; and the loss of intact habitat, the authors urge achievement of a basis of understanding from which a well-informed policy of conservation and development can be developed. With impressive breadth, the authors examine the processes that have evolved to evidence our current wealth of diversity and what should be strong, well-adapted species. Ethical questions as to the choices societies collectively make and the role of a wide variety of conservation programs such as cryobiology, embryo transfer and artificial insemination in ex situ animal conservation programs are raised. The causes and consequences of the loss of diversity in forest zones, mediterranean areas, grasslands, coastal zones and other areas, including urban areas, are explored. The importance of information gathering, monitoring systems and the role of science and technology defined. Restoration explored in general and with specifics.

68. Yeang, Ken, *The Skyscraper Bioclimatically Considered: a design primer.* 1996. 269 pages. Academy Editions, London.

Full of information that applies to more than just skyscrapers. Examples from Asia and the Pacific Rim climates.

69. Zeiher, Laura C., *The Ecology of Architecture: A Complete Guide for Creating the Environmentally Conscious Building.* 1996. 269 pages. Whitney Library of Design, New York.

A number of applications fill Dr. Zeiher's book, which begins with a history of ecology in architecture. The history continues into a description of 'socially conscious' architecture and covers renewable resource technologies as well as the necessary public "process" of creating ecologically conscious architecture. Business case studies include The Body Shop, Energy Resources, the National Audubon Society Headquarters and the Women's Humane Society Animal Shelter in Bensalem, Pennsylvania. The book ends with a review of national environmental legislation and case law and culminates in a call to action for environmentally conscious building.

Web sites

General Community Resources:

City of Portland Office of Sustainable Development - www.ci.portland.or.us/energy/peohome.htm

State of Oregon, Govenor's Executive Order, Sustainable Solutions – www.oregonsolutions.net

Building Resources:

US Green Building Council – www.usgbc.org

Environmental Building News –www.buildingreen.com/

Sustainable Building Sources - www.greenbuilder.com

Dept. of Energy Center for Sustainable Development – www.sustainable.doe.gov

Green Building Source - www.oikos.com

Certified Forest Products Council – www.certifiedwood.org

NW Ecobuilding Guild – www.ecobuilding.org

Minnesota Sustainable Design Guide – www.sustainabledesignguide.umn.edu

Rocky Mountain Institute – www.rmi.org

American Solar Energy Society – www.ase.org

Energy Star – www.epa.gov/energystar

Solstice- http:// solstice.crest.org/index.shtml

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Task 4

Conceptual Design Report
Environmental Improvement Projects
Sustainable Development

for Tainan City, Taiwan

August 15, 2001

TDA Mission Statement

The U.S. Trade and Development Agency (TDA) assists in the creation of jobs for Americans by helping U.S. companies pursue overseas business opportunities. By funding feasibility studies and related support activities, TDA directly assists American firms with market entry efforts through early involvement in the planning stage of infrastructure and industrial projects in the difficult to penetrate middle-income and developing countries.

The US Trade and Development Agency
1621 North Kent Street, Suite 200
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Task 4

CONCEPTUAL DESIGN REPORT
ENVIRONMENTAL IMPROVEMENT PROJECTS
SUSTAINABLE DEVELOPMENT
FOR TAINAN CITY, TAIWAN

Team Oregon, LLC

August 15, 2001

I. INTRODUCTION TO THE PROJECT

The US Trade and Development Agency (TDA) provided a grant to The International Sustainable Development Foundation (ISDF) to provide project services to Tainan City, Taiwan.

Tainan City is a rapidly growing city in southern Taiwan. In 1661, Cheng Cheng-kung, a military leader and Ming Dynasty loyalist, sailed across the Taiwan straits, expelled Dutch leaders, and established his capital at Tainan City and started developing the surrounding lands. Because of its history, Tainan City is considered the cultural capital of Taiwan with more than three hundred important temples and a rich historic milieu. The Tainan region also is an emerging metropolis of 1.6 million, with close economic ties to the nearby port city of Kaohsiung. Development of Taiwan's second national science park is now underway. The economic future of the city is strengthened by the presence of the National Cheng Kung University.

Team Oregon, LLC (TO), the contractor to ISDF for services to Tainan City, is responsible for developing a single integrated sustainable development (SD) approach, called the SD Framework, to provide guidance to three projects in Tainan City including the wastewater treatment system, Tainan Ecological School (Eco-School), and the Chai Tou Gang Shi (CTGS) cleanup and beautification. (See Appendix 1 for a summary of Team Oregon, LLC and ISDF.) The SD Framework will be applied to each of the three projects and guide the overall work of the project.

Team Oregon's work plan includes the following responsibilities:

- Develop the SD principles for Tainan City
- Apply the principles and guidelines to the projects
- Assess and rank a limited number of options
- Develop conceptual designs for the selected options
- Provide technical support and review the work of local firms
- Assist the city with tender preparations
- Submit a list of providers of products and services for the three projects under review and development

This report is a summary of the SD principles and guidelines developed by Team Oregon, in consultation with ISDF and Tainan City, a summary of how they can be applied to the three projects under review and development, and conceptual designs with preliminary cost estimates and ranking for the three projects.

To accomplish its work, Team Oregon traveled to Tainan City in November, 2000 and April, 2001. During the first trip, Team Oregon met with the Mayor of Tainan City, department heads, and other officials from the city and Taiwan authorities to gather basic information on the city and the three projects under review and development, and to obtain information on the sustainable development policies of Tainan City, other cities in Taiwan, and the Taiwan authorities.

During the second trip, Team Oregon gathered more information and presented its recommended SD Framework to the Mayor and agency officials. Team Oregon also met with Taiwan authorities to review project status, and with other city officials to review the SD Framework and its application to projects in Tainan.

This report details the conceptual design for each of the environmental improvement projects – the Wastewater Treatment System, the Chai Tou Gang Shi Restoration and Beautification project, and the Tainan Ecological School.

The conceptual design for each projects addresses similar elements: a description of the current situation, Team Oregon's work with Tainan City to date, the sustainable principles and guidelines and their application to the projects. Concept designs include assessment of alternatives, strategies to implement the designs, ranking of priorities, cost information for each strategy, and exhibits which provide source information on each strategy.

In addition, Appendix 4 provides information on several funding sources which may be sources of funding for the sustainability elements of the concept plans for each of the three environmental improvement projects. The international funding agencies include:

- World Bank
- Asian Development Bank
- Global Environment Facility (GEF)
- United Nations Environment Programme (UNEP)
- United Nations Development Programme (UNDP)
- USAID
- US-Asia AEP
- US Trade and Development Agency (TDA)
- Conservation International
- Turner Foundation

II. SUSTAINABLE DEVELOPMENT PRINCIPLES AND GUIDELINES

Team Oregon members met with several Taiwan authorities to gather the primary source documents and identify how they are currently being applied in Taiwan. Team Oregon found that, although Taiwan documents and research on sustainable development are exemplary, it is not clear how the vision of sustainable development is applied in practical terms to city government. Although there seems to be a general understanding of sustainable development goals, there are no readily available examples of how the research and policy recommendations can be transformed into action plans at the city level.

Although Taiwan has undertaken several efforts to identify sustainable development policies, an integrated set of sustainability principles and guidelines has not been recommended to Taiwanese cities or to Tainan City, specifically.

To date, the most important Taiwan-based documents on sustainable development include:

- *Strategic Guidelines for Sustainable Development of the Republic of China* (1998) published by the Council for Economic Planning and Development
- *Agenda 21 National Sustainable Development Strategy Guidelines* for Taiwan published by the Council for Economic Planning and Development
- *1999 Annual Report of National Sustainable Development* (1999) published by the National Council for Sustainable Development
- *Evaluation Manual for Green Building in Taiwan* (1999) published by the Ministry of the Interior

These reports were reviewed to identify the definitions of sustainable development, visions of the future, principles and guidelines recommended, and for recommendations on applying them to urban development. These primary source documents were supplemented by Team Oregon source material reviewed in Appendix 2 - Bibliography.

In developing the SD Framework, Team Oregon built on the work of Taiwan authorities. TO also reviewed the work of US cities, especially the Sustainable Portland Commission, academic research and publications in the field, and examples from other US and Pacific Rim cities.

Tainan City, through the leadership of the Mayor and departments, agreed that a clear set of examples of how an SD Framework can be applied to several practical applications is needed. Team Oregon agreed to apply the SD Framework to the projects addressed in the TDA-funded projects in Tainan City—the wastewater treatment system, Eco-School, and the Chai Tou Gang Shi cleanup and beautification.

The recommended SD Framework provided by Team Oregon includes the following six components, which are summarized in Table 1.

Definition of Sustainable Development. The common definition of sustainable development is based on *Our Common Future*, published by the 1987 Commission of Global Environment and Development of the United Nations. The definition defines the scope or the "what" of

sustainable development. The commonly accepted definition is: "development which can meet today's needs without sacrificing the ability of future generations to meet their needs." This also is the definition used commonly in Taiwanese policy documents on SD and elsewhere in the world.

Vision of a Sustainable Future. Three important visions of sustainable development were identified, based on Taiwan's *Agenda 21 National Sustainable Development Strategy Guidelines*: a sustainable ecosystem, sustainable communities and a sustainable economy. These "visions" define the primary development goals of society looking 20 to 50 years into the future. The three visions are seen as interrelated, mutually supportive, and widely shared. They can be used to define the basis for city urban development policy.

Principles of Sustainable Development. Ten sustainable development principles are included in the *Agenda 21 report on National Sustainable Development Strategy Guidelines*. These principles can be used as a decision-making checklist to help guide the development of plans, policies, programs, or projects. The principles used in the SD Framework include:

1. Consider intergenerational equity — Consider the impact of current decisions on future generations.
2. Prevent environmental overloading — Prevent pollution which causes the environment (air, water, land and ecosystems) to be overloaded to the extent that their future health is compromised.
3. Balance environment, economy and community needs — Balance the three visions of a sustainable future. Better yet, try to make decisions which benefit all three.
4. Consider impacts of decisions on human health and the environment — Develop systematic techniques such as environmental impact statements (EIS's) that consider the impacts of decisions on human health including current disease levels and causes of diseases.
5. Promote fairness and justice — Make decisions which promote the equal distribution of economic, environmental, and community costs and benefits.
6. Involve and educate the public — Use sustainable development plans, programs, and projects to involve and educate those affected.
7. Internalize costs — Include total life cycle costs in decisions on plans, programs, and projects.
8. Apply science and technology solutions to solve problems — Use new, advanced technologies to reduce and eliminate pollution and conserve and produce energy. Examples include: use of renewable energy and low energy use machinery, zero waste engineering of production facilities, etc.
9. Integrate public, private and NGO efforts — Develop cross-sector alliances for planning, programs, and projects.
10. Learn from others globally — Participate in international forums and exchanges to identify new sustainable development plans, programs, and projects from throughout the world. Of special use are the APEC Sustainable Development Network (Portland, Oregon) and the Agenda 21 Cities Network in Aalborg, Denmark.

Guidelines for Applying Sustainable Development. Guidelines on how to apply the SD Framework are included for each vision of the future—the environment, economy, and community—in Table 1. These guidelines indicate the actions necessary to achieve the visions of a sustainable environment, sustainable economy, and sustainable community. The guidelines were identified from primary Taiwanese sources cited above and other Team Oregon source materials such as those in Appendix 2—Bibliography. These guidelines can be used by Tainan City and other public and private organizations to guide the developing plans, policies, projects and programs.

Urban Development Decision-Making. Team Oregon, working with Tainan City officials, Taiwan authorities, and academic leaders in Taiwan, found that most of these leaders had a good grasp of the basic concepts of sustainable development. What they lack is a way of making urban development decisions using sustainable development concepts on a systematic basis. To address this challenge, Team Oregon developed the SD Framework to provide a way to review activities at each step in the development process, including:

- Policy-making for legislation, programs, and budgets
- Plan-making for land use, functions such as transportation, and areas such as neighborhoods
- Architectural and engineering design for sites, buildings, and public facilities
- Construction of buildings and public facilities
- Facility management

Adopting the SD Framework. To achieve the full benefit of the SD Framework, Team Oregon believes Tainan City should consider the following recommendations:

- Adopt the SD Framework through executive and/or legislative action;
- Appoint a sustainable development commission or coordinating committee for Tainan City;
- Institute a training program for city employees;
- Develop an outreach program to involve citizens, academic institutions, the private sector, and non-governmental organizations; and
- Identify obstacles to the application of the SD framework and work with the Taiwan authorities to remove those barriers.

Table 1

SUSTAINABLE DEVELOPMENT FRAMEWORK

"Sustainable development is that development which meets the needs of the present without compromising the ability of future generations to meet their own needs." --Our Common Future, 1987.

VISIONS

- A Sustainable Environment is the "Basis of Life"
- A Sustainable Economy is the "Basis for Prosperity"
- Sustainable Communities are the "Basis of Happiness and Comfortable Living"

PRINCIPLES

1. Consider intergenerational equity
2. Prevent environmental overloading
3. Balance environment, economy and community needs
4. Consider impacts of decisions on human health and the environment
5. Promote fairness and justice
6. Involve and educate the public
7. Internalize costs/full cost accounting
8. Apply science and technology solutions to solve problems
9. Support public, private, academic, and NGO cooperation
10. Learn from others globally

GUIDELINES

ENVIRONMENT

- Support clean *atmosphere*, water, land, and marine resources
- Avoid habitat destruction
- Protect and restore ecosystems
- Protect and restore biological diversity
- Assess and encourage programs to reduce negative impacts
- Develop resources consistent with prevention of natural disasters
- Reduce the output of greenhouse gases

ECONOMY

- Increase the productivity of all forms of capital
- Increase the quality and durability of goods
- Reduce, recycle and, reuse raw materials
- Substitute embodied and solar energy for produced energy
- Reduce and eliminate all forms of waste and pollution
- Apply science and technology to problems
- Develop transportation and energy supply systems consistent with SD
- Substitute non-toxic and biodegradable substances for toxic substances
- Review/revise tax, capital investment, and regulatory policies to increase SD and eliminate subsidies for non-SD
- Use life cycle cost analysis in procurement decisions

COMMUNITY

- Provide clean air, water, and food.
- Provide clean and safe shelter
- Provide a safe, clean, and beautiful community living environment
- Protect and enhance the arts and cultural and historic resources
- Provide public education on sustainable development
- Promote public involvement in decisions
- Provide collaborative, community-based decision-making with public, private, NGO participants
- Promote cooperation among levels of government and globally
- Provide access to information on decisions
- Undertake social and economic impact analysis of major decisions

INTEGRATED DECISION-MAKING

POLICY

- ✓ Leadership
- ✓ Education and information
- ✓ Tax policy
- ✓ Budget priorities
- ✓ Investment policy
- ✓ Regulation
- ✓ Procurement/ purchasing

PLANNING

- ✓ Strategic and visioning
- ✓ Comprehensive
- ✓ Agency
- ✓ Land Use
- ✓ Area or neighborhood
- ✓ Impact Analysis
- ✓ Metrics and Benchmarks

DESIGN AND ENGINEERING

- ✓ Qualification
- ✓ Concept *Development* (pre-design, programming, concepts)
- ✓ Design Process (site analysis, cost-estimating, schematic design, design development, permitting, construction documents)
- ✓ Tender
- ✓ Bidding
- ✓ Construction Administration
- ✓ Start-up and testing
- ✓ Close-out

CONSTRUCTION

- ✓ Estimation
- ✓ Qualification
- ✓ Selection
- ✓ Inspections
- ✓ Permitting
- ✓ Construction plans
- ✓ Project management
- ✓ Start-up
- ✓ Close-out

FACILITY MANAGEMENT

- ✓ Environmental Management System (EMS)
- ✓ Training
- ✓ O&M Plan
- ✓ Schedule
- ✓ Monitoring
- ✓ Cleaning
- ✓ Repair
- ✓ Remodel and replace
- ✓ Waste management (reduce, reuse, recycle)
- ✓ Energy management

- Applied to:
- Infrastructure
- Services (HVAC, electrical, telecom, lighting, controls)
- Fixed interior
- Supplies
- Furnishings
- Mechanical and industrial
- equipment
- Energy supply

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III. APPLICATION OF PRINCIPLES AND GUIDELINES

Using the SD Framework, three projects were reviewed and are summarized below.

Wastewater Treatment System. Team Oregon reviewed planning documents and conducted interviews with Tainan City, Taiwan authorities, and other city officials to gain a better understanding of the overall wastewater treatment system plan for the Tainan region. Team Oregon identified the major wastewater treatment system elements (treatment plants, collection and conveyance system, pumping station, etc.) and developed an understanding of how each of these elements operate and integrate with each other. Based on this understanding, Team Oregon applied the SD Framework to the development of the wastewater treatment system conceptual designs.

Chai Tou Gang Shi. The Chai Tou Gang Shi is a small urban watershed that is currently developed with commercial, residential and light industrial land uses. The CTGS currently holds raw sewage effluent and heavy seasonal rains. Several interrelated issues are being addressed in this clean-up and beautification project: sewage treatment, stream flow and flooding; stream-bank beautification and parklands including a possible greenbelt; bridge crossings, parking and transportation issues; and possible commercial development. Concept designs to address these issues will be developed using the SD Framework.

Tainan Ecological School. Tainan City is designing and developing a new primary school to reflect SD principles and guidelines and be a national model for a "green building." The design for the Eco-School will focus on integrating the SD Framework into the project by addressing the management of water, energy usage, indoor air quality and the toxicity of materials, resource guidelines, and related subjects. Team Oregon worked specifically with the school architect and Tainan Bureau of Education to integrate sustainable design elements into the conceptual designs of the Eco-School.

IV. WASTEWATER TREATMENT SYSTEM CONCEPTUAL DESIGN

Untreated wastewater can affect the environment in several ways. It contains many pathogens that can cause disease and contains nutrients that can negatively impact surrounding environments by causing eutrophication of water bodies; and it depletes the dissolved oxygen supply in receiving waters and may contain toxic substances from industrial wastes. Also, if allowed to accumulate, it can be the source of malodorous gases negatively impacting the quality of life for nearby residents. The role of wastewater treatment is to protect the environment in a way that addresses public health, economic, social, and political concerns (Metcalf & Eddy, 1991).

Through two visits—in November, 2000 and April, 2001—Team Oregon was able to review planning documents and interview Tainan City and Taiwan authorities Government officials to gain an understanding of the wastewater treatment system facilities planned for Tainan City. The City's plans call for the wastewater collection and treatment system to be completed by 2021.

The design and planning for the treatment facilities is primarily funded through Taiwan Central Government authorities. Tainan City currently has plans to construct a wastewater collection system consisting of small pipelines, trunks, and mainlines. Some of these pipelines already have been constructed. Flow through these pipelines will be primarily by gravity and, due to the topography of the city, flows will be directed to one of six wastewater treatment plants. The treatment plants, which are in various stages of planning and design, have design flows ranging from 12,000 to 181,000 cubic meters per day (CMD) or 3.2 to 47.8 million gallons per day (MGD). Currently, there are no plans for intermediate wastewater pump stations.

Of the six wastewater treatment plants, two are currently constructed—one is currently in testing, and the other is not expected on-line for approximately 18 months. The remaining four treatment facilities are in planning stages. In addition to these facilities, Tainan County has plans for at least one wastewater treatment facility close to one of the treatment plants planned for the City. Current plans show a main collection trunk line for each of these plants on opposite sides of the Chai Tou Gang Shi, a local waterway.

The treatment plants are all designed for secondary treatment, and discharge to nearby water bodies. Typical wastewater treatment plant processes are planned for each of these plants. Liquid processes include screening, primary and secondary settling, aeration, and disinfection. Solid handling processes include sludge thickening, aerobic and/or anaerobic digestion, and dewatering. In addition to the large processes, monitoring and sampling equipment also will be necessary.

Review of the planned wastewater treatment system facilities shows that Tainan City has plans to systematically reduce the impact of sanitary waste on the environment. The following report describes additional features that can be considered to incorporate sustainable concepts into Tainan's wastewater treatment system.

DESIGN PRINCIPLES & GUIDELINES

Wastewater treatment facilities inherently strive to achieve some of the goals of sustainable development by cleaning wastewater and supporting clean water resources. Wastewater treatment plants (WWTP's) are designed to operate reliably, economically, and unobtrusively to meet discharge standards. In addition, the design of the facilities should address regulatory requirements, public goals, financial constraints, and incorporate appropriate technology to achieve these goals (WEF, 1998).

Integrating sustainable concepts into the wastewater treatment systems results in the list of sustainable strategies shown in Tables IV-2 through IV-4. The tables also show how the strategies are related and prioritized against the Sustainable Guidelines described in Section II of this report. Higher priorities (a score of 1) were given to strategies that have a more significant positive impact on the environment in Tainan.

DESIGN ALTERNATIVES

Several sustainable design alternatives related to wastewater treatment systems are being used in various communities throughout the United States. The alternatives or strategies that should be considered in Tainan can be broken down into five main approaches. These include:

- Treatment System Alternatives
- Regional Governments
- Use of Natural Systems
- Recycle/Reuse of Waste
- Life Cycle Cost Estimation

Treatment System Alternatives

Centralized Treatment vs. Decentralized Treatment. Large centralized treatment facilities have been the norm for larger communities. Recently, a closer look at utilizing cluster systems to treat wastewater has been examined. Cluster systems are "wastewater collection and treatment systems where two or more dwellings, but less than the entire community, are served. The wastewater from several homes may be pretreated onsite by individual septic tanks or package plants before being transported through low cost, alternative technology sewers to a treatment unit that is relatively small compared to centralized systems" (USEPA, 1997).

The choice for communities without wastewater treatment systems has been whether or not to build one centralized treatment facility or to build several smaller facilities. The most cost-effective solution is based on a combination of population density, distance to sewer

interceptor, topography, and availability of land. Other costs to consider include operation, maintenance, and the ability of the receiving environment to assimilate the effluent.

Typically, the choice of a decentralized system is best suited for areas with low population densities. Constructing centralized treatment facilities in these areas is often economically unfeasible because of the large distances between homes, the significant piping required to tie in all the connections, and the inability to achieve economies of scale (i.e., a certain number of users to support system costs) (USEPA, 1997).

Alternately, in areas where population density is high (i.e., urban or suburban areas), large-scale, centralized collection and treatment of wastewater is usually most cost-effective (USEPA, 1997). In these areas the system costs can be distributed across a large number of users.

Wastewater Lift Stations. Current plans in Tainan call for six large treatment plants to treat wastewater generated within the city. The number of plants has been dictated by the relatively flat topography of the landscape. Wastewater lift stations are facilities designed to move wastewater from lower to higher elevations through pipes. This technology is particularly applicable where the elevation of the source is not sufficient for gravity flow and/or when the use of gravity conveyance will result in excessive excavation depths and high sewer construction costs (USEPA, 2000b). The incorporation of these types of facility into Tainan's collection system could reduce the number of necessary wastewater treatment plants by enabling wastewater flows to be efficiently moved from one section of the city to another.

The primary advantage of wastewater lift stations is in the reduction of capital costs for collection system construction. Pipe installation costs can be minimized if trench depths can be kept at a minimum (less than three meters or ten feet). In addition, pumping wastewater can convey the same amount of flow using a smaller pipe at a shallower depth, further reducing pipeline costs (USEPA, 2000b).

Disadvantages to pump stations include the relatively high cost to construct the pump station facility compared to the construction of conveyance systems. Construction costs depend on design flow rate. Costs can range from US $130,000 for a 0.5 MGD (1,900 CMD) facility to US $128,000,000 for a 750 MGD (2,84,000 CMD). Additional costs for the pump station facilities include the building construction costs, a source for power and emergency power, odor and noise control, operation and maintenance, and addressing public concerns and/or negative reaction. Typically power costs account for 85 to 95 percent of the total operation and maintenance costs, while labor costs average 1 to 2 percent. Overall operation and maintenance costs vary, depending on the complexity of the equipment and instrumentation (USEPA, 2000b). See item 1 in the Wastewater Treatment (WWT) Conceptual Design Information section.

Despite the potentially high capital and operation and maintenance costs of wastewater pump stations versus collection systems, they are by far less expensive than the construction of complete treatment plants. Savings could be realized by utilizing pump stations at various points within Tainan City to transport wastewater to fewer treatment plants. As a result of the reduced number of treatment plants, fewer discharge points into nearby water bodies would be necessary, reducing the impact on the environment.

For example, the collection system for the city of Portland, Oregon serves approximately 530,000 people over 94,000 acres (38,000 ha). The system is comprised of over 2,250 miles (3,620 km) of sewer and storm pipe, and 90 lift stations. This system transports the City's wastewater and stormwater to one of two wastewater treatment plants (City of Portland Web site).

Disinfection Alternatives. There are three main methods of disinfection being used in wastewater treatment facilities today: chlorine disinfection, ozone disinfection, and ultraviolet (UV) disinfection. Chlorine disinfection is the most widely used method of disinfecting municipal wastewater. It does, however, have certain health and safety limitations (USEPA, 1999a). Ozone disinfection has the ability to achieve a higher level of disinfection than either chlorine or UV. The capital costs and operation and maintenance costs, however, are higher for this technology (USEPA, 1999b). UV disinfection is as effective as chlorine but, being a physical process rather than based on a chemical process, eliminates the exposure to toxic/hazardous or corrosive chemicals (USEPA, 1999c). Advantages and disadvantages for each technology are listed in Table IV-1. The complete USEPA Fact Sheets are presented as items 2-4 of the Wastewater WWT Conceptual Design Information section.

Disinfection processes are included in each of Tainan's planned treatment plants. Chlorine disinfection is the primary technology planned. Alternative disinfection technologies should be evaluated to determine if economic, community, or environmental benefits can be achieved.

TABLE IV-1
Advantages & Disadvantages of Disinfection Alternatives

Disinfection Alternative	Advantages	Disadvantages
Chlorine[1]	• Chlorination is a well-established technology. • Chlorine is more cost-effective than either UV or ozone disinfection. • The chlorine residual that remains in the wastewater effluent can prolong disinfection even after initial treatment and can be measured to evaluate the effectiveness. • Chlorine disinfection is reliable and effective against a wide spectrum of pathogenic organisms. • Chlorine is effective in oxidizing certain organic and inorganic compounds. • Chlorination has flexible dosing control. • Chlorine can eliminate certain noxious odors during disinfection.	• The chlorine residual, even at low concentration, is toxic to aquatic life and may require dechlorination. • All forms of chlorine are highly corrosive and toxic. Thus, storage, shipping, and handling pose a risk, requiring increased safety regulations. • Chlorine oxidizes certain types of organic matter in wastewater, creating more hazardous compounds. • The level of total dissolved solids is increased in the treated effluent. • The chlorine content of the wastewater is increased. • Chlorine residual is unstable in the presence of high concentrations of chlorine-demanding materials, thus requiring higher doses to effect adequate disinfection. • Some parasitic species have shown resistance to low doses of chlorine, including oocysts of Cryptosporidium parvum, cysts of Endamoeba histolytica, and Giardia lambila, and eggs of parasitic worms. • Long-term effects of discharging dechlorinated compounds into the environment are unknown.
Ozone[2]	• More effective than chlorine in destroying viruses and bacteria. • The ozonation process utilizes a short contact time. • No harmful residuals need to be	• Low dosage may not effectively inactivate some viruses, spores, and cysts. • Ozonation is a more complex technology than is chlorine or UV

Disinfection Alternative	Advantages	Disadvantages
	removed after ozonation because ozone decomposes rapidly. • No regrowth of microorganisms, except for those protected by the particulates in the wastewater stream. • Ozone is generated onsite, and thus, there are fewer safety problems associated with shipping and handling. • Elevates the dissolved oxygen concentration of the effluent which can eliminate the need for re-aeration and also raise the level of dissolved oxygen in the receiving stream.	disinfection, requiring complicated equipment and efficient contacting systems. • Ozone is very reactive and corrosive, thus requiring corrosion-resistant material such as stainless steel. • Ozonation is not economical for wastewater with high levels of suspended solids, biological oxygen demand, chemical oxygen demand, or total organic carbon. • Ozone is extremely irritating and possibly toxic, so off-gases from the contactor must be destroyed to prevent worker exposure. • The cost of treatment can be relatively high in capital and power intensiveness.
Ultraviolet[3]	• Effective at inactivating most viruses, spores, and cysts. • Physical process rather than a chemical disinfectant, eliminating the need to generate, handle, transport, or store toxic/hazardous or corrosive chemicals. • No residual effect that can be harmful to humans or aquatic life. • User-friendly for operators. • Has a shorter contact time when compared with other disinfectants. • Requires less space than other methods.	• Low dosage may not effectively inactivate some viruses, spores, and cysts. • Organisms can sometimes repair and reverse the destructive effects of UV through a "repair mechanism." • A preventative maintenance program is necessary to control fouling of tubes. • Turbidity and total suspended solids in the wastewater can render UV disinfection ineffective. • UV disinfection is not as cost-effective as chlorination, but costs are competitive when chlorination dechlorination is used and fire codes are met.

[1] USEPA, 1999a
[2] USEPA, 1999b
[3] USEPA, 1999c

Regional Governments

Regional governments are typically developed to deal with issues that are more efficiently addressed on a large scale, or when cooperation among government agencies is required. They also are effective where government agencies, such as cities and counties, cannot afford the cost of large projects like sewage treatment plants. Considering multiple priorities cities and counties have for their financial resources, a regional government can relieve these economic pressures.

A regional government is a governing body that, in some cases, coordinates land use planning and services for a region. This body frequently can be is responsible for maintaining and enhancing the livability for a region. In Portland, Oregon, for example, the local regional government known as Metro is responsible for regional land use and transportation planning, solid waste issues, and is further empowered to address any other issues of "metropolitan concern" (Metro Web site).

Metro is a directly elected regional government that serves residents in three counties and 24 cities in the Portland, Oregon metropolitan area. Its primary mission is to manage growth in the region. To that end, it provides transportation and land-use planning services and oversees regional garbage disposal and recycling waste reduction programs. Metro is governed by an executive officer (elected region-wide), and a seven-member council (elected by districts). Citizen advisory committees play an important part in this government by providing input and advice to the council, executive officer, and staff on various regional issues (Metro Web site).

Another type of regional government in the Portland area is CleanWater Services. This agency addresses water pollution problems in a local watershed, which covers portions of three counties and 15 cities. CleanWater Services owns, operates, and maintains or controls the sanitary sewerage collection and treatment system within its service area. It also maintains the public drainage and flood management systems and is responsible for surface water quality in the area (CleanWater Services Web site).

The CleanWater Services Advisory Commission is a body within the CleanWater Services organization that consists of 15 members, each serving three-year terms. Their purpose is to review, discuss and make recommendations to the Board of Directors on major policy issues and programs (CleanWater Services Web site).

The advantage of establishing a regional government is that region-wide issues are addressed and solutions are established for a region, thus eliminating duplicate efforts in several nearby cities and/or counties. This type of arrangement for water, wastewater, and other services between Tainan City and Tainan County may be beneficial.

Natural Systems

Natural systems used to treat wastewater are designed to emulate nature's ability to treat itself. There are many systems being used around the world today, but two seem suited to Tainan: constructed wetlands and Living Machine™ technology. The construction and operations and

maintenance costs of these systems vary widely and are dependent on size, operational procedures, and waste treated.

Constructed Wetlands. Constructed wetlands for wastewater treatment systems are engineered systems that utilize natural processes. These systems are designed to mimic a natural wetland system, utilizing wetland plants, soils and their associated microorganisms to remove contaminants from wastewater effluents. In addition, constructed wetlands provide an opportunity to create valuable wetland habitat for wildlife use and environmental enhancement (USEPA, 1993).

There are two types of constructed wetlands - subsurface flow and free water surface systems. Subsurface flow systems are designed to keep the water to be treated beneath the surface contained in a permeable membrane. The main feature of this design is to avoid the development of odors and other nuisance problems. Free water surface systems, on the other hand, are designed to simulate natural wetlands with the water flowing over the soil surface at shallow depths. Both types are typically constructed in basins or channels with a natural or constructed subsurface barrier to limit seepage (USEPA, 1993).

The USEPA document, "Constructed Wetlands for Wastewater Treatment and Wildlife Habitat: 17 Case Studies," presents case studies of several different applications from across the United States where constructed wetlands are being used to treat wastewater and provide enhancement opportunities for local resources. This document can be ordered directly from the USEPA or viewed over the Internet at: www.epa.gov/OWOW/wetlands/construc/.

The USEPA has several other documents describing the use of constructed wetlands for wastewater treatment. Many are available through their Web site (www.epa.gov). Some are listed in the References in the WWT Conceptual Design Information section. Two fact sheets discussing the subsurface flow and free water surface wetland systems are included as items 5 and 6 of the WWT Conceptual Design Information section.

A free surface constructed wetland system may be well suited for Tainan. An existing fish pond could be converted into a constructed wetland to polish treatment plant effluent. In the process, the system would create a natural habitat in the city for birds and other local wildlife.

Living Machines™. Living Machine™ technology is a relatively new technology first developed in the 1970's. This technology stresses using natural ecosystems to treat wastes. They are ecologically designed aquatic systems that utilize a diverse community of biological organisms, from bacteria to plants and fish, to treat water to advanced levels (Living Machines, Inc. Web site). Although this is a relatively new technology, there are several installations around the United States and globally where systems are in successful operation. Most applications are for smaller flows, up to 80,000 gallons per day (GPD) (303 CMD), although there is work being done to evaluate these systems for use with larger flow rates.

Systems typically include anaerobic and aerobic treatment areas which can contain plants, fish, snails, bacteria, and many other organisms that act together to breakdown pollutants in wastewater. The effluent from these systems can be discharged, recirculated, creating a

completely closed treatment cycle, or reused for irrigation or other purposes (e.g., used for flushing toilets).

There are several applications of the Living Machine™ technology in place in the United States. One application, located at Ethel M® Chocolates in Henderson, Nevada, uses a Living Machine™ to treat 32,000 GPD (121 CMD) of process wastewater. The effluent from the Living Machine™ treatment process is reused on-site for landscape irrigation. On average, the BOD in the effluent is 6 mg/l, reduced from 1,270 mg/l. Total suspended solids are decreased from 309 mg/l to 5 mg/l. Additional information for this facility, as well as two other facilities where Living Machines™ are being used, is available in items 7-9 of the WWT Conceptual Design Information section. More information on Living Machines™ can be obtained at the Web sites listed in the References section of the WWT Conceptual Design Information section.

In Tainan, this technology can used to treat localized treatment flows (e.g., the Eco-school, museums, small community developments) and can provide an excellent opportunity for community education.

Recycle/Reuse Waste

Chai Tou Gang Shi Restoration. The Chai Tou Gang Shi is an urban channel that acts as the border between Tainan City and Tainan County. Currently water in this channel is very polluted and, for the most part, consists primarily of raw sewage. Flow rates in the channel fluctuate with rainfall, and flooding occurs in places along the channel creating a health hazard for those who live nearby.

Plans to restore and revitalize this channel are underway and should include cleaning up the water. The City has plans for a wastewater treatment facility near the upstream end of this channel. Tainan County also has plans to locate a wastewater treatment facility nearby. Plans for each facility show an associated main trunk line running parallel to the Chai Tou Gang Shi on opposite banks. To avoid this costly duplication, a single line, jointly owned, could be installed under the river channel. This line would be used and maintained by both Tainan City and Tainan County.

In addition, the restoration process for the Chai Tou Gang Shi could include the collection of sewage and stormwater that currently flow into this channel, and route it to one new treatment facility located in either Tainan City or within Tainan County. Treated effluent could be discharged into the channel providing cleaner water and a more steady flow with which to incorporate further beautification features. See the Chai Tou Gang Shi Conceptual Design Information section for conceptual sketches and cross sections of this proposal.

Fuel Cell Technology. A fuel cell is an electrochemical device that uses hydrogen and oxygen to produce electricity and heat. The source of oxygen is typically obtained from the air. The source of hydrogen can be obtained from natural gas, propane, and methane (Nice, Web page). There are some fuel cells currently being used that obtain their hydrogen source from anaerobic digester gas. The methane in this gas is used to extract the necessary hydrogen to run the fuel cell.

In Portland, Oregon, the Columbia Boulevard Wastewater Treatment Plant is currently using one of these fuel cells to generate electricity for use in the facility. Their fuel cell consumes approximately 50 cubic feet (1.4 cubic meters) of digester gas a minute to produce approximately 175 kW of power. It is estimated that they produce as much as 1.6 million kW-hr per year (Simonson, 2001).

Fuel cells range in size from 5 to 2,000 kW. Initial installation costs run approximately US $3,000-US $4,000 per kW for the system, which includes the fuel cell, a hydrogen stripper, a DC to AC converter, and equipment for making use of waste heat. Cost to generate electricity runs about US $0.10-US $0.15 per kWh (NRECA, 2001).

This technology installed at Tainan's treatment facilities will help minimize the amount of digester gas that must be vented into the atmosphere and also will subsidize the electricity needed to operate the plant facilities.

Microturbine Technology. Microturbines are smaller versions of a traditional fuel-burning, power-producing turbine. They are, however, smaller and cleaner burning. They operate using a variety of liquid and gas fuels, including natural gas or methane. Although they are not as clean burning as a fuel cell, microturbines are significantly cleaner than traditional turbines or combustion engines. In addition, the waste heat generated can be used for hot water, chilling, or direct heat.

Microturbines are less expensive than fuel cells. Installation costs are estimated to be US $1,000-US $1,500 per kW. The cost to generate electricity is roughly US $0.08-US$0.10 per kWh (NRECA, 2001). The Natural Rural Electric Cooperative Association (NRECA) white paper further describing fuel cell and microturbine technology is included as item 10 of the WWT Conceptual Design Information section.

Land Application of Biosolids. Biosolids are a natural, nutrient-rich by-product of municipal wastewater treatment. Recycling this by-product of wastewater treatment through land application returns a useful resource to the land. Biosolids are rich in nutrients and organic matter that aid the growth of farm crops, gardens, forests, and parks (City of Portland Web site).

The application of biosolids must be carefully monitored. Application rates must not exceed the nutrient requirements of the vegetation to prevent excess nutrients from leaching into groundwater or impacting surface water. Maintenance of a buffer zone between application areas and surface water bodies will also help to minimize impacts to surface waters. Monitoring of the application biosolids also helps to prevent the accumulation of metals to harmful levels. Although some metals such as nickel, zinc, and copper are necessary nutrients in small amounts, their accumulation could negatively impact human health (USEPA, 2000a). The USEPA Fact Sheet further describing the process of land application of biosolids, its advantages and disadvantages, is included as item 11 of the WWT Conceptual Design Information section.

Current plans in Tainan call for the disposal the of treatment plant biosolids to a local land fill, and possibly through incineration. While these are appropriate methods of disposal, there is

the opportunity to use these solids in a more beneficial manner. Plant biosolids could be used for land application on local farms or large nurseries. By recycling the biosolids to land application, landfill space will be freed up, air emissions from incineration will be eliminated, and nutrients and organic matter will be returned to the soils.

Composting of Biosolids. Another opportunity to use biosolids generated through the wastewater treatment process is through composting. Composting is the breakdown of organic materials through biological means under controlled aerobic conditions. The process is used to stabilize wastewater solids, destroy pathogens, minimize odors, and reduce their potential vector attraction properties. The stabilized solids are then used as a soil amendment or mulch in landscaping, horticulture, and agriculture (USEPA, 2000c).

There are three general methods for composting biosolids: windrow, aerated static pile, and in-vessel. Of these three methods, in-vessel composting allows for the best control of the composting process. This process is further described in the EPA Fact Sheet, item 12 in the WWT Conceptual Design Information section. For all three composing methods, however, the physical qualities (moisture content, volatile solids content, carbon content, nitrogen content, and bulk density) of the biosolids are important to achieve successful composting (USEPA, 2000c).

Composting produces a reusable product that returns valuable nutrients to the soil and enhances conditions for vegetative growth. It also is easier to handle than other biosolids products. Composting costs, particularly for in-vessel systems, can be significant. Costs for composting have been estimated at between US $100 and US $280 per dry ton of biosolids processed, with in-vessel systems falling into the high end of the cost range (USEPA, 2000c).

In-vessel composting is more suitable in urban and suburban areas because the system allows for containment and treatment of air to remove odors before release. The process requires a relatively small amount of land which also makes this technology well-suited for the urban and suburban setting.

Life Cycle Cost Analysis

When evaluating products or systems, the total cost of an alternative should not be limited to merely the construction, operations and maintenance costs. Life cycle cost analysis is a better indicator of cost and benefits that a system or product will provide. Life cycle cost is the "amortized annual cost of a product, including capital costs, installation costs, operating costs, maintenance costs, and disposal costs discounted over the lifetime of a product" (USEPA, 1995). By performing a life cycle cost analysis, the most cost-effective approach for using available resources over the entire lifespan of the product or system can be selected. Not only financial costs, but also environmental and societal costs are taken into account when conducting this type of analysis. Life cycle cost analysis, then, can be used as an effective tool to compare sustainable alternatives.

TABLE IV-2
Application of Sustainable Development Guidelines for the Environment

	Environment Sustainable Guidelines	Strategy	Priority
1	Support clean atmosphere, water, land, and marine resources	• Collection & treatment system.	1
2	Avoid habitat destruction	• Clean waterways—Chai Tou Gang Shi restoration.	1
3	Protect and restore ecosystems	• Use of constructed wetlands for treatment/polishing.	2
4	Protect and restore biological diversity	• Use of constructed wetlands for treatment/polishing.	2
5	Assess and encourage programs to reduce negative impacts	N/A	--
6	Develop resources consistent with prevention of natural disasters	N/A	--
7	Reduce the output of greenhouse gases	• Use methane gas produced as a power source (fuel cells, microturbines, etc.).	2

TABLE IV-3
Application of Sustainable Development Guidelines for the Economy

	Economy Sustainable Guidelines	Strategy	Priority
1	Increase the productivity of all forms of capital	• Consider establishing Regional Government for wastewater management.	3
		• Centralized vs. decentralized treatment systems.	2
		• Chai Tou Gang Shi restoration will generate economic opportunity in adjacent community.	1
		• Compost biosolids for sale to agriculture industry.	2
2	Increase the quality and durability of goods	• Evaluate and maximize life-span of products being used (pipe, equipment, materials, etc.).	2
3	Reduce, recycle and, reuse raw materials	• Use treated effluent for irrigation, influent to fish ponds, etc.	2
		• Use Living Machine™ to grow food.	3
4	Substitute embodied and solar energy for produced energy	• Use methane gas generated as power source (fuel cells, microturbines, etc.).	2
5	Reduce and eliminate all forms of waste and pollution	• Use methane as power source (fuel cells, microturbines, etc.).	2
		• Land application of sludge.	2
6	Apply science and technology to problems	• Use of constructed wetlands or Living Machine™ technology and other "state of the art" treatment systems.	3
		• Use most energy and resource efficient equipment in buildout of plan.	1
7	Develop transportation and energy supply systems consistent with SD	• Use methane gas generated as power source at treatment plant (fuel cells, microturbines, etc.).	2
8	Substitute non-toxic and biodegradable substances for toxic substances	• Use non-toxic substances in treatment processes (e.g., UV or ozone instead of chlorine).	2
9	Review/revise tax, capital investment, and regulatory policies to increase SD and eliminate subsidies for non-SD	• Review/revise government policies that promote multiple treatment plants over pump stations.	2
10	Use life cycle cost analysis in procurement decisions	• Perform life cycle cost analysis to wastewater treatment process.	2

TABLE IV-4
Application of Sustainable Development Guidelines for the Community

	Community Sustainable Guidelines	Strategy	Priority
1	Provide clean air, water, and food	• Collection & treatment system.	1
2	Provide clean and safe shelter	• Utilize green building techniques for treatment plant buildings.	2
3	Provide a safe, clean, and beautiful community living environment	• Discharge effluent from treatment plant near Chai Tou Gang Shi to Chai Tou Gang Shi removing raw sewage from channel.	1
		• Constructed wetlands as wildlife habitat.	2
4	Protect and enhance the arts and cultural and historic resources	N/A	--
5	Provide public education on sustainable development	• Use treatment plant site for educational opportunity to educate the local community.	2
		• Provide public space for meetings or other local community activities.	3
6	Promote public involvement in decisions	N/A	--
7	Provide collaborative, community-based decision-making with public, private, NGO participants	N/A	--
8	Promote cooperation among levels of government and globally	• Consider establishing Regional Government for wastewater management.	3
9	Provide access to information on decisions	N/A	--
10	Undertake social and economic impact analysis of major decisions	N/A	--

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Exhibits

IV-1	USEPA Collection Systems Technology Fact Sheet: Sewers, Lift Station
IV-2	USEPA Wastewater Technology Fact Sheet: Chlorine Disinfection
IV-3	USEPA Wastewater Technology Fact Sheet: Ozone Disinfection
IV-4	USEPA Wastewater Technology Fact Sheet: Ultraviolet Disinfection
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IV-7	Case Study: Ethel M® Chocolates, Henderson, Nevada
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IV-10	NRECA White Paper on Distributed Generation
IV-11	USEPA Biosolids Technology Fact Sheet: Land Application of Biosolids
IV-12	USEPA Biosolids Technology Fact Sheet: In-Vessel Composting of Biosolids

United States Environmental Protection Agency
Office of Water Washington, D.C.
EPA 832-F-00-073 September 2000

Collection Systems Technology Fact Sheet
Sewers, Lift Station

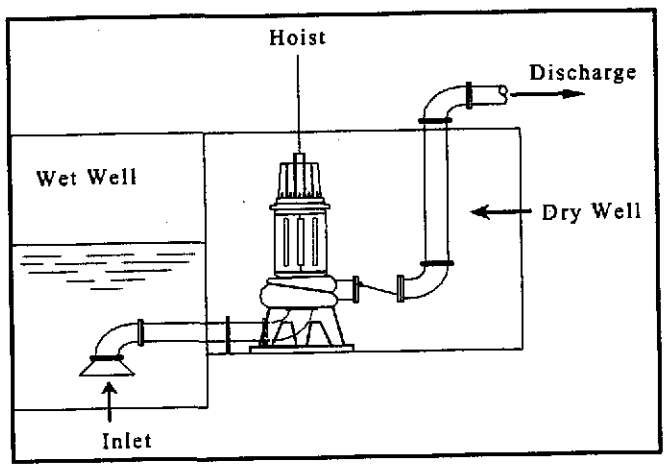
DESCRIPTION

Wastewater lift stations are facilities designed to move wastewater from lower to higher elevation through pipes. Key elements of lift stations include a wastewater receiving well (wet-well), often equipped with a screen or grinding to remove coarse materials; pumps and piping with associated valves; motors; a power supply system; an equipment control and alarm system; and an odor control system and ventilation system.

Lift station equipment and systems are often installed in an enclosed structure. They can be constructed on-site (custom-designed) or pre-fabricated. Lift station capacities range from 76 liters per minute (20 gallons per minute) to more than 378,500 liters per minute (100,000 gallons per minute). Pre-fabricated lift stations generally have capacities of up to 38,000 liters per minute (10,000 gallons per minute). Centrifugal pumps are commonly used in lift stations. A trapped air column, or bubbler system, that senses pressure and level is commonly used for pump station control. Other control alternatives include electrodes placed at cut-off levels, floats, mechanical clutches, and floating mercury switches. A more sophisticated control operation involves the use of variable speed drives.

Lift stations are typically provided with equipment for easy pump removal. Floor access hatches or openings above the pump room and an overhead monorail beam, bridge crane, or portable hoist are commonly used.

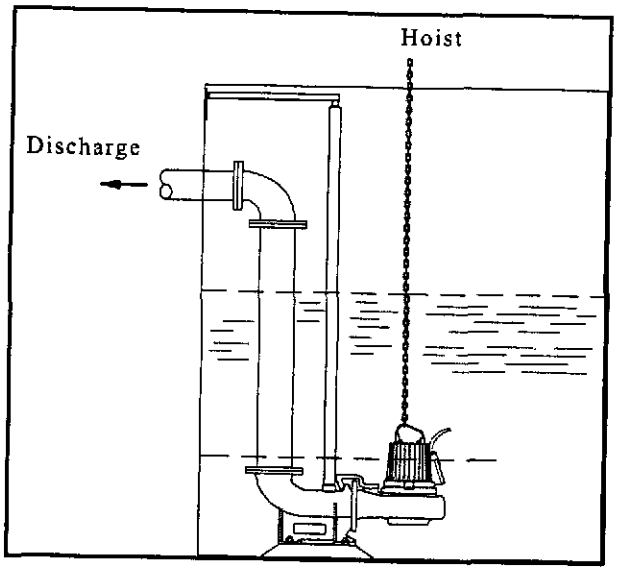
The two most common types of lift stations are the dry-pit or dry-well and submersible lift stations. In dry-well lift stations, pumps and valves are housed in a pump room (dry pit or dry-well), that is easily accessible. The wet-well is a separate chamber attached or located adjacent to the dry-well (pump room) structure. Figures 1 and 2 illustrate the two types of pumps.



Source: Qasim, 1994.

FIGURE 1 DRY-WELL PUMP

Submersible lift stations do not have a separate pump room; the lift station header piping, associated valves, and flow meters are located in a separate dry vault at grade for easy access. Submersible lift stations include sealed pumps that operate submerged in the wet-well. These are removed to the surface periodically and reinstalled using guide rails and a hoist. A key advantage of dry-well lift stations is that they allow easy access for routine visual inspection and maintenance. In general, they are easier to repair than submersible pumps. An advantage of submersible lift stations is that they typically cost less than dry-well stations and operate without frequent pump maintenance. Submersible lift stations do not usually include



Source: Qasim, 1994.

FIGURE 2 WET-WELL SUBMERSIBLE

large aboveground structures and tend to blend in with their surrounding environment in residential areas. They require less space and are easier and less expensive to construct for wastewater flow capacities of 38,000 liters per minute (10,000 gallons per minute) or less.

APPLICABILITY

Lift stations are used to move wastewater from lower to higher elevation, particularly where the elevation of the source is not sufficient for gravity flow and/or when the use of gravity conveyance will result in excessive excavation depths and high sewer construction costs.

Current Status

Lift stations are widely used in wastewater conveyance systems. Dry-well lift stations have been used in the industry for many years. However, the current industry-wide trend is to replace dry-well lift stations of small and medium size (typically less than 24,000 liters per minute or 6,350 gallons per minute) with submersible lift stations mainly because of lower costs, a smaller footprint, and simplified operation and maintenance.

Variable speed pumping is often used to optimize pump performance and minimize power use. Several types of variable-speed pumping equipment are available, including variable voltage and frequency drives, eddy current couplings, and mechanical variable-speed drives. Variable-speed pumping can reduce the size and cost of the wet-well and allows the pumps to operate at maximum efficiency under a variety of flow conditions. Because variable-speed pumping allows lift station discharge to match inflow, only nominal wet-well storage volume is required and the well water level is maintained at a near constant elevation. Variable-speed pumping may allow a given flow range to be achieved with fewer pumps than a constant-speed alternative. Variable-speed stations also minimize the number of pump starts and stops, reducing mechanical wear. Although there is significant energy saving potential for stations with large friction losses, it may not justify the additional capital costs unless the cost of power is relatively high. Variable speed equipment also requires more room within the lift station and may produce more noise and heat than constant speed pumps.

Lift stations are complex facilities with many auxiliary systems. Therefore, they are less reliable than gravity wastewater conveyance. However, lift station reliability can be significantly improved by providing stand-by equipment (pumps and controls) and emergency power supply systems. In addition, lift station reliability is improved by using non-clog pumps suitable for the particular wastewater quality and by applying emergency alarm and automatic control systems.

ADVANTAGES AND DISADVANTAGES

Advantages

Lift stations are used to reduce the capital cost of sewer system construction. When gravity sewers are installed in trenches deeper than three meters (10 feet), the cost of sewer line installation increases significantly because of the more complex and costly excavation equipment and trench shoring techniques required. The size of the gravity sewer lines is dependent on the minimum pipe slope and flow. Pumping wastewater can convey the same flow using smaller pipeline size at shallower depth, and thereby, reducing pipeline costs.

Disadvantages

Compared to sewer lines where gravity drives wastewater flow, lift stations require a source of electric power. If the power supply is interrupted, flow conveyance is discontinued and can result in flooding upstream of the lift station, It can also interrupt the normal operation of the downstream wastewater conveyance and treatment facilities. This limitation is typically addressed by providing an emergency power supply.

Key disadvantages of lift stations include the high cost to construct and maintain and the potential for odors and noise. Lift stations also require a significant amount of power, are sometimes expensive to upgrade, and may create public concerns and negative public reaction.

The low cost of gravity wastewater conveyance and the higher costs of building, operating, and maintaining lift stations means that wastewater pumping should be avoided, if possible and technically feasible. Wastewater pumping can be eliminated or reduced by selecting alternative sewer routes or extending a gravity sewer using direction drilling or other state-of-the-art deep excavation methods. If such alternatives are viable, a cost-benefit analysis can determine if a lift station is the most viable choice.

DESIGN CRITERIA

Cost effective lift stations are designed to: (1) match pump capacity, type, and configuration with wastewater quantity and quality; (2) provide reliable and uninterruptible operation; (3) allow for easy operation and maintenance of the installed equipment; (4) accommodate future capacity expansion; (5) avoid septic conditions and excessive release of odors in the collection system and at the lift station; (6) minimize environmental and landscape impacts on the surrounding residential and commercial developments; and (7) avoid flooding of the lift station and the surrounding areas.

Wet-well

Wet-well design depends on the type of lift station configuration (submersible or dry-well) and the type of pump controls (constant or variable speed). Wet-wells are typically designed large enough to prevent rapid pump cycling but small enough to prevent a long detention time and associated odor release.

Wet-well maximum detention time in constant speed pumps is typically 20 to 30 minutes. Use of variable frequency drives for pump speed control allows wet-well detention time reduction to 5 to 15 minutes. The minimum recommended wet-well bottom slope is to 2:1 to allow self-cleaning and minimum deposit of debris. Effective volume of the wet-well may include sewer pipelines, especially when variable speed drives are used. Wet-wells should always hold some level of sewage to minimize odor release. Bar screens or grinders are often installed in or upstream of the wet-well to minimize pump clogging problems.

Wastewater Pumps

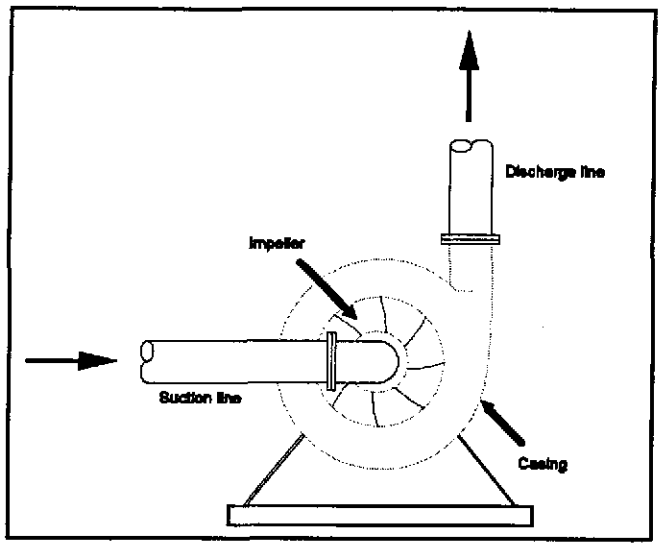
The number of wastewater pumps and associated capacity should be selected to provide head-capacity characteristics that correspond as nearly as possible to wastewater quantity fluctuations. This can be accomplished by preparing pump/pipeline system head-capacity curves showing all conditions of head (elevation of a free surface of water) and capacity under which the pumps will be required to operate.

The number of pumps to be installed in a lift station depends on the station capacity, the range of flow and the regulations. In small stations, with maximum inflows of less than 2,640 liters per minute (700 gallons per minute), two pumps are customarily installed, with each unit able to meet the maximum influent rate. For larger lift stations, the size and number of pumps should be selected so that the range of influent flow rates can be met without starting and stopping pumps too frequently and without excessive wet-well storage.

Depending on the system, the pumps are designed to run at a reduced rate. The pumps may also alternate to equalize wear and tear. Additional pumps may provide intermediate capacities better matched to typical daily flows. An alternative option is to provide flow flexibility with variable-speed pumps.

For pump stations with high head-losses, the single-pump flow approach is usually the most suitable. Parallel pumping is not as effective for such stations because two pumps operating together yield only slightly higher flows than one pump. If the peak flow is to be achieved with multiple pumps in parallel, the lift station must be equipped with at least three pumps: two duty pumps that together provide peak flow and one standby pump for emergency backup. Parallel peak pumping is typically used in large lift stations with relatively flat system head curves. Such curves allow multiple pumps to deliver substantially more flow than a single pump. The use of multiple pumps in parallel provides more flexibility.

Several types of centrifugal pumps are used in wastewater lift stations. In the straight-flow centrifugal pumps, wastewater does not change direction as it passes through the pumps and into the discharge pipe. These pumps are well suited for low-flow/high head conditions. In angle-flow pumps, wastewater enters the impeller axially and passes through the volute casing at 90 degrees to its original direction (Figure 3). This type of pump is appropriate for pumping against low or moderate heads. Mixed flow pumps are most viable for pumping large quantities of wastewater at low head. In these pumps, the outside diameter of the impeller is less than an ordinary centrifugal pump, increasing flow volume.



Source: Lindeburg, revised edition 1995.

FIGURE 3 CENTRIFUGAL ANGLE-FLOW PUMP

Ventilation

Ventilation and heating are required if the lift station includes an area routinely entered by personnel. Ventilation is particularly important to prevent the collection of toxic and/or explosive gases. According to the Nation Fire Protection Association (NFPA) Section 820, all continuous ventilation systems should be fitted with flow detection devices connected to alarm systems to indicate ventilation system failure. Dry-well ventilation codes typically require six continuous air changes per hour or 30 intermittent air changes per hour. Wet-wells typically require 12 continuous air changes per hour or 60 intermittent air changes per hour. Motor control center (MCC) rooms should have a ventilation system adequate to provide six air changes per hour and should be air conditioned to between 13 and 32 degrees Celsius (55 to 90 degrees F). If the control room is combined with an MCC room, the temperature should not exceed 30 degrees C or 85 degrees F. All other spaces should be designed for 12 air changes per hour. The minimum temperature should be 13 degrees C (55 degrees F) whenever chemicals are stored or used.

Odor Control

Odor control is frequently required for lift stations. A relatively simple and widely used odor control alternative is minimizing wet-well turbulence. More effective options include collection of odors generated at the lift station and treating them in scrubbers or biofilters or the addition of odor control chemicals to the sewer upstream of the lift station. Chemicals typically used for odor control include chlorine, hydrogen peroxide, metal salts (ferric chloride and ferrous sulfate) oxygen, air, and potassium permanganate. Chemicals should be

closely monitored to avoid affecting downstream treatment processes, such as extended aeration.

Power Supply

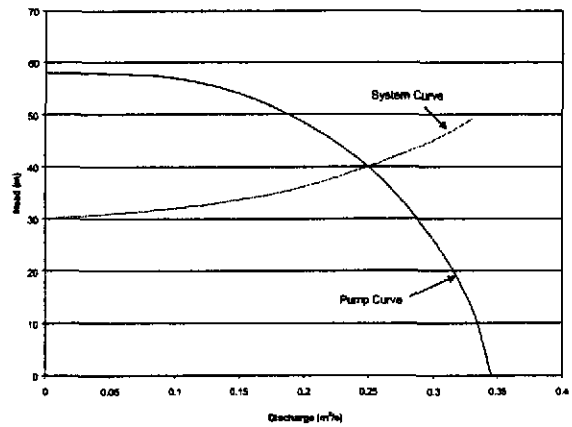
The reliability of power for the pump motor drives is a basic design consideration. Commonly used methods of emergency power supply include electric power feed from two independent power distribution lines; an on-site standby generator; an adequate portable generator with quick connection; a stand-by engine driven pump; ready access to a suitable portable pumping unit and appropriate connections; and availability of an adequate holding facility for wastewater storage upstream of the lift station.

PERFORMANCE

The overall performance of a lift station depends on the performance of the pumps. All pumps have four common performance characteristics: capacity, head, power, and overall efficiency. Capacity (flow rate) is the quantity of liquid pumped per unit of time, typically measured as gallons per minute (gpm) or million gallons per day (mgd). Head is the energy supplied to the wastewater per unit weight, typically expressed as feet of water. Power is the energy consumed by a pump per unit time, typically measured as kilowatt-hours. Overall efficiency is the ratio of useful hydraulic work performed to actual work input. Efficiency reflects the pump relative power losses and is usually measured as a percentage of applied power.

Pump performance curves (Figure 4) are used to define and compare the operating characteristics of a pump and to identify the best combination of performance characteristics under which a lift station pumping system will operate under typical conditions (flows and heads). Pump systems operate at 75 to 85 percent efficiency most of the time, while overall pump efficiency depends on the type of installed pumps, their control system, and the fluctuation of influent wastewater flow.

Performance optimization strategies focus on different ways to match pump operational characteristics with system flow and head requirements. They may include the following



Source: Adapted from Roberson and Crowe, 1993.

FIGURE 4 PUMP PERFORMANCE CURVE

options: adjusting system flow paths installing variable speed drives; using parallel pumps installing pumps of different sizes trimming a pump impeller; or putting a two-speed motor on one or more pumps in a lift station. Optimizing system performance may yield significant electrical energy savings.

OPERATION AND MAINTENANCE

Lift station operation is usually automated and does not require continuous on-site operator presence. However, frequent inspections are recommended to ensure normal functioning and to identify potential problems. Lift station inspection typically includes observation of pumps, motors and drives for unusual noise, vibration, heating and leakage, check of pump suction and discharge lines for valving arrangement and leakage, check of control panel switches for proper position, monitoring of discharge pump rates and pump speed, and monitoring of the pump suction and discharge pressure. Weekly inspections are typically conducted, although the frequency really depends on the size of the lift station.

If a lift station is equipped with grinder bar screens to remove coarse materials from the wastewater, these materials are collected in containers and disposed of to a sanitary landfill site as needed. If the lift station has a scrubber system for odor control, chemicals are supplied and replenished typically every three months. If chemicals are added for odor control ahead of the lift station, the

chemical feed stations should be inspected weekly and chemicals replenished as needed.

The most labor-intensive task for lift stations is routine preventive maintenance. A well-planned maintenance program for lift station pumps prevents unnecessary equipment wear and downtime. Lift station operators must maintain an inventory of critical spare parts. The number of spare parts in the inventory depends on the critical needs of the unit, the rate at which the part normally fails, and the availability of the part. The operator should tabulate each pumping element in the system and its recommended spare parts. This information is typically available from the operation and maintenance manuals provided with the lift station.

COSTS

Lift station costs depend on many factors, including (1) wastewater quality, quantity, and projections; (2) zoning and land use planning of the area where the lift station will be located; (3) alternatives for standby power sources; (4) operation and maintenance needs and support; (5) soil properties and underground conditions; (6) required lift to the receiving (discharge) sewer line; (7) the severity of impact of accidental sewage spill upon the local area; and (8) the need for an odor control system. These site and system specific factors must be examined and incorporated in preparing a lift station cost estimate.

Construction Costs

The most important factors influencing cost are the design lift station capacity and the installed pump power. Another cost factor is the lift station complexity. Factors which classify a lift station as complex include two or more of the following: (1) extent of excavation; (2) congested site and/or restricted access; (3) rock excavation; (4) extensive dewatering requirements, such as cofferdams; (5) site conflicts, including modification or removal of existing facilities; (6) special foundations, including piling; (7) dual power supply and on-site switch stations and emergency power generator; and (8) high pumping heads (design heads in excess of 200 ft).

Mechanical, electrical, and control equipment delivered to a pumping station construction site typically account for 15 to 30 percent of total construction costs. Lift station construction has a significant economy-of-scale. Typically, if the capacity of a lift station is increased 100 percent, the construction cost would increase only 50 to 55 percent. An important consideration is that two identical lift stations will cost 25 to 30 percent more than a single station of the same combined capacity. Usually, complex lift stations cost two to three times more than more simple lift stations with no construction complications.

Table 1 provides examples of complex lift stations and associated construction costs in 1999 dollars.

TABLE 1 LIFT STATION CONSTRUCTION COSTS

Lift Station	Design Flowrate (MGD)	Construction Costs (1999 $US)
Cost curve data[1]	0.5	$134,467
Cost curve data[1]	1	$246,524
Cost curve data[1]	3	$392,197
Valencia, California[2]	6	$1,390,000
Sunneymead, California[2]	12	$3,320,000
Sunset/Heahfield, California[2]	14	$2,600,000
Springfield, Oregon Terry Street Pumping Station[2]	20	$5,470,000
Detroit, Michigan[2]	750	$128,800,000

Source: [1]Qasim, 1994 and [2] James M. Montgomery Consulting Engineers, 1998.

Operation and Maintenance Costs

Lift station operation and maintenance costs include power, labor, maintenance, and chemicals (if used for odor control). Usually, the costs for solids disposal are minimal, but are included if the lift station is equipped with bar screens to remove coarse materials from the wastewater. Typically, power costs account for 85 to 95 percent of the total operation and maintenance costs and are directly proportional to the unit cost of power and the actual power used by the lift station pumps. Labor costs average 1 to 2 percent of total costs. Annual maintenance costs vary, depending on the complexity of the equipment and instrumentation.

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September 2000

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United States Environmental Protection Agency
Office of Water Washington, D.C.
EPA 832-F-99-062 September 1999

EPA

Wastewater Technology Fact Sheet
Chlorine Disinfection

DESCRIPTION

The impact of untreated domestic wastewater on community reservoirs has raised several health and safety concerns. The organisms of concern in domestic wastewater include enteric bacteria, viruses, and protozoan cysts. Table 1 summarizes the most common microorganisms found in domestic wastewater and the types of human diseases associated with them. In response to these concerns, disinfection has become one of the primary mechanisms for the inactivation/destruction of pathogenic organisms. In order for disinfection to be effective wastewater must be adequately treated.

APPLICABILITY

Chlorine is the most widely used disinfectant for municipal wastewater because it destroys target organisms by oxidizing cellular material. Chlorine can be supplied in many forms, which include chlorine gas, hypochlorite solutions, and other chlorine compounds in solid or liquid form. Some alternative disinfectants include ozonation and ultraviolet (UV) disinfection. Choosing a suitable disinfectant for a treatment facility is dependent on the following criteria:

- Ability to penetrate and destroy infectious agents under normal operating conditions.
- Safe and easy handling, storage, and shipping.
- Absence of toxic residuals and mutagenic or carcinogenic compounds after disinfection.

TABLE 1 INFECTIOUS AGENTS POTENTIALLY PRESENT IN UNTREATED DOMESTIC WASTEWATER

Organism	Disease Caused
Bacteria	
Escherichia coli	*Gastroenteritis*
Leptospira (spp.)	*Leptospirosis*
Salmonella typhi	*Typhoid fever*
Salmonella (=2100 serotypes)	*Salmonellosis*
Shigella (4 spp.)	*Shigellosis (bacillary dysentery)*
Vibrio cholerae	*Cholera*
Protozoa	
Balantidium coli	*Balantidiasis*
Cryptosporidium parvum	*Cryptosporidiosis*
Entamoeba histolytica	*Amebiasis (amoebic dysentery)*
Giardia lamblia	*Giardiasis*
Helminths	
Ascaris lumbricoides	*Ascariasis*
T. solium	*Taeniasis*
Trichuris trichiura	*Trichuriasis*
Viruses	
Enteroviruses (72 types) e.g., polio echo and coxsackie viruses)	*Gastroenteritis, heart anomalies, meningitis*
Hepatitis A virus	*Infectious hepatitis*
Norwalk agent	*Gastroenteritis*
Rotavirus	*Gastroenteritis*

Source: Adapted from: Crites and Tchobanoglous (1998) with permission from The McGraw-Hill Companies.

- Affordable capital and operation and maintenance (O&M) costs.

ADVANTAGES AND DISADVANTAGES

Chlorine is a disinfectant that has certain health and safety limitations, but at the same time, has a long history of being an effective disinfectant. Before deciding whether chlorine meets the municipality's needs, it is necessary to understand the advantages and disadvantages of this product.

Advantages

- Chlorination is a well-established technology.
- Presently, chlorine is more cost-effective than either UV or ozone disinfection (except when dechlorination is required and fire code requirements must be met).
- The chlorine residual that remains in the wastewater effluent can prolong disinfection even after initial treatment and can be measured to evaluate the effectiveness.
- Chlorine disinfection is reliable and effective against a wide spectrum of pathogenic organisms.
- Chlorine is effective in oxidizing certain organic and inorganic compounds.
- Chlorination has flexible dosing control.
- Chlorine can eliminate certain noxious odors during disinfection.

Disadvantages

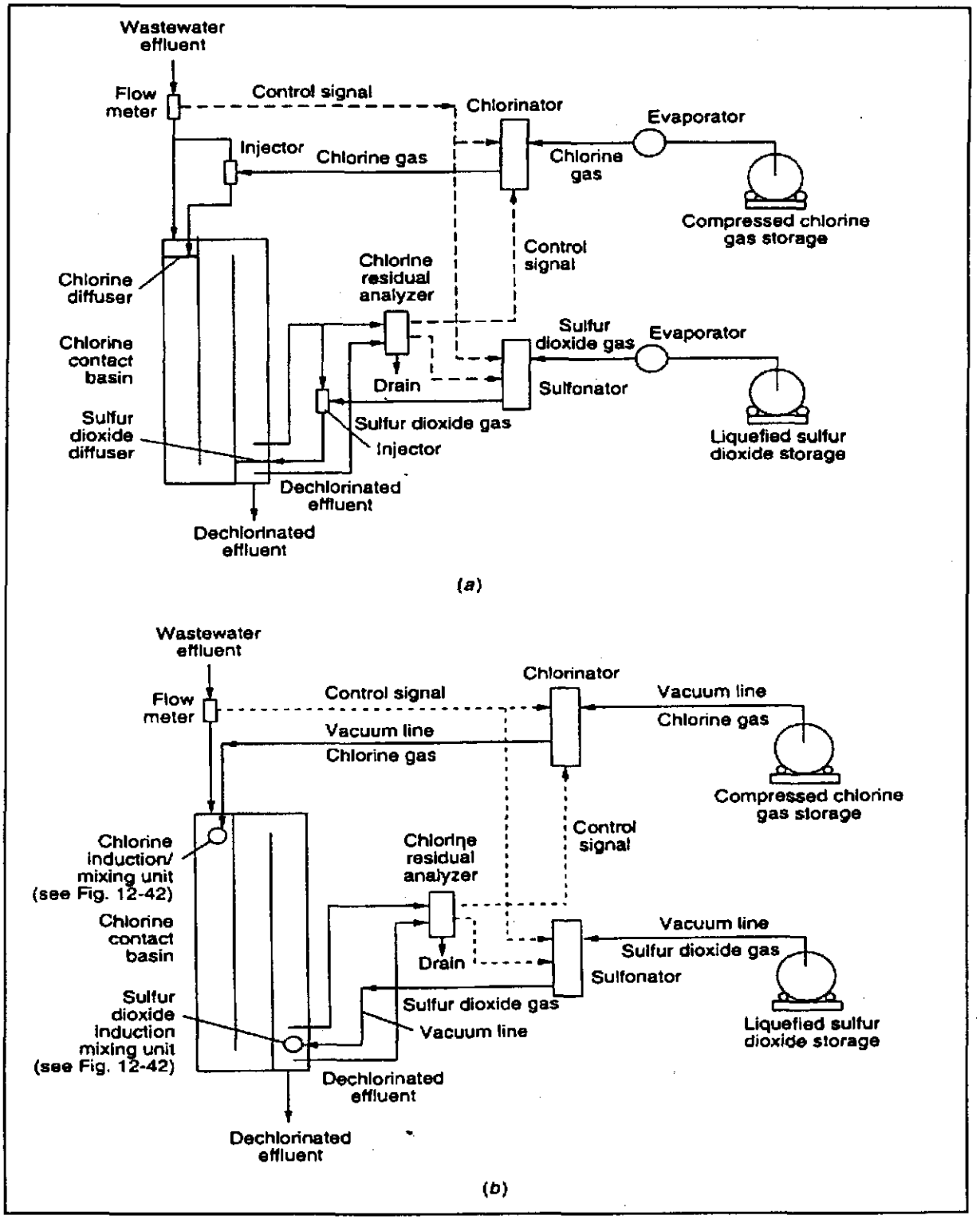
- The chlorine residual, even at low concentrations, is toxic to aquatic life and may require dechlorination.
- All forms of chlorine are highly corrosive and toxic. Thus, storage, shipping, and handling pose a risk, requiring increased safety regulations.
- Chlorine oxidizes certain types of organic matter in wastewater, creating more hazardous compounds (e.g., trihalomethanes [THMs]).
- The level of total dissolved solids is increased in the treated effluent.
- The chloride content of the wastewater is increased.
- Chlorine residual is unstable in the presence of high concentrations of chlorine-demanding materials, thus requiring higher doses to effect adequate disinfection.
- Some parasitic species have shown resistance to low doses of chlorine, including oocysts of *Cryptosporidium parvum*, cysts, of *Endamoeba histolytica* and *Giardia lamblia*, and eggs of parasitic worms.
- Long-term effect of discharging dechlorinated compounds into the environment are unknown.

DESIGN CRITERIA

When chlorine gas and hypochlorite salts are added to water, hydrolysis and ionization take place to form hypochlorous acid (HOCl) and hypochlorite ions (OCl) also referred to as free available chlorine. Free chlorine reacts quickly with ammonia in non-nitrified effluents to form combined chlorine, principally monochloramine, which actually is the predominant chlorine species present.

Chlorination

Figure 1 shows a flow chart of the chlorination process using liquid and gaseous chlorine. For optimum performance, a chlorine disinfection system should display plug flow and be highly turbulent for complete initial mixing in less than one second. The goal of proper mixing is to enhance disinfection by initiating a reaction between the free chlorine in the chlorine solution stream with the ammonia nitrogen. This prevents prolonged chlorine concentrations from existing and forming other chlorinated compounds.



Source: Crites and Tchobanoglous, used with permission from the McGraw-Hill Companies, 1998.

FIGURE 1 A COMPOUND-LOOP CONTROL SYSTEM FOR CHLORINATION WITH CHLORINE AN DECHLORINATION WITH SULFUR DIOXIDE: (a) INJECTION OF LIQUID CHLORINE AND (b) INJECTION OF CHLORINE GAS BY INDUCTION

Another important process that contributes to optimal disinfection is contact. The contact chamber should be designed to have rounded corners to prevent dead flow areas and be baffled to minimize short-circuiting. This design allows for adequate contact time between the microorganisms and a minimal chlorine concentration for a specific period of time.

The required degree of disinfection can be achieved by varying the dose and the contact time for any chlorine disinfection system. Chlorine dosage will vary based on chlorine demand, wastewater characteristics, and discharge requirements. The dose usually ranges from 5 to 20 milligrams per liter (mg/L). Table 2 describes some of the more common wastewater characteristics and their impact on chlorine. There are several other factors that ensure optimum conditions for disinfection and they include temperature, alkalinity, and nitrogen-content. All key design parameters should be pilot tested prior to full-scale operation of a chlorine disinfection system.

Dechlorination

After disinfection, chlorine residual can persist in the effluent for many hours. Most states will not allow the use of chlorination alone for pristine receiving waters because of its effect on aquatic species. To minimize the effect, chlorinated wastewater must often be dechlorinated.

Dechlorination is the process of removing the free and combined chlorine residuals to reduce residual toxicity after chlorination and before discharge. Sulfur dioxide, sodium bisulfite, and sodium metabisulfite are the commonly used dechlorinating chemicals. Activated carbon has also been used. The total chlorine residual can usually be reduced to a level that is not toxic to aquatic life. Chlorination/dechlorination systems are more complex to operate and maintain than chlorination systems. Figure 1 shows a schematic of the chlorination/dechlorination system using sulfur dioxide.

TABLE 2 WASTEWATER CHARACTERISTICS AFFECTING CHLORINATION PERFORMANCE

Wastewater Characteristic	Effects on Chlorine Disinfection
Ammonia	Forms chloramines when combined with chlorine
Biochemical Oxygen Demand (BOD)	The degree of interference depends on their functional groups and chemical structures
Hardness, Iron, Nitrate	Minor effect, if any
Nitrite	Reduces effectiveness of chlorine and results in THMs
pH	Affects distribution between hypochlorous acid and hypochlorite ions and among the various chloramine species
Total Suspended Solids	Shielding of embedded bacteria and chlorine demand

Source: Darby et al., with permission from the Water Environment Research Foundation, 1995.

PERFORMANCE

Marsh Creek Wastewater Treatment Plant in Geneva, New York

The Marsh Creek Wastewater Treatment Plant in Geneva, New York, met stringent state permitting requirements for residual chlorine and fecal coliforms by adopting a new chlorine control strategy. The strategy was devised to monitor the plant's changing chlorine demand and to feed the required chlorine by measuring the oxidation reduction potential (ORP).

After conducting a three-month study, the plant installed an ORP system to monitor and regulate the amount of chlorine present in solution. The control system measured the chlorine demand and regulated the amount of chlorine needed to achieve and maintain the ORP setpoint parameters. The system was calibrated to maintain the total chlorine control limit between 0.2 and 0.1 mg/L.

An electrode, placed about 300 feet upstream from the injection point, measured the ORP, which was then converted to a 4 to 20 milliampere signal. Based on the signal, the control system drove the chlorinator and matched the feed rate to the changing chlorine demand in the system. A second electrode was used on the discharge fallout line to monitor the accuracy of the chlorine control system.

The treatment plant was then able to meet the fecal coliform limits and maintain an effluent chlorine residual of less than 0.25 mg/L. In addition to meeting the permit requirements, the plant significantly lowered the chlorine consumption cost. At the time of the study, it was estimated that the ORP control system could be paid for in approximately 30 months due to the reduction in the chlorine consumption cost.

East Bay Municipal Utility District's Wastewater Plant in Oakland, California.

The East Bay Municipal Utility District in Oakland, California, owned and operated a wastewater treatment plant with a design flow of 310 million gallons per day (mgd), where chlorination and dechlorination were mandated parts of the treatment process. With this requirement, optimizing the dechlorination system was a critical part in meeting the National Pollution Discharge Elimination System permit limit of no chlorine residual during dry and wet weather operations.

A sodium bisulfite (SBS) system was added as backup to the dechlorination operation. It performed very well and kept the plant in compliance. This system is similar to a typical liquid chemical addition facility with a storage system, feed pump, metering system, control valve, and injection device.

The SBS system was integrated into the overall dechlorination operation by control set points on the sulfur dioxide (SO_2) residual analyzer and set to maintain a concentration of 3 to 4 mg/L. The SBS system is set to kick in at a calculated SO_2 concentration of 1.5 mg/L. It is also set to begin operation when the SO_2 leak detection system automatically shuts off the SO_2 feed, or during wet weather operations when the SO_2 demand may exceed the SO2 system's capacity.

The treatment plant also had to optimize chemical usage with the continued increase in chemical costs. The original chlorine dose was 15 mg/L, where 5 to 6 mg/L was consumed with 9 to 10 mg/L as a residual. The residual chlorine was then gradually lowered from 9 to 10 mg/L to 3 to 5 mg/L, without affecting the compliance requirements. This also resulted in using less SO_2 in addition to the reduction in chlorine usage.

By adopting a strategy to increase the focus on controlling costs through process optimization, the treatment plant was able to reduce its chemical costs by more than 30%.

OPERATION AND MAINTENANCE

A routine O&M schedule should be developed and implemented for any chlorine disinfection system. Regular O&M includes the following activities:

- Disassembling and cleaning the various components of the system, such as meters and floats, once every six months.
- Iron and manganese deposits should be removed with, for example, muriatic acid.
- Booster pumps should be maintained.
- Valves and springs should be inspected and cleaned annually.
- All manufacturer's O&M recommendations should be followed.
- Equipment must be tested and calibrated as recommended by the equipment manufacturer.
- An emergency response plan for onsite storage of gaseous chlorine must be developed.

When using chlorine it is very important to properly and safely store all chemical disinfectants. The storage of chlorine is strongly dependent on the compound phase. For further details on the safe use

and storage of chlorine refer to chemical's Material Safety Data Sheets. Chlorine gas is normally stored in steel containers (150-pound or 1-ton cylinders) and transported in railroad cars and tanker trucks. Sodium hypochlorite solution must be stored in rubber-lined steel or fiberglass storage tanks. Calcium hypochlorite is shipped in drums or tanker trucks and stored with great care.

COSTS

The cost of chlorine disinfection systems is dependent on the manufacturer, the site, the capacity of the plant, and the characteristics of the wastewater to be disinfected. Hypochlorite compounds, for example, tend to be more expensive than chlorine gas. On the other hand several large cities have switched to hypochlorite, despite the expense, in order to avoid transporting chlorine through populated areas. In addition to the costs incurred by the chlorination process, some municipalities will also have to consider the costs of introducing the dechlorination process. The total cost of chlorination will be increased by approximately 30 to 50% with the addition of dechlorination.

Table 3 summarizes the results of a 1995 study conducted by the Water Environment Research Federation for secondary effluents from disinfection facilities at average dry weather flow rates of 1, 10, and 100 mgd (2.25, 20, and 175 mgd peak wet weather flow, respectively). The annual O&M costs for chlorine disinfection include power consumption, cleaning chemicals and supplies, miscellaneous equipment repairs, and personnel costs. The costs associated with the Uniform Fire Code requirements can be high for small facilities (as high as 25%).

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TABLE 3 ESTIMATED TOTAL ANNUALIZED COST FOR CHLORINATION/DECHLORINATION

Flow (mgd)			Estimated Capital Costs ($)				
ADWF	PWWF	Cl_2 Dose (mg/L)	Chlorination	Dechlorination	UFC*	Total	Estimated O&M Costs
1	2.25	5	410,000	290,000	239,000	1,127,000	49,300
10	20.00	5	1,804,000	546,000	264,000	3,137,000	158,200
100	175.00	5	10,131,000	1,031,000	788,000	14,340,000	660,000
1	2.25	10	441,000	370,000	239,000	1,260,000	59,200
10	20.00	10	2,051,000	664,000	264,000	3,575,000	226,700
100	175.00	10	10,258,000	1,258,000	788,000	14,765,000	721,800
1	2.25	20	445,000	374,000	239,000	1,270,000	76,600
10	20.00	20	2,113,500	913,500	264,000	3,949,000	379,100
100	175.00	20	10,273,000	1,273,000	788,000	14,801,000	1,311,000

*UFC = Uniform Fire Code (Costs include provisions to meet Article 80 of the 1991 UFC)
ADWF = average dry weather flow PWWF = peak wet weather flow

Source: Darby et al., with permission from the Water Environment Research Foundation, 1995.

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United States Environmental Protection Agency
Office of Water Washington, D.C.
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EPA

Wastewater Technology Fact Sheet
Ozone Disinfection

DESCRIPTION

Disinfection is considered to be the primary mechanism for the inactivation/destruction of pathogenic organisms to prevent the spread of waterborne diseases to downstream users and the environment. It is important that wastewater be adequately treated prior to disinfection in order for any disinfectant to be effective. Table 1 lists some common microorganisms found in domestic wastewater and the diseases associated with them.

Ozone is produced when oxygen (O_2) molecules are dissociated by an energy source into oxygen atoms and subsequently collide with an oxygen molecule to form an unstable gas, ozone (O_3), which is used to disinfect wastewater. Most wastewater treatment plants generate ozone by imposing a high voltage alternating current (6 to 20 kilovolts) across a dielectric discharge gap that contains an oxygen-bearing gas. Ozone is generated onsite because it is unstable and decomposes to elemental oxygen in a short amount of time after generation.

Ozone is a very strong oxidant and virucide. The mechanisms of disinfection using ozone include:

- Direct oxidation/destruction of the cell wall with leakage of cellular constituents outside of the cell.
- Reactions with radical by-products of ozone decomposition.
- Damage to the constituents of the nucleic acids (purines and pyrimidines).
- Breakage of carbon-nitrogen bonds leading to depolymerization.

TABLE 1 INFECTIOUS AGENTS POTENTIALLY PRESENT IN UNTREATED DOMESTIC WASTEWATER

Organism	Disease Caused
Bacteria	
Escherichia coli (enterotoxigenic)	Gastroenteritis
Leptospira (spp.)	Leptospirosis
Salmonella typhi	Typhoid fever
Salmonella (≈2,100 serotypes)	Salmonellosis
Shigella (4 spp.)	Shigellosis (bacillary dysentery)
Vibrio cholerae	Cholera
Protozoa	
Balantidium coli	Balantidiasis
Cryptosporidium parvum	Cryptosporidiosis
Entamoeba histolytica	Amebiasis (amoebic dysentery)
Giardia lamblia	Giardiasis
Helminths	
Ascaris lumbricoides	Ascariasis
T. solium	Taeniasis
Trichuris trichiura	Trichuriasis
Viruses	
Enteroviruses (72 types, e.g., polio, echo, and coxsackie viruses)	Gastroenteritis, heart anomalies, meningitis
Hepatitis A virus	Infectious hepatitis
Norwalk agent	Gastroenteritis
Rotavirus	Gastroenteritis

Source: Adapted from Crites and Tchobanoglous, 1998.

When ozone decomposes in water, the free radicals hydrogen peroxy (HO_2) and hydroxyl (OH) that are formed have great oxidizing capacity and play an active role in the disinfection process. It is generally believed that the bacteria are destroyed because of protoplasmic oxidation resulting in cell wall disintegration (cell lysis).

The effectiveness of disinfection depends on the susceptibility of the target organisms, the contact time, and the concentration of the ozone. A line diagram of the ozonation process is shown in Figure 1. The components of an ozone disinfection system include feed-gas preparation, ozone generation, ozone contacting, and ozone destruction.

Air or pure oxygen is used as the feed-gas source and is passed to the ozone generator at a set flow rate. The energy source for production is generated by electrical discharge in a gas that contains oxygen. Ozone generators are typically classified by:

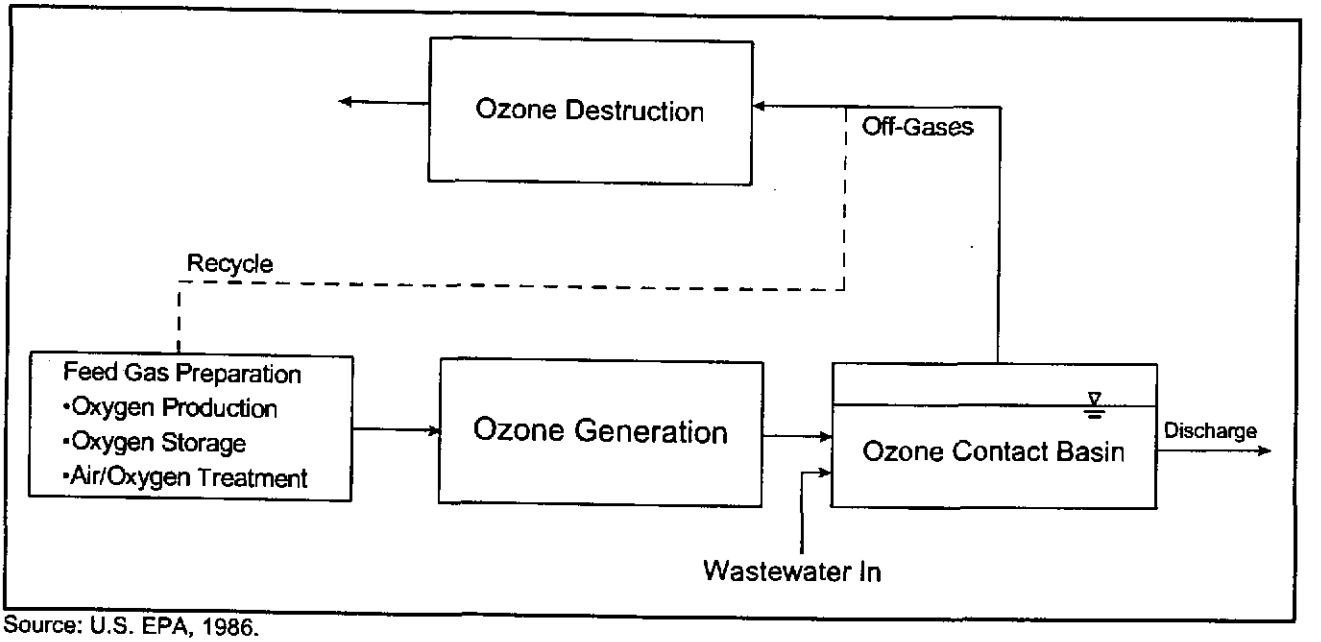
- The control mechanism (either a voltage or frequency unit).
- The cooling mechanism (either water, air, or water plus oil).
- The physical arrangement of the dielectrics (either vertical or horizontal).
- The name of the inventor.

However, generators manufactured by different companies have unique characteristics but also have some common configurations.

The electrical discharge method is the most common energy source used to produce ozone. Extremely dry air or pure oxygen is exposed to a controlled, uniform high-voltage discharge at a high or low frequency. The dew point of the feed gas must be -60°C (-76°F) or lower. The gas stream generated from air will contain about 0.5 to 3.0% ozone by weight, whereas pure oxygen will form approximately two to four times that concentration.

After generation, ozone is fed into a down-flow contact chamber containing the wastewater to be disinfected. The main purpose of the contactor is to transfer ozone from the gas bubble into the bulk liquid while providing sufficient contact time for disinfection. The commonly used contactor types diffused bubble (co-current and counter-current) are positive pressure injection, negative pressure (Venturi), mechanically agitated, and packed tower. Because ozone is consumed quickly, it must be contacted uniformly in a near plug flow contactor.

The off-gases from the contact chamber must be treated to destroy any remaining ozone before



Source: U.S. EPA, 1986.

FIGURE 1 OZONE PROCESS SCHEMATIC DIAGRAM

release into the atmosphere. Therefore, it is essential to maintain an optimal ozone dosage for better efficiency. When pure oxygen is used as the feed-gas, the off-gases from the contact chamber can be recycled to generate ozone or for reuse in the aeration tank. The ozone off-gases that are not used are sent to the ozone destruction unit or are recycled.

The key process control parameters are dose, mixing, and contact time. An ozone disinfection system strives for the maximum solubility of ozone in wastewater, as disinfection depends on the transfer of ozone to the wastewater. The amount of ozone that will dissolve in wastewater at a constant temperature is a function of the partial pressure of the gaseous ozone above the water or in the gas feed stream.

It is critical that all ozone disinfection systems be pilot tested and calibrated prior to installation to ensure they meet discharge permit requirements for their particular sites.

APPLICABILITY

Ozone disinfection is generally used at medium to large sized plants after at least secondary treatment. In addition to disinfection, another common use for ozone in wastewater treatment is odor control.

Ozone disinfection is the least used method in the U.S. although this technology has been widely accepted in Europe for decades. Ozone treatment has the ability to achieve higher levels of disinfection than either chlorine or UV, however, the capital costs as well as maintenance expenditures are not competitive with available alternatives. Ozone is therefore used only sparingly, primarily in special cases where alternatives are not effective.

ADVANTAGES AND DISADVANTAGES

Advantages

- Ozone is more effective than chlorine in destroying viruses and bacteria.
- The ozonation process utilizes a short contact time (approximately 10 to 30 minutes).
- There are no harmful residuals that need to be removed after ozonation because ozone decomposes rapidly.
- After ozonation, there is no regrowth of microorganisms, except for those protected by the particulates in the wastewater stream.
- Ozone is generated onsite, and thus, there are fewer safety problems associated with shipping and handling.
- Ozonation elevates the dissolved oxygen (DO) concentration of the effluent. The increase in DO can eliminate the need for reaeration and also raise the level of DO in the receiving stream.

Disadvantages

- Low dosage may not effectively inactivate some viruses, spores, and cysts.
- Ozonation is a more complex technology than is chlorine or UV disinfection, requiring complicated equipment and efficient contacting systems.
- Ozone is very reactive and corrosive, thus requiring corrosion-resistant material such as stainless steel.
- Ozonation is not economical for wastewater with high levels of suspended solids (SS), biochemical oxygen demand (BOD), chemical oxygen demand, or total organic carbon.
- Ozone is extremely irritating and possibly toxic, so off-gases from the contactor must be destroyed to prevent worker exposure.
- The cost of treatment can be relatively high in capital and in power intensiveness.

PERFORMANCE

Belmont and Southport Wastewater Treatment Plants in Indianapolis, Indiana

In 1985, the City of Indianapolis, Indiana, operated two-125 million gallons per day (mgd) advanced wastewater treatment plants at Belmont and Southport using ozone disinfection. The rated capacity of the oxygen-fed ozone generators was 6,380 pounds per day, which was used to meet geometric mean weekly and monthly disinfection permit limits for fecal coliforms of 400 and 200 per 100 ml, respectively.

Disinfection was required at both Indianapolis treatment plants from April 1 through October 31, 1985. Equipment performance characteristics were evaluated during the 1985 disinfection season and consequently, disinfection performance was optimized during the 1986 season. The capital cost of both ozone systems represented about 8% of the plants' total construction cost. The ozone system's Operation and Maintenance (O&M) cost represented about 1.9% and 3.7% of the total plant O&M costs at the Belmont and Southport plants, respectively.

In 1989, a disciplined process monitoring and control program was initiated. Records indicated a significant effect on process performance due to changes in wastewater flow, contactor influent fecal coliform concentration, and ozone demand.

Previously, ozone demand information was unknown. Several studies were conducted to enable better control of the ozone disinfection process. These included the recent installation of a pilot-scale ozone contactor to allow the plant staff to measure ozone demand on a daily basis. Also, tracer tests were conducted to measure contactor short-circuiting potential. Results demonstrated a noticeable benefit of adding additional baffles. Results also indicated operating strategies that could maximize fecal coliform removal, such as reducing the number of contactors in service at low and moderate flow conditions.

OPERATION AND MAINTENANCE

Ozone generation uses a significant amount of electrical power. Thus, constant attention must be given to the system to ensure that power is optimized for controlled disinfection performance.

There must be no leaking connections in or surrounding the ozone generator. The operator must on a regular basis monitor the appropriate subunits to ensure that they are not overheated. Therefore, the operator must check for leaks routinely, since a very small leak can cause unacceptable ambient ozone concentrations. The ozone monitoring equipment must be tested and calibrated as recommended by the equipment manufacturer.

Like oxygen, ozone has limited solubility and decomposes more rapidly in water than in air. This factor, along with ozone reactivity, requires that the ozone contactor be well covered and that the ozone diffuses into the wastewater as effectively as possible.

Ozone in gaseous form is explosive once it reaches a concentration of 240 g/m^3. Since most ozonation systems never exceed a gaseous ozone concentration of 50 to 200 g/m^3, this is generally not a problem. However, ozone in gaseous form will remain hazardous for a significant amount of time thus, extreme caution is needed when operating the ozone gas systems.

It is important that the ozone generator, distribution, contacting, off-gas, and ozone destructor inlet piping be purged before opening the various systems or subsystems. When entering the ozone contactor, personnel must recognize the potential for oxygen deficiencies or trapped ozone gas in spite of best efforts to purge the system. The operator should be aware of all emergency operating procedures required if a problem occurs. All safety equipment should be available for operators to use in case of an emergency. Key O&M parameters include:

- Clean feed gas with a dew point of -60°C (-76°F), or lower, must be delivered to the ozone generator. If the supply gas is moist,

the reaction of the ozone and the moisture will yield a very corrosive condensate on the inside of the ozonator. The output of the generator could be lowered by the formation of nitrogen oxides (such as nitric acid).

- Maintain the required flow of generator coolant (air, water, or other liquid).
- Lubricate the compressor or blower in accordance with the manufacturer's specifications. Ensure that all compressor sealing gaskets are in good condition.
- Operate the ozone generator within its design parameters. Regularly inspect and clean the ozonator, air supply, and dielectric assemblies, and monitor the temperature of the ozone generator.
- Monitor the ozone gas-feed and distribution system to ensure that the necessary volume comes into sufficient contact with the wastewater.
- Maintain ambient levels of ozone below the limits of applicable safety regulations.

COSTS

The cost of ozone disinfection systems is dependent on the manufacturer, the site, the capacity of the plant, and the characteristics of the wastewater to be disinfected. Ozonation costs are generally high in comparison with other disinfection techniques.

Table 2 shows a typical cost estimate (low to medium) for ozone disinfection system used to disinfect one mgd of wastewater. The costs are based on the wastewater having passed through both primary and secondary treatment processes of a properly designed system (the BOD content does not exceed 30 milligrams per liter [mg/L] and the SS content is less than 30 mg/L). In general, costs are largely influenced by site-specific factors, and thus, the estimates that follow are typical values and can vary from site to site.

Because the concentration of ozone generated from either air or oxygen is so low, the transfer efficiency to the liquid phase is a critical economic consideration. For this reason, the contact chambers used are usually very deep and covered.

The overall cost of an ozonation system is also largely determined by the capital and O&M expenses. The annual operating costs for ozone disinfection include power consumption, and supplies, miscellaneous equipment repairs, and staffing requirements.

Another consideration for the cost is that each ozonation system is site specific, depending on the plant's effluent limitations. Chemical suppliers should be contacted for specific cost information.

TABLE 2 TYPICAL COST ESTIMATE OF AN OZONE DISINFECTION

Items	Costs
Capital Costs	
Oxygen feed gas and compressor	$245,500
Contact vessel (500 gpm)	$4,000-5,000
Destruct unit:	
Small (around 30 cfm)	$800
Large (around 120)	$1,000-1,200
Non-component costs	$35,000
Engineering	$12,000-15,000
Contingencies	30%
Annual O&M Costs	
Labor	$12,000
Power	90 kW
Other (filter replacements, compressor oil, spare dielectric, etc.)	$6,500

gpm = gallons per minute
cfm = cubic feet per minute

Source: Champion Technology, 1998.

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Wastewater Technology Fact Sheet
Ultraviolet Disinfection

DESCRIPTION

Disinfection is considered to be the primary mechanism for the inactivation/destruction of pathogenic organisms to prevent the spread of waterborne diseases to downstream users and the environment. It is important that wastewater be adequately treated prior to disinfection in order for any disinfectant to be effective. Some common microorganisms found in domestic wastewater and the diseases associated with them are presented in Table 1.

An Ultraviolet (UV) disinfection system transfers electromagnetic energy from a mercury arc lamp to an organism's genetic material (DNA and RNA). When UV radiation penetrates the cell wall of an organism, it destroys the cell's ability to reproduce. UV radiation, generated by an electrical discharge through mercury vapor, penetrates the genetic material of microorganisms and retards their ability to reproduce.

The effectiveness of a UV disinfection system depends on the characteristics of the wastewater, the intensity of UV radiation, the amount of time the microorganisms are exposed to the radiation, and the reactor configuration. For any one treatment plant, disinfection success is directly related to the concentration of colloidal and particulate constituents in the wastewater.

The main components of a UV disinfection system are mercury arc lamps, a reactor, and ballasts. The source of UV radiation is either the low-pressure or medium-pressure mercury arc lamp with low or high intensities.

TABLE 1 INFECTIOUS AGENTS POTENTIALLY PRESENT IN UNTREATED DOMESTIC WASTEWATER

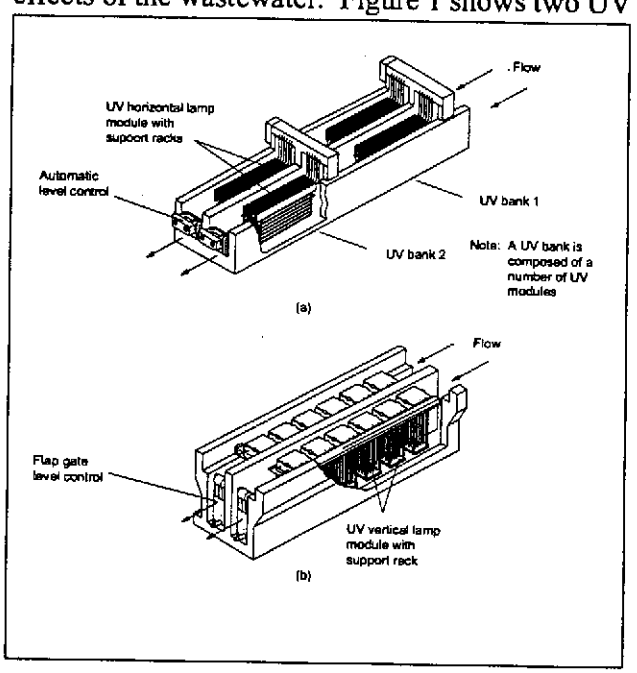
Organism	Disease Caused
Bacteria	
Escherichia coli (enterotoxigenic)	Gastroenteritis
Leptospira (spp.)	Leptospirosis
Salmonella typhi	Typhoid fever
Salmonella (=2,100 serotypes)	Salmonellosis
Shigella (4 spp.)	Shigellosis (bacillary dysentery)
Vibrio cholerae	Cholera
Protozoa	
Balantidium coli	Balantidiasis
Cryptosporidium parvum	Cryptosporidiosis
Entamoeba histolytica	Amebiasis (amoebic dysentery)
Giardia lamblia	Giardiasis
Helminths	
Ascaris lumbricoides	Ascariasis
T. solium	Taeniasis
Trichuris trichiura	Trichuriasis
Viruses	
Enteroviruses (72 types, e.g., polio, echo, and coxsackie viruses)	Gastroenteritis, heart anomalies, meningitis
Hepatitis A virus	Infectious hepatitis
Norwalk agent	Gastroenteritis
Rotavirus	Gastroenteritis

Source: Adapted from Crites and Tchobanoglous, 1998.

The optimum wavelength to effectively inactivate microorganisms is in the range of 250 to 270 nm. The intensity of the radiation emitted by the lamp dissipates as the distance from the lamp increases. Low-pressure lamps emit essentially monochromatic light at a wavelength of 253.7 nm. Standard lengths of the low-pressure lamps are 0.75 and 1.5 meters with diameters of 1.5 - 2.0 cm. The ideal lamp wall temperature is between 95 and 122°F.

Medium-pressure lamps are generally used for large facilities. They have approximately 15 to 20 times the germicidal UV intensity of low-pressure lamps. The medium-pressure lamp disinfects faster and has greater penetration capability because of its higher intensity. However, these lamps operate at higher temperatures with a higher energy consumption.

There are two types of UV disinfection reactor configurations that exist: contact types and noncontact types. In both the contact and the noncontact types, wastewater can flow either perpendicular or parallel to the lamps. In the contact reactor, a series of mercury lamps are enclosed in quartz sleeves to minimize the cooling effects of the wastewater. Figure 1 shows two UV contact reactors with submerged lamps placed parallel and perpendicular to the direction of the wastewater flow. Flap gates or weirs are used to control the level of the wastewater. In the noncontact reactor, the UV lamps are suspended outside a transparent conduit, which carries the wastewater to be disinfected. This configuration is not as common as the contact reactor. In both types of reactors, a ballast—or control box—provides a starting voltage for the lamps and maintains a continuous current.



Source: Crites and Tchobanoglous, 1998.
(a) adapted from Trojan Technologies, Inc.
(b) adapted from Infilco Degremont, Inc.

FIGURE 1 ISOMETRIC CUT-AWAY VIEWS OF TYPICAL UV DISINFECTION SYSTEMS

ADVANTAGES AND DISADVANTAGES

Advantages

- UV disinfection is effective at inactivating most viruses, spores, and cysts.
- UV disinfection is a physical process rather than a chemical disinfectant, which eliminates the need to generate, handle, transport, or store toxic/hazardous or corrosive chemicals.
- There is no residual effect that can be harmful to humans or aquatic life.
- UV disinfection is user-friendly for operators.
- UV disinfection has a shorter contact time when compared with other disinfectants (approximately 20 to 30 seconds with low-pressure lamps).
- UV disinfection equipment requires less space than other methods.

Disadvantages

- Low dosage may not effectively inactivate some viruses, spores, and cysts.
- Organisms can sometimes repair and reverse the destructive effects of UV through a "repair mechanism," known as photo reactivation, or in the absence of light known as "dark repair."

- A preventive maintenance program is necessary to control fouling of tubes.

- Turbidity and total suspended solids (TSS) in the wastewater can render UV disinfection ineffective. UV disinfection with low-pressure lamps is not as effective for secondary effluent with TSS levels above 30 mg/L.

- UV disinfection is not as cost-effective as chlorination, but costs are competitive when chlorination dechlorination is used and fire codes are met.

APPLICABILITY

When choosing a UV disinfection system, there are three critical areas to be considered. The first is primarily determined by the manufacturer; the second, by design and Operation and Maintenance (O&M); and the third has to be controlled at the treatment facility.

Choosing a UV disinfection system depends on three critical factors listed below.

- Hydraulic properties of the reactor: Ideally, a UV disinfection system should have a uniform flow with enough axial motion (radial mixing) to maximize exposure to UV radiation. The path that an organism takes in the reactor determines the amount of UV radiation it will be exposed to before inactivation. A reactor must be designed to eliminate short-circuiting and/or dead zones, which can result in inefficient use of power and reduced contact time.

- Intensity of the UV radiation: Factors affecting the intensity are the age of the lamps, lamp fouling, and the configuration and placement of lamps in the reactor.

- Wastewater characteristics: These include the flow rate, suspended and colloidal solids, initial bacterial density, and other physical and chemical parameters. Both the concentration of TSS and the concentration of particle-associated microorganisms determine how much UV radiation ultimately reaches the target organism. The higher these concentrations, the lower the UV radiation absorbed by the organisms. Various wastewater characteristics and their effects on UV disinfection are given in Table 2.

TABLE 2 WASTEWATER CHARACTERISTICS AFFECTING UV DISINFECTION PERFORMANCE

Wastewater Characteristic	Effects on UV Disinfection
Ammonia	Minor effect, if any
Nitrite	Minor effect, if any
Nitrate	Minor effect, if any
Biochemical oxygen demand (BOD)	Minor effect, if any. Although, if a large portion of the BOD is humic and/or unsaturated (or conjugated) compounds, then UV transmittance may be diminished.
Hardness	Affects solubility of metals that can absorb UV light. Can lead to the precipitation of carbonates on quartz tubes.
Humic materials, Iron	High absorbency of UV radiation.
pH	Affects solubility of metals and carbonates.
TSS	Absorbs UV radiation and shields embedded bacteria.

UV disinfection can be used in plants of various sizes that provide secondary or advanced levels of treatment.

PERFORMANCE

Gold Bar Wastewater Treatment Plant in Edmonton, Alberta, Canada

The Gold Bar Wastewater Treatment Plant (GBWTP) in Edmonton, Alberta, was required to use disinfection to meet water quality standards for

contact recreation in Alberta. During that period, the average and peak design flow rates for this treatment facility were 82 and 110 million gallons per day (mgd), respectively. A pilot study was conducted to review current UV disinfection systems, effectiveness of lamp intensities, and costs. UV disinfection was determined to be the most efficient disinfection system to achieve the required treatment levels.

Lamp fouling is a potential problem among UV systems, but with proper cleaning and O&M, it should not interrupt the system's disinfection capability. Lamp cleaning at the GBWTP was achieved by a mechanical wiping mechanism accompanying each cluster of lamps. Lamps were cleaned on a regular basis using an in-channel cleaning system. The safety concerns for both low-pressure and high-intensity UV systems regarding exposure to UV radiation and electrical hazards are low under normal operating conditions. However, precautionary measures should be taken when operating high-intensity lamps to avoid overexposure. The risk was not considered major by the GBWTP and was outweighed by the potential savings of using high-intensity UV systems. At the GBWTP, a medium-pressure, high-intensity system was found to be more economical than the conventional low-pressure systems in both capital and life-cycle costs.

Northwest Bergen County Utility Authority Wastewater Treatment Plant in Waldwick, New Jersey

The use of UV disinfection for wastewater treatment has increased dramatically in the last few years due to the impact of chlorinated organics from sewage effluent on receiving waters. Such was the case with the Northwest Bergen County Utility Authority (NBCUA) Wastewater Treatment Plant located in Waldwick, New Jersey. In 1989, the treatment plant had to convert from chlorination to an alternative disinfection technology with zero residual after treatment. This change was brought about when the "zero residual" regulation was imposed by the New Jersey Department of Environmental Protection with the passage of the Toxic Catastrophic Prevention Act.

Several factors, such as public safety and recent findings and concerns over the environmental impact of chemical releases and spills, have led to more stringent permit requirements for chlorine. Also, there were other conditions that the treatment plant had to meet if chlorine use was to continue. To avoid the escalated costs that could be incurred and to be in compliance with the new regulations, the wastewater treatment plant switched to UV disinfection. The UV system was installed within the existing chlorine contact tanks, along with an extension to the existing building for easy maintenance during bad weather. The UV system at NBCUA was able to meet fecal coliform levels (200 count per 100 ml) better than chlorination since its installation in August 1989.

OPERATION AND MAINTENANCE

The proper O&M of a UV disinfection system ensures that sufficient UV radiation is transmitted to the organisms to render them sterile. All surfaces between the UV radiation and the target organisms must be clean, and the ballasts, lamps, and reactor must be functioning at peak efficiency. Inadequate cleaning is one of the most common causes of a UV system's ineffectiveness. The quartz sleeves or Teflon tubes need to be cleaned regularly by mechanical wipers, ultrasonics, or chemicals. The cleaning frequency is very site-specific, some systems need to be cleaned more often than others.

Chemical cleaning is most commonly done with citric acid. Other cleaning agents include mild vinegar solutions and sodium hydrosulfite. A combination of cleaning agents should be tested to find the agent most suitable for the wastewater characteristics without producing harmful or toxic by-products. Noncontact reactor systems are most effectively cleaned by using sodium hydrosulfite.

Any UV disinfection system should be pilot tested prior to full-scale operation to ensure that it will meet discharge permit requirements for a particular site.

The average lamp life ranges from 8,760 to 14,000 working hours, and the lamps are usually replaced after 12,000 hours of use. Operating procedures should be set to reduce the on/off cycles of the

lamps, since their efficacy is reduced with repeated cycles.

The ballast must be compatible with the lamps and should be ventilated to protect it from excessive heating, which may shorten its life or even result in fires. Although the life cycle of ballasts is approximately 10 to 15 years, they are usually replaced every 10 years. Quartz sleeves will last about 5 to 8 years but are generally replaced every 5 years.

COSTS

The cost of UV disinfection systems depends on the manufacturer, the site, the capacity of the plant, and the characteristics of the wastewater to be disinfected. Total costs of UV disinfection can be competitive with chlorination when the dechlorination step is included.

The annual operating costs for UV disinfection include power consumption; cleaning chemicals and supplies; miscellaneous equipment repairs (2.5% of total equipment cost); replacement of lamps, ballasts and sleeves; and staffing requirements.

Costs have decreased in recent years due to improvements in lamp and system designs, increased competition, and improvements in the systems' reliability.

Medium-pressure lamps cost four to five times as much as low-pressure lamps. However, the reduced number of lamps necessary for adequate disinfection could make medium-pressure lamps cost-effective. Table 3A summarizes the costs of some of the lamps used in UV disinfection. This information was collected in a study conducted by the Water Environment Research Federation in 1995 for secondary effluents from disinfection facilities at average dry weather flow rates of 1, 10, and 100 mgd (2.25, 20, and 175 mgd peak wet weather flow, respectively). Table 3B describes the typical capital and O&M costs that are associated with a UV disinfection.

TABLE 3A LAMP COSTS FOR UV DISINFECTION SYSTEMS

Item	Range*	Typical*
UV lamps	($/lamp)	($/lamp)
1-5 mgd	397-1,365	575
5-10 mgd	343-594	475
19-100 mgd	274-588	400
Construction cost for physical facilities	(% of UV lamp cost) 75-200	(% of UV lamp cost) 150

* Costs are based on a 1993 Engineering News Record Construction Cost Index of 5,210.
Source: Adapted from: Darby et al. (1995) with permission from the Water Environment Research Foundation.

TABLE 3B CAPITAL AND O&M COSTS FOR UV DISINFECTION SYSTEMS

Cost Item	UV System Cost ($)
Capital Costs	
Equipment	120,000
Structural modifications	64,000
Electrical	20,000
Miscellaneous	40,000
Total:	**244,000**
Annual operating and maintenance costs	
Energy	3300
Lamps and chemicals	2840
Cleaning	1180
Maintenance	1440
Process control	6240
Testing	4160
Total	**19,190**

Source: Hanzon and Vigilia, 1999.

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United States Environmental Protection Agency
Office of Water Washington, D.C.
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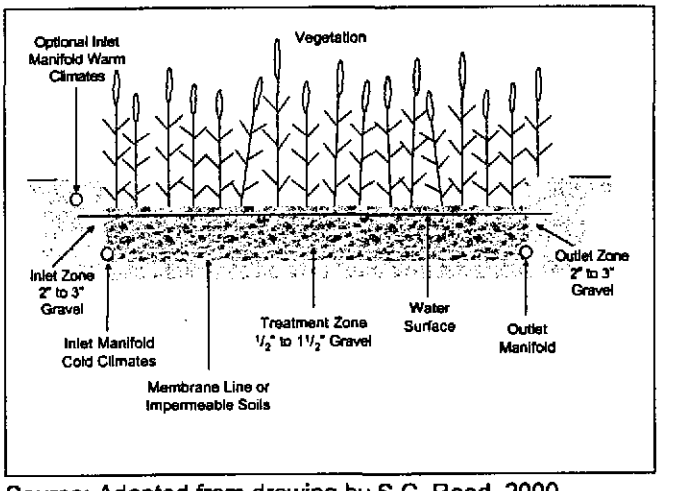
EPA

Wastewater Technology Fact Sheet
Wetlands: Subsurface Flow

DESCRIPTION

Wetland systems are typically described in terms of the position of the water surface and/or the type of vegetation grown. Most natural wetlands are free water surface systems where the water surface is exposed to the atmosphere; these include bogs (primary vegetation mosses), swamps (primary vegetation trees), and marshes (primary vegetation grasses and emergent macrophytes). A subsurface flow (SF) wetland is specifically designed for the treatment or polishing of some type of wastewater and are typically constructed as a bed or channel containing appropriate media. An example of a SF wetland is shown in Figure 1. Coarse rock, gravel, sand and other soils have all been used, but a gravel medium is most common in the U.S. and Europe. The medium is typically planted with the same types of emergent vegetation present in marshes, and the water surface is designed to remain below the top surface of the medium. The main advantages of this subsurface water level are prevention of mosquitoes and odors, and elimination of the risk of public contact with the partially treated wastewater. In contrast, the water surface in natural marshes and free water surface (FWS) constructed wetlands is exposed to the atmosphere with the attendant risk of mosquitoes and public access.

The water quality improvements in natural wetlands had been observed by scientists and engineers for many years and this led to the development of constructed wetlands as an attempt to replicate the water quality and the habitat benefits of the natural wetland in a constructed ecosystem. Physical, chemical, and biochemical reactions all contribute to water quality improvement in these wetland



Source: Adapted from drawing by S.C. Reed, 2000.

FIGURE 1 SUBSURFACE FLOW WETLAND

systems. The biological reactions are believed due to the activity of microorganisms attached to the available submerged substrate surfaces. In the case of FWS wetlands these substrates are the submerged portion of the living plants, the plant litter, and the benthic soil layer. In SF wetlands the available submerged substrate includes the plant roots growing in the media, and the surfaces of the media themselves. Since the media surface area in a SF wetland can far exceed the available substrate in a FWS wetland, the microbial reaction rates in a SF wetland can be higher than a FWS wetland for most contaminants. As a result, a SF wetland can be smaller than the FWS type for the same flow rate and most effluent water quality goals.

The design goals for SF constructed wetlands are typically an exclusive commitment to treatment functions because wildlife habitat and public recreational opportunities are more limited than FWS wetlands. The size of these systems ranges

from small on-site units designed to treat septic tank effluents to a 1.5×10^7 liters per day (4 MGD) system in Louisiana treating municipal wastewater. There are approximately 100 systems in the U.S. treating municipal wastewater, with the majority of these treating less than 3.8×10^3 m^3/day (1 MGD). Most of the municipal systems are preceded by facultative or aerated treatment ponds. There are approximately 1,000 small scale on-site type systems in the U.S. treating waste waters from individual homes, schools, apartment complexes, commercial establishments, parks, and other recreational facilities. The flow from these smaller systems ranges from a few hundred gallons per day to 151,400 liters per day (40,000 gallons per day), with septic tanks being the dominant preliminary treatment provided. SF wetlands are not now typically selected for larger flow municipal systems. The higher cost of the rock or gravel media makes a large SF wetland uneconomical compared to a FWS wetland in spite of the smaller SF wetland area required. Cost comparisons have shown that at flow rates above 227,100 liters per day (60,000 gallons per day) it will usually be cheaper to construct a FWS wetland system. However, there are exceptions where public access, mosquito, or wildlife issues justify selection of a SF wetland. One recent example is a SF wetland designed to treat the runoff from the Edmonton Airport in Alberta, Canada. The snow melt runoff is contaminated with glycol de-icing fluid and a SF wetland treating 1,264,190 liters per day (334,000 gallons per day) was selected to minimize habitat values and bird problems adjacent to the airport runways.

SF wetlands typically include one or more shallow basins or channels with a barrier to prevent seepage to sensitive groundwaters. The type of barrier will depend on local conditions. In some cases compaction of the local soils will serve adequately, in other cases clay has been imported or plastic membrane (PVC or HDPE) liners used. Appropriate inlet and outlet structures are employed to insure uniform distribution and collection of the applied wastewater. A perforated manifold pipe is most commonly used in the smaller systems. The depth of the media in these SF wetlands has ranged from 0.3 to 0.9 meters (1 to 3 feet) with 0.6 meters (2 feet) being most common. The size of the media in use in the U.S. ranges from fine gravel (≥0.6 centimeters or ≥ 0.25 in.) to large crushed rock (≥15.2 centimeters or ≥6 in.); A combination of sizes from 1.3 centimeters to 3.8 centimeters (0.5 to 1.5 inches) are most typically used. This gravel medium should be clean, hard, durable stone capable of retaining it's shape and the permeability of the wetland bed over the long term.

The most commonly used emergent vegetation in SF wetlands include cattail (*Typha* spp.), bulrush (*Scirpus* spp.), and reeds (*Phragmites* spp.). In Europe, *Phragmites* are the preferred plants for these systems. *Phragmites* have several advantages since it is a fast growing hardy plant and is not a food source for animals or birds. However, in some parts of the U.S. the use of *Phragmites* is not permitted because it is an aggressive plant and there are concerns that it might infest natural wetlands. In these cases cattails or bulrush can be used. In areas where muskrat or nutria are found, experience has shown that these animals, using the plants for food and nesting material, can completely destroy a stand of cattails or bulrush planted in a constructed wetland. Many of the smaller on-site systems serving individual homes use water tolerant decorative plants. The vegetation on a SF wetland bed is not a major factor in nutrient removal by the system and does not require harvesting. In cold climates, the accumulating plant litter on top of the gravel bed provides useful thermal insulation during the winter months. The submerged plant roots do provide substrate for microbial processes and since most emergent macrophytes can transmit oxygen from the leaves to their roots there are aerobic microsites on the rhizome and root surfaces. The remainder of the submerged environment in the SF wetland tends to be devoid of oxygen. This general lack of available oxygen limits the biological removal of ammonia nitrogen (NH_3/NH_4 - N) via nitrification in these SF wetlands, but the system is still very effective for removal of BOD, TSS, metals, and some priority pollutant organics since their treatment can occur under either aerobic or anoxic conditions. Nitrate removal via biological denitrification can also be very effective since the necessary anoxic conditions are always present and sufficient carbon sources are usually available.

The limited availability of oxygen in these SF systems reduces the capability for ammonia removal

via biological nitrification. As a result, a long detention time in a very large wetland area is required to produce low levels of effluent nitrogen with typical municipal wastewater influents unless some system modification is adopted. These modifications have included installation of aeration tubing at the bottom of the bed for mechanical aeration, the use of an integrated gravel trickling filter for nitrification of the wastewater ammonia, and vertical flow wetland beds. These vertical flow beds usually contain gravel or coarse sand and are loaded intermittently at the top surface. The intermittent application and vertical drainage restores aerobic conditions in the bed permitting aerobic reactions to proceed rapidly. Cyclic filling and draining of a horizontal flow system has been successfully demonstrated at the 130,000 gallons per day SF wetland system in Minoa, NY. The reaction rates for BOD_5 and ammonia removal during these cyclic operations were double the rates observed during normal continuously saturated flow.

The phosphorus removal mechanisms available in all types of constructed wetlands also require long detention times to produce low effluent levels of phosphorus with typical municipal wastewater. If significant phosphorus removal is a project requirement then a FWS wetland will probably be the most cost effective type of constructed wetland. Phosphorus removal is also possible with final chemical addition and mixing prior to a final deep settling pond.

The minimal acceptable level of preliminary treatment prior to a SF wetland system is the equivalent of primary treatment. This can be accomplished with septic tanks or Imhoff tanks for smaller systems or deep ponds with a short detention time for larger systems. The majority of existing SF wetland systems treating municipal waste waters are preceded by either facultative or aerated ponds. Such ponds are not necessarily the preferred type of preliminary treatment. At most of these existing systems the SF wetland was selected to improve the water quality of the pond effluent. Since the SF wetland can provide very effective removal for both BOD_5 and TSS, there is no need to provide for high levels of removal of these constituents in preliminary treatments.

The SF wetland does not provide the same level of habitat value as the FWS wetland because the water in the system is not exposed and accessible to birds and animals. However, wildlife will still be present, primarily in the form of nesting animals, birds, and reptiles. If provision of more significant habitat values is a project goal it can be accomplished with deep ponds interspersed between the SF wetland cells. The first pond in such a system would be located after the point where water quality is approaching at least the secondary level

APPLICABILITY

SF wetland systems are best suited for small to moderate sized applications (≤ 227,100 liters/day or ≤60,000 gallons per day) and at larger systems where the risk of public contact, mosquitoes, or potential odors are major concerns. Their use for on-site systems provides a high quality effluent for in-ground disposal, and in some States a significant reduction in the final disposal field area is allowed. SF wetlands will reliably remove BOD, COD, and TSS, and with sufficiently long detention times can also produce low levels of nitrogen and phosphorus. Metals are removed effectively and about a one log reduction in fecal coliforms can be expected in systems designed to produce secondary or advanced secondary effluents.

ADVANTAGES AND DISADVANTAGES

Some advantages and disadvantages of subsurface flow wetlands are listed below.

Advantages

- SF wetlands provide effective treatment in a passive manner and minimize mechanical equipment, energy, and skilled operator attention.

- SF wetlands can be less expensive to construct and are usually less expensive to operate and maintain as compared to mechanical treatment processes designed to produce the same effluent quality.

- Year-round operation for secondary treatment is possible in all but the coldest climates.

- Year-round operation for advanced or tertiary treatment is possible in warm to moderately temperate climates. The SF wetland configuration provides more thermal protection than the FWS wetland type.

- SF wetland systems produce no residual biosolids or sludges requiring subsequent treatment and disposal.

- The SF wetland is very effective and reliable for removal of BOD, COD, TSS, metals, and some persistant organics in municipal wastewaters. The removal of nitrogen and phosphorus to low levels is also possible but requires a much longer detention time.

- Mosquitoes and similar insect vectors are not a problem with SF wetlands as long as the system is properly operated and a subsurface water level maintained. The risk of contact by children and pets with partially treated wastewater is also eliminated.

Disadvantages

- A SF wetland will require a large land area compared to conventional mechanical treatment processes.

- The removal of BOD, COD, and nitrogen in SF wetlands are continuously renewable processes. The phosphorus, metals, and some persistent organics removed in the system are bound in the wetland sediments and accumulate over time.

- In cold climates the low winter water temperatures reduce the rate of removal for BOD, NH_3, and NO_3. An increased detention time can compensate for these reduced rates but the increased wetland size in extremely cold climates may not be cost effective or technically possible.

- Most of the water contained in the SF wetland is anoxic and this limits the potential for nitrification of wastewater ammonia. Increasing the wetland size and detention time will compensate, but this may not be cost effective. Alternative methods for nitrification in combination with a SF wetland have been successful. SF wetlands cannot be designed for complete removal of organic compounds, TSS, nitrogen, and coliforms. The natural ecological cycles in these wetlands produce "background" concentrations of these substances in the system effluent.

- SF wetland systems can typically remove fecal coliforms by at least one log. This is not always sufficient to meet discharge limits in all locations and post disinfection may be required. UV disinfection has been successfully used in a number of applications.

- Although SF wetlands can be smaller than FWS wetlands for the removal of most constituents, the high cost of the gravel media in the SF wetland can result in higher construction costs for SF systems larger than about 227,100 liters per day (60,000 gallons per day).

DESIGN CRITERIA

Published models for the design of SF wetland systems have been available since the late 1980's. More recent efforts in the mid to late 1990's have produced three text books containing design models for SF wetlands (Reed, et al 1995, Kadlec & Knight 1996, Crites & Tchobanoglous, 1998). In all three cases, the models are based on first order plug flow kinetics, but results do not always agree due to the author's developmental choices and because the same databases were not used for derivation of the models. The Water Environment Federation (WEF) presents a comparison of the three approaches in their Manual of Practice on Natural Systems (WEF, 2000) as does the US EPA design manual on wetland systems (EPA, 2000). The designer of a SF wetland system should consult these references and select the method best suited for the project under

consideration. A preliminary estimate of the land area required for a SF wetland can be obtained from Table 1 of typical areal loading rates. These values can also be used to check the results from the previously cited references.

The SF wetland size is determined by the pollutant which requires the largest land area for it's removal. This is the bottom surface area of the wetland cells and, for that area to be 100 percent effective, the wastewater flow must be uniformly distributed over the entire surface. This is possible with constructed wetlands by careful grading of the bottom surface and use of appropriate inlet and outlet structures. The total treatment area should be divided into at least two cells for all but the smallest systems. Larger systems should have at least two parallel trains of cells to provide flexibility for management and maintenance.

These wetland systems are living ecosystems and the life and death cycles of the biota produce residuals which can be measured as BOD, TSS, nitrogen, phosphorus and fecal coliforms. As a result, regardless of the size of the wetland or the characteristics of the influent, in these systems there will always be a residual background concentration of these materials. Table 2 summarizes these background concentrations.

It is necessary for the designer to determine the water temperature in the wetland because the removal of BOD, and the various nitrogen forms are temperature dependent. The water temperature in large systems with a long HRT (>10 days) will approach the average air temperature except during subfreezing weather in the winter. Methods for estimating the water temperature for wetlands with a shorter HRT (<10 days) can be found in the published references mentioned previously.

It is also necessary to consider the hydraulic aspects of system design because there is significant frictional resistance to flow through the wetland caused by the presence of the gravel media and the plant roots and other detritus. The major impact of this flow resistance is on the configuration selected for the wetland cell. The longer the flow path the higher the resistance will be. To avoid these hydraulic problems an aspect ratio (L:W) of 4:1 or less is recommended. Darcy's law is generally accepted as the model for the flow of water through SF wetlands and descriptive information can again be found in the published references mentioned previously. The flow of water through the wetland cell depends on the hydraulic gradient in the cell and on the hydraulic conductivity (k_s), size, and porosity (n) of the media used. Table 3 presents typical characteristics for potential SF wetland media. These values can be used for a preliminary estimate and for design of very small systems. For large scale systems the proposed media should be tested to determine these values.

TABLE 1 TYPICAL AREAL LOADING RATES FOR SF CONSTRUCTED WETLANDS

Constituent	Typical Influent Concentration mg/L	Target Effluent Concentration mg/L	Mass Loading Rate lb/ac/d*
Hydraulic Load (in./d)	3 to 12**		
BOD	30 to175	10 to 30	60 to 140
TSS	30 to150	10 to 30	40 to 150
NH_3/NH_4 as N	2 to 35	1 to 10	1 to 10
NO_3 as N	2 to 10	1 to 10	3 to 12
TN	2 to 40	1 to 10	3 to 11
TP	1 to 10	0.5 to 3	1 to 4

Note: Wetland water temperature » 20°C.

TABLE 2 "BACKGROUND" SF WETLAND CONCENTRATIONS

Constituent	Units	Concentration Range
BOD_5	mg/L	1 to 10
TSS	mg/L	1 to 6
TN	mg/L	1 to 3
NH_3/NH_4 as N	mg/L	less than 0.1
NO_3 as N	mg/L	less than 0.1
TP	mg/L	less than 0.2
Fecal Coliforms	MPN/100ml	50 to 500

Source: Reed et al., 1995 and U.S. EPA, 1993.

PERFORMANCE

A lightly loaded SF wetland can achieve the "background" effluent levels given in Table 2. In the general case, the SF constructed wetland is typically designed to produce a specified effluent quality and Table 1 can be used for a preliminary estimate of the size of the wetland necessary to produce the desired effluent quality. The design models in the referenced publications will provide a more precise estimate of treatment area required. Table 4 summarizes actual performance data for 14 SF wetland systems included in a US EPA Technology Assessment (EPA, 1993).

In theory, the performance of a SF wetland system can be influenced by hydrological factors. High evapotranspiration (ET) rates may increase effluent concentrations, but this also increases the HRT in the wetland. High precipitation rates dilute the pollutant concentrations but also shorten the HRT in the wetland. In most temperate areas with a moderate climate these influences are not critical for performance. These hydrological aspects need only be considered for extreme values of ET and precipitation.

OPERATION AND MAINTENANCE

The routine operation and maintenance (O&M) requirements for SF wetlands are similar to those for facultative lagoons, and include hydraulic and water depth control, inlet/outlet structure cleaning, grass mowing on berms, inspection of berm integrity, wetland vegetation management, and routine monitoring.

The water depth in the wetland may need periodic adjustment on a seasonal basis or in response to increased resistance over a very long term from the accumulating detritus in the media pore spaces. Mosquito control should not be required for a SF wetland system as long as the water level is maintained below the top of the media surface. Vegetation management in these SF wetlands does not include a routine harvest and removal of the

TABLE 3 TYPICAL MEDIA CHARACTERISTICS FOR SF WETLANDS

Media Type	Effective Size D_{10} (mm)*	Porosity, n (%)	Hydraulic Conductivity k_s ($ft^3/ft^2/d$)*
Coarse Sand	2	28 to 32	300 to 3,000
Gravelly Sand	8	30 to 35	1,600 to 16,000
Fine Gravel	16	35 to 38	3,000 to 32,000
Medium Gravel	32	36 to 40	32,000 to 160,000
Coarse Rock	128	38 to 45	16×10^4 to 82×10^4

* mm x 0.03937 = inches

** $ft^3/ft^2/d$ x 0.3047 = $m^3/m^2/d$, or x 7.48 = $gal/ft^2/d$

Source: Reed et al., 1995.

TABLE 4 SUMMARY OF PERFORMANCE FOR 14 SF WETLAND SYSTEMS*

Constituent	Mean Influent mg/L	Mean Effluent mg/L
BOD_5	28** (5-51)***	8** (1-15)***
TSS	60 (23-118)	10 (3-23)
TKN as N	15 (5-22)	9 (2-18)
NH_3/NH_4 as N	5 (1-10)	5 (2-10)
NO_3 as N	9 (1-18)	3 (0.1-13)
TN	20 (9-48)	9 (7-12)
TP	4 (2-6)	2 (0.2-3)
Fecal Coliforms (#/100ml)	270,000 (1,200-1,380,000)	57,000 (10-330,000)

* Mean detention time 3 d (range 1 to 5 d).
** Mean value.
*** Range of values.

Source: U.S. EPA, 1993.

harvested material. Plant uptake of pollutants represents a relatively minor pathway so harvest and removal on a routine basis does not provide a significant treatment benefit. Removal of accumulated litter is unnecessary, and in cold climates it serves as thermal insulation to prevent freezing in the wetland bed. Vegetation management may also require wildlife management, depending on the type of vegetation selected for the system, and the position of the water. Animals such as nutria and muskrats have been known to consume all of the emergent vegetation in constructed wetlands. These animals should not be attracted to a SF wetland as long as the water level is properly maintained. Routine water quality monitoring will be required for all SF systems with an NPDES permit, and the permit will specify the pollutants and frequency. Sampling for NPDES monitoring is usually limited to the untreated wastewater and the final system effluent. Since the wetland component is usually preceded by some form of preliminary treatment, the NPDES monitoring program does not document wetland influent characteristics. It is recommended, in all but the smallest systems that periodic samples of the wetland influent be obtained and tested for operational purposes in addition to the NPDES requirements. This will allow the operator a better understanding of wetland performance and provide a basis for adjustments if necessary.

COSTS

The major items included in the capital costs for SF wetlands are similar to many of those required for lagoon systems. These include land costs, site investigation, site clearing, earthwork, liner, gravel media, plants, inlet and outlet structures, fencing, miscellaneous piping, etc., engineering, legal, contingencies , and contractor's overhead and profit. The gravel media and the liner can be the most expensive items from this list. In the Gulf States where clay soils often eliminate the need for a liner the cost of imported gravel can often represent 50 percent of the construction costs. In other locations where local gravel is available but a membrane liner is required the liner costs can approach 40 percent of the construction costs. In many cases compaction of the in-situ native soils provides a sufficient barrier for groundwater contamination. Table 5 provides a summary of capital and O & M costs for a hypothetical 378,500 liters/day (100,000 gallons per day) SF constructed wetland, required to achieve a 2 mg/L ammonia concentration in the effluent. Other calculation assumptions are as follows: influent NH_3= 25 mg/L, water temperature 20°C (68°F), media depth = 0.6 meters (2 ft), porosity = 0.4, treatment area = 1.3 hectares (3.2 ac), land cost=$12,355/hectare ($5,000/ac).

TABLE 5 CAPITAL AND O&M COSTS FOR 100,000 GALLONS PER DAY SF WETLAND

Item	Cost $*	
	Native Soil Liner	Plastic Membrane Liner
Land Cost	$16,000	16,000
Site Investigation	3,600	3,600
Site Clearing	6,600	6,600
Earthwork	33,000	33,000
Liner	0	66,000
Gravel Media**	142,100	142,100
Plants	5,000	5,000
Planting	6,600	6,600
Inlets/Outlets	16,600	16,600
Subtotal	$229,500	$295,500
Engineering, legal, etc.	$133,000	$171,200
Total Capital Cost	**$362,500**	**$466,700**
O & M Costs, $/yr	$6,000/yr	$6,000/yr

* June 1999 costs, ENR CCI = 6039
**12,000 cy of 0.75 in. gravel

TABLE 6 COST COMPARISON SF WETLAND AND CONVENTIONAL WASTEWATER TREATMENT

Cost Item	Process	
	Wetland	SBR
Capital Cost	$466,700	$1,104,500
O &M Cost	$6,000/yr	$106,600/yr
Total Present Worth Costs*	$530,300	$2,233,400
Cost per 1000 gallons treated**	$0.73	$3.06

*Present worth factor 10.594 based on 20 years at 7 percent interest (June 1999 costs, ENR CCI = 6039).
**Daily flow rate for 365 d/yr, for 20 yr, divided by 1000 gallons

Source: WEF, 2000.

Table 6 compares the life cycle costs for this wetland to the cost for a conventional treatment system designed for the same flow and effluent water quality. The conventional process is a sequencing batch reactor (SBR).

REFERENCES

Other Related Fact Sheets

Free Water Surface Wetlands
EPA 832-F-00-024
September, 2000

Other EPA Fact Sheets can be found at the following web address:
http://www.epa.gov/owmitnet/mtbfact.htm

1. Crites, R.W., G. Tchobanoglous (1998) *Small and Decentralized Wastewater Management Systems,* McGraw Hill Co., New York, New York.

2. Kadlec, R.H., R. Knight (1996)*Treatment Wetlands,* Lewis Publishers, Boca Raton, Florida.

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4. U.S. EPA (1999) *Free Water Surface Wetlands for Wastewater Treatment: A Technology Assessment,* US EPA, OWM, Washington, DC. (in press.)

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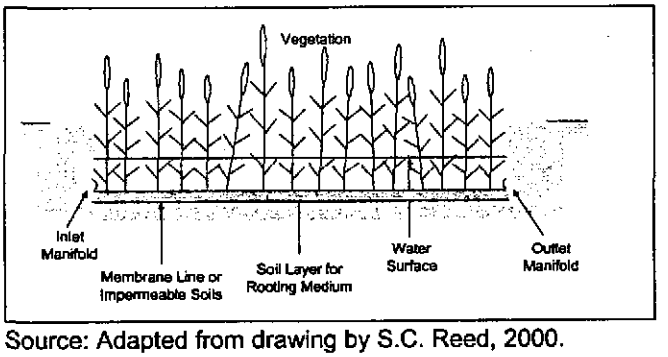
United States Environmental Protection Agency
Office of Water Washington, D.C.
EPA 832-F-00-024 September 2000

EPA

Wastewater Technology Fact Sheet
Free Water Surface Wetlands

DESCRIPTION

Free water surface (FWS) wetlands are defined as wetland systems where the water surface is exposed to the atmosphere. Most natural wetlands are FWS systems, including bogs (primary vegetation mosses), swamps (primary vegetation trees), and marshes (primary vegetation grasses and emergent macrophytes.) The observation of water quality improvements in these natural wetlands for many years led to the development of constructed wetlands in an effort to replicate the water quality and habitat benefits of natural wetlands in a constructed ecosystem. The majority of FWS constructed wetlands designed for wastewater treatment are marshes, but a few operating examples of bogs and swamps exist. In FWS treatment wetlands, water flows over a vegetated soil surface from an inlet point to an outlet point. In some cases, water is completely lost to evapotranspiration and seepage within the wetland. A diagram of FWS wetland is shown in Figure 1.



Source: Adapted from drawing by S.C. Reed, 2000.

FIGURE 1 FREE WATER SURFACE WETLAND

There are relatively few examples of the use of natural wetlands for wastewater treatment in the United States. Because any discharge to a natural wetland must satisfy National Pollutant Discharge Elimination System (NPDES) limits, these wetlands are typically used for advanced wastewater treatment (AWT) or tertiary polishing. The design goals for constructed wetlands range from an exclusive commitment for basic treatment functions to systems which provide advanced treatment and/or combine with enhanced wildlife habitat and public recreational opportunities. The size of the FWS wetland systems ranges from small on-site units designed to treat septic tank effluents to large units with more than 16,188 hectares (40,000 acres). A large system is being used to treat phosphorus from agricultural storm water drainage in south Florida. Operational FWS wetlands designed for municipal wastewater treatment in the United States range from less than 3785 liters per day (1,000 gallons per day) to more than 75,708 m^3/day (20 million gallons per day).

Constructed FWS wetlands typically consist of one or more shallow basins or channels with a barrier to prevent seepage to sensitive ground waters and a submerged soil layer to support the roots of the selected emergent macrophyte vegetation. Each system has appropriate inlet and outlet structures to ensure uniform distribution and collection of the applied wastewater. The most commonly used emergent vegetations in constructed FWS wetlands include cattail (*Typha* spp.), bulrush (*Scirpus* spp.), and reeds (*Phragmites* spp.). In systems designed primarily for treatment, it is common to select only one or two species for planting. The plant canopy formed by the emergent vegetation shades the water surface, preventing growth and persistence of algae, and reduces wind-induced turbulence in the water

flowing through the system. Perhaps most important are the submerged portions of the living plants, the standing dead plants, and the litter accumulated from previous growth. These submerged surfaces provide the physical substrate for the periphytic-attached growth organisms responsible for much of the biological treatment in the system. The water depth in the vegetated portions of these systems ranges from a few inches to two feet or more.

The influent to these wetlands spreads over a large area of shallow water and emergent vegetation. The subsequent low velocity and essentially laminar flow provides for very effective particulate removal in the front part of the system. This particulate material, characterized as total suspended solids (TSS), contains Biochemical Oxygen Demand (BOD) components, fixed forms of total nitrogen (TN) and total phosphorus (TP), and trace levels of metals and more complex organics. The oxidation or reduction of these particulates releases soluble forms of BOD, TN, and TP to the wetland environment, which are available for adsorption by the soils and removal by the active microbial and plant populations throughout the wetland. Oxygen is available at the water surface, microsites on living plant surfaces, and on root and rhizome surfaces, allowing some aerobic activity the wetland. It is, however, prudent to assume that the bulk of the liquid in the FWS wetland is anoxic or anaerobic. The lack of oxygen can limit the biological removal of ammonia nitrogen (NH_3/NH_4 - N) via nitrification, but the FWS wetland is still effective for removal of BOD, TSS, trace metals, and some complex organics because the treatment of these occurs under both aerobic and anoxic conditions.

If nitrogen removal and/or enhancement of wildlife habitat is a project goal, consideration should be given to alternating shallow water emergent vegetated zones with deeper (greater than 1.83 meters or six feet) water zones containing selected submerged vegetation. Deeper water zones provide a completely exposed water surface for atmospheric re-aeration and submerged vegetation provides an additional source of oxygen for nitrification. The deeper water zones will also attract and retain a large variety of wildlife, particularly ducks and other water birds. This concept, in use at Arcata, California, and Minot, North Dakota, can provide excellent treatment on a year-round basis in warm climates and on a seasonal basis in colder climates where low temperatures and ice formation occur. The hydraulic residence time (HRT) in each of the open water zones should be limited to about three days at design flow to prevent the re-emergence of algae. Such systems should always start and end with shallow emergent vegetation zones to ensure retention and treatment of particulate matter and to minimize wildlife toxicity in the open water zones. The use of FWS constructed wetlands has increased significantly since the late 1980's. The systems are widely distributed in the United States and are found in about 32 states.

Common Modifications

In the United States, it is routine to provide some preliminary treatment prior to a FWS wetland. The minimal acceptable level is the equivalent of primary treatment which can be achieved with septic tanks, with Imhoff tanks for smaller systems, or with deep ponds with a short HRT. About 45 percent of operational FWS wetland systems use facultative lagoons for preliminary treatment, but these systems have also been used behind other treatment systems. For example, some of the largest FWS systems, in Florida and Nevada, were designed for tertiary effluent polishing and receive effluent from mechanical AWT plants.

Non-discharging, total retention FWS systems have been used in arid parts of the United States where the water is completely lost through a combination of seepage and evapotranspiration. These systems require that attention be paid to the long term accumulation of salts and other substances which might become toxic to wildlife or plants in the system. While it is impossible to exclude wildlife from FWS wetlands, it is prudent to minimize their presence until the water quality approaches secondary levels of treatment. This can be accomplished by limiting open water zones to the latter part of the system and using dense stands of emergent vegetation in the front part of the wetland. Selecting vegetation with little food value for animals or birds may also help. In colder climates or where large land areas are not available for wetland removal of nitrogen, a smaller wetland system can

be designed for BOD/TSS removal. Nitrogen removal can be achieved with a separate process. Wetland systems in Kentucky and Louisiana successfully use an integrated gravel trickling filter for nitrification of wastewater ammonia. Seasonally operated FWS wetlands are also used in very cold climates, in which the wastewater is retained in a lagoon during the winter months and discharged to the wetland at a controlled rate during the warm summer months.

APPLICABILITY

FWS wetlands require a relatively large land area, especially if nitrogen or phosphorus removal is required. The treatment is effective and requires little in the way of mechanical equipment, energy, and skilled operator attention. Wetland systems can be a most cost effective treatment alternative where suitable land is available at reasonable cost. They also provide enhanced habitat and recreational values. Land requirements and costs tend to favor application of FWS technology in rural areas.

FWS wetland systems reliably remove BOD, Chemical Oxygen Demand (COD), and TSS. With a sufficiently long HRT, they can also produce low levels of nitrogen and phosphorus. Metals are also removed and a reduction in fecal coliforms of about a one log can be expected. In addition to municipal wastewaters, FWS systems are used to treat mine drainage, urban storm water, combined sewer overflows, agricultural runoff, livestock and poultry wastes, landfill leachates, and for mitigation purposes. Because the water is exposed and accessible to humans and animals, the FWS concept of receiving partially treated wastewater may not be suited for use in individual homes, parks, playgrounds, or similar public facilities. A gravel bed subsurface flow (SF) wetland is a choice for these applications.

ADVANTAGES AND DISADVANTAGES

Some advantages and disadvantages of FWS wetlands are listed below:

Advantages

- FWS wetlands offer effective treatment in a passive manner, minimizing mechanical equipment, energy, and skilled operator requirements.
- FWS wetlands may be less expensive to construct, and are less costly to operate and maintain than conventional mechanical treatment systems.
- Year-round operation for secondary treatment is possible in all but the coldest climates. Year-round operation for advanced or tertiary treatment is possible in warm to moderately temperate climates.
- Wetland systems provide a valuable addition to the "green space" in a community, and include the incorporation of wildlife habitat and public recreational opportunities.
- Wetland systems produce no residual biosolids or sludges requiring subsequent treatment and disposal.
- The removal of BOD, TSS, COD, metals, and persistent organics in municipal wastewaters can be very effective with a reasonable detention time. The removal of nitrogen and phosphorus can also be effective with a significantly longer detention time.

Disadvantages

- The land area required for FWS wetlands can be large, especially if nitrogen or phosphorus removal are required.
- The removal of BOD, COD, and nitrogen are biological processes and essentially continuously renewable. The phosphorus, metals, and some persistent organics removed by the system are bound in the wetland sediments and accumulate over time.

- In cold climates low winter temperatures reduce the rate of removal for BOD and the biological reactions responsible for nitrification and denitrification. An increased detention time can compensate for this, but the increased wetland size required in extremely cold climates may not be cost effective or technically feasible.

- The bulk water in most constructed FWS wetland systems is essentially anoxic, limiting the potential for rapid biological nitrification of ammonia. Increasing the wetland size and, therefore, the detention time, may compensate for this, but may not be cost effective. Alternate methods for nitrification in combination with a FWS wetland have performed successfully.

- Mosquitoes and other insect vectors can be a problem.

- The bird population in a FWS wetland can have adverse impacts if an airport is nearby.

- FWS constructed wetlands can remove fecal coliforms by at least one log from typical municipal wastewaters. This may not be sufficient to meet discharge limits in all locations and supplemental disinfection may be required. The situation is further complicated because birds and other wildlife in the wetland produce fecal coliforms.

DESIGN CRITERIA

Published models for the pollutant removal design of FWS wetland systems have been available since the late 1980's. More recent efforts have produced three textbooks containing design models for FWS wetlands (Reed, et al., 1995; Kadlec & Knight, 1996; Crites & Tchobanoglous, 1998) All three models are based on first order plug flow kinetics but provide different results based on the use of different databases. The Water Environment Federation (WEF) presents a comparison of the three approaches in the Manual of Practice on Natural Systems (WEF, 2000.) Another comparison is found in the U.S. EPA design manual on wetland systems (U.S. EPA, 2000.) This manual also includes design models developed by Gearheart and Finney. The designer of a FWS wetland system should consult these references and select the method best suited for the project under consideration. A preliminary estimate of the land area required for an FWS wetland can be obtained from Table 1 of typical areal loading rates presented below. These values can also be used to check the results from other references.

The pollutant requiring the largest land area for removal determines the necessary treatment area for the wetland, which is the bottom surface area of the wetland cells. The wastewater flow must be uniformly distributed over the entire surface for that area to be 100 percent effective. This is possible with constructed wetlands by careful grading of the bottom surface and the use of appropriate inlet and outlet structures. Uniform distribution of wastewater is more difficult when natural wetlands are used for treatment or polishing. The existing configuration and topography are typically retained in these natural wetlands, which can result in significant short circuiting of flow. Dye tracer studies in such wetlands have shown that the effective treatment area can be as little as 10 percent of the total wetland area. The total treatment area should be divided into at least two cells for all but the smallest systems. Larger systems should have at

TABLE 1 TYPICAL AREAL LOADING RATES

Constituent	Typical Influent Conc. (mg/L)	Target Effluent Conc. (mg/L)	Mass Loading Rate (lb/ac/d)*
Hydraulic Load (in/d)	0.4 - 4**		
BOD	5 - 100	5 - 30	9 - 89
TSS	5 - 100	5 - 30	9 - 100
NH_3/NH_4 as N	2 - 20	1 - 10	1 - 4
NO_3 as N	2 - 10	1 - 10	2 - 9
TN	2 - 20	1 - 10	2 - 9
TP	1 - 10	0.5 - 3	1 - 4

least two parallel trains of cells to provide flexibility for management and maintenance.

Wetland systems are living ecosystems. The life and death cycles of the biota produce residuals which can be measured as BOD, TSS, nitrogen, phosphorus, and fecal coliforms. As a result, regardless of the size of the wetland or the characteristics of the influent, there will always be a residual background concentration of these materials in wetland systems. Table 2 summarizes these background concentrations.

Because removal of BOD and various nitrogen forms is temperature dependent, the temperature of the wetland must be known for proper design. The water temperature in large systems with a long HRT (greater than 10 days) will approach the average air temperature except during subfreezing weather in the winter. Methods to estimate the water temperature for wetlands with a shorter HRT (less than 10 days) can be found in the references cited.

TABLE 2 "BACKGROUND" FWS WETLAND CONCENTRATIONS

Constituent	Concentration Range
BOD_5 (mg/L)	1 - 10
TSS (mg/L)	1 - 6
TN (mg/L)	1 - 3
NH_3/NH_4 as N (mg/L)	< 0.1
NO_3 as N (mg/L)	< 0.1
TP (mg/L)	< 0.2
Fecal Coliforms (MPN/100mL)	50 - 500

Because living plants and litter provide significant frictional resistance to flow through the wetland , it is necessary to consider the hydraulic aspects of system design. Manning's equation is generally accepted as the model for the flow of water through FWS wetlands. Descriptive information is found in the references cited. Flow resistance impacts the configuration selected for the wetland cell: the longer the flow path, the higher the resistance. To avoid hydraulic problems, an aspect ratio (L:W) of 4:1 or less is recommended.

PERFORMANCE

A lightly loaded FWS wetland can achieve the "background" effluent levels shown in Table 2. In general, an FWS constructed wetland is designed to produce a specified effluent quality. Table 1 can be used to estimate the size of the wetland necessary to produce the desired effluent quality. The design models in the referenced publications provide a more precise estimate of required treatment area. Table 3 summarizes actual performance data for 27 FWS systems from a recent Technology Assessment (U.S. EPA, 2000).

In theory, the performance of a wetland system can be influenced by hydrological factors. High evapotranspiration (ET) rates may increase effluent concentrations, but may also increase the HRT in the wetland. High precipitation rates dilute the pollutant concentrations but also shorten the HRT in the wetland. In most temperate areas with a moderate climate, these influences are not critical for performance. Hydrological aspects only need to

TABLE 3 SUMMARY OF PERFORMANCE FOR 27 FWS WETLAND SYSTEMS

Constituent	Mean Influent (mg/L)	Mean Effluent (mg/L)
BOD_5	70	15
TSS	69	15
TKN as N	18	11
NH_3/NH_4 as N	9	7
NO_3 as N	3	1
TN	12	4
TP	4	2
Dissolved P	3	2
Fecal Coliforms (#/100mL)	73,000	1320

Source: U.S. EPA, 2000.

be considered for extreme values of ET and precipitation.

OPERATION AND MAINTENANCE

The routine operation and maintenance (O&M) requirements for FWS wetlands are similar to those for facultative lagoons. They include hydraulic and water depth control, inlet/outlet structure cleaning, grass mowing on berms, inspection of berm integrity, wetland vegetation management, mosquito and vector control (if necessary), and routine monitoring.

The water depth in the wetland may need adjustment on a seasonal basis or in response to increased resistance from the accumulating plant litter in the wetland channel. Mosquitoes may require control, depending on local conditions and requirements. The mosquito population in the treatment wetland should be no greater than in adjacent natural wetlands.

Vegetation management in FWS wetlands does not include the routine harvest and removal of the harvested material. Plant uptake of pollutants represents a relatively minor pathway, so harvest and removal on a routine basis does not provide a significant treatment benefit. Removal of accumulated litter may become necessary if there are severe restrictions to flow. Generally, this will only occur if the wetland channels have been constructed with very high aspect ratios (L:W > 10:1). Vegetation management may also include wildlife management, depending on the type of vegetation selected for the system. Animals such as nutria and muskrats have been known to consume all emergent vegetation in FWS constructed wetlands.

Routine water quality monitoring is required for all FWS systems with an NPDES permit. The permit specifies the monitoring requirements and frequency of monitoring. Sampling for NPDES monitoring is usually limited to untreated wastewater and the final system effluent. Since the wetland component is usually preceded by some form of preliminary treatment, the routine monitoring program does not document wetland influent characteristics. Periodic samples of the wetland influent should be obtained and tested for all but the smallest systems to provide the operator with an understanding of wetland performance and a basis for adjustments, if necessary.

COSTS

The major items included in the capital costs for FWS wetlands are similar to those for lagoon systems, including land, site investigation, site clearing, earthwork, liner, rooting media, plants, inlet and outlet structures, fencing, miscellaneous piping, engineering, legal, contingencies, and contractor's overhead and profit. The liner can be the most expensive item. For example, a plastic membrane liner can approach 40 percent of construction costs. In many cases, compaction of the in-situ native soils provides a sufficient barrier for groundwater contamination. Table 4

TABLE 4 CAPITAL AND O&M COSTS FOR 100,000 GAL/D FWS WETLAND

Item	Cost ($)*	
	Native Soil Liner	Plastic Membrane Liner
Land Cost	16,000	16,000
Site Investigation	3,600	3,600
Site Cleaning	6,600	6,600
Earthwork	33,000	33,000
Liner	0	66,000
Soil Planting Media	10,600	10,600
Plants	5,000	5,000
Planting	6,600	6,600
Inlets/Outlets	16,600	16,600
Subtotal	98,000	164,000
Engineering, legal, etc.	56,800	95,100
Total Capital Cost	154,800	259,100
O&M Costs ($/year)	6,000	6,000

* June 1999 Costs, ENR CCI = 6039

Source: Water Environment Federation, 2000.

summarizes capital and O&M costs for a hypothetical 378,500 liters per day (100,000 gallon per day) FWS constructed wetland, required to achieve a 2 mg/L ammonia concentration in the effluent. Other calculation assumptions include the following: influent NH_3 = 25 mg/L; water temperature = 20°C (68°F); water depth = 0.46 meters (1.5 ft); porosity = 0.75; treatment area = 1.3 hectares (3.2 ac); and land cost = $12,355/hectare ($5,000/ac).

Table 5 compares the life cycle costs for this wetland to the cost of a conventional sequencing batch reactor (SBR) treatment system designed for the same flow and effluent water quality.

TABLE 5 COST COMPARISON FOR FWS WETLAND AND CONVENTIONAL WASTEWATER TREATMENT

Cost Item	Process	
	Wetland	SBR
Capital Cost ($)	259,000	1,104,500
O&M Cost ($)	6,000/yr	106,600/yr
Total Present Worth Costs* ($)	322,700	2,233,400
Cost per 1000 gal treated ** ($)	0.44	3.06

*Present worth factor 10.594 based on 20 years at 7 percent interest

**Daily flow rate for 365 d/yr for 20 yr, divided by 1000 gal.

Source: Water Environment Federation, 2000.

REFERENCES

Other Related Fact Sheets

Wetlands: Subsurface Flow
EPA 832-F-00-023
September, 2000

Other EPA Fact Sheets can be found at the following web address:
http://www.epa.gov/owmitnet/mtbfact.htm

1. Crites, R.W. and G. Tchobanoglous, 1998, *Small and Decentralized Wastewater Management Systems,* McGraw Hill Co., New York, NY.

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6. Water Environment Federation, 2000, *Natural Systems for Wastewater Treatment,* MOP FD-16, WEF, Alexandria, VA.

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EXHIBIT IV-7

Ethel M® Chocolates

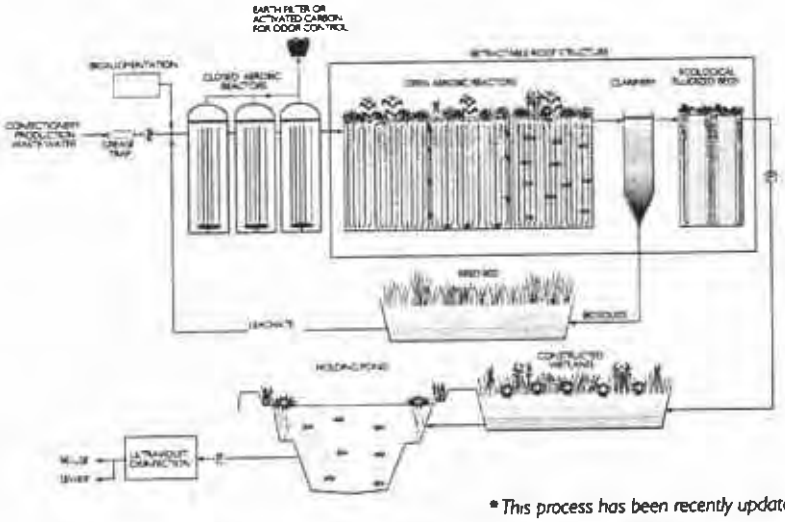
HENDERSON, NEVADA

Ethel M® Chocolates dates back less than two decades, but the story begain in 1911 when Frank and Ethel Mars started making and selling chocolates from their kitchen in Tacoma, Washington. They began a family tradition of producing quality confections which has been passed down through several generations and is still closely followed today in every product made by Mars, Inc.

Background

Senior management at Mars were familiar with Dr. John Todd and his patented technology, the Living Machine®. When planning an expansion of their Ethel M Chocolates plant, they looked to a Living Machine to help them meet tighter discharge requirements. The Living Machine at Ethel M provides advanced treatment of their confectionery process wastewater. The resulting purified water is reused for on-site landscape irrigation. Sludge is also treated on-site by a composting reed bed, making this a zero discharge facility.

LIVING MACHINE SCHEMATIC DIAGRAM FOR ETHEL M CHOCOLATES



** This process has been recently updated.*

Closed aerobic reactors and operators checking the clarifier

The aerobic reactors, clarifiers and EFBs are housed within an 8 foot high wall and under a retractable roof which automatically covers the system when it gets cold

We provide the system, nature does the work.

NATIONAL AUDUBON'S

Corkscrew Swamp Sanctuary

NAPLES, FLORIDA

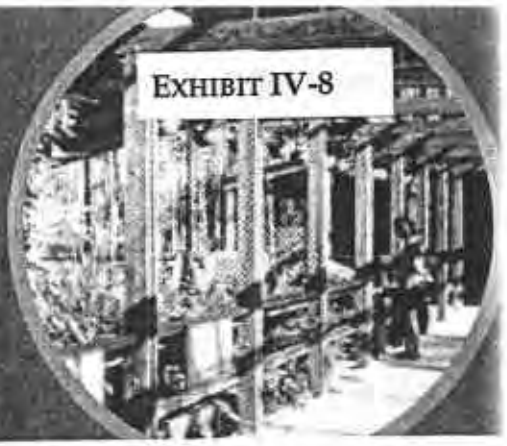


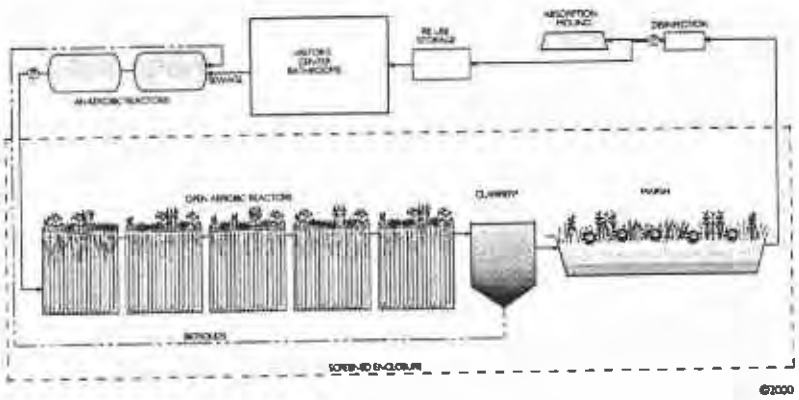
EXHIBIT IV-8

National Audubon Society's Corkscrew Swamp Sanctuary is located near Naples Florida. This sanctuary is home to a wide variety of native plants and animals. Swamps, marshes, and pine forests bring this 11,000 acre sanctuary to life. Corkscrew Swamp contains the world's largest remaining old-growth Bald Cypress Forest, has a two-mile boardwalk that takes visitors through a primeval cathedral of towering 500 year old trees, and provides a haven for birders and photographers.

Background

Because of limited leachfield capacity, the National Audubon Society was unable to expand its visitor facilities at the Corkscrew Swamp Sanctuary. Conventional wastewater options would have altered a large portion of the swamp. A Living Machine® modeled after the ecology of the swamp now treats wastewater from the Visitor's Center and recycles the treated water back to the toilets, reducing discharge by approximately 90 percent.

LIVING MACHINE SCHEMATIC DIAGRAM FOR NATIONAL AUDUBON SOCIETY



*This process has been recently updated.

"We believe in the wisdom of nature's design. We know that soil, water, plants, and wild creatures depend upon each other and are vital to human life. We recognize that each living thing links to many others in the chain of nature. We believe that persistent research into the intricate patterns of outdoor life will help to assure the wise use of earth's abundance. So we will be vigilant to protect wilderness areas, refuges, and parks and to encourage good use of nature's storehouse of resources."

— A Statement of Audubon Philosophy from Corkscrew Swamp Sanctuary, A Self Guided Tour of the Boardwalk

EXHIBIT IV-9

Darrow School

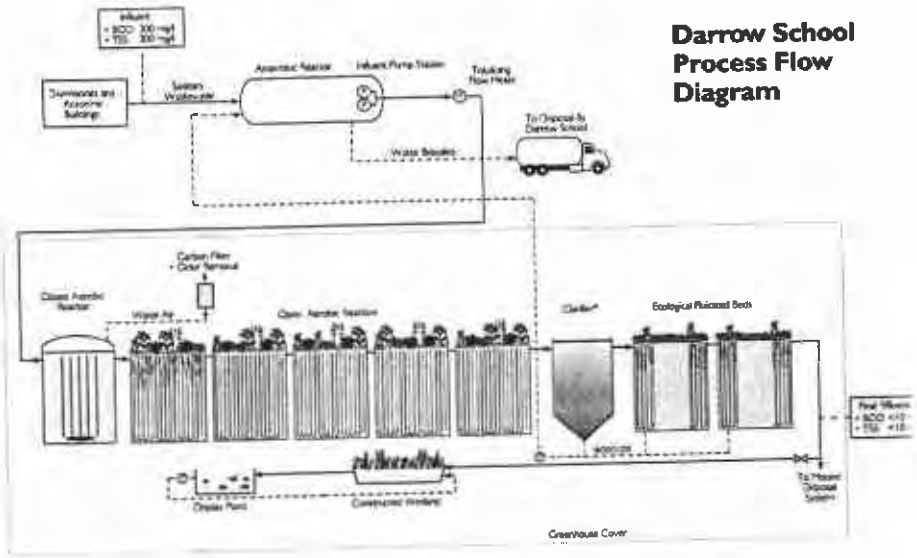
NEW LEBANON, NEW YORK

The Darrow School is a private residential high school, of 90 students, located on an old Shaker community site tucked away in the scenic Berkshire Mountains.

Background

Several years ago, Darrow School administrators found they needed to replace an aging septic system. Instead of using traditional septic tanks and leach fields, they decided to purchase a Living Machine®. Besides processing the school's wastewater, the Living Machine provides a setting for a wide variety of educational activities. The Living Machine is an integral part of the School's new Samson Environmental Center. The Center was designed using principles of sustainable design and construction. The innovative nature of the Living Machine, coupled with the educational programs that tie into its use, draw positive outside attention to the school, its mission and philosophy.

Darrow School Process Flow Diagram



** This process has been recently updated.*

"Hands-To-Work, Hearts-To-God was the motto of the Shakers that once livec on this site. This tradition of hard work, and hands-on experience is being carried on at Darrow School. Besides academics though, the Living Machine is helping the students to appreciate larger environmental issues."

— Steven Westcott, NPR's The Environment Show

EXHIBIT IV-10

WHITE PAPER

ON

DISTRIBUTED GENERATION

National Rural Electric Cooperative Association

Acknowledgements

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INTRODUCTION

Distributed generation (DG) is not a new concept. A small number of consumers have been installing their own generation on-site for decades. Recently, however, the creation of competitive retail electric markets and the development of new generation technologies, including proton exchange membrane (PEM) fuel cells and micro-turbines, has sparked new and broader interest in distributed generation.

Increasingly, properly planned and operated DG can provide consumers and society with a wide variety of benefits, including economic savings, improved environmental performance, and greater reliability. Technologies that are now sensible only in niche applications may soon be economical for broader use. Many cooperatives and other utilities have acted to bring the benefits of DG to their systems and are funding research to develop new technologies.

There is a danger, however, that DG is being oversold. The interconnection of DG with the electric grid continues to pose genuine safety and reliability risks. Moreover, because DG could replace or reduce the demand for traditional utility service, DG could also pose an economic risk to some incumbent utilities and their consumers.

That has created a conflict between industry stakeholders and other interest groups. On the one hand, proponents of DG are telling decision makers that utilities and regulators have imposed technical and economic barriers to the development, installation, and interconnection of DG facilities with the electric grid. They are asking regulators and legislators to act to remove those barriers so that consumers can benefit from DG.

On the other hand, some utilities have insisted that if decision makers adopted the DG proponents' recommendations, it would significantly degrade the safety and stability of electric systems and would require utilities and their residential and small commercial consumers to subsidize uneconomic technology investments by others.

In fact, the truth probably lies somewhere in between. Decision makers should address the legitimate concerns of DG proponents to help attain the potential benefits of DG. But, decision makers must first address a number of real safety, reliability, and economic issues. To accomplish that goal, decision makers should look carefully at different applications of different technologies. Separate rules can and should apply to each. The electrical grid is very complex and there are too many variations between the different applications of different DG technologies for any one rule to be universally applicable.

DEFINITION OF "DISTRIBUTED GENERATION"

Almost every participant in discussions about DG defines the term "distributed generation" differently. And, unfortunately, participants in discussions about DG seldom make their definition of the term clear at the outset, making it difficult to evaluate competing proposals.

At one end, DG could include only small-scale, environmentally friendly technologies – such as photovoltaics (PV), fuel cells, micro-turbines, or small wind turbines – that are installed on and designed primarily to serve a single end-user's site. At the other end, DG could encompass any generation built near to a consumers' load regardless of size or energy source. The latter definition could include large co-generation facilities capable of exporting hundreds of megawatts of energy to the grid.

Other definitions of DG include some or all of the following:

- any qualifying facilities under the Public Utility Regulatory Policies Act of 1978 (PURPA);
- any generation interconnected with distribution facilities;
- commercial back-up diesel generators installed, for example, in hospitals and hotels;
- residential back-up generators sold at hardware stores;
- generators installed by a utility at a substation for voltage support or other reliability purposes;
- any on-site generation with less than "X" kW or MW of capacity. "X" ranges everywhere from 10 kW to 50 MW;[1]
- facilities located at or near a load center;
- facilities that provide an enhanced value other than energy and capacity;
- facilities that are automated, modular, and mass produced;
- demand side management (DSM), energy efficiency, and other tools for reducing energy usage on the consumers' side of the meter. The alternative to this definition would be to abandon the term distributed generation altogether and use instead "distributed resources" (DR)[2] or "distributed energy resources." (DER)[3]

Stakeholders also see DG as fitting into different applications, including:

- Providing emergency or back-up supply to increase the reliability and stability of power supply at a consumer's site;
- Providing a portion of a consumer's load, particularly at peak times, to lower the consumer's total power bill;
- Providing a consumer's complete requirements most of the time. At times, the consumer may export excess generation to the grid or purchase some generation from the grid when their generation does not meet their demand;
- Providing a consumer's complete requirements so that the consumer can operate apart from the grid altogether;
- Providing power or ancillary services to the grid. This application can be exclusive of other uses, where the utility has the sole right to dispatch the facility for peak power or to provide system support. Or, it

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[1] For example, California's Public Utilities Commission established a 20 MW cap in its definition of distributed generation. See California Public Utilities Commission, "Opinion Regarding Distributed Generation and Electric Distribution Competition," Decision 99-10-065 (Oct. 21, 1999), p. 16. (hereinafter "CPUC 99-10-065").

[2] See Regulatory Assistance Project, "Draft Report: Profits and Progress Through Distributed Resources," (Nov. 1999) p.7 (http://www.rapmaine.org/distribution.html (1/10/00)) (hereinafter, "RAP Draft Report").

[3] See CPUC 99-10-065, p. 14 (defining "DG" to refer in part to small scale electric generating technologies and "DER" as including distributed generation technologies, storage technologies, end-use technologies, and DSM technologies).

can be combined with most of the other possible applications. For example, a co-generation unit that supplies only part of the requirements of an industrial consumer can still sell voltage control services to the grid operator and/or energy to the local utility or on the open market.

Why all of these definitions? As discussed below, many decision makers believe that DG is beneficial and are likely to adopt regulations or legislation that removes barriers to or subsidizes the development and installation of DG. Depending on the definition of DG that the decision makers adopt, and the different applications of DG that the decision makers address, different industry participants, or different interest groups will share in the benefits of the new regulatory programs. No industry or interest group wants to be left out.

For the purpose of this paper, *it is not necessary* to propose yet another competing definition. Instead, the paper will use the term "DG" generically to refer to any or all of the above concepts. For that reason, the paper will try not to make any categorical statements about DG generally, unless they truly can be said to apply regardless of the reader's definition. Whenever a comment applies only to a single technology or application, the paper will try to make that clear. Decision makers may benefit from the same approach. They may find much greater consensus in the industry on a range of technical and policy issues if they avoid wide ranging debates about "DG" generally and instead focus on narrow questions about specific applications of particular generation technologies.

REGULATORY BACKGROUND

CURRENT REGULATORY FRAMEWORK

To date, most state provisions addressing DG fall into one of two categories. First, most states have adopted rules implementing PURPA.[4] PURPA required utilities to interconnect with "qualifying facilities" (QFs),[5] to sell power to QFs,[6] and to purchase QF power at avoided cost.[7] Those rules, however, do not address the whole spectrum of DG. Under PURPA, QFs include only qualifying solar, wind, waste, or geothermal facilities with a power production capacity of no more than 80 MW and qualifying cogenerating facilities. QFs must also be owned by persons not primarily engaged in the generation or sale of electric power. And, with minor exceptions, renewable facilities qualify only if construction of the facility was begun before the end of 1999.[8]

Second, at least 30 states have so called "net metering" rules to date.[9] The purpose of those requirements is to provide a simple means to compensate consumers for certain forms of self generation. Although net metering rules vary widely between states, most cover only fairly small facilities powered with renewable resources: wind, photovoltaics, small hydro, and/or biomass. Most rules require utilities to interconnect with eligible consumer-owned generation and effectively run the consumer's meter backwards every time the consumer's generator exports net energy to the system. If the consumer uses more energy over the course of a billing period than they have generated, they pay only for the net energy that they have imported from the system. State rules vary widely if the consumer generates more than they have used over the course of a billing period. While some states prohibit any payment to consumers for net exports, others

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[4] Pub. L. No. 95-617, 92 Stat. 3117 (1978).
[5] See PURPA § 202, codified in § 210 of the Federal Power Act (FPA), 16 U.S.C. 824(i).
[6] See PURPA § 210. Congress may soon repeal PURPA's mandatory purchase obligation prospectively, but the reform is unlikely to affect existing QF contracts or PURPA's obligation to interconnection.
[7] See PURPA § 210.
[8] See FPA §§ 17,18.
[9] For a summary of state net metering provisions, please see Appendix A.

require utilities to pay consumers "avoided cost" like with PURPA or credit consumers the full retail price for their excess power.

Only a few states, including Texas and New York, have addressed DG more comprehensively. The New York Public Service Commission (PSC) recently established standards for residential and commercial applications of DG facilities with a capacity of up to 300 kVa[10] operating in parallel with the radial distribution facilities of utilities.[11] The Texas Public Utility Commission (PUC) established standards for interconnection of distributed generation pursuant to Texas' recent restructuring law, which guaranteed consumers' right "to have access to . . . on-site distributed generation . . . ."[12] The Texas rule defined "on-site distributed generation" as an electrical generating facility located at a customer's point of delivery of 10 MW or less and connected at a voltage of 60 kV or less.[13]

Both Texas and New York established uniform interconnection requirements, a standard contract, and standard application process for interconnection.[14] Texas also drafted a standard "Tariff for Interconnection and Parallel Operation of Distributed Generation". The New York PSC will also open a generic proceeding to look at the costs and benefits of DG and to examine utility rates for connecting residential DG and providing back up power.[15]

Vermont, Ohio, and California have open proceedings addressing these issues,[16] and others will likely open proceedings soon. California is taking a two track approach. The first track will address a range of issues pertaining to distributed generation, including interconnection requirements and rate issues.[17] The second track, to be addressed initially by a staff study and report, will investigate the broader questions of distribution competition and the role of the distribution company in a competitive retail electric market.[18]

Other than PURPA, the federal role is largely limited to funding research and development through the Department of Energy (DOE). As Assistant Secretary Dan Reicher has said, DOE has already made a substantial investment in research and development on a number of distributed technologies, such as industrial gas turbines, microturbines, combined heat and power, fuel cells, hybrid fuel cell/gas turbine systems, photovoltaics, concentrating solar dish engine systems, wind energy, batteries and superconducting magnetic energy storage. DOE recently began work on small modular biopower systems and is initiating efforts to develop a cleaner more efficient reciprocating engine technology.

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[10] "kVa" or kilovolt amp is roughly equivalent to "kW" or kilowatt. It is a more accurate description of a unit's electrical generating capacity. Different source materials and regulations appear to use the terms interchangeably.

[11] New York Public Service Commission, Opinion 99-13, "Opinion and Order Adopting Standard Interconnection Requirements for Distributed Generation Units," Case 94-E-0952 (December 31, 1999), p. 3 (hereinafter "NYPSC 99-13).

[12] Senate Bill 7 (SB 7), Act of May 21, 1999, 76th Legislature, Regular Session, chapter 405, 1999 Texas Session Law Service 2543, 2561 (Vernon) (to be codified as an amendment to the Public Utility Regulatory Act (PURA), Texas Utilities Code Annotated §39.101(b)(3)).

[13] Interconnection of On-Site Distributed Generation, 16 Tex. Reg. § 25.211(c)(a) (1999), to be codified at 16 Tex. Admin. Code § 25.211(c)(9) (hereinafter, "PUCT § 25.xx").

[14] See NYPSC 99-13, Appendix A; PUCT §25.211(c)(6) & (c)(15).

[15] Order pending, docket number not available as of January 12, 2000.

[16] See Re. Distributed Utility Planning, Dkt. No. 6290, Sept. 30, 1999 (Vt.. P.S.B.); CPUC 99-10-065; Public Utilities Commission of Ohio, "In the Matter of the Commission's Promulgation of Amendments to Rules for Electric Service and Safety Standards Pursuant to Chapter 4928, Revised Code," Case No. 99-1613-EL-ORD) December 21, 1999).

[17] CPUC 99-10-065, p. 3.

[18] Id.

Among other programs:

- In September 1999, DOE awarded grants to four fuel cell manufacturers to attempt to overcome the major barrier to increased fuel cell use – high capital cost;

- DOE, with financial assistance from the Department of Defense, is paying $1,000/kW to purchasers of fuel cells in the 100 to 300 kW size range, attempting to drive down the capital cost through increased production;

- DOE's Million Solar Roof Program has awarded more than $5,000,000 to fund assistance for PV roof top systems;

- DOE provided funding to help Kotzebue Electric Association in Alaska to install a 10 wind-turbine hybrid diesel 66kW wind farm north of the Arctic Circle.

There are also a number of other groups actively involved in looking at DG issues.

- The Institute of Electrical and Electronics Engineers (IEEE) is engaged in an ongoing process to develop uniform technical interconnection standards for connecting DG facilities to the grid. The IEEE has already issued a draft report and is expected to have a final report by 2002.[19] The IEEE defines "Distributed Generation" as "the generation of electricity by facilities sufficiently smaller than central generating plants as to allow interconnection at nearly any point in an electric power system. A subset of distributed resources."[20]

- The National Association of Regulatory Utility Commissioners (NARUC) is also closely involved. DG was a significant topic of discussion in the Electricity and the Energy Resources and the Environment Committees at both of NARUC's national meetings in 1999. With DOE funding, NARUC has commissioned two studies of DG. The first, being conducted by R.W. Beck, was intended to look at technical interconnection standards and standard interconnection contract issues. The second, being conducted by the Regulatory Assistance Project (RAP), was intended to look how to remove regulatory barriers to the implementation of DG. RAP has already completed two drafts of its report and intends to hold one or more workshops with NARUC on the issue. NRECA commented on the first draft, and will continue to provide input. RAP is also working on a study to look at ratemaking issues related to DG.

- The Consumer Energy Council of America Research Foundation (CECA/RF) has also begun a roundtable process, involving representatives of the DOE, NARUC, and a number of industry and stakeholder groups. That process is likely to produce a white paper on regulatory and technical issues with respect to DG by the end of 2000. Because of the range of participants and the senior industry persons involved, the report may be given significant weight at both NARUC and DOE. NRECA is participating in that process.

REGULATORY PROPOSALS

A number of industry stakeholders, advocacy groups and think tanks have proposed a broad range of regulatory approaches intended to advance different DG technologies or public goods. Some of those proposals would:

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[19] The standards are being developed by the IEEE SCC21 P1547 Distributed Resources and Electric Power Systems Interconnection Working Group. See IEEE's Standards Coordinating Committee 21 Website, http://grouper.ieee.org/groups/scc21/.

[20] IEEE Std. P1547 Draft 02.

- Create a well-advertised central source for information about DG for consumers and utilities, including who sells it, what it costs, and the requirements for installing and interconnecting it;

- Require utilities to offer net metering for DG;[21]

- Require utilities to adopt pricing structures that return to consumers who install DG some of the benefits that the DG unit provides the system;[22]

- Replace rate caps and cost-of-service rates with revenue caps to make utilities neutral as to whether or not their consumers install DG;[23]

- Combine distribution company integrated resource planning (DIRP) with performance-based rate making.[24]

- Subject consumers to the true cost of distribution service – also called de-averaging of distribution rates. A related proposal would include congestion charges in distribution rates;[25]

- Standardize technical and study requirements for interconnecting DG to distribution systems;[26]

- Make technical requirements for interconnecting DG to distribution systems "technology neutral";[27]

- Standardize the engineering review and approval – or "type testing" – of specific DG units, and require utilities to accept third party certification of the safety and reliability of those specific units. Third parties could include organizations such as UL and the IEEE;[28]

- Standardize power purchase agreements between electric service providers and owners of DG facilities;[29]

- Simplify power purchase agreements for small residential DG units;[30]

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[21] E.g., CPUC 99-10-065, p. 21 (cites to CPUC in this section indicate that participants have raised the issue in California, and not that the CPUC has necessarily adopted the proposal); Thomas J. Starrs, Howard J. Wenger, "Policies to Support a Distributed Energy System," http://repp.org/articles/pv/3/3.html (Dec. 2, 1999), p.3 (hereinafter, "Starrs"); H.R. 1828, 106th Cong., 1st Sess. § 403 (1999) (hereinafter "Administration Bill"); H.R. 2944, 106th Cong., 1st Sess. § 702 (1999) (hereinafter "Barton Bill").

[22] E.g., CPUC 99-10-065, p.20; RAP Draft Report, p. 20.

[23] E.g., Oregon Public Utility Commission, Order No. 98-191, "In the Matter of the Revised Tariff Schedules in Oregon Filed by Pacificorp, dba Pacific Power and Light Co.," (May 5, 1998) (Adopting revenue caps for PP&L's distribution cost recovery) (hereinafter, "OPUC 98-191"); RAP Draft Report, p.18; Starrs, p. 19.

[24] E.g., CPUC 99-10-065, p.36 (requested by United States Fuel Cell Council).

[25] E.g., RAP Draft Report, p.19; Starrs, p. 20.

[26] E.g., NYPSC 99-13; PUCT § 25.212; CPUC 99-10-065, p. 28; Starrs, p. 3; Barton Bill, § 542; Administration Bill, § 405.

[27] E.g., CPUC 99-10-065, p. 28.

[28] E.g., CPUC 99-10-065, p. 30; TX §25.212(b)(4).

[29] E.g., NYPSC 99-13; PUCT "Agreement for Interconnection and Parallel Operation of Distributed Generation".

[30] E.g., Starrs, p. 3.

- Limit or prohibit the imposition of fees or other charges associated with permitting, installation, and or operation of DG units, such as charges for engineering design review of new units, annual inspection or calibration of units, metering service, or liability insurance;[31]

- Limit or prohibit the imposition of charges for stand-by or back-up service, for all customers or just for residential customers with small units;[32]

- Limit or eliminate governmental charges on DG, including building permit fees, property taxes, sales taxes, etc.;[33]

- Limit or prohibit the imposition of utility stranded costs or transition costs on consumers that install DG;[34]

- Impose renewable portfolio standards that give extra renewable credits to renewable DG or include DG as "renewable";[35]

- Permit the owner of a DG unit to select the interconnection voltage level;[36]

- Train utility personnel, environmental regulators, and building inspectors concerning the impact that DG may have on them;[37]

- Require utilities to sell an unbundled distribution only wheeling service for consumers that sell power from their DG facilities to other consumers on the same distribution grid;[38]

- Directly subsidize DG through:

- Pay up-front capital cost pay-downs for consumers who install DG;[39]

- Provide renewable or distributed resource tax credits;

- Direct payments to consumers who install DG in "DG development zones;"

- Waive of stand-by or other charges for consumers who install DG in economically desirable areas;

- Require utilities to compare the cost of line extensions and replacement with the cost of installing DG;[40]

- Encourage new developments to install DG and form micro-grids separate from any distribution system, possibly by imposing the cost of line extensions and new construction directly on housing developers;[41]

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[31] E.g., Starrs, p. 3.
[32] E.g., CPUC 99-10-065, p. 44.
[33] E.g., Starrs, p. 3
[34] E.g., Starrs, p. 14; RAP Draft Report, p.21; Administration Bill, § 101 (adding PURPA § 609(e)(2)).
[35] E.g., Starrs, p. 20.
[36] E.g., CPUC 99-10-065, p. 30
[37] E.g., CPUC 99-10-065, p. 30.
[38] E.g., CPUC 99-10-065, p. 39.
[39] E.g., Starrs, p. 20.
[40] E.g., Starrs, p. 21.
[41] E.g., Starrs, p. 21.

- Establish pricing structures to encourage the use of existing back-up generators;
- Prohibit utilities from owning, installing or operating DG on the consumer side and/or the grid side of the meter;[42]
- Ensure that homeowners association rules do not discourage installation of PV systems;[43]
- Enact and enforce zoning rules that protect solar access for consumers with PV systems.[44]

TECHNICAL BACKGROUND

STATE OF THE TECHNOLOGY

Anyone looking at DG should be aware of the continuing technical challenges involved in developing certain forms of DG. Not all DG technologies available today are necessarily more efficient, cleaner, or more economical than central station generation. Several analyses of the costs of DG technologies are available, including those by the Gas Research Institute,[45] Southern California Edison,[46] Henry Linden of the Illinois Institute of Technology,[47] and the Cooperative Research Network. (CRN).[48]

Fuel Cells

Fuel cells are a promising technology. The basic concept of fuel cells is over a century old. Essentially, they behave like batteries. But unlike batteries, they are almost endlessly charged. They run on hydrogen, which can be extracted from natural gas, propane, or any other hydrocarbon source. The hydrogen reacts with oxygen from the air and voltage is generated between two electrodes. Power produced by fuel cells is relatively emission-free.

Fuel cells range in size from around 5 to 2000 kW. A typical single-family home would require a fuel cell around 3 to 8 kilowatts.

Initial installation costs will run high, around $3,000- $4,000 per kW for the actual fuel cell "stack", a "reformer" to strip hydrogen from fuel, an inverter to convert direct current (DC) to alternating current (AC), and equipment for making use of the waste heat. The cost to make electricity using a fuel cell appears today to run between 10¢ and 15¢ per kWh. Fuel cell manufacturers are predicting that capital costs could decline to as low as $1000 per kW in three to five years as production volumes increase, and could drop further after that if auto manufacturers successfully develop automotive applications. Energy costs could fall to 8¢ per kWh, depending on the costs of fuel.

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[42] E.g., CPUC 99-10-065, pp. 18, 24.
[43] See Starrs, p. 3.
[44] See Starrs, p. 3.
[45] Gas Research Institute, Distributed Generation Forum, March 1999.
[46] Southern California Edison Co., "Response of Southern California Edison Co. to Order Instituting Rulemaking to Solicit Comments and Proposals on Distributed Generation and Competition in Electric Distribution Service," March 17, 1999.
[47] Harry Linden, "Distributed Power Generation: The Logical Response to Restructuring and Convergence," Slide Presentation, April 8, 1999.
[48] Steven P. Lindenberg, "Distributed Generation: An Action Plan for Co-ops," Management Quarterly, Summer 1999, p. 20.

Although costly, the technology is highly reliable, which makes it appealing for certain commercial operations. For example, the computer system at the First Bank of Omaha, Neb., processes $6 million in credit card purchases an hour. The bank has installed four fuel cells for primary power. The 800-kW system will limit computer down time to 3 seconds or less per year.

Microturbines

Microturbines are also promising. These very small turbines contain essentially one moving part and use either air or oil for lubrication. Units under development range in size from about 25 kW to 75 kW. Microturbines can run on a variety of fuels, including natural gas, propane, and fuel oil. Four firms are approaching commercial development of this technology.

Microturbines could be less expensive than fuel cells. According to current estimates, a microturbine unit costs around $1,000 to $1,500 per installed kW and the cost to make electricity using a microturbine appears today to run between 7.5¢ and 10¢ per kWh. That could lead to niche applications in areas with high energy costs for power quality, peak shaving or replacement energy.

Microturbines are less efficient than other existing generation technologies. A microturbine at full load is only around 30 percent efficient. At half load, it drops rapidly to 10 to 15 percent efficient. Efficiency can be increased considerably, however, if consumers can make use of the unit's waste heat.

Moreover, microturbines are just now coming into commercial operation. Although there have been some test models running, there is not yet enough data to judge how well or economically they would work in actual daily operation over years of service.

McDonald's Corporation is vying to become one of the first major industrial users of microturbines. The fast-food chain sees the technology as a competitive tool, offering ways to reduce energy costs and to protect against food spoilage during power outages. The company also wants to be known as the restaurant that's always open. For example, a Bensenville, Ill., McDonalds is already testing a microturbine. If the application proves successful, the company could deploy this technology at thousands of restaurants in the US and abroad.

Wind and Photovoltaics

Both wind and PV have been around for a while, and both have useful applications in certain settings. But neither one is as economical as central station generation for most consumers who have access to grid power. Wind turbines have a capital cost of around $1,000-$1,500/kW and a power cost of 5.5¢-15¢/kWh. Photovoltaics have a capital cost of approximately $1,500-$6,500/kW, and a power cost of 15¢-20¢/kWh. Also, because they depend on the presence of wind or sun their output is intermittent and less dependable.

Both wind and solar energy have been touted as environmentally friendly. But, while they have no emissions, wind generators do have environmental impacts, including bird kills, noise, interference with radio and television reception, and visual impact. In fact, proposals to develop three wind farms, one in California and two in the southeast, have recently been tabled because of public opposition.[49] Rooftop solar-thermal and photovoltaic arrays have been banned or severely restricted by homeowners associations.

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[49] See "Public Opinion Blows Down Windmills Planned for Tennessee Mountain," Chattanooga Times/Free Press (Nov. 4, 1999); "Audubon Campaigns Against Wind Power Installations," http//www.energyone.com/restructuring/news_reports/news/u14ren.html (1/13/00).

Internal Combustion Engines

The most commonly installed distributed generation facilities today are small diesel or combustion turbine units ranging from 50 to 5,000 kW. These units have a capital cost of between $200 and $800/kW, and a power cost of 5.5¢-10¢/kWh. While diesel units emit more air pollutants than gas fired units or central generation, they can be valuable for reliability purposes, load management, and system control purposes. And, because they have much lower capital costs and diesel is readily available and relatively low cost, they are economical today for far more applications than most other DG technologies. This is especially true in areas, such as islands, where transmission connections to power grids are impossible or very expensive.

Summary and Discussion

The following table, summarizes the present costs and uses of DG facilities.

Characteristics	Internal Combustion Engine	Wind Turbine	Microturbine	Fuel Cell	Solar Cell
Size Range (kW)	5,000 50	2,000 50	75 25	2,000 5	100 1
Current Installed Cost ($/kWh)	$200 $800	$1,000 $1,500	$1,000 $1,500	$3,000 $4,000	$1,500 $6,500
Electricity Cost (¢/kWh)	5.5 10.0	5.5 15.0	7.5 10.0	10.0 15.0	15.0 20.0
Year Commercial	Available	Available	2000	2005 One Mfr. Available Now	Available
Applications	Back-up Power Peak Reduction	Green Power Remote Locations	Peak Reduction Back-up Power	Power Quality Base Load	Stock watering Communications Grid Indep.

Cooperative Research Network, Summer 1999

To put these figures in context, and understand why these technologies have limited applicability today, it is necessary to compare the costs in this chart with costs faced by consumers who take traditional electric service. A consumer with access to the grid today pays only a single rate for their energy that covers both the fixed capital costs of generation – equivalent to the installed cost in row two above – and the variable cost of the generation – equivalent to the electricity cost in row three above. For residential consumers, that

rolled in rate ranges from 13.92¢ per kWh in New Hampshire to 5.03¢ per kWh in Washington. Commercial rates range from 11.64¢ per kWh in New Hampshire to 4.34¢ in Idaho.

A consumer that is considering DG would have to compare their existing rate to the cost of DG. Take, for example, a typical residential consumer considering a fuel cell. That consumer would need a generator with a capacity of about 3 to 8 kW. That would mean that they would have to make an up-front capital investment of between $9,000 and $32,000 for the fuel cell. They would also have to pay certain other up-front costs to install the unit and interconnect it with the system. Those costs are not quantified, and are the subject of most of the discussion below. Additionally, they would have to pay between 10¢ and 15¢ per kWh for fuel, maintenance, and any other operating costs. And finally, depending on the rules established by the state, the consumer may have to pay certain distribution costs; stand-by or back-up service charges; and some fixed charges imposed on all consumers by the state such as taxes, stranded costs, transition costs, and public benefits charges.

Even in a high cost state like New Hampshire, with electricity rates of more than 13¢ per kWh, it would be difficult to make the fuel cell economic for broad applications today. In a low cost state like Washington, with electric rates of just over 5¢ per kWh, it could only be justified if the customer were unreachable by wire or had an extraordinary need for reliability.

Some manufacturers of DG are asking decision makers to compare the cost of DG, summarized above, with costs faced by a utility or independent power supplier considering options for new generation. A new simple cycle gas generator with a capacity of 100 MW can be installed today at a cost of $350/kW. Depending on the cost of gas, that generator will be able to produce energy at a cost of 4¢/kW. A combined-cycle gas turbine with a capacity of 250 MW can be installed today at a cost of $500-600/kW and produce energy at a cost of 2¢/kW. While this may be a useful exercise for statewide resource management, the comparison is not meaningful for most consumers considering DG. As explained above, those consumers do not have to choose between new central station generation and new DG. They get to choose between new DG and grid power, which includes a number of depreciated, low cost plants. A DG unit that costs less today than new central station generation, but more than grid power, is not economic for most consumers.

CO-OP INVOLVEMENT IN DISTRIBUTED GENERATION

In their continuing efforts to find ways to lower costs for rural electric consumers, electric cooperatives have been actively exploring DG technologies.

For example, the cooperatives in Florida have installed more than 125 MW of distributed generation. These are almost totally diesel, or small engine generator sets. These units were added on the customer side of the meter, initially as a reliability device: that is, to support cooperative service at a prison complex, or a chicken farm, where reliable power is a must. Engine-generator sets with years of demonstrated capability were added to ensure that reliability. Once installed, however, this equipment also offered the distinct advantage of serving as a peak shaving device to lower the system peak demand. The distribution cooperatives worked closely with Seminole Electric Cooperative and the state to be able to take advantage of this peak shaving.

In the area of microturbines there are many cooperatives committed to buying equipment from the four North American manufacturers now approaching commercial delivery of this technology. For example, in August 1999, Energy Co-Opportunity, a national energy cooperative, installed an Allied Signal 75 kW microturbine at their headquarters building in Herndon, VA for beta testing before offering this technology to its members. NRECA's CRN also expects to acquire commercial grade units in early 2000, with installation in the fall.

With respect to fuel cells, Energy Co-Opportunity signed a partnership agreement in June 1999 with H Power Corporation to introduce residential and small commercial fuel cell systems to rural electric cooperatives and their customers. Separately, Flint Energies, a Georgia cooperative, entered into an agreement with Plug Power to distribute their fuel cells.

Moreover, CRN has been working on developing distributed generation issues for nearly a decade. CRN helped to fund a large demonstration of emerging technology in the 1980s at Santa Clara, California. A molten carbonate fuel cell apparatus was constructed and operated. This was not a fully integrated system and it had many first generation challenges. ERC, the contractor, has made major strides since then and recently began operation of a new compact design 250 kW molten carbonate fuel cell system in Connecticut.

CRN has owned an ONSI PC-25 fuel cell for the past three years and successfully demonstrated that rural co-ops are capable of running a phosphoric acid system with the personnel they have on staff at most moderately sized co-ops. The system is now in Anchorage, Alaska. Several owners have demonstrated that this system is reliable, but more expensive to purchase and operate, than established distributed generators.

Together with the United States Department of Energy, CRN managed an analysis of a biomass gasifier and fuel cell integrated system. This could be an attractive energy supply in some settings. CRN is also looking seriously at the PEM fuel cell systems as they might apply to residential service. This technology is making rapid progress in transportation applications. Future application to stationary energy generation seems feasible, but reliable demonstrations are required.

CRN recently made the first financial commitment to a possible test of a solid oxide fuel cell in Barrow, Alaska. This large combined heat and power application is probably a couple years in the future. The technology holds promise and demonstrations are underway in Europe.

CRN is also helping Chugach Electric Association to install five fuel cells to power the U.S. Postal Service's 300,000-square-foot mail processing hub in Anchorage, Alaska. The cells will provide both 1 MW of nearly emission-free power and heat to warm the facility.

Regarding wind and photovoltaic systems many other organizations and CRN have tested and demonstrated these technologies, and they are being applied in those special settings where they are economical.

NRECA is also participating in a number of DG study groups, including the Fuel Cell Propulsion Institute, the Utility Wind Interest Group, the Utility PhotoVoltaic Group, the Biomass Interest Group, and the United BioEnergy Commercialization Association. NRECA is also exploring whether to join the Fuel Cell Commercialization Group.

DISCUSSION

BENEFITS OF DISTRIBUTED GENERATION

In certain applications, some DG technologies can provide consumers, cooperatives, and society tremendous benefits, including reduced transmission and distribution costs, reduced emissions, and enhanced reliability. Generation located near demand can reduce energy losses; permit utilities to defer upgrades to substations, distribution facilities and transmission facilities; and provide black start capability and spinning reserves. Microturbines, turbines, and internal combustion engine generators can provide voltage support and reduce reactive power losses. Some DG technologies, including fuel cells, microturbines, and internal

combustion engines can gain increased efficiency by taking advantage of waste heat. DG powered by renewable resources or fuel cells can substitute for central station generation that could have greater emissions and land-use impacts. As the industry restructures, DG can also provide some consumers a "self-help" alternative to volatile markets and market abuses. Finally, because they can be faster to build and easier to move; need less existing infrastructure; and require less total (not per kW) up-front capital investment than large central station generators, some DG technologies could have a tremendous role to play internationally in less developed countries.

There is a risk, however, that the immediate benefits of DG are being oversold today to justify aggressive legislative and regulatory proposals to support the development and installation of distributed generation. As discussed above, not all DG technologies have yet proven to be cheap, clean or reliable for broad application. Some of the presumed benefits of DG are speculative. They rely, for example, on the presumption made by manufacturers of fuel cells and microturbines that their technologies will eventually prove to be as inexpensive and reliable as they have projected they will be. In reality, it will take several years of further development and testing before those projections can be evaluated objectively. Some of the presumed benefits also rely on assumptions about the costs or needs of some model distribution system that may not reflect the realities of any particular system. The Distributed Power Coalition of America (DPCA), for example, has announced that DG will achieve the following transmission and distribution savings:[50]

Substation Deferral	$1.60 - $60.27/MWH
Transmission System Losses	$2.34 - $3.14/MWH
Transmission Wheeling	$2.78 - $7.14/MWH
Distribution Feeders	$0.67 - $1.72/MWH

Although quite impressive, nowhere in the chart or on the public areas of the web site where the chart is published are any of the underlying data that would allow decision makers to evaluate whether the claims would be applicable to any particular state or utility system.

Moreover, as discussed below, many of the presumed benefits are highly dependent on the manner in which DG facilities are planned, installed and operated. Policies that encourage DG without taking those factors into account could not only fail to capture any of the presumed benefits, but instead could be extremely costly. As in other areas of electric utility regulation, economic policies ought to take into account the impacts of different technologies and different applications on each distribution system. Good decisions cannot be made without the input of engineers who understand how specific systems really operate.

Finally, few have asked the question, "benefits for whom?" As discussed below, there are a number of proposed policies under which one group of consumers could be asked to subsidize another. There should be some relation between costs and benefits. One group of consumers should not be asked to pay for policies the benefits of which accrue to others.

For these reasons, decision makers should be careful not to require utilities, consumers, or tax payers to pay for expensive capital investments or subsidies to support DG applications whose benefits may

[50] http://www.dpc.org/utilities.html (12/27/99).

not ultimately be as great as predicted. PURPA's mandatory purchase obligation and the Power Plant and Industrial Fuel Use Act of 1978 provide good reminders of the risks of such policies.

SAFETY

DG imposes a widely recognized risk to public safety that must be addressed in any interconnection requirements. On most distribution systems today, generation flows only one way. Even most distribution systems with two-way flows are still fairly simple compared to the interconnected transmission system, and the distribution utility will generally know which way power is flowing. Thus, if a line goes down, the utility will know whether the line is energized and can respond safely. Consumer ownership and operation of generation can change that. Consumer-owned generation could unexpectedly energize a line that the utility believes is cold, thereby injuring or killing a utility worker or a citizen or starting a fire.

Texas and New York have responded to the risk by requiring any distributed generator to have a positive disconnect that automatically isolates the generator from the distribution system almost immediately when there is a fault on the system. The generator may not reconnect to the system until the fault is cleared and the system regains its stability.[51] California has recognized the need for similar protections. New York has also required all interconnected DG facilities to have a utility accessible manual disconnect switch.[52]

RELIABILITY

The electric grid is a complicated "machine" that does not work by itself. If a utility is to provide reliable power, it must have adequate generation, transmission, and distribution capacity and must be able to control the voltage and the frequency of the system. If the utility fails by a small margin – even momentarily – voltage or frequency sags and spikes could ruin expensive computer and manufacturing equipment. If the system goes far off balance, it could experience serious failures: transformers and control systems could burn out, lines could sag into trees and start fires, neighborhoods could black-out. As both Consolidated Edison in New York and Commonwealth Edison in Chicago learned during the summer of 1999, those kinds of failures can be extremely expensive and even dangerous for the utility and its members or consumers.

That means the operator has to keep generation and demand exactly balanced at all times; has to provide adequate "voltage support" on the lines; has to keep sufficient distribution capacity on all lines to move the power being used; and has to build and maintain sufficient generation, transmission, and distribution capacity to respond to contingencies, including the failure of lines or generators or the sudden addition or loss of large loads.

Moreover, that control process is location sensitive. Where generation and voltage support have to be located depends on the location of load and the design of the distribution system. That means that load, generation, and distribution facilities all have to be planned together. It also means that the addition or removal of a large load or generation source can require the construction of new distribution facilities; the re-engineering of existing distribution facilities; and/or the redispatch of existing generation facilities. The problem is further complicated because no two systems have the same structure or geography. One rule for responding to changes in system architecture will not work for any two systems, or even for any two changes on the same system.

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[51] PUCT § 25.212(b) (General Interconnection and Protection Requirements); NYPSC 99-13, Appendix A, pp. 6-7,9,12.

[52] NYPSC 99-13, Appendix A, pp.10-11. See also CPUC 99-10-065, p. 29 (considering whether such a requirement would be necessary).

The process is made even more difficult by the interconnected nature of the system. Every connected generation source affects the system and is affected by the system, regardless of whether it exports power. For example, if a small generator operating in parallel with the system cannot keep up with the 60 cycles frequency on the distribution system, it will be dragged along and burnt out. If a large generator operating in parallel with a small system lags behind or leads the system, it can affect the voltage and capacity of the system, even if the generator produces less energy than the consumer at that site is using.

Further every connected load affects and is affected by the system. If an industrial customer that generates its own power drops load without simultaneously dropping generation, it could create a surge that burns out utility control equipment as well as any connected electronic equipment operating in the surrounding neighborhood. If the industrial customer instead loses its generator without simultaneously dropping load, it could create a destructive voltage sag.

New generation sources can also change the direction and volume of power flows on the system, possibly causing some wires to be underutilized while overloading others. Those changes may require the distribution company to reinforce its system, build new lines, or install new control equipment.

New generation could also force the system operator to redispatch the rest of the generation on the system. That is, it could require the operator to shut down cheap plants and run more expensive plants in order to maintain system reliability.

Obviously, the potential for harm varies widely according to the type and size of the generator installed, whether the generator is intended to be isolated or operated in parallel with the system, or whether the generator is intended either to meet only a fraction of the consumer's load or to export significant amounts of power.

An isolated generator may have economic impacts on a distribution system, stranding distribution or generation facilities built for a consumer, but is not going to have reliability impacts. A small interconnected generator (10 kVa or less) serving less than a consumer's total demand is also likely to have little impact if appropriate control technology is installed between it and the system. At the other end of the spectrum, however, a large interconnected generator with a capacity of a few hundred kVa or more could have an enormous impact on the system, whether or not it exports power.

Most of the reliability risks discussed here can be addressed with the proper equipment on the grid and customer sides of the meter. The complexity and cost of such equipment varies widely depending on the size, application, location, and technology of the DG facility, the voltage at which it connects, and the size and architecture of the system to which it connects. Without speaking to whether they reached the right engineering judgments, the New York and Texas PUCs should be complimented for addressing these subtleties.[53]

Both commissions' rules require DG facilities to protect the reliability of the system by meeting a range of specific functional requirements that differ based on a number of these factors. The Texas rule also allows for exceptions in the event that the rule appears inappropriate for any particular facility.[54]

Of course, the risks discussed in this section are only one side of the picture. Distributed generation can provide enormous reliability benefits to distribution systems. If planned with and operated by the

[53] See, PUCT 25.211, 25.212; NYPSC 99-13.
[54] See, PUCT 25.212(a)(4).

distribution utility some DG technologies, including microturbines and combustion turbines,[55] can provide peak shaving, spinning reserves, voltage support, and other ancillary services that improve reliability. The key is coordination. The utility needs to be able to dispatch and control a unit if it is to be able to benefit from the services it can provide.

That is not to suggest that all DG must be owned by utilities. Instead, utilities could contract with consumers for the right to operate consumer-owned generation for the benefit of the system. For example, a utility could enter into an agreement with an industrial consumer with a large cogeneration unit. In exchange for a fee, the utility would have the right to dispatch the generator or adjust its operation to provide voltage support when needed by the system. Such an agreement could turn a unit that would otherwise pose a risk to reliability into a positive asset to the system. The agreement would also share the financial benefit with the consumer that installed the unit.

Ultimately, the technology and engineering skills exist to address reliability problems. But, some of those fixes are complicated and expensive.[56] Therefore, most of these reliability questions come down to several cost-related questions:

- Do the costs of integrating a particular DG unit with the grid, while ensuring continued safety and reliability, outweigh the economic and other potential benefits of the unit?[57]

- Who will bear the costs of ensuring safety and reliability? Obviously, the answer to this question could impact the answer to the first. If a consumer that is considering installing DG will bear the cost, that consumer will weigh the costs and benefits of the unit very differently than it would if the utility and its other customers would bear the cost.

- What actions can decision makers take to lower the costs of protecting reliability so as to make more DG units more economical without adverse system impacts? Some of the proposals have included:

  - Government funding for research on interconnection technologies;

  - Government support for type testing of DG units;

  - Providing uniform interconnection requirements to lower transaction costs;

  - Encouraging coordination between consumers and utilities to maximize any possible system benefit from DG.

INTERCONNECTION AGREEMENTS

As discussed in detail elsewhere in this paper, properly planned and coordinated additions of distributed generation can allow a system to postpone expansion of distribution or central station generation

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[55] Some technologies, however, like wind and photovoltaics are not dispatchable and are thus cannot provide these benefits reliably.

[56] At the extreme, some large generators simply cannot be integrated reliably with some distribution systems. In such cases, the utility would have to string a radial line from the customer's site to the higher voltage transmission system.

[57] That question cannot be answered in a vacuum or on a generic basis. It must be made on a unit-by-unit basis. New York was very sensitive to that issue in its Order, requiring utilities to make an independent analysis of the impact of every DG unit on its system, even where the unit was type-tested, NYPSC 99-13, p. 6, and requiring owners of DG units, no matter how small, to pay the costs of integration. Id. at 8.

plants, provide reliability benefits, and save consumers money. But those benefits can only be achieved when the newly installed generation is planned in coordination with the utility responsible for serving that territory. Because of the nature of the electric grid, the addition of generation to a system is neither simple, nor without cost and risks.

These types of concerns lie behind the interconnection agreements that many utilities are requiring consumers to sign before installing DG. These agreements include provisions addressing, inter alia:

- certification of the reliability and safety of the proposed DG facility and physical interconnection equipment;
- the conduct and costs of interconnection studies to determine the impact that the proposed facility would have on the distribution system;
- the need for and costs of any distribution system upgrades required to integrate the DG facility;
- responsibility and requirements for the control, operations, and maintenance of the DG facility and related equipment;
- metering and payment for any net energy exported to the system;
- inspection rights; and,
- insurance.

The purpose of interconnection agreements is to ensure that consumers that are installing DG address these issues up front. If properly drafted, the interconnection agreements should ensure appropriate coordination between the utility and the consumer to maximize the benefits of the DG facility and minimize the costs and risks associated with the facility. Where unavoidable, they should also require consumers to take financial responsibility for any reduced operating efficiencies their DG facility causes, any system improvements their new unit will require ,and for the risk that their new unit will damage property.

Some commentators have expressed concern that utilities are drafting complicated and burdensome interconnection agreements to discourage consumers from installing DG. These agreements, they have suggested, are inappropriate barriers to the development of DG. In fact, most of the requirements complained of have been included in interconnection agreements for years without causing consternation. The problem with those provisions arises from the increasing interconnection of smaller commercial and residential DG units. The large industrial consumers that have been installing cogeneration units with the expectation of saving thousands of dollars per year understandably have been willing to bear much larger up-front costs to interconnect their generation facilities than are small residential consumers whose units may save them little more than $100 per year over their lifetime.[58] The impact of interconnection requirements on the economics of a project differs dramatically depending on the size of the application.

Decision makers should not react to the charges about some interconnection agreements by broadly prohibiting appropriate contractual terms. That would eliminate consumers' obligation to minimize or mitigate the adverse impacts they impose on the system, and require other customers to subsidize those consumers who install distributed generation.

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[58] See, e.g., Starrs, p. 13 (Estimating that a 500 W PV system would save a consumer less than $10/month even before taking into account any interconnection charges or other fees).

Instead, decision makers, consumers, and utilities should try to adjust interconnection requirements to recognize the different costs and risks that different DG technologies and applications impose on the system. In response to these conflicting concerns, the Texas PUC has drafted a uniform interconnection agreement and tariff. Combined with the Texas PUC's interconnection rule and Tariff,[59] the Agreement for Interconnection clearly designates the rights and responsibilities of the utility and the customer and assigns liability for interconnection costs.

Without judging whether the Texas rule, Tariff, and Agreement for Interconnection make the appropriate balance between interests, they provide a useful example for other decision makers because they reflect the wide range of applications for DG. They establish different interconnection requirements and impose different cost obligations on the parties depending on the size, and specific application of, the DG facility involved. For example, while the Texas rule provides that a utility may recover the costs of conducting most pre-interconnection studies from the consumer, the rule exempts pre-certified distributed generation units up to 500 kW in capacity that export not more than 15% of the total load on a single radial feeder and contribute not more than 25% of the maximum potential short circuit on a single radial feeder.[60] Based on considerable comment from stakeholders in Texas, the PUC made the judgment that the risk to system reliability from these units is small enough, and the economics of installing these units is tight enough, that consumers who install these units should not have to bear the cost of interconnection studies. While the balance may or may not be right in this instance, the process is laudable. Moreover, in the future, utilities, consumers and distributors of DG facilities may be able to reach consensus on most of the terms of a standard interconnection agreement and simplify the process in other states.[61]

New York's rule also makes an important effort to balance the interests of different parties with some sensitivity to the different requirements imposed by different applications of DG. For example, the New York PSC drafted different standard application forms for interconnection of DG units of 15 kVa or less and for larger units up to 300 kVa.[62] The PSC also exempted interconnections involving units of 15 kVa or less from the standard application fee of $350.00.[63] The PSC also imposed different insurance obligations on different sized units. While owners of units up to 15 kVa have to maintain $100,000 of liability insurance, owners of larger units up to 300 kVa must maintain $1,000,000 in liability insurance.[64]

Ultimately, it will be up to decision makers to ensure that interconnection requirements properly assign those costs and risks that are unavoidable to the consumer that is imposing them on the system. If they do, and the distributed generation project is still economical, taking into account the costs it imposes on the system, then it makes sense and will go forward. If the project is no longer economical after internalizing the costs it imposes, then it may not, and perhaps should not go forward. It is a principle of economics that uneconomic incentives are created whenever the costs of an investment, such as distributed generation plant, are shifted to others. If a consumer does not bear all of the costs caused by its installation of DG, it is likely to build generation when it would be economically inefficient.

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[59] PUCT §25.211.
[60] PUCT §25.211(g)(1)(D).
[61] An additional benefit of the uniform agreement is its ability to reduce transaction costs by eliminating the need for utilities and consumers to negotiate separate agreements for every project.
[62] NYPSC 99-13, p. 7.
[63] Id. at 7-8. Note that the order nevertheless made it clear that applicants would still have to pay for the utility's review of the electrical system and design package as well as any utility modifications to the electric system.
[64] Id. at 29.

NET METERING

To date, at least 30 states have provided for "net metering." While not clearly or uniformly defined, net metering rules generally provide that consumers with certain self generation capabilities should have a meter that rolls forwards when the customer consumes power from the grid and rolls backwards when the customer exports power to the grid. The range of technologies and applications entitled to benefit from net metering has been contentious and different states have reached very different results. At one end, California provides net metering only for residential solar units with a capacity of no more than 10 kVa.[65] At the other, Wisconsin provides for net metering for any unit owned by any retail customer if the unit's capacity does not exceed 20 kVa.[66] Some states have also imposed a limit on the total number of consumers, or total capacity of consumer-owned generation, for which any utility has to provide net metering service. California, for example, provides that an electric service provider (ESP) need only enter into net metering contracts until the total capacity of contracts equals 0.1% of the ESP's aggregate customer peak demand.[67]

Net metering rules are supported by many proponents of distributed generation and even some utilities – at least as applied to some DG technologies – because they provide a very simple, easily administered way of integrating small consumer-owned generation into the system. Because there are today only a few small units that can benefit from the net metering rules, their cost is limited.

On the other hand, net metering policies unquestionably subsidize consumers with qualifying generation facilities, and could become burdensome as more qualifying facilities are installed. The policies require utilities to pay consumers retail price for wholesale power. That is an even greater subsidy than the "avoided cost" price required by PURPA. Moreover, the policies require utilities to pay high costs for what is often low-value power. Power from wind and photovoltaic systems is intermittent, cannot be scheduled or dispatched reliably to meet system requirements, and is expensive to integrate into the system.

Net meters also allow customers to under-pay the distribution, operation and maintenance (O&M), administrative and general (A&G), and other fixed costs they impose on the system. As discussed in detail below, a utility has to install sufficient facilities to meet the peak requirement of the consumer and recover the costs of those facilities through a kWh charge. When the net meter rolls backwards, it understates the total electricity, capacity, and energy used by the consumer, and thus understates the consumer's impact on the fixed costs of the system. It also understates the consumer's total share of other fixed charges borne by all consumers such as taxes, stranded costs, transition costs, and public benefits charges.

Further, net meters can be deliberately or inadvertently gamed. Consumers can take power from the system at peak times when it costs the utility the most to provide it, and then roll their meters backwards by generating power at non-peak times when the utility has little need for it. That is a particular risk, for example, with wind power. During the hottest days when power demand peaks, wind turbines are often becalmed. The turbines do not begin generating power again until the evenings when the cooler air starts to move in and demand for energy falls.

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[65] See Appendix A.
[66] Id.
[67] Id.

COST AND COST RECOVERY ISSUES

Presumption of Profit Motive

Investor-Owned Utilities

Several comentators in discussions about DG have expressed concern that utilities will have a built-in bias against DG installed on the consumer side of the meter. They believe that because most utilities charge consumers a fixed rate per kWh, utility revenue – and thus utility profits – are dependent on the volume of sales made. As a result, they say, utilities will oppose any development that tends to reduce total throughput, including consumer-owned generation and demand-side management.[68]

There could be some validity to that concern, particularly as applied to a pure wires company that relies entirely on a unit charge to recover its costs and margin. The more units it sells, the more income it makes. It could also be valid with respect to a vertically integrated investor-owned utility that has a fuel clause that would allow it to pass its power purchase costs through to its consumers when prices spike. Again, the utility's income would be entirely dependent on the number of units sold. The fuel clause makes the utility indifferent to the marginal and variable costs of generation. In response to that concern, some have recommended new ratemaking strategies that would make utilities less sensitive to throughput. These include revenue caps,[69] de-averaging rates,[70] and a number of others.

Unfortunately, however, the presumption that all utilities will have a bias in favor of throughput misses some complexities with respect to utilities that have an obligation to provide generation at a fixed price per kWh. The presumption could lead decision makers to view utility contributions to DG discussions with unnecessary suspicion and could lead to unnecessarily aggressive efforts to encourage DG over "utility opposition."

First, the presumption fails to take into account the fact that utilities (particularly generation utilities) do experience some savings from reduced volume. If a consumer installs DG or engages in demand side management, the utility does not have to incur some variable costs such as fuel and variable O&M. Thus, there is not a direct one-to-one relationship between reduced sales volumes and reduced profits.[71]

Moreover, there are instances when drops in volume, and thus revenue, significantly lowers costs. That is why utilities seek to shave their peaks. For example, when prices peaked during the summers of 1998 and 1999, cutting a marginal kWh of customer load could cause utilities to lose 7-15¢ in marginal revenues but save the utilities $7.00 or more in marginal power costs. Those utilities with demand side management on the consumer side of their meters who were caught short of power experienced significantly lower losses. Those with demand-side management who had surplus power could make significantly larger profits.

As mentioned, a utility with a fuel clause that permits it to pass through those price spikes may not care about peak shaving. But, as the industry restructures, fewer and fewer utilities have that luxury. Incumbent utilities are operating under price caps and new marketers are signing fixed price contracts.

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[68] E.g., RAP Draft Report, *passim*.
[69] See OPUC 98-191; RAP Draft Report, p. 18.
[70] See RAP Draft Report, pp. 19-20.
[71] Compare RAP Draft Report, pp. 15-16 (stating that costs and kWh sales are unrelated, and thus that sales volume bears a direct relationship with utility profits).

Cooperative Difference

The presumption that all utilities have a throughput bias also fails to recognize the differences between cooperatives and investor-owned utilities (IOUs). Unlike IOUs, rural electric cooperatives are not-for-profit entities. They are required by law and by their by-laws to recover only the actual cost of providing service. If income exceeds cost, cooperatives must return the excess to their members.

It is true that cooperatives must recover sufficient revenues to cover all of their costs in order to preserve their fiscal health. But, that is a very different motivation than the IOU's need to maximize profits and returns to their stockholders. First, to maintain their fiscal health, cooperatives need only recover their costs plus a small margin for reserves. Investor-owned utilities, on the other hand, have a fiduciary obligation to earn as large a margin as possible. Second, revenue shortfalls can be eliminated either by lowering costs, or by maximizing revenues. Unlike IOUs, cooperatives are cost minimizers, not profit maximizers. Because a cooperative is owned by its consumers, and the consumers elect the cooperatives's board of directors, the cooperative has a direct obligation to its consumer-owners to minimize costs That means, among other things, that the cooperative has an obligation to be able to shave peaks so that it can minimize the number of times it has to purchase high price power.

The cooperative difference has been plainly visible in practice. The presumption that utilities must maximize throughput states that distributed resources located on the customer's side of the meter almost always hurt utility profits. Yet, many cooperatives are installing distributed generation on the customer side of the meter because doing it that way can sometimes better preserve reliability and shave peak loads. Profit is not the motivation, reliability and lowered system costs are.

It is important for regulators to recognize the differences between different industry participants. Regulations that may be appropriate to protect IOU customers could harm consumers served by electric cooperatives. For example, IOU customers may not be harmed by regulatory policies that raise utility costs so long as the costs are not recovered in rates. In that case, the utility shareholders have to absorb the costs. That approach, however, does not work for cooperatives. Because cooperatives are owned by their member-consumers, and have no separate shareholders, all costs imposed on cooperatives are paid for by retail consumers.

Moreover, cooperatives are much smaller than most IOUs. Cooperatives average fewer than 57 employees and 10,000 consumers. That compares to IOUs, which average over 2,200 employees and 315,000 consumers. As a result, regulatory costs impose a higher per-capita burden on cooperatives' members. Imagine for example a state rule that bars utilities from requiring consumers with DG to buy insurance or otherwise indemnify the utilities for damage. If an uninsured DG unit causes $100,000 damage to an IOU's distribution system, it will cost each IOU customer only a few pennies on average. An equivalent uninsured accident on a cooperative system could cost each cooperative consumer over $10.00.

On the other hand, regulators ought not presume that rural electric cooperatives are such a small part of the industry that their differences need not be recognized. Although cooperatives are very small individually, taken together cooperatives are a significant segment of the industry. Cooperatives serve over 32 million consumers in 46 states. Cooperatives operate over 45% of the distribution facilities in the nation and serve 75% of the country's total land mass.[1] As a result, any policies that affect distribution system safety, reliability, and costs can have an enormous impact on cooperatives and their members.

Distributed Generation As A Substitute To T&D Investments

In some cases, the installation of DG can lower transmission and distribution costs, or substitute for new transmission and distribution investment. That is one reason why many cooperatives and other utilities are already encouraging such use where economically viable.

But, decision makers need to be aware that the availability of cost savings is highly dependent upon the specific needs of a system and the manner in which the distributed generation will be planned and operated. Decision makers should be wary, therefore, of policy proposals that would require utilities to either share presumed cost savings with consumers who install distributed generation or otherwise take those presumed savings into account in determining whether to support or subsidize the development and installation of DG. Any benefit sharing policies should depend on the existence of real cost savings, if any, arising from a particular project proposal.

Remote areas to which the distribution system does not yet reach

In a number of cases, rural electric cooperatives have saved money by installing DG on a customer's property rather than stringing wire out to the customer's remote location. There are also a lot of stock tanks with windmills or photovoltaic arrays powering their pumps and electric fences with photovoltaic battery chargers. Intermittent operation is acceptable for these applications. Moreover, within one to two years, fuel cells will likely be able to provide a good dependable source of power for entire homes for less than the cost of long distribution extensions. That small scale distributed generation is or will soon be a lot more sensible than running wire into remote areas. But, existing cost incentives are more than sufficient to encourage consumers and utilities to install DG for those applications.

Areas experiencing load growth

In some areas experiencing load growth, particularly large cities with underground distribution systems, it can cost far less to install a generator to serve a neighborhood's load growth than it would to upgrade the distribution system to import the same power. First Rochdale, an electric cooperative in New York City, has already planned to install a microturbine to serve a large housing cooperative in Manhattan. Some incentives that allow utilities and consumers to share in the benefit of DG development could be beneficial for these applications.

But, only a few technologies, such as gas turbines, make economic sense for this purpose. Wind and PV are generally too intermittent to substitute for central station power and fuel cells are unlikely to be economical for most interconnected applications for at least three to five more years.

Moreover, for the system to get any benefit, any generator would have to be planned with the distribution utility, properly located, and properly dispatched. A generator located on one distribution trunk could be highly useful, whereas the same generator located on another trunk one block over could be useless or even counter productive.

Similarly, a generator that the utility has the right to dispatch when demand exceeds the distribution system's import capacity could provide enormous system benefits, whereas a generator whose dispatch schedule is unrelated to distribution system needs could be counterproductive.

Moreover, the utility would have to have assurances that the generator would be properly maintained and operated to ensure the greatest possible reliability. And, the generator's maintenance schedule would have to be planned to coincide with the distribution system's low demand periods.

The utility cannot use the generator to substitute for new facilities if it cannot be confident that the generator will be reliable. If the generator is routinely unavailable due to planned or unplanned outages during the utility's peak, the utility will have to build new generation, transmission, and distribution facilities as well to meet its obligation to provide reliable service. If that were so, there would be no savings, and thus no benefits to share.

Large customers not connected to the grid

A utility can save distribution expansion costs if a new large customer at either a green field location or a location previously occupied by a customer with a low peak demand chooses to build its own generation instead of connecting to the grid. The utility will not have to build new transmission or distribution facilities, or reinforce existing facilities, to meet the customer's large demand. For example, utilities are already installing DG for recreational areas and remotely located resort complexes. These are usually large internal combustion generators.

The system, however, will not get any benefit if the customer is on a site previously occupied by a customer with an equally large peak demand. In that case, the system will experience stranded costs when the customer disconnects. Either the customer that is disconnecting or the other customers on the system will have to pay for the cost of the distribution facilities that previously served the now disconnected site.

Nor will the system get any benefit if a new large customer builds its own generation to meet its own energy demand but intends to lean on the utility for back up power if its generator is out of service. In that instance, the utility may still have to reinforce its transmission or distribution facilities to serve the customer's peak demand.

De-averaging Rates

In an effort to encourage the development of DG in areas where it will provide distribution cost savings and to discourage development of DG in areas where it will strand distribution costs, some commentators have suggested "de-averaging" prices so that consumers see their actual distribution costs. Those consumers in areas with high distribution costs would then have an incentive to self-generate, while those in areas with low distribution costs would find it more expensive comparatively to build their own generation facilities.

That proposal, however, has two serious flaws. First, there may not be a connection between high distribution costs and the need or ability to obtain savings from deferred distribution investment. Some areas have high distribution costs, for example, because they have recently upgraded their systems to prepare for system growth or to replace worn out facilities. Other areas may have high distribution costs because they are remote and/or rugged, with few consumers per mile of line to divide up the high cost of running conductor.[72] In those instances, de-averaging rates will provide exactly the wrong incentive, because new DG will strand, not save distribution costs.

Second, the de-averaging proposal is inequitable. In many instances, the most expensive areas to serve – including rugged rural areas and urban areas with buried lines – are also the most vulnerable areas with the highest proportion of low income consumers. De-averaging will necessarily raise costs for these low-income consumers.

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[72] Rural electric cooperatives average a $2,000 investment, 5.76 consumers, and an annual revenue of $7,038 per mile of line. Investor-owned utilities average a $1,550 investment, 34.85 consumers, and an annual revenue of $59,355 per mile of line. Municipal utilities average a $1,500 investment, 47.76 consumers, and an annual revenue of $72,255 per mile of line.

Moreover, if de-averaging rates is successful in encouraging increased development of DG, it could have the effect of increasing rates for these vulnerable consumers even more. The more consumers who install DG, the fewer consumers are left to pay the cost of these expensive distribution facilities. At the extreme, de-averaging could push electricity beyond the financial reach of many consumers.

Offsetting Costs

DG can strand distribution investments. If a utility replaces old copper wire – reconductors – or otherwise expands its system to ensure that it can reliably serve its growing load for the next several decades, one large DG project or several small ones that mask the load growth could strand the investment in new distribution facilities. That stranded cost should be taken into account in analyzing the costs and benefits of a particular DG project as much as any savings would be. Utilities and their consumers should not be penalized for engaging in prudent system upgrades.

Even if there are distribution expansion savings, they may be offset by other costs. For example, in order to permit a large urban apartment building to install its own generation, a utility may need to reconductor the neighborhood or install new control equipment. In calculating the system benefits of the DG project, the costs of that reengineering project must be balanced against any savings that might be gained from deferred distribution expansions.

Moreover, some utilities have large generation reserves that were planned and built to provide for future load growth. If a customer installs its own generation to serve its own load growth, it could strand the utility's investment. Those stranded costs should also be balanced against the savings in distribution investment.

Distribution System Planning

A related point here is that the increasing use of DG complicates utilities' obligation to plan their distribution systems. Traditionally, utilities have been responsible for predicting load growth and planning distribution system upgrades to address that growth, including the addition of any resources needed to provide voltage support or other distribution ancillary services. The need for facilities was comparatively predictable because with the exception of a few large customers, the utility was the only source of such facilities. With the development of DG, both load growth and the need for support facilities will be less predictable. Whether new or existing consumers install DG is outside the utility's control, and that installation can make long planned, or even recently installed, improvements unnecessary or accelerate the need for improvements that were on the distant horizon.

Several of the pricing proposals, including de-averaging, certain performance-based ratemaking (PBR) proposals, and benefit sharing are intended to align consumer incentives for constructing DG with the utility's need for new facilities, or otherwise to require the utility to take the possibility of DG into account in its planning process. None of these proposals yet can be said to clearly solve the problem. Considerably more work needs to be done on this issue.[73]

Stand-by and Fixed Costs

As manufacturers of DG facilities have sought to sell systems in California and elsewhere, they have complained that utilities are requiring consumers who install DG to pay a variety of fixed charges to cover stand-by or back-up service, stranded costs, or other fixed costs of the system. Those new charges, they say, are discouraging consumers from installing DG by making self-generation more costly, and in some

[73] See CPUC 99-10-065, pp. 36-37.

cases, uneconomic. Some of these complaints may be valid, as there is a risk that some utilities may deliberately impose barriers to self-generation. Unjustified new fixed charges could unreasonably limit economical uses of DG technologies.

On the other hand, some charges may be necessary both to ensure that utilities continue to earn sufficient revenue to cover their operating costs and to prevent cost shifting between consumers. The incremental rates that utilities have charged under a regime characterized by monopoly service territories and regulation are not well designed for a competitive regime in which consumers will increasingly be able to generate some of their own power requirements.

A retail energy customer is responsible today for a number of different costs. Among the more significant costs are:

- the customer's share of the cost of the physical transmission and distribution facilities over which the utility delivers energy to the customer;
- the customer's share of the cost of the physical generation facilities that were built to serve the customer and/or the customers' share of the capacity costs that the utility pays a generating company to guarantee the utility access to the power its customers may require;
- the customer's share of the costs of operating and maintaining the physical transmission, distribution, and generation facilities (O&M);
- the customer's share of the administrative and general costs required to run its utility (A&G);
- the customer's share of taxes the utility is required to pay and the public benefits the utility is required to provide; and,
- the cost of fuel to generate the power the customer actually consumes.

Few of these costs are directly assigned to individual customers and reflected on the customers' bills. Instead, these costs are generally bundled or rolled in together and collected through an undifferentiated per kWh charge.

There are, of course, some variations. Many utilities, for example, have tiered, or graduated, kWh charges that lower the unit charge for all energy consumed above a certain threshold. Some others have coupled their unit charge with a low fixed monthly fee to collect certain A&G costs, taxes, or other fixed costs. Some others add to their bill a variable unit charge to reflect changes in fuel costs.

Ultimately, however, the goal of most utilities has been to try to ensure that charges on each customer's bills in some way reflect the actual costs for which that customer is responsible. Unfortunately, monthly total kWh is not a very good indicator of cost causation.

Of the costs itemized above, only total fuel costs vary much according to a customer's total monthly energy usage. The more kWh the customer consumes, the more fuel generators have to consume. With limited exceptions, the other costs itemized above vary according to either a customer's peak demand or the customer's contribution to the utility's peak demand.

A utility has an obligation to deliver all the power a consumer wants, when the consumer wants it. If a consumer turns on her air conditioner when the temperature exceeds 100 degrees, the power needs to be there to cool the room. The utility has to have enough generation, or the right to enough generation, to cool

that room; the utility has to have enough capacity on its transmission and distribution facilities to get the power from the generator to the customer's meter; and the utility has to have adequately planned and maintained its entire system so that nothing fails when the switch is thrown. If the air conditioner does not turn on, the utility will not be excused because it did not have enough generation, transmission, or distribution capacity available, even on the hottest day of the year, when all of its consumers are turning on their air conditioners. When New York City and Chicago experienced black outs during the summer of 1999, politicians and regulators did not want to hear that Consolidated Edison or Commonwealth Edison had not built or maintained enough capacity in their distribution systems to handle the load.[74]

That means that a utility cannot have only just enough generation, transmission, and distribution to handle its average load. It must build its system to be able to handle its peak load, the largest volume of power its customers could possibly use. And, it must either own or have a right to enough generation to meet its system peak plus some reserve for emergencies.

Take for instance a large industrial consumer that has a peak demand of 50 MW that is coincident with the utility's peak demand, that is the industrial customer draws a full 50 MW at the utility's busiest times of day and seasons. To serve that customer, the utility must build strong enough distribution facilities to bring that customer 50 MW of power on top of all of the utility's other obligations. It may need to install particularly heavy gauge wire, large transformers, and other control equipment to handle that large 50 MW distribution load. The utility will also need to make certain that its transmission system has enough capacity. And finally, the utility will have to own or have the right to enough generation to satisfy that 50 MW load at peak times.

Of course, the customer may not be drawing the full 50 MW at all times. At night, the same customer could be drawing less than 1 MW. The customer's average demand may, therefore, be well below its peak of 50 MW. But the utility still has to build to serve the customer's peak load.

As now formulated, the rate structure has been designed to take that fact into account, and the per kWh rate has been set at a high enough level to recover all of the costs of the system based on historical experience. And, in most cases, there is at least a rough approximation between what each customer pays and the burden they place on the system.

Now presume that the same large industrial consumer chooses to install a 50 MW generator on its site to provide its daily energy needs. But, because that generator will need periodic maintenance and could fail unexpectedly, the industrial consumer opts to remain hooked to the grid for back-up or stand-by power. Most of the time, the customer will be drawing no power from the system. But occasionally and with little warning the customer could start drawing a full 50 MW from the system, even during the system peak.

That could have a dramatic impact on the utility's ability to recover its cost of providing service – not profit – just basic cost of service. When the industrial customer builds its generator without disconnecting from the system, the utility does save the marginal cost – generally just the fuel cost – of the generation that the customer is not taking. But, the utility saves little or nothing on the other costs it incurs on that customers' behalf. It must still maintain enough distribution, transmission, and generation capacity to serve the customer's full 50 MW load at any time, just as it would if the customer had never built its own generator. And, it must still incur the O&M and A&G costs associated with those facilities.

On the other hand, however, the utility's revenue drops to practically nothing when the consumer installs its own generation because the consumer is not drawing much total power from the system each

[74] See, e.g., "Interim Report of the U.S. Department of Energy's Power Outage Study Team: Findings From The Summer Of 1999" (January 2000).

month. The unit charge no longer recovers much, if any, of the costs the utility has to incur to guarantee the consumer service on demand.

At that point, the utility has two choices. It can let all of its other consumers pick up the difference, thereby subsidizing the consumer that installs generation and raising costs for other consumers. Or, it can find a new pricing structure that assigns costs more equitably. *That is the purpose* of stand-by charges and fixed charges. If properly designed, such charges assign to individual customers the costs that those customers actually impose on the system.

Unfortunately, changing the price structure can get an angry response from consumers. Prior to restructuring, most customers have received a bundled bill with transmission, distribution, generation, fixed, and variable costs all bundled together into a single unit charge. With competition, more consumers are seeing their bills unbundled with separate charges for generation, transmission, and distribution. But each of those individual charges is still generally assessed by kWh usage. Because it has always been that way, consumers naturally presume that their bill should vary by usage. They think they should pay for the amount of power used, not for the interconnection and the right to draw power on demand. Thus, if they are on vacation for a month, or use their own generation for a month, they presume their bill should be low. If subjected to a fixed charge, they may be surprised and angry that their bill has not dropped much. But, as the industry restructures and new technologies develop, decision makers at least will have to reconsider some of these well settled expectations.

If regulators do not want to change pricing structures for all customer classes, they have several choices. They can allow stand-by power rates that apply only to the individual customers that are causing the utility to incur costs that are not recoverable through per kWh charges. Or, regulators can allow utilities to adopt fixed charges only for certain customer classes, such as large C&I customers. It is the largest customers that impose the largest individual fixed costs on the system. Their large loads can require significant upgrades to physical facilities to stiffen the transmission and distribution system. Their loads can also have a larger impact on a utility's peak demand, and thus on the amount of generation capacity the utility needs to own or have reserved. If a residential customer's 1 kW solar array fails during system peak it has a much smaller impact on system reliability than the failure of an aluminum smelter's 100 MW combustion turbine.

The California Public Utilities Commission has also listed a number of other options for designing creative stand-by charges. For example, *utilities could offer firm and non-firm standby service* with different rates. Standby charges could also be adjusted depending on how frequently the consumer used standby power or could be structured with low reservation charges and very high use charges. Charges could also vary depending on the time of use or whether the consumer gave notice before relying on standby service.[75]

The point is, there are as many different ways to design rates as there are accountants, but regulators should allow utilities to adopt a rate structure that requires customers that install DG to continue to pay for the costs that they continue to impose on the system. Regulators should not assume that utilities are merely trying to impose barriers to the deployment of DG.

Stranded Costs and Transition Charges

Generation Stranded Costs and Transition Charges

In every state that has enacted restructuring to date, incumbent utilities have been permitted to collect from consumers all or part of the generation costs that were stranded by the onset of competition. And, in most states, utilities have also been permitted to collect from consumers all or part of the transition

[75] CPUC, 99-10-065, p. 45.

costs that they incur in moving to a competitive environment. These include start-up costs for independent system operators, power exchanges, consumer education programs, employee retraining and other similar costs. In most instances, these charges are being recovered through a fixed charge set by the state and imposed on all retail consumers.

In the restructuring bill it proposed in 1999, the Clinton Administration would require states to consider allowing consumers who install certain DG to bypass stranded cost charges.[76] Other commentators have also argued that consumers with DG should be excused from paying some or all of the stranded cost or transition charges that other consumers must pay.[77] If implemented by the states, that proposal would encourage consumers to self-generate by making it appear more economical compared to the alternative.

The bypass proposals do not challenge the states' near universal conclusion that utilities have a right to recover stranded and transition costs. Nor can they logically be based on a conclusion that consumers who self-generate are less responsible for a utility's stranded and transition costs than any other consumer. Under most state plans, those costs are borne equally by all consumers regardless of whether they wanted restructuring or took advantage of it, i.e., regardless of cost causation. Finally, the proposals would not necessarily affect the total amount of stranded and transition costs that each utility would be entitled to recover under state law; they would only subsidize one class of consumers by shifting costs to other classes.

Of course, states are free to subsidize any behavior they believe to be in the public interest. Nevertheless, as discussed below, decision makers need to recognize when a policy constitutes a subsidy and then decide whether the particular approach best allocates costs and benefits.

Wholesale Requirements Contract

There is an additional cost issue that is specific to electric cooperatives. Most IOUs have traditionally been vertically integrated companies providing generation, transmission and distribution service. Most cooperatives, on the other hand, developed a different structure. The first cooperatives formed in the 1930s and 1940s were distribution only utilities. The power they delivered to their rural members was purchased from neighboring IOUs or municipally-owned utilities.

Starting in the 1960s, groups of distribution cooperatives joined together to form new cooperatives to provide generation and transmission services. Most of those new generation and transmission co-ops (G&Ts) were formed with loans and loan guarantees from the Rural Electrification Administration (REA), now the Rural Utilities Service (RUS). In order to provide security for the loans, the REA required the distribution cooperatives to sign long term all-requirements contracts with their G&Ts. Under the contracts, the distribution cooperatives had to purchase all of their generation needs from their G&T and the G&T had to sell generation to its members at cost. Most distribution cooperatives today still obtain their power pursuant to their all-requirements contracts.

The Federal Energy Regulatory Commission (FERC) recognized this issue in its implementation of PURPA. PURPA required that utilities interconnect with qualifying facilities (QFs), sell power to consumers with QFs, and purchase power from the QFs at their avoided cost. With vertically integrated IOUs, that was fairly simple. All of the obligations to interconnect, sell, and purchase power could be satisfied by the same company. But, because of the cooperative's structure and the all requirements contract, that was not possible. Accordingly, FERC divided up the PURPA obligations between distribution cooperatives and G&Ts. Distribution cooperatives would sell power; G&Ts would buy QF power; and the interconnection

[76] Administration Bill, § 101.
[77] See supra, n. 34.

responsibility was divided between the distribution co-op and the G&T depending on whether the QF interconnected at the distribution or transmission level.

Similar accommodation will have to be made with respect to non-QF distributed generation. For example, most net metering rules require a distribution utility to buy power from consumer-owned generation. Those rules, without some accommodation, could abrogate the all requirements contract.

Moreover, cooperatives and decision makers will need to find a way to guarantee G&Ts continued recovery of their costs and protect RUS's security for their loans and loan guarantees, while also permitting cooperatives and their members to take advantages of the potential benefits of DG. As things stand today, it could potentially violate the all requirements contract for distribution cooperatives to install their own DG facilities. It could also violate the contract for distribution cooperatives to permit or encourage their members to install DG. Until RUS and the cooperatives can reach an agreement, it will be important for decision makers to take cooperatives' contractual needs into account in addressing DG issues.

Stranded Distribution Costs

Related to this issue is the question of stranded distribution costs. As discussed above, utilities incur significant capital costs to provide distribution service to consumers – costs that could be stranded by self-generating consumers if they continue to pay only a per kWh rate. For that reason, this paper suggested the development of new ratemaking approaches.

In opposition to that approach, one commentator has argued that states should reject the concept of stranded distribution costs. Unlike generation, they argue no one forced distribution companies to build "uneconomic" distribution and transmission facilities. If the facilities are not used and useful, they argue, then there should not be any cost recovery. In fact, however, these are exactly the same arguments that were made with respect to stranded generation, and the two are very similar in these regards. Like generation utilities, distribution utilities had and have a continuing regulatory obligation to build and maintain facilities to provide their consumers with service, and they have done so with the expectation that they will be able to recover prudently incurred costs. It is not the purpose of this paper to reargue that underlying question: it would seem that most states have already answered it in favor of stranded cost recovery.

The second argument is that DG does not strand distribution facilities because it is equivalent to demand side management (DSM) in that it reduces consumer demand and provides utilities a "bonus" in the form of deferred transmission and distribution investment. This argument is half-true. If DG does provide system benefits and legitimately permits utilities to defer new investment, then there are no stranded costs by definition. But, as discussed above, not all DG can substitute for new investments. Some DG instead substitutes for existing prudent investments in distribution facilities that were used and useful until the DG was installed. In those instances, DG no longer looks like DSM: a coordinated effort to shave peaks for system benefit. Instead, it strands facilities and shifts costs to other consumers.

Subsidies

In each of the issues discussed above, there is a significant risk that policies intended to encourage or "remove barriers to" DG could go too far, instead subsidizing those who install DG at the expense of other consumers. For example:

Interconnection Requirements: Interconnection requirements are intended to ensure that consumers who install DG minimize their impact on the system and pay the costs for which they are responsible. Proposals that would allow consumers who install DG to avoid the costs of necessary interconnection studies, system

upgrades, and control equipment, or would insulate consumers from liability for harm to the system, would shift those costs to other consumers;

Net Metering: Net metering requires utilities to pay above-market prices for low-value energy. Other consumers must pay more for their energy to support that program;

Benefit Sharing: Some proposals would require utilities to share the presumed system benefits of DG with the DG owners through rate credits or through exemption from payment of certain fixed costs including stranded costs, transition costs, public benefit funds, stand-by or back-up services charges, and others. If the presumed system benefits of the DG unit are not as great in practice as the benefit given to the DG owner, the utility's other consumers must make up the difference. Even if costs and benefits of the sharing program are equivalent, some of the utility's other consumers may either receive a lesser share of the benefits or bear a heavier share of the costs.

By masking some of the true costs of a DG facility, these subsidies will encourage consumers to install new generation that cannot be justified economically. If a particular DG facility still makes economic sense after a customer pays all of the costs that they impose on the system, then the facility will, and should, be built. If the facility is too expensive to build after all costs are taken into account, then perhaps it should not be built.

Some have argued that it may be worthwhile to build DG that is not otherwise economically efficient, either to encourage the development of new technologies or to achieve environmental benefits. If so, states should recognize that they are deliberately subsidizing an uneconomic investment for other purposes, and then consider carefully the different options for funding that subsidy.

States should not avoid that question simply by asking the utility to bear a share of the costs of an uneconomical project. That policy merely shifts costs from one consumer to the rest of the utility's consumers. True, it is possible that an investor-owned utility's shareholders could absorb part of the cost, but that is not an option for electric cooperatives. Their owners are their consumers, and they must bear all of the cooperatives' operating costs. This is another reason for highlighting the differences between cooperatives and other industry participants.

Moreover, the subsidy in this instance would be decidedly regressive. Until the size and unit cost of new DG technologies drops, most DG facilities will be larger diesel or combustion turbine units installed by large industrial or commercial consumers. Another significant portion may be expensive household units installed by higher income consumers.[78] That means that the large or wealthy customers would be shifting costs to smaller, less well off residential customers. Obviously, that is a policy choice that decision makers will need to make. But, at a time when large industrial customers are getting far more benefit than rural and residential customers from retail competition, it does not make much sense to ask the least advantaged consumers to shoulder another burden.

As mentioned above, however, states have a number of options for providing direct subsidies, including up-front capital cost buy-downs, direct payments to consumers who install DG in "DG development zones," tax deductions for consumers who install DG, and others. Each of these options could distribute the cost of subsidies more broadly across the entire tax base. That may not seem critical to decision makers thinking about large investor-owned utilities, which average 315,000 consumers. With a customer base that large, no consumer needs to bear much burden from a DG subsidy. But, the burden each consumer bears could be much higher in small cooperative and municipal systems. Cooperatives, for example, serve an

[78] See "RKS: Yuppies Yearn For On-Site Power," Electricity Daily (September 29, 1999).

average of fewer than 10,000 consumers. Spread among so few consumers, any state-required subsidy could have a noticeable impact on each consumer's bill.

ENVIRONMENTAL ISSUES

As mentioned above, one of the most touted benefits of DG is environmental. DG, some proponents have argued, produces less air emissions than most central station generation. While that is certainly true of some technologies, decision makers need to be skeptical of accepting broad environmental claims.

At one end of the spectrum, some technologies are extremely clean. PV and wind energy have no emissions and fuel cells that operate on hydrogen produce no air emissions other than water vapor. Even those fuel cells that operate on natural gas or methanol emit few pollutants.

In the middle, the new micro-turbines operating on natural gas may be cleaner than some central station generation. Nevertheless, even some environmental groups are concerned about the possible proliferation of these units. Because they operate on fossil fuels, they do have NO_x, SO_2, and CO_2 emissions. But, they are today subject to much less stringent environmental regulation than central station generators. The thought of tens of thousands of new generating units operating without permits makes some groups very nervous.

And, at the other end of the spectrum, however, by far the largest number of existing DG units today are diesel and combustion turbine units. Some of those units, particularly that operate intermittently for back-up purposes, can have far greater emissions. In fact, this points out one of the areas where some of the touted benefits of DG can conflict. Some commentators have suggested that regulators should find a way to encourage the use of existing generators in schools, hospitals, hotels, etc. to provide back-up or supplemental service when there are power shortages or reliability is seriously threatened.[79] But, because most of these small scale consumer-owned units are noisy, high maintenance, diesel generators with significant air emissions, it could be environmentally harmful to encourage increased usage. In fact, most were permitted by state environmental agencies only on the presumption that they would be operated for only a very limited number of hours per year and only for emergencies.

CONTINUED UTILITY ROLE

Pursuant to Decision 99-10-065, California is currently investigating the question whether incumbent utilities should be permitted to install DG or to sell DG facilities to their consumers. Some commentators have suggested that distribution utilities may have an unfair advantage in the development and installation of distributed generation because independent power producers may not have equal access to the information needed to determine where to place facilities.

Lining up on the other side are a number of utilities, and some manufacturers of DG technologies. The manufacturers are concerned that limitations on utility participation in DG will limit their market for their products. Utilities are concerned both that they could lose the system benefits they can obtain by directly installing DG and the potentially profitable business of selling DG facilities at retail.

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[79] RAP Draft Report, p.21.

Although California is continuing to look at the issue, the PUC found initially that "except for market power arguments, none of the parties expressed compelling reasons why the regulated UDCs and their unregulated affiliates should not be allowed to participate in customer side distributed generation."[80]

In response to that remaining market power concern, others have noted that it should not be difficult or overly burdensome for an independent power producer to figure out where it can find markets for DG. Many of these entities – like Enron – are very large, well funded and highly sophisticated. Moreover, it does not take a lot of inside knowledge to recognize where in a utility's service territory it is experiencing load growth. One needs only to get the plans for new strip malls or new industrial sites from the city or county planning office to learn that. Moreover, many independent power producers (IPPs) are already working directly with commercial and industrial customers to plan generation plants. Those are the customers that have the interest, the capital, the land, and the large loads now required to justify the installation of DG technology economically. When the cost and technical issues have been addressed to permit a broad spectrum of consumers to benefit from DG, there will no longer be any argument that utilities are at an information advantage; IPPs will be equally well situated to advertise their products to mass audiences.

CONCLUSION

Both existing and developing DG technologies have the potential to bring cooperatives and their members significant benefits. Those benefits, however, cannot be taken for granted. Every application of different DG technologies will need to be examined on its own through the lenses of technological capability, safety, reliability and cost.

Before consumers or utilities install DG, and before decision makers act to support DG, they should ask themselves a series of important questions:

- Has the particular DG technology at issue proven itself to be economically viable, or proven itself to be reliable in commercial operation?
- Has the particular DG technology at issue been properly matched to the particular application for which it will be installed/supported?
- Is the technology capable of providing the required service as a matter of engineering?
- Is the technology economic for the intended application?
- Has the DG installation been planned and coordinated with the local distribution utility?
  - As installed, will the DG unit provide the consumer or system any economic benefit?
  - As installed, what effect will the DG unit have on system safety and reliability?
  - As installed, who will bear the costs and risks of the DG unit: the consumer who installs it? The system? Other consumers on the system? Or society, through a broad-based subsidy?
- Will the operation of the DG be coordinated with the local distribution utility?
  - As it will be operated, will the technology provide the consumer or system any benefit?

[80] CPUC 99-10-065, p.19.

- As it will be operated, what effect will the DG unit have on system safety and reliability?

- As it will be operated, who will bear the costs and risks of the DG unit: the consumer who installs it? The system? Other consumers on the system? Or society, through a broad-based subsidy?

If consumers or decision makers choose to install or support a DG technology that is not economic for a particular application to support other goals, they should still ask themselves:

- Will the DG installation be safe and reliable? That must be the sine qua non of any addition to a distribution system.

- Has every effort been made to ensure maximum coordination with the local distribution utility to maximize system benefits/minimize system costs?

- Will the costs of an uneconomic DG unit be fairly allocated to those who receive the non-economic benefits of the unit?

By asking themselves these questions, and working together to find solutions, consumers, utilities, and decision maker should be able to attain the tremendous potential benefits of DG while still addressing the real safety, reliability and economic risks posed by DG.

United States Environmental Protection Agency
Office of Water Washington, D.C.
EPA 832-F-00-064 September 2000

Biosolids Technology Fact Sheet
Land Application of Biosolids

DESCRIPTION

Biosolids are primarily organic materials produced during wastewater treatment which may be put to beneficial use. An example of such use is the addition of biosolids to soil to supply nutrients and replenish soil organic matter. This is known as land application. Biosolids can be used on agricultural land, forests, rangelands, or on disturbed land in need of reclamation.

Recycling biosolids through land application serves several purposes. It improves soil properties, such as texture and water holding capacity, which make conditions more favorable for root growth and increases the drought tolerance of vegetation. Biosolids application also supplies nutrients essential for plant growth, including nitrogen and phosphorous, as well as some essential micro nutrients such as nickel, zinc, and copper. Biosolids can also serve as an alternative or substitute for expensive chemical fertilizers. The nutrients in the biosolids offer several advantages over those in inorganic fertilizers because they are organic and are released slowly to growing plants. These organic forms of nutrients are less water soluble and, therefore, less likely to leach into groundwater or run off into surface waters.

There are several methods to apply biosolids. The selection of the method depends on the type of land and the consistency of the biosolids. Liquid biosolids are essentially 94 to 97 percent water with relatively low amounts of solids (3 to 6 percent). These can be injected into the soil or applied to the land surface. Specialized vehicles are used to inject biosolids into the soil, as shown in Figure 1. These tankers have hoses leading from the storage tank to injection nozzles which release the biosolids.

Source: U.S. EPA, 1984.

FIGURE 1 BIOSOLIDS INJECTION EQUIPMENT

Modified tanker trucks are used for surface application (Figure 2). Biosolids applied to the land surface are usually incorporated into the soil with conventional farm equipment.

It is often economical to reduce the volume of biosolids prior to transportation or storage. The amount of water in biosolids can be reduced through mechanical processes such as draining, pressing, or centrifuging, resulting in a material composed of up to 30 percent dry solids. This material will be the consistency of damp soil. Dewatered biosolids do not require any specialized equipment and can be applied with conventional agricultural equipment, such as manure spreaders pulled by tractors.

Source: U.S. EPA, 1986.

FIGURE 2 LIQUID APPLICATION OF BIOSOLIDS

Figure 3 shows the spraying of biosolids, an application method primarily used in forested or reclamation sites. Liquid biosolids are sprayed from a tank towed by a truck or other vehicle.

The Environmental Protection Agency's 40 CFR Part 503, *Standards for the Use and Disposal of Sewage Sludge* (the Part 503 Rule), requires that wastewater solids be processed before they are land applied. This processing is referred to as "stabilization" and helps minimize odor generation, destroys pathogens (disease causing organisms), and reduces vector attraction potential. There are several methods to stabilize wastewater solids, including:

- Adjustment of pH, or alkaline stabilization.
- Digestion.
- Composting.
- Heat drying.

The Part 503 Rule defines two types of biosolids with respect to pathogen reduction, Class A and Class B, depending on the degree of treatment the solids have received. Both types are safe for land application, but additional requirements are imposed on Class B materials. These are detailed in the Part 503 Rule and include such things as restricting public access to the application site, limiting livestock grazing, and controlling crop harvesting schedules. Class A biosolids (biosolids treated so that there are no detectable pathogens) are not subject to these restrictions.

In addition to stabilization, the Part 503 Rule sets maximum concentrations of metals which cannot be exceeded in biosolids that will be land applied. These are termed Ceiling Concentrations. Part 503 also establishes Cumulative Pollutant Loading Rates for eight metals which may not be exceeded at land application sites. A third set of metals criteria is also included in Part 503, known as Pollutant Concentrations. If these concentrations are not exceeded in the biosolids to be land applied, the Cumulative Pollutant Loading Rates do not need to be tracked. Table 1 shows the three sets of federal limits applicable to biosolids to be land applied.

Source: U.S. EPA, 1986.

FIGURE 3 APPLICATION OF LIQUID BIOSOLIDS TO FOREST LAND

TABLE 1 MAXIMUM METAL CONCENTRATIONS

Metal	Ceiling Concentration (mg/kg)	Cumulative Pollutant Loading Rates (kg/hectare)	Pollutant Concentrations (mg/kg)
Arsenic	75	41	41
Cadmium	85	39	39
Copper	4,300	1,500	1,500
Lead	840	300	300
Mercury	57	17	17
Molybdenum	75	NL	NL
Nickel	420	420	420
Selenium	100	100	100
Zinc	7,500	2,800	2,800

NL = No limit

Source: U.S. EPA, 1993 and 1994.

The term *Exceptional Quality* is often used to describe a biosolids product which meets Class A pathogen reduction requirements, the most stringent metals limits (Pollutant Concentrations), and vector attraction reduction standards specified in the Part 503 Rule. Vectors (flies, mosquitoes, rodents, birds, etc.) Can transmit diseases directly to humans or play a specific role in the life cycle of a pathogen as a host. Vector attraction reduction refers to processing which makes the biosolids less attractive to vectors thereby reducing the potential for transmitting diseases. Exceptional Quality biosolids products are as safe as other agricultural and horticultural products and may be used without site restrictions.

APPLICABILITY

Land application is well-suited for managing solids from any size wastewater treatment facility. As the method of choice for small facilities, it offers cost advantages, benefits to the environment, and value to the agricultural community. However, biosolids produced by many major metropolitan areas across the country are also land applied. For example, biosolids from the Blue Plains Wastewater Treatment Facility serving the District of Columbia and surrounding communities in Virginia and Maryland have been land applied since the plant began operation in 1930. The cities of Philadelphia, Chicago, Denver, New York, Seattle, and Los Angeles all land apply at least part of their biosolids production.

Land application is most easily implemented where agricultural land is available near the site of biosolids production, but advances in transportation have made land application viable even where hauling distances are greater than 1,000 miles. For example, Philadelphia hauls dewatered biosolids 250 miles to reclaim strip-mines in western Pennsylvania and New York City ships some of its biosolids over 2,000 miles to Texas and Colorado.

ADVANTAGES AND DISADVANTAGES

Land application offers several advantages as well as some disadvantages that must be considered before selecting this option for managing biosolids.

Advantages

Land application is an excellent way to recycle wastewater solids as long as the material is quality-controlled. It returns valuable nutrients to the soil and enhances conditions for vegetative growth. Land application is a relatively inexpensive option and capital investments are generally lower than other biosolids management technologies. Contractors can provide the necessary hauling and land application equipment. In addition, on-site

spatial needs can be relatively minor depending on the method of stabilization selected.

Disadvantages

Although land application requires relatively less capital, the process can be labor intensive. Even if contractors are used for application, management oversight is essential for program success. Land application is also limited to certain times of the year, especially in colder climates. Biosolids should not be applied to frozen or snow covered grounds, while farm fields are sometimes not accessible during the growing season. Therefore, it is often necessary to provide a storage capacity in conjunction with land application programs. Even when the timing is right (for example, prior to crop planting in agricultural applications), weather can interfere with the application. Spring rains can make it impossible to get application equipment into farm fields, making it necessary to store biosolids until weather conditions improve.

Another disadvantage of land application is potential public opposition, which is encountered most often when the beneficial use site is close to residential areas. One of the primary reasons for public concern is odor. In worst case situations, municipalities or counties may pass ordinances which ban or restrict the use of biosolids. However, many successful programs have gained public support through effective communications, an absolutely essential component in the beneficial use of biosolids.

Environmental Impacts

Despite many positive impacts to the environment, land application can have negative impacts on water, soil, and air if not practiced correctly.

Negative impacts to water result from the application of biosolids at rates that exceed the nutrient requirements of the vegetation. Excess nutrients in the biosolids (primarily nitrogen compounds) can leach from the soil and reach groundwater. Runoff from rainfall may also carry excess nutrients to surface water. However, because biosolids are a slow release fertilizer, the potential for nitrogen compounds to leach from biosolids amended soil is less than that posed by the use of chemical fertilizers. In areas fertilized by either biosolids or chemicals, these potential impacts are mitigated by proper management practices, including the application of biosolids at agronomic rates (the rate nutrients are used by the vegetation.) Maintenance of buffer zones between application areas and surface water bodies and soil conservation practices will minimize impacts to surface water.

Negative impacts to soil can result from mismanagement of a biosolids land application. Federal regulations contain standards related to all metals of concern and application of biosolids which meets these standards should not result in the accumulation of metals to harmful levels. Stringent record keeping and reporting requirements on both the federal and state level are imposed to prevent mismanagement.

Odors from biosolids applications are the primary negative impact to the air. Most odors associated with land application are a greater nuisance than threat to human health or the environment. Odor controls focus on reducing the odor potential of the biosolids or incorporating them into the soil. Stabilization processes such as digestion can decrease the potential for odor generation. Biosolids that have been disinfected through the addition of lime may emit ammonia odors but they are generally localized and dissipate rapidly. Biosolids stabilization reduces odors and usually results in an operation that is less offensive than manure application.

Overall, a properly managed biosolids land application program is preferable to the use of conventional fertilizers for the following reasons:

- Biosolids are a recycled product, use of which does not deplete non-renewable resources such as phosphorous.
- The nutrients in biosolids are not as soluble as those in chemical fertilizers and are therefore released more slowly.
- Biosolids appliers are required to maintain setbacks from water resources and are often subject to more stringent soil conservation and erosion control practices, nutrient

management, and record keeping and reporting requirements than farmers who use only chemical fertilizers or manures.

- Biosolids are closely monitored.

- The organic matter in biosolids improves soil properties for optimum plant growth, including tilth, friability, fertility and water holding capacity. They also decrease the need for pesticide use.

A joint policy statement of the U.S. Department of Agriculture, the U.S. Food & Drug Administration, and the U.S. Environmental Protection Agency states, "...the use of high quality biosolids coupled with proper management procedures, should safeguard the consumer from contaminated crops and minimize any potential adverse effect on the environment" (U.S. EPA, 1981).

DESIGN CRITERIA

Design criteria for land application programs address issues related to application rates and suitable sites. Design criteria for physical facilities (such as stabilization) that are part of land application programs are discussed in separate fact sheets. Biosolids, site, and vegetative characteristics are the most important design factors to consider.

Biosolids must meet regulatory requirements for stabilization and metals content. In addition, nutrient content and physical characteristics, such as percent solids, are used to determine the appropriate application rate for the crop that will be grown and the soil in which the crops will be grown.

Site suitability is determined based on such factors as soil characteristics, slope, depth to groundwater, and proximity to surface water. In addition, many states have established site requirements to further protect water quality. Some examples include:

- Sufficient land to provide areas of non-application (buffers) around surface water bodies, wells, and wetlands.

- Depth from the soil surface to groundwater equal to at least one meter.

- Soil pH in the range of 5.5 to 7.5 to minimize metal leaching and maximize crop growing conditions.

Site suitability is also influenced by the character of the surrounding area. While odors and truck traffic many not be objectionable in an agricultural area, both will adversely impact residential developments and community centers close to fields where biosolids are applied.

The type of vegetation to be grown is also a design consideration. Vegetation, like soil characteristics, will generally not exclude biosolids application since most vegetation will benefit from the practice. However, the type of vegetation will impact the choice of application equipment, the amount of biosolids to be applied, and the timing of applications. The effect of vegetation on the choice of application equipment is discussed above in the description of this technology. The amount of biosolids that may be applied to a site is a function of the amount of nutrients required by the vegetation and the amount of metals found in the biosolids. Table 2 summarizes the application frequency, timing, and rates for various types of sites.

Another factor to be considered in designing a land application program is the timing of applications. Long periods of saturated or frozen ground limit opportunities for application. This is an important consideration in programs using agricultural lands; applications must be performed at times convenient

Typical Biosolids Application Rate Scenario

The recommended minimum amount of nitrogen needed by a typical corn crop to be grown in New Jersey is 120 pounds per acre per year. Biosolids containing 3 percent nitrogen could be applied at up to 5.4 dry tons per acre if used to supply all the nitrogen needed by the crop (i.e., no other nitrogen fertilizers used.) A city producing 10 dry tons of biosolids per day would require access to almost 700 acres of corn. If the biosolids contained only 1.5 percent nitrogen, twice as many tons could be applied per acre, requiring only half as many acres to land apply the same amount of biosolids generated.

TABLE 2 TYPICAL BIOSOLIDS APPLICATION SCENARIOS

Type of Site/Vegetation	Schedule	Application Frequency	Application Rate
Agricultural land			
Corn	April, May, after harvest	Annually	5 to 10 dry tons per acre
Small grains	March-June, August, fall	Up to 3 times per year	2 to 5 dry tons per acre
Soybeans	April-June, fall	Annually	5 to 20 dry tons per acre
Hay	After each cutting	Up to 3 times per year	2 to 5 dry tons per acre
Forest land	Year round	Once every 2 - 5 years	5 to 100 dry tons per acre
Range land	Year round	Once every 1 - 2 years	2 to 60 dry tons per acre
Reclamation sites	Year round	Once	60 to 100 dry tons per acre

Source: U.S. EPA, 1994.

to the farmer and must not interfere with the planting of crops. Most application of biosolids to agricultural land occurs in the early spring or late fall. As a result, storage or an alternate biosolids management option must be available to handle biosolids when application is not possible. Forest lands and reclamation sites allow more leeway in the timing of applications. In some areas of the United States, application can proceed year round.

Application is most beneficial on agricultural land in late fall or early spring before the crop is planted. Timing is less critical in forest applications when nutrients can be incorporated into the soil throughout the growing period. Winter application is less desirable in many locales. Rangelands and pasturelands also are more adaptable to applications during various seasons. Applications can be made as long as ground is not saturated or snow covered and whenever livestock can be grazed on alternate lands for at least 30 days after the application. The timing of single applications in land reclamation programs is less critical and may be dictated by factors such as regulatory compliance schedules.

PERFORMANCE

In 1995, approximately 54 percent of wastewater treatment plants managed biosolids through land application, an increase of almost 20 percent from information reported in 1993 (WEF, 1997 and U.S. EPA, 1993.) The vast majority of these land application programs use agricultural land, with minor amounts applied to forest lands, rangelands, or land in need of reclamation.

The use of land application increased steadily in the 1980s for several reasons, including decreasing availability and increasing costs associated with landfill disposal. Research also helped refine procedures for proper land application. Meanwhile, implementation of the Nationwide Pretreatment Program resulted in significant improvements in biosolids quality. The 1993 adoption of the Part 503 Rule created a structure for consistent application procedures across the nation. The regulations were developed with input from the U.S. Department of Agriculture, the U.S. Food and Drug Administration, biosolids generators, environmental groups, the public, state regulators, and academic researchers. Conservative assumptions were used to create regulations to "protect public health and the environment from all reasonably anticipated adverse effects" (U.S. EPA, 1993).

Land application is a reliable biosolids management option as long as the system is designed to address such issues as storage or alternate management for biosolids during periods when application cannot take place due to unfavorable weather or field conditions. Public opposition rather than technical constraints is the most common reason for discontinuing land application programs.

"In fact, in all the years that properly treated biosolids have been applied to the land, we have been unable to find one documented case of illness or disease that resulted."

Martha Prothro, Former Deputy Assistant Administrator for Water, U.S. Environmental Protection Agency.

Source: Water Environment Web, 1998.

OPERATION AND MAINTENANCE

Land application systems generally use uncomplicated, reliable equipment. Operations include pathogen reduction processing, dewatering, loading of transport vehicles, transfer to application equipment, and the actual application. Operations and maintenance considerations associated with pathogen reduction processing are discussed in other fact sheets. The other operations require labor skills of heavy equipment operators, equipment maintenance personnel, and field technicians for sampling, all normally associated with wastewater treatment facilities.

In addition, the biosolids generator is responsible for complying with state and local requirements as well as federal regulations. The biosolids manager must be able to calculate agronomic rates and comply with record keeping and recording requirements. In fact, the generator and land applier must sign certification statements verifying accuracy and compliance. The generator should also allocate time to communicate with farmers, landowners, and neighbors about the benefits of biosolids recycling. Control of odors, along with a viable monitoring program, is most important for public acceptance.

COSTS

It is difficult to estimate the cost of land application of biosolids without specific program details. For example, there is some economy of scale due to large equipment purchases. The same size machine might be needed for a program that manages 10 dry tons of biosolids per day as one managing 50 dry tons per day; the cost of that machine can be spread over the 10 or 50 dry tons, greatly affecting average costs per dry ton. One source identified costs for land application varying from $60 to $290 per dry ton (O'Dette, 1996.) This range reflects the wide variety in land application methods as well as varying methods to prepare biosolids for land application. For example, costs for programs using dewatered biosolids include an additional step whereas costs for programs using liquid biosolids do not reflect the cost of dewatering. They do, however, include generally higher transportation costs.

Despite the wide range of costs for land application programs, several elements must be considered in estimating the cost of any biosolids land application program:

- Purchase of application equipment or contracting for application services.
- Transportation.
- Equipment maintenance and fuel.
- Loading facilities.
- Labor.
- Capital, operation and maintenance of stabilization facilities.
- Ability to manage and control odors.
- Dewatering (optional).
- Storage or alternate management option for periods when application is not possible due to weather or climate.
- Regulatory compliance, such as permit applications, site monitoring, and biosolids analyses.
- Public education and outreach efforts.

Land must also be secured. Some municipalities have purchased farms for land application; others apply biosolids to privately held land.

Some operating costs can be offset through the sale of the biosolids material. Since the biosolids

reduce the need for fertilizers and pH adjustment, farmers sometimes pay to have biosolids applied to their lands.

REFERENCES

Other Related Fact Sheets

Odor Management in Biosolids Management
EPA 832-F-00-067
September 2000

Centrifugal Dewatering/Thickening
EPA 832-F-053
September 2000

Belt Filter Press
EPA 832-F-00-057
September 2000

Filter Press, Recessed Plate
EPA 832-F-00-058
September 2000

Alkaline Stabilization of Biosolids
EPA 832-F-00-052
September 2000

Other EPA Fact Sheets can be found at the following web address:
http://www.epa.gov/owmitnet/mtbfact.htm.

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United States Environmental Protection Agency
Office of Water Washington, D.C.
EPA 832-F-00-061 September 2000

EPA

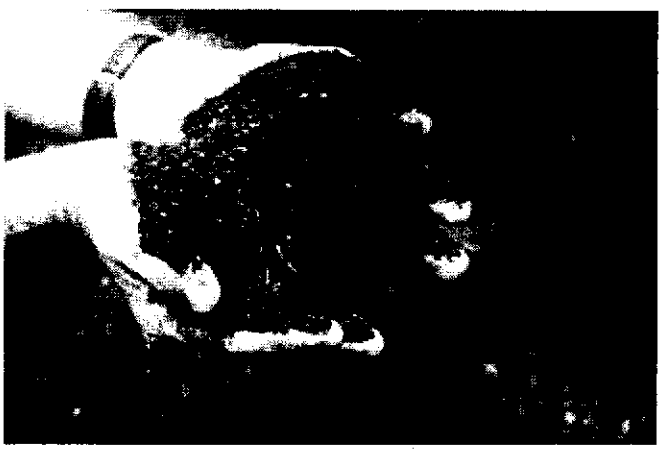
Biosolids Technology Fact Sheet

In-Vessel Composting of Biosolids

DESCRIPTION

Biosolids are primarily organic materials produced during wastewater treatment which may be put to beneficial use. Composting is the biological degradation of organic materials under controlled aerobic conditions. The process is used to stabilize wastewater solids prior to their use as a soil amendment or mulch in landscaping, horticulture, and agriculture. Figure 1 shows an example of a finished product of compost. Stabilization of wastewater solids prior to their use serves to destroy pathogens (disease causing organisms), minimize odors, and reduce vector attraction potential.

The Environmental Protection Agency's (EPA's) 40 CFR Part 503, *Standards for the Use and Disposal of Sewage Sludge*, (the Part 503 Rule) defines two types of biosolids with respect to pathogen reduction: Class A and Class B. The difference is defined by the degree of pathogen reduction on the solids. When federal performance standards are met, composting insures full destruction of pathogens to *non-detectable levels* in the wastewater solids (i.e., to Class A standards.) The Part 503 Rule requires the composting process to maintain a temperature of at least 55 degrees Celsius for a minimum of three days to effectively destroy pathogens and qualify as Class A.



Source: U.S. EPA, 1986.

FIGURE 1 FINISHED COMPOST PRODUCT

In addition to performance standards for the composting process, the Part 503 Rule established maximum concentrations for nine metals which cannot be exceeded in biosolids products, including compost. These are known as ceiling concentrations. The federal maximum allowable metals concentrations are provided in Table 1. The Part 503 Rule also established more stringent pollutant concentrations. Biosolids products which do not exceed pollutant concentrations, meet Class A pathogen reduction requirements, and are processed to reduce vector attraction potential are often referred to as *Exception Quality* products. Products meeting these requirements may be freely distributed for a variety of uses.

There are three general methods of composting biosolids: windrow, aerated static pile, and in-vessel. Each method uses the same scientific principals but varies in procedures and equipment needs. This Fact Sheet addresses in-vessel composting.

In-vessel composting occurs within a contained vessel, enabling the operator to maintain closer control over the process in comparison with other composting methods. A typical flow diagram for in-vessel composting is shown in Figure 2.

There are several types of in-vessel composting reactors: vertical plug-flow, horizontal plug-flow, and agitated bin. The primary difference involves

TABLE 1 MAXIMUM METAL CONCENTRATIONS

Metal	Ceiling Concentration (mg/kg)	Pollutant Concentrations (mg/kg)
Arsenic	75	41
Cadmium	85	39
Copper	4,300	1,500
Lead	840	300
Mercury	57	17
Molybdenum	75	NL
Nickel	420	420
Selenium	100	100
Zinc	7,500	2,800

NL = No established limit

Source: U.S. EPA, 1993 and 1994.

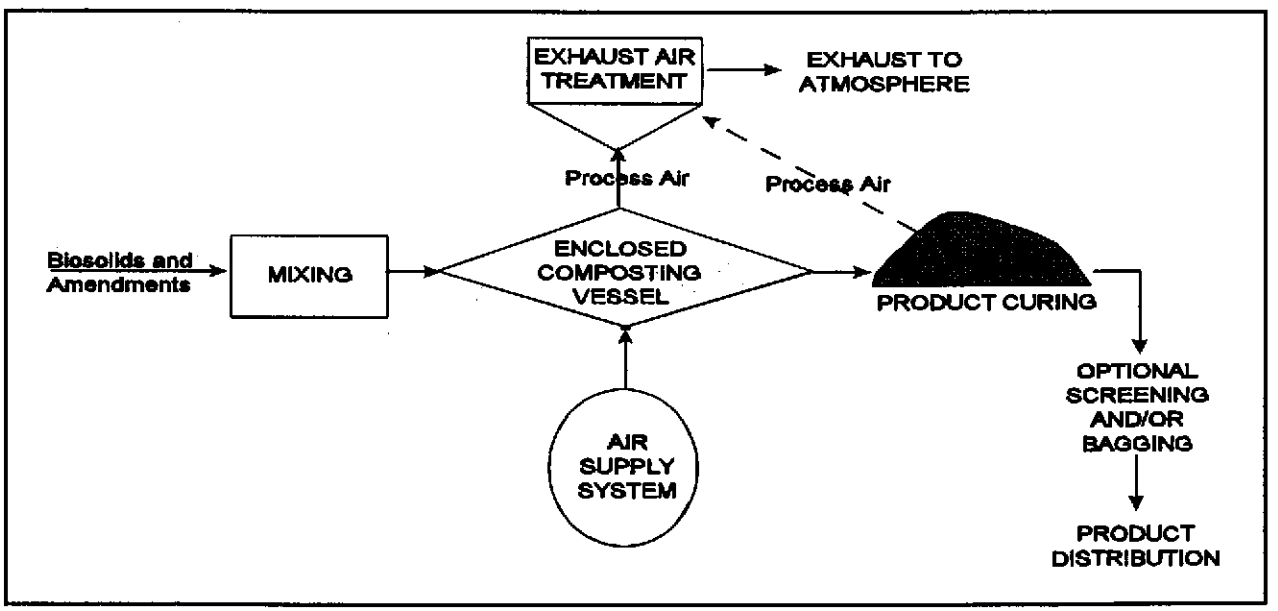
the aeration systems and loading/unloading provisions. The first two systems operate as plug-flow, which means that biosolids and bulking agent are loaded on a periodic basis (typically daily or weekly) while "finished" compost is discharged from the opposite end of the system on roughly the same schedule. The vessel is only completely emptied for maintenance.

In vertical plug-flow systems, the biosolids and bulking agent mixture is introduced into the top of the reactor vessel and compost is discharged out the bottom by a horizontally rotating screw auger. Air is introduced in these systems either from the bottom and travels up through the composting mass where it is collected for treatment or through lances hanging from the top of the reactor.

In horizontal plug-flow systems, the compost and bulking agent mixture is loaded into one end of the reactor. A steel ram pushes the mixture through the reactor. Air is introduced and exhausted through slots in the floor of the reactor. Compost is discharged from the end of the reactor opposite the ram.

The agitated bed reactors are typically open topped. The biosolids and bulking agent mixture is loaded from above. The composting mass is periodically agitated using a mechanical device and air is introduced through the floor of the reactors. Agitated bed reactors can be operated as either plug flow or batch operations. In batch operations, the vessel is loaded with biosolids and bulking agent, processing takes place, and the vessel is emptied.

As with other composting methods, the resulting product is generally cured for at least 30 days after



Source: Modified from U.S. EPA, 1989.

FIGURE 2 FLOW DIAGRAM OF A TYPICAL IN-VESSEL COMPOSTING FACILITY

Composting Basics

During composting, microorganisms break down organic matter in wastewater solids into carbon dioxide, water, heat, and compost. To ensure optimal conditions for microbial growth, carbon and nitrogen must be present in the proper balance in the mixture being composted. The ideal carbon-to-nitrogen ratio ranges from 25 to 35 parts carbon for each one part of nitrogen by weight. A lower ratio can result in ammonia odors. A higher ratio will not create optimal conditions for microbial growth causing degradation to occur at a slower rate and temperatures to remain below levels required for pathogen destruction. Wastewater solids are primarily a source of nitrogen and must be mixed with a higher carbon-containing material such as wood chips, saw dust, newspaper or hulls. In addition to supplying carbon to the composting process, the bulking agent serves to increase the porosity of the mixture. Porosity is important to ensure that adequate oxygen reaches the composting mass. Oxygen can be supplied to the composting mass through active means such as blowers and piping or through passive means such as turning to allow more air into the mass. The proper amount of air along with biosolids and bulking agent is important. Haug (1980) provides the basis for calculating the appropriate amounts of these materials.

active composting and before use. A properly operated facility produces a stable compost which can be easily handled and safely stored. Compost enhances soil properties, such as water holding capacity, nutrient availability, and texture. In *Compost Engineering*, R.T. Haug (1980) discusses several ways to determine the degree of stability achieved during composting including:

- Oxygen uptake rate.
- Low degree of reheating in curing piles.
- Organic content of the compost.
- Presence of nitrates and the absence of ammonia and starch in the compost.

Because this process results in a usable material, an important and often overlooked part of any composting facility is product storage and marketing. Unlike disposal-oriented technologies, end users and markets for the product are seasonal with peak demand in the spring and fall. Therefore, provisions for storage of the final product until it is sold are necessary. In addition, product marketing efforts are essential to insure that end users understand the material, recognize its value, and are familiar with proper application techniques.

APPLICABILITY

The physical characteristics of most biosolids allow for their successful composting. However, many characteristics will impact design decisions. These characteristics are discussed in the Design Criteria section.

In-vessel technology is more suitable than other composting technologies in suburban and urban settings because the system allows for containment and treatment of air to remove odors before release. The requirement for a relatively small amount of land also increases its applicability in these settings over other types of composting. However, a market for use of the resulting product will generally be more readily available in suburban and rural areas rather than urban settings.

ADVANTAGES AND DISADVANTAGES

Advantages

Composting offers advantages and disadvantages that must be considered before selecting this option for managing biosolids. First, composting produces a reusable product as long as the feed materials are suitable. Use of the product returns valuable nutrients to the soil and enhances conditions for vegetative growth. Compost can be handled more easily than some other biosolids products such as digested biosolids. It is very friable and has the consistency of a peat soil. In addition, compost, unlike other Class A products, is not subject to end use restrictions. However, composting somewhat increases the amount of material to be managed through addition of bulking agent to improve aeration in the composting mass. Typically, one cubic yard of cake will produce three cubic yards of compost. Some bulking agents can be screened out and reused to minimize this disadvantage. This "disadvantage" may also be an advantage because the product can be sold.

In comparison with other types of composting, the in-vessel technology offers the following conveniences:

- The composting process can be more closely controlled.
- The effects of weather are diminished.
- Less bulking agent may be required.
- The quality of the resulting product is more consistent.
- Less manpower is required to operate the system and staff is less exposed to the composting material.
- Process air can be more easily collected for treatment to reduce odor emissions.
- Less land area is required.
- Public acceptance of the facility may be better.

Disadvantages

There are also disadvantages associated with in-vessel composting which must be considered before selecting this technology for wastewater solids management. In-vessel composting is generally more costly than other composting methods, particularly with respect to capital expenditures. In addition, because it is more mechanized, more equipment maintenance is necessary. A significant drawback of composting that must be addressed during facility design is the potential for fires. The large amount of carbonaceous material stored and used at composting facilities creates the potential for fires in storage areas as well as in the active composting mass. Sufficient aeration and moisture are necessary to avoid fires.

Environmental Impacts

Several aspects of an in-vessel composting facility can result in environmental impacts if the facility is mismanaged. Proper design and operation can reduce environmental impacts. Storage, distribution, and use of the resulting product can also result in environmental impacts if not performed properly.

In-vessel composting facilities can impact air, water, and soil. The primary impact to the air is nuisance odors if process air is not properly treated before emission to the atmosphere. Most in-vessel composting facilities treat process air with either a biofilter or chemical scrubbing system prior to release to the atmosphere. Odors can result from several possible constituents in the air exiting a composting vessel. Much work has been done in the last several years to characterize and control odors from composting operations. Bioaerosols (organisms or biological agents in air that affect human health) are also a concern in compost emissions. The most widely studied bioaerosol is *Aspergillus fumigatus,* a fungal spore. Endotoxins (non-living components of cell walls of gram-negative bacteria) and organic dust (such as pollens) are also bioaerosols. These contaminants are primarily of concern to workers at the composting facilities and are generally not present in quantities that would cause reactions in most humans. Health effects to compost facility workers have not been readily apparent in studies conducted to identify such effects (Epstein *et al.*, 1998.)

Impacts to surface water bodies resulting from in-vessel composting are unlikely. The enclosed nature of the technology greatly diminishes the potential for impacts to surface water due to high nitrogen concentrations in runoff. Buildings should be designed with floor drains to sewers or holding tanks. Any unenclosed portions of an in-vessel composting operation, such as materials receiving and mixing, product curing, and product storage should be designed with leachate/runoff containment and provisions for disposal or treatment to avoid runoff potential.

The use of biosolids compost as a soil conditioner results in the following:

- Increases water holding capacity.
- Increases aeration and drainage for clay soils.

- Provides organic nitrogen, phosphorus, and potassium.
- Provides essential plant micronutrients.
- Can reduce the need for pesticides.

Other environmental benefits of producing and using compost include the recycling of a valuable resource, reduction of dependence on chemical fertilizers, and offsetting the use of natural resources such as trees or peat moss as mulch material.

DESIGN CRITERIA

The following biosolids characteristics must be considered in designing an in-vessel composting system:

- Moisture content.
- Volatile solids content.
- Carbon content.
- Nitrogen content.
- Bulk density.

These factors are discussed in detail in *Composting Engineering* (Haug, 1980.)

The following bulking agent characteristics must also be considered:

- Size.
- Cost/availability.
- Recoverability.
- Carbon availability.
- Preprocessing requirements.
- Porosity.
- Moisture content.

Metals content of the biosolids will affect the usability of the final product and must be considered during design to ensure a market for the final product.

An odor control system is an inherent part of in-vessel design. The cost of an odor control system can account for up to 50 percent of both capital and operation and maintenance costs. Composting facilities usually use either wet scrubbers or biofilters for odor control. The level of odor control required is a function of the quality and quantity of air to be treated, the results of air dispersion modeling, and proximity to occupied dwellings.

The most important design feature of a composting system is the ability to maintain uniform aerobic conditions during composting. The air distribution system may be controlled by cycle timers and/or temperature feedback control. The design must avoid compaction of the composting mass to maintain sufficient pore space for aeration. In addition, provisions for routine monitoring of temperatures must be included.

Equipment should be designed to provide maintenance staff with safe access. Equipment and instrumentation should be able to be removed or repaired without having to relocate composting material.

Systems that minimize worker exposure to hot exhaust process gases are preferable because workers can maintain the system and control odors with greater ease, including minimizing the volume of process air that must be treated.

Many in-vessel systems include a water spray system to add moisture to the composting mass, to control temperatures, and for fire protection.

Detention times, which vary with system configuration, will affect many design considerations, including equipment sizing. Horizontal agitated bed systems are designed for 21 days of aerated composting followed by curing. Other in-vessel systems use 10 to 21 days of active composting. Some state regulations dictate detention times for composting systems. In general, about 21 days is a good minimum time for adequate

stabilization. Provisions to monitor the degree of stabilization allow operators to determine when the biosolids are adequately processed and ready for removal to curing piles.

Features of the site on which the in-vessel composting facility is to be located must be considered during design, including size, relative position to residential areas, availability of wastewater treatment, drainage, and access. Examples of optimum locations for in-vessel composting include a large tract of land in an industrial area or a site near a municipal solid waste landfill. One needs to determine the meteorology of a potential site so that odors can be adequately treated, diluted and dispersed.

PERFORMANCE

According to a survey conducted by *BioCycle, Journal of Composting and Recycling,* in January 1999, there were 54 in-vessel composting facilities processing wastewater residuals across the United States (Goldstein and Gray, 1999) and 11 more facilities were in various stages of design or construction. Since that survey, at least two facilities (Portland, Oregon and Camden County, New Jersey) have closed. The vendor systems used at the facilities listed in this survey include:

- Davis Composting and Residuals Management (formerly Taulman Composting Systems.)
- Bedminster Bioconversion (co-composting with municipal solid waste.)
- US Filter/International Process Systems.
- Longwood Manufacturing.
- American Biotech Systems.
- Purac.
- Gicon Tunnels.
- Resource Optimization Technology (ROT Box.)
- Compost System Company Paygro.
- Green Mountain Technologies.
- Waste Solutions.
- Royer.
- Fairfield.
- Conporec.
- Compost System Company Dynatherm.
- Dano.

In addition to these, there are several aerated static pile systems contained within a building that are categorized as in-vessel systems.

The above list is not intended to be a comprehensive list of vendors who offer in-vessel composting facilities. There are also many facilities in operation which use non-patented systems and components.

The number of operating in-vessel composting facilities for biosolids in the United States has steadily increased in the last two decades but has leveled off in recent years. In spite of early operational difficulties and challenges, many early facilities have been upgraded and are successfully operating today.

OPERATION AND MAINTENANCE

In-vessel composting systems can be relatively complex but the skills required for successful operation are common to wastewater treatment plant personnel. Typical labor requirements include heavy equipment operators, maintenance personnel, and instrumentation/computer operators. A clear understanding of biological systems is necessary. Additional staff or consultants are needed to manage end use and to market the compost.

In-vessel composting facilities can require significant maintenance. Many early composting facilities constructed in the United States experienced a variety of operating problems. Odor complaints from neighboring residents have caused

facilities to operate at reduced capacity or to shut down for extended periods of time for system modification. For example, a horizontal plug-flow system in Hickory, North Carolina, was shut down for more than a year while an odor issue was addressed. The system reopened after the addition of air pollution control equipment. The lack of available spare parts has also caused extensive periods of downtime at some facilities. Design configurations have caused some facilities, primarily vertically oriented plug-flow systems, to experience month-long periods of inoperation while routine maintenance was performed. Difficulties in emptying the vessels have been cited as a reason for significant maintenance requirements (O'Brien, 1986.) A system in Lancaster, Pennsylvania, was shut down when state regulators determined it did not meet temperature requirements for Class A pathogen reduction.

There are three basic compost market strategies. The first is the use of compost areas used by the public sector, such as parks, ball fields, landfill cover, and urban reclamation projects. Second, direct marketing to users maximizes revenue and improves the public image of the producer. This strategy could include distribution centers run by the compost facility where customers, such as homeowners, greenhouses, landscapers, and nurseries, can come to pick up the compost. The third strategy is to use a compost broker. This may result in lower revenue but removes the administrative burden of compost marketing. About 25 percent of composters employ a broker. It should be noted that revenue from compost sales will not cover production costs but should offset market development costs. Sale prices range from $5 to $60 per ton.

COSTS

Costs associated with in-vessel composting systems vary considerably from facility to facility. Site specific factors and the many configurations and equipment choices make it difficult to provide general costs for this technology. Annual operation and maintenance costs as low as $61 and as high as $534 per dry ton of biosolids composted were cited in a 1989 survey (Alpert *et. al.*, 1989.) A more recent assessment estimated costs for composting between $100 and $280 per dry ton of biosolids processed. In-vessel systems generally represent the high end of such cost ranges (O'Dette, 1996.)

The following items must be considered when estimate costs for a specific in-vessel composting facility:

- Land acquisition.
- Equipment procurement, including the composting vessel, loading equipment, conveyors, air supply equipment, temperature monitoring equipment, and odor control equipment.
- Operation and maintenance labor.
- Additives, such as bulking agents, to be used in the specific vessel selected.
- Energy (electricity and fuel for equipment).
- Water and wastewater treatment.
- Equipment maintenance and upkeep.
- Product distribution expenses and marketing revenues.
- Regulatory compliance expenses such as permitting, product analysis, process monitoring, record keeping and reporting.
- Preprocessing equipment for bulking agent.

REFERENCES

Other Related Fact Sheets

Odor Management in Biosolids Management
EPA 832-F-00-067
September 2000

Centrifugal Dewatering/Thickening
EPA 832-F-00-053
September 2000

Belt Filter Press
EPA 832-F-00-057
September 2000

Other EPA Fact Sheets can be found at the following web address:
http://www.epa.gov/owmitnet/mtbfact.htm.

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V. CHAI TOU GANG SHI CONCEPTUAL DESIGN

The Chai Tou Gang Shi is a small drainage which forms the northeastern boundary of Tainan City. The west bank of the River lies in Tainan City, with the east bank in Tainan County. The Chai Tou Gang Shi currently emerges from a large culvert and flows approximately 3.9 kilometers to its confluence with the Yen Shui Shi, and from there, out to the ocean.

According to City officials, the Chai Tou Gang Shi no longer contains a natural base flow of water coming from a natural headwaters spring. Instead, the flow in the river is entirely formed by both untreated sewage and stormwater runoff coming from the County and City neighborhoods that flank it. The river channel ranges from 10 to 60 meters in width and in depth from 2.5 to 7 meters, below the top of bank. Flows in the channel vary from about .5 to 4.5 cubic meters per second.

The Chai Tou Gang Shi discharges through a primarily residential part of Tainan, with few office, commercial, or industrial uses. The character of the residential development includes very small shelters up to major apartment buildings of 6 or more stories. The land within Tainan City adjacent to the river is zoned medium to high-density residential. With undeveloped and under-developed parcels common along the river, development potential is high.

SITE INVESTIGATION

Preliminary investigation of the river, data collection, and consultation with City officials was accomplished in two separate trips to Taiwan: November 13 to 16, 2000 and April 9 to 12, 2001. Extensive site analysis and photo documentation of the river was conducted with assistance from City staff and Mr. Kai-Yao Chang, the lead engineer from Moh and Associates, a local Taiwanese Civil Engineering consulting firm.

Team Oregon also reviewed the Chai Tou Gang Shi Master Plan, prepared by Moh and Associates in September, 2000. This report is very informative, with key information on the hydrology and existing conditions of the river. The task was to present ideas and concepts that could be used to enhance the Moh and Associates Plan for beautification and restoration. Specific issues addressed include: stream flow and flooding; streambank beautification and parklands, including a possible greenbelt; bridge crossings; parking and transportation issues; and possible commercial development.

During the April, 2001 visit to Tainan, TO learned that the Tainan City wishes to move ahead in June with a detailed design of a demonstration project along the Chai Tou Gang Shi. The project area is approximately 165 meters in length, located between the railway bridge and the Nan Kang Bridge.

CHAI TOU GANG SHI DEMONSTRATION AREA CONCEPT PLAN

The Chai Tou Gang Shi flows though the demonstration area in a relatively straight channel. The channel appears to have endured many high velocity floods that have caused the channel to become deeply incised. The banks are covered with both invasive and native vegetation that, along with the steep banks, makes the river virtually inaccessible. Accessibility to the Shi is not desirable because of environmental and health risks of the untreated, raw sewage flowing through the channel.

The purpose of this report is to illustrate and discuss ways that the Chai Tou Gang Shi can become an amenity to Tainan City. If steps are taken to prevent the release of untreated sewage into the local streams and rivers, control flooding, and provide pedestrian access to the Shi, it could become a highly desirable amenity for the citizens of Tainan.

The untreated sewage and storm sewage can both be diverted from the Chai Tou Gang Shi into a single sanitary sewer line under the Shi (see CTGS - Conceptual Design Information Illustrations 2-4 : Site Sections A-C) that will carry the sewage to a nearby wastewater treatment plant where it can be cleaned and released back into the channel to create a clean base flow. If this primary goal is achieved, then it will be possible to implement the rest of the steps needed to turn this demonstration area, and eventually the entire 3.9 KM of the Shi, into a greenbelt of pedestrian activity and civic pride.

Current plans for this Demonstration Area show a concrete lined box channel to control and convey floodwaters downstream as quickly as possible to the Yen Shui Shi. In the 1950's and 1960's, many cities and counties throughout the U.S. implemented similar types of floodwater control that failed because of unforeseen damage to downstream systems, and loss of the natural ecosystems of the rivers. Many of these concrete-lined channels are being removed and restored to original, natural channels in an attempt to stop or reverse the damage (see CTGS - Conceptual Design Information Reference 5 : *"The Los Angeles River: Reshaping the Urban Landscape"*; and Reference 6 : *"An Alternative Flood Control"*). The conceptual site plan for the Demonstration Area shows a three-tiered channel design (see CTGS - Conceptual Design Information Illustration 1 : Demonstration Area Conceptual Plan). The first tier is the main channel, which is shown as a restored meandering, braided channel, and is designed for low-flow conditions. The second tier is designed to hold "Ordinary High Water" flow or two to ten-year flood conditions. The third tier is designed to hold up to 50-year flood conditions. The banks in each tier are laid back at 3:1 slopes and, where possible, bio-engineered and vegetated to withstand their respective flood conditions (see CTGS - Conceptual Design Information Illustration 2 : Site Section B). All development is located above the 50-year flood plain for stability and longevity.

One of the greatest opportunities in the restoration and development of the Chai Tou Gang Shi is the potential for a long, vehicular-free pedestrian promenade. The Demonstration Area Conceptual Site Plan shows a two to four meter wide Pedestrian Promenade along the Shi that will have rest areas, overlooks every 60-80 meters, and small trailhead plazas with parking as needed. This concept could easily be carried out along the length of Shi.

The environmental impacts are another important consideration in the redevelopment of the Chai Tou Gang Shi. The government of Taiwan has stated very clearly that it supports environmentally sustainable projects in accordance with the Central Governments "Green Silicon Island" vision. Putting the Chai Tou Gang Shi into a concrete channel would impact the environment because of the removal of the riverside vegetation that provides both wildlife habitat and CO_2 reduction benefits. It also would reduce the overall aesthetic quality of Tainan by removing one of the last remnants of natural green space remaining in the city. The Demonstration Area Conceptual Plan retains the majority of existing significant vegetation and would provide for removal of exotic invasive species and re-vegetation with native plant material. One of the most important elements of the conceptual plan is the addition of stormwater treatment facilities. Even if every bit of sewage is removed from the channel, the stormwater runoff from surrounding roads and property would pollute the Shi to unacceptable levels. By adding bio-filters or filtration swales in appropriate places, the runoff could be treated, and the toxins removed from the water before it flows into the Chai Tou Gang Shi.

The recommendations that follow can be implemented in both the demonstration project area and the entire reach of the Chai Tou Gang Shi. Dollar amounts noted are in year 2001 US dollars, unless otherwise specified.

APPLICATION OF SUSTAINABLE DEVELOPMENT GUIDELINES

Environment

1. Support Clean Atmosphere, Water, Land, and Marine Resources

Sustainable Alternative Strategies:

a. Separate and isolate sewer effluent from storm drainage in surrounding areas. This removal of the sanitary sewage flow from the river is critical to all other improvements. This can be accomplished by constructing a single sanitary sewer main under the river channel. To avoid costly duplication, this single line could be jointly owned, used and maintained by both Tainan City and Tainan County.
(see CTGS - Conceptual Design Information Illustrations 2-4 : Site Sections A-C)

b. Take sewage to new Wastewater Treatment Plant (WWTP). This could be the new plant currently completing construction on the eastern boundary of Tainan City (WWTP #3), or a new proposed plant in Tainan County, just east of the confluence of the Chai Tou Gang Shi and Yen Shui Shi.

c. Direct clean effluent from WWTP #3 to create the base flow for Chai Tou Gang Shi. This clean water would flow year-round, helping to turn the sewage channel into an attractive stream for people and wildlife.
(see CTGS - Conceptual Design Information Illustration 1 : Demonstration Area Conceptual Plan)

d. Prevent soil erosion on the riverbank using bioengineered bank treatments, geotechnical stabilization fabrics, terracing, and extensive vegetation to prevent increasing the turbidity of the water in the channel.
(see CTGS - Conceptual Design Information Illustrations 2-4 : Site Sections A-C ; and Reference 13 : "Streambank and Shoreline Erosion Management Measures")

(Cost: $1,500-2,500/linear meter)

e. Capture and treat stormwater runoff before it enters the river with biological filtration swales and underground filter systems. It is important that stormwater runoff be intercepted prior to entering the channel using either biological filtration swales or mechanical filtration systems.
(see CTGS - Conceptual Design Information Reference 7 : "Technology Assessment Report - Stormceptor")

(Cost: $5,000-25,000, depending on size, capacity & land ownership)

d. Encourage walking instead of scooters with a beautiful riverwalk connecting key areas. Much of the pollution carried into the rivers comes from the poor air quality of Tainan. By encouraging alternative methods of transportation such as walking, biking and mass transit, scooters—which account for the vast majority of air pollution in Tainan—would be reduced.

2. Protect and Restore Ecosystems

Sustainable Alternative Strategies:

a. Recreate a native riparian (streamside) plant community along the river. Tainan is a subtropical area that supports a broad diversity of plant species. To provide the most beneficial habitat possible, the greatest likelihood of success and the least amount of ongoing maintenance required, only native plants should be used.

(Cost: $75-200/tree installed)

The following trees are native to Taiwan, suitable for the Chai Tou Gang Shi project in Tainan, and are generally commercially available.

Botanical Name	Common Name
Acacia confusa	
Acer serrulatum	
Alnus formosana or Alnus japonica	*Formosan Alder*
Alstonia sholaris	
Ampelopsis brevipedunculata	
Bischofia javanica	*Autumn Maple Tree*
Casuarina equistifolia	
Cinnamomum camphora	*Camphor Tree*
Ficus fistulosa	*Common Yellow-Stem Fig*
Ficus stipulosa	
Garcinia subelliptica	*Common Garcinia*
Idesia polycarpa	*Many Seed Idesia*
Machilus kusanoi	
Machilus zuihoensis var. zuihoensis	
Planchonella obovata	*Pouteria*
Pongamia pinnata	
Prunus phaeosticta	*Dark-Spotted Cherry*
Sapium discolor	*Taiwan Tallow-Tree*
Trema orientalis	*Indiacharcal Trema*
Viburnum luzonicum	
Viburnum odortissimum	

b. Protect and preserve undeveloped lowland floodplains. These areas are critical to help reduce flooding during infrequent floods and are a source of extremely valuable open space for residents and habitat for wildlife.

(No direct cost unless land must be purchased)

c. Preserve and maintain meandering character of stream course. Straightening a stream channel and making the banks "smooth" was once thought to decrease the likelihood of flooding by moving water quickly through an area. However, research has shown that to recharge aquifers below the surface and to minimize the damage to downstream riverbanks that high velocity flows cause, a natural meandering stream channel is preferable.[1] This creates large flood storage areas, excellent habitat, and open space.
(see CTGS - Conceptual Design Information Illustration 1 : Demonstration Area Conceptual Plan)

(Cost: significantly less per linear meter than a straight, concrete-lined channel)

d. Strive to develop a greenbelt that extends 20-25 meters beyond top of bank. There is a real potential to make the Chai Tou Gang Shi a major ecological corridor, connecting people and wildlife. However, to benefit both, the "greening" of the river cannot end at the top of bank. It should be extended into the urban fabric by use of a parkway or linear park. This civic amenity will have the collateral benefit of increasing property values along the river frontage.

(Cost: $1,500-2,500/linear meter)

3. Protect and Restore Biological Diversity

Sustainable Alternative Strategies:

a. Utilize only plants that are native to the Tainan area, as these plants are the most likely to support indigenous fauna. With assistance from leading scientists, develop a list of the plant species that are most valuable for local and migratory wildlife. Create a plant nursery industry that can supply these plants for restoration projects in the area.

(No additional cost for native plants)

b. Install bird boxes and other artificial habitat structures to attract native and migratory bird species.

(Cost: $50-$100/box for construction and installation)

c. Create a dense and diverse forest overstory of trees with understory shrubs and groundcover. These plants should be grouped according to their natural

[1] *Cities and Natural Processes*, by Michael Hough, Routledge Publishing, New York, NY, 1995.

hydrologic associations, with differing plant communities at the bottom, midslope and top of the Chai Tou Gang Shi riverbank.

(Cost: $20-30 per square meter)

d. Prohibit use of toxic herbicides and pesticides along the corridor.

(No direct additional cost)

4. **Develop Resources Consistent with Prevention of Natural Disasters**

Sustainable Alternative Strategies:

a. Ensure all improvements below the 100-year-storm-event elevation can withstand periodic flooding. Improvements appropriate in the lower channel area include the Greenbelt trail, water access points, overlooks and planted areas. All these improvements should be designed to withstand inundation.
(see CTGS - Conceptual Design Information Illustration 1 : Demonstration Area Conceptual Plan)

(No direct additional cost)

b. Ensure floors of all buildings are above the 100-year flood elevation. This will prevent the economic and personal catastrophes that occur when residential areas are flooded. Structures can be designed with parking and storage areas under the 100-year elevation, with occupied floors above.
(see CTGS - Conceptual Design Information Illustration 3 : Site Section B)

(No direct additional cost)

c. Create a dense and diverse forest overstory of trees with understory shrubs and groundcover. These plants should be grouped according to their natural hydrologic associations, with differing plant communities at the bottom, midslope and top of the Chai Tou Gang Shi riverbank.
(see CTGS - Conceptual Design Information Illustration 3 : Site Section B)

(Cost included in 3c, above)

5. **Reduce Output of Greenhouse Gases**

Sustainable Alternative Strategies:

a. Save intact areas of significant native vegetation, and augment with an aggressive "greening" of the Chai Tou Gang Shi corridor.
(see CTGS - Conceptual Design Information Illustration 1 : Demonstration Area Conceptual Plan)

(No direct additional cost)

b. Reduce energy inputs by using materials containing recycled content and locally available, indigenous materials. Avoid extensive use of petroleum-based products.

(Cost not ascertainable)

APPLICATION OF SUSTAINABLE DEVELOPMENT GUIDELINES

Economy

1. Increase the Productivity of all Forms of Capital

Sustainable Alternative Strategies:

a. Convert the Chai Tou Gang Shi to a beautiful civic amenity, dramatically increasing the value of all properties in the area. This enhancement of the River will spur a major economic redevelopment along the corridor, with new residential, commercial and office uses finding the river to be a desirable location.
(see CTGS - Conceptual Design Information Reference 8 : "The Economic Benefit of Greenways")

(Cost: $750 to 1,000/linear meter)

b. Develop restoration-based industries as key contributors to the local economy. Examples include native plant nurseries, recycling collection, sorting and processing facilities, and restoration contractors.

(Cost not ascertainable)

2. Increase the Quality and Durability of Goods

Sustainable Alternative Strategies:

a. Utilize long-lasting materials such as stone, concrete, ceramic tile, brick, and metal for structures along the Greenbelt. Utilize renewable material such as wood in places where it can be replaced easily every 10 to 20 years.

(Cost not ascertainable)

3. Reduce, Recycle and Reuse Raw Materials

Sustainable Alternative Strategies:

a. Use indigenous Taiwanese construction materials such as stone, brick, wood, and block that are grown or manufactured locally. Establish a preference for renewable materials such as sustainably harvested wood.

(No direct additional cost)

b. Use construction materials that either contain recycled content, are being reused with minor processing, or can themselves be recycled in the future. Examples include reprocessed concrete or asphalt for paving or retaining wall systems, steel for structural members and railings that contain at least 50% recycled content, and wood members that have been salvaged from construction sites.
(see CTGS - Conceptual Design Information Reference 9 : "Characterization of Building-Related Construction and Demolition Debris in the United States"; and Reference 10 : "Recycled Aggregate" and "Asphalt Pavement Recycling")

(Cost not ascertainable)

4. **Reduce and Eliminate all Forms of Waste and Pollution**

Sustainable Alternative Strategies:

a. Create and follow a construction waste management plan. Plans for construction should strive to eliminate waste through use of standardized building material dimensions. During construction, measures should be implemented to educate construction contractors, eliminate off-site erosion, rigorously control use and disposal of hazardous materials, and sort construction waste for reprocessing. An on-site construction manager, preferably a city employee, should monitor the plan carefully.
(see CTGS - Conceptual Design Information Reference 11 : "Lumber Waste" and "Urban Wood Waste")

(No direct additional cost)

5. **Apply Science and Technology to Problems**

Sustainable Alternative Strategies:

a. Intercept surface stormwater runoff before it enters the Chai Tou Gang Shi. Use inground stormwater filtration systems that remove sediments, petrochemicals, and other compounds that degrade water quality.
(see CTGS - Conceptual Design Information Reference 7 : "Technology Assessment Report - Stormceptor")

(No direct additional cost)

b. Utilize latest innovations in bio-engineering design and construction materials to provide stable riverbanks that can support native riparian forest on the banks. These materials include geotechnical fabrics, modular retaining wall systems, reusable modular paving systems, and erosion control materials.
(see CTGS - Conceptual Design Information Illustrations 2-4 : Site Sections A-C; and Reference 12 : "Bioengineering for Hillslope, Streambank and Lakeshore Erosion Control")

(Cost: $1,500-2,500/linear meter)

6. **Develop Transportation and Energy Supply Systems Consistent with Sustainable Development Guidelines**

Sustainable Alternative Strategies:

a. By creating a greenbelt trail system, encourage pedestrian and bicycle circulation along the river as an alternative to vehicles. By encouraging a diversity of development along the corridor, including commercial, office and residential development, the greenbelt will function as an important circulation corridor.

(No direct additional cost)

APPLICATION OF SUSTAINABLE DEVELOPMENT GUIDELINES

Community

1. **Provide Clean Air, Water and Food**

Sustainable Alternative Strategies:

a. Establish Chai Tou Gang Shi Greenbelt with dense broadleaf trees to assist in CO_2 abatement.

(Cost: $75-200/tree installed)

b. Create a network of public "community gardens" in floodplain areas along the CTGS corridor for residents to grow vegetables and fruit in individual plots for their own consumption.

(Cost: $250/plot for city to administer and mark)

2. **Provide a Safe, Clean and Beautiful Community Living Environment**

Sustainable Alternative Strategies:

a. Create a unified Park District for the CTGS Greenbelt, supported by Tainan City and County for the ongoing operations and maintenance of the park.

(No direct additional cost)

b. Create a maintenance and management plan for the CTGS Greenbelt. This cooperative venture between Tainan City and County will form the basis for the Greenbelt to be recognized as a community park for the surrounding neighborhoods.

(Cost: $1500 for city & county administrative time)

c. Ensure there are access/egress points along the Greenbelt trail at least every 100 meters. This will ensure that neighborhoods are linked physically with the trail and river, and will build a citizen constituency for the future.

(Cost not ascertainable)

d. Select plant materials that provide for seasonal variation in flower, fruit and foliage color.

(No direct additional cost)

3. **Protect and Enhance the Arts, Culture and Historic Resources**

Sustainable Alternative Strategies:

a. Integrate public art into the Greenbelt trail. Art can be used as landmarks along the trail, serve to provide visual interest, and will form an important civic and tourist attraction as an "art walk" that displays significant works of art of Tainan City as the cultural center of Taiwan.

(Cost: allocate 1% of construction costs to public art installations)

b. Identify and interpret significant cultural and historical sites along the Chai Tou Gang Shi. Maps of the surrounding neighborhood could be very useful in helping trail users orient to their location and the attractions that are nearby.

(Cost: $5,000/porcelain enamel map design, fabrication and installation)

4. **Provide Public Education on Sustainable Development**

Sustainable Alternative Strategies:

a. Create environmental education and interpretive exhibits along the trail that explain ecological processes in the Chai Tou Gang Shi. These should discuss the plants, wildlife, and hydrology of the Chai Tou Gang Shi watershed.

(Cost: $5,000/porcelain enamel interpretive sign design, fabrication and installation)

b. Create "before" and "after" interpretive exhibits so people can see and appreciate the investment and changes along the Chai Tou Gang Shi.

(Cost: $5,000/porcelain enamel interpretive sign design, fabrication and installation)

5. **Promote Cooperation among Levels of Government and Globally**

Sustainable Alternative Strategies:

a. Tainan City and County create a memorandum of agreement to jointly fund the design, construction and maintenance of CTGS and sanitary sewer improvements.

(Cost: $1,500 for city & county administrative time)

TABLE V-1
CHAI TOU GANG SHI
Application of Sustainable Development Guidelines

	Environment	Strategies	Sustain-ability Priority
1	Support clean atmosphere, water, land, and marine resources	a. Separate and isolate sewer from storm drainage in surrounding areas	1
		b. Take sewage to new Waste Water Treatment Plant	2
		c. Direct clean effluent from WWTP #3 to create the base flow for Chai Tou Gang Shi	1
		d. Prevent soil erosion on riverbank	2
		e. Capture and treat stormwater runoff before it enters CTGS with biofiltration swales and underground filter systems	1
		f. Encourage walking instead of scooters with beautiful riverwalk connecting key areas	3
2	Avoid habitat destruction	N/A	
3	Protect and restore ecosystems	a. Recreate native riparian (streamside) plant community along CTGS	2
		b. Protect and preserve undeveloped lowland floodplain areas	1
		c. Preserve and maintain meandering character of stream course	1
		d. Strive to develop a greenbelt that extends 20-25 meters beyond top of bank	3
4	Protect and restore biological diversity	a. Utilize only plants that are native to the Tainan area	2
		b. Install bird boxes along Greenbelt for native species	3
		c. Create a dense and diverse forest overstory with understory shrubs and groundcover	1
		d. Prohibit use of herbicides and pesticides along the CTGS	3
5	Manage environment programs	N/A	
6	Develop resources consistent with prevention of natural disasters	a. Ensure all improvements below 100-year flood elevation can withstand periodic flooding	2
		b. Ensure floors of all buildings are higher than 100-year flood elevation	2
7	Reduce output of greenhouse gases	a. Save native ecosystems	2
		b. Reduce energy inputs	3

	Economy	Strategies	Sustain-ability Priority
1	Increase the productivity of all forms of capital	a. Convert CTGS to beautiful civic amenity, increasing value of all properties in the area b. Develop restoration-based industries as key contributors to the local economy	2 2
2	Increase the quality and durability of goods	a. Use long-lasting materials such as stone, concrete and metal	2
3	Reduce, recycle and, reuse raw materials	a. Use indigenous Taiwanese construction material b. Use recycled construction materials	2 2
4	Substitute embodied and solar energy for produced energy	N/A	1
5	Reduce and eliminate all forms of waste and pollution	a. Create and follow a construction waste management plan	1
6	Apply science and technology to problems	a. Use in-ground stormwater filtration systems b. Use bio-engineered riverbank solutions	1 1
7	Develop transportation and energy supply systems consistent with SD	a. By creating Greenbelt trail system, encourage pedestrian and bicycle circulation along CTGS as alternative to vehicles	2
8	Substitute non-toxic and biodegradable substances for toxic substances	N/A	
9	Review/revise tax, capital investment, and regulatory policies to increase SD and eliminate subsidies for non-SD	N/A	
10	Use life cycle cost analysis in procurement decisions	N/A	

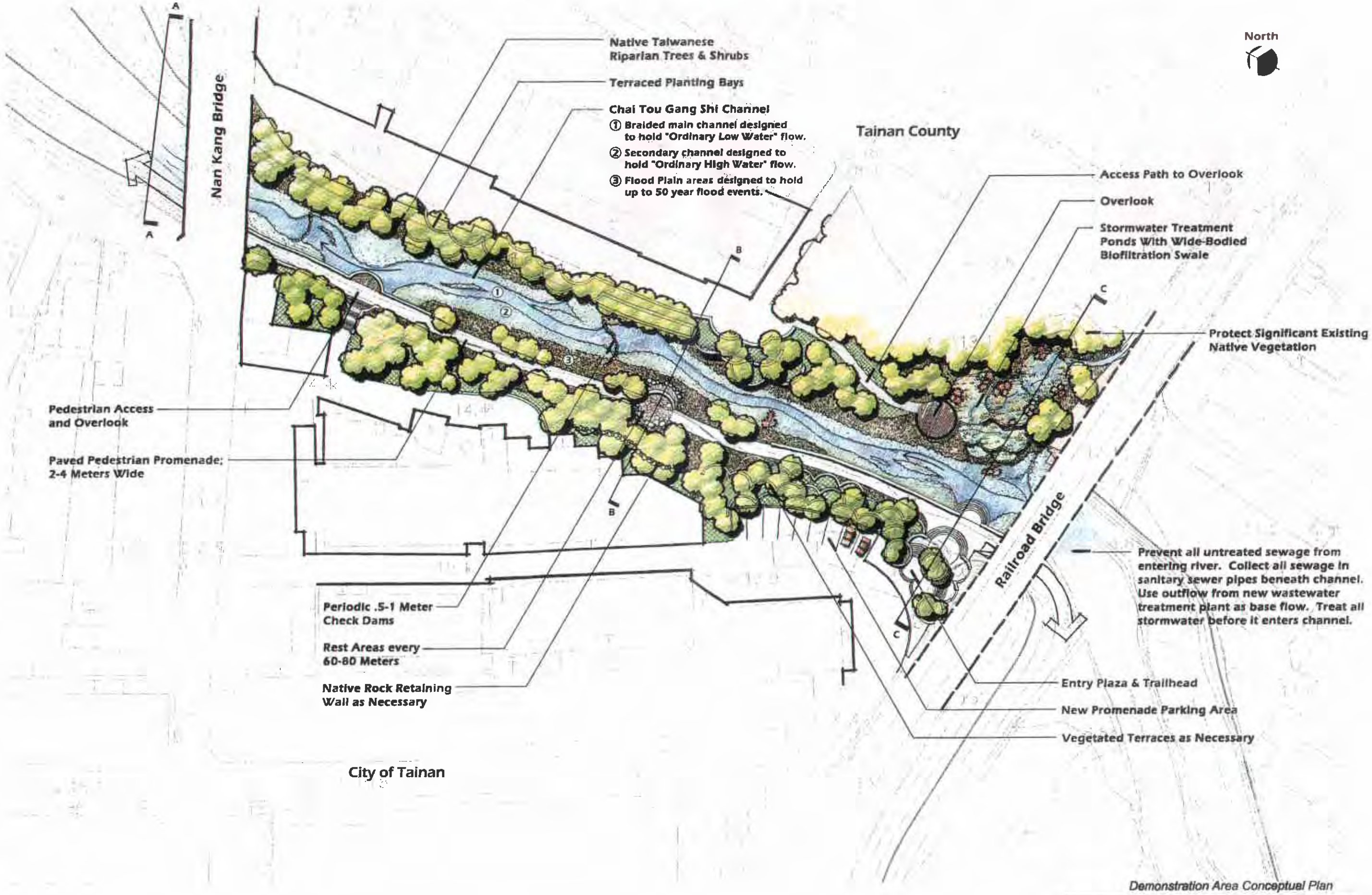
	Community	Strategies	Sustain-ability Priority
1	Provide clean air, water, and food	a. Establish Greenbelt with dense broadleaf trees to assist in CO_2 abatement b. Create a network of public "community gardens" in floodplain areas	1 2
2	Provide clean & safe shelter	N/A	
3	Provide a safe, clean, and beautiful community living environment	a. Create a unified CTGS Greenbelt park district, supported by Tainan City and County for operation and maintenance b. Create a maintenance and management plan for CTGS Greenbelt c. Ensure access/egress points along Greenbelt trail at least every 100 meters d. Select plant materials that provide for seasonal variation in flower, foliage color, etc.	1 2 2 1
4	Protect and enhance the arts and cultural and historic resources	a. Integrate public art into the Greenbelt trail b. Identify and interpret significant cultural and historical sites along the CTGS	2 2
5	Provide public education on sustainable development	a. Create environmental education and interpretive exhibits that explain ecological processes in CTGS b. Create "before" and "after" interpretive signs so people can see and appreciate the change	1 1
6	Promote public involvement in decisions	N/A	
7	Provide collaborative, community-based decision-making with public, private, NGO participants	N/A	
8	Promote cooperation among levels of government and globally	a. Tainan County and City create a memorandum of agreement to jointly fund the design, construction and maintenance of CTGS sanitary sewer improvements	1
9	Provide access to information on decisions	N/A	
10	Undertake social and economic impact analysis of major decisions	N/A	

Illustrations

Demonstration Area Conceptual Plan
Site Section A
Site Section B
Site Section C

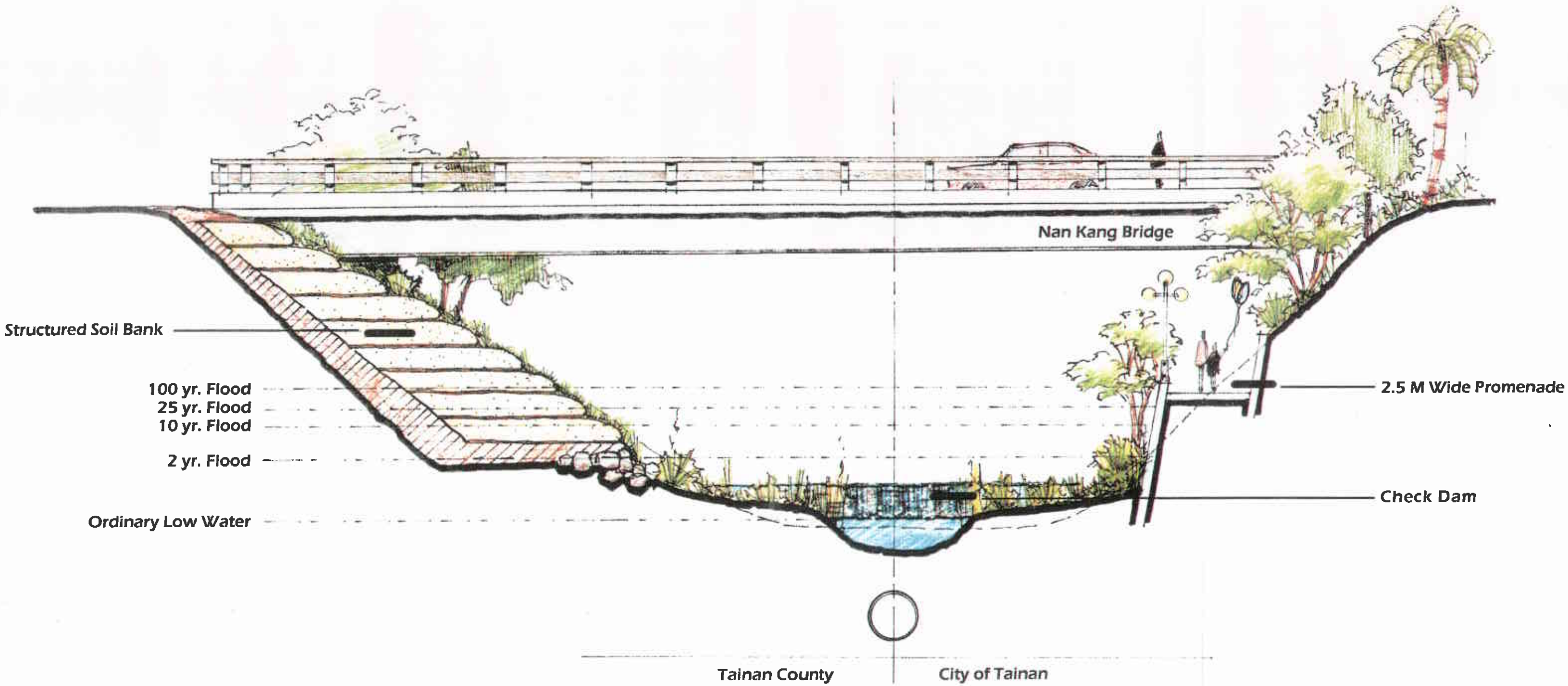
Exhibits

V-1 The Los Angeles River: Reshaping the Urban Landscape
V-2 An Alternative Flood Control
V-3 Technology Assessment Report – Stormceptor
V-4 Excerpt from "The Economic Benefit of Greenways"
V-5 Excerpt from "Characterization of Building-Related Construction and Demolition Debris in the United States"
V-6 Recycled Aggregate and Asphalt Pavement Recycling
V-7 Lumber Waste and Urban Wood Waste
V-8 Bioengineering for Hillslope, Streambank and Lakeshore Erosion Control
V-9 Streambank and Shoreline Erosion Management Measure



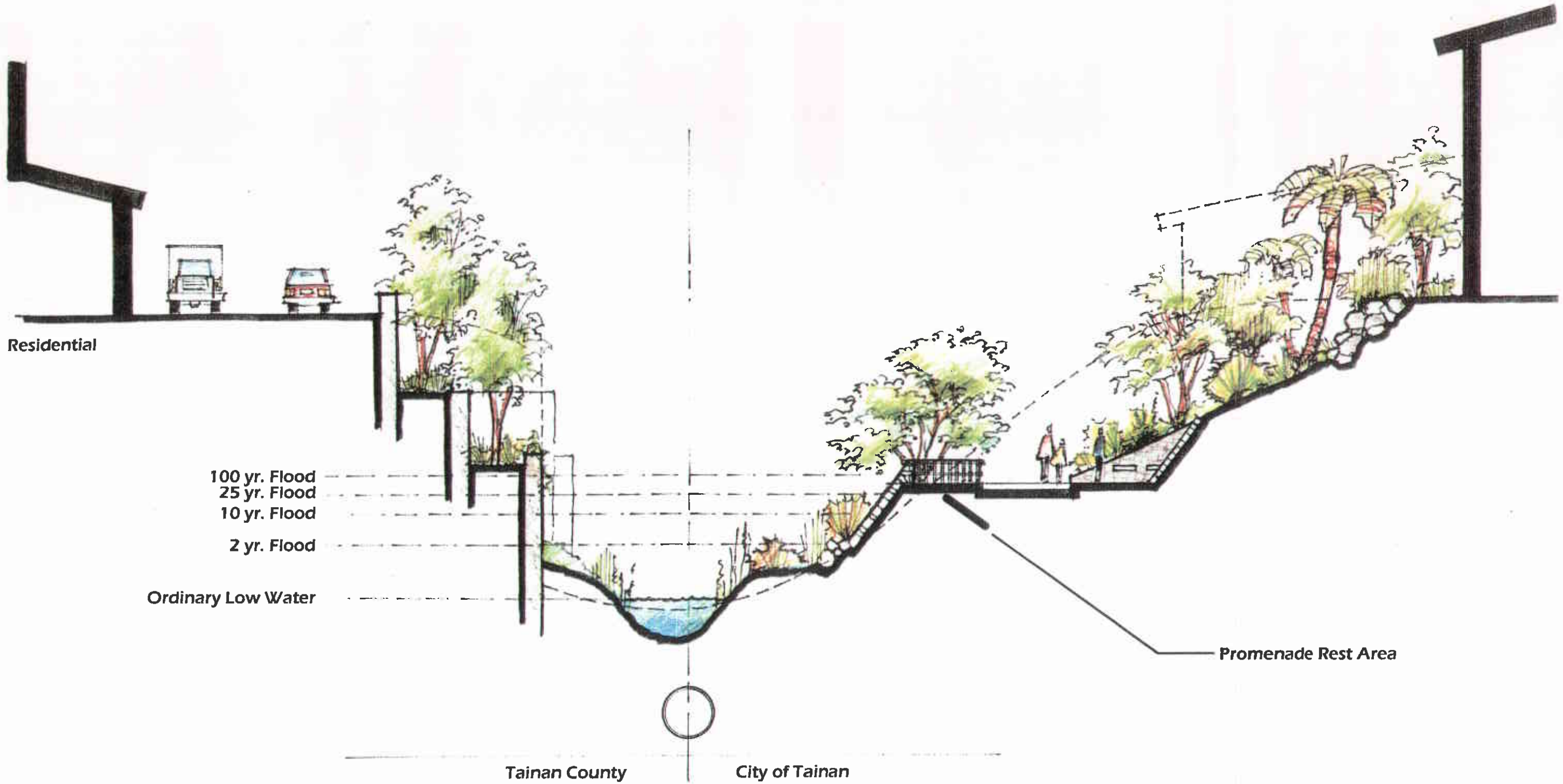
Demonstration Area Conceptual Plan

July 30, 2001 *Illustration 1*



Site Section A

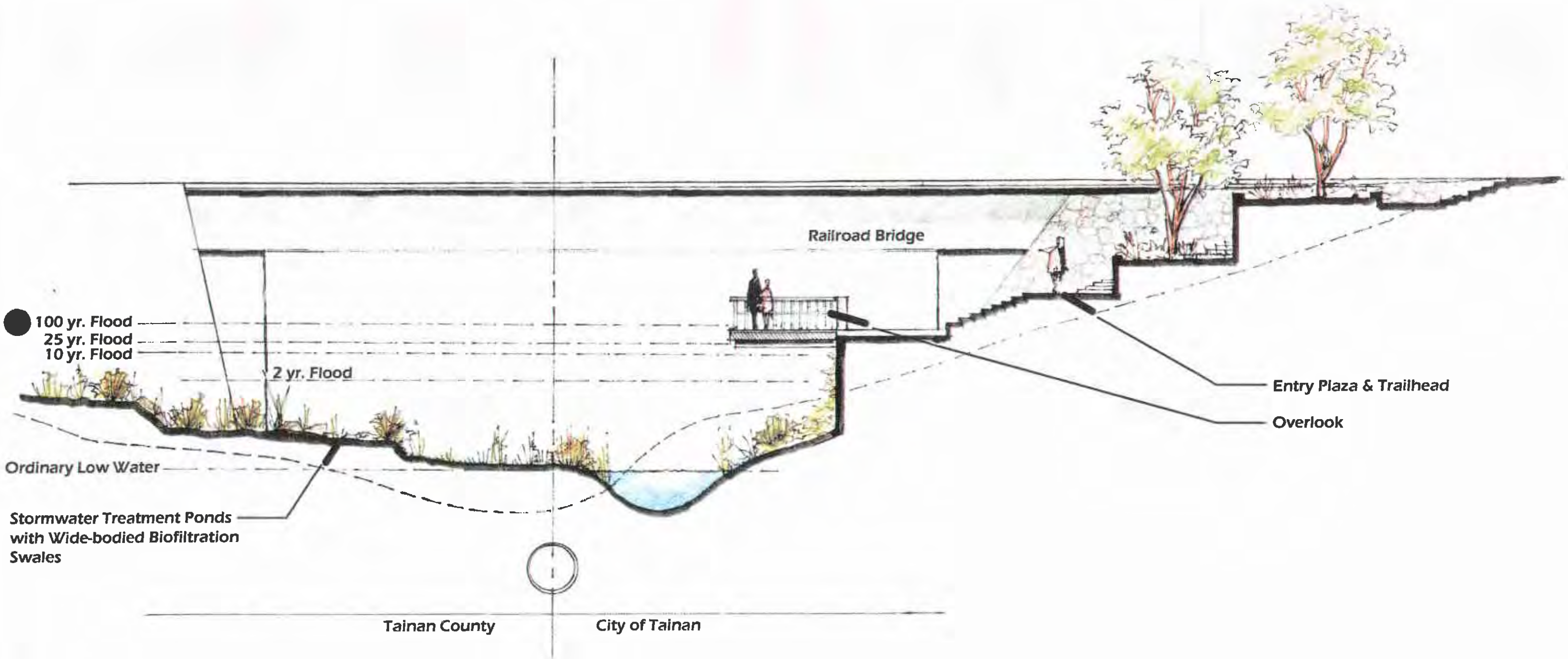
July 30, 2001 *Illustration 2*



Site Section B

July 30, 2001

Illustration 3



Site Section C

July 30, 2001

Illustration 4

[Los Angeles River Connection]

EXHIBIT V-1

The Los Angeles River: Reshaping the Urban Landscape

By Arthur Golding, Chair of the Los Angeles River Task Force of the American Institute of Architects, Los Angeles Chapter

When the Los Angeles pueblo was founded in 1781, the mountains, the river and the shore formed the landscape. Today, extended grids of streets and a superimposed network of freeways cover the lowlands of basin and valleys. Punctuated by periodic clusters of tall buildings and seen against the mountains and shoreline, they define the urban landscape of Los Angeles, providing occasional landmarks and the structural underpinnings of the city's identifiable neighborhood places.

Only the river is invisible, reduced to concrete-lined drainage channels, denuded of its riparian vegetation, bounded by rail lines, hidden behind industrial plants and beneath freeways. We are abruptly reminded of the river's extent and significance every few years when a storm leads to a loss of life in the swift-moving brown waters of its channels, but in our everyday perceptions the river no longer plays a role.

Downtown Los Angeles owes its seemingly haphazard location to the river, on which it has long turned its back. Following Native American precedent, the

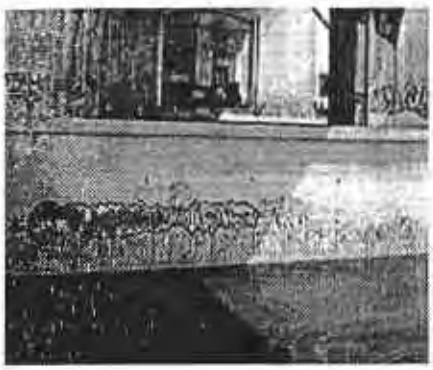
pueblo was located adjacent to the river, well below the big bend where the water, flowing eastward through the valley, swung wide as it curved southward around what is now Griffith Park. It was sighted below the seasonally turbulent confluence with the Arroyo Seco, in an area easily forded, well above the marshes (las cienegas) that stretched inland from the sea. For an agricultural settlement the location was ideal, and the river served as the principal source of water for pueblo and growing city until the opening of Mulholland's aqueduct in 1913.

With the selection of San Pedro as the site for the city's harbor in 1899, rail lines were needed to connect the city to its port, and the river provided a direct route with minimum grade change. Industry followed, and after repeated floods, so did flood control. Never navigable, already a back rather than a front, the river was finally reduced to a storm drain system, little more than concrete plumbing.

Following the railroads and similarly attracted by the level grades, freeways were built along and sometimes over the Los Angeles River system. The Arroyo Parkway, in 1938

"The Corps' ill-conceived solution to this flood hazard now proposes adding 21 miles of two to eight foot high concrete walls atop the levees from the Rio Hondo southward to the river's mouth...at a cost of some $280 million."

the first freeway, with its native California sycamores and its chain of parks along the Arroyo Seco channel, might have established a precedent that combined roadway, parks, and desirable frontage for residential and commercial development. It could also have accommodated alternative flood control and channel design strategies, but by 1960, when the Pasadena /Golden State Freeway interchange was



constructed, obliterating the confluence of the Arroyo Seco and the Los Angeles River, and the freeway severed Griffith Park from the river, even the memory of a living river system was gone. The Golden State (5), Long Beach (710) and San Gabriel River Angeles River (605) freeways were all developed without sensitivity to or mitigation of the riparian environment.

The Los Angeles River today is a relic of the physical, economic and intellectual landscape of the 1930's that shaped it. The river was channelized to control flooding by means of a great engineering and public works project begun in 1938. Mountain runoff was captured at a series of dams and flood control basms, with excess water carried swiftly to the ocean in concrete channels. Large, heavy industrial plants backed up to the river and its flanking rail lines.

In the years since the river was paved, every condition of the 1930's landscape has changed, save only the Southern California pattern of rainfall. Rain still concentrates most often in the mountains, but unanticipated downstream runoff from the great increase in built and paved areas of the San Fernando Valley and LA basin, reducing percolation and accelerating the flow to the river, is the new cause of flood danger. Improved weather data, too, suggest that the engineers of the 1930's may have underestimated the magnitude of storms.

Now the constructed river is obsolete and on its lower reaches, according to the Corps of Engineers, it is an accident waiting to happen. The channel is too small for the enormous and very rapid urban runoff projected in a major storm. The Corps' ill-conceived solution to this flood hazard now proposes adding 21 miles of two to eight foot high concrete walls atop the levees from the Rio Hondo southward to the river's mouth, modifying some 25 bridges, armoring the backs of levees and other "improvements" at a cost of some $280 million. Alternative flood control strategies, the Corps asserts, would not be cost-effective,

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"Friends of the Los Angeles River (FoLAR)) and Unpave LA, a coalition of environmental groups, have been advocating restoration of the river, creation of a wildlife corridor from the mountains to the sea and a radical change in the way we deal with rainwater on individual properties."

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but critics question the outmoded single-purpose planning and cost modeling the Corps employs.

The Corps proposes to treat the symptom (channel -capacity) rather than the cause (urban runoff). We ought instead to recognize that the flood hazard presents the necessity for change and with it an opportunity to rethink the river and to reform our regional approach to storm water management.

The urban flood hazard attending the unprecedented extent and density of development is only one of the new, conditions along the river. Heavy industry is gone. Auto and tire plants, closed as part of the worldwide realignment of industrial production and distribution, will not return. Many large sites are underutilized or vacant. The Alameda Corridor project is being designed to move, nonstop freight trains through, not to serve, the lower LA River area. Railyards like Taylor Yard on the river opposite Elysian Park or the Cornfields in the City North area are now for sale. Much of the rail right-of-way along the river has recently been acquired by the transit agency, MTA.

Population has continued to grow along the river corridor. Recent immigrants are crowded into neighborhoods once occupied by the workers at the defunct plants. Continuing densification increases the need for public open space and recreational facilities in a city already severely underserved.

Taken together, these changed conditions present an opportunity to rethink and revitalize the river, to reverse and remediate our approach to storm water management, to begin to use public policy and public investment to improve both the physical and the economic environment rather than to perpetuate the myopic engineering of the 1930's.

Several public agencies and nonprofits have begun the process. In a January 1992 report the Mayor's Los Angeles River Task Force called attention to the potential of a revitalized river. While its 11 goals, including meeting flood control needs, restoring the river's natural ecosystem wherever possible and maximizing public uses and recreation opportunities along the river, were endorsed by then-Mayor Bradley, its three proposed demonstration projects remain unrealized. The only tangible result of the effort to date are a few blue signs on city bridges identifying the river.

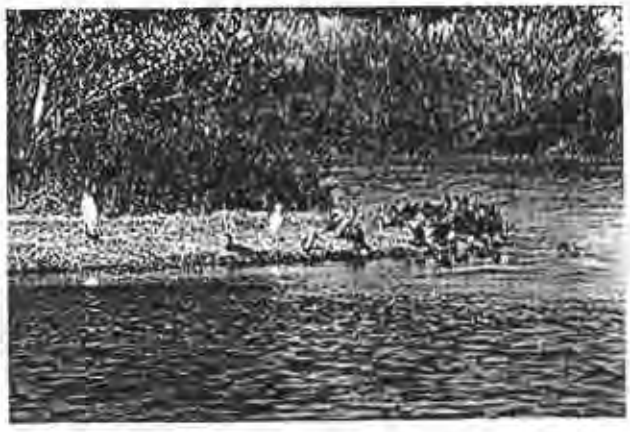
Presently, as part of the current General Plan Framework effort, the Department of City Planning and its consultant team are proposing a series of "Natural System and Open Space Connections." The proposal includes watershed management, incorporation of the river into a City-wide regional open space network, protection of riverside rights-of-way and improvements for public access.

The Los Angeles County Departments of Public Works, Parks and Recreation, and Regional Planning are engaged in preparing a "Master Plan" for the river. Although it does not deal with the entire river system the County's planning process, under way for over two years, has included representatives of 13 cities and various agencies, environmental and community groups. Goals of the plan include: improving river aesthetics, promoting economic development, preserving and restoring environmental resources, meeting flood control needs, involving public participation, coordinating among jurisdictions, and providing a variety of recreational opportunities.

"To deny the river is to deny the origin of the city. To rethink the river is to discover a unique opportunity to define urban places, join neighborhoods and communities together and reconnect us to our landscape and our history.

The County's success in bringing most of the interested jurisdictions together and initiating conversations about the river and its future is tempered by its timidity in dealing with any potential controversy. Jurisdictional turf is sacrosanct, governance is not a subject, nothing requiring significant expenditures is discussed and the Corps' flood control plan is taken as a given. The County's plan threatens to come out in full support of motherhood and apple pie, but the staff has produced very valuable mapping and analysis of land use, ownership, jurisdictions, vacancy and other data essential for any future planning efforts.

Friends of the Los Angeles River (FoLAR) and



Unpave LA, a coalition of environmental groups, have been advocating restoration of the river, creation of a wildlife corridor from the mountains to the sea and a radical change in the way we deal with rainwater on individual properties.

The Mountains Recreation and Conservation Authority, a new player in the river drama, has a powerful State mandate to connect Elysian and Griffith Parks to the mountains. With an initial budget of $1,000,000, MRCA is evaluating the acquisition of properties to create parks and trails along the river between the two large parks. (See the article by Ester Feldman in the April '94 TPR).

The California Coastal Conservancy, a state agency, published its Los Angeles River Park and Recreation Study in 1993, identifying potential projects along the river. This past November, Unpave LA sponsored a well attended conference, Rethinking the River, to promote discussion of LA River management options. The flood control hazard and the Corps' proposal are reason enough to look seriously at the river. The economic development potential of a revitalized river corridor, accommodating miles of frontage for residential and commercial development together with active and passive recreation and a renewed riparian habitat, is even more significant. Though it is no longer a principal source of water sustaining the city, a living river would be an emblem of responsible water management in a dry climate and a symbol of sustainable development. To deny the river is to deny the origin of the city. To rethink the river is to discover a unique opportunity to define urban places, join neighborhoods and communities together and reconnect us to our landscape and our history.*

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HTML by Cameron London

An Alternative for Flood Control

By Mary Losure
May 17, 1999

The Red River between Minnesota and North Dakota flows north into Canada through what was once a vast wetland. For generations, farmers in the valley built dams and straightened rivers to protect their land from flooding. Now, such flood control projects are languishing, unable to get permits or funding. Environmental groups and government agencies are trying to convince farmers to try new, more environmentally friendly tactics in their decades-long battle against water.

IN ITS CONSTRUCTION HEYDAY in the '40's, '50's and '60's, the Army Corps of Engineers and other agencies built hundreds of dams on Minnesota tributaries of the Red River. In later years, local farmers built dozens more. But that era is over now. In 1993 the corps suspended the permits for 33 new dams on the Minnesota side of valley, citing concern over possible environmental problems. Projects like the Winger dam were what triggered the moratorium.

> **Wilkins:** Now this would have backed the water up six miles, and I can take you up we'll go up to the other end.

Dan Wilkins stands on the highway at the site of the dam, which was planned for the Sand Hill River near the small town of Winger. It would have flooded a valley in otherwise level farmland, creating a reservoir to hold storm water and protect downstream farmland from flooding. Local supporters said it would have recreational benefits as well - motorboating and lakeshore cabins. Dan Wilkens, a farmer who directs the local board that oversees flood control projects, says everyone in the area jumped at the prospect.

> **Wilkins:** Like I said, I think it was the local lions club went out and in no time had like, 23 out of the 26 landowners signed up. It was really...I thought it was kind of neat.

In an earlier era, the town of Winger would likely have gotten its dam - but by today's federal and state environmental standards, it was a non-starter. It would have drowned more than 700 acres of wetlands. The reservoir would have been polluted with sediment, farm chemicals and algae. Army Corps of Engineers studies showed despite its $5 million price tag, the dam would have provided only local flood-control benefits, not protection for downstream cities.

The benefits of the other 32 dam projects whose permits were suspended by the Corps are equally doubtful. According to the Corps own studies, all the projects together would have lowered the peak flood stage on the Red River by a total of less than one inch.

In the minds of people like Luther Aadland, a research scientist with the Minnesota department of Natural Resources at Fergus Falls, it was time to try something new; flood

control, he says, would benefit, not damage, the environment.

> **Aadland:** One of the approaches we've been advocating is restoring rivers as a flood damage reduction strategy.

The Red River Valley has thousands of miles of rivers that are candidates for restoration. They've been dug out and straightened in the name of flood control. A section of the Ottertail River on the south end of the Valley not far from Aadland's office is a typical example. In stark contrast to the curving, willow-lined stream above and below it, this stretch of the river is a straight, treeless ditch. The water is muddy and there are few fish.

> **Aadland:** It really is sickening for a stream. In terms of species, for a tributary, this is probably the most diverse rivers in the red river basin, by far. But you won't find that diversity in stretches like this.

Aadland says restoring the stream's natural curves would slow it down and allow it to hold water on the land longer, so water from storms wouldn't rush straight through and flood people downstream. He and others are also advocating restoring drained wetlands, so they too can hold water back on the land.

But for many, such "green" methods of flood control will be a tough sell. Don Oogaard is a 72-year-old retired farmer who heads the Red River Watershed Management Board, which oversees all the flood control projects on the Minnesota side of the Red River valley. Oogaard has been winning dams for farmers for half a century. He began his lifelong crusade after he saw his father's crops drowned out, for seven years in a row.

> **Oogaard:** I saw my father destroyed by excess water. His spirit was destroyed, he had no desire to continue farming because of that.

In his home office in the tiny farm town of Ada, Oogard shows slides of aerial photos taken during flood years. They show the Red River Valley awash in water--crops drowned, roads swept away, the roofs of barns and houses protruding above what looks like a vast lake. Then he shows a section of the valley now protected by conventional means of flood control.

> **Oogaard:** This area was flooded 35 times in 30 years prior to 1979. In 1979 we put a series of large channels in the area, and two dams upstream, and they've only had two floods since, and that's the spring of '96 and '97, otherwise no summer floods, and [before] they had continual [flooding]. It was the worst flooded area in the red river basin, with the highest damages.

Oogard says alternatives to dams and channeling are expensive and unproven and will only work in a few geographic areas. Even though dams projects are stalled for now, he believes traditional methods offer the ultimate solution to flooding in the valley.

Cheryl Miller of Minnesota's National Audobon Society disagrees. She says dams and channels face growing resistance not only from environmental groups, but from downstream

communities who have seen their own flooding problems worsen.

> **Miller:** I think that the floods here in the Midwest in the last ten years have convinced more people that we've got a real problem here, that the way we're managing these watersheds is not working. That we might have been able to do this for awhile, but cumulatively all of the different decisions that we've made over time, particularly in a wet cycle like we've been having, the system is broken.

After the disastrous Red River floods of 1997, the state of Minnesota called in mediators to break the stalemate between dam opponents and supporters. Late last year, all sides of the flood control dispute signed a non-binding agreement, saying new projects must show net benefits for the environment.

The first pilot projects are on the drawing boards, but whether they are built will depend on whether local farmers in each place the projects are proposed are willing to accept them.

Lowell Dyrud's family has farmed in the Red River Valley since 1886. He supports new methods of flood control, but understands how hard it is for many of his neighbors.

> **Dyrud:** When you think about it, for over 100 years there's been the feeling of 'cut your ditches, gouge the land, and flood downstream and once the water is out of my land, it really doesn't matter what happens below it.' That is changing it I think. This is a new era and I think people are more receptive now than they have been in the past, but it is a hard mindset to change.

In Dyruds area near Fergus Falls, farmers face a stark choice between the flood control methods of the past, and what environmentalists hope will be those of the future. Some farmers along the Thief River want to make a stretch of it into a drainage ditch - to clean out all the trees and stream-side vegetation and create straight pipe to take water off their land. Environmental groups and the state of Minnesota are asking the farmers to consider alternatives, such as storing excess water in restored wetlands upstream. So far, the jury is still out, but it's the kind of decision that will likely be repeated in sites across the valley and shape the land for years to come.

Major funding for Minnesota Public Radio's regional Internet activities is provided by the Corporation for Public Broadcasting.

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EXHIBIT V-3

Technology Assessment Report

Stormceptor®

CSR™ New England Pipe

Prepared for
The Massachusetts Strategic
Envirotechnology Partnership
STEP

December, 1997

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The University Of Massachusetts and The Massachusetts Division of Energy Resources

PREFACE

The STEP technology assessment process is designed to identify those technologies that will support the economic and environmental/energy goals of the Commonwealth of Massachusetts and may benefit from STEP assistance. The process is meant to be one of screening, in which technologies are evaluated by independent technical specialists. Recommendation from this process does not constitute an endorsement of the technology or of the absolute validity of the technology. Rather, STEP technical assessments attest only that, through the screening process, the reviewers feel there may be benefit to the Commonwealth of Massachusetts.

EXECUTIVE SUMMARY

The technology described in this review is Storm*ceptor*® and is currently owned by Storm*ceptor*® Corporation and licensed to CSR/New England Pipe (CSR/NEP) of Wauregan, CT, for distribution in Massachusetts, among other states. The system is being commercialized by CSR/NEP. The Storm*ceptor* technology addresses treatment of stormwater runoff. It is proposed as an effective spill control and stormwater quality enhancement system, capable of retaining grit, suspended solids, oils and grease during periods of both low and high flows. It is proposed as a replacement for conventional manholes within a storm drain system. It is not designed as a catch basin or detention system. It can be used within any new or existing lateral piped conveyance system and comes in several sizes with outlets up to 60". The system is claimed as capable of removing 50 - 80% of TSS when properly sized. The Storm*ceptor* system is recommended as a stand alone or as a component to a system or in combination with different BMPs. An example configuration may include the following components: catch basin or water quality inlet, Storm*ceptor*, detention basin or infiltration system.

The system is a prefabricated well type structure which provides sedimentation, oil, and grease separation. It is manufactured in both concrete or fiberglass. Current sizes range from 900 to 7200 gallons, with diameters between 6 and 12 feet. The design of the system provides two sections, a treatment chamber and bypass chamber. The structural components of the system are separated by an insert which has a weir, inflow drop pipe, and outflow riser. Operation of the system is passive with respect to flow control and treatment. During low flows or frequent storm events, stormwater from the inlet is directed down the inflow drop pipe located adjacent to the inlet of the treatment chamber. Flow in excess of the inflow drop pipe capacity is directed into the bypass chamber to the outlet of the system. The effective treatment capacity is set by a weir which surrounds the inflow drop pipe at the inlet and the volume of the treatment chamber. Effluent from the treatment chamber exits via the outflow riser which extends below the water surface in the treatment chamber up to the overflow chamber and to the system outlet. Sediment is retained in the bottom of the treatment chamber and oils and grease are retained at the top of the treatment chamber in a quiescent area.

The Storm*ceptor* system is stormwater treatment structure providing event based solids separation. The value added in the Storm*ceptor* system is the ability to reduce turbulence in the treatment chamber, which makes it better at removing TSS and TPH than conventional BMPs of the same category. The Storm*ceptor* system has been demonstrated to provide at least 52% removal of TSS when sized according to Storm*ceptor's* "Treatment Train" criteria and 77% when sized according to Storm*ceptor's* "Sensitive Area" criteria. It is likely that a higher removal efficiency, greater than 80%, could be expected if the contributing drainage area is smaller than the sizing recommended. The system is likely to remove grease and oils with its inflow and outflow pipe configurations. The Storm*ceptor* system appears to be a good control technology in areas of higher pollution potential, Standard 5 described in the Stormwater Management Handbooks (DEP and CZM, 1997). Storm*ceptor* system may be used as a component in combination with different BMPs or may be used as a stand alone installation provided it is sized for 80% TSS removal. STEP recommends collection of additional data representing a varied set of operating conditions over a realistic maintenance cycle to verify TSS removal rates greater than 80%.

HIGHLIGHTS

- Performance data available demonstrates that the Storm*ceptor* system can provide TSS removal rates of 77% when sized according to the "Sensitive Area" criteria. Evidence suggests that the Storm*ceptor* system may be capable of achieving TSS removal rates between 89% and 99% when sized accordingly, under conditions similar to those reported in the Westwood Massachusetts site, including: climate and land use intensity.
- Performance data available to this reviewer suggest that the Storm*ceptor* system can provide TSS removal rates of 52% when sized according to the "Treatment Train" criteria.
- Use of the Storm*ceptor* system as a pretreatment component in combination with different BMPs, when sized according to the "Treatment Train" criteria, will likely meet standards 4 and 6 of the Stormwater Management Handbooks (DEP and CZM,1997). Use as a stand alone device may be justified when sized according to the "Sensitive Area" criteria.
- The Storm*ceptor* system is likely to perform in areas with higher potential pollutant levels in Standard 5 of the Stormwater Management Handbooks (DEP and CZM,1997).
- The Storm*ceptor* system is useful for new and retrofit installations in Standard 7 of the Stormwater Management Handbooks (DEP and CZM,1997), especially where space is limited.
- The Storm*ceptor* system is also suited for secondary sediment control from construction related sediment loads specified in Standard 8 (DEP and CZM,1997).

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TECHNOLOGY PROPONENT

The technology described in this review is Storm*ceptor*® and is currently owned by Storm*ceptor*® Corporation and licensed to CSR/New England Pipe (CSR/NEP) of Wauregan, CT, for distribution in Massachusetts, among other states. The system is being commercialized by CSR/NEP. CSR/NEP is a subsidiary of CSR Hydro Conduit Corporation which manufactures Storm*ceptor* in the most of the United States.

TECHNOLOGY DESCRIPTION

The Storm*ceptor* technology addresses treatment of stormwater runoff. It is proposed as an effective spill control and stormwater quality enhancement system, capable of retaining grit, suspended solids, oils and grease during periods of both low and high flows. It is proposed as a replacement for conventional manholes within a storm drain system. It is not designed as an inlet or detention system. It can be used within any lateral piped conveyance system and comes in several sizes with outlets up to 60". The system is claimed as capable of removing 50 to 80% of TSS when properly sized. The Storm*ceptor* system may be used as a stand alone BMP or as a component within a combination of different BMPs. An example of a combination of different BMPs is a catch basin, Storm*ceptor,* and detention pond. It is compatible with any existing conveyance system. It is proposed that the system has an added value in its small size and its added removal capability over similar conventional BMPs such as catch basins and deep sumps. The system is currently protected by a United States Patent No. 4,985,148.

The system is a prefabricated well type structure which provides sedimentation, oil, and grease separation (Figure 1). It is manufactured in both concrete or fiberglass. Current sizes range from 900 to 7200 gallons, with diameters between 6 and 12 feet. The design of the system provides two sections, a treatment chamber and bypass chamber. The structural components of the system are separated by an insert which has a weir, inflow drop pipe, and outflow riser (Figure 2). The size of the insert and its associated components depends on the overall size of the treatment chamber and bypass chamber.

Operation of the system is passive with respect to flow control and treatment. During low flows or frequent storm events, stormwater from the inlet is directed down the inflow drop pipe located adjacent to the inlet of the treatment chamber. Flow in excess of the inflow drop pipe capacity is directed into the bypass chamber to the outlet of the system. The effective treatment capacity is set by a weir which surrounds the inflow drop pipe at the inlet and the volume of the treatment chamber. Effluent from the treatment chamber exits via the outflow riser which extends below the water surface in the treatment chamber, up to the overflow chamber, and to the system outlet. Sediment is retained in the bottom of the treatment chamber and oils and grease are retained at the top of the treatment chamber in a quiescent area. Oil and grease are prevented from leaving the chamber by the outflow riser.

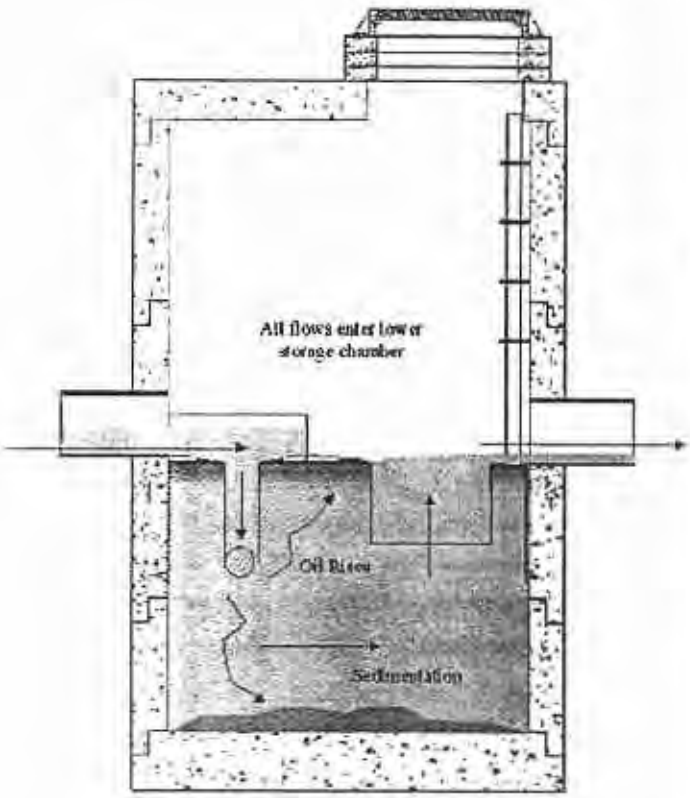

Figure 2. Stormceptor operation during average flow conditions.

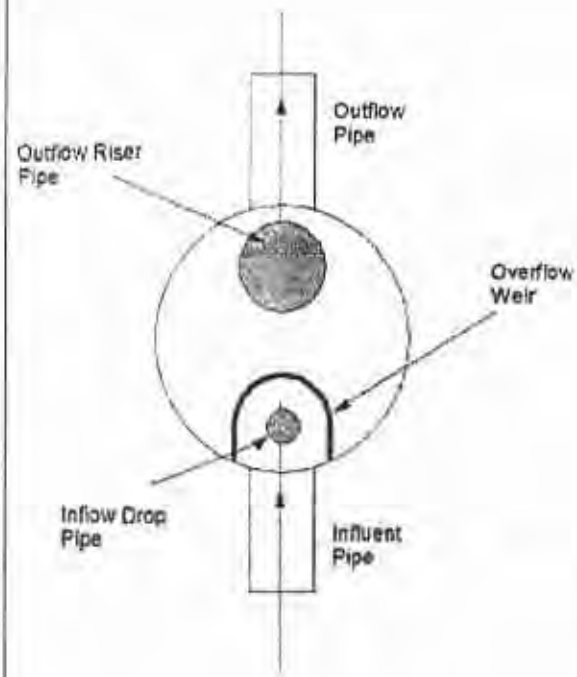

Figure 1. Top view of Stormceptor insert.

The inlet and outlet elevations of the system are kept at a minimum with 1" difference in the concrete and fiberglass units. The multiple inlet units have a 3" difference between the inlet and outlet. Approximately 9 inches of hydrostatic head is developed from the influent elevation in the weir. A low head system is designed to reduce the potential for scouring from higher velocities in the treatment chamber. During storm events exceeding the treatment capacity of the chamber the head on the system is kept constant because stormwater elevation over the drop pipe is nearly equivalent to the head over the outflow riser. Studies prepared by Stormceptor Corporation (Marsalek et al., 1994) demonstrated when total flow to the system was increased, in excess of the treatment chamber capacity, flow through the treatment chamber increased initially and then decreased slightly. This implies that treatment performance would not be lowered during high flow events and scouring and resuspension of previously settled solids is prevented.

The system is suited for local or lateral lines within any conveyance system. The system is not recommended for large storm drain trunk lines. The system is not designed to be used as an inlet catch

basin. Stormceptor Corporation produces 8 models with different sediment and oil capacities illustrated in Table A1 in the Appendix. Preliminary sizing recommendations are presented in Technical Design Manual (Stormceptor Corporation, 1997) and in Table A2 in the Appendix. The preliminary recommended sizing table specifies units per impervious drainage area based on percentages of treatment.

TECHNICAL FEASIBILITY

The Stormceptor system is stormwater treatment structure providing event based solids separation. The Stormceptor has a greater TSS removal efficiency than water quality inlets. The value added in the Stormceptor system is the ability to reduce turbulence in the treatment chamber, which makes it better at removing TSS and TPH than conventional BMPs of the same category. A significant amount of design engineering has gone into the Stormceptor. In particular, the flow control device developed for the insert is capable of reducing turbulence in the treatment chamber to quiescent levels. This directly increases removal efficiencies for TSS and grease and oils. The system appears to be capable of limiting resuspension of settled particles, a common problem in catch basins.

The basic principle of operation is sedimentation. In addition, some minimal treatment to pollutant parameters associated with the settled solids is likely to occur. In particular, BOD_5, COD, particulate N, P, and pathogens may be associated with the finer fractions of sediments and removed from the stormwater. Oil and grease are less dense than water so they float to the top of the treatment chamber. Since the outflow riser extends below the surface of the water in the treatment chamber, oil and grease will be trapped in the treatment chamber.

COMPETING TECHNOLOGIES

Several direct competing technologies exist for Stormceptor, including other sedimentation chamber technologies like oil and grit separators. Information submitted by a competing technology suggests that Stormceptor is a cost competitive product. However, no comparative data on oil and grit separators was submitted by CSR/NEP on these technologies. Typical oil and grit separators are not likely to achieve the same level of treatment as the Stormceptor system. The Stormceptor system should be competitive with other technologies that produce comparable removal efficiencies. The Stormceptor system has spatial requirement advantages over detention ponds and artificial wetlands which have large area requirements. The Stormceptor system is not a recharging system and therefore not comparable to recharging systems such as infiltration basins and trenches. It may produce equivalent treatment levels as recharging systems, when sized properly. The Stormceptor system is not suitable for meeting recharge Standard 3 as a singular treatment system (DEP and CZM, 1997), but may be well suited for pretreatment in a mixed component system with recharge. The system should be competitive with the other BMPs in the deep sump catch basin category.

DATA SUPPORTING CLAIMS

Prior to considering performance data from any treatment technology, the following notation is advised. Data collected from isolated stormwater treatment systems may be variable. Some of this variability may be due to differences in land use, climate, and soil type. Additionally, it is possible that storm events may have variable pollutant loads, resulting in varied treatment system performance at an individual site. The combination of these two sources of variability, inherent in all BMP performance verification, presents an unknown level of uncertainty. In order to overcome this uncertainty a larger set of data would be required to predict the performance of the technology under a variety of conditions. The Storm*ceptor* system has a limited set of performance data.

The data submitted by CSR/NEP are intended to demonstrate performance capable of achieving Standards 4, 5, 6 and 7 of the Department of Environmental Protection (DEP) Stormwater Management Handbooks (DEP and CZM,1997). In this Technical Assessment, performance is based on available data in the proponent's submission from installations in Toronto and Edmonton Canada. Bench scale testing and modeling data were used as predictors of performance but not for sizing. A third installation, in Westwood, Massachusetts, supports performance claims at Storm*ceptor's* "Sensitive Area" criteria of 80%. Storm*ceptor* has more than 1600 units installed in the U.S. and Canada. Additional data from other installations may become available for future performance verifications.

Analytical Modeling and Bench Scale Studies

Storm*ceptor* Corporation has committed resources to study the Storm*ceptor* system using analytical models with bench and pilot scale validation. Several modeling scenarios were developed for Storm*ceptor* by Marshall Macklin Monaghan, LTD. (1994) to evaluate the removal of TSS under a variety of storm event conditions using the Stormwater Management Model (SWMM). Some of the parameters for the model include: rainfall data, temperature, and runoff. The analytical model results are based on non-ideal settling and do not account for flocculation effects due to its considerable complexity. Predicted long term TSS removal rates were calculated as a function of drainage area per unit for 4 different Storm*ceptor* models. Results from this modeling study suggest that in small drainage areas the Storm*ceptor* units had higher removal rates. The long term TSS removal rates for a 1.2 acre/unit drainage area were calculated at 53%, 46%, 39%, and 30% for systems sized at 6800 gal., 4850 gal., 2800 gal., and 1820 gal., respectively. Removal rates decreased proportionately by 25% of the highest rate when the drainage area was doubled. Removal rates were less than 20% at 4.25 acres/unit.

Another laboratory study performed by Marcalek et al. (1994) suggests a much larger variation for TSS removal rates, ranging from 6% to 95%. In these studies flow rate was manipulated along with configurations of the inflow drop pipe and outflow riser. Systems used in these tests were 1/4 size and the sediment used was an ABS polymer used to control particle size more effectively. A scaling factor of 32 was used to estimate the actual prototype design flows based on equivalent Froude

number under the special case where no free fluid surface exists with incompressible fluid. The removal rates for fine to medium sands were 95% at 95 gal/min, 77% at 206 gal/min, 68% at 285 gal/min, and 6% at 634 gal/min.

A study from the University of Conventry (Pratt, 1996) tested the equivalent to the STC 900 system at 144 gal/min in a 20 minute event. Sand and crankcase oil were loaded at 4100 mg/l and 90 mg/l, respectively to the influent water. Removal efficiencies were reported at 83% for sand and 98% for oil. While this was a full scale study, the conditions of the test may not accurately reflect field conditions under all circumstances. In particular, the flow rates do not fall within the recommended ranges specified in the Storm*ceptor* Design Manual (Storm*ceptor* Corporation, 1997). Additionally, the use of model sands do not always reflect the behavior of sediments under field conditions. Lastly, the number of replicates do not warrant statistical significance due to limited replications.

Storm*ceptor* Corporation and CSR/NEP have indicated that the preliminary sizing recommendations are based on their field installations and not the laboratory data or modeling data. Review of these data indicate that the laboratory data and modeling data do not give a definitive picture of system performance under field conditions. It is suggested that additional performance data be gathered from field installations and return to the modeling data for model calibration. Analysis of model sensitivity would be appropriate once additional field data has been collected.

Field Installations

A field test of the Storm*ceptor* system was carried out in The City of Edmonton Canada at a parking lot located in the Westmount Shopping center on Fountain Lake. A single Storm*ceptor* unit (Model STC2000, which is equivalent to an STC2400) was installed to treat an approximate impervious drainage area of 9.8 acres. This installation had a unit undersized by a factor of 3. The unit was fitted with automated samplers on inflow and outflow pipes. Water quality was measured on 4 storm events, and included TSS, metals, oil and grease. Average removal efficiencies were 51.5%, 39 to 53%, and 43%, respectively (Table 1). No additional data on the variability of these data were available. Precipitation data for the storm events were not made available to this reviewer at the time of this assessment. Therefore, it is unclear whether these events were 0.5 inch or more. The Storm*ceptor* Corporation's recommended impervious drainage area for the STC 2000 (equivalent to the STC 2400) is 3.35 acres, therefore the system was largely under-sized. The performance of this system exceeded the predicted performance based on the sizing guidelines set by Storm*ceptor*. Under similar environmental conditions, including climate, land use intensity, and soil conditions as that at the Edmonton installation, it is possible that the undersized Storm*ceptor* system will provide at least 52% removal of TSS, sized under Storm*ceptor's* "Treatment Train" criteria (50% TSS removal).

Table 1. Water Quality Tests at Westmount Shopping Center, Edmonton Canada, 1996

Water Quality Parameter	Average Percent Removal Efficiency
TSS	52%
Metals (Fe, Pb, Zn, Cr, and Cu)	39 - 53%
Oil and Grease	43%

Storm*ceptor* conducted a survey of sediment loads to 23 Storm*ceptor* units installed in the City of Toronto, Canada (Bryant et al., 1995). Analysis of the sediment accumulations and estimates of TSS removal efficiency were calculated based on predicted flow and loadings. In this study, a mass balance was not utilized to measure removal efficiency. Rather, estimates based on regional precipitation data and estimated mean concentration (EMC) (Novotny, 1992) were used to determine loadings. The removal efficiency was calculated from the ratio of sediment collected in the unit and corrected for water content, and estimated loading. Solids removal efficiency increased with greater storage capacity (r^2=0.60) (Figure 3). The range of removal efficiencies was 18 to 95%. The authors did not verify whether there were significant losses of sediment out of the units (Bryant et al., 1995). These data indicate a relatively high potential for removal, especially where sediment storage capacity is high. Data from this study were used to calculate preliminary sizing recommendations, detailed later in this review (Appendix, Table A1). The approach used to estimate performance and the subsequent sizing recommendations is based on rational assumptions. Actual performance under conditions other than those tested may require verification to compare with these results.

In Westwood Massachusetts, an ongoing study of a Storm*ceptor* STC 2600, sized according to the "Sensitive Area" criteria, demonstrated 77% TSS removal efficiencies from six storm events. Two events produced no appreciable sediment load over the composite sampling period. The first three events had a mean of 90% TSS removal based on first flush grab samples. Three of the six events had removal rates in excess of 89% and as high as 99%. One event produced a low removal rate of 28% and may have been an artifact of the sampling procedure. Overall the removal efficiency for TSS is near 80%. Removal of TPH averaged 93%, based on first flush grab samples of the first three storm events. Overall TPH removal, based on composite sampling over 5 events, was 80% with 3 events contributing no data to the mean. The mean precipitation and duration of these events were 0.4 inches and 13 hours, respectively.

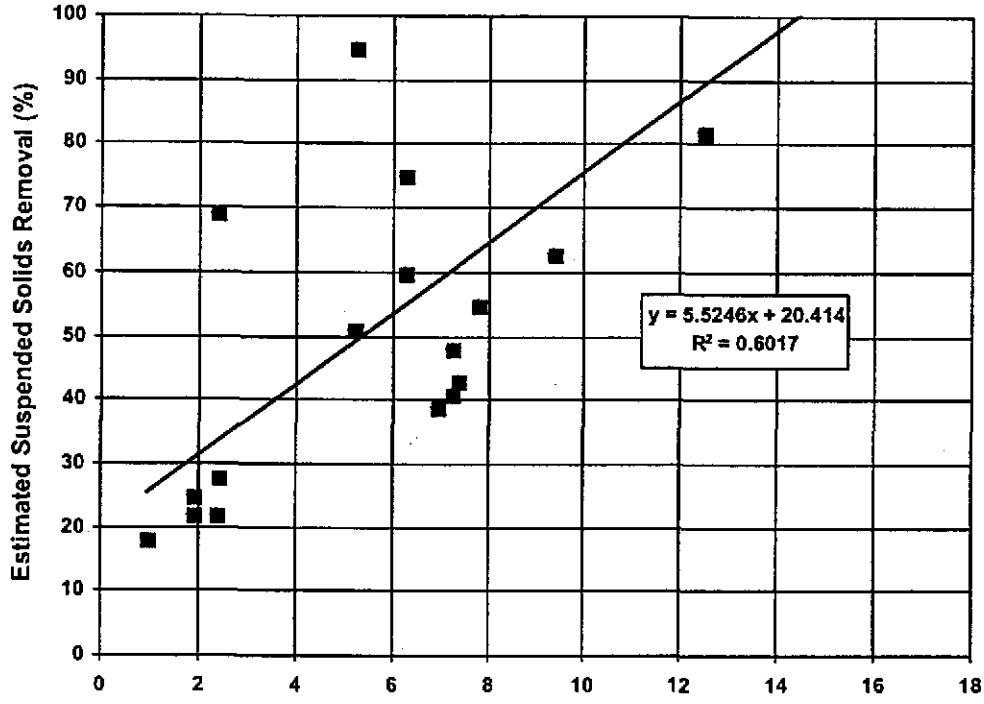

Figure 3: Stormceptor® Sizing Guideline - Removal efficiency as a function of storage capacity from 23 Stormceptor units in Toronto Canada.

Performance Summary

The Stormceptor system has been demonstrated to provide at least 77% removal of TSS when sized under Stormceptor's "Sensitive Area" criteria and 52% TSS removal when sized under Stormceptor's "Treatment Train" criteria. Based on these data, the Stormceptor systems receiving stormwater from a drainage area sized according to the "Sensitive Area" criteria are likely to provide a removal efficiency of 80%, on the annual stormwater runoff. While the set of data useful for predicting the relationship between treatment efficiency and loading rates is limited, it is likely that the STC 2400 is capable of meeting standards 4 and 6, for 80% removal of TSS in the first 0.5 or 1.0 inch of a storm event, if sized appropriately. STC 2400 Furthermore, performance of larger and smaller sized units may be capable of achieving removal rates that meet Standards 4 and 6. However, data to support this claim are not currently available.

SITE SUITABILITY RECOMMENDATIONS

The applicability of this technology with respect to TSS removal is similar to that of several other BMPs, including: sand and organic filters, catch basins, and water quality inlets, all described in the Stormwater Management Handbooks (DEP and CZM, 1997). The use of this technology can be made to Standards 4, 5, 6, and 7 in the Stormwater Management Handbooks (DEP and CZM, 1997).

The system is suitable for new and retrofit situations. The Storm*ceptor* system is particularly well suited for constricted areas, areas that require pretreatment for a multi-component treatment system, and redevelopment and retrofits described under Standard 7 in the Stormwater Management Handbook (DEP and CZM, 1997). The Storm*ceptor* system appears to have the ability to trap spills of hydrocarbons, oils, and grease. This makes the system suitable for use on areas with higher potential pollutant loads, specified under Standard 5 in the Stormwater Management Handbooks (DEP and CZM, 1997).

The system can be used on sites with a wide range of drainage areas provided it is sized correctly. On larger drainage area installations, units can be located throughout the drainage area rather than in a central location and provide treatment of runoff closer to its source. The system is suitable on small drainage areas or on individual inlets. The system is generally associated with a conveyance system and is recommended as part of a combination of different BMPs. The system is not designed as a recharge system and is not applicable to Standard 3 (DEP and CZM, 1997) unless combined with an approved recharge system. The system may be used as a pretreatment device for recharging systems. In this application, the life of the recharging system should be extended due to reduced clogging of the infiltrative surface. In high groundwater conditions the system is likely to withstand the hydrostatic pressures created by the saturated soil conditions around the unit. Care must be taken to assure the seam in the concrete unit does not leak. Buoyancy of the unit should be considered in the engineering plan. Storm*ceptor* Corporation recommends use of fiberglass tanks where there is potential for spills of hazardous materials. The precast concrete units are applicable to other installations including roads, highways, and parking lots.

Sizing

The recommended sizing, presented in the Appendix Table A1, was developed by Storm*ceptor* Corporation based on calculated loadings from the Toronto survey of system performance (Bryant et al., 1995). Based on the Edmonton Study, removal efficiencies determined for the STC 2000 (equivalent to the STC 2400) fall within the range of removal rates specified in the sizing guidlines. The performance ratings for the STC 2400, listed in Table A1 under "Treatment Train" criteria, may be conservative estimates, since that system was grossly undersized. When sized appropriately, the system is likely to perform as claimed under similar environmental and operating conditions including: climate, land use intensity, and soil conditions. The larger sized units listed in Table A1 have not been verified. The performance characteristics of these systems may vary as a function of scale. Performance of other sized units may have comparable removal efficiencies and are likely to

meet Standards 4 and 6, requiring 80% TSS removal of the first 0.5 and 1 inch of rainfall respectively. The Storm*ceptor* system may be used as a stand alone BMP or as a component within a combination of different BMPs.. It is possible that sizing which corresponds to the "Sensitive Area" category in Table A1 may meet Standard 4 and 6, requiring 80% TSS removal of the first 0.5 and 1.0 inch of rainfall, respectively.

Maintenance

All BMPs require periodic maintenance. Inspection of the sediment load and oil and grease volumes is easily made from the surface with a tube dipstick inserted through a 6" vent tube. Depths of sediment indicating maintenance are presented the Appendix, under maintenance. Inspection of the internal structure should be part of the routine inspection plan. The unit is designed to accept 15% of its capacity in solids annually based on maximum drainage area loading listed in Table 4 of the Technical Design Manual (Storm*ceptor* Corporation, 1997). Removal of sediment, oils, and grease from the system will depend on rates of accumulation. Sediment removal is recommended annually but is likely to vary widely based on site conditions and loadings. The Stormwater Management Handbook (DEP and CZM, 1997) recommends quarterly maintenance. Reduced or more frequent maintenance frequency can be determined after experience with the system increases. Typical maintenance cleaning can be done with a vacuum truck. Maintenance costs are not expected to be in excess of normal costs for maintaining deep sump catch basins. Costs for cleaning, not adjusted for economies of scale, range from $250 to $500 depending on the size of the system and disposal fees.

REGULATORY ISSUES

The performance requirements for stormwater treatment systems are established by the DEP Stormwater Management Standards listed in the Stormwater Management Handbook (DEP and CZM, 1997). Projects subject to the standards may be required to file a Notice of Intent when they are sited in wetlands jurisdictional areas. Under the Wetlands Protection Act, conservation commissions, must apply the standards to new or modified discharges. Permits for surface water discharges under the National Pollutant Discharge Elimination System (NPDES), issued by the Massachusetts DEP Bureau of Resource Protection Division of Watershed Management, are not required if the discharge is tied to a conveyance or system of conveyances operated primarily for the purpose of collecting and conveying uncontaminated stormwater runoff.

CROSS MEDIA IMPACTS

Disposal of sediment from stormwater treatment systems is permitted in lined or unlined permitted solid waste landfills. In the absence of written approval from DEP, sediments are considered non-hazardous

solid waste and may be treated in accordance with all DEP regulations policies and guidelines. Typical removal of sediment and biofilter material can be performed with a vacuum truck and disposed of. Grease and oils may accumulate in the sedimentation chambers and can be removed and disposed as non-hazardous solid waste. If the system has received influent from a hazardous materials spill, the system should be managed in accordance with an approved emergency response plan and appropriate state requirements. The Storm*ceptor* system does not present more restrictions for removal of wastes than would be associated with any other BMP.

ENERGY ISSUES{TC "ENERGY ISSUES"}

There are no specific energy issues related to this technology as it is not an energy consumer. There may be energy benefits when this "passive" system is compared to other technologies that may consume energy resources.

NEED FOR ADDITIONAL RESEARCH, DEMONSTRATION, AND STEP SUPPORT

The Storm*ceptor* technology is a unique approach for stormwater pretreatment and appears to be technically feasible based on a preliminary analysis of the available data. Further research on the Storm*ceptor* system should include studies to assess actual sediment loading under a variety of environmental conditions. To establish removal rates in excess of those reported herein, further research on the Storm*ceptor* system should include: i) evaluation of seasonal variation in performance, ii) performance as a function of flow rate, iii) efficiency with dual or multiple inlets, and iv) bacteria and pathogen removal efficiency in dry weather periods. The STEP program will be able to assist in performance verification on an as needed basis. Installations already being monitored by CSR and Storm*ceptor* will continue to provide performance data in a variety of environmental conditions. Existing monitoring programs may be augmented with STEP support through STEP oversight and reporting. STEP support may include development of experimental plans and review of data. Additional data would be useful for confirming field performance claims greater than 80% TSS removal efficiency.

SUMMARY RECOMMENDATION

The Storm*ceptor* system is based on reasonable and accepted principles applied to water treatment and conveyance systems. Review of available data suggests that the Storm*ceptor* system should be capable of providing an effective solution for treatment of stormwater runoff. At present, it is not possible to verify the performance of all the Storm*ceptor* models under the recommended sizing guidelines. The system is likely to be capable of TSS removal for Standards 4 and 6 when sized according to the "Sensitive Area" criteria. Other sized Storm*ceptor* models may provide similar TSS removal rates when sized accordingly under similar climatic conditions, land use intensities, and soil conditions. The Storm*ceptor* system is

uniquely designed to trap hydrocarbons and is well suited for areas of higher pollutant potential, Standard 5 in the Stormwater Management Handbook (DEP and CZM, 1997). The system is also likely to remove grease and oils.

Based on available data, the Storm*ceptor* technology may be capable of meeting Standards 4, 5, 6, and 7 in the Stormwater Management Handbook (DEP and CZM, 1997) if installed, designed, and operated according to manufacturer's instructions. Additional data representing a varied set of operating conditions over a realistic maintenance cycle on other Storm*ceptor* models will assist in further clarification of TSS removal rates. Performance claims can be further verified as data is generated on systems currently being monitored. The Storm*ceptor* system compares favorably to other conventional BMP technologies with similar TSS removal rates, offering enhanced treatment and application.

Highlights

- Performance data available demonstrates that the Storm*ceptor* system can provide TSS removal rates of 77% when sized according to the "Sensitive Area" criteria. Evidence suggests that the Storm*ceptor* system may be capable of achieving TSS removal rates between 89% and 99% when sized accordingly, under conditions similar to those reported in the Westwood Massachusetts site, including: climate and land use intensity.
- Performance data available to this reviewer suggest that the Storm*ceptor* system can provide TSS removal rates of 52% when sized according to the "Treatment Train" criteria.
- Use of the Storm*ceptor* system as a pretreatment component in combination with different BMPs, when sized according to the "Treatment Train" criteria, will likely meet standards 4 and 6 of the Stormwater Management Handbooks (DEP and CZM,1997). Use as a stand alone device may be justified when sized according to the "Sensitive Area" criteria.
- The Storm*ceptor* system is likely to perform in areas with higher potential pollutant levels in Standard 5 of the Stormwater Management Handbooks (DEP and CZM,1997).
- The Storm*ceptor* system is useful for new and retrofit installations in Standard 7 of the Stormwater Management Handbooks (DEP and CZM,1997), especially where space is limited.
- The Storm*ceptor* system is also suited for secondary sediment control from construction related sediment loads specified in Standard 8 (DEP and CZM,1997).

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APPENDIX

Table A1. Stormceptor® Capacities*					
Model	Maximum Treatment Flowrate (gal/min.)**	Down Riser Pipe / Orifice Diameter (in.)	Sediment Capacity (ft^3)	Oil Capacity (gal)	Total Holding Capacity (gal)
STA/STC 900	285	6	75	280	950
STA/STC 1200	285	6	110	280	1230
STA/STC 1800	285	6	195	280	1830
STA/STC 2400	475	8	180	880	2495
STA/STC 3600	475	8	345	880	3750
STA/STC 4800	800	10	465	1025	5020
STA/STC 6000	800	10	610	1025	6095
STA/STC 7200	1110	12	725	1100	7415

* approximate, ** without by-passing

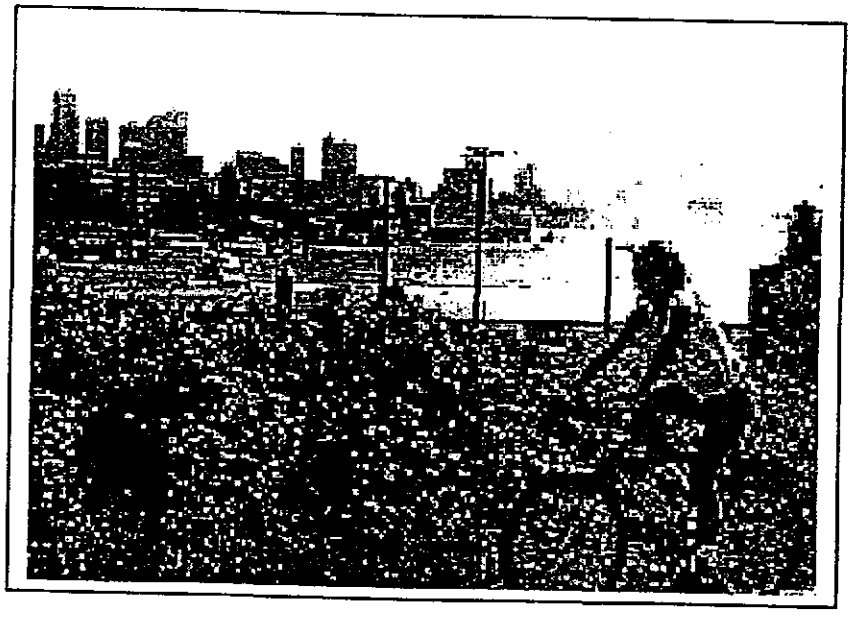
Table A2. Maximum Impervious Drainage Area Guidelines (acres)				
Stormceptor® Model (STA / STC)	Sensitive Area (80% TSS removal)	Standard Area (70% TSS removal)	Degraded Area (60% TSS removal)	Treatment Train (50% TSS removal)
900	0.45	0.55	0.70	0.90
1200	0.70	0.85	1.05	1.45
1800	1.25	1.50	1.90	2.55
2400	1.65	2.00	2.50	3.35
3600	2.60	3.15	3.95	5.30
4800	3.60	4.30	5.40	7.25
6000	4.60	5.55	6.95	9.25
7200	5.55	6.70	8.40	11.25

Table 6. Sediment Depths Indicating Required Maintenance*{tc "Table 6. Sediment Depths Indicating Required Maintenance*"}**Table A3. Sediment Depths Indicating Required Maintenance***	
Model	**Sediment Depth (feet)**
900	0.50
1200	0.75
1800	1.00
2400	1.00
3600	1.25
4800	1.00
6000	1.50
7200	1.25

* based on 15% of the interceptor's sediment storage

EXHIBIT V-4

The Economic Benefits Of Greenways



Seattle's Burke-Gilman Trail

Prepared for:
North Macadam Greenway & Park Work Group

Prepared by:
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February, 1999

The Economic Benefits of Greenways

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Introduction

This report outlines the benefits of greenways, with a particular emphasis on the positive economic impacts greenways have in urban areas. The first section discusses greenways and their social, environmental, transportation and economic benefits. The second section includes a brief summary of funding sources and acquisition strategies. Also included in the section is an overview of three organizational structures for implementing greenways.

The bulk of this report is case studies of fifteen projects that include, or will include, greenways. The type and scope of these projects vary greatly. Some projects include greenways as an element of larger redevelopment projects. Other are exclusively greenway projects. They range in size from a single-block plaza in San Luis Obispo to a county-wide trail that will connect four major cities in Florida. The projects also differ according to their current stage of implementation. For instance, the Southeast False Creek Sustainable Neighborhood Project in Vancouver B.C., a large scale project is still in the policy making stage, while the Burke-Gilman Trail in Seattle was developed well over a decade ago.

It may be incorrect to describe any of these projects as complete. If these case studies are any indication, greenways are not only popular with residents, tourists and business people, they are contagious. Without exception, people interviewed for this report stated that plans were underway to expand greenway trails or connect them to other greenway and trail systems.

The final section of the report provides a list of resources used in writing this report. It includes a bibliography of printed material, a list of interviewees, names of websites and list of organizations. This is by no means an exhaustive set of resources, but it provides a taste of information available on greenways and urban redevelopment.

GREENWAYS AS TRANSPORTATION ROUTES

Greenway trails, which are usually developed for recreational use, have grown in popularity as community routes. According to the Rails-to-Trails Conservancy, about 85 million people used rail-trails in 1994. However, in many areas these trails also become favored commuting routes as well. For example:

- In Chattanooga, about 1 million people visit the Riverwalk area each year. Of the trail users, about 10 percent are commuters. This ratio is expected to increase as missing links of the trail are filled in.

- The Pinellas Trail, located in Pinellas County Florida (the most densely populated county in the state) has about one million users a year, one third of which are commuters. Plans are underway to develop a new leg of the trail and commuter use is expected to increase as a result.

- A study done on the economic impacts of Seattle's Burke-Gilman Trail indicates that in 1987 about three-quarter of a million people used the trail annually. At the time, the trail had about 4,000 – 5,000 users a day, 16 percent of which were commuters.

The potential exists for increased bicycle and pedestrian commuting. Between 1982 and 1992, the number of bicyclists in the country grew from 72 million to 99 million, a 38 percent increase (National Bicycle and Pedestrian Clearinghouse, Sept. 1995). In 1991, bicycling and walking trips in the U.S. replaced nearly 18 billion motor vehicle miles (NBWS final report). In addition, a report by the Federal Highway Administration's National Bicycling and Walking Study found that about 42 percent of all trips are for personal business (doctor visits, errands, and visits with friends). Of these personal travel trips, nearly half are less than 3 miles long, within easy bicycling range. Trails provide safer alternatives for pedestrian and cycling commuters, including children, and elderly and disabled citizens. These routes provide links to transit, schools, workplaces, commercial and cultural centers.

SOCIAL BENEFITS OF GREENWAYS

Greenway trails provide connections between communities and become casual meeting places for community members. They link residential areas, employment, schools and shopping. Often greenways offer a public space for the community to gather and celebrate events.

Greenways provide recreational opportunities close to home that are especially important and popular among people living in highly urban and park deficient areas. Greenways also provide access to other parks, trails and recreational activities, some outside the urban area. In Denver, someone traveling on the South Platte River Greenway can travel on another trail along Cherry Creek to a boat chute concession where they can take a gondola-like ride. Users of the Pinellas Trail benefit from access to state parks along the

beaches of western Florida. In Chattanooga, the Riverwalk leads to parks with fishing piers. In several cities, rowing clubs and boat launches are located along greenways.

Trails contribute to a sense of community well-being. Along Seattle's Burke-Gilman Trail, nearly two-thirds of residents interviewed said that the trail "increased the quality of life in the neighborhood" and none of the residents said the trail should be closed.

Often trails become places of community pride. Bicycle and pedestrian facilities are developed to reflect elements of local and regional character. Chattanooga's Riverwalk incorporates elements of the area's history, economy and natural environment. In Pittsburgh, signage for the LTV Steel South Sides Project will be made of materials used in the steel-making process.

HEALTH BENEFITS OF TRAIL ACCESS

The U.S. Department of Transportation, in its National Bicycling and Walking Study, estimated that 131 million Americans regularly bicycle, walk, skate or jog for exercise, sport or recreation. Trails of all sorts provide opportunities for adults and children to exercise while they travel to work, school, the library, or shopping (NBWS final report). These types of opportunities for exercise are a key attractor for residential and office tenants.

ENVIRONMENTAL BENEFITS OF GREENWAYS

Greenway systems can incorporate natural areas with passive recreation, protecting and improving water resources. In addition, greenways can lessen environmental impacts or correct past damage to environmental systems. Some projects incorporate stormwater mitigation measures including natural buffers and water retention/detention devices. In Pittsburgh, plans for a brownfield redevelopment project include developing open space with ponds for recreation and stormwater retention.

Stream bank treatments, including planting vegetation and site grading, can slow velocity of water into rivers and provide filtration to reduce silt runoff. The result is increased water quality and moderated water temperature through shading and filtration. Another Pittsburgh project, Washington's Landing, was developed on a denuded site. As part of the project, a riverfront trail was developed with landscaping of native grasses and trees.

Greenways can also provide habitat for native and migrating wildlife, including fish and birds by incorporating natural food sources and shelter. Trail Manager of the Fox River Trail in Illinois stated, "The habitat for wildlife... has been dramatically improved by the rail-trail. The wildlife along the rail-trail is abundant compared to other sections of the river where there are private homes and manicured lawns abutting the river's edge" (as cited in National Bicycle and Pedestrian Clearinghouse, Sept. 1995).

Many greenways mitigate environmental problems associated with urban areas. Air quality can be increased as a result of planting trees that absorb pollutants. A 1975 study of the National Park Service recorded a 19% reduction in particulate concentrations downwind from parks with Ohio conifer stands.

Reductions in auto travel associated with commuting on greenways can also contribute to better air quality. In 1991, reductions in motor vehicle miles resulting from bicycling and walking trips saved about 850 million gallons of gasoline, which would have added 10.4 million metric tons of exhaust emission air pollution into the atmosphere (NBWS Final Report).

Greenways may reduce noise pollution by maintaining distance between the noise source and receiver and by absorbing, deflecting and refracting sound. A forestry study done in 1983 found that wide belts of tall, dense trees could reduce sound levels of 10 decibels or greater, and soft surfaces such as grass or plowed ground adjacent to a tree belt, reduced noise levels by 8 to 12 decibels (National Park Service 1992).

Greenways can also contribute to a more moderate micro-climate by reducing extreme heat and cold temperatures. Trees are particularly valuable temperature mediators. In the winter, trees act as wind breaks; in the summer they provide shade and transpire water, which can lower temperatures. A single, isolate tree under ideal conditions can transpire energy equivalent to five average room air conditioners running 20 hours per day (National Park Service 1992).

ECONOMIC BENEFITS OF GREENWAYS

Greenways as Amenities for Commercial and Industrial Uses

Bicycle and pedestrian trails can attract high quality businesses by providing commuting options for employees, scenic views for employees and customers and enjoyable places for lunchtime activities. In addition, greenways provide an appealing option for noontime exercise, a benefit for health-conscious employees and employers alike.

Corporate real estate executives say that the most important factor for a business selecting an office location is choosing a location that will help attract and retain key personnel. They add that for most businesses employee "quality of life" is equally as important as costs when selecting a location for an office or factory (National Bicycle and Pedestrian Clearinghouse, Sept. 1995).

- The American River Bike Trail in Sacramento is promoted to business people in Chamber of Commerce publications. The 30 mile bike route, which runs through downtown, features a variety of outdoor experiences close to the work place including fishing, hiking and horseback riding.

- Closer to home, projects in Beaverton and Tigard incorporate existing creeks and constructed wetlands as focal points for corporate office parks. These natural areas offer an attractive view and a relaxing place for employees to enjoy lunch or a break.

- In Chattanooga, industrial businesses recognize the value of the Riverpark and are among its strong supporters, advocating for its expansion to other property owners.

- Like many other greenways, Washington's Landing in Pittsburgh includes a rowing club and a marina, but it also is the location for a company that manufactures tennis equipment. The business has an agreement with the city to use public tennis courts on the greenway to test equipment.

- Washington's Landing had a natural appeal to Pittsburgh's local EPA offices.

Increased Commercial Vitality Associated with Greenways

Throughout the country , both urban and suburban greenway trails have become important revenue sources and economic tools. For example:

- The 400,000 trail users of suburban California's Lafayette-Moraga Trail spend an average of $3.97 each. Total annual revenue from the trail exceeded $1.2 million. (National Bicycle and Pedestrian Clearinghouse, Sept. 1995).

- The town of Dunedin, Florida (population 37,000) was suffering a 35 percent storefront vacancy rate in the early 1990s. The town now has a storefront occupancy of 100 percent. The Chamber Commerce considers the trail to be a key contributing factor to the commercial area's revitalization (along with beautification projects and increased parking).

- The South Platte River Greenway in Denver has begun to bring to life a river that had long been a dumping ground for garbage, industrial waster and sewage. Now the greenway is a focal point of the city, with hotels advertising their location along the river.

- San Antonio's River Walk, also know as Paseo Del Rio, is perhaps the best known path in the country. River Walk is the second most visited attraction in the state of Texas, behind the Alamo. River Walk forms the spine of the downtown shopping and entertainment district and has been a key selling point for the city's growing convention business.

Affect on Residential Property Values

Greenways are appealing because they provide passive and active recreation and exercise opportunities for health-conscious buyers. Open space and greenways also provide a green respite amidst the hard surfaces of the urban environment. Access to the water is an additional benefit for kayakers, canoeists and sailing or crew enthusiasts. Greenways

also offer enhanced views and opportunities for bird watching for urban naturalists. In addition to these "natural" benefits, greenways provide increased connections to shopping, transit, employment centers and entertainment districts. (See table below for additional case studies.)

A greenway trail and waterfront access has been a major selling point for the residential component of the Washington's Landing Project. According to Pittsburgh's Urban Redevelopment Authority, the greenway was the primary factor contributing to residences selling faster and for higher prices than projected.

Across the country, real estate agencies use greenways as selling points for properties. In In Pinellas County Florida, a real estate company even posts a map of the Pinellas Trail, with accompanying pictures and graphics, as promotional materials.

The increased salability of listings is considered to be the greatest value that the Northern Central Rail-Trail has brought to trailside properties in Baltimore County, Maryland. According to a 1994 study conducted for the Maryland Department of Natural Resources, "if two identical properties are for sale and one is near the trail and the other is not, the trail is used as a selling point and helps many nearby owners sell their property faster" (National Bicycle and Pedestrian Clearinghouse, Sept. 1995).

Studies on Increased Salability of Property

Source	Year	Source	Finding
National Association of Home Builders	1995	Florida Planning	Residential property is 10 to 20 percent higher in the vicinity of park facilities.
New Jersey Open Space Fund	1994	A Citizen's Guide to Greenways	Publicly owned open space added 15 to 20 percent to the value of nearby property.
Center for Urban Studies at University of Akron	1994	A Citizen's Guide to Greenways	Property values increase 5 to 20 percent within 500 feet of parks and open areas.
Baltimore, San Francisco, San Antonio, Seattle, New Orleans	1995	Florida Planning	Studies indicate that economic development follows the creation of well-designed and properly maintained parks, greenways and open space.
Burke-Gilman Trail	1987	Seattle	A survey of real estate agents said that the trail increased saleability near the trail and a neutral effect for homes directly on it. Agents routinely advertise properties as being on or near the trail.

Source: National Association of Home Builders as quoted in Florida Greenways web page

Greenways are also credited with increases in property values. In a study done by the National Bicycle and Pedestrian Clearinghouse, 63 percent of survey respondents, comprised of trail users, nearby landowners and local businesses, felt the trail added value to nearby properties. Preliminary results from a pilot impact study now underway

in Vancouver B.C. indicate that property values have increased after the development of greenways. Other case studies are given in the following table.

Increased Property Values

Greenway	Location	Salability	Value near greenway	Value on greenway
Burke-Gilman Trail	Seattle (1987)	Increased	6% more	Same as others in area
	Boulder, Colorado (1978)	Increased		32% greater than properties over 3,200' away
Eno River open space corridor	Durham, North Carolina			Decrease in value of $5.51 for every foot away from corridor
	Worchester, Massachusetts (1982)			$2,675 more than house 2,000' away
	Dayton, Ohio Columbus, Ohio (1985)			7.35% greater

Sources: National Parks Service *Economic Impacts of Protection Rivers, Trails and Greenway Corridors: A Resource Book* and Florida Greenways web site

FUNDING SOURCES

Typically, developing a greenway project involves tapping a wide variety of funding sources at the local, state and national level. Funding usually comes from a combination of government, nonprofit and private sources. In most cases volunteer labor and in-kind donations also play an important role in developing and maintaining a greenway trail.

Federal

Two sources were most frequently cited sources of federal funding for projects described in this report, T21 (formerly known as ISTEA – Intermodal Surface Transportation Efficiency Act) and the U.S. Environmental Protection Agency (EPA).

Grants from T21/ISTEA Transportation Enhancement Funds are administered through federal transportation agencies. These grants have funded a variety projects that link pedestrian and bicycle ways to other modes of transportation.

- The majority of funding for the Connecticut River Walk and Bikeway in Springfield, Massachusetts, came from ISTEA funds (over $2.6 million of a total project cost of $3.3 million). When completed, the RiverWalk will be a 23-mile linear park along both sides of the Connecticut River. This is a multifaceted project, which is part of a larger effort to develop a multimodal transportation system, stimulate economic development, as well as provide river access and recreation opportunities. The project also includes an environmental component aimed at improving water quality and protecting environmentally sensitive areas.

- In Staten Island New York, the North Shore Esplanade Extension is funded in part by ISTEA . The project will result in the development of a multimodal transportation hub that will connect ferry, bus and train service with 30'foot wide plaza with a view of the harbor. The plaza is envisioned as a place for public activities such as a farmers' market, art fairs and performances. The project will serve as a tourist destination, and a tool for spurring economic and social vitality in the area.

- ISTEA Funds, along with money from the Federal Transit Authority, made up part of redevelopment funding for the Ferry Building Depot in San Francisco. Like the Staten Island project, this will be a transportation hub linking water- and land-based modes, including light rail, trolley and pedestrian facilities. The project improves public access to the waterfront and will be developed as a mixed-use development with retail uses, restaurants and a conference center.

The EPA's Brownfield Assessment Demonstration Pilot Project focuses considerable attention to brownfield redevelopment. Since 1995, the project has funded 228 projects nationwide, some of which contain greenway elements. Grants are typically $200,000 and provide money for planning and site assessment.

- In Lowell, Massachusetts $200,000 in EPA funds helped pay for preliminary work on a riverfront project that included the construction of two sports facilities connected by a riverwalk. The riverwalk provides connections to the Lowell campus of the University of Massachusetts and the Lowell National Historical Park.

- Site assessment costs were covered by EPA funds on a much larger project in Wilmington, Delaware. The 500-acre site is being redeveloped with a budget of over $25 million dollars, of which $300,000 came from the EPA for site assessment. Portions of the project have been completed, including industrial and office development, a museum and exhibition hall, a restaurant, Riverfront Park, and homeless shelter. Elements of the project will all be connected by a greenway along the Christiana River.

Other sources of federal funding for redevelopment projects includes U.S. Economic Development Administration for Washington's Landing in Pittsburgh and gas tax funds for the Burke-Gilman Trail in Seattle.

State

Many projects make use of state economic development, environmental or park grants. In Florida, state parks funding has been instrumental in the development of greenways. A less conventional source of state funding comes from public universities that benefit from greenway development. For instance, the University of Washington gave funds for a portion of Seattle's Burke-Gilman Trail. In Lowell Massachusetts, a sports arena was constructed as part of the river walk project through a partnership between the City of Lowell and the University of Massachusetts.

Local

Local governments provide support for greenways through a variety of greenway, trails and open space funds. In some cases, funding comes from dedicated bond measures. In other jurisdictions, a portion of sales tax revenue is dedicated to open space projects. A greenway project in Casper Wyoming, was funded in part through a fund that dedicated one percent of sales tax revenues to civic improvements. Sales tax revenues were also a major funding source for the development of the Pinellas Trail in Florida. Trail advocates were successful in getting Florida voters to approve a special sales tax that set aside one-half of the proceeds for trail development.

When a project includes a strong connection to buses, trolleys or light rail, local transit funds are a logical funding source. For projects in distressed areas; Community Development Block Grants are often used.

Tax increment financing is a common financing strategy for projects that include massive redevelopment. For example, the LTV Steel South Sides Works project in Pittsburgh relies heavily on this funding mechanism.

In some cases, redevelopment authorities hold enough assets to help finance their own projects. The Pittsburgh Urban Redevelopment Authority commonly provides financing for its projects. The money is used as part of a larger financing package for land assembly and remediation. After site preparations and planning efforts are complete, the redevelopment authority then sells or leases property for private development.

Private

Another tool used to finance trail construction and maintenance is to lease utility easements within the trail right-of-way (see table below for examples). Trails may also be located within existing utility easements through agreements with local power providers. Pinellas County is currently working with Florida Power to develop an extension of the Pinellas Trail within the right-of-way for power lines.

Greenway Trails Funded in Part by Easement Leasing

Trail	Jurisdiction	Utility	Fee
Ojai Valley Trail	Ventura County CA		$36,000 annually
Paint Creek Trail	Michigan	Electric /pipelines	$2,000 annually
Burke-Gilman Trail	Seattle	US West	$728,000 over 25 years
Cedar Valley Nature Trail	Iowa	Northwest Bell	$12,000 perpetual easement
Washington & Old Dominion Railroad Trail	Northern Virginia Regional Park Authority	AT&T natural gas, cable, telephone, fiber-optics	$1,000,000
Iron Horse Trail	State of Washington	Fiber-optics	In-kind donation surfacing 36-mile trail
University of Washington, school trails	Seattle	U.S. Sprint fiber-optic	$113,000 In-kind donation of fiber optic cable
The Glacial Drumlin State Park Trail	Florida	U.S. Telecomm	$375,000 In-kind donation Trail surfacing perpetual easement

(source: Florida Department of Environmental Protection)

Conservancy groups provide support for greenway projects. Perhaps one of the best known of these groups is the Trust for Public Lands, which assists in land acquisition and open space development.

Many greenway projects have "friends" groups that raise funds through special events and membership drives. These groups help supplement projects that are implemented by government agencies, which are not able to conduct fundraising campaigns.

A variety of foundations support greenways projects. A survey of foundations listed with the Foundation Center in Washington D.C. identified 43 national, 20 regional, and 93 state-level foundations with special interest in greenways.

Business associations and property owner associations commonly provide support for greenway projects. For example, an owners association pays for maintenance and security costs at Washington's Landing in Pittsburgh. Corporate contributions also fund projects, particularly when greenways are part of economic development efforts or will be located near donors.

ACQUISITION STRATEGIES

Most land for greenway developments is acquired at no cost. Typically the land is made available through land donations, conservation easements, or as part of a developer's open space contribution. Under another strategy, revocable permits are granted that let property owners allow greenway access, without giving up property ownership. In some cases incentives for donation of land or easements are given, such as allowing the transfer of development rights. In other cases, where an impact nexus can be demonstrated, land can be exacted. Land located within a floodplain may be donated or purchased at relatively low cost.

A common strategy for government and nonprofit redevelopment agencies is to purchase, divide and resell property to acquire the portion needed for a greenway. This practice works well when a site requires master planning and environmental remediation. A hybrid nonprofit/government redevelopment agency used this technique for a redevelopment project in Wilmington, Delaware. The technique is also used extensively by the Urban Redevelopment Authority of Pittsburgh.

ORGANIZATIONAL STRUCTURE

This section profiles three models for implementation of greenway projects. The examples and discussion are taken primarily from the book *Greenways for America*, by Charles Little.

Government-led

Examples: Boulder Greenway

Raleigh North Carolina
Pinellas Trail Florida
Burke-Gilman Trail, Seattle
Washington's Landing, Pittsburgh
Vancouver Greenways Plan
Mission Plaza, San Luis Obispo

Recommendations: A greenway effort should cut across department boundaries. Work should be assigned to a greenway commission that has no other duties and therefore no potential conflicts of interest.

Advantage: Has authority associated with official status

Disadvantages: Limited by geographic jurisdiction
Subject to political pressures and sudden structural changes
Subject to changes in funding cycles
Limited ability to raise money through private donations and grants

Private Nonprofit Association

Examples: Ferryboat Corridor Greenway in the San Juan Islands, Washington

Advantages: Is not limited by geographic jurisdiction
Ability to raise money through private donations and grants

Disadvantages: Lacks authority, either actual or implied by official status

Public-Private Partnerships

Description: Single-purpose, publicly authorized greenway foundation, with a board of directors representing citizen organizations, business corporations, professional and academic associations, and government departments. These groups are usually legislatively chartered, an outgrowth of a government committee, or arise on their own.

Examples: Chattanooga Riverpark was legislatively chartered.
Yakima Greenway was an outgrowth of a government committee.
Casper's Platte River Parkway arose on its own.

Benefits: Can work with landowners more flexibly, move quickly and decisively than organizations.

Allows a group authority, either actual or implied, associated with official status.
Can work closely with public agencies for regulation of land or may have use of public funds and authorities for acquisition, construction, and maintenance.
Is not limited by geographic jurisdiction ability to raise money through private donations and grants

Chapter 2

GENERATION OF CONSTRUCTION AND DEMOLITION DEBRIS

INTRODUCTION

For the purposes of this initial national report, emphasis has been placed on the generation of construction and demolition (C&D) debris from building construction, demolition, and renovation activities. Examples of locally generated data for the other C&D-related generating sectors, e.g., roadway, bridge, and land clearing debris, are presented.

BUILDING-RELATED CONSTRUCTION AND DEMOLITION DEBRIS GENERATION

For analysis purposes, building C&D debris is divided into six categories: residential construction, demolition, and renovation and nonresidential construction, demolition, and renovation. These categories were selected based on the relationship between available Census data and empirical composition factors.

The following sections describe the data used and the methods for estimating the amount of building-related C&D debris generated, on a weight basis. Tables A-1 through A-6 in Appendix A are worksheets that provide details of the calculations used to arrive at generation for each component of the C&D debris stream.

Construction Debris

Residential. Empirical data for new residential construction have been identified from five sources: The NAHB Research Center; METRO in Portland, Oregon; Woodbin 2 in Cary, North Carolina; McHenry County, Illinois; and Cornell University. Each of these groups has conducted waste assessments at new construction sites.

The National Association of Homebuilders (NAHB) Research Center has developed a detailed methodology for conducting waste assessments at construction sites. Assessment data have been analyzed for single-family residential construction debris at four sites, including Largo, Maryland; Anne Arundel County, Maryland; Portland, Oregon; and Grand Rapids, Michigan. The NAHB Research Center also conducted a waste assessment at a 36-unit condominium construction project in Odenton, Maryland.

The Metropolitan Service District in Portland, Oregon (METRO) conducted a series of sampling projects at a large number of residential construction sites in Oregon over the last 5 or more years.

Wake County, North Carolina and the North Carolina Division of Pollution Prevention and Environmental Assistance conducted five residential construction waste assessments in the Raleigh, North Carolina area. Woodbin 2, a non-profit organization of the County, organized the assessments.

McHenry County, Illinois conducted waste audits at a single-family construction site and a 6-unit apartment building, and Cornell University conducted a waste audit at a single-family residence in New York.

The data from the five sources are summarized in Table 3. A total of 93 dwelling units are represented on this table. Generation rates ranged from 2.41 to 11.3 pounds per square foot of floor space. Geography does not appear to be the reason for the spread in data; it is more likely the types of houses, the specific practices of the builders, and the lack of uniform standards for the collection and storage of the sampled materials. The weighted average value from the five sources is 4.38 pounds per square foot.

Extrapolation factors are Census Bureau data that record the number of construction permits and the total square feet of new construction. According to the Department of Commerce Current Construction Reports (C-30), in 1996 the value of new private and public residential construction put in place totaled $181.795 billion. Data from areas where permits are required were used to calculate an average dollars per square foot. Total value in areas where permits are required was $127.9 billion for a total of 2,172 million square feet of floor space (1995). This amounts to $58.89 per square foot. Applying this factor to the total C-30 value and correcting 3 percent for inflation results in a total of 2,997 million square feet of new residential construction in 1996. At 4.38 pounds per square foot (Table 3), total generation is **6.56** million tons per year.

Nonresidential. The methodology for nonresidential construction debris is similar to that for residential construction debris. However, nonresidential buildings are much more varied than residential buildings and fewer waste assessments have been done, making the quantity estimates more uncertain.

Nonresidential buildings include private industrial, office, hotels/motels, other commercial, religious, educational, hospital and institutional, and miscellaneous buildings plus public industrial, educational, hospital, and other categories.

Table 3
ESTIMATED GENERATION OF RESIDENTIAL CONSTRUCTION DEBRIS

EMPIRICAL WASTE ASSESSMENTS

Date	Research Group	Type of data	Location	No. of Units	Building Size (Sq ft)	Total Waste (Pounds)	Generation rate (Lb/sq ft)	Average generation (Lb/sq ft)
1992	NAHB	Single-family	Portland, OR	1	3,000	13,684	4.56	
1994	NAHB	Single-family	Grand Rapids, MI	1	2,600	12,182	4.69	
1994	NAHB	Single-family	Largo, MD	1	2,200	10,210	4.64	
1995	NAHB	Single-family	Ann Arundel Cty, MD	1	2,450	9,436	3.85	
		Totals			10,250	45,512		4.44
1993	METRO	Single-family	Portland, OR	1	2,800	13,800	4.93	
1994	METRO	Single-family	Portland, OR	1	1,290	8,600	6.67	
1994	METRO	Single-family	Portland, OR	1	1,290	10,600	8.22	
		Totals			5,380	33,000		6.13
<1994	METRO (1)	Single family	Portland, OR	37	2,080	7,720	3.71	3.71
1996-97	Woodbin 2 (2)	Single-family	North Carolina	1	3,250	19,382	5.96	
1996-97	Woodbin 2	Single-family	North Carolina	1	3,250	36,722	11.30	
1996-97	Woodbin 2	Single-family	North Carolina	1	3,250	25,296	7.78	
1996-97	Woodbin 2	Single-family	North Carolina	1	3,250	28,805	8.86	
1996-97	Woodbin 2	Single-family	North Carolina	1	3,250	23,122	7.11	
					16,250	133,326		8.20
1993	County (3)	Single-family	McHenry Co. IL	1	2,000	14,880	7.44	
	Cornell U.	Single-family	Highland Mills, NY	1	1,890	4,556	2.41	
1996	NAHB	Multi-family (4)	Odenton, MD	36	50,400	204,000	4.05	
1993	County (3)	Multi-family (5)	McHenry Co. IL	6	9,000	33,580	3.73	
					59,400	237,580		4.00
Totals for 93 dwelling units				93	172,130	754,494		4.38

EXTRAPOLATION

Value of new private and public construction put in place (6)	181,795	million
Average cost of construction (7)	$60.66	per square foot
Total square feet of new construction	2,997	million square feet
Average C&D debris generation rate	4.38	pounds per square foot
Total Generation of Residential Construction Debris	**6.56**	**million tons**

(1) Average of 37 residential construction sites. Metro Report, 1994.
(2) Wake County SWM & NC Div of Pollution Prevention. Coordinated by Woodbin 2, a non-profit organization. Five sites were between 3000 and 3500 square feet each.
(3) Audit by McHenry County, assisted by Cornerstone Material Recovery.
(4) 36-unit condominium, average 1400 square feet.
(5) 6-unit apartment building.
(6) Department of Commerce, Current Construction Reports.
(7) Based on 1995 construction permits, 3% adjustment to 1996 for inflation.
Source: Franklin Associates

Table 4 shows the results of six nonresidential waste assessments. Ranging from 1.61 to 4.21 pounds per square foot, the average generation rate of the individual sampling studies is 3.89 pounds per square foot. These buildings include a retail store, restaurant, institutional building, and two office buildings.

Table 4
ESTIMATED GENERATION OF NONRESIDENTIAL CONSTRUCTION DEBRIS

EMPIRICAL WASTE ASSESSMENTS

Date	Research Group	Type of data	Location	Building Size (Sq ft)	Total Waste (Pounds)	Generation Rate (Lb/sq ft)
1995	Turner Construction	Retail Store Construction	Seattle, WA	37,000	148,000	4.00
1995	METRO	County Justice Center	Portland, OR	41,850	176,000	4.21
1992	METRO	Restaurant	Portland, OR	5,000	10,940	2.19
1994	METRO	Office construction (1)	Portland, OR	7,452	12,000	1.61
1997	Sellen Construction	Office construction	Seattle, WA	297,115	1,163,560	3.92
			Totals	388,417	1,510,500	
			Average			3.89

EXTRAPOLATION

Value of new private and public construction put in place (2)	198,700	million dollars
Average cost of construction (3)	$90.40	per square foot
Total square feet of new construction	2,198	million square feet
Average C&D debris generation rate	3.89	pounds per square foot
Total Generation of Nonresidential Construction Debris	**4.27**	**million tons**

(1) Two office buildings.
(2) Department of Commerce Current Construction Reports.
(3) Based on 1995 construction permits, with 3% adjustment to 1996 for inflation.

Source: Franklin Associates

The 1996 value of nonresidential buildings, as reported in Current Construction Reports, is $198.7 billion. Average construction costs in 1995 were $87.77 per square foot, resulting in an estimated 2,197.7 million square feet of new construction, after making a 3 percent correction for inflation. Multiplying by 3.89 pounds per square foot results in a total estimated generation of **4.27** million tons per year.

Demolition Debris

Residential. Demolition debris is estimated, starting with the number of residential demolitions per year, estimating the average house size when demolished, and then multiplying by the waste material per square foot, from empirical demolition waste assessments.

The NAHB economists have estimated the number of demolitions per year, based on Component of Inventory Change (CINCH) data (Carliner 1996). They estimate that the units actually destroyed through intentional demolitions or disasters such as fires or weather-related incidents between 1980 and 1993 averaged 245,000 per year. This is about three times the number reported by the Census Bureau based on permit data. Reasons for the higher number include unpermitted demolitions, municipalities that do not require permits, and

demolition permits that are handled by municipal offices other than building departments. Although CINCH data have been discontinued in 1995 due to federal budget cuts, these data are expected to be available through the American Housing Survey (AHS).

Houses of all ages and sizes may be demolished, but on average it is recognized that older houses are demolished more frequently, and older houses are on average smaller than new ones. New single-family housing units and multi-family housing units (including apartments and condominiums) built in 1995 averaged 2,100 square feet and 1,050 square feet, respectively. Figure 2 shows how average new house sizes have increased over the last 20 years. Multi-family houses have remained nearly the same, while new single-family houses grew from 1,600 square feet to 2,100 square feet. For this analysis, we assumed the average single-family and multi-family house sizes are 1,600 and 1,000 square feet, respectively, when demolished.

Figure 2. Average size of new house constructio:

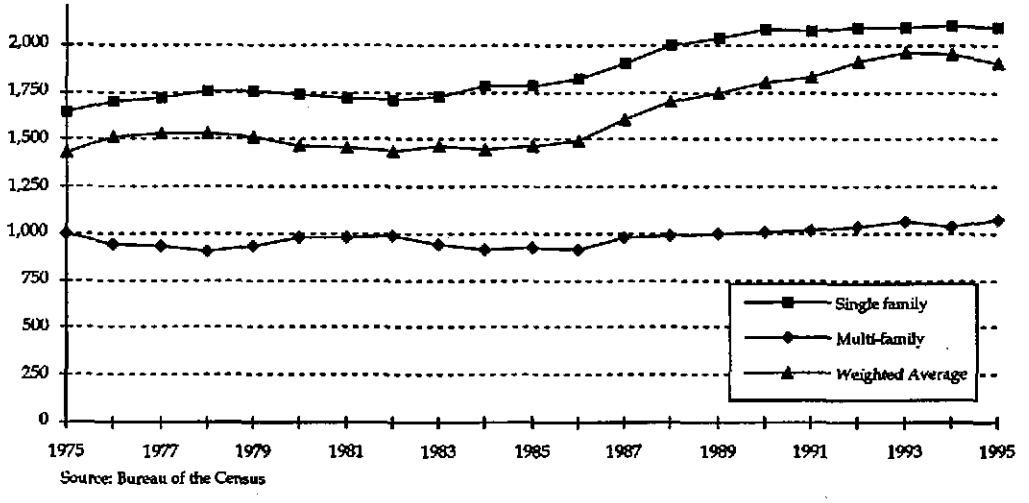


Table 5 shows three single-family house demolition assessments and one multi-family deconstruction assessment. The weight of houses when demolished depends critically on whether the houses have concrete foundations and basement walls or not. The use of masonry in exterior cladding also affects the house weight significantly. None of the three single-family houses in Table 5 had full basements. Therefore, we made adjustments to the sampling data to develop an estimate of residential demolition debris which reflects the likely impact of some of the demolished houses having basements.

Table 5

ESTIMATED GENERATION OF RESIDENTIAL DEMOLITION DEBRIS

EMPIRICAL WASTE ASSESSMENTS

Date	Research Group	Type of data	Location	Building Size (Square feet)	C&D Debris (Pounds)	Generation rate (Lb/sq ft)
1992	METRO	SF Demolition (1)	Portland, OR	1,280	66,000	52
1994	METRO	SF Demolition (2)	Portland, OR	1,200	63,000	53
1994	METRO	SF Demolition (3)	Portland, OR	750	31,000	41
	Total Single-family, without foundations			3,230	160,000	50
	Adjustment for concrete (4)				197,000	61
	Total Single-family, including concrete			3,230	357,000	111
1997	NAHB	4 unit MF Deconstruction	Maryland	2,000	254,400	127
	Weighted average for single-family and multi-family (Appendix A-3)					**115**

EXTRAPOLATION

Estimated number of residential demolitions per year	245,000
Estimated average size of residences demolished (sq ft)	1,396
Average C&D debris generation rate (pounds per square foot)	115
Total Generation of Residential Demolition Debris (tons/yr)	**19,700,000**

(1) 1920s house. Concrete rubble not included.
(2) Concrete rubble not included.
(3) Small house without basement.
(4) Franklin Associates estimate. See Table A-3 for calculation of amount of concrete, in lb/sq ft. (Assumes a composite house, i.e., partial basement, garage, etc.)

Source: Franklin Associates

The Census Bureau provides data on the types of foundations in existing houses in *Current Housing Reports*. Forty-five percent of single-family houses have basements, 26 percent are on concrete slabs, and the remainder have crawl spaces. Table A-3 in the appendix describes an analysis using these percentages to estimate that on average the amount of concrete in a 1,600 square foot single family house is 61 pounds per square foot. The amount can range from zero for houses without basements, garages, or driveways to more than 150 pounds per square foot.

We estimate the total C&D debris generated when single-family houses are demolished is 111 pounds per square foot. For multi-family housing, NAHB Research Center's value of 127 pounds per square foot (Table 5) was used, resulting in an average for all residences of 115 pounds per square foot. Applying this rate to the 245,000 housing units demolished per year results in a waste generation estimate of **19.7** million tons per year, as shown in Table 5.

Nonresidential. The method used to estimate the generation of nonresidential demolition debris is to first determine the number of demolitions per year, then estimate the average size (in square feet) of buildings being demolished. The number of square feet is then multiplied by the generation per square foot, as determined by empirical waste assessments.

The Census Bureau has, until 1995, monitored the number of demolitions, based on permits issued by permit issuing entities. This data series is now discontinued because of federal budget cuts. In 1995, a total of 43,795 nonresidential demolition permits were issued. That number is used in this study as an estimate for 1996. In 1994 there were 45,061 permits issued, which suggests that using the 1995 number for 1996 is a reasonable estimate. Data were not found indicating that the number of demolitions is actually larger than the permits would indicate. Therefore, no correction was made, as was done for residential demolitions. It is less likely that nonresidential demolitions escape the permitting requirements than residential demolitions, because nonresidential demolition is more closely regulated.

We estimated the average nonresidential building size at 13,300 square feet by the following method. The 1996 ***Statistical Abstract*** characterizes existing commercial buildings by type, including the number of buildings, and total square feet based on the time period (decade) when the buildings were built (EIA 1992). Based on those data, we determined that buildings now standing that were built between 1920 and 1969 average 13,300 square feet per building.

Table 6 shows the results of waste assessments at 23 nonresidential buildings over the last several years. The average generation rate is 155 pounds per square foot. Multiplying by the square feet per building and the total number of demolition permits results in a nonresidential demolition debris generation of **45.1** million tons per year.

Renovation Debris

Renovation (or remodeling) includes improvements and repairs to existing buildings. Renovation debris consists of both construction and demolition materials. Remodeling waste quantities are even more variable than construction or demolition waste. Renovation debris ranges from single materials being generated, such as when driveways or roofs are replaced, to multiple material generation, such as when buildings are modified or enlarged. For this analysis, we made estimates for wastes generated when major improvements are made.

Table 6

ESTIMATED GENERATION OF NONRESIDENTIAL DEMOLITION DEBRIS

EMPIRICAL WASTE ASSESSMENTS

Date	Research Group	Type of Building	Location	Building Size Square feet	Total Waste Tons	Generation rate Lb/sq ft
1991	NAHB	Prison shop	Oakalla, BC	12,000	1,301	217
1994-1995	METRO	Warehouse	Portland, OR	86,400	1,566	36
1992	METRO	Department store	Portland, OR	44,000	3,639	165
1994	METRO	Institutional building	Portland, OR	60,000	5,454	182
1997	Argonne	Office building	Chicago, IL	5700	289	101
1997	W. County	Cold storage building	Washington Co., OR	73,600	13,163	358
1995-1996	R.W. Rhine	17 Industrial buildings	Northwestern U.S.	2,204,000	167,200	152
		Totals		2,485,700	192,612	
		Average				155

EXTRAPOLATION

Total demolitions (1)	43,795	
Average building size (2)	13,300	sq ft
Average C&D debris generation rate	155	pounds per square foot
Total nonresidential demolition debris	**45,100,000**	**tons/year**

(1) U.S. Census Bureau, Manufacturing and Construction Division, 1995.
(2) U.S. Energy Information Administration, 1992. From 1996 Statistical Abstract.

Source: Franklin Associates

Residential. In 1996, the value of residential improvements and repairs amounted to $114.3 billion (Census 1997). Of this, 68 percent (or $77.7 billion) was for improvements and 32 percent (or $36.6 billion) was for repairs. Improvements are defined by the Census Bureau to include additions, alterations, and major replacements which add to the value or useful life of a property, or adapt a property to a new or different use. Repairs include incidental maintenance and repairs to keep a property in ordinary operating condition (C-Series Reports).

Because of the wide variation in remodeling projects, waste assessments to determine generation per square foot are not very useful for estimating total generation. More important is the amount of material produced per job, e.g., per kitchen addition or bath remodeling or roof replacement. Table 7 shows the results of five waste assessments that have been made at residential sites, showing a wide variation in generation rates on a square foot basis. Remodeling typically generates more waste per square foot than new construction, largely because of the demolition that accompanies remodeling. However, some remodeling jobs, like roof replacement, produce relatively low amounts of material on a square foot basis.

Table 7
EMPIRICAL WASTE ASSESSMENTS FOR RESIDENTIAL RENOVATION DEBRIS

Date	Research Group	Type of data	Location	Size of Project (Sq ft)	Total Waste (Pounds)	Generation rate (Lb/sq ft)	Average generation (Lb/sq ft)
1997	NAHB	SF Remodel (Kit & rm add.)	Maryland	560	11,020	19.68	
1997	NAHB	SF Remodel (bathroom)	Chapel Hill, NC	40	2,883	72.10	
		Totals		600	13,903		23.17
1993	METRO	Kitchen remodel	Portland, OR	150	9,600	64.00	
1993-1994	METRO	House remodel	Portland, OR	1,330	26,000	19.55	
		Totals		1,480	35,600		24.05
1997	NAHB	SF Remodel (New roof)	Maryland	1,400	4,640	3.31	3.31

Source: Franklin Associates

We estimated renovation debris generation for this analysis by reviewing the number of major home improvements, then estimating the amount of material produced by each type of improvement. Although all home improvement projects cannot be included in a study of this type, selection of the major projects can be useful for making first estimates.

Appendix A Tables A-7, A-8, A-9, and A-10 show some of the assumptions made and the results of estimating the amount of material produced when driveways are replaced, when asphalt and wood roofs from residences having one to four units per structure are replaced, and when residential heating and cooling equipment is replaced. Based on the assumptions made, replacement of these categories produces 13 million tons of concrete from driveways, 6.4 million tons of asphalt roofs, 1.4 million tons of wood roofing, and 1.6 million tons of heating, ventilating, and air conditioning (HVAC) equipment.

The analysis above assumes that 60 percent of residential driveways are made of concrete and are on average 45 feet long (NAHB 1995). Asphalt driveways are also very common, but replacement generates much less waste than concrete, since asphalt driveways are usually overlaid with new asphalt rather than being replaced.

Approximately 67 percent of residences have asphalt roofs (NAHB 1997a). For this analysis, 25 percent were assumed to have wood roofs. Other residential roofing materials include slate, tile, metal, and concrete. These materials are used much less than asphalt and wood, and generally are used over long periods before being replaced.

The NAHB Research Center has compiled estimates of waste generation rates by type of remodeling projects (Yost 1998). The major waste generation remodeling activities involve kitchens, bathrooms, and room additions. Generation from these job types are shown in Table A-5 in Appendix A.

Annually there are approximately 1.25 million major kitchen remodeling jobs (complete tear-out), with an average generation of 4.5 tons per job, and 1.25 million minor kitchen remodeling jobs (facelift, e.g., cabinet replacement) at 0.75 tons per job. Major bath remodelings (1.2 million per year) produce on average one ton of waste material each, and 1.8 million minor bath remodeling jobs produce on average 0.25 tons of waste each. Room additions, estimated at 1.25 million per year, produce on average 0.75 tons apiece. On this basis, we estimated total residential renovation generation, from the improvement or replacement projects itemized above, to be **31.9** million tons per year.

Nonresidential. Based on Census Bureau data, total dollars spent for nonresidential renovation projects in 1996 was $100.4 billion. We calculated this number by assuming the ratio of residential to nonresidential dollars is the same in 1996 as in 1992. We could not find any information on total renovation dollars for 1996.

Very few waste assessments are available for nonresidential renovation. Therefore, the previous methodology cannot be used to estimate this amount. Lacking specific assessment data, we compared total dollars spent on nonresidential and residential renovation and assumed that the amount of waste generated is proportional to dollars spent in these two sectors. (See Table A-6 for more details of this analysis.)

Based on the assumption that waste generation per dollar is equal to the residential rate, total nonresidential renovation is equal to **28.04** million tons per year, less than residential generation by the ratio of dollars spent.

Summary of Building-Related C&D Generation

Table 8 summarizes the estimates for C&D debris generation from the construction, demolition, and renovation of residential and nonresidential buildings in the United States. The estimated total for 1996 is almost 136 million tons, with 43 percent coming from residential and 57 percent from nonresidential sources. Forty-eight percent of the C&D debris generated is from building demolitions, 44 percent is from renovation, and 8 percent is from building construction.

Figure 3 provides a breakdown, in percent of total, of the six building sectors that generate C&D debris. The largest sector is nonresidential demolition at 33 percent. Residential and nonresidential renovation debris make up 23 and 21 percent, respectively, followed by residential demolition at 15 percent. New construction represents 8 percent of total C&D debris, with residential at 3.4 percent and nonresidential at 4.8 percent.

Table 8

SUMMARY OF ESTIMATED BUILDING-RELATED C&D DEBRIS GENERATION, 1996*
(Roadway, Bridge, and Land Clearing Debris not included)
(Thousand Tons)

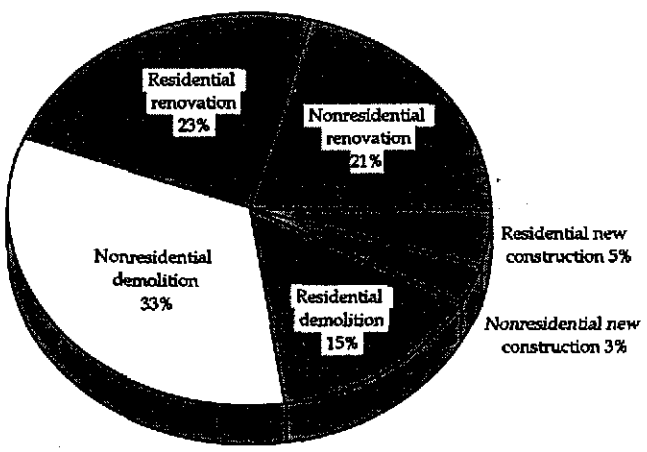
Source	Residential		Nonresidential		Totals	
	Thou tons	Percent	Thou tons	Percent	Thou tons	Percent
Construction	6,560	11	4,270	6	10,830	8
Renovation	31,900	55	28,000	36	59,900	44
Demolition	19,700	34	45,100	58	64,800	48
Totals	58,160	100	77,370	100	135,530	100
Percent	43		57		100	

* C&D debris managed on-site should, in theory, be deducted from generation. Quantities managed on-site are unknown.

Source: Franklin Associates

The estimate of 136 million tons per year is equal to 2.8 pounds per capita per day (pcd). This compares to 4.3 pcd of MSW generation. Note that the 2.8 pcd does not include C&D debris from roadway and bridge construction and demolition or from land clearing projects. These wastes are discussed briefly in the following section.

Figure 3. Generation of construction and demolition debris from buildings



CONSTRUCTION AND DEMOLITION DEBRIS GENERATION FROM ROAD, BRIDGE, AND OTHER NON-BUILDING ACTIVITIES

In this initial characterization study, we developed a methodology to estimate C&D debris generation from building construction, demolition, and renovation. However, because point source data were not available, we did not estimate the generation of site clearance materials, excavated materials, and roadwork materials. These are waste streams that will require further investigation in future editions of EPA's C&D work. These other wastes are typically managed by many of the same processors and landfills that manage building-related wastes.

We have made attempts, however, to provide certain cameo examples of locally generated data on most of these other generating sectors within the context of this report. Most communities and states that report C&D debris include the total C&D debris stream, which of course varies according to applicable regulations and definitions.

In 1995, a report was completed for Anne Arundel County, Maryland (part of the Metro Washington, DC area) that attempted to quantify total C&D debris generated and/or disposed in that County (GBB 1995). The report concluded that 138,000 tons per year of in-County generated C&D waste was being disposed at area C&D landfills (called "rubblefills" in the State of Maryland), while 435,000 tons per year of C&D debris materials were processed/recycled. This latter figure was reported to be about 12 percent wood waste and 88 percent concrete, asphalt, brick, block and porcelain waste generated in the County. This particular report is significant in the sense that it represents an example of total C&D generation in a large developing community.

STATE CONSTRUCTION AND DEMOLITION DEBRIS GENERATION RATES

We identified six states that have C&D debris generation records available. They are California, Florida, Massachusetts, Oregon (Portland metropolitan area), South Carolina, and Vermont. Generation of C&D debris from these states ranged from 1.43 pcd in South Carolina to 3.41 pcd for Massachusetts.

All of these states except Massachusetts report rates lower than 2.8 pcd, which is our estimate for building-related debris alone. The state data may include road debris as well. There are several reasons some of the states' estimates may be low. The six states' data reflect reports from facilities receiving C&D debris. Some of the many locations typically accepting C&D debris—ranging from established landfills to processors to sites with temporary permits (or no permits)—may be missed when C&D debris quantities are reported. Also, C&D debris mixed with MSW may be missed. In some states, road debris (asphalt and concrete) is mostly reused or recycled; it either remains on site or is incorporated into other roads. Thus, very little road debris would be expected in the states' quantities.

It is important to note that the methodology used in this report includes all building-related C&D debris, whether managed in C&D or MSW landfills, processing centers, land clearing landfills, or unpermitted landfills. It also includes on-site managed waste, if any, e.g., concrete or asphalt that is used as fill material, since no method was determined for making a correction. An important feature of the methodology used for residential demolition debris estimation, i.e., changes in housing inventory, is that residential buildings destroyed by natural disasters are included in this estimate.

We contacted two of the states by phone to discuss their C&D debris generation estimates. Florida reported a generation rate in 1995 of 2.01 pounds per capita per day. This rate was determined from reports to the state by each of the counties. The waste reported consists primarily of building waste, and is thought by the official contacted to be under-reported by many of the counties (Moreau 1997).

South Carolina has a reported generation rate of 1.43 pcd. The person contacted thinks that number is also grossly under-reported (Pitt 1997). C&D debris landfills for utilities and manufacturing and short term landfills are not required to report their quantities in South Carolina, and are not monitored by the State.

COMPOSITION OF CONSTRUCTION AND DEMOLITION DEBRIS

Six sets of C&D sorting data that provide some empirical measurements of the composition of C&D debris were identified. Each of the sampling studies was conducted with the specific goal of developing composition data for C&D debris. Probably the most rigorous assessments have been conducted at residential construction sites. These waste assessment projects are:

1. The National Association of Homebuilders (NAHB) Research Center conducted waste assessments at four residential construction sites: Largo, Maryland; Anne Arundel County, Maryland; Portland, Oregon; and Grand Rapids, Michigan. The Research Center also conducted a waste assessment at a four-unit multi-family demolition (or deconstruction) site (NAHB 1997b).

2. The Metropolitan Service District in Portland, Oregon (METRO) conducted a series of sampling projects at a number of residential and nonresidential construction, demolition, and renovation sites in Oregon.

3. Cunningham Environmental Consulting and the Cascadia Consulting Group sampled loads of C&D debris at disposal sites and transfer stations. Loads of residential and commercial construction, demolition, and remodeling debris from the Seattle area were selected (Cunningham 1996). Detailed sorting of these loads was done.

4. Gershman, Brickner & Bratton, Inc. (GBB) conducted a C&D sorting study for the Town of Babylon, New York that was funded by the New York State Energy Research and Development Authority (NYSERDA). The three-week study included C&D samples from waste loads from all or parts of 16 residential and nonresidential construction, demolition, and renovation projects (Brickner 1993). A total of 161.5 tons were sorted.

5. GBB, in association with the Metro Waste Authority, also sampled C&D debris from residential and commercial construction, demolition, and remodeling projects in Des Moines, Iowa for a one-week period (Brickner 1995).

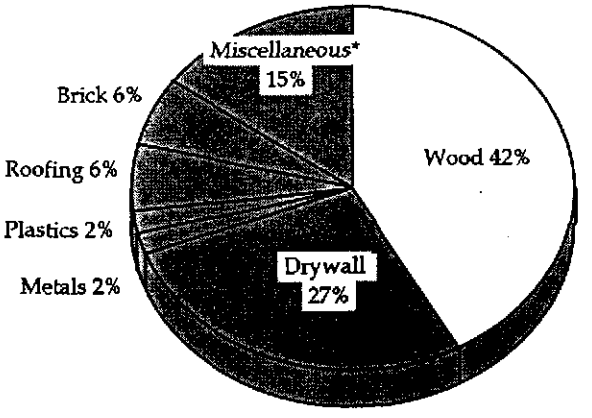
6. R.W. Rhine, Inc. of Tacoma, Washington, a demolition contractor, provided waste assessment data from the demolition of 19 nonresidential (industrial/commercial) buildings in the greater Northwest area.

In addition to the analyses listed above, the University of Florida is conducting waste audits at Florida residential construction sites. Data from these studies are expected to be available soon.

The detailed composition data from the sampling studies are shown in Tables A-11 through A-18 in Appendix A of this report. A review of these tables demonstrates that the composition of C&D debris is highly variable, as may be expected because of the many different types of buildings and construction practices in existence. The data collections were done under many different conditions and levels of detail. Therefore, we made no attempt to average all the compositions. Although different, there are some observations that can be made.

The first two (Tables A-11 and A-12) and sixth (Table A-16) sets of data characterize waste at the source, i.e., at specific construction or demolition sites. The other three data sets (Cunningham in the Seattle area and GBB in Babylon, New York and Des Moines, Iowa) characterize debris as disposed at the landfills. The sectors (or sources) for each load of C&D debris that was sorted are identified, but the specific phase of construction or demolition is not identified.

Figure 4. Sample composition of residential new construction debris (Average of assessments in four locations)



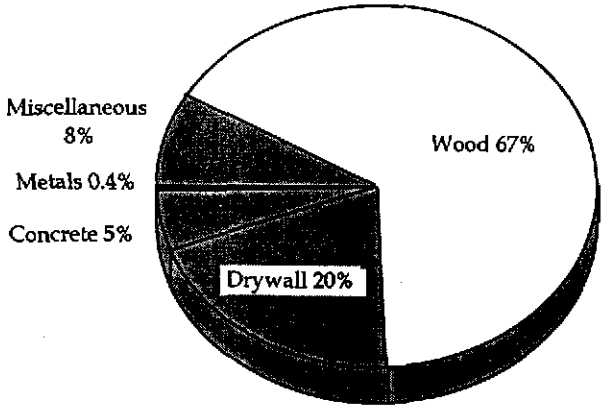
Source: NAHB Research Center * Refuse, dirt, sweepings, and aggregat

NAHB and Metro examined both composition and quantity per square foot of floor space for single-family housing. Both of these groups developed data from well-defined construction projects, i.e., the materials consist of trim scraps from beginning to end of the residential construction process, without serious contamination from other sources. Figures 4 and 5 show these data in percent by weight. Figure 4 shows the average composition for four single-family houses, two in the East, one in the Midwest, and one in the Northwest. Wood is the largest component, followed by drywall.

Figure 5 shows the composition from three new residential construction sites in the Portland, Oregon area. The percentage of wood in the Northwest samples is considerably higher, as may be expected, because a large fraction of homes in the Northwest have wood roofs. Residential construction debris in the Southwest and southern United States is expected to contain a lower percentage of wood than in the East and Midwest, and more brick and cinder blocks. As waste assessment data become available in other regions of the country, it will be possible to develop an overall composition for residential construction debris and to relate composition to total generation, i.e., estimate total C&D debris generation by material type.

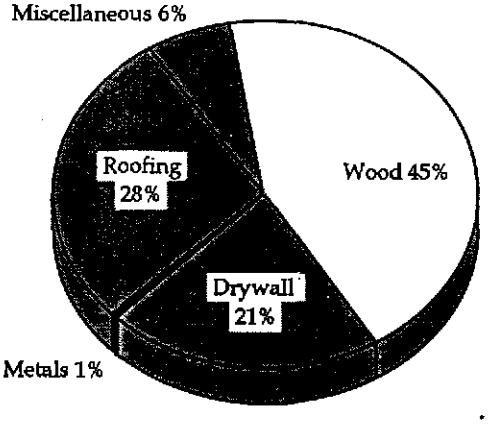
Figure 6 shows the composition of residential renovation debris in the Northwest. This stream is similar to the construction debris stream, but with an obvious difference, an increase in the amount of roofing materials. Only trim pieces of roofing are included in new construction debris.

Figure 5. Sample composition of residential new construction debris (Average of three sites, Portland, Oregon)



Source: METRO Portland, Oregon

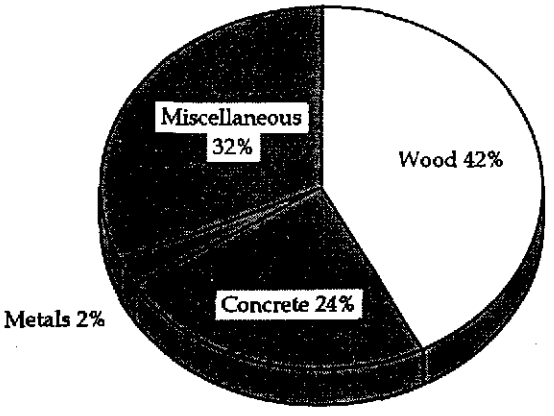
Figure 6. Sample composition of residential renovation debris (Average of two sites, Portland, Oregon)



Source: METRO Portland, Oregon

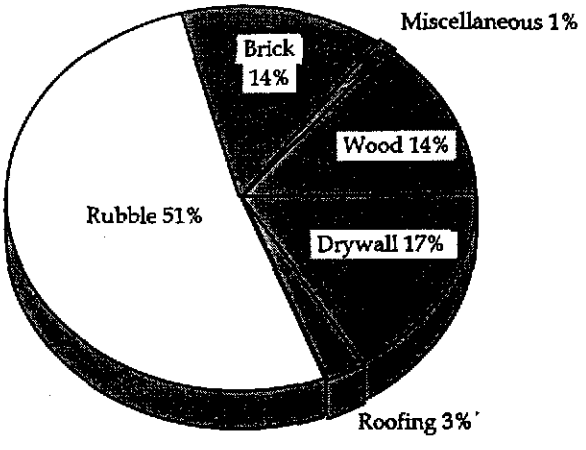
Concrete is missing from the renovation stream of Figure 6. Obviously these two projects did not include projects like driveway replacement. This demonstrates that many samples are required before we can report an overall composition that represents the U.S. average with confidence.

Figure 7. Sample composition of residential demolition debris (Average of three sites, Portland, Oregon)



Source: METRO Portland, Oregon.

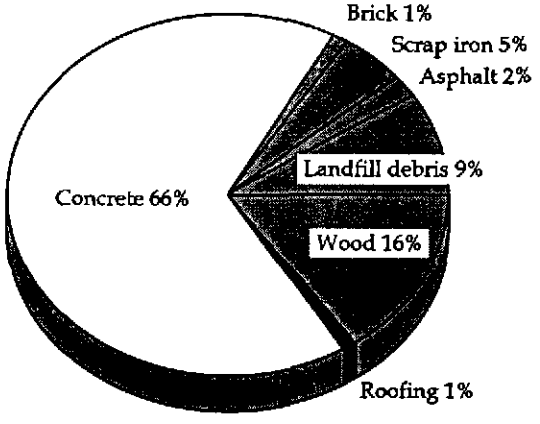
Figure 8. Sample composition of multi-family demolition debri



Source: NAHB Research Center, Inc.

Figure 7 displays the composition of residential demolition debris. Concrete is an obvious component of this stream, as it is in Figure 8, which shows the composition of a 2,000 square foot two story four-plex that was disassembled by NAHB in a demonstration project for the USEPA.

Figure 9. Sample composition of demolition debris (19 nonresidential projects in the Pacific Northwest)



Source: R.W. Rhine, Inc., Tacoma, WA

Figure 9 shows the average composition of 19 nonresidential buildings that were demolished in the Northwest area. These were large industrial/ commercial type buildings that ranged in weight from 891 tons to 37,500 tons. While this figure represents the average composition, the percentage of wood ranged from 0.03 percent to 88 percent in the 19 buildings. This demonstrates the huge variability of building types.

Some general observations can be made from these figures. Residential construction and renovation projects tend to yield significant quantities of wood and drywall, whereas demolition sites are heavily weighted toward concrete and rubble. The debris from 19 nonresidential demolition projects of Figure 9 averaged 66 percent concrete.

Chapter 2

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Chapter 3

MANAGEMENT OF CONSTRUCTION AND DEMOLITION DEBRIS IN THE UNITED STATES

INTRODUCTION

Construction and demolition (C&D) debris is managed in a variety of ways, ranging from reuse to recycling to disposal in landfills or combustion facilities. The most common management method is landfilling, including specially permitted C&D landfills and municipal solid waste (MSW) landfills, as well as unpermitted inert debris sites.

In most states there is no formal reporting mechanism that documents C&D debris disposal, recovery, or recycling activities. The information collected by many state agencies is largely anecdotal. In addition, information from private companies is generally considered to be proprietary and not available for public dissemination.

LANDFILLING

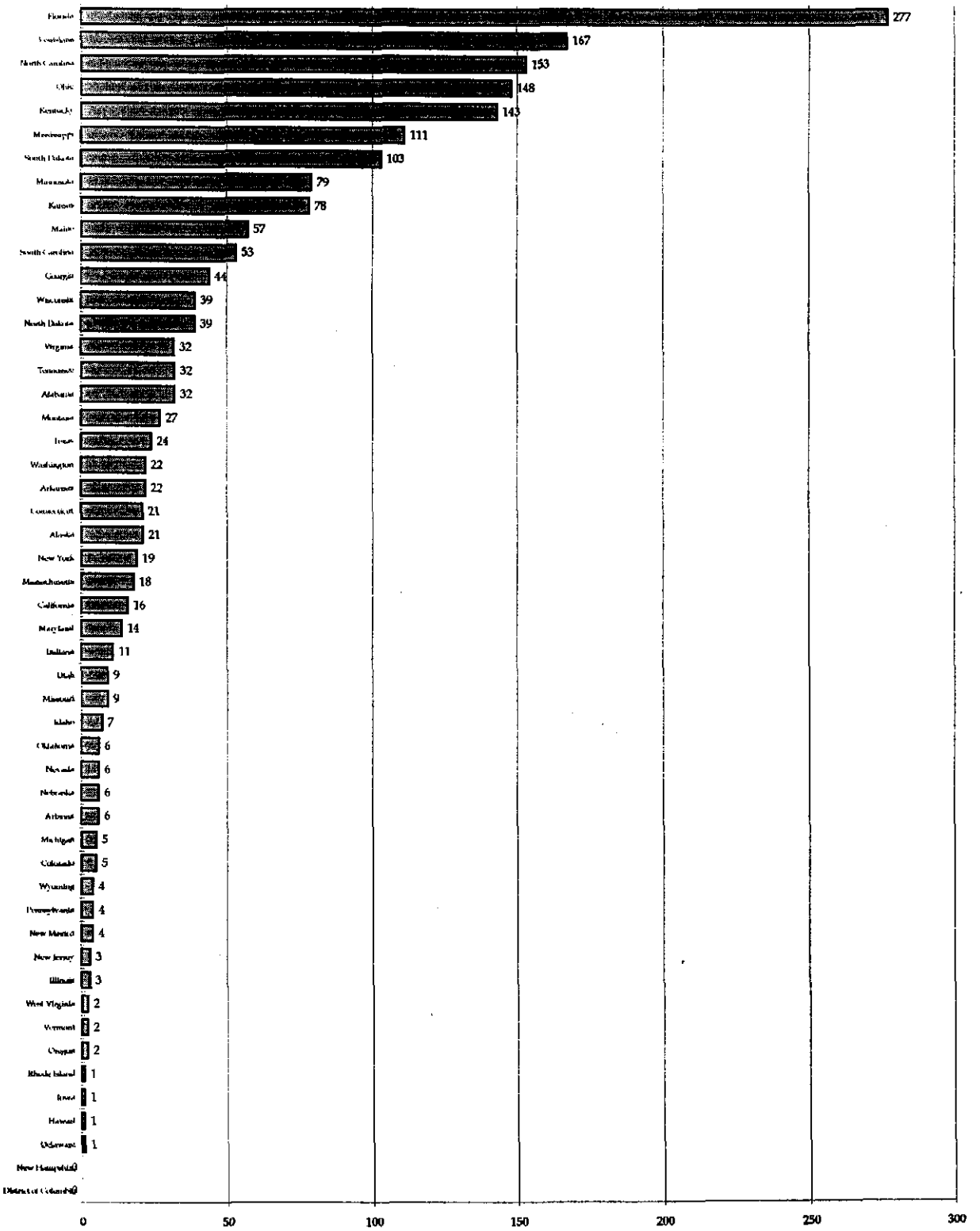
A large fraction of C&D debris generated in the United States ends up in C&D landfills. Since much of this waste stream is inert, solid waste rules in most states do not require the landfills to provide the same level of environmental protection (liners, leachate collection, etc.) as landfills licensed to receive MSW. Therefore, C&D landfills generally have lower tipping fees, and handle a large fraction of the C&D debris.

A 1994 survey done for the EPA identified about 1,900 active C&D landfills in the United States (ERG 1994). Florida had the largest number (280), followed by six other states (Louisiana, North Carolina, Ohio, Kentucky, Mississippi, and South Dakota) with over 100 C&D landfills apiece. (See Appendix A, Table A-19 and Figure 10.)

A recent survey of 850 randomly selected C&D landfills in the United States (40 percent response rate) found that on average, C&D landfills received 29,300 tons of material in 1995 (Bush 1997). Assuming that average holds true for the 1,900 active landfills, 55.6 million tons per year are disposed of in permitted C&D landfills. This amount is equal to about 41 percent of the estimated 136 million tons of building related C&D debris, as estimated in the previous chapter. However, this 55.6 million tons is likely to contain significant amounts of non-building C&D debris.

The amount of C&D debris disposed of in MSW landfills is not known. It is significant, however, because in many areas, particularly where landfill tipping fees are low, disposal in MSW landfills is the most common management method for C&D debris.

Figure 10. Number of C&D debris landfills in the United States



Source: ERG List prepared for USEPA, September 30, 1994.

A significant fraction of residential renovation debris is discarded by homeowners into the household trash and disposed of in MSW landfills. Discarded items include replacement plumbing and electrical fixtures, lumber, and other building materials used in home repair or improvement projects.

Unpermitted landfills for C&D debris are also very common in many states. These are fill areas for inert materials, with little or no control or record keeping by the state or local governments. Some of these are on-site facilities that are used only for the disposal of C&D debris generated at a specific site and may be closed following completion of the activity. Little data exists on the number of unpermitted C&D landfills nationwide. Georgia, the only state known to count them, has about 900 such sites (ICF 1995).

Open burning of C&D debris at construction sites is practiced in many rural areas as well as in many small to medium size cities. The amount of material burned is unknown.

Regulatory schemes used by states for C&D landfills have been divided into four categories as summarized in Table 9. Eleven states require C&D landfills to meet state MSW landfill requirements or requirements similar to these. Twenty-four states regulate C&D landfills separately from MSW landfills. In addition to the 24 states that regulate all C&D landfills as a landfill unit separate from sanitary landfills, eight states have defined further separate requirements for on-site and off-site C&D landfills. Of those eight states, Maine requires both off-site and on-site landfills to meet MSW landfill rules if they are greater than six acres. Seven states exempt all on-site landfills from regulatory requirements. Of these seven, sanitary landfill regulations apply to all off-site landfills in Colorado and New Mexico.

In summary, disposal in landfills is the major waste management option for C&D debris from buildings. We estimate that C&D, MSW, and other landfills account for roughly 65 to 85 percent of that waste stream.

RECOVERY OF C&D DEBRIS FOR RECYCLING

The six major constituents of C&D debris, if not too severely contaminated, have all been recovered and processed into recycled-content products that have been marketed somewhere in the United States. The materials most frequently recovered and recycled are concrete, asphalt, metals, and wood. To a much lesser degree, gypsum wallboard and asphalt shingles have been processed and recycled. The technologies to recover and process these materials for reuse are available. The major barriers to increased recovery rates at this time are:

Table 9

STATE REGULATORY SCHEMES FOR C&D LANDFILLS

State	Must meet MSW Landfill Requirements	Separate C&D Debris Regulations	Separate Requirements for On-Site and Off-Site Landfills	Exempt On-Site C&D Debris Landfills from Regulation
Alabama		Yes		
Alaska	Yes			
Arizona	Yes			
Arkansas		Yes		
California		Yes		
Colorado				Yes
Connecticut	Yes			
Delaware		Yes		
Florida		Yes		
Georgia		Yes		
Hawaii				Yes
Idaho	Yes			
Illinois			Yes	
Indiana		Yes		
Iowa	Yes			
Kansas		Yes		
Kentucky			Yes	
Louisana				Yes
Maine			Yes	
Maryland		Yes		
Massachusetts	Yes			
Michigan			Yes	
Minnesota		Yes		
Mississippi				Yes
Missouri		Yes		
Montana		Yes		
Nebraska	Yes			
Nevada	Yes			
New Hampshire		Yes		
New Jersey			Yes	
New York		Yes		
New Mexico				Yes
North Carolina		Yes		
North Dakota	Yes			
Ohio		Yes		
Oklahoma	Yes			
Oregon				Yes
Pennsylvania			Yes	
Rhode Island	Yes			
South Carolina		Yes		
South Dakota		Yes		
Tennessee			Yes	
Texas		Yes		
Utah				Yes
Vermont		Yes		
Virginia		Yes		
Washington		Yes		
West Virginia			Yes	
Wisconsin		Yes		
Wyoming		Yes		
Total Number	**11**	**24**	**8**	**7**

Source: ICF Incorporated. "Construction and Demolition Waste Landfills." February 1995.

- the cost of collecting, sorting, and processing;
- the low value of the recycled-content material in relation to the cost of virgin-based materials, and
- the low cost of C&D debris landfill disposal.

Responses to a survey of North American aggregate producers indicated that plant permitting issues, as well as product specifications that favor the use of virgin materials, were also problems facing recyclers (Deal 1997).

The number of recycling facilities for C&D debris has been growing rapidly in the last few years. In 1996, it was estimated there were at least 1,800 operating C&D recycling facilities (Brickner 1997). That number includes more than 1,000 asphalt and concrete crushing facilities, 500 wood waste processing plants, and 300 mixed-waste C&D facilities. No information is available on the average throughput of these facilities.

The estimate of 1,800 C&D facilities does not include quarry rock crushing plants, brush/tree tub grinding plants, or pallet grinding operations. The asphalt and concrete crushing plants handle large quantities of road debris, but also concrete recovered from building construction, renovation, and demolition.

The largest number of C&D recycling facilities were reported to be in the Western States (28 percent) and the Mid-Atlantic states (27 percent). The Southwestern and Rocky Mountain States each have only three percent of the total, and the Southeastern, Upper Midwestern, and New England states have 12, 13, and 14 percent of the facilities, respectively.

Because of the effort being exerted to develop markets for recovered materials, the number of C&D recycling facilities is continuing to grow. A July 1997 status update lists 37 new recycling plants or equipment additions in the United States, including planned projects for the rest of 1997 (Leiter 1997). The editor of **C&D Debris Recycling** estimates there are now more than 3,500 C&D debris recycling facilities in operation (Turley 1998).

Deconstruction

Deconstruction is a new expression to describing the process of selective dismantling or removal of materials from buildings before or instead of demolition (NAHB 1996a). A common practice in the United States is to remove materials of value from buildings prior to and during demolition for recycling or reuse. Reuse and recycling examples include electrical and plumbing fixtures that are reused, steel, copper, and lumber that are reused or recycled, wood flooring that is remilled, and doors and windows that are refinished for use in new construction.

Demolition contractors have been practicing deconstruction in varying degrees for a number of years to remove some of the more valuable materials prior to demolition by conventional methods. This activity, along with recovery of demolition materials after the building has been knocked down, has increased significantly since the 1970s and 1980 (Taylor 1997). Deconstruction minimizes contamination of demolition debris, thus increasing the potential for marketing the recovered materials. It is, however, labor intensive, and may require more time than traditional demolition.

Several deconstruction demonstration projects have been completed recently, showing that high diversion rates may be achieved. The NAHB Research Center completed the deconstruction of a two-story, four-unit apartment building in Maryland (NAHB 1997). The Research Center measured the volume and the weight of all materials on site, whether salvaged, recycled, or landfilled. The diversion rate was 76 percent by weight and 70 percent by volume.

In another recent demonstration project, three buildings were deconstructed at the recently closed Fort Ord Army Base, located in Monterey County, California (Schneider 1997). The buildings included a one-story clinic, a single-story administration building, and a two-story barracks. Goals of this project include the evaluation of costs and potential recovery.

Asphalt and Concrete Recycling

Concrete is made up of cement, water, and aggregate, such as crushed stone, sand, or grit. Concrete can be recycled by first crushing it to remove any metals. The primary use of crushed concrete is as a replacement for road-base gravel. Other applications include use as an aggregate in asphalt or concrete. Concrete recycling is practiced in most areas of the country. The practice is most prevalent in areas where landfill tipping fees are high or aggregate is in short supply.

Asphalt pavements are made of asphalt concrete (AC), which consists of asphalt (the bituminous binder) and aggregate. The aggregate makes up the bulk of the asphalt concrete, while the asphalt binder comprises about 5 to 7 percent CIWMB 1997).

While no reports have been identified showing the amount of asphalt and concrete recycled, some datapoints that provide indications of the amounts recycled are discussed below (Brickner 1997).

As stated above, it is estimated there are more than 1,000 asphalt and concrete crushing facilities in the United States. GBB estimates that potentially 50 million tons per year of milled pavement in the United States is reused. Twenty to 50 percent goes back into pavement as Reclaimed Asphalt Pavement (RAP), with the remainder finding its way into aggregate base or subbase. GBB research in the Pacific Northwest, for example, has estimated that for the State of Washington alone, the use of RAP is between 650,000 and 1,000,000 tons per year.

Based on data collected for the State of Washington from waste concrete processors/recyclers, GBB has estimated that 1.4 to 1.5 million tons of waste concrete in that state are recovered, crushed, and recycled on an annual basis.

In Anne Arundel County, Maryland, an area between Washington, DC and Baltimore, Maryland, GBB field work in 1995 indicated that the concrete and asphalt processors in that County alone were receiving, crushing and recycling over 850,000 tons per year of these two types of materials (includes out-of-county generation).

In California, asphalt pavement and concrete are not reported separately. The state estimated generation of "inert solid waste," which consists of concrete, asphalt, dirt, brick and other rubble, at 8.2 million tons per year. The estimated recycling rate for inert solid wastes is 57 percent; the remainder is disposed of (CIWMB 1997).

Waste Wood Recycling

Wood waste produced at construction sites generally has a better potential for reuse than wood from demolition sites due to the ease of separating the materials. Demolition wood is often less desirable because of contamination and because of the difficulty in separating the wood from other building materials.

Wood processing facilities have sprung up in many areas of the United States in recent years, particularly in areas with high landfill costs. Many of these facilities accept wood from C&D debris as well as other wood. Processed (chipped) wood is used as mulch, composting bulking agent, animal bedding, and fuel. Wood waste from construction or demolition is attractive as a fuel because of its low moisture content. Depending on the wood waste boiler system design and the state/regional air pollution permit requirements for the facility, a level of quality control may be necessary at the wood processing plant to reduce and/or avoid the processing of treated and/or painted wood if used as a fuel source in a combustion process.

The American Forest & Paper Association (AF&PA) has located 315 wood processing facilities in the United States that process C&D debris, as shown in Table A-20 of the Appendix. These facilities were included in the estimate of 500 wood processing plants as discussed above. The leading states for these wood processing plants are North Carolina (44), Oregon (35), and California (34). Quantities of wood processed are not given in the AF&PA report.

Metals Recycling

Metals have the highest recycling rates among the materials recovered from C&D sites. Good markets for ferrous metals, as well as copper and brass, have existed for many years. The Steel Recycling Institute estimates the recycling rate for C&D steel is about 85 percent (18.2 million tons out of 21.4 million tons generated). These numbers include not only scrap steel from buildings but also from streets, bridges, and highways (Heenan 1996). The percentage of metals coming from roads and bridges is unknown.

A 1997 survey of North American aggregate producers by Vanderbilt University and C&D Recycling Magazine found that the markets for waste rebar removed from the concrete rubble appear to have increased from 1994 to 1997 (Deal 1997). Twenty-one percent of the 1994 recyclers depended on disposal for their rebar compared to 4 percent in 1997.

Asphalt Shingles

Asphalt shingles are most commonly used on slanted residential roofs. Built-up roofing, which consists of roofing felt between layers of tar and gravel, is traditionally used on flat commercial roofs. These two materials represent the majority of the waste coming from roof replacement or repair. About two-thirds of the residential roofing market is made up of asphalt shingles (NAHB 1996b). Other roofing materials include wood, tile, and concrete.

The common uses for recycled roofing asphalt include hot mix asphalt for paving, cold mix asphalt paving product, and new roofing materials. Meeting the specifications for paving and roofing materials is still limiting the growth of these applications. Preconsumer manufacturing scrap (approximately one million tons per year) is currently being used in hot mix asphalt; however, postconsumer scrap (estimated at 8 to 10 million tons per year), which is less uniform in composition, is not nearly as widely used or recommended for use in hot mix asphalt (Button 1997).

Drywall (Sheetrock, Gypsum)

Drywall is being recycled in several locations by first separating the paper backing, which is recycled into new paper backing, and then remixing the gypsum and using it in the manufacture of new drywall. Recovered drywall has also been used as animal bedding, cat litter, and as a soil amendment.

Estimated Recovery Rate

Because of the relatively benign nature of C&D debris (i.e., much of it is inert), there has been no concerted effort in the past to track and quantify the generation or recovery rate from a national perspective. Therefore, only general estimates can be made based on data from those local communities and states that monitor the waste stream.

A total survey of states was not feasible for this project, but several states were contacted in an attempt to estimate of the national recovery rate for C&D debris. States representing more than 50 percent of the U.S. population were contacted. Most states contacted have no statewide records available on the quantity of C&D debris generated or recovered for recycling. We identified five states that report recycling rate data for C&D debris. The recovery rates in the five states range from 37 percent to 77 percent. The five states and their reported recovery rates are:

Massachusetts	77 percent
Florida	46 percent
Vermont	37 percent
Oregon (Metro)	42 percent
South Carolina	40 percent
Average	48 percent

These data confirm that there is significant recovery of C&D debris for recycling in these locations. However, it is not likely that these five states are representative of the United States as a whole. We expect that the states that keep records have higher recovery rates than the national average.

The definitions of what constitutes C&D debris and what constitutes recycling among the states are not standardized, as was discussed earlier, although most C&D debris definitions include both building-related wastes and as road and bridge debris. Massachusetts includes asphalt and concrete from roads in both the numerator and denominator of the recovery rate calculation, but does not include land clearing debris, (i.e., stumps, soil, rock, etc.). Florida's recovery numbers include primarily building debris and land clearing debris. Road debris is generally not counted (Moreau 1997).

Several methods were explored for estimating a national recovery rate for C&D debris. The first is to look at the relationship of recovery rate and landfill tipping fees. It might be expected that states with low C&D landfill tipping fees have lower recovery rates.

Lowest C&D landfill tipping fees are generally in the lower population density states, such as the Midwest, where the average has been reported at $19.70 per ton, compared to $46 and $42.60 per ton in the Northeast and West, respectively (Bush 1997). A large number of states in the Midwest do not have recovery rate records. In the South, the average is $27.10 per ton. Using tipping fees as a guide, a conservative estimate would be that the average recovery rate might be about half of the average of the five states reporting recovery rates, or 20 to 30 percent of generation.

To test how reasonable the 20 to 30 percent estimate is, consider the 1,800 C&D debris recovery facilities referred to above. Assuming the 1,000 concrete and asphalt plants handle primarily road debris, there are 800 or more wood and mixed waste processors that are thought to handle primarily building debris. Recycling rates of 20 to 30 percent (27 to 41 million tons per year) would result in an average throughput of 90 to 140 tons per day, which appears to be a reasonable average size.

SUMMARY OF C&D DEBRIS MANAGEMENT PRACTICES

Over the past 10 years a significant amount of data has been collected on the amount of C&D debris disposed of at C&D and MSW landfills and the amount processed at recycling facilities. The studies were conducted at the municipal, county, or state levels. Research has also been conducted on the number of C&D landfills and processing facilities in operation on the national level. This foundation of new research was used to estimate how C&D debris is managed on a national level.

Table 10 summarizes our estimated C&D debris management practices in the United States in 1996. These quantity estimates apply to building-related wastes, as estimated in Chapter 2. An estimated 35 to 45 percent of the waste generated is managed in C&D landfills, 20 to 30 percent is recovered for recycling, and 30 to 40 percent is disposed of in MSW landfills and other disposal sites, such as unpermitted landfills or combustion facilities.

Table 10
ESTIMATED MANAGEMENT OF BUILDING-RELATED C&D DEBRIS IN THE UNITED STATES, 1996

Management Option	Million tons/year	Percent of Total
Recovered for recycling	25-40	20-30
C&D landfills	45-60	35-45
MSW landfills and other*	40-55	30-40
Totals	136	100

* Includes combustion and disposal in unpermitted sites.
Source: Franklin Associates

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Recycled Aggregate

Introduction

This fact sheet is an overview of recycled aggregate, which is produced by crushing concrete, and sometimes asphalt, to reclaim the aggregate. Recycled aggregate can be used for many purposes. The primary market is road base.

Benefits of Recycled Aggregate
The use of recycled aggregate can save money for local governments and other purchasers, create additional business opportunities, save energy when recycling is done on site, conserve diminishing resources of urban aggregates, and help local governments meet the goal of reducing disposal by 50 percent by the year 2000.

What About Recycling Asphalt into New Asphalt Pavement?
This fact sheet is NOT about recycling asphalt pavement into new asphalt pavement. See *Asphalt Pavement Recycling*, CIWMB Pub. #431-95-067.

Quantities

Source
The 1990 waste stream composition data were reported to the California Integrated Waste Management Board (CIWMB) by local governments, in response to the Integrated Waste Management Act of 1989. These reports supplied the following information:

Construction and Demolition (C&D)
C&D materials made up about 28 percent of California's waste stream, or approximately 11 million tons.

Asphalt and Concrete
While asphalt and concrete were not reported separately in these data, generation of "inert solid waste," which consists of concrete, asphalt, dirt, brick, and other rubble, was conservatively estimated at 8.2 million tons. The estimated recycling rate for inert solid wastes was 57 percent; the remainder was disposed of.

Materials/Definitions

Aggregate consists of hard, graduated fragments of inert mineral materials, including sand, gravel, crushed stone, slag, rock dust, or powder.

Inert solid waste is concrete, asphalt, dirt, brick, and other rubble.

Portland cement concrete (PCC) and **asphalt concrete (AC)** consist primarily of aggregate. The cement and asphalt serve as binders. Some PCC contains steel reinforcement bars, or "rebar," such as a bridge deck or tilt-up slabs. When a road or structure is demolished, the rebar can often be seen protruding from the broken chunks of PCC.

Recycled aggregate comes primarily from PCC and AC from road rehabilitation and maintenance, demolition, and leftover batches of AC and PCC. After processing, the rocks retain bits of cement or asphalt.

A **roadway** is built in several layers: pavement, base, and sometimes subbase. The **pavement** is the surface layer, and is made of PCC or AC. The **base** layer supports the pavement, and is made of **aggregate base (AB)**. The subbase layer supports the base and is made of **aggregate subbase (ASB)**. The subbase layer allows more sand, silt and clay than the AB layer; the subbase layer has less strength, but is used because it is more economical when bringing the road up to grade.

Equipment

The AC and PCC generally arrive at the processor in chunks. Heavy crushing equipment is required to break up the chunks into aggregate. Some equipment is portable and can be set up on site for immediate use of product. A crushing plant may include a **hopper** to receive the material, a **jaw** to break it into more manageable pieces, a **cone** or **impact crusher** to further reduce its size, a vibrating **screen** to sort to the required specification, and a

conveyor belt with a rotating **magnet** to remove metal contamination such as rebar.

Butte County. Butte County does not require recycling of inerts; however, the local landfill does use clean loads of inerts on site as roadbase or wet weather pads.

Recyclers

According to the Board's current information, there are approximately 100 producers of recycled aggregate in California. Some receive PCC and/or AC at the plant; others have mobile equipment for in-place recycling. Aggregate recyclers are included in two databases: *Construction/Demolition Recyclers—Processors & Receivers* and *Recycled-Content Construction Products*, which can be searched at the Board's C&D web site, http://www.ciwmb.ca.gov/mrt/cnstdemo/default.htm. Hard copies of the lists can be ordered from the CIWMB (see p. 4).

Markets

Uses

Recycled aggregate can be used:

In paved roads as aggregate base, aggregate subbase, and shoulders.

In gravel roads as surfacing.

As base for building foundations.

As fill for utility trenches.

At this time, the primary market is aggregate base and subbase in road projects.

Local Governments

Local governments can help promote markets for recycled aggregate because they are large purchasers of aggregate and other road construction products. Some communities are taking steps to promote recycled aggregate, including the following:

Los Angeles. In March 1995, the City of Los Angeles passed a motion requiring that roadbase in all city projects include "crushed miscellaneous base (CMB) with 100 percent recycled asphalt, concrete, and other inerts, except when site conditions or standards require another specification." (See discussion of CMB under *Greenbook* Specifications below.)

Modesto. The City of Modesto has a purchasing practice for on-site street recycling that includes recycled aggregate.

Palo Alto. The City of Palo Alto requires that concrete and asphalt in city projects is recycled.

Specifications

Many local jurisdictions use Caltrans specifications. In Southern California, the *Greenbook* is commonly used. (See *Greenbook* discussion below.) Where recycled aggregate is allowed, it must also, of course, meet the same grading and quality specifications as virgin aggregate.

Caltrans Specifications—Procedures

Caltrans takes a new specification through three stages:

1. **Special Provision (SP).** First it is an SP where it is used initially on a number of projects.
2. **Standard Special Provision (SSP).** After the SP has been used successfully for a period of time, it usually becomes an SSP which means that it is a method approved by Caltrans.
3. **Standard Specification.** After the SSP has been used successfully for a period of time, then it usually becomes a Standard Specification, and is included in Caltrans *Standard Specifications*, which is published every four years. The latest edition using English measurements is dated July 1992. A metric edition was published July 1995; all subsequent editions will be metric. The next edition is anticipated in 1998 or 1999.

Caltrans Specifications—Existing

Caltrans' *Standard Specifications, July 1995* covers aggregate base and aggregate subbase in Sections 25 and 26. These sections do not mention recycled aggregate. However, Caltrans SSPs do allow "reclaimed asphalt concrete, portland cement concrete, lean concrete base, cement treated base," or "glass" in Class 2 and 3 aggregate base, and also in Class 1, 2, and 3 aggregate subbases.

There are two ways to obtain SSPs:

Internet. To download SSPs via the Caltrans web site, you must have a computer, a modem, and a web browser to access the Internet.

1. Go to the web site: ftp://trescftp.dot.ca.gov/pub/Specifications/SSPs/92-SSPs/Sec_10/22-42/.
2. Select the desired file(s) from among the following:

   Subbase, "25-010"

   Base, "26-010," "26-030," "26-080," and "26-100"

If a message appears requesting a log-on as "anonymous" or "user," click on "cancel."

CIWMB. If you don't have access to the Internet, contact Casey Robb at CIWMB (916) 341-6308 to request hard copies or e-mailed copies.

Greenbook Specifications

What is the Greenbook? The *Greenbook*, or *Standard Specifications for Public Works Construction*, is used by the city and county of Los Angeles and 200 other local governments and agencies in the Los Angeles area.

Who Publishes It? It is published by the Joint Cooperative Committee of the Southern California Chapter of the American Public Works Association, and the Southern California Districts of the Associated General Contractors of California.

How Often? It is updated and republished every three years. Supplements are published yearly.

Where Can I Get It? The 1997 *Greenbook* includes both English and metric units, and is available for $49.95 through:

BNI Building News
1612 S. Clementine St.
Anaheim, CA 92802
(714) 517-0970.

Aggregate Base Specifications. In Section 200-2, "Untreated Base Materials," the *Greenbook* includes four categories of aggregate base that are of interest here:

1. **Crushed Aggregate Base (CAB)** does NOT include recycled aggregate. CAB may sometimes be specified where recycled base (CMB or PMB) would also meet requirements.
2. **Crushed Miscellaneous Base (CMB)** allows recycled aggregate. The *Greenbook* states that CMB "shall consist of broken and crushed AC or PCC and may contain crushed aggregate base or other rock."
3. **Processed Miscellaneous Base (PMB)** also allows recycled aggregate. The *Greenbook* states that PMB "shall consist of broken or crushed AC, PCC, railroad ballast, glass, crushed rock, rock dust, or natural material."
4. **Select Subbase** is the *Greenbook*'s only aggregate subbase category. It allows recycled aggregate.

Siting

Setting up a new concrete and asphalt recycling plant requires certain State and local permits, such as air and water, and zoning.

Where Can I Get Help?

Businesses starting or expanding into recycling activities may get financial, technical, marketing, business and permitting assistance from the "R-Team" at CIWMB, at (916) 341-6526.

Air Permits

The local air districts may be concerned about nuisance odors and various emissions, and may require processors to spray materials with water to control dust. Locate your local air district by calling the Air Resources Board at (916) 322-2990 or by checking their web site at http://arbis.arb.ca.gov/capcoa/roster.htm.

Water Permits

The Regional Water Quality Control Board may need to permit the facility depending on feedstock and location. Look up your regional board in a local phone book under State Government, Water Quality Control Board or check their web site at http://www.swrcb.ca.gov/loc_link.htm.

Solid Waste Permits

The CIWMB is currently developing a tiered permitting system for solid waste facilities. However, processors that accept segregated C&D debris should not require a solid waste facilities permit. Contact your Local Enforcement Agency (LEA) for updates. To find out who the LEA is for the project area, call the

CIWMB LEA/EA Branch at (916) 341-6333 or check the web site at http://www/ciwmb.ca.gov/pe/lea/directry.htm.

Related Organizations

Aggregate Producers Association of Northern California
400 Capitol Mall, Suite 900

Southern California Rock Producers Association
P. O. Box 40
South Pasadena, CA 91030
(818) 441-3107

San Diego County Rock Products Association
2831 Camino Del Rio South, Suite 110
San Diego, CA 92108
(619) 260-8316

American Public Works Association
2345 Grand, Suite 500
Kansas City, MO 64105
(816) 472-6100

California Mining Association
1 Capitol Mall, Suite 220
Sacramento, CA 95814
(916) 447-1977 (represents mining companies, including some aggregate)

National Aggregates Association
900 Spring St.
Silver Springs, MD 20910
(301) 587-1400

Department of Conservation Division of Mines and Geology
801 K St.
Sacramento, CA 95814
(916) 445-5716

Publications

Free CIWMB Publications
CIWMB has published a series of fact sheets, case studies, and resource lists on construction and demolition recycling. CIWMB publications can be obtained in two ways:

Mail. To order through the mail, call the CIWMB Recycling Hotline (800) 553-2962, or (916) 341-6308 from outside California. To find out what is available, request the four-page summary of the C&D program and publications, *Construction & Demolition Recycling Program* (Pub #431-97-030).

Sacramento, CA 95814
(916) 443-5353

Central Valley Rock, Sand, and Gravel Association
P. O. Box 1464
Los Banos, CA 93635
(209) 826-5955

Internet. Visit the CIWMB Internet web site at http://www.ciwmb.ca.gov. To locate the C&D page, select "Waste Management Programs" and "Construction & Demolition Debris Recycling." You can view, print, or download most publications, and search the databases.

Related CIWMB Publications

C&D Recyclers—Processors & Receivers. A 10-page list of ~500 sites in California that receive construction and/or demolition materials for recycling or reuse, including concrete, asphalt and brick. (Pub. #431-96-017)

Recycled-Content Construction Products. An 8-page list of ~450 manufacturers of recycled construction products sold in California, including aggregate. (Pub. #431-96-018)

Asphalt Roofing Shingles in Aggregate Base. A 2-page overview of recycling ground asphalt roofing shingles into aggregate base. (Pub. #431-97-032)

Resource Guide for Recycling-Based Businesses. A 57-page directory of information from the public and private sectors, including business development, technical, financial and feedstock assistance. (Pub. #412-97-028)

Market Status Report: Recycled Inerts (October 1996). An 11-page report discussing recycled aggregate, asphalt pavement, asphalt roofing shingles, and drywall. (Pub #431-96-063)

Free Directory of Construction Industry

The Blue Book—Building & Construction
PO Box 500
Jefferson Valley, NY 10535-0500
(800) 431-2584
(916) 485-3832 (Sacramento rep)
Web site: www.thebluebook.com

Free Magazine Subscription

C&D Debris Recycling
Intertech Publishing
9800 Metcalf
Overland Park, Kansas 66212
(800) 441-0294

Reports

A Study of the Use of Recycled Paving Material, Report to Congress as specified in the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), Report No. FHWA-RD-93-147, EPA/600/R-93/095.

CIWMB Contact

For more information about recycled aggregate, contact CIWMB at (916) 341-6308 or by e-mail at crobb@ciwmb.ca.gov.

Publication #431-95-052 Revised April 1998

The Integrated Waste Management Board (IWMB) does not discriminate on the basis of disability in access to its programs. IWMB publications are available in accessible formats upon request by calling the Public Affairs Office at (916) 341-6308. Persons with hearing impairments can reach the IWMB through the California Relay Service, 1-800-735-2929.

Asphalt Pavement Recycling

Introduction

This fact sheet is an overview of recycling reclaimed asphalt pavement back into new asphalt pavement.

Benefits of Recycling Asphalt
Recycling of asphalt pavement can save money for local governments and other purchasers, create additional business opportunities, save energy when recycling is done on site, conserve diminishing resources of aggregates and petroleum products, and help local governments meet the goal of reducing disposal by 50 percent by the year 2000.

What About Aggregate Base?
This fact sheet is NOT about recycling asphalt pavement into aggregate base. See *Recycled Aggregate*, CIWMB Pub. #431-95-052.

Quantities

Source
The 1990 waste stream composition data were reported to the California Integrated Waste Management Board (CIWMB) by local governments in response to the Integrated Waste Mangement Act of 1989. These reports supplied the following information:

Construction and Demolition (C&D)
C&D materials made up about 28 percent of California's waste stream, or 11 million tons.

Asphalt Pavement
While recycled asphalt pavement was not reported separately in these data, generation of "inert solid waste," which consists of concrete, asphalt, dirt, brick and other rubble, was conservatively estimated at 8.2 million tons. The estimated recycling rate for inert solid wastes was 57 percent; the remainder was disposed of.

Definitions

In the western United States, **asphalt** refers to the bituminous substance used to bind aggregate together to make asphalt concrete (AC). The aggregate makes up the bulk of the AC, while the asphalt binder comprises about 5 to 7 percent.

Reclaimed asphalt pavement (RAP) is used AC pavement that has been processed.

Recycled asphalt concrete (RAC) is the product of mixing RAP with new aggregates, asphalt and/or recycling agent.

A **recycling agent** is used to soften and rejuvenate the existing asphalt pavement.

Pavement is the top layer of roadway, and is made of portland cement concrete (PCC) or AC. The pavement is supported by the base and sub-base, which consist of aggregate and other materials. The pavement can be crushed and used as recycled aggregate base or, if it is AC, it can be reprocessed into RAC.

Cold planing, also called **cold milling,** is the removing or milling of a layer of pavement by a cold planing machine. The exposed surface can be used temporarily as a driving surface and is usually overlaid with new material.

Road Recycling Methods

Purpose
Roads are rehabilitated to correct deficiencies such as rutting, cracking, oxidation, brittleness, irregular shrinkage, and aggregate stripped of asphalt.

Methods
The following methods of roadway rehabilitation recycle old pavement into new:

Cold, In-Place Recycling. The pavement is removed by cold planing to a depth of 3 to 4 inches. The material is pulverized, sized, and mixed with an additive. Virgin aggregate may be added to modify RAP characteristics. An asphalt emulsion or a recycling agent is added, then the material is placed and compacted. An additional layer is optional, such as a chip seal, or 1 to 3 inches of hot-mix asphalt.

A 3-piece "train" may be used, consisting of a cold planing machine, a screening/crushing/ mixing unit, and conventional laydown and rolling

equipment. This "train" occupies only one lane, thus maximizing traffic flow. Caltrans has used

According to the Asphalt Recycling and Reclaiming Association, cost savings can range from 20 to 40 percent over conventional techniques. Because no heat is used, energy savings can be from 40 to 50 percent.

Hot Recycling. At a central plant, RAP is combined with hot new aggregate, and asphalt or a recycling agent to produce AC, using a batch or drum plant. The RAP is usually obtained from a cold planing machine, but could also be from a ripping/crushing operation.

Hot, In-Place Recycling. The pavement is softened by heating, and is scarified or hot milled to a depth of 3/4 to 1-1/2 inches and mixed. New hot mix material and/or a recycling agent is added in a single pass of the machine. A new wearing course may also be added with an additional pass after compaction.

Hot mix—Remixing. The road is heated to 1-1/2 to 2 inches, and the existing AC is removed to that depth. It is then mixed with virgin mix and/or rejuvenating agents and laid as a single course.

Hot mix—Repave. This method is the same as remixing, but it is overlaid with new hot mix.

Hot mix—Heater Scarification. This method is appropriate for roadways that have a stable and structurally adequate base. The road is heated, scarifiers scrape and loosen the pavement, rejuvenating agent is applied, and the surface is leveled in preparation for the addition of a final, thin, wearing course.

Full Depth Reclamation. All of the asphalt pavement section and a portion of the underlying materials are processed to produce a stabilized base course. The materials are crushed and additives are introduced; the materials are then shaped and compacted, and a surface or wearing course is applied.

RAC Producers

According to the Board's current information, there are at least 25 plants producing RAC in California. Some receive RAP at the plant; others have mobile equipment for in-place recycling. AC recyclers are included in two databases: *Construction/Demolition Recyclers—Processors & Receivers* (Pub. #431-96-017) and *Recycled-Content Construction Products* cold in-place recycling in over 25 projects in California.

(Pub. #431-96-018). The databases are searchable on the CIWMB's C&D Web site. Hard copy lists are available from the CIWMB Publications Clearinghouse at (800) CA-WASTE.

Purchasing

Caltrans and local public works departments put their road jobs out to bid. The contractors who win the bid are the actual purchasers of the AC. However, if a project is to use recycled AC, Caltrans or the local agency must specify recycled AC in the bid.

Markets

Uses
AC is found in roadways (State highways, local public roads, and private roads), airport runways, parking lots, driveways, and tennis courts. The primary market for RAC is roadways.

Southern California
There are many markets in southern California because most local governments use the *Greenbook*, which supplies RAP specifications. (See "Specifications," next page.)

Northern California
Most local governments in Northern California, however, are waiting for Caltrans to finalize their specifications. RAC is not in ready supply in the area, because the AC recycling industry requires a certain volume of business before investing in equipment. One exception to this rule is Gallager & Burke, which supplies RAC to several cities in the East Bay.

Local Governments

Local governments can help promote markets for RAC because they are large purchasers of asphalt and other road construction products. Some communities are taking steps to promote RAC, including the following:

Los Angeles
In March 1995, the City of Los Angeles passed a motion requiring that all asphalt surfacing purchased by city departments include a minimum of 15 percent RAP.

Modesto
The City of Modesto has a purchasing practice for on-site street recycling that includes RAC.

San Diego
The City and County of San Diego routinely allows 15 percent RAP in new asphalt for public projects.

San Jose
The City of San Jose allows 15 percent RAP in asphalt base, the AC layer under the 2-inch surface layer.

Specifications

Most local jurisdictions use Caltrans specifications. In southern California, the *Greenbook* is commonly used. (See *Greenbook* discussion below.) Where RAC is allowed, it must also, of course, meet the same grading and quality requirements as virgin AC.

Caltrans Specifications—Procedures
Caltrans takes a new "spec" through three stages:

1. **Special Provision (SP).** First it is an SP where it is used initially on a number of projects.
2. **Standard Special Provision (SSP).** After the SP has been used successfully for a period of time, then it usually becomes an SSP which means it is a method approved by Caltrans.
3. **Standard Specification.** After the SSP has been used successfully for a period of time, then it usually becomes a Standard Specification, and is included in the Caltrans Standard Specifications which is published every four years. The latest edition using English measurements is dated July 1992. A metric edition was published July 1995; all subsequent editions will be metric. The next edition is anticipated in 1998 or 1999.

Caltrans Specifications—Pending
Caltrans specifications for two AC processes are being modified: "Hot Recycling at a Central Plant" (25-50 percent recycled) and "Cold, In-Place" (100 percent recycled). The specifications are expected to be completed in 1997. Temporary versions are currently being used in Caltrans projects, and are available to local governments and the public through Caltrans.

Caltrans Specifications—Future
Caltrans is investigating various technologies for future specification:

Stockpile Study. Caltrans is doing a "pilot study" to determine the feasibility of using up to 15 percent RAP from contractor-generated multisource stockpiles. Progress has been slow in this area because few projects have been constructed using this type of recycling. The evaluation period will continue at least through the 1997 construction season.

Microwave. One company produces 100 percent RAC by using a patented cool flow and microwave process to reheat it. Caltrans completed the second test project with this technology in the summer of 1995 using up to 70 percent RAP. Results have been evaluated. Although the process looks favorable, the recycle mix did not meet Caltrans' specifications on this project.

Hot, In-Place. Caltrans also tested hot, in-place AC recycling on two projects. A recycling agent was used to rejuvenate the old asphalt. Up to 15 percent new AC was added in some sections; the new AC is 100 percent recycled. The process is available as a "Special Provision." However, the results are inconclusive, so they classify the method as experimental, which means that Caltrans does not use the procedure routinely. Caltrans plans to use this type of recycling on future test projects.

Greenbook Specifications

***What is the* Greenbook?**
The *Greenbook* is another name for the *Standard Specifications for Public Works Construction*, and is used by the City and County of Los Angeles and 200 other local governments and agencies in the Los Angeles area.

Who Publishes It?
It is published by the Joint Cooperative Committee of the Southern California Chapter of the American Public Works Association, and the Southern California Districts of the Associated General Contractors of California.

How Often?
It is updated and republished every three years. Supplements are published yearly.

Where Can I Get It?
The 1997 *Greenbook* includes English and metric units, and is available for $49.95 through:

BNI Building News,
1612 S. Clementine St.,

Anaheim, CA 92802
(714) 517-0970.

RAC Specifications
The *Greenbook* has specifications for "Recycled Asphalt Concrete—Hot Mixed" in Section 203-7.

Siting

Setting up a new asphalt recycling plant requires certain State and local permits, such as air, water, and zoning.

Where Can I Get Help?
Businesses starting or expanding into recycling activities may get financial, technical, marketing, business, and permitting assistance from the "R-Team" at CIWMB, at (916) 341-6526.

Air Permits
The local air districts may be concerned about nuisance odors and various emissions, and may require processors to spray with water to control dust. Locate your local air district by calling the Air Resources Board at (916) 322-2990 or by checking their Web site at o3.arb.ca.gov/capcoa/roster.htm.

Water Permits
The Regional Water Quality Control District may need to permit the facility depending on feedstock and location. Look up your district in a local phone book under State Government, Water Quality Control Board or check their Web site at www.swrcb.ca.gov/html/rwqcbs.html.

Solid Waste Permits
The CIWMB is currently developing a tiered permitting system for solid waste facilities. However, processors that accept segregated C&D debris should not require a permit. Contact your Local Enforcement Agency (LEA) for updates. To find out who the LEA is for the project area, call the CIWMB LEA/EA Branch at
(916) 341-6321 or check the Web site at www.ciwmb.ca.gov/LEACentral/LEA/LEADirectory/.

Related Organizations

Asphalt Recycling & Reclaiming Association
#3 Church Circle, Suite 250
Annapolis, MD 21401
(410) 267-0023

Southern California Chapter
American Public Works Association
c/o Jim Biery, Director of Public Works

Methods are outlined for batch plants and drier-drums. Up to 15 percent of RAP is allowed in the virgin mix. Larger percentages of RAP are allowed if test data is submitted to the Chief Engineer of the Agency.

City of Southgate
8650 California Ave.
Southgate, CA 90280
(213) 563-9537

San Diego/Imperial County Chapter American Public Works Association
c/o James P. Casey
3208 Westcliffe Place
San Diego, CA 92106
(619) 223-8244

American Public Works Association
2345 Grand, Suite 500
Kansas City, MO 64105
(816) 472-6100

Northern California Asphalt Producers Association
c/o Roger Smith
P. O. Box 2201
Nevada City, CA 95959
(916) 265-5622

National Asphalt Paving Association
NAPA Building
5100 Forbes Blvd.
Lanham, MD 20706-4413
(301) 731-4748

National Center for Asphalt Technology (NCAT)
Publications Dept.
Auburn University
211 Ramsay Hall
Auburn, AL 36849-5354
(334) 844-6228

Publications

Free Magazine Subscription
C&D Debris Recycling,
Intertech Publishing
9800 Metcalf
Overland Park, KS 66212
(800) 441-0294

Reports
Asphalt Hot-Mix Recycling, The Asphalt Institute, Lexington, KY, $8, (606) 288-4960.

A Study of the Use of Recycled Paving Material, Report to Congress as specified in the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), Report No. FHWA-RD-93-147, EPA/600/R-93/095.

CIWMB Contact

For more information about asphalt recycling, contact Marylou Taylor at (916) 341-6499 or by e-mail at mtaylor@ciwmb.ca.gov.

Publication #431-95-067 Revised July 1999

The Integrated Waste Management Board (IWMB) does not discriminate on the basis of disability in access to its programs. IWMB publications are available in accessible formats upon request by calling the Public Affairs Office at (916) 341-6308. Persons with hearing impairments can reach the IWMB through the California Relay Service, 1-800-735-2929.

Lumber Waste

Introduction

Construction and demolition (C&D) activities generate significant amounts of waste. It has been estimated by the California Integrated Waste Management Board (CIWMB) that C&D waste represents approximately 28 percent of the solid waste stream. Wood waste represents one component of C&D, estimated at approximately 25 percent. The portion of wood waste that can be reused as lumber is considerably less, but no accurate estimates are currently available.

There are several alternatives to disposal for wood waste that can be reused as lumber for both structural and ornamental applications. These alternatives can save money in avoided disposal fees and potentially generate income from the sale of salvageable materials.

Construction

Construction activities tend to generate wood scraps rather than whole lumber for reuse. The scraps lend themselves to reuse through the manufacture of particle board and strand board or are joined together through finger joints to produce larger dimensional wood that can be used in nonstructural applications. Whole lumber that is unused on a site is generally incorporated into the next job.

As a result, efforts at construction sites should be focused on developing techniques that minimize the generation of waste on site. These could include the use of prefabricated wall panels and trusses or designing structures around standard dimensional lumber. Use of these techniques minimizes the waste that is generated and expedites assembly of the structure. However, specifying this type of construction requires forethought in the planning stages and may limit design options.

For more information on reuse of wood waste scraps from the construction site, please refer to the CIWMB fact sheets Urban Wood Waste and Job Site Source Separation.

Demolition

Demolition operations tend to yield very little reusable lumber due to the practice of using heavy machinery to demolish structures. However, hand demolition or "deconstruction" significantly increases the amount of reusable lumber and architectural fixtures that can be salvaged for reuse. Hand demolition often involves higher labor costs to dismantle a structure. This higher cost can be offset by the increased income from salvaged material, decreased disposal costs, and decreased costs from avoided time and expense needed to bring heavy machinery to a job site.

Hand demolition has been documented as cost competitive with mechanized demolition. The "Whole House Recycling Project" in southeast Portland, Oregon documented the hand demolition of a home, which proved to be more cost competitive than using mechanized equipment. The base bid for the hand demolition was $5400 while the bids for the mechanized demolition ranged from $8000 to $10,000. The only drawback was that the duration of the demolition essentially doubled. The project yielded 4,748 board feet of lumber from the framing, siding, and flooring, or approximately 3.7 board feet recovered per square foot of structure.

Demolition of older or unique structures can yield valuable materials such as wooden fixtures, moldings, casings, sashes, framing, and timbers for reuse or remilling. These types of structures are more likely to contain structural components worthy of remilling, for both structural and ornamental applications, and fixtures of interest. Businesses that deal in architectural fixtures can be located in the telephone directory yellow pages under "salvage," "demolition," or "building materials-used, antique."

Large timbers and dimensional lumber removed from demolition operations can be reused or recut for other construction projects. However, in many cases the lumber will need to be

regraded by a certified grader if it is used for

This, of course, can only be determined on a case-by-case basis and may limit reuse options.

There are services that are licensed to inspect and grade lumber at a job site. Several of the services are listed at the end of this fact sheet. If a contractor or individual plans on hiring a lumber grading service, it should be verified that the service is approved by the American Lumber Standards (ALS), which is the accrediting body for lumber graders.

When salvaging wood from a structure, exposed structural elements will often be painted for appearance and protection. If the structure was built before 1978, there is the potential that the paint contains lead. Most homes built before 1960 are likely to contain lead-based paint. Paints produced before 1960 contain higher concentrations of lead than paints produced in later years.

If the lumber is painted, it may not be accepted or may have to be tested for lead content at salvage, milling, reuse, or wood processing facilities. Inexpensive lead test kits can be obtained at many home improvement or hardware stores. Contact the facilities in your area to determine their requirements on accepting painted lumber and their testing criteria. If no other option is available other than disposal for painted lumber, be aware of the position the California Department of Toxic Substance Control (DTSC) has taken regarding hazardous designation of lead-based paints. The DTSC has stated that demolition debris that is painted with lead based paint that is intact, may or may not be considered hazardous waste. In order for the entire item to be hazardous, the lead concentration in the paint and the painted item (i.e door, beam, etc.) must exceed hazardous levels. In most cases, the lead concentration from the intact paint alone will not exceed hazardous lead levels for both the item and the intact paint.

If the paint has been separated from the building material (e.g., chemically or physically removed) then the paint waste should be evaluated independently from the building material to determine if it is hazardous and to identify the proper management practice. For a more complete explanation of this policy, contact DTSC. In Sacramento, the phone number is anything other than ornamental purposes.

(916) 324-1826. Consult your telephone directory for regional offices.

Facilities

The following is a list of facilities that accept lumber for reuse or can recut large timbers:

New World Furniture
Located at Guadalupe Sanitary Landfill. Accepts redwood at a reduced tipping fee. Produces furniture with reclaimed redwood. May sell lumber for large jobs or on a contractual basis. No small jobs.

P.O. Box 20957
San Jose, CA 95160
(408) 268-9040

Jefferson Lumber
Mt. Shasta, CA 96067
(916) 235-0609

Recycled Lumberworks
1500 W. Mott Rd.
596 Park Blvd.
Ukiah, CA 95482
(707) 462-2567

Wesco Used Lumber
911 Ohio Avenue
Richmond, CA 94804
(510) 235-9995

Into The Woods
300 North Water Street
Petaluma, CA 94952
(707) 763-0159

The following services can be hired to grade or regrade lumber or may offer technical advice on grading:

California Lumber Inspection Service
(private service)
Sacramento: (916) 722-2500
San Jose: (408) 241-2960
L.A.: (714) 962-9994

West Coast Lumber Inspection Bureau
(nonprofit organization)
P.O. Box 23145
Portland, OR 97281
(503) 639-0651

Western Wood Products Association

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Nonprofit organization that can be accessed for technical information and offers some limited testing services.

In addition to the facilities listed in this fact sheet, there are numerous salvage operations and wood waste processors that accept lumber for either reuse or processing into mulch, chip board, and/or fuel. There are also various "wrecking" companies throughout the state that perform hand demolition. Refer to your local telephone directories for these companies.

Contractors should also consider contacting their local government (city, county, municipality, etc.) for publications on lumber reuse and recycling. They will often list local operations.

522 SW 5th Ave.
Portland, OR 97204-2122
(503) 224-3930

Publications

The following documents are among those published by the CIWMB:

Construction and Demolition Recyclers—Processors & Receivers (Pub. #431-96-017)

Construction and Demolition Recycling Program (Pub. #431-97-030)

Urban Wood Waste (Pub. #443-95-057)

Waste Exchanges (Pub. #443-95-061)

Job Site Source Separation (Pub. #443-95-066)

California Materials Exchange (CalMAX quarterly catalog)

To see a complete publications list or order publications, visit the Board's Web site at www.ciwmb.ca.gov (most are available electronically) or call the CIWMB Hotline at:

(800) 553-2962 (from CA only)
(916) 341-6308 (outside CA)

Urban Wood Waste

Introduction

Urban wood waste is the portion of the wood waste stream that can include sawn lumber, pruned branches, stumps, and whole trees from street and park maintenance. The primary constituents of urban wood waste are used lumber, trim, shipping pallets, trees, branches, and other wood debris from construction and demolition clearing and grubbing activities.

The disposal of wastes generated from construction and demolition (C&D) activities represents a significant portion of operating expenses in addition to consuming valuable landfill space. C&D waste represents a significant part of the solid waste steam, with current estimates at 28 percent of total tonnage. Its reduction will help meet the State mandated diversion goal of 50 percent by 2000.

Wood waste is, by far, the largest portion of the waste stream generated from construction and demolition activities. As such, this fact sheet is geared toward contractors and local governments considering alternatives to disposal. These alternative uses represent significant potential savings in disposal costs.

Quantities

The quantity of urban wood waste documented in California varies depending on the study and the source. Based on information compiled from local waste generation studies, the California Integrated Waste Management Board (CIWMB) estimates that approximately 3.8 million tons of wood waste (this does not include yard waste) are generated throughout the state and enter the municipal waste stream in California every year. Of the 3.8 million tons generated, approximately 3.35 million tons are disposed of in permitted disposal facilities and the remaining 450,000 tons are diverted from landfilling.

A considerable amount of wood waste is also consumed by the biomass industry for boiler fuel to produce electricity, and steam in some cases. Based on figures supplied by the biomass industry, it currently consumes approximately 1.3 million tons of urban wood waste. This is above and beyond the 3.8 million tons quantified in the previous paragraph. The biomass industry's fuel consumption is decreasing due to closures and curtailment of operations of private and public plants contracted to sell power to utilities in the state.

Markets

Markets for wood waste include use as feedstocks for engineered woods, landscape mulch, soil conditioner, animal bedding, compost additive, sewage sludge bulking medium, and boiler fuel. All these end uses have similar processing requirements in that the wood waste must be separated from other wastes, cleaned by removing contaminants and fasteners, and processed through grinding or chipping. The final use of the wood waste often determines how clean and consistent the feedstock must be.

Reuse

The most desirable option for wood waste management is reuse of structural members and architectural elements such as casings, banisters, and moldings. Large timbers from older or unique structures can be salvaged and reused as structural elements in new buildings. However, lumber to be reused as structural elements must first be recertified by a lumber inspector.

One option that may be potentially cost effective is the employment of firms that offer certified lumber inspectors that can grade lumber for use on site. If you are considering hiring this type of service, verify that it is approved by American Lumber Standards (ALS). ALS is the licensing body for lumber graders. Refer to the CIWMB fact sheet Lumber Waste for a listing of inspection and grading services.

Engineered Wood Products

The next most desirable option for wood waste is as a feedstock for engineered woods. Engineered wood is the term given to material derived from smaller pieces of wood that are bound together with glues, resins, and other chemicals to make a wood-like product. These

include particle boards, laminated woods, and plywoods.

Biomass Fuel, Mulch, and Compost
Because of the limited options available to reuse wood waste as building materials or feedstocks for engineered woods, the largest markets for urban wood waste are as a feedstock for biomass fuel, mulch, and compost. The processing requirements for all three products are similar and recyclers of wood waste for this type of end use are more plentiful throughout the state.

Recovery

The end uses of wood recovered from demolition activities are sometimes limited because the wood is commingled with other materials and contaminants or is in such poor condition that the cost of processing and cleaning limits the economic viability of processing and reusing the material.

Construction Sites
Wood waste generated at residential and commercial wood frame construction sites offers a greater potential for reuse due to the ease of separating the wood during the various stages of construction. Cut-offs and scraps generated during the framing and trimming stages constitute a relatively clean and homogeneous waste steam that can make an excellent feedstock for engineered wood production. This is a highly desirable form of wood waste that processors are eager to obtain.

To minimize disposal costs and potentially generate income, contractors should contact local wood waste processors and inquire about setting up drop boxes on site for wood waste scraps. Contractors should also consider collecting pallets and crates that building materials and equipment are shipped in. There are usually several businesses listed in the phone directories, under "pallets" or "skids," that collect and remanufacture pallets.

Demolition Activities
Demolition operations usually generate a far less desirable form of wood waste due to the nonuniform nature of the wood waste compounded by the commingling of the wood with other materials. The wood can still be reused, but generally has a lower value and is destined for uses such as boiler fuel or mulch feedstock. Wood waste processors may still be interested in this material for processing. Since demolition activities generate far more waste per square foot than construction activities, disposal costs represent a much greater portion of operating expenses. It is therefore worth the time to contact local processors to determine if a savings in disposal costs can be realized.

Processing

The CIWMB maintains a list of businesses that receive and process construction and demolition materials. This list contains the names of more than 100 wood waste processors in addition to other businesses that are interested in whole pallets or reusable building materials.

The wood waste processors vary in what they require for a feedstock. Some request only clean wood that is untreated or unpainted while others will take a mixture of waste woods. Disposal fees vary with each facility and some facilities may pick up loads and supply drop-off boxes. It is therefore important to contact the wood waste processors in the area to determine the most cost effective option for each situation.

Publications

The following documents are among those published by the CIWMB:

Construction and Demolition Recyclers—Processors & Receivers (Pub. #431-96-017)

Job Site Source Separation (Pub. #443-95-066)

Nonyard Wood Waste (Pub. #500-94-045)

Nonyard Wood Waste Report: Annual Update for 1995 (Pub. #443-95-026)

Lumber Waste (Pub. #443-96-028)

CalMAX: California Materials Exchange (quarterly catalog)

Waste Exchanges (Pub. #443-96-025)

Construction and Demolition Recycling Program (Pub. # 431-97-030)

Wood Waste: How to Keep Wood Waste Out of Landfills (Pub. #500-94-017)

The Integrated Waste Management Board (IWMB) does not discriminate on the basis of disability in access to is programs. IWMB publications are available in accessible formats upon request by calling the Public Affairs Office at (916) 341-6308. Persons with hearing impairments can reach the IWMB through the California Relay Service, 1-800-735-2929.

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NebGuide

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Bioengineering for Hillslope, Streambank and Lakeshore Erosion Control

This NebGuide describes bioengineering techniques for hillslope, streambank and lakeshore erosion control. Tips for a successful bioengineering installation and demonstration project are described.

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Soil erosion occurs whenever water meets land with enough force to move soil. Often this occurs along streambanks and lakeshores or where excess water flows over hillslopes. While streambank and hillslope erosion can be dramatic, especially after large rainfalls or floods, normal streamflows, excess runoff from urbanized areas and wave action along lakeshores continually erode soil. Erosion can be severe, as is the case in many man-made lakes, where shorelines are composed of easily erodible soil. Traditional methods of controlling streamflow and wave induced erosion have relied on structural practices like rip rap, retaining walls and sheet piles. In many cases these methods are expensive, ineffective or socially unacceptable. An alternative approach is bioengineering, a method of construction using live plants alone or combined with dead or inorganic materials, to

produce living, functioning systems to prevent erosion, control sediment and provide habitat. Bioengineering uses combinations of structural practices and live vegetation to provide erosion protection for hillslopes, streambanks and lakeshores. Bioengineering is a diverse and multi-disciplinary field, requiring the knowledge of engineers, botanists, horticulturalists, hydrologists, soil scientists and construction contractors. It is a rapidly growing field, subject to innovations and changing design specifications. Terms such as biotechnical erosion control, biostabilization or soil-bioengineering are often used synonymously with bioengineering.

History

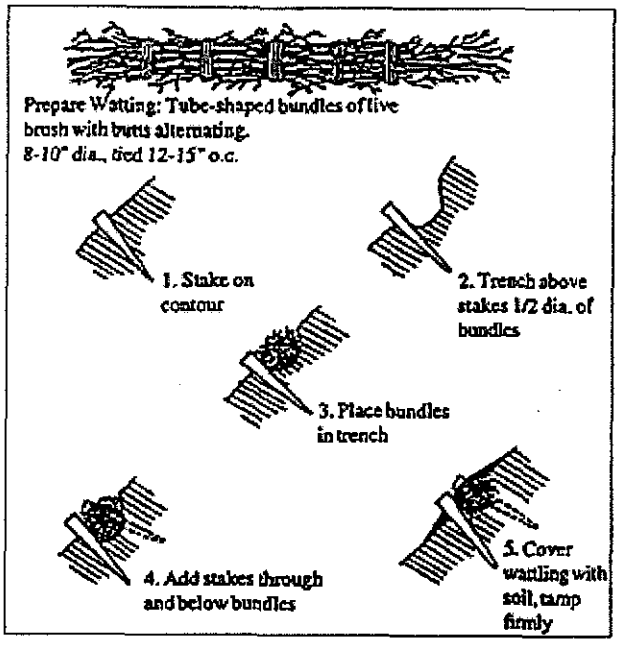
The use of bioengineering methods dates back to 12th century China, when brush bundles were used to stabilize slopes. In the early 20th century, similar techniques were used in China to control flooding and erosion along the Yellow River. In Europe, especially Germany, bioengineering methods have been used for over 150 years. Documented use of bioengineering in the United States dates to the 1920s and '30s. Streambank stabilization, timber access road stabilization and slope restoration were common applications. After World War II, with increased access to earth-moving equipment and the development of new structural slope stabilization and erosion control methods, bioengineering practices all but disappeared. In the last 20 years bioengineering has been recognized as a re-emerging technique to provide erosion control, environmentally sound design and aesthetically pleasing structures. Gray and Leiser (1982) published the first U.S. textbook on bioengineering: *Biotechnical Slope Protection and Erosion Control.*

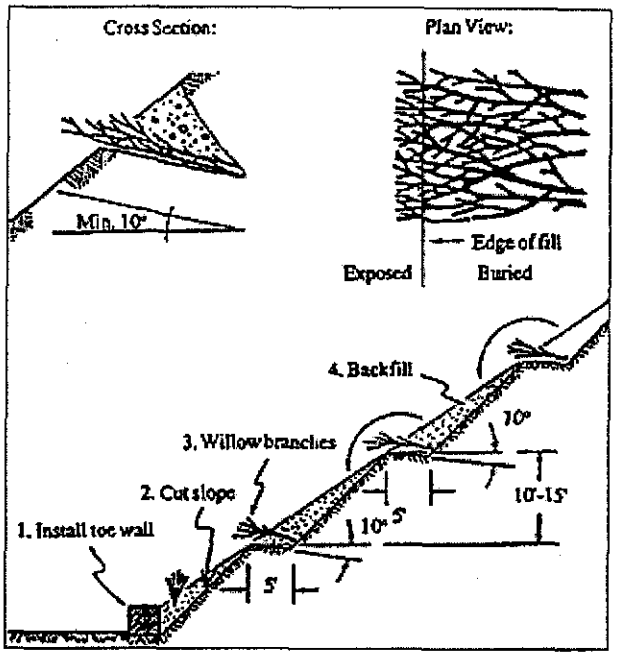
Applications, Advantages and Limitations

Bioengineering solutions can be adopted in many soil stabilization and erosion control situations from streambank and lakeshore protection to upland gully restoration and slope stabilization. Bioengineered restoration of flood or high water damage to streams and lakes provides a more natural-looking solution than traditional rip rap or concrete structures.

Advantages of bioengineering solutions are: 1) low cost and lower long-term maintenance cost than traditional methods; 2) low maintenance of live plants after they are established; 3) environmental benefits of wildlife habitat, water quality improvement and aesthetics; 4) improved strength over time as root systems develop and increase structural stability; and 5) compatibility with environmentally sensitive sites or sites with limited access.

Limitations to bioengineering methods include: 1) the installation season is often limited to plant dormant seasons, when site access may be limited; 2) the availability of locally adapted plants may be limited; 3) labor needs are intensive and skilled, experienced labor may not be available; 4) installers may not be familiar with bioengineering principles and designs so upfront training may be required; and 5) alternative practices are aggressively marketed and often more widely accepted by society and contractors.





Bioengineering Techniques

Homeowners who have streamside or lakeside property, contractors required to work in difficult environmental circumstances or professionals interested in natural restoration of landscapes will find useful bioengineering techniques. New methods of application and materials being developed will result in new and improved bioengineering design.

Contour Wattling

Figure 1. Preparation of wattling and installation procedure. Installation starts at the bottom of the cut or fill and proceeds upslope. Numbered sequence of operations is shown schematically. (From Gray and Leiser, 1982)

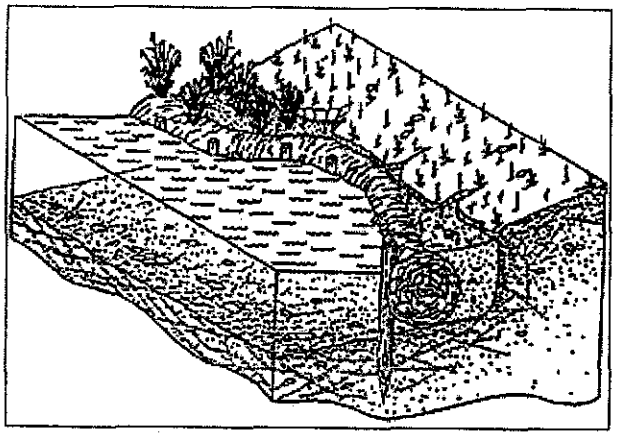
This method is used to control surface erosion by breaking long slopes into shorter slopes. Bundles of branches, called wattles or fascines, are placed in shallow trenches along the slope or streambank contour (*Figure 1*). Trenches are excavated by hand to half the diameter of the bundles. Wattles are typically 8 to 10 inches in diameter and branches secured with twine. After the wattle is staked in place, the trench is backfilled until only the top of the bundle is exposed. Wattles can be used for hillslope restoration, road embankments, wide gullies, or slump areas.

Brush Layering

Figure 2. Installation of brush layering. Numbered sequence of operations is shown. Vertical spacing depends on slope angel. (From Gray and Leiser, 1982)

This method is used to restore slopes by constructing a fill-slope consisting of alternating layers of live branches and soil, creating a series of reinforced benches (*Figure 2*). Large

quantities of dormant willow branches are often used. While about 75 percent to 80 percent of the branch is buried, the tips are left exposed. The layers of branches help reinforce the fill, which improves as the branches develop roots throughout the fill area. Brush layering can be used to place new fill or repair old fill areas, restore shallow slumps, repair narrow gullies and stabilize loose soil slopes.



Trench Packing

This method is used to slow or spread water by placing live plants in a trench perpendicular to the flow. To reduce wave impact, live plants are placed in trenches running parallel to the shoreline. Several trenches may be used with different plants in each, depending on the distance to water. Generally, a wide planting area is needed to dissipate wave energy. In upland areas, trench packing serves to slow water and spread it over the soil surface, reducing its erosion potential. Trench packing can also be used to control shallow seeps, protect wetland construction and renovation and protect abandoned roads.

Brush Matting

This method protects streambanks by placing a mattress-like layer of branches over it to protect soil and slow water velocity. The mat is composed of interwoven, usually dead, branches secured to the soil by live stakes, wire, twine or live branches. Live stakes are often cut from dormant willow. Brush matting helps collect sediment and enables establishment of vegetation on banks. Like brush layering, this method requires large quantities of branches.

Live Cuttings

Live cuttings can be used to secure materials in place and to increase plantings on a slope. Live cuttings can be from 18 inches to 4 feet in length. Longer cuttings are used for live staking of wattles, while shorter cuttings are used for plantings.

Coir Fascines

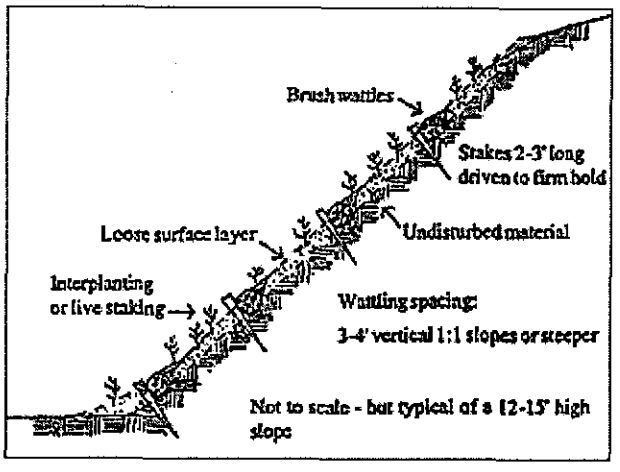
Figure 3. Coir fascines stabilize banks and help establishment of wetland plants. The coconut fiber accumulates sediment and biodegrades as plant roots develop and become a stabilizing system. (From Bestmann-Green Systems)

Coir fascines are wattles made from the fibrous outer husk of coconuts. Coir is denser than water so it won't float and is very slow to decay. Coir fascines are a readily available manufactured product and are popular for streambank and wetland restoration where a

natural look is desired (*Figure 3*). Coir fascines are placed with their tops at the water surface. Live plants can be placed into coir fascines to create a natural look.

Prevegetated Mats

Prevegetated mats are live plants grown on a movable mat of organic material. They come in many sizes and materials and are moved and installed in one piece. They are generally 4 by 8 feet in size for easy handling. Mats are grown in nurseries for up to a year or more to provide a good plant stand. Thin mats can be rolled up and shipped without special packing. Thick mats are handled with heavy equipment because of their weight. Prevegetated mats are made of coir or other slowly degradable material and can use many types of plants. Mats are usually used in wetland or lakeshore environments so wetland plants are the most common. Currently, most prevegetated mats are custom ordered one to two years in advance.



Interplanting Rip Rap

Rip rap is often used to protect streambanks and lakeshores. Rip rap is composed of various size large stones placed on the soil surface where the water contacts the soil. Live cuttings can be interplanted in rip rap to provide additional slope stability. Root growth below the rip rap will improve soil strength and live vegetation will hide the rocks, presenting a more natural look.

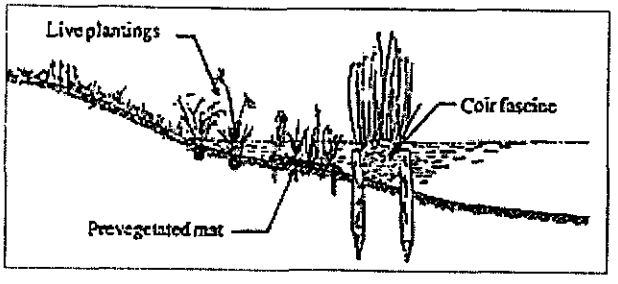
Staking

Staking is used extensively in bioengineering practice. Stakes can be live or dead. Live staking is often done with willows to stabilize soil or to stake other materials in place. Manufactured timber stakes, 2 to 3 feet long, are used to secure wattles and coir fascines. Timber stakes for upland application need to have a bias, or angle, cut making them easier to install. For wetland or streamside applications, stakes need straight parallel sides to prevent heaving from water pressure.

Combinations

Figure 4. Slope treatment using wattles and live plants or stakes. Use for loose surface soils with sheet, rill or small gully erosion. (From A.T. Leiser)

Combinations of the above practices are usually used for most bioengineering designs. For example, brush wattles and live staking is a common combination used to stabilize



slopes (*Figure 4*). A coir fascine can be used with live plantings, brush matting and trench packing to restore wetlands or stream channels (*Figure 5*). New combinations of existing methods, and the use of new materials, will provide creative applications of bioengineering techniques.

Figure 5. Lakeshore erosion control using a combination design of coir fascine and wetland plantings, prevegetated mat and live plantings. (From A.T. Leiser)

Plantings

Bioengineering involves the use of live plants to add structural strength to soil. Many different plant materials are used. Live cuttings should be soaked in cold water for at least 24 hours before they are used. This not only provides the cuttings with needed moisture but also improves rooting. Live potted plants are often used. Care of live plants before and during planting is critical for success. Live plants raised indoors need to be acclimatized to the outdoor environment before planting.

Plants can be planted directly into coir fascines, coir pots or mats. Prevegetated mats, as described earlier, are another method used to transplant live plants. A plant roll can be developed by wrapping several live plants in a roll of degradable material and placing the roll in the ground like a wattle. This method also can be used for trench packing.

Seeding can be used where appropriate. Seeding and mulching are not appropriate in areas of flooding, high water flow or rapid changes in water depth, as the mulch and seed will be washed away. Proper seedbed preparation, fertilization and irrigation may be needed to assure seedling survival.

Expect some failure of plantings in all bioengineering application. A 75 percent to 80 percent survival rate is considered very good. Replanting is generally inexpensive and often the plants will reestablish themselves in time. Some loss of vegetation does not seriously impact a project as long as most of the soil stays in place and the structural features of the design are sound.

Protect Plantings

Protect live plantings from animals, especially ducks and geese along lakeshores and streamsides. Deer, muskrats, beaver, dogs and humans can also pose a threat. Signs may keep people away, but fencing may be needed if animals are a problem. For lakeshore or streamsides, an enclosed fencing layout is best to keep waterfowl away. One fence should be placed 1 to 2 feet into the water away from the shoreline plantings with a parallel fence 2 to 3 feet upslope from the plantings. Also, protection from flooding or excess water

flowing across the planting is important to establish all bioengineering plantings. Be sure surface drainage and water flow is directed away from the new plantings or protected slope.

Vegetation Type

Selection, procurement and installation of the proper plant material is essential for a successful design. In the case of lakeshore and streambank protection, both herbaceous and woody plants are needed. Herbaceous plants, or wetland plants, will be needed at and near the water's edge. These plants can grow with their roots underwater. This root growth adds considerable strength to the soil. Generally, using several different wetland plant species increases the chance of a successful planting. However, woody plants placed too near the water or water table will not provide good structural strength and may not survive. Woody plants should be used on the upper slope and upland areas where their roots can grow in soil above the water table.

Native vegetation existing at or near the site will give good guidance concerning plant selection. As mentioned, willow cuttings are often used for wattles and live cuttings. Proper species selection is important. Willows need not be native, but should be well adapted to the region. The use of introduced species allows the potential for increasing the number of different species available.

The availability of plant species, in the appropriate size and quantity, is often a limiting factor in the final selection process. Local nurseries may not carry the types of wetland plants needed. They may be able to propagate the species needed, but this will take 12 to 18 months. A compromise between use of native species and what may be locally or regionally available will be needed to develop a successful design. Consult horticulturalists and botanists for plant selection assistance. The International Erosion Control Association (IECA) publishes a products and services directory listing sources of plant material and professional assistance (see references for address).

Improving Success With Bioengineering

Bioengineering can be effective in many streambank, lakeshore and hillslope erosion situations, but it will not solve all soil erosion or slope failure problems. The success of a project hinges on many factors including proper design, plant selection, proper installation, weather conditions and outside factors like animal damage. Site evaluation is important to determine whether there is adequate sunlight, soil type and water quality to support vigorous plant growth. Do not expect bioengineering solutions to stop slope failure caused by high water tables or landslides. Nor are they ideal for high stress areas with severe wave action, rapid or long-term water level fluctuations or fast water flows. The following list includes tips that may help ensure a successful bioengineering project.

1. Do not attempt bioengineering solutions in situations where: 1) there is severe soil or water contamination; 2) the stream bottom is degrading; 3) you can not control

human or animal traffic at the site; or 4) there is too much shade for selected plant species to thrive.

2. Check with local, state and federal regulatory agencies before beginning the project. Do not alter a wetland area without proper permits. In Nebraska, check with the local Natural Resources District or the Natural Resources Conservation Service to inquire about permits.

3. Water elevation is the most critical element in a successful installation. Be sure you know the normal, high and low water elevations for the site. Know the seasonal changes in water elevation and how rapidly these changes occur.

4. Be sure to fence out animals and people, if needed. If damage occurs, supplemental planting may be necessary.

5. Be aware of flood or drought conditions that could impact your installation. Severe weather will reduce seedling survival. Supplemental planting may be needed.

6. Provide regular monitoring and maintenance, especially in the first year, to assure adequate plant survival.

7. Plan ahead. Involve the proper design professionals and experts to provide information on hydrology, plantings and structural design. A multi-disciplinary approach will assure success.

When To Seek Expert Help

There are bioengineering consultants available to help with all aspects of site assessment, design and installation. Their input could make the difference between success or failure. Use the IECA Products & Services Directory to seek out professional assistance (see references for address). Many bioengineering techniques can be used successfully without input from consultants, however it is best to consider expert help if characteristics of your site are such that: 1) stream velocities are greater than 3 to 5 feet per second; 2) streambank heights are greater than 3 feet; or 3) wave impacts are from waves greater than 1 foot high.

Tips For A Successful Demonstration

Demonstration projects can help show the advantages and benefits of bioengineering solutions. Keep demonstration projects small, from 100 to 500 feet in length for most situations. A smaller project puts less property and dollars at risk. A demonstration lets you evaluate what methods or plant species perform best under similar conditions. Incorporate some variety into the project so you can compare differences. To start, choose a simple project, in a low impact area, with a low profile or incorporate some bioengineering methods into larger projects and collect data to evaluate their success. Provide adequate maintenance and keep good monitoring records. Schedule agency

personnel and public visits to the site to maximize public relations. Plan to hold these visits during installation and again after one growing season.

References

Gray, D.H. and A.T. Leiser. 1982. Biotechnical slope protection and erosion control. Van Nostrand Reinhold Company Inc., New York, 271 pp.

International Erosion Control Association. 1995-1996 Products & services directory. IECA, PO Box 4904, Steamboat Springs, CO 80477-4904. 94 pp.

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IV. STREAMBANK AND SHORELINE EROSION MANAGEMENT MEASURE

Streambank erosion is used in this guidance to refer to the loss of fastland along nontidal streams and rivers. *Shoreline erosion* is used in this guidance to refer to the loss of beach or fastland in tidal portions of coastal bays or estuaries. Erosion of ocean coastlines is not regarded as a substantial contributor of NPS pollution in coastal waterbodies and will not be considered in this guidance.

The force of water flowing in a river or stream can be regarded as the most important process causing erosion of a streambank. All of the eroded material is carried downstream and deposited in the channel bottom or in point bars located along bends in the waterway. The process is very different in coastal bays and estuaries, where waves and currents can sort the coarser-grained sands and gravels from eroded bank materials and move them in both directions along the shore, through a process called *littoral drift*, away from the area undergoing erosion. Thus, the materials in beaches of coastal bays and estuaries are derived from shore erosion somewhere else along the shore. Solving the erosion of the source area may merely create new problems with beach erosion over a much wider area of the shore.

The seepage of ground water and the overland flow of surface water runoff also contribute to the erosion of both streambanks and shorelines. The role of ground water is most important wherever permeable subsurface layers of sand or gravel are exposed in banks and high bluffs along streams, rivers, and coastal bays (Palmer, 1973; Leatherman, 1986; Figure 6-10). In these areas, the seepage of ground water into the waterway can cause erosion at the point of exit from the bank face, leading to bank failure. The surface flow of upland runoff across the bank face can also dislodge sediments through sheet flow, or through the creation of rills and gullies on the shoreline banks and bluffs.

The erosion of shorelines and streambanks is a natural process that can have either beneficial or adverse impacts on the creation and maintenance of riparian habitat. Sands and gravels eroded from streambanks are deposited in the channel and are used as instream habitat during the life stages of many benthic organisms and fish. The same materials eroded from the shores of coastal bays and estuaries maintain the beach as a natural barrier between the open water and coastal wetlands and forest buffers. Beaches are dynamic, ephemeral land forms that move back and forth onshore, offshore, and along shore with changing wave conditions (Bascom, 1964). The finer-grained silts and clays derived from the erosion of shorelines and streambanks are sorted and carried as far as the quiet waters of wetlands or tidal flats, where benefits are derived from addition of the new material.

There are also adverse impacts from shoreline and streambank erosion. Excessively high sediment loads can smother submerged aquatic vegetation (SAV) beds, cover shellfish beds and tidal flats, fill in riffle pools, and contribute to increased levels of turbidity and nutrients. However, there are few research results that can be used to identify levels below which streambank and shoreline erosion is beneficial and above which it is an NPS-related problem.

The Chesapeake Bay is one coastal waterbody for which sufficient data exist to characterize the relative importance of shore erosion as a source of sediment and nutrients (Ibison et al., 1990, 1992). Erosion of the shores above mean sea level contributes 6.9 million cubic yards of sediment per year, or 39 percent of the total annual sediment supply to the Chesapeake Bay (USACE, 1990). The contribution of nitrogen from shore erosion is estimated at 3.3 million pounds per year, which is 3.3 percent of the total nonpoint nitrogen load to the Bay. The contribution of phosphorus from shore erosion is estimated at 4.5 million pounds per year, which is approximately 46 percent of the total nonpoint phosphorus load to the Bay (USEPA-CBP, 1991).

For many watersheds, it will be necessary to consider four questions about streambank and shoreline erosion simultaneously in developing an NPS pollution reduction strategy:

1. Is sediment derived from coastal erosion helping to maintain aquatic habitat elsewhere in the system?
2. Is coastal erosion a significant contributor of nonpoint sediment and nutrients?
3. Is coastal erosion causing a loss of wetlands and riparian areas, with resultant loss of aquatic habitat and reduction of capacity to remove NPS pollutants from surface waters?
4. Are activities along the shoreline and in adjacent surface waters increasing the rate of coastal erosion above natural (background) levels?

The answers to these questions will determine the emphasis that should be given to each of the three elements in the Management Measure for Eroding Streambanks and Shorelines.

A. Management Measure for Eroding Streambanks and Shorelines

1. **Where streambank or shoreline erosion is a nonpoint source pollution problem, streambanks and shorelines should be stabilized. Vegetative methods are strongly preferred unless structural methods are more cost-effective, considering the severity of wave and wind erosion, offshore bathymetry, and the potential adverse impact on other streambanks, shorelines, and offshore areas.**
2. **Protect streambank and shoreline features with the potential to reduce NPS pollution.**

3. **Protect streambanks and shorelines from erosion due to uses of either the shorelands or adjacent surface waters.**

1. Applicability

This management measure is intended to be applied by States to eroding shorelines in coastal bays, and to eroding streambanks in coastal rivers and creeks. The measure does not imply that all shoreline and streambank erosion must be controlled. Some amount of natural erosion is necessary to provide the sediment for beaches in estuaries and coastal bays, for point bars and channel deposits in rivers, and for substrate in tidal flats and wetlands. The measure, however, applies to eroding shorelines and streambanks that constitute an NPS problem in surface waters. It is not intended to hamper the efforts of any States or localities to retreat rather than to harden the shoreline. Under the Coastal Zone Act Reauthorization Amendments of 1990, States are subject to a number of requirements as they develop coastal NPS programs in conformity with this measure and will have some flexibility in doing so. The application of management measures by States is described more fully in *Coastal Nonpoint Pollution Control Program: Program Development and Approval Guidance*, published jointly by the U.S. Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration (NOAA) of the U.S. Department of Commerce.

2. Description

Several streambank and shoreline stabilization techniques will be effective in controlling coastal erosion wherever it is a source of nonpoint pollution. Techniques involving marsh creation and vegetative bank stabilization ("soil bioengineering") will usually be effective at sites with limited exposure to strong currents or wind-generated waves. In other cases, the use of engineering approaches, including beach nourishment or coastal structures, may need to be considered. In addition to controlling those sources of sediment input to surface waters which are causing NPS pollution, these techniques can halt the destruction of wetlands and riparian areas located along the shorelines of surface waters. Once these features are protected, they can serve as a filter for surface water runoff from upland areas, or as a sink for nutrients, contaminants, or sediment already present as NPS pollution in surface waters.

Stabilization practices involving vegetation or coastal engineering should be properly designed and installed. These techniques should be applied only when there will be no adverse effects to aquatic or riparian river habitat, or to the stability of adjacent shorelines, from stabilizing a source of shoreline sediments. Finally, it is the intent of this measure to promote institutional measures that establish minimum set-back requirements or measures that allow a buffer zone to reduce concentrated flows and promote infiltration of surface water runoff in areas adjacent to the shoreline.

3. Management Measure Selection

This management measure was selected for the following reasons:

1. Erosion of shorelines and streambanks contributes significant amounts of NPS pollution in surface waters such as in the Chesapeake Bay;
2. The loss of coastal land and streambanks due to shoreline and streambank erosion results in reduction of riparian areas and wetlands that have NPS pollution abatement potential; and
3. A variety of activities related to the use of shorelands or adjacent surface waters can result in erosion of land along coastal bays or estuaries and losses of land along coastal rivers and streams.

4. Practices

As discussed more fully at the beginning of this chapter and in Chapter 1, the following practices are described for illustrative purposes only. State programs need not require the implementation of these practices. However, as a practical matter, EPA anticipates that the management measure set forth above generally will be implemented by applying one or more management practices appropriate to the source, location, and climate. The practices set forth below have been found by EPA to be representative of the types of practices that can be applied successfully to achieve the management measure described above.

Preservation and protection of shorelines and streambanks can be accomplished through many approaches, but preference in this guidance is for nonstructural practices, such as soil bioengineering and marsh creation.

• ***a. Use soil bioengineering and other vegetative techniques to restore damaged habitat along shorelines and streambanks wherever conditions allow.***

Soil bioengineering is used here to refer to the installation of living plant material as a main structural component in controlling problems of land instability where erosion and sedimentation are occurring (USDA-SCS, 1992). Soil bioengineering largely uses native plants collected in the immediate vicinity of a project site. This ensures that the plant material will be well adapted to site conditions. While a few selected species may be installed for immediate protection, the ultimate goal is for the natural invasion of a diverse plant community to stabilize the site through development of a vegetative cover and a reinforcing root matrix (USDA-SCS, 1992).

Soil bioengineering provides an array of practices that are effective for both prevention and mitigation of NPS problems. This applied technology combines mechanical, biological, and ecological principles to construct protective systems that prevent slope failure and erosion. Adapted types of woody vegetation (shrubs and trees) are initially installed as key structural components, in specified configurations, to offer immediate soil protection and reinforcement. Soil bioengineering systems normally use cut, unrooted plant parts in the form of branches or rooted plants. As the systems establish themselves, resistance to sliding or shear displacement increases in streambanks and upland slopes (Schiechtl, 1980; Gray and Leiser, 1982; Porter, 1992).

Specific soil bioengineering practices include (USDA-SCS, 1992):

Live Staking. Live staking involves the insertion and tamping of live, rootable vegetative cuttings into the ground (Figure 6-11). If correctly prepared and placed, the live stake will root and grow. A system of stakes creates a living root mat that stabilizes the soil by reinforcing and binding soil particles together and by extracting excess soil moisture. Most willow species are ideal for live staking because they root rapidly and begin to dry out a slope soon after installation. This is an appropriate technique for repair of small earth slips and slumps that frequently are wet.

Live Fascines. Live fascines are long bundles of branch cuttings bound together into sausage-like structures (Figure 6-12). When cut from appropriate species and properly installed, they will root and immediately begin to stabilize slopes. They should be placed in shallow contour trenches on dry slopes and at an angle on wet slopes to reduce erosion and shallow face sliding. This system, installed by a trained crew, does not cause much site disturbance.

Brushlayering. Brushlayering consists of placing live branch cuttings in small benches excavated into the slope. The width of the benches can range from 2 to 3 feet. The portions of the brush that protrude from the slope face assist in retarding runoff and reducing surface erosion. Brushlayering is somewhat similar to live fascine systems because both involve the cutting and placement of live branch cuttings on slopes. The two techniques differ principally in the orientation of the branches and the depth to which they are placed in the slope. In brushlayering, the cuttings are oriented more or less perpendicular to the slope contour. In live fascine systems, the cuttings are oriented more or less parallel to the slope contour. The perpendicular orientation is more effective from the point of view of earth reinforcement and mass stability of the slope.

Brush Mattressing. Brush mattressing is commonly used in Europe for streambank protection. It involves digging a slight depression on the bank and creating a mat or mattress from woven wire or single strands of wire and live, freshly cut branches from sprouting trees or shrubs. Branches up to 2.5 inches in diameter are normally cut 3 to 10 feet long and laid in criss-cross layers with the butts in alternating directions to create a uniform mattress with few voids. The mattress is then covered with wire secured with wooden stakes up to 3 feet long. It is then covered with soil and watered repeatedly to fill voids with soil and facilitate sprouting; however, some branches should be left partially exposed on the surface. The structure may require protection from undercutting by placement of stones or burial of the lower edge. Brush mattresses are generally resistant to waves and currents and provide protection from the digging out of plants by animals. Disadvantages include possible burial with sediment in some situations and difficulty in making later plantings through the mattress.

Branchpacking. Branchpacking consists of alternating layers of live branch cuttings and compacted backfill to repair small localized slumps and holes in slopes (Figure 6-13). Live branch cuttings may range from 1/2 inch to 2 inches in diameter. They should be long enough to touch the undisturbed soil at the back of the trench and extend slightly outward from the rebuilt slope face. As plant tops

begin to grow, the branchpacking system becomes increasingly effective in retarding runoff and reducing surface erosion. Trapped sediment refills the localized slumps or holes, while roots spread throughout the backfill and surrounding earth to form a unified mass.

Joint Planting. Joint planting (or vegetated riprap) involves tamping live cuttings of rootable plant material into soil between the joints or open spaces in rocks that have previously been placed on a slope (Figure 6-14). Alternatively, the cuttings can be tamped into place at the same time that rock is being placed on the slope face.

Live Cribwalls. A live cribwall consists of a hollow, box-like interlocking arrangement of untreated log or timber members (Figure 6-15). The structure is filled with suitable backfill material and layers of live branch cuttings, which root inside the crib structure and extend into the slope. Once the live cuttings root and become established, the subsequent vegetation gradually takes over the structural functions of the wood members.

These techniques have been used extensively in Europe for streambank and shoreline protection and for slope stabilization. They have been practiced in the United States only to a limited extent primarily because other engineering options, such as the use of riprap, have been more commonly accepted practices (Allen and Klimas, 1986). With the costs of labor, materials, and energy rapidly rising in the last two decades, however, less costly alternatives of stabilization are being pursued as alternatives to engineering structures for controlling erosion of streambanks and shorelines.

Additionally, bioengineering has the advantage of providing food, cover, and instream and riparian habitat for fish and wildlife and results in a more aesthetically appealing environment than traditional engineering approaches (Allen and Klimas, 1986).

Local agencies such as the USDA Soil Conservation Service and Extension Service can be a useful source of information on appropriate native plant species that can be considered for use in bioengineering projects (USDA-SCS, 1992). For the Great Lakes, the U.S. Army Corps of Engineers has identified 33 upland plant species that have the potential to effectively decrease surface erosion of shorelines resulting from wind action and runoff (Hall and Ludwig, 1975). Michigan Sea Grant has also published two useful guides for shorefront property owners that provide information on vegetation and its role in reducing Great Lakes shoreline erosion (Tainter, 1982; Michigan Sea Grant College Program, 1988).

When considering a soil bioengineering approach to shoreline stabilization, several factors in addition to selection of plant materials are important. Shores subject to wave erosion will usually require structures or beach nourishment to dampen wave energy. In particular, the principles of soil bioengineering, discussed previously, will be ineffective at controlling that portion of streambank or shoreline erosion caused by wave energy. However, soil bioengineering will typically be effective on the portion of the eroding streambank or shoreline located above the zone of wave attack. Subsurface seepage and soil slumping may need to be prevented by dewatering the bank material. Steep banks

may need to be reshaped to a more gentle slope to accommodate the plant material (Hall and Ludwig, 1975).

Marsh creation and restoration is another useful vegetative technique that can be used to address problems with erosion of coastal shorelines. Marsh plants perform two functions in controlling shore erosion (Knutson, 1988). First, their exposed stems form a flexible mass that dissipates wave energy. As wave energy is diminished, both the offshore transport and longshore transport of sediment are reduced. Ideally, dense stands of marsh vegetation can create a depositional environment, causing accretion of sediments along the intertidal zone rather than continued erosion of the shore. Second, marsh plants form a dense mat of roots (called rhizomes), which can add stability to the shoreline sediments.

Techniques of marsh creation for shore erosion control have been described by researchers for various coastal areas of the United States, including North Carolina (Woodhouse et al., 1972; Knutson, 1977; Knutson and Inskeep, 1982; Knutson and Woodhouse, 1983), the Chesapeake Bay (Garbisch et al., 1973; Sharp et al., undated), and Florida and the Gulf Coast (Lewis, 1982). The basic approach is to plant a shoreline area in the vicinity of the tide line with appropriate marsh grass species. Suitable fill material may be placed in the intertidal zone to create a wetlands planting terrace of sufficient width (at least 18 to 25 feet) if such a terrace does not already exist at the project site.

For shoreline sites that are highly sheltered from the effects of wind, waves, or boat wakes, the fill material is usually stabilized with small structures, similar to groins (see practice b below), which extend out into the water from the land. For shorelines with higher levels of wave energy, the newly planted marsh can be protected with an offshore installation of stone that is built either in a continuous configuration (Figure 6-16) or in a series of breakwaters (Figure 6-17).

Knutson and Woodhouse (1983) have developed a method for evaluating the suitability of shoreline sites for successful creation of marshes. The method uses a Vegetative Stabilization Site Evaluation Form (Figure 6-18) to evaluate potential for planting success on a case-by-case basis. The user measures each of four characteristics for the area in question, identifies the categories on the form that best describe the area, calculates a cumulative score, and uses the score to determine the potential success rate for installation of wetland plants in the intertidal zone. Sites with a cumulative score of 300 or greater have been correlated with 100 percent success rates at actual field planting sites (Lewis, 1982). Sites with scores between 201 and 300 generally have a success rate of 50 percent, which often constitutes an acceptable risk for undertaking a shoreline erosion control project emphasizing marsh creation (Lewis, 1982).

- ***b. Use properly designed and constructed engineering practices for shore erosion control in areas where practices involving marsh creation and soil bioengineering are ineffective.***

Properly designed and constructed shore and streambank erosion control structures are used in areas where higher wave energy makes biostabilization and marsh creation ineffective. There are many sources of information concerning the proper design and construction of shoreline and streambank erosion control structures. Table 6-4 *(28k)* contains several useful sources of design information. In addition to careful consideration of the engineering design, the proper planning for a shoreline or streambank protection project will include a thorough evaluation of the physical processes causing the erosion. To complete the analysis of physical factors, the following steps are suggested (Hobbs et al., 1981):

1. Determine the limits of the shoreline reach;
2. Determine the rates and patterns of erosion and accretion and the active processes of erosion within the reach;
3. Determine, within the reach of the sites of erosion-induced sediment supply, the volumes of that sediment supply available for redistribution within the reach, as well as the volumes of that sediment supply lost from the reach;
4. Determine the direction of sediment transport and, if possible, estimation of the magnitude of the gross and net sediment transport rates; and
5. Estimate factors such as ground-water seepage or surface water runoff that contribute to erosion.

The most widely-accepted alternative engineering practices for streambank or shoreline erosion control are described below. These practices will have varying levels of effectiveness depending on the strength of waves, tides, and currents at the project site. They will also have varying degrees of suitability at different sites and may have varying

types of secondary impacts. One important impact that must always be considered is the transfer of wave energy, which can cause erosion offshore or alongshore. Finding a satisfactory balance between these three factors (effectiveness, suitability, and secondary impacts) is often the key to a successful streambank or shore erosion control project.

Fixed engineering structures are built to protect upland areas when resources become impacted by erosive processes. Sound design practices for these structures are essential (Kraus and Pilkey, 1988). Not only are poorly designed structures typically unsuccessful in protecting the intended stretch of shoreline, but they also have a negative impact on other stretches of shoreline as well. One example of accelerated erosion of unprotected properties adjacent to shoreline erosion structures is the Siletz Spit, Oregon, site (Komar and McDougal, 1988).

For sites where soil bioengineering marsh creation would not be an effective means of streambank or shoreline stabilization, a variety of engineering approaches can be considered. One approach involves the design and installation of fixed engineering structures. Bulkheads and seawalls are two types of wave-resistant walls that are similar in design but slightly different in purpose. Bulkheads are primarily soil-retaining structures designed also to resist wave attack (Figure 6-19). Seawalls are principally structures designed to resist wave attack, but they also may retain some soil (USACE,

1984). Both bulkheads and seawalls may be built of many materials, including steel, timber, or aluminum sheet pile, gabions, or rubble-mound structures.

Although bulkheads and seawalls protect the upland area against further erosion and land loss, they often create a local problem. Downward forces of water, produced by waves striking the wall, can produce a transfer of wave energy and rapidly remove sand from the wall (Pilkey and Wright, 1988). A stone apron is often necessary to prevent scouring and undermining. With vertical protective structures built from treated wood, there are also concerns about the leaching of chemicals used in the wood preservatives (Baechler et al., 1970; Arsenault, 1975). Chromated copper arsenate (CCA), the most popular chemical used for treating the wood used in docks, pilings, and bulkheads, contains elements of chromium, copper, and arsenic, which have some value as nutrients in the marine environment but are toxic above trace levels (Weis et al., 1991; Weis et al., 1992).

A revetment is another type of vertical protective structure used for shoreline protection. One revetment design contains several layers of randomly shaped and randomly placed stones, protected with several layers of selected armor units or quarry stone (Figure 6-20). The armor units in the cover layer should be placed in an orderly manner to obtain good wedging and interlocking between individual stones. The cover layer may also be constructed of specially shaped concrete units (USACE, 1984).

Sometimes gabions (stone-filled wire baskets) or interlocking blocks of precast concrete are used in the construction of revetments. In addition to the surface layer of armor stone, gabions, or rigid blocks, successful revetment designs also include an underlying layer composed of either geotextile filter fabric and gravel or a crushed stone filter and bedding layer. This lower layer functions to redistribute hydrostatic uplift pressure caused by wave action in the foundation substrate. Precast cellular blocks, with openings to provide drainage and to allow vegetation to grow through the blocks, can be used in the construction of revetments to stabilize banks. Vegetation roots add additional strength to the bank. In situations where erosion can occur under the blocks, fabric filters can be used to prevent the erosion. Technical assistance should be obtained to properly match the filter and soil characteristics. Typically blocks are hand placed when mechanical access to the bank is limited or costs need to be minimized. Cellular block revetments have the additional benefit of being flexible to conform to minor changes in the bank shape (USACE, 1983).

Groins are structures that are built perpendicular to the shore and extend into the water. Groins are generally constructed in series, referred to as a groin field, along the entire length of shore to be protected. Groins trap sand in littoral drift and halt its longshore movement along beaches. The sand beach trapped by each groin acts as a protective barrier that waves can attack and erode without damaging previously unprotected upland areas. Unless the groin field is artificially filled with sand from other sources, sand is trapped in each groin by interrupting the

natural supply of sand moving along the shore in the natural littoral drift. This frequently results in an inadequate natural supply of sand to replace that which is carried away from

beaches located farther along the shore in the direction of the littoral drift. If these "downdrift" beaches are kept starved of sand for sufficiently long periods of time, severe beach erosion in unprotected areas can result.

As with bulkheads and revetments, the most durable materials used in the construction of groins are timber and stone. Less expensive techniques for building groins use sand- or concrete-filled bags or tires. It must be recognized that the use of lower-cost materials in the construction of bulkheads, revetments, or groins frequently results in less durability and reduced project life.

Breakwaters are wave energy barriers designed to protect the land or nearshore area behind them from the direct assault of waves. Breakwaters have traditionally been used only for harbor protection and navigational purposes; in recent years, however, designs of shore-parallel segmented breakwaters, such as the one shown in Figure 6-17, have been used for shore protection purposes (Fulford, 1985; USACE, 1990; Hardaway and Gunn, 1989; Hardaway and Gunn, 1991). Segmented breakwaters can be used to provide protection over longer sections of shoreline than is generally affordable through the use of bulkheads or revetments. Wave energy is able to pass through the breakwater gaps, allowing for the maintenance of some level of longshore sediment transport, as well as mixing and flushing of the sheltered waters behind the structures. The cost per foot of shore for the installation of segmented offshore breakwaters is generally competitive with the costs of stone revetments and bulkheads (Hardaway et al., 1991).

Selection of Structural Stabilization Techniques

Five factors are typically taken into consideration when choosing from among the various alternatives of engineering practices for protection of eroding shorelines (USACE, 1984):

1. Foundation conditions;
2. Level of exposure to wave action;
3. Availability of materials;
4. Initial costs and repair costs; and
5. Past performance.

Foundation conditions may have a significant influence on the selection of the type of structure to be used for shoreline or streambank stabilization. Foundation characteristics at the site must be compatible with the structure that is to be installed for erosion control. A structure such as a bulkhead, which must penetrate through the existing substrate for stability, will generally not be suitable for shorelines with a rocky bottom. Where foundation conditions are poor or where little penetration is possible, a gravity-type structure such as a stone revetment may be preferable. However, all vertical protective structures (revetments, seawalls, and bulkheads) built on sites with soft or unconsolidated bottom materials can experience scouring as incoming waves are reflected off the structures. In the absence of additional toe protection in these circumstances, the level of scouring and erosion of bottom sediments at the base of the structure may be severe enough to contribute to structural failure at some point in the lifetime of the installation.

Along streambanks, the force of the current during periods of high streamflow will influence the selection of bank stabilization techniques and details of the design. For coastal bays, the levels of wave exposure at the site will also generally influence the selection of shoreline stabilization techniques and details of the design. In areas of severe wave action or strong currents, light structures such as timber cribbing or light riprap revetment should not be used.

The effects of winter ice along the shoreline or streambank also need to be considered in the selection and design of erosion control projects. The availability of materials is another key factor influencing the selection of suitable structures for an eroding streambank or shoreline. A particular type of bulkhead, seawall, or revetment may not be economically feasible if materials are not readily available near the construction site. Installation methods may also preclude the use of specific structures in certain situations. For instance, the installation of bulkhead pilings in coastal areas near wetlands may not always be permissible due to disruptive impacts in locating pile-driving equipment at the project site.

Costs are influenced not only by the availability of materials but also by the type of structure that is selected for protection of the shoreline. The total cost of a shoreline or streambank protection project should be viewed as including both the initial costs of materials and the annual costs of maintenance. In some parts of the country, the initial costs of timber bulkheads may be less than the cost of stone revetments. However, stone structures typically require less maintenance and have a longer life than timber structures. Other types of structures whose installation costs are similar may actually have a wide difference in overall cost when annual maintenance and the anticipated lifetime of the structure are considered (USACE, 1984).

Other engineering practices for stabilizing shorelines and streambanks rely less on fixed structures. The creation or nourishment of existing beaches provides protection to the eroding area and can also provide a riparian habitat function, particularly when portions of the finished project are planted with beach or dune grasses (Woodhouse, 1978). Beach nourishment requires a readily available source of suitable fill material that can be effectively transported to the erosion site for reconstruction of the beach (Hobson, 1977). Dredging or pumping from offshore deposits is the method most frequently used to obtain fill material for beach nourishment. A second possibility is the mining of suitable sand from inland areas and overland hauling and dumping by trucks. To restore an eroded beach and stabilize it at the restored position, fill is placed directly along the eroded sector (USACE, 1984). In most cases, plans must be made to periodically obtain and place additional fill on the nourished beach to replace sand that is carried offshore into the zone of breaking waves or alongshore in littoral drift (Houston, 1991; Pilkey, 1992).

One important task that should not be overlooked in the planning process for beach nourishment projects is the proper identification and assessment of the ecological and hydrodynamic effects of obtaining fill material from nearby submerged coastal areas (Thompson, 1973). Removal of substantial amounts of bottom sediments in coastal areas can disrupt populations of fish, shellfish, and benthic organisms. Grain size analysis

should be performed on sand from both the borrow area and the beach area to be nourished. Analysis of grain size should include both size and size distribution, and fill material should match both of these parameters. Fill materials should also be analyzed for the presence of contaminants, and contaminated sediment should not be used. Turbidity levels in the overlying waters can also be raised to undesirable levels (Sherk et al., 1976; O'Connor et al., 1976). Certain coastal areas may have seasonal restrictions on obtaining fill from nearby submerged coastal areas (Profiles Research and Consulting Group, Inc., 1980). Timing of nourishment activities is frequently a critical factor since the recreational demand for beach use frequently coincides with the best months for completing the beach nourishment. These may also be the worst months from the standpoint of impacts to aquatic life and the beach community such as turtles seeking nesting sites.

Design criteria should include proper methods for stabilizing the newly created beach and provisions for long-term monitoring of the project to document the stability of the newly created beach and the recovery of the riparian habitat and wildlife in the area.

• ***c. In areas where existing protection methods are being flanked or are failing, implement properly designed and constructed shore erosion control methods such as returns or return walls, toe protection, and proper maintenance or total replacement.***

Toe Protection. A number of qualitative advantages are to be gained by providing toe protection for vertical bulkheads. Toe protection usually takes the form of a stone apron installed at the base of the vertical structure to reduce wave reflection and scour of bottom sediments during storms (Figure 6-21). The installation of rubble toe protection should include filter cloth and perhaps a bedding of small stone to reduce the possibility of rupture of the filter cloth. Ideally, the rubble should extend to an elevation such that waves will break on the rubble during storms.

Return Walls. Whenever shorelines or streambanks are "hardened" through the installation of bulkheads, seawalls, or revetments, the design process must include consideration that waves and currents can continue to dislodge the substrate at both ends of the structure, resulting in very concentrated erosion and rapid loss of fastland. This process is called flanking (Figure 6-22). To prevent flanking, return walls should be provided at either end of a vertical protective structure and should extend landward for a horizontal distance consistent with the local erosion rate and the design life of the structure.

Maintenance of Structures. Periodic maintenance of structures is necessary to repair the damage from storms and winter ice and to address the effects of flanking and off-shore profile deepening. The maintenance varies with the structural type, but annual inspections should be made by the property owners. For stone revetments, the replacement of stones that have been dislodged is necessary; timber bulkheads need to be backfilled if there has been a loss of upland material, and broken sheet pile should be replaced as necessary. Gabion baskets should be inspected for corrosion failure of the wire, usually caused either by improper handling during construction or by abrasion from the stones inside the

baskets. Baskets should be replaced as necessary since waves will rapidly empty failed baskets.

Steel, timber, and aluminum bulkheads should be inspected for sheet pile failure due to active earth pressure or debris impact and for loss of backfill. For all structural types not contiguous to other structures, lengthening of flanking walls may be necessary every few years. Through periodic monitoring and required maintenance, a substantially greater percentage of coastal structures will perform effectively over their design life.

- ***d. Plan and design all streambank, shoreline, and navigation structures so that they do not transfer erosion energy or otherwise cause visible loss of surrounding streambanks or shorelines.***

Many streambank or shoreline protection projects result in a transfer of energy from one area to another, which causes increased erosion in the adjacent area (USACE, 1981a). Property owners should consider the possible effects of erosion control measures on other properties located along the shore.

- ***e. Establish and enforce no-wake zones to reduce erosion potential from boat wakes.***

No-wake zones should be given preference over posted speed limits in shallow coastal waters for reducing the erosion potential of boat wakes on streambanks and shorelines. Posted speed limits on waterways generally restrict the movement of recreational boating traffic to speeds in the range of 6-8 knots, but motorboats traveling at these speeds in shallow waters can be expected to throw wakes whose wave heights will be at or near the maximum size that can be produced by the boats.

In theory, the boat speed that will produce the maximum wake depends on the depth of the water and the speed of the boat (Johnson, 1957). The ratio of these variables is called the Froude Number, named after an early scientific investigator of fluid mechanics. As the Froude Number (**F**) approaches 1, the wakes produced by a boat will reach their maximum value. The relationship between the Froude Number, the boat speed, and the basin depth is described by the following equation (Johnson, 1957):

$$F = V_s / \sqrt{gd}$$

where:

Vs = Velocity of boat speed (knots)
g = Gravity constant (ft/sec2)
d = Basin depth (ft)

It is important to note that this equation can be used only to describe the boat speed at which a maximum wake will occur in water of a known depth. The equation cannot be used to calculate the actual height of the maximum wake.

Table 6-5 contains values for **F** calculated for different combinations of boat speed and water depth, prepared as part of a study of wakes produced by recreational boating traffic on the Chesapeake Bay in Maryland (Maryland Department of Natural Resources, 1980). The dotted line drawn through this table shows those combinations for which **F** approximately equals 1. For instance, boats traveling 6 to 8 knots can be expected to produce their maximum wake in water depths of 4 to 6 feet, while boats traveling 10 to 12 knots can be expected to produce their maximum wake in water depths of 12 feet. These depths are typical of conditions in small creeks and coves in coastal areas where there is generally the greatest concern about shore erosion resulting from recreational motorboat traffic.

Table 6-5 was verified with field data collected in a shallow creek in Maryland's Chesapeake Bay for two types of motorboats. The results are presented in Figure 6-23. As predicted from Table 6-5, maximum wake heights were produced at speeds ranging from 6 to 8 knots. Wake heights did not increase with increasing speed.

These results show that boats can be expected to still produce damaging wakes as they slow from high speed to enter a narrow creek or cove with a posted 6-knot limit. Locating the speed reduction zones in open water, so that boats are slowing through the critical range of velocities far from shore, would reduce the potential for shore erosion from boat wakes. The designation of no-wake zones, rather than posted speed limits, would also reduce the potential for shore erosion from boat wakes.

• ***f. Establish setbacks to minimize disturbance of land adjacent to streambanks and shorelines to reduce other impacts. Upland drainage from development should be directed away from bluffs and banks so as to avoid accelerating slope erosion.***

In addition to the soil bioengineering, marsh creation, beach nourishment, and structural practices discussed on the preceding pages of this guidance, another approach that should be considered in the planning process for shoreline and streambank erosion involves the designation of setbacks. Setbacks most often take the form of restrictions on the siting and construction of new standing structures along the shoreline. Where setbacks have been implemented to reduce the hazard of coastal land loss, they have also included requirements for the relocation of existing structures located within the designated setback area. Setbacks can also include restrictions on uses of waterfront areas that are not related to the construction of new buildings (Davis, 1987).

A recent report, *Managing Coastal Erosion* (NRC, 1990), summarizes the experience of coastal States in the implementation and administration of regulatory setback programs. The NRC report also discusses "the taking issue," which views setbacks as a severe restriction on the rights of private landowners to fill or build in designated setback areas. Setback regulations implemented in some States have been challenged in the courts on the grounds of "the taking issue," i.e., that the setback requirements are so restrictive that they "take" the value of the property without providing compensation to the property owners, violating the Fifth Amendment to the U.S. Constitution. The courts, however, have provided general approval of floodplain and wetlands regulations, and the NRC

report concludes: "there is a strong legal basis for the broader use of setbacks for coastal construction based on the best available scientific estimates of future erosion rates."

Table 6-6 contains a summary of State programs and experiences with setbacks. In most cases, States have used the local unit of government to administer the program on either a mandatory or voluntary basis. This allows local government to retain control of its land use activities and to exceed the minimum State requirements if this is deemed desirable (NRC, 1990).

Web Note: Table 6-6 is unavailable in the web version.

Technical standards for defining and delineating setbacks also vary from State to State. One approach is to establish setback requirements for any "high hazard area" eroding at greater than 1 foot per year. Another approach is to establish setback requirements along all erodible shores because even a small amount of erosion can threaten homes constructed too close to the streambank or shoreline. Several States have general setback requirements that, while not based on erosion hazards, have the effect of limiting construction near the streambank or shoreline.

The basis for variations in setback regulations between States seems to be based on several factors, including (NRC, 1990):

The language of the law being enacted;
The geomorphology of the coast;
The result of discretionary decisions;
The years of protection afforded by the setback; and
Other variables decided at the local level of government.

From the perspective of controlling NPS pollution resulting from erosion of shorelines and streambanks, the use of setbacks has the immediate benefit of discouraging concentrated flows and other impacts of storm water runoff from new development in areas close to the streambank or shoreline. These effects are described and discussed in Chapter 4 of this guidance document. In particular, the concentration of storm water runoff can aggravate the erosion of shorelines and streambanks, leading to the formation of gullies, which are not easily repaired. Therefore, drainage of storm water from developed areas and development activities located along the shoreline should be directed inland to avoid accelerating slope erosion.

The best NPS benefits are provided by setbacks that not only include restrictions on new construction along the shore but also contain additional provisions aimed at preserving and protecting coastal features such as beaches, wetlands, and riparian forests. This approach promotes the natural infiltration of surface water runoff before it passes over the edge of the bank or bluff and flows directly into the coastal waterbody. This approach also helps protect zones of naturally occurring vegetation growing along the shore. As discussed in the section on "bioengineering practices," the presence of undisturbed

shoreline vegetation itself can help to control erosion by removing excess water from the bank and by anchoring the individual soil particles of the substrate.

Almost all States with setback regulations have modified their original programs to improve effectiveness or correct unforeseen problems (NRC, 1990). States' experiences have shown that procedures for updating or modifying the setback width need to be included in the regulations. For instance, application of a typical 30-year setback standard in an area whose rate of erosion is 2 feet per year results in the designation of a setback width of 60 feet. This width may not be sufficient to protect the beaches, wetlands, or riparian forests whose presence improves the ability of the streambank or shoreline to respond to severe wave and flood conditions, or to high levels of surface water runoff during extreme precipitation events. A setback standard based on the landward edge of streambank or shoreline vegetation is one alternative that has been considered (NRC, 1990; Davis, 1987).

From the standpoint of NPS pollution control, the approach that best designates coastal wetlands, beaches, or riparian forests as a special protective feature, allows no development on the feature, and measures the setback from the landward side of the feature is recommended (NRC, 1990). In some cases, provisions for soil bioengineering, marsh creation, beach nourishment, or engineering structures may also be appropriate since the special protective features within the designated setbacks can continue to be threatened by uncontrolled erosion of the shoreline or streambank. Finally, setback regulations should recognize that some special features of the streambank or shoreline will change position. For instance, beaches and wetlands can be expected to migrate landward if water levels continue to rise as a result of global warming. Alternatives for managing these situations include flexible criteria for designating setbacks, vigorous maintenance of beaches and other special features within the setback area, and frequent monitoring of the rate of streambank or shoreline erosion and corresponding adjustment of the setback area.

5. Costs for All Practices

This section describes costs for representative activities that would be undertaken in support of one or more of the practices listed under this management measure. The description of the costs is grouped into the following three categories: (1) costs for streambank and shoreline stabilization with vegetation; (2) costs for streambank and shoreline stabilization with engineering structures; and (3) costs for designation and enforcement of boating speed limits.

a. Vegetative Stabilization for Shorelines and Streambanks

Representative costs for this practice can include costs for wetland plants and riparian area vegetation, including trees and shrubs. Additional costs could be incurred depending on the level of site preparation that is required. The items of work could include (1) clearing the site of fallen trees and debris; (2) extensive site work requiring heavy construction equipment; (3) application of seed stock or sprigging of nursery-reared

plants; (4) application of fertilizer (most typically for marsh creation); and (5) postproject maintenance and monitoring. For a more extensive description of these tasks, refer to the sections of Chapter 7 describing marsh restoration efforts.

1. Costs reported in 1989 for bottomland forest plants using direct seeding were $40 to $60 per acre (NRC, 1991). If vegetation is assumed to be planted across a 50-foot width along the shoreline or streambank, the cost per linear foot of shore or streambank, in 1990 dollars, can be calculated as $0.05 - $0.08/foot.
2. Costs reported in 1990 for nursery-reared tree seedlings were $212.50 per acre (Illinois Department of Conservation, 1990). If vegetation is assumed to be planted across a 50-foot width along the shoreline or streambank, the costs per linear foot of shore or streambank, in 1990 dollars, can be calculated as $0.25/foot.
3. Costs reported for restoration of riparian areas in Utah between 1985 and 1988 included extensive site work: bank grading, installation of riprap and sediment traps in deep gullies, planting of juniper trees and willows, and fencing to protect the sites from intrusion by livestock. Assuming a 100-foot width along the shore or streambank for this work, the reported costs, in 1990 dollars, of $2,527 per acre can be calculated as $5.94 per foot.
4. Costs were reported in 1988 for vegetative erosion control projects involving creation of tidal fringe marsh, using nursery-reared *Spartina alterniflora* and *S. patens* along the shorelines of the Chesapeake Bay in Maryland (Maryland Eastern Shore Resource Conservation and Development Area). Two projects involving marsh creation along a total of 4,650 linear feet of shoreline averaged $20.48 per foot. Costs of 12 projects involving marsh creation combined with grading and seeding of the shoreline bank ranging in height from 5 to 12 feet averaged $54.82 per foot along a total of 8,465 feet. These costs can be calculated in 1990 dollars as:
    - Marsh creation - no bank grading . . . . . $21.44 per foot
    - Marsh creation - bank grading . . . . . $57.40 per foot

b. Structural Stabilization for Shorelines and Streambanks

Representative costs for structural stabilization typically include costs for survey and design and for extensive site work, including costs to gain access for trucks and front-end loaders necessary to place the stone (for revetments) or sheet pile (for bulkheads). As indicated in the data described below for specific projects, costs frequently vary depending on the level of wave exposure at the site and on the overall length of shoreline or streambank that is being protected in a single project. In some of the examples shown below, construction costs were reported along with design and administration costs. For cases where only installation costs were reported in the source document, a total project cost was computed by adding 15 percent of first construction costs to the reported installation cost, and then dividing by the reported project length to compute cost per foot. Thus, all costs shown below include design and administration costs.

1. Costs for timber bulkhead on private property along 100 linear feet of shore on Cabin Creek, York County, Virginia (less than 2 miles of wave exposure), in 1990 dollars, were $69 per foot (Virginia Department of Conservation and Recreation, undated).
2. Costs for replacement of timber bulkhead on private property along 375 linear feet of shore on the Rappahannock River, Middlesex County, Virginia (2 to 5 miles of wave exposure), in 1990 dollars, were $60 per foot (Virginia Department of Conservation and Recreation, undated).
3. Costs for timber bulkhead at Whidbey Island Naval Air Station, Oak Harbor, Washington (more than 5 miles of wave exposure), in 1990 dollars, were $129 per foot (USACE, 1981a).
4. Costs for timber and steel bulkhead along 200 feet of shoreline of a County park at Port Wing, Bayfield County, Wisconsin (more than 5 miles of exposure), in 1990 dollars, were $356 per foot (USACE, 1981a).
5. Costs for stone revetment on private property along 270 feet of shoreline on Linkhorn Bay, Virginia Beach, Virginia (less than 2 miles of wave exposure), in 1990 dollars, were $63 per foot (Virginia Department of Conservation and Recreation, undated).
6. Costs for stone revetment and bank grading along 420 linear feet of shoreline on James River, Surry County, Virginia (2 to 5 miles of exposure), in 1990 dollars, were $342 per foot (Virginia Department of Conservation and Recreation, undated).
7. Costs for stone revetment on private community property along 2000 linear feet of shoreline on Lorain Harbor, Ohio (more than 5 miles of exposure), in 1990 dollars, were $1,093 per foot (USACE, 1981b).
8. Costs for beachfill and dune construction on a city public beach along 10,000 feet of shoreline at North Nantasket Beach, Hull, Massachusetts (more than 5 miles of exposure), in 1990 dollars, were $162 per foot (USACE, 1988).
9. Costs for six riprap and six gabion breakwaters with beachfill on State Wildlife Management Area property along 1250 linear feet of shore on the James River, Surry County, Virginia (2 to 5 miles of exposure), in 1990 dollars, were $62 per foot (Hardaway et al., 1991).
10. Costs for breakwaters, beachfill, and beachgrass planting at a County park along 1100 feet of shoreline at Elm's Beach, Chesapeake Bay, Maryland (more than 5 miles of exposure), in 1990 dollars, were $292 per foot (Hardaway and Gunn, 1991).
11. Costs for breakwaters, beachfill, and revetment along 11,000 feet of shoreline at Maumee Bay State Park, Ohio (more than 5 miles of exposure), in 1990 dollars, were $961 per foot (USACE, 1982).

c. Designation and Enforcement of Boating Speed Limits

Representative costs for this practice can be broken down into the following two tasks:

1. Providing notification of a posted speed limit or "no-wake" zone in navigational channels along coastal waterways. One approach used to advise boaters of posted

speed limits is the placement of marked buoys along the channel in speed reduction zones. Alternatively, signs designating speed reduction zones can be placed on pilings that are driven into the bottom of the coastal creek or bay. In narrow creeks or coves, signs can be mounted onshore along the streambank. The number of signs, buoys, or beacons that will be required will depend on the length and configuration of the channel. For a channel 1 mile in length that is fairly straight and linear, with good visibility on both the downstream and upstream approaches, three posted speed limit signs could be deployed for upstream traffic and three for downstream traffic. Representative costs for this practice, in 1990 dollars, can be estimated from data provided by the Maryland Department of Natural Resources Marine Police Administration. These costs include all labor, materials, and installation:

- Costs for purchasing, marking, and setting six buoys at $285 each are $1,710.
- Costs for six onshore signs mounted on 2-ft by 3-ft by 8-ft posts at $165 each are $990.
- Costs for six channel beacons mounted on offshore 4-ft by 4-ft by 42-ft pilings at $1,850 each are $11,100.

2. The enforcement of designated boating speed limit zones, which can be expected to include costs for the acquisition and maintenance of marine police vessels and costs for marine police personnel to monitor boating patterns. Representative costs, in 1990 dollars, which are incurred for these items by the Maryland Department of Natural Resources (Gwynne Schultz, personal communication, 1992) are listed below:
    - One large patrol boat (suitable for areas of open water in coastal bays or rivers):
        - Acquisition $180,000
        - Annual maintenance per vessel per year $ 2,000
        - Crew of three marine police $ 90,000
    - One small patrol boat (suitable for protected creeks and coves):
        - Acquisition $20,000
        - Annual maintenance per vessel per year $ 2,000
        - Crew of two marine police $60,000

These costs do not consider overtime that is provided to members of the Maryland Marine Police for any shift greater than 8 hours in length. No overtime is paid for holidays.

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VI. TAINAN ECOLOGICAL SCHOOL CONCEPTUAL DESIGN

The Tainan Ecological School (Eco School) is currently in design development by the office of Marshal Liu, architect, selected through a competition among Taiwan architects. The site is located on a full block of 3 hectares just east of the Yi Tsai Ching Cheng (Eternal Castle) in the Anping District. The overall school use area is approximately 12,200 sq. meters plus outdoor pools, gardens, play areas, running track and tennis courts. There are additional public spaces for community meetings and lectures.

There are several general educational design goals for the school, which were described to Team Oregon by the architect during workshop discussions:

1. Innovative open classroom areas will support a group of four traditionally organized classrooms.
2. Green architectural features will be integrated to demonstrate sustainable principles to all users.
3. The school will foster interactive learning through the use of the entire site as a place of teaching.
4. Classrooms will use team teaching with diverse curricula and materials.

This school is a radical departure from traditional teaching methods in Taiwan. It will implement creative, new educational processes with a focus on the environment and sustainability. The building, therefore, is meant to educate and inform the occupants of its relationship and response to the environment.

In November, 2000, during the first trip to Tainan (Task 1), Team Oregon visited the site and met briefly with the architect. They also visited two other relatively new schools in the area to establish a baseline for typical construction methods and detailing. From that visit, the Team outlined a list of questions and additional information that would be required to complete Tasks 2 and 3.

Team Oregon's role is to review the design development process to date with the school architect, discuss alternatives, and choose the desired alternatives for further development and refinement. This portion of the interim report summarizes a single integrated sustainable development approach based on the SD Framework, design alternatives, ranking and preliminary general costs that apply to the Eco School. Also, the school architect and his team have expressed an interest in new technologies and products. Team Oregon brought to Taiwan many examples of US materials and technologies that are considered "green" building products.

During the March, 2001 visit, Team Oregon met with the architect, his design team, City officials, and school board representatives. Over a two-day period, the group established goals for five basic subject areas of green building design: sites, water, energy, materials, and facilities management. Within each category, specific strategies and measurable criteria were identified to reach these goals.

Workshop Day 1. Team Oregon held a one-day workshop on April 11 with the Eco School architects and their electrical consultants. In the afternoon the subjects of Sites and Water were covered. After dinner, the discussion continued with Energy and Materials. The final agenda topic was to have been Facilities Management but the meeting had to adjourn. This category is included in the Design Alternative Assessment and rankings.

Workshop Day 2. The school architect, Mr. Liu and the Director of the Bureau of Education, Mr. Cheng, joined the presentation to the Mayor and staff. Sirs Cheng and Liu indicated that the construction schedule for the first phase had to be completed by the end of December, 2001 to accommodate 435 students. This was deemed by the Mayor and staff to be too aggressive for the amount of work in Phase 1, which includes the parking garage and electrical vault plus three of the six classroom blocks located on the south and east corner of the property. Team Oregon members suggested that the three classrooms at the north-east side of the site could be constructed first, leaving more time to complete the parking.

On another evening, one member of the Team, Logan Cravens, joined some of the architect's staff at their office to continue discussion of specific detailing of design features regarding natural ventilation, water features, building placement, and green roofs.

GUIDELINES AND STRATEGIES

Sustainable Development Framework Guidelines

There are three categories of guidelines that define sustainable development: Environmental, Economic, and Community. Within each of these categories, specific guidelines outline the basic decisions that should be addressed for any project. Resulting from the two-day workshop on the Eco School, specific design strategies were established as possible alternatives for Team Oregon to study further. Each of these strategies responds to one <u>or more</u> of the guidelines. In fact, the more guidelines any given strategy can address, the higher priority it gains in future tasks. The tables at the end of this report section summarize the guidelines and strategies for the Eco School.

Environmental Design Strategies

Five basic areas of investigation address the sustainable design goals for the Eco School: Sites, Water Quality, Energy Savings and Conservation, Materials Conservation and Quality, and Facilities Management. Each of these has a number of strategies that are to be measured by an agreed benchmark of performance. As a point of reference, Team Oregon used many of the measurements from *The Evaluation Manual for Green Building in Taiwan* published by the Architectural Building Research Institute (ABRI Manual).

Concept Design Information

Following Specific Environmental Design Strategies is a reference to Concept Design Information. Each concept is given a number and brief title, which corresponds to its order of attachment at the end of this section of the report. Some strategies have more than one attachment and are numbered with the addition of a decimal point and digit.

Sites

The existing site is in a developing neighborhood. To the east it is zoned for high rise residential (five stories or more). To the south, west and north, mid-rise residential and mixed-use is planned (five stories or less). The current architectural concept refers to two forts that are currently visible from the site. An Ping Fort to the north inspired the design of the new entry tower. The Eternal Fortress to the south and west of the site determined the rotation in orientation of the buildings.

Primary questions regarding the site design are: How much open space is preserved by minimizing the building footprint? Is there extensive landscaping, designed to require minimal maintenance and water? Is erosion controlled and stormwater collected for on-site uses? Are impervious surfaces minimized? The answers to these questions have significant impacts on the site. In an urban condition, these impacts extend to the neighborhood.

1. Open Space and Reduced Heat Island Effect

The coverage by building and pervious paving in the current plan is about one-third of the site. This is a good ratio if the remainder of the site is landscaped for maximum shading. The ratio may be improved by adding green roofs.

Sustainable Alternative Strategies:

a. Increase plantings and place to shade 85% of any impervious paving and at least 50% of open areas.

Cost: $10,000-20,000

b. Add green roofs to the Administrative Wing, Gym and Lecture Room.

Cost: $53-86/sq. meter

2. CO_2 Absorption

Currently there is no accounting of how much CO_2 is tied up in the landscape design for the project. This can be easily determined by the formula and charts provided by the ABRI Manual. Once this is done, it can be confirmed if the minimum average standard of 600 kg/m^2 of $C0_2$ absorption is achieved.

Sustainable Alternative Strategies:

a. Increase planting of trees and shrubs to achieve an average of 800 kg/m² of $C0_2$ absorption. This is to be considered the average over the entire 3-hectare site.

Cost: $10,000-20,000

b. Suggested Strategy and Criteria: As an offset to embodied CO_2 in all construction, establish and maintain a program of neighborhood tree-planting and regular tree planting field trips in the region. This can become an important precedent for all city projects.

Cost: $1/tree

3. Reduced Parking

A major cost of this project is in the parking structure, which is underground. While this is a very good strategy to reduce the heat island effect, it may be possible to reduce the number of required parking spaces (currently 100 cars, 100 motor scooters), thereby reducing the structural mass overall. Since concrete is itself a large contributor to CO_2 emissions and water pollution, reduction in its use serves multiple purposes.

Sustainable Alternative Strategies:

a. Reduce area for parking by at least 25%. Reduce building mass and replace with pervious materials and landscaping.

Net savings per contractor's unit costs

b. Provide connection to city bus system for employees.

Cost: coordinate cost estimate with Tainan transit system

ENERGY SAVINGS AND CONSERVATION

Air conditioning will be used only in certain areas during the hottest summer days. Therefore the simplest move towards energy efficiency is in natural ventilation, building orientation and properly sized sunscreens. Another key consideration for the future is the sources of energy. As energy prices continue to rise, alternative low-impact technologies become more cost-effective. Solar-based sources are closer to "free" energy than nuclear or fossil fuel-based technologies.

The Eco School is designed for 100 kw/hour peak demand. At least a 20% reduction of this amount would be feasible and desirable. While most of the classrooms are daylit, there are lights and mechanical systems which may be considered in the reduction concept. Photo-voltaics and small wind turbines are of primary interest to the architect. Fuel cells could also be considered if they would prove cost-effective and fuel-ready. All of these technologies can be consolidated into one system that effectively produces more energy than is consumed by the facility, rating it a 0% energy consumer.

1. Natural Ventilation

Sustainable Alternative Strategies:

a. The classrooms are designed in a traditional style of architecture. Their roof tiles are installed over a concrete structural roof. A detail was recommended to allow air circulation between the tile and the concrete and still maintain the traditional ridge detailing. This detail should be reviewed with code officials for fire safety; however, as it is over a concrete frame, there does not appear to be any problem with smoke or flame development.

Cost: Double-skin roof system $9.67/sq. meter

b. Various stair wells can be used as 'heat chimneys' to enhance vertical stacking of ventilation air in the community use and administrative buildings. Those floors that require air conditioning could still be closed off at the stairwell, but the intent would be to eliminate the need for air conditioning as much as possible.

Cost: Thermal chimneys $800-1,200/stairwell

c. The Lecture Hall has several opportunities for improved natural ventilation. On the roof are three gabled-roof air monitors. The gables themselves, facing south, may be used for air vents. However, the amount of free air is limited. An alternative design would be to provide an asymmetrical cross-section to the roof monitor with the roof shape simulating a wing. The vents should then be oriented to the east or "lee" side of the roof monitors thereby creating negative pressure to pull air up and out of the hall. This could be coupled with supply vents in the risers of the seating platforms.

Cost: Lecture Hall natural ventilation $50,000-75,000

2. Reduced Lighting Loads

Sustainable Alternative Strategy:

a. Other than people, the primary source of heat in buildings is the lighting. Reduction of lighting reduces both heat and energy requirements. Combined with daylight and lighting controls, this measure will significantly reduce the energy requirements of the building. The architect for the Eco School reports that these strategies are to be included. However, a goal of percent reduction has not been set.

Reduce lighting loads by at least 20% with the following actions:

- Incorporate T-5 (16mm) fluorescent tubes
- Separate zones for lighting adjacent to windows
- Use task lighting whenever possible
- Lay out electrical circuitry to allow users flexible control of lights

Cost savings is determined by power/unit cost

3. **Sun Screens**

Sustainable Alternative Strategy:

a. The original architectural concept presented by the architect mixes two styles—modern and traditional. The classrooms reside in the traditionally detailed structures, which use deep overhangs and arcades to moderate the bright sunlight. The community spaces and the gymnasium occupy the modern architecture that has minimal shading of windows and walks. This can be modified to accept sun screens and still maintain the modern 'language' of architecture. The workshop discussion focused on the Gymnasium, which in the original plan and model faced west. Team Oregon suggested rotating the long axis and adding sun screens on the south facade, along with a green roof to reduce heat gains on the envelope. In fact, the architect had already begun a re-study of the 'modern' buildings on the site, including a rotation of the gymnasium. However, sun screens and roof overhangs are still minimal.

Cost: Sun screens at all south-facing elevations, over windows, along exterior walkways $328/lineal meter; vertical broad-leaf deciduous trees for west building facades $500/tree installed

4. **Photo-Voltaics (P-V)**

Sustainable Alternative Strategies:

a. Team Oregon is investigating various sources of photo-voltaic systems. If they are to be used, the school should seek private funding as a market test case. Taiwan authorities have financing through the Environmental Protection Agency to fund up to 50% of renewable energy systems. Their application can be applied readily to individual landscape lighting on a stand-alone basis. Pumps for the pools and constructed streams can also be run as stand-alone systems for low cost.

Cost: Agricultural Pumps - $1100 each.

b. More extensive roof-applied systems should be sized for specific task areas, such as cafeteria or gymnasium lighting. If such a system is depended upon for night time power, **net metering** should be made available. This will allow the school to sell energy back to the energy grid when it has a surplus and draw off the grid during the nighttime hours of operation. Care must be taken in the placement of photo-voltaic panels, considering shade from trees.

5. **Ground Source Heat Pump**

Sustainable Alternative Strategy:

a. This system acts just like any heat pump. Operating in one direction, it removes heat from the air and puts it in the ground acting as an air conditioner. Operating in the other direction, it can draw heat from the ground to provide heat for water or other purposes. Tainan climate dictates cooling over most of the year, but the heat drawn from the air may be used to preheat water before it is dispersed into the ground. The system has some costs involved with its installation; however, its efficiency provides a quick pay-back.

Cost: Ground source hydronic heat pump system $125,000

6. **Fuel Cells**

Sustainable Alternative Strategy:

a. Fuel cell technology, in its optimal state, runs on hydrogen. The only by-products are pure water or steam and heat. Current technologies include another piece of hardware to convert fossil fuels and biomass into hydrogen, thus producing some pollutants at a much lower level than combustion engines. Fuel cells could be retrofitted at any time to the school's electrical system as cheap sources of hydrogen become available. Like the photo-voltaic systems, they may be used to generate more electricity than is needed by the facility, which could be sold back to the utility.

Cost: Commercial 250 kw fuel cell system or multiple residential-size systems
$375,000 for 250 kw fuel cell over the next 10 years

7. **Wind Turbines**

Sustainable Alternative Strategy:

a. Either tower-mounted or roof-mounted, wind turbines of the appropriate scale can supply electricity for a portion of the Eco-School's demand. This sort of technology also can be taught in the schools. By integrating it with other systems, wind turbines can supplement the amount of energy being sold to the power utility. If one single turbine is used, the larger diameter may require off-site installation. In this case, the grid intertie would credit the school for the energy produced.

Cost: Wind turbines to provide up to 20KW of the school energy demand.
Approximately $26,160 for 20 KW Grid Intertied System

WATER QUALITY

The Eco School can be a model of good water management. A sustainable goal is to use no more water than is received from rainfall. To understand the impacts, Team Oregon did a brief analysis of the water budget:

- Annual rainfall: approximately 250 cm per year
- Roof area – approximately 5,670 square meters
- Amount of collected rainwater from roofs alone: 14,175,000 liters per year
- Estimated water use (handwash, wash basins, wastewater): 3,465,000 liters per year

Clearly, the estimated uses for handwashing, toilet flushing, and wash basins can be provided by the annual rainfall. The question is raised as to how much savings are possible. There is currently a Taiwanese program that subsidizes Green Building water savings if it is at least 20% more. The Eco School may reach this level by employing two-section toilet fixtures, faucet aerators, motion-sensor water taps and motion sensors at urinals. All of these should pass the "water savings proof" of the Water Resources Bureau, Ministry of Economic Affairs. Beyond that effort, there are three areas for improvement.

1. Stormwater Filtration

Sustainable Alternative Strategy:

a. Use bio-filtration swales and storm water filtration systems to filter all stormwater leaving the site, with a standard for oil and particulate levels of less than 10 mg per liter of total suspended solids. Not all stormwater may be used by the facility, especially during a storm. The quality of runoff into the city system is a factor in the quality of water flowing into the rivers and the water treatment plants. Any filtration of water leaving the site is desirable; however, the architect cannot establish an acceptable level of sediment and chemicals without seeing costs of systems designed to remove these. Team Oregon will recommend several systems at different cost levels for the school board and architect to assess. Levels of water quality are usually set by the Environmental Protection Agency.

Cost: $10,000

2. Reduce Toilet Water Requirements

The flushing of toilets accounts for 35% of the water used in Taiwan (ABRI Manual, chapters 2 to 3) A system that recaptures "gray" wastewater from hand washing and other light uses can be filtered for toilet flushing and irrigation. The use of waterless urinals can save as much as 151,400 liters per fixture, per year.

Sustainable Alternative Strategies:

a. Reduce water consumption levels of fixtures as follows:

Toilets:	4.2 liters/flush
Urinals:	2.7 liters/flush
Faucets*:	6.8 liters/minute

*based on 4.63 kg/cm² water pressure

Cost: neutral

b. Install composting toilets that use little or no water. They do require maintenance and servicing that are not common. Larger units may require lower level access to the system.

Cost: varies per system

c. Waterless urinals require no water supply and connect to the same waste line as traditional urinals. They require regular cleaning maintenance and replacement of filters is required on a regular basis. They can save up to 151,400 liters annually in high-use facilities.

Cost: $400/fixture installed

3. **Living Machine™**

Sustainable Alternative Strategy:

a. Treat water to tertiary level with the removal of organics, solids and nutrients as well as biological or chemical polishing, generally to effluent levels of 10 mg/BOD_5 and 10 mg/liter Total Suspended Solids with the use of a living machine. A living machine is a combination of human knowledge, technology and biological processes that works as a sewage treatment plant. Tertiary levels of water treatment can be reached. This would be suitable for uses such as flushing toilets or irrigation systems—any use without human contact. Once the system is established it maintains itself if no major deviations occur in the makeup of water sources. Costs will vary depending on capacity and complexity. Living machines allow for the re-use of water that typically goes straight to the rivers or sewage treatment plant.

Cost: varies because it replaces the cost of sewer charges and services

MATERIALS CONSERVATION AND QUALITY

The efficient use of resources and the health impacts to building occupants are two primary concerns with the use of materials. All materials should be non-toxic and procured through sustainable processes. Certain materials embody significant environmental impacts such as concrete, plastics, and synthetic adhesives. Specifications should be reviewed to eliminate toxic substances in materials and increase recycled content.

1. Reduce, Reuse, Recycle

The three guidelines of materials are reduce, reuse, and recycle. Reduction of materials and finishes saves money and time. In some cases finishes are required to maintain durability and quality, but in other cases additional materials are used for ornamentation and decoration and should be reconsidered for utility and necessity.

Reuse of building materials ranges from construction processes to building equipment and furnishings. Wood and metal concrete forms can be reused and eventually recycled. Some suppliers of building products are now taking back their product in order to refurbish and reuse or recycle.

Recycling in Tainan is dependent upon existing facilities that provide a market for the basic materials of wood, plastics, metal, glass, paper and cardboard. While steel and aluminum are recycled at a rate of 80% in Taiwan, other materials are at very low levels. The city of Tainan should support such industries as a network of small businesses or integrated into city services. This will give contractors incentive to recycle on the job.

Sustainable Alternative Strategies:

a. Minimize construction waste and materials:

- Specify minimal packaging for products delivered to the site
- Require suppliers to remove and recycle any packaging associated with their tasks
- Require reusable concrete forms
- Require contractor to prepare a waste management plan, including recycling bins for wood, metal, glass, cardboard, paper, plastic, and cementitious product

Cost: neutral where contract already includes waste management.

b. Recycle the following materials at a rate of 80% or better:

- Metals, including steel and aluminum
- Glass
- Paper
- Tile and grout
- Concrete
- Wood
- Plastics, including sheet wraps and containers

Cost: Determined by recycle service to pick up materials

2. CO_2 Reduction in Construction

Reinforced concrete construction is the primary mode of construction in Taiwan. Concrete contributes substantially to CO_2 gases and water quality degradation. Even though its CO_2 contribution per kilogram is less than steel, it must be used in greater quantities to achieve safe structural performance. Thus, lighter steel frame construction is an improvement over concrete. Also, recycled steel produces half the CO_2 of new production steel.

Energy used in the transportation of products to the construction is based on fossil fuels, therefore contributes a sizeable portion of CO_2 to the atmosphere.

Sustainable Alternative Strategies:

a. Consider lightweight steel construction for 30% of the structures. The 'modern' style buildings that serve community functions may be good examples of this type of construction. Proper attention must be paid to insulation in walls and ceilings as well as seismic requirements.

Cost: Verify with contractor as alternate to concrete system; should be a net savings of 10-20%

b. Use up to 50% flyash content in concrete to replace Portland cement. Approximately one ton of CO_2 is generated in one ton of Portland cement through the burning of lime. Flyash replaces the cement. This requires careful concrete mix designs. Using less water reduces the cure time. The low workability is offset by the plasticizing effect of high flyash content.

Cost: Savings depends on local availability of flyash from coal-burning industrial processes

3. Kitchen Waste Recycling

Sustainable Alternative Strategy:

a. Compost 100% kitchen food waste on site. Use compost bins and worm boxes coupled with classroom gardens. Part of the goal of the Eco School is that the building will teach ecological principles. The organic food wastes from the kitchen can be used as compost for classroom gardens. This would reduce the load on solid waste as well as sewage.

Cost: $80/compost bin

4. Eliminate Toxic Materials

Sustainable Alternative Strategy:

a. Have architect prepare a new specification section listing levels of environmental

performance required of various products. Include % recycled content, allowable maximums for Volatile Organic Compounds (VOC's), and a list of banned substances. Many materials contain toxic substances in their manufacture. These escape from the material over time as VOC's, leachates or particulates. Careful consideration must be taken in the preparation of specifications to ensure that the contractor understands the requirements for the project as well as the available products. Each section of the specification must be reviewed by the architect for known toxic and hazardous materials.

Cost: 8-40 FTE hours

FACILITIES MANAGEMENT

The operations and maintenance of buildings accounts for costs many times higher than the cost to build the facility. Building commissioning, energy management systems, good training manuals and scheduled maintenance will ensure the Eco School has a long life. Cleaning products should contain no toxic substances. Paints should comply with the original specification. Replacement materials should have the same or better environmental standard as the original product.

1. Eliminate Toxic Cleaning Materials

Sustainable Alternative Strategy:

a. Choose 100% low toxic, biodegradable cleaning agents. The choice of materials and finishes in the design phase will partially dictate the types of materials used for cleaning and maintenance.

Cost: neutral

2. Maintain Energy Performance of Building Systems

Schedule regular maintenance. Replace system components before they fail. Measure and record performance of systems using energy and water.

Sustainable Alternative Strategies:

a. Install energy management system with reporting capabilities.

Cost: $2,000 - $4,000

b. Establish schedules of maintenance for all major mechanical, electrical and plumbing systems.

Cost neutral

c. Monitor and display building energy performance or energy production of specific system such as P-V arrays.

Cost: $200-400

3. **Landscape Maintenance**

Sustainable Alternative Strategy:

a. Eliminate pesticides and fertilizers. Implement a pest management program and use compost from cafeteria. Fertilizer and pesticide use involved with landscaping affects water quality negatively.

Cost: 0-low

4. **Building Life-Cycle**

Sustainable Alternative Strategy:

a. Allow for expansion, change of use, de-construction, de-mountability, and/or recycling of buildings. Over the life of the building, the structure and systems will have to be changed, adjusted, replaced and modified. Therefore, threaded fasteners are preferable to permanent connections.

Cost: 0-low

5. **Building Waste Reuse and Recycling**

a. Establish and monitor a waste recycling program. Collection of waste materials should be designed into the building and a program established to set what materials will be recycled. The program should be maintained and monitored by a designated director. Reliable sources for recycling must be identified if this program is to be successful. Community action and cooperation could make this a popular program beyond the school itself.

Cost: 0-low

TABLE VI-1
ECO SCHOOL
Sustainable Development Guidelines for Economy

	Economy	Strategy	Priority
1	Increase the productivity of all forms of capital	a. Increase plantings and place to shade 85% of the pervious paving and at least 50% of open areas	2
		b. Increase planting of trees and shrubs to achieve an average of 800 kg/m² CO_2 absorption	1
		c. As an offset to embodied CO_2 in all construction, establish and maintain a program of neighborhood tree planting	1
2	Increase the quality and durability of goods	a. Eliminate toxic materials	1
		b. Eliminate toxic cleaning materials	1
3	Reduce, recycle and, reuse raw materials	a. Recycle common use materials at a rate of 80% or better	2
4	Substitute embodied and solar energy for produced energy	a. Photo-voltaic water pumps for pools and constructed stream	3
		b. Photo-voltaic landscape lighting	3
		c. Ground source hydronic heat pump system for air conditioning and water heating	2
		d. Wind Turbines to provide 20% of the school energy demand.	1
5	Reduce and eliminate all forms of waste and pollution	a. Minimize construction waste and materials	1
		b. Eliminate toxic materials	1
		c. Eliminate toxic cleaning materials	1
6	Apply science and technology to problems	a. Add green roofs to the Administrative Wing, Gym and Lecture Room.	3
		b. Natural ventilation	1
		c. Reduced lighting loads	1
		d. Living Machine	3

	Economy	Strategy	Priority
7	Develop transportation and energy supply systems consistent with SD	a. Fuel Cells b. Wind Turbines	3 3
8	Substitute non-toxic and biodegradable substances for toxic substances	a. Eliminate Toxic Materials b. Eliminate Toxic Cleaning Materials	1 1
9	Review/revise tax, capital investment, and regulatory policies to increase SD and eliminate subsidies for non-SD	Not applicable	N/A
10	Use life-cycle cost analysis in procurement decisions	N/A	N/A

TABLE VI-2
ECO SCHOOL
Sustainable Development Guidelines for Economy

Community		Strategy	Priority
1	Provide clean air, water, and food	a. Natural ventilation	1
		b. Increased landscaping to capture CO_2	1
		c. Green roofs	3
		d. Tree planting program	1
		e. Stormwater filtration	1
		f. Living Machine	3
		g. Eliminate toxic building materials	1
		h. Eliminate toxic cleaning materials	1
2	Provide clean and safe shelter	a. Natural ventilation	1
		b. Minimize construction waste and materials	1
		c. Eliminate toxic building materials	1
		d. Eliminate Toxic Cleaning Materials	1
		e. Day lighting	1
3	Provide a safe, clean, and beautiful community living environment	a. Open space and reduce heat island effect	1
		b. Increased landscaping to capture CO_2	2
		c. Neighborhood tree planting program	2
4	Protect and enhance the arts and cultural and historic resources	a. Basic design concept respects context of site	1
5	Provide public education on sustainable development	N/A	N/A
6	Promote public involvement in decisions	a. Several community meetings were held with architect during conceptual design phase	1

7	Provide collaborative, community-based decision-making with public, private, NGO participants	N\A	N\A
8	Promote cooperation among levels of government and globally	a. Team Oregon and TDA grant	1
9	Provide access to information on decisions	a. Team Oregon products assessments	1
10	Undertake social and economic impact analysis of major decisions	N\A	N\A

TABLE VI-3
ECO SCHOOL
Sustainable Development Guidelines for Economy

	Environment	Strategy	Priority
1	Support clean atmosphere, water, land, and marine resources	a. Increase planting of trees and shrubs to achieve an average of 800 kg/m²	1
		b. As an offset to embodied CO_2 in all construction, establish and maintain a program of neighborhood tree planting	1
		c. Living Machine	
		d. Composting Toilets that use little or no water	1
		e. Waterless urinals	1
2	Avoid habitat destruction	a. Increase planting of trees and shrubs to achieve an average of 800 kg/m²	1
3	Protect and restore ecosystems	a. As an offset to embodied CO_2 in all construction, establish and maintain a program of neighborhood tree planting	1
		b. Stormwater filtration	1
4	Protect and restore biological diversity	N\A	N\A
5	Assess and encourage programs to reduce negative impacts	N\A	N\A
6	Develop resources consistent with prevention of natural disasters	N\A	N\A
7	Reduce the output of greenhouse gases	a. As an offset to embodied CO_2 in all construction, establish and maintain a program of neighborhood tree planting	1
		b. Reduced parking	2
		c. Consider lightweight steel construction for 30% of the structures	3

	Exhibits	
VI-1	Green Roof Technology	North American Market
		Potential Issues
		Components
		Annotated Bibliography
VI-2	$C0_2$ Offsets	Reduction ABRI Manual, Chapter 2, Green Index
VI-3	Pervious Paving Systems –	Uni Eco-Stone
		Stormwater Management Benefit of Porous Pavements
		BMP- Permeable Interlocking Concrete Pavement
VI-4	Solar Powered/Photo Voltaic Systems Technology	Water Pumping –M3 Solar –Driven Agricultural Pump
		SOL, Inc. Overview
		Applied Power Corp.- Grid Connected Power Systems
		Ashland solar Pioneer Program
VI-5	Ground Source Heat Pump Systems	GeoExchange and School Buildings
		GeoExchange: How Does It Work?
		GeoExchange: The Best Course to Energy Savings for Schools and Universities
VI-6	Fuel Cell Technologies	International Fuel Cells: Fact Sheet
		Fuel Cells 2000: What is a Fuel Cell?
		Fuel Cells 2000: Types of Fuel Cells
		International Fuel Cells: System Solutions
VI-7	Wind Turbine Technologies	American Wind Energy Association: Manufacturers of Small Wind Turbines
		AWEA: What are "Net Billing" & "Net Metering?"
		Wind Turbine Industries Corp. – Products and Systems
		Aeromax Corp. – Windseeker™ 503 Stealth Acoustic
VI-8	Storm Water Filtration Systems	Stormwater Management
		Invisible Systems, Inc.

VI-9	Composting Toilets	Clivus Multrum
		NSF Standard 41 – Non – Liquid Saturated Treatment Systems
VI-10	Waterless Urinal Technology	Waterless Company Information
VI-11	Living Machine™ Systems	Living Technologies, Inc. Information
		Article from ENN.com: "Wastewater treatment innovators honored"
VI-12	Construction Demolition and Waste Management Language	Example Specification Language
VI-13	Cement Substitute	Article: "High Volume Flyash: A Concrete Solution"
VI-14	Composting	Compost for Home Gardens
VI-15	Environmental Requirements	Example Specification Language
VI-16	Safe Cleaning Agents	Environmental and Safety Specifications
VI-17	Energy Management Systems	Honeywell, Inc.
VI-18	Pest Management Program	Best Practices Santa Monica

F:\Current Projects\0024-TDA Tainan\Conceptual Design Report\Task4 ReportBODY-EDITS8601.doc

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UPCOMING EVENTS

NORTH AMERICAN MARKET

American Hydrotech, Inc.

American Hydrotech, Inc. is located in Chicago, Illinois. Hydrotech is a global leader in the development of waterproofing and roofing technology, and is considered a single source supplier of greenroof systems. They are associated with ZinCo GmbH of Germany, their partner in the development of the Garden Roof™ Assembly. Hydrotech claims greenroofs "add beauty to the once forgotten area of a building, reclaiming this neglected 'fifth elevation' for both man and nature by integrating the building and surrounding landscape." Hydrotech has numerous completed greenroof projects within the U.S., including the Gap Headquarters outside of San Francisco, CA (www.hydrotechusa.com).

Source: www.hydrotechusa.com

Their Garden Roof™ Assembly combines Hydrotech's waterproofing technology with ZinCo's patented engineered system of drainage/water retention components. Their greenroof assembly includes a high endurance liquid waterproofing roofing membrane; a lightweight or heavy-duty root barrier/protection course; an optional moisture resistant insulation layer; and a three-dimensional polyethylene panels for water storage, drainage, and substrate soil aeration.

In addition, Hydrotech can work together with the landscape architect to provide technical guidance on the selection of appropriate lightweight soils and vegetation. Hydrotech excludes costs of soil and vegetation in their estimates; average installed costs for extensive greenroofs begin at $9 - 15/sf and $12 - 18/sf for intensive greenroofs.

Contact Info: Matthew Carr, Garden Roof Product Manager, Phone 804.378.6125. Bill Shaeffer or Sherry Uhlemann, 303 East Ohio Street, Chicago, IL 60611-0731, Phone 312.337.4998; Fax 312.661.0731; www.hydrotechusa.com.

Hydrotech Membrane Corporation: 10, [illegible] Parkway, Ville D'Anjou, Quebec HIJ 1S1, Canada.
Montreal: Phone 800.361.8924 or 514.353.6000; FAX 514.354.6649.
Toronto: Phone 800.668.8963 or 905.471.6677; FAX 905.471.6699.

Soprema Inc.

Soprema Inc. is headquartered in Wadsworth, Ohio and is a single-source greenroof manufacturer with international affiliations with Canada and France, where they have numerous completed greenroof installations. They have years of research and climatic experimentation into developing their Sopranature® concept, which can be applied to roof slopes up to 40%.

The Sopranature ® system consists of a 2-ply waterproofing membrane which also contains root repelling agents; a drainage layer; a synthetic geotextile soil particle filter; the engineered SOPRAFLOR growing medium; and the vegetation which has been selected for its ability to adapt to extreme weather situations.

Soprema has tested 125 species of perennials for drought resistance and hardiness levels in zones 2 through 8 at the University in Quebec. In extensive greenroof systems, Sopranature® uses ground covers of regenerative annuals, and perennials. With extensive greenroofs they utilize perennials, shrubs and grasses with supplemental irrigation.

The Sopranature® system includes an edge protection of a 500 mm band of gravel or pavers. A prefabricated border of precast concrete, metal or wood is installed to contain the vegetation areas.

The Sopranature® greenroof system has been installed with success in the northern regions of Canada. A first experimental roof at Laval University is still blooming after five severe winters. They also have several other greenroofs and rooftop gardens that are performing well since their installation in 1996 in different regions of Quebec and Toronto.

Contact Info: Robert Yoder, East Regional Manager, 602 Arbor Trace Dr. #108, Frederick, MD 21703. Phone 301.695.7700; Fax 301.694.7577; yodernet@att.net. Soprema's Head Office is located in Strasbourg, France: Phone 33.3.88.79.84.00.

The Garland Company

The Garland Company is located in Cleveland, Ohio, and has a Canadian affiliate with Garland Canada, Inc. They have been manufacturing and distributing roofing and building maintenance systems since 1895. The Garland Company's toolbox of roofing systems includes a broad selection of materials for new construction and retrofit applications (www.garlandco.com).

According to product literature, The Garland Company's Green Roof and GreenShield™ product have been a natural

evolution in a 100-year-plus tradition of product innovations that are good for the planet. Garland's greenroofing research began in 1991 with an exclusive partnership with FAMOS GmbH, a roof greening company from the former East Germany.

FAMOS photos Courtesy The Garland Company 98 Brochure

Along with a staff of horticultural experts, they have successfully experimented with compatible plant species applicable to the varied climate zones of North America. The Garland Company has maintained a very successful greenroof atop their headquarters in Cleveland for approximately two years.

Below is a typical Garland Living Roof section:

Plant material is custom designed.

Soil material is lightweight, and absorbs and retains water.

The filter layer prevents soil from clogging the drainage system.

The drainage layer allows excess moisture to exit the system.

The root-resistant compound prevents penetration to the roofing membrane.

The StressPly Plus roofing membrane uses recycled tires.

Contact Info: Brian Lambert, 3800 East 91 St., Cleveland Ohio, 44105. Phone 1.800.321.9336; Fax 216.641.0633; www.garlandco.com.

Roofscapes, Inc.

Roofscapes, Inc. is located in Philadelphia, Pennsylvania. Roofscapes, Inc. develops greenroof projects throughout the United States, offering the Roofmeadow family of greenroofs. These are light-weight, low-maintenance vegetated roof covers that are ideal for retrofit installations on existing buildings or for new buildings that can accommodate only small increases in dead load.

Courtesy Charlie Miller, Roofscapes, Inc.

Roofscapes, Inc. is pioneering the use of greenroofs for stormwater control in the United States. Specific projects can be tailored to satisfy local stormwater requirements. Computer simulation of runoff can include the analysis of design storm events specified by the client.

Roofscapes, Inc. is associated with Optigrün International. The low-profile, light-weight systems which are certified under the Roofmeadow™ trademark are complemented by the intensively landscaped Optigrün® designs which are also offered through Roofscapes, Inc. Optigrün® systems allow the introduction of integrated irrigation systems, highly diverse plant communities, and recreational features. In many projects some blending of these two systems will provide a pleasing roofscape while minimizing cost and maintenance requirements. Experienced European designers will be actively involved with Optigrün® installations in the US.

Optigrün photo Courtesy Roofscapes, Inc. www.roofmeadow.com

Roofscapes, Inc. is the only greenroof provider that is based in the landscape industry. Roofscapes, Inc. maintains a national network of highly regarded landscape contracting companies that are licensed to install the Roofmeadow™ and Optigrün® families of vegetated roof covers. The goal of the Network is to:

- Provide experienced, professional crews that are comfortable with all aspects of green roof installation, including coordination with a variety of waterproofing providers.
- Satisfy client expectations for the appearance and a maintenance requirements.

- Promote successful integration of the *roofscape* with the surrounding *landscape*.

While relying on time-tested design principals, Roofmeadow™ vegetated covers are also customized to satisfy the unique demands of regional climates and conditions. All designs begin from the standpoint of appearance and durability of the vegetated cover. Building on the experience of local Network members, they will tend to incorporate local plant species and regional approaches to landscape design.

Roofscapes, Inc.'s members are free to work with any qualified roofing or waterproofing company. In the United States, a variety of waterproofing systems are available that have been tested for use with vegetated covers and have a successful track record in Europe. Although they prefer to work with inherently root-proof waterproofing materials PVC, TPO) crews can install supplemental root-barrier layers as necessary to make their installations compatible with waterproofing materials that are not roof penetration safe. These include modified bituminous membranes and liquid applied rubberized asphalt.

Roofscapes, Inc. offers many ancillary features, including two types of integrated leak detection systems, integrated water management systems, such as 'gray-water' recycle systems and runoff infiltration facilities.

Contact Info: Charlie Miller, P.E., Principal, 7114 McCallum Street, Philadelphia, PA 19119. Phone 215.247.8784; Fax 215.247.4659; cmiller@roofmeadow.com; www.roofmeadow.com.

American Wick Drain Corporation

American Wick Drain Corporation (AWD) is located in Monroe, North Carolina and is America's largest full-line producer of prefabricated soil sheet and strip drain material. The company was established in 1982 to design, manufacture and market technically advanced materials for subsurface drainage applications. The objective was to combine new geotextiles with specially designed drainage cores in order to offer new drainage materials having significant advantages over aggregate drains.

They offer a complete Amerdrain® GreenRoof ™ roof garden system as an "ergonomic pollution solution." The heart of the GreenRoof system is their AMERIDRAIN 4+1, which is suitable for sedum varieties or the 5+1 roof garden drain, which may be used for perennials, large shrubs and small trees. The drain has three components: a top filter fabric to retain soil yet allow for drainage; a high-strength dimpled, punched polymeric core which provides water storage capacity and drainage; and a bottom cushion fabric to protect the roofing material and provide added water storage capacity (above photos and information from www.americanwick.com/greenroof.html).

American Wick Drain Corporation has had successful residential and commercial applications of earth-sheltered structures, extensive and intensive greenroofs.

Contact Info: 1209 Airport Road, Monroe, NC 28110. Phone 704.821.8200; www.americanwick.com/greenroof.html.

Sarnafil, Inc.

Sarnafil, Inc., Sarnafil Roofing Systems, is located in Canton, MA, and the Sarnafil Division is headquartered in Sarnen/Switzerland. They have been a leading manufacturer of high quality roofing and waterproofing systems for the international construction and civil engineering market for over 33 years. Sarnafil has over 20 years experience assisting professionals with system recommendations, design and specification review for green roofs and planters. Their products may be applied to retrofit and new construction.

Source: www.sarnafilus.com

The range of Sarnafil systems includes polymeric waterproofing membranes made from various materials, accessories, application devices and a broad spectrum of service programs (www.sarnafilus.com). Sarnafil's waterproofing membrane is engineered to provide long term performance in sub-grade environments. Sarnafil membranes are root and rot resistant and will not support root growth. These roofing membranes are usually specified by the local greenroof project designer or project manager as part of a sub-contracted design team.

Contact Info: Craig Boucher, 100 Dan Road, Canton, MA 02021. Phone 781.828.5400; Fax 781.828.5365; www.sarnafilus.com.

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POTENTIAL ISSUES

In my enthusiasm for the potential benefits of greenroofs, I would certainly be remiss if the potential problems of greenroofs were not also explored. A discussion of some of the possible physical, environmental, and aesthetic issues follow:

PHYSICAL ISSUES:

Waterproofing Integrity

Every reputable roofing company will guarantee and provide a warranty for the waterproofing integrity of their membrane (s), including greenroofing providers. Water leakage from drainage backups or possible root puncture could lead to interior damage if the correct waterproofing membrane system, root barrier, and drainage layer are not selected. Of course, when choosing a greenroof system and/or contractor, it is advisable to check references on completed projects for waterproofing success. Vulnerable areas where leakage is possible include abutting vertical walls, roof vent pipes, outlets, air conditioning units, perimeter areas, etc. A thorough water flood test needs to be conducted for leaks after installation of the waterproofing membrane to ensure quality control, certainly before the other layers are applied.

Pesticide Leakage from Roof Materials

Recently, an environmental science magazine began testing drainage from greenroofs in an effort to measure any pesticide runoff. The potential does exist for certain elements, such as iron and aluminum, to seep out and infiltrate our ground water. Care must be exercised in selecting thick membranes to ensure no release of pollutants, and the materials used in foundations and pathways on a greenroof should not leach carbonates. This would also be a good opportunity to choose greenroofing companies who use environmentally friendly roofing components.

Additional Support Considerations

For extensive and intensive greenroofs with projected live loads of higher than 17 pounds per square foot, consultation with a structural engineer is a requirement. Additional soil depths, large plants such as trees, walkways, seating areas, parking areas, etc. will command greater structural support, and a greater layer build-up of the greenroof system. For example, deeper planting beds can be constructed over internal columns and walls to provide a higher loading capacity. Considerable costs can be associated with these high interactive projects, especially with renovation or retrofitting projects.

Unwelcome Wildlife Problems

I have had people ask be about the possibility of attracting rats, raccoons, squirrels, spiders and the like with greenroofs. Because of their watertight quality, I would suspect it would be extremely difficult (or impossible) for these larger animals to enter a home through the roof. But because a natural habitat is created, perhaps some undesirable critters would be invited, and then their proximity might put off some folks. I actually haven't read or heard anything regarding this issue; please share any thoughts or experiences.

ENVIRONMENTAL ISSUES:

Certain aspects of greenroof technology could be challenged in terms of their positive environmental characteristics and sustainability factors. While examining these issues, perhaps the ultimate answer lies in the varying degrees to which a concept is considered environmentally sound and sustainable. In other words, there may not be black and white, or cut and dry responses to these important concerns.

Native vs. Cultivated Plants

For example, is it environmentally correct to use plants other than natives on greenroofs? Purists would probably say that only natives should be used in most landscaping projects, including greenroofs. A true representation of the land would, in fact, aim to replicate its original natural habitat, and therefore native plants would be considered essential to the design.

However, several factors come into play here. First of all, these are very planned landscapes, and we are trying to replicate the physical conditions of plants living in the ground, but many feet above. Soil substrates definitely aren't native soils (too heavy, easily compacted, etc.) - so certainly this isn't a natural design to begin with. We are already limited somewhat with the greenroof plant palette due to their exposure to harsher climatic conditions. (For the most part, the reference here is to extensive greenroofs, as plant selection is much greater for intensive greenroofs because of their higher soil depths, etc.) Secondly, we are importing an established European technology with proven plant species, and many of these are readily cultivated and available here. Also, if we self-limit our plant selection, the greenroof environment will be lower in bio-diversity.

Greenroofs will only function if the vegetation is successful, so initially it may be necessary to use proven adaptive species, and then introduce and promote our own native plants as they are proven successful. Unless a specific design program calls for an exotic look, I believe that ultimately, it will be in our own best environmental interest to establish natives as the

primary plant material for greenroofs.

Irrigation Requirements

Upon reviewing my first draft, UGA Professor Darrell Morrison asked me to consider a couple of possible criticisms, the first being "In a hot, dry climate, is it environmentally sound to have a green roof if it requires irrigation to establish/maintain it as a green roof?"

First of all, a hot and dry climate would dictate a distinct list of plants that are extremely drought and heat tolerant, especially succulents. Many species that grow in full sun have developed mechanisms to reduce leaf evaporation, e.g., wax coated and spiked leaves.

Of course, any landscape requiring regular irrigation would be high maintenance and expensive in terms of supplemental water usage and cost. If you design a golf course on a greenroof, then it would not be very environmentally sound because of these factors, in addition to the negative aspects of the monoculture of turfgrass. However, as seen from the Optima and ZinCo examples in the Greenroof Components section, techniques have been developed to automatically capture and release stored rainwater within the greenroof system. Although these details would increase the initial capital investment cost of the greenroof, they would quickly pay for themselves in terms of irrigation savings as well as providing an argument for sustainability.

If you compare all the natural processes that are mimicked by a greenroof environment to its potential irrigation requirements, I believe the greenroof would still be considered environmentally sound, although not necessarily self-sustainable.

AESTHETIC VALUES

Professor Morrison also asked, "Are the aesthetics of green roofs always positive? Can the good points about green roofs be sufficient to 'lose' the aesthetic quality?" The examples offered throughout were selected to reflect the wide variety of greenroof styles chosen by the owners and designers. Some are more natural, some very designed, but certainly all are organic in that there are plants on the roof! If not planned correctly, an unsightly, overgrown appearance could result. Also, the organic nature of plants needs to be acknowledged in that seasonal fluctuations and periods of severe drought and heat will be reflected in the look of the plants themselves. Therefore, colors, heights, and plant density will most likely change with the seasons.

Some people may feel organic architecture is inappropriate or "unnatural" for any building, and that is their own aesthetic value. If no maintenance is desired, then the design must dictate the correct choice and placement of plant material. A hands-off program may result in a wild and overgrown look. Beauty is in the eye of the beholder, but surely the many arguments for the ecological and economic benefits of greenroofs can outweigh aesthetically weak designs. Below are some examples of less structured organic design which some may find either objectionable or lovely because of its wildness:

Source: ReNatur, www.re-natur.de

Source: Optigrun, www.optigruen.de

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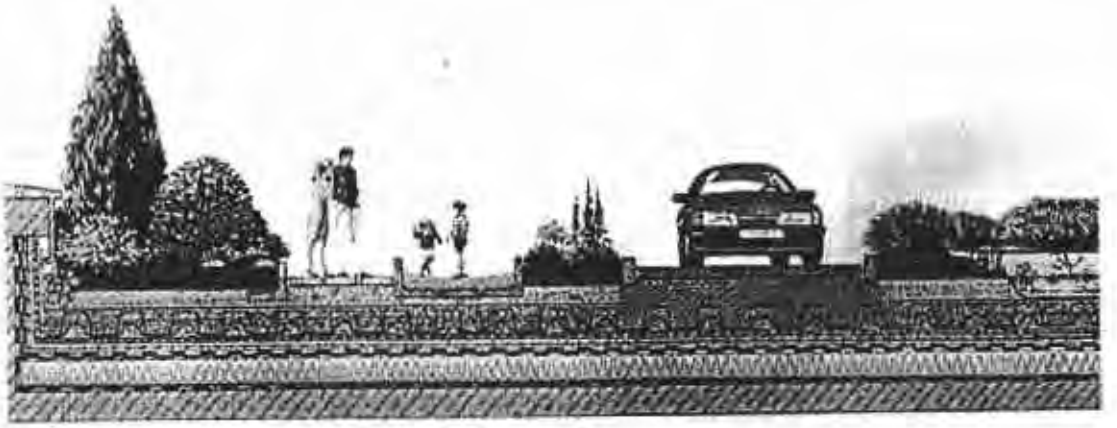
GREENROOF COMPONENTS



Source: ZinCo International 3/98 Brochure

The layered greenroof system can be installed at almost any time of the year. Planting can only occur at specific times throughout the year, depending on the method of planting used (Zinco brochure, March, 1998).

NEWS LINKS

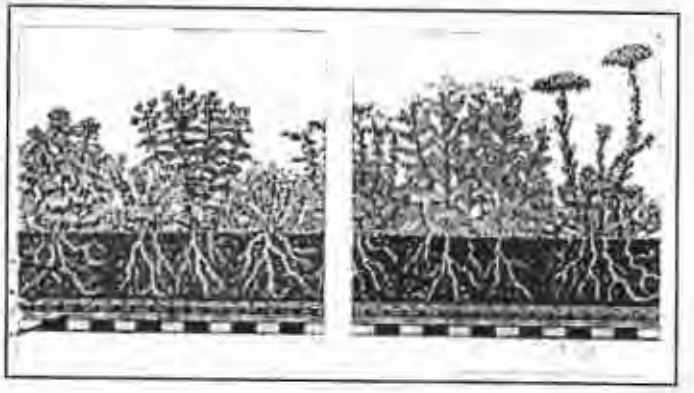
Typical Extensive Greenroof Material Section from Optima:

Simple Plant Communities: Height: 2 - 3 inches

Light Weight **Heavier Weight**

UPCOMING EVENTS

THE GREEN ROOF INFRASTRUCTURE MONITOR



Source: Optima Planungs-Unterlage 9/97

A -"Optima-Kennkorper" Extensive Soil Substrate
B - Insulation Layer
C - Root Barrier Course
D - Waterproof Membrane Protective Barrier

Typical Intensive Greenroof Material Section from Optima:

Diverse plant communities useful for achieving architectural accents:

Height: 36 inches - 15 feet

1 - Lighter Weight

2 - Heavier Weight

A -"Optima-Kennkorper" Intensive Soil Substrate

B - Fleece Filter Fabric Screen

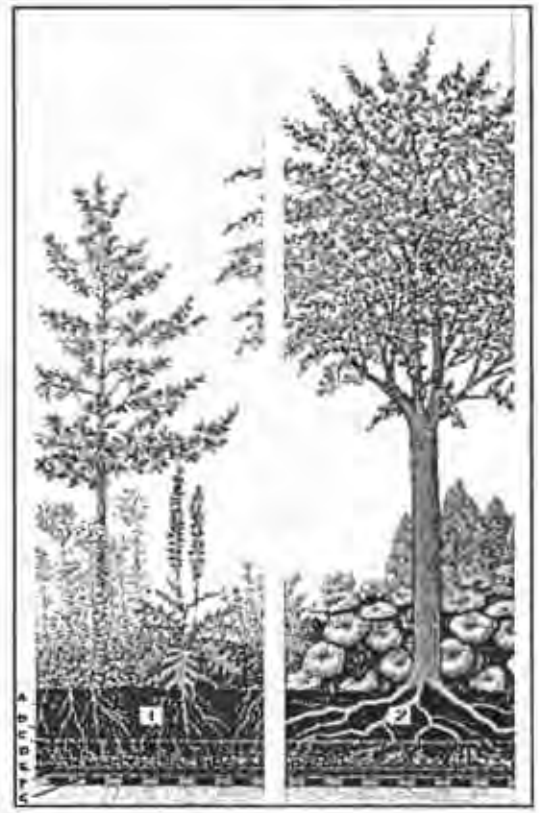
C - "Optima Perlite" Drainage Layer

D - Rainwater Retention Layer

E - Insulation Layer

F - Root Barrier Course

G - Waterproof Membrane Protective



Source: Optima Planungs-Unterlage 9/97

After deciding upon either an extensive or intensive greenroof for your particular needs and evaluating the slope in question, the essential design criteria to be considered for any project are the selection of the:

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[Waterproof Membrane] [Insulation Layer] [Drainage Layer] [Filter Membrane] [Soil Substrate] [Plant Material]
[Water Storage & Irrigation]

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Beaudry, John, personal communications, June 2000. John was the original Chicago Greenroof Project Coordinator, and provided a project write up for the Green Roof Infrastructure Workshop we all attended in June, 2000 in Toronto.

Bender, Steve, Editor. **The Southern Living Garden Book**. Birmingham: Oxmoor House, Inc., 1998. Here's a beautifully illustrated 512-page comprehensive plant reference for gardens of the south.

Bookman, Jay. "Water, Water Everywhere; But is it Pure?" **The Atlanta Journal-Constitution** (April 12, 1999): E3. The associate editor of the Constitution's editorial pages examines the Atlanta region's critical water supply and quality issues.

Burke, Kevin, personal communications, March 1999. E-mail, photos and documentation. Kevin was the Project Manager at William McDonough + Partners overseeing the Gap Headquarters in San Bruno, near San Francisco.

CNN.com, "In-Depth Special: City Limits; Urban hot spots, New York, Atlanta, and Salt Lake City, United States," (October 28, 2000). Access the complete article regarding urban heat island studies of these three U.S. cities from the Ecological section of Environmental Advantages.

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THE GREEN ROOF INFRASTRUCTURE MONITOR

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DJC.COM,"Green' Buildings," by Elizabeth Daniels (September 15, 2000). Access the complete online article from The Seattle Daily Journal of Commerce from NEWS LINKS.

Dramstad, Wenche E., and James D. Olson, and Richard T. T. Forman. **Landscape Ecology Principles in Landscape Architecture and Land-Use Planning.** Washinton, D.C.: Harvard University Graduate School of Design, Island Press and the American Society of Landscape Architects, 1996. Pp 5,11, 12, 39, 47. This book provides a common language for the introduction of landscape ecology, and was used as a textbook for my Fall 1999 Applied Ecology class at UGA.

ENN.com, "Chicago hopes rooftop garden cools air," by United Press International (May 17, 2000). Access the complete Environmental News Network article from the NEWS LINKS section of my website.

ENN.com, "Green rooftop technology saves energy, cools air," by Suzanne Elston (December 31, 2000). Access the complete article from the NEWS LINKS section of my website.

Erisco-Bauder Limited, Suffolk, England, April 1999. Numerous product and service brochures describe the value and effects and technical aspects of their greenroofing system.

Erosion Control Magazine, "Natural Carpets Protect Roof and Soil." (November/December 1998): 25-26. This article in the Stormwater Management section describes how erosion is reduced by controlling stormwater before it even hits the ground.

Estes, Maury, personal communications, January 2000. Maury is with NASA's Global Climate and Hydrology Center at the Marshall Space Flight Center in Huntsville, Alabama, and has sent me thermal photos for my website.

Ferguson, Bruce K. "Preventing the Problems of Urban Runoff." **Renewable Resources Journal.** (Winter 1995-96): 14-17. This article highlights the need for true understanding of natural systems so that we may holistically design environments to maintain the health of the world. FASLA, UGA professor of landscape architecture.

Ferguson, Bruce K. **Introduction to Stormwater: Concept, Purpose, Design.** New York: John Wiley & Sons, Inc. 1998. Pp. 5, 8, 13-18, 20. This book is a detailed primer for landscape architects and site engineers, among others, interested in stormwater management and its safe and meaningful integration within urban communities and ecosystems.

Flanders, Danny C. "Taking the Heat" **The Atlanta Journal-Constitution** (February 29, 1999): G1. Garden centers tag plants according to their high-temperature and heat tolerance.

Golley, Frank B. **A Primer for Environmental Literacy.** New Haven and London: Yale University Press, 1998. This broad-ranging book was used for my Landscape Ecology class at UGA (1999) and presents key concepts of ecological science.

Hendriks, Nico and Jim Hooker. "The Green Roofs of Europe, February 22, 1994." Jim Hooker, of the British Flat Roofing Council (UK) and Professor Nico Hendriks of Eindhoven University (the Netherlands) presented an informative paper with six case studies to The National Roofing Contractors Association's 107th Annual Convention & Exhibit.

Holtcamp, Wendee. "A Grass-Roofs Effort - Secret Gardens Conserve Energy & Cool the Air." **sierra magazine** (May/June 2001): Hearth & Home. Access the complete online article from NEWS LINKS.

Hussong, Walter and Krebs, Dr., Michael, personal communications, March, 1999. Faxes and my personal visit to the Optima North Headquarters in Tornesch, Germany provided me with numerous photos and on site information concerning the design and installation of extensive and intensive greenroofs and knowledge of their ongoing soil, water retention and plant selection test areas.

Krakauer, Jon and David Roberts. Iceland: **Land of the Sagas.** New York: Harry N. Abrams, 1990. Pp. 30-31, 68-69, 134-135. The land, history and character of the people are examined while the beautiful color photos illustrate the rugged beauty of Iceland.

Lawrence, Mike. **Step-By-Step Guide to Outdoor Woodworking Projects.** San Francisco: 1995. P. 54. Decks, patios and outdoor spaces are easily designed.

Liptan, Tom, ASLA, personal communications, February and April 1999; February 2000. Tom is a landscape architect and stormwater expert working for the city of Portland, Oregon, who constructed a greenroof on top of his garage at home. Our telephone conversations emphasized the opportunities here in the U.S. to build greenroofs for storm water management, and he provided me with numerous industry leads and the stormwater runoff and retention monitoring techniques.

Luvall, Dr., Jeffrey C., personal communications, May 1999 through May 2001. Jeff specializes in surface energy budgets and the urban heat island effect at NASA's Marshall Space Center. He has provided all the color and thermal imagery and specifics for measuring and analyzing thermal comparisons of greenroofs vs. conventional non-porous roofs.

Magnusson, Thor. **A Showcase of Icelandic National Treasures.** Reykjavik: Iceland Review, 1987. Pp.38, 77, 83. The three pictures found in the History section were scanned from this informative and colorful book of historical relics.

McDonough + Partners, personal communications, April, 1999. Kevin Burke, AIA, mailed me copies of a task report prepared by their office assessing greenroof technology and manufacturers' product literature.

McMarlin, Robert. "Green Roofs Add Aesthetic, Practical Benefits to Building Rooftops." **Western Roofing Magazine** (May/June, 1996): 89-92. Robert McMarlin is manager, product/systems evaluation and testing at Pittsburgh Corning, makers of FOAMGLASS cellular glass insulation.

Miller, Charlie, P. E. "Vegetated Roof Covers: A New Method for Controlling Runoff in Urbanized Areas." publication in the **Proceedings of the 1998 Pennsylvania Stormwater Management Symposium** (October 21-23, 1998): 1-10.

Miller, Charlie, P. E., personal communications, February 1999, and March through May 2000. Telephone conversations, letters, photos emails, and other materials explain vegetated roof systems and the services offered by his firm, Roofscapes, Inc.

Morrison, Darrel. FASLA, UGA professor of landscape architecture. Gave me a beginning list of potentially successful plants for the Piedmont region, April 1999. UGA Applied Ecology lecture of September 1999.

NaturalNewsNetwork.com, "Green Roof Saves City," (December 2000). Access the complete online article from NEWS LINKS.

NaturalNewsNetwork.com, "Solar House," by Editor John Wilson (ongoing). Access the story from www.naturallifenetwork.com.

New York Times.com, "It's Not Easy Selling a Green Roof, but They're Trying," by Sam Hooper Samuels (January 16, 2001). Access the complete online article from NEWS LINKS.

Optigrun Planungsunterlage 98/99, "Die Dachbegruner!" A 72-page manual in German describes the entire green roofing systems, including benefits, methods, soils, plants, slopes, construction details and numerous color photos.

Optima Planungs-Unterlage, "Lasst uns Dacher Professionell Begrunen!" 1997. A 54-page greenroof system planning color catalog with all the necessary information to construct extensive and intensive greenroofs.

Osmundson, Theodore, FASLA, personal communication, April 1999. He referred me to "Time Saver Standards for Landscape Architecture" for construction details, and advised me of his book, "Roof Gardens: History, Design and Construction," published by W.W. Norton & Company, New York, 1999.

ReNatur "Ein Stuck Natur Zuruckgeholt," January 1999. ReNatur product literature of various greenroof and other ecological services; brochures presented in German.

Rosenblatt, Roger. "The Man Who Wants Buildings to Love Kids." **Time Magazine** (February 22, 1999): 62-65. William McDonough + Partners and their environmental design for The Gap Headquarters, including greenroofs, are given kudos.

S & S Seeds "Seed Selection Guide," 1992. This is a comprehensive catalog for seeds for reclamation and landscape wildflowers, grasses, native plants, trees, Shrubs and ground covers. They also sent me a fax with a list of wildflower species appropriate for Georgia, May 1999.

Santos, Ed. "Living Wonder." **Landscape Architect & Specifier News** (November 1998): 84. The current responsible Horticulturalist at Zoo Atlanta writes about how the Conservation Action Resource Center continues to demonstrate innovative stewardship of the land.

Scholz-Barth, Katrin, personal communications, February and April, 1999 and April and May 2000. Katrin is an environmental engineer and has designed several greenroofs, one with a slope of 45%. She has helped me immensely with my UGA

Senior Project in terms of greenroof structure and plant selection.

Scholz-Barth, Katrin. "Green Roofs: Stormwater Management From the Top Down." **Environmental Design & Construction Home** (January/February 2001). Access the complete online article from NEWS LINKS.

Seabrook, Charles. "Scalping of the Land Makes Atlantans Hot" **The Atlanta Constitution** (February 19, 1999):A1 Satellite data show the detrimental effects of rapid clear-cutting practices affect the temperature in the metro Atlanta area.

The Garland Company, Cleveland, Ohio, June, 1999. Product literature and numerous greenroof material sections, including brochures regarding FAMOS and related articles pertaining to greenroofs.

The London Ecology Unit. **Building Green: A Guide to Using Plants on Roofs, Walls and Pavements.** London: Jacklyn Johnston and John Newton, 1993. Pp. 7-21, 47-72, 79-88. Including an introduction by H. R. H. The Prince of Wales, the book describes the numerous ecological, aesthetic and economic advantages of green development in our urban settings.

Thelen, Edmund, Wilford C. Grover, and Arnold J. Holberg, and Thomas I. Haigh. **Investigation of Porous Pavements for Urban Runoff Control, 11034 DUY.** Washington, D.C.: U.S. Environmental Protection Agency, 1972. Pp. iii, 17, 22, 104-105. An EPA sponsored study determines the feasibility of utilizing porous pavements for alleviating combined sewer overflow pollution and reducing design parameters of storm sewer systems.

Thompson, J. William. "Grass-Roofs Movement." **Landscape Architecture Magazine** (May, 1998): 47-51. An article under the Technology Section, the thriving eco-roof design industry in Germany and other parts of Europe is described offering many environmental benefits and asking the question: Is the time ripe to import the concept?

Thompson, J. William. "Meadows Above - The green-roof movement gains a foothold in North America." **Landscape Architecture Magazine** (September, 2000): 36-39, 125. LAM Editor "Bill" Thompson follows up his May, 1998 article on the continued interest and promising projects in greenroof architecture.

TIME.com, "Heroes for the Planet," by Roger Rosenblatt (February 15, 1999). Architect William McDonough is profiled and honored with Time Magazine's award for ecological design. Access the complete online article from NEWS LINKS.

Van der Ryn, Sim and Stuart Cowan. **Ecological Design.** Washington, D.C.: Island Press, 1996. Pp. x, 10, 18, 28, 55. This very informative book was used as part of our Applied Ecology UGA class, Fall 1999. Ecological design principles can be applied to help build a more efficient, less toxic, healthier, and more sustainable world.

Vick, Alfie. UGA MLA graduate. Spoke on "Landscape Health" for my Applied Landscape Ecology lecture at UGA of September, 1999.

Washingtonpost.com, "Going Green to Reduce Energy Access the complete online Washington Post article from NEWS LINKS.

Wasowski, Sally with Andy. **Gardening with Native Plants of the South.** Dallas: Taylor Publishing Company, 1994. This beautifully color photographed book offers ecological insight into the many rewards of designing and gardening with native plants, as well as their complete descriptions and habitats, etc.

Westmacott, Richard. UGA professor of landscape architecture. Landscape Ecology lecture of August 23, 1999.

ZinCo International, "Landscaped Roofs in Their Most Attractive Form," March, 1998. ZinCo GmbH's promotional 50- page color brochure in English is extremely informative with numerous case studies, details, etc.

bacqube.bayareacouncil.org/901. This San Francisco website profiles The Gap project for its environmental quality and design factors.

science.msfc.nasa.gov. NASA's daily Space Science News website from the Marshall Space Flight Center highlighted two articles on "Hot'lanta" and Salt Lake City. I downloaded their hot and cold image of SLC.

www.casp.it/. Cooperativa Agricola Sviluppo Piemonte, in association with Optigrun and Arboriculture On-line, has a website in Italian discussing nature's role in safeguarding the built environment through the use of greenroofs.

www.cnn.com/NATURE/9903/25/heat.island.enn/ "CNN interactive's" website has an article titled "Team probes Atlanta heat island," posted on March 24, 1999.

www.ecover.com/factory/factory2.htm. The Ecological Factory designed by ECOVER, an ecological product manufacturer in Belgium, is discussed in detail regarding building to minimize the burden on the environment and designing with organic architecture. I downloaded a picture of their 5,000 square meter grass roof.

www.garlandco.com. The Garland Company's website offers a complete description of their products and services, and has informative "green" website links.

www.ghcc.msfc.nasa.gov/atlanta/ NASA's Global Hydrology and Climate Center website headquartered in Huntsville, Alabama, discusses their urban heat island studies of several rapidly growing U.S. cities, including Atlanta. I downloaded their ATLAS thermal image of downtown Atlanta.

www.greentarget.com. Tetto Verde s.r.l., the Italian franchise of Zinco, offers the complete philosophy and product line, as well as many related greenroof garden subjects, in Italian.

www.hydrotechusa.com/index2.html. American Hydrotech, Inc.'s home page describes its waterproofing and roofing membranes used for garden roofs and discusses the many environmental and economic reasons to build a greenroof. They worked on the Gap project.

www.mcdonough.com. William McDonough + Partners' website offers descriptions of their services, projects and pictures, and associates.

www.peck.ca. /grhcc. This is the very informative website for the Green Roofs for Healthy Cities established under the leadership of Peck & Associates "to promote the more rapid diffusion of green roof technologies in Canada."

www.re-natur.de/english/2_dach/1.htm. ReNatur's website in either English or German describes their many ecological services, including complete greenroof systems.

www.roofmeadow.com. Green technology for the urban environment is examined in Roofscapes Inc.'s very informative and interesting website containing useful graphs, charts, and color pictures.

www.zinco.de/ehome.htm. Zinco's website in German or English discusses greenroof success through an ecological sense of responsibility. It contains informative pictures and greenroof system details.

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Questions regarding this web site should be directed to LindaSV@greenroofs.com.
Website designed by DragonScape Consulting, Inc.

Chapter 2 Technology of Evaluation

1. Green Index

1.1 What is "green"?

The meaning of the turn "green" is to cultivate various plants on the natural soil of a building base, roof, balcony, exterior wall, artificial land, etc.

1-2 What is the goal for "green"?

Healthy living demands of greenness, otherwise there is no living quality despite continual development. If we can cultivate a lot of flowers and trees in our environment, it not only can reduce stress, but can also promote the activity of microorganisms that are much beneficial to the environment. For example, Greening has been considered as the best policy to absorb carbon dioxide in the atmosphere, which can reduce the catastrophic effects of global warming. This index hopes to use CO_2 fixation effect of plants as the unit to evaluate the greening design of open land, balcony, roof, or wall of a building, so that more oxygen can be generated and more carbon dioxide can be absorbed, and the ecological environment can be improved.

Figure 4: Green is the first index of Green Building

1-3 How can green designs be evaluated?

In the past, in order to promote greening, the green covering rate, tree cultivation, and cultivating density were also specified in urban construction regulations. However, it only emphasized trees, and neglected the shrubs, vines, and grass. In fact, the largest contribution of plants to the environment is their photosynthesis to fix CO_2 from air, which can reduce global warming (i.e., CO_2 can cause the greenhouse effect that is the major reason of global warming). So, CO_2 fixation has been used to evaluate the greening amount.

According to the study of botany, the amount of photosynthesis is proportional to the area of leaves of a plant. Table 2 shows seven categories of plants, which have different CO_2 fixation effects. The data are abstracted from the Architectural Engineering Institute of National Cheng Kung University. The unit is CO_2 fixation effect per square meter of green land within 40 years (standard life cycle of a building). A detailed description follows:

(1) The CO_2 fixation effect of big trees with large leaves

In Taiwan, the common big trees with large leaves are banyan, sassafras, maple, yellow cypress, firmiana, hinden, etc. They are big, and the shadow area is large, and have the best CO_2 fixation effect. Different big trees have different CO_2 fixation value. The datum in Table 2 is the average value of five common big trees, which is used as the standard evaluation value of big trees with large leaves.

(2) The CO_2 fixation effect of small trees with large leaves, needle evergreens, or trees with sparse leaves

The CO_2 fixation effect of these plants is smaller than above said trees. The datum in Table 2 is the average value of three common small trees, which is used as the standard evaluation value of these plants.

(3) The CO_2 fixation effect of big palm trees

Palm trees that are thin and tall are common in tropical areas. These include big king coconut, yellow coconut, Alexander coconut, Washington coconut, coconut palm, etc., in Taiwan. Their CO_2 fixation effect is about half that of big trees. The datum in Table 2 is the value of big king coconut, which is used as the standard evaluation value of these plants.

(4) The CO_2 fixation effect of shrubs

These include bougainvillea, rosa-sinensis, tree-peony, azalea, jasmine, violet, sage palm frond, orange jessamin, Ixora Chinegsis, etc., in Taiwan. They are short and dense and can be used as a fence. Their CO_2 fixation effect is about 27% of big trees.

(5) The CO_2 fixation effect of multiple year cultivating vines

These are the best plants to use for stereo greening of buildings, for they can clean air effectively. But there is no evaluation method for these plants. Table 1-1 shows the simulation value of 50cm shrubs, which is about 37% of shrub bush. The covering area of vines is used to calculate their green area. Annual vines are classified as herbs for the evaluation.

(6) The CO_2 fixation effect of herbs and flowers

Most herbs and flowers are annual plants. Their CO_2 fixation effect is not as good as trees. So, Table 2 shows annual CO_2 fixation analysis value for the actual area of wild grass. As for the meadow, the CO_2 fixation effect is almost zero, because the photosynthesis in the daytime and respiration in the night cancel each other out.

The above analysis shows the big trees have the best CO_2 fixation effect, which is about 3.7 times of shrubs and 17.6 times of herbs. It means the tree is better than the shrub, and the shrub is better than the herb. Generally speaking, the CO_2 fixation effect of herbs is not good, especially the meadow. So, good greening policy shall use trees mainly and use shrubs as auxiliary. The decorative herbs and meadow not only waste manpower, but also pollute the environment. They are not recommended.

Table 2: CO_2 fixation amount per unit area of various plants in Taiwan, Gi (kg / (m^2•40 years))

Kind of plant	CO_2 fixation amount
Big trees with large leaves (above 9m^2 per tree, soil depth above 0.9m)	808
Small trees with large leaves, needle evergreens or trees with sparse leaves (above 6.25m^2 per tree, soil depth above 0.9m)	536
Big palm trees (above 6.25m^2 per tree, soil depth above 0.7m)	410
Shrubs (below 1m tall, soil depth above 0.4m)	217
Multiple year cultivating vines (stereo climbing area, soil depth above 0.25m)	82
Herbs, flowers or high-stem wild grass (below 1m tall, soil depth above 0.25m)	46
Annual vines or low-stem grass (about 25cm tall, soil depth above 0.25m)	16
Meadow	0

1-4 Greening CO_2 fixation index and basis

As for the compensation basis of Green Buildings, we hope 50% of bare land shall be greened, and the calculated CO_2 fixation value shall be greater than base value of 600 (kg / m^2). It means total greening CO_2 fixation amount TCO_2 shall meet the following equations to satisfy the compensation standard of "greening index".

$$T\,CO_2 = \Sigma G_i \times A_i \times \alpha \quad \text{----------(1-1)}$$

$$T\,CO_2 > T\,CO_2c = 0.5 \times A' \times 600 \quad \text{----------(1-2)}$$

Definition of parameters:

$T\,CO_2$: Calculation value of total CO_2 fixed amount at green base [kg]

$T\,CO_2c$: Basic value of total CO_2 fixed amount at Green Building [kg]

G_i: The CO_2 fixed amount per unit area of certain plant [kg / m^2], see Table 1-1

A_i: The area of certain plant [m^2], 9.0 m^2 for big tree, 6.25 m^2 for small tree, conifer, and big palm. The overlapped and shield area should be deducted. Actual planting area is used for shrub, flower and grass. Stereo area is used for climbing plant.

α: Biological diversity compensation factor which is suitable for some mesophyte, bird and butterfly friendly plant, anti-pollution plant. It shall be approved by the committee. The value is 1.1-1.5.

A': The least green area [m^2], $A' = A_0 \times (1 - r)$, if $A < 0.1 < A_0$, then $A = 0.1 \times A_0$

AO: base area [m^2]

r : Legal base coverage rate [--]

600 (kg / m2): Basic CO_2 fixation amount per unit green area

The related regulations and cautions are described as follows:

(1) Basis description

For the meaning of basis in equation (1-2), if the base area is 10000m^2 and thw construction coverage rate is 0.6, then TCO_2c is $0.5 \times 10000 \times (1-0.6) \times 600$ = 1200000kg. It means 1200000kg of CO_2 shall be fixed within 40 years to reach "greening index" standard. In the equation, the number 0.5 means 50% of bare land shall be greened, and the other 50% of land can be used as driveway, walkway, and ditch. The basic value of 600 (kg / m^2) is slightly more strict than that of small trees. So, cultivating small trees on 50% of land and cultivating shrubs and flowers under the tree can reach the standard. If the green land is not sufficient, we can cultivate big trees or roof garden to meet the acceptable standard.

(2) The inspection for distance between plants

In order to assure sufficient growth space of plants, there shall be suitable space among trees. The minimum cultivation area is 9.0m^2 (3.0 x 3.0) for big trees, and

$6.25m^2$ (2.5 ×2.5) for small trees, needle evergreens, trees with sparse leaves and palm trees. So square lattice is used to inspect the minimum cultivation area to see if there is any overlap or obstacle. It is not necessary to cover all land, if it meets the requirement specified in (3) of soil covering depth.

(3) The inspection for soil covering depth

In order to assure sufficient growth space for roots of plants, there shall be sufficient soil covering depth. It shall be above 1.0m for trees, above 0.7m for big palm trees, above 0.5m for shrubs and vines, above 0.3m for flowers and herbs. If it cannot meet these conditions, the greening amount shall be negated.

(4) To note the classification of special plants

Because there are so many kinds of plants, the CO_2 fixation value can not be provided for all plants in this manual. Table 1-1 shall be used to simulate the value of other plants. The classification in Table 1-1 is only used for ease of analysis. Because the CO_2 fixation effect is proportional to the leaf area of a plant, so the shape of a plant and the number of leaves can be used for the evaluation. For example, different kinds of bamboo can be considered as different kinds of plants for the calculation. The similarity of plants shall be applied as the major principle. The photosynthesis of potted plants and dwarf tree is not good, so they shall be evaluated as shrubs (to reduce its CO_2 fixation effect).

(5) To promote multiple layer stereo greening

It is better to use multiple layer stereos greening for the variety of biology. So, shrubs can be cultivated under trees. The CO_2 fixation value can be added. For example, it is 536 kg / m^2 for small tree, but it becomes 753 kg / m^2 for small tree and shrub cultivated together, which is 1.40 times of CO_2 fixation effect.

(6) The evaluation of stereo greening

The greening of roof, and balconies, wall surface is beneficial to climate and ecological environment. But there is no suitable evaluation in the past. Equation (1-1) can be used according to actual cultivating area of plant.

(7) Simplified evaluation of greening for high density trees

Equations (1-1) and (1-2) are used as rigorous calculations based on the distance and the area of trees. It is slightly complex, but it is only suitable for smaller greening density. In fact, different kinds of plants are cultivated together normally, and the distance is always less than 2.5m ($6.25m^2$ area). So, the highest value of

808 kg / m^2 can be applied.

(8) The evaluation of the 40-year life cycle

A life cycle of 40 years for buildings and plants has been adopted by the Ministry of Interior. It is applied to small or large plants without the limitation of their size and height. It meets the ecological greening policy of "greening from small trees".

1-5 How is the accepted standard met?

In order to meet the above said requirements, the following items of the greening design shall be noted:

Figure 5: Green index encourages multi-level greening.

(1) The design shall reduce construction coverage rate to expand the space of green land. Generally, a reduction of 10% to 20% of coverage rate can meet the accepted greening standard.

(2) On bare construction land, keep it as green land except for artificial pavement.

(3) Cultivate trees in the large area first, then palm trees and shrubs.

(4) Cultivate shrubs under trees and palm trees to achieve the multiple layer greening function.

(5) Cultivate dwarf trees and potted plants on artificial pavement. If there is

sufficient soil coverage depth, the CO_2 fixation effect is the same as a normal tree.

(6) Reduce the greening of garden and grass, especially some meadow is not beneficial for air cleaning.

(7) Use multiple-year-cultivating vines on the building to increase greening amount.

(8) Design flower-platform on the roof and balcony to enhance greening and note its soil coverage amounts and waterproof capacity.

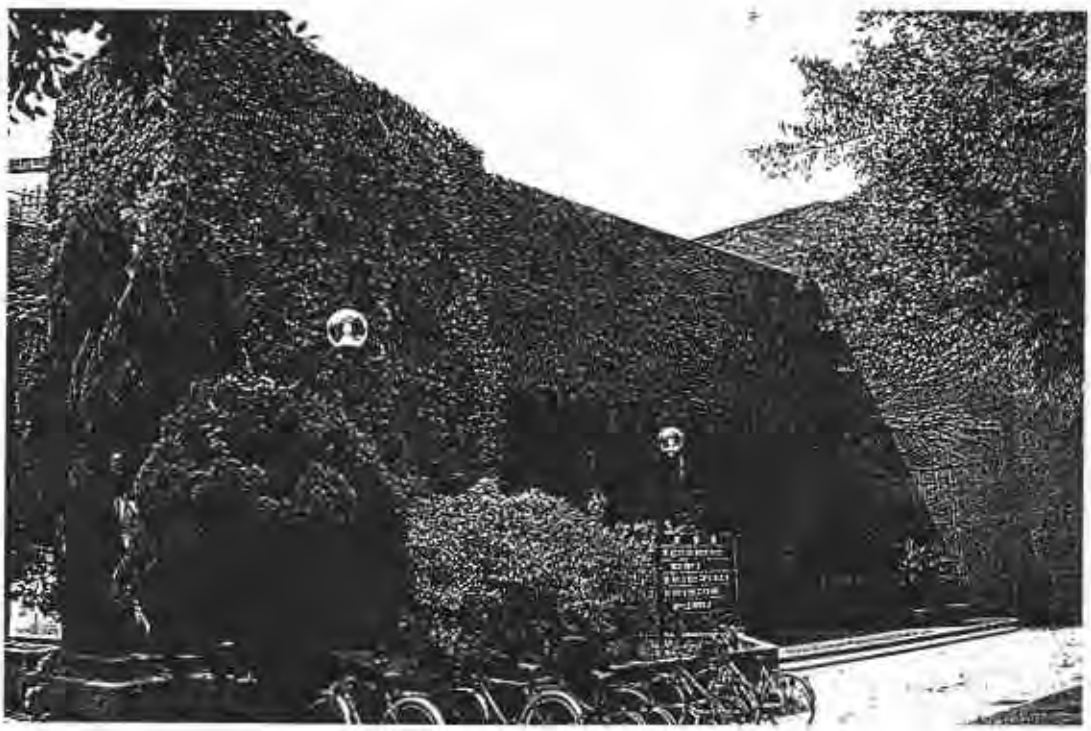


Figure 6: Green index encourages three-dimensional greening.

1-6 Case study example

(The related design drawing, description drawing and index calculation sheets and documents are omitted)

Example 1 : A residence house

1. Basic condition of building:

Base area: 3486m^2

Floor area: 1352m^2

Legal construction coverage rate: 60%

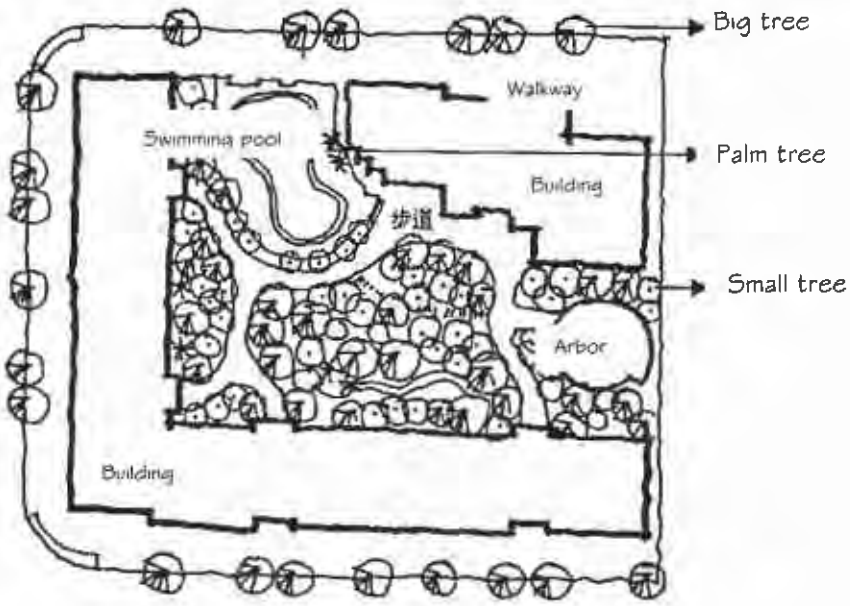
Actual construction coverage rate: 38.8%

2.Outline of greening design:

(1) Sparse greening measure is used on the walkway and around the swimming pool.

(2) High-density greening is used in the foyer with multiple layer greening, and cultivates shrubs and herbs and flowers under trees.

The soil coverage depth is about 1 m.



3.Index calculation and review

STEP 1 The inspection of soil coverage depth

It is 1 m, so that meets the requirement.

STEP2 The inspection of plant distance to determine the calculation method

Because sparse greening measure is used on walkway and around swimming pool (distance of big trees > 3m, distance of small trees and palm trees > 2.5m), the accumulation of the area for each plant is used.

Since high density greening is used in the foyer, it can be calculated as trees.

STEP3 The calculation is accumulated for the walkway, body and swimming pool:

There are 23 big trees, 8 small trees, 3 palms, 30 m^2 of flower area. So the CO_2 fixation amount is:

23x808x9 + 8x536x6.25 + 3x410x6.25 + 30x16 = 202223.5 (kg)

Lobby area:

Total plant area is 593 m^2, which includes 250 m^2 of tree and 220 m^2 of flower. So the CO_2 fixation amount is:

593x808 + 250x217 + 220x16 = 536914 (kg)

So total CO_2 is:

202223.5 + 536914 = 739137.5 (kg)

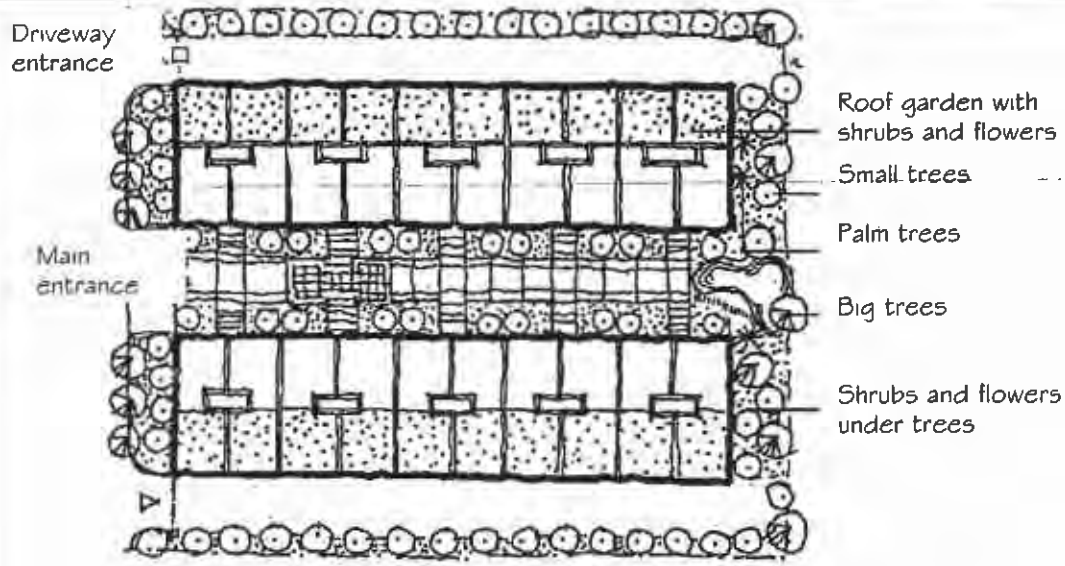
STEP4 To get acceptable greening value and confirmation

~~Acceptable value = 0.5 x 3486 x (1-60%) x 600 = 418320 (kg)~~

Total CO_2 fixation amount = 739137.5 kg > 418320 kg

So, the greening index is acceptable.

Example 2: residence house



1. Basic condition of building:

Base area: 2500m^2

Legal construction coverage rate: 50%

Floor area: 1250m^2

Actual construction coverage rate: 50%

2. Outline of greening design:

(1) Sparse greening measure is used on the ground with multiple layer greening. There are shrubs and flowers under trees. And there are shrubs and flowers on the garden of roof.

(2) No basement, the depth of garden on the roof is 50 cm.

3. Index calculation and review

STEP 1 The inspection of soil coverage depth

It is larger than 1m, and 50cm for flowers and herbs, so it meets the requirement.

STEP2 The inspection of plant distance to determine the calculation method

Because sparse greening measure is used on the ground (distance of big trees > 3m, distance of small trees and palm trees > 2.5m), the accumulation of area for each plant is used.

STEP3 The calculation is accumulated according to its calculation way

There are 12 big trees, 69 small trees, 3 palms, 120 m^2 of ground shrub, 60 m^2 of flower area, 200 m^2 of top shrub, 240 m^2 of top flower area.

So, the total CO_2 fixation amount is

$12 \times 808 \times 9 + 69 \times 536 \times 6.25 + 3 \times 410 \times 6.25 + (120 + 200) \times 217 + (60 + 240) \times 16 = 400341.5$ (kg)

STEP4 To get acceptable greening value and confirmation

Acceptable value = 0.5 x 2500 x (1-50%) x 600 = 375000 (kg)

Total CO_2 fixation amount = 400341.5 kg > 375000 kg

So, the green index is acceptable.

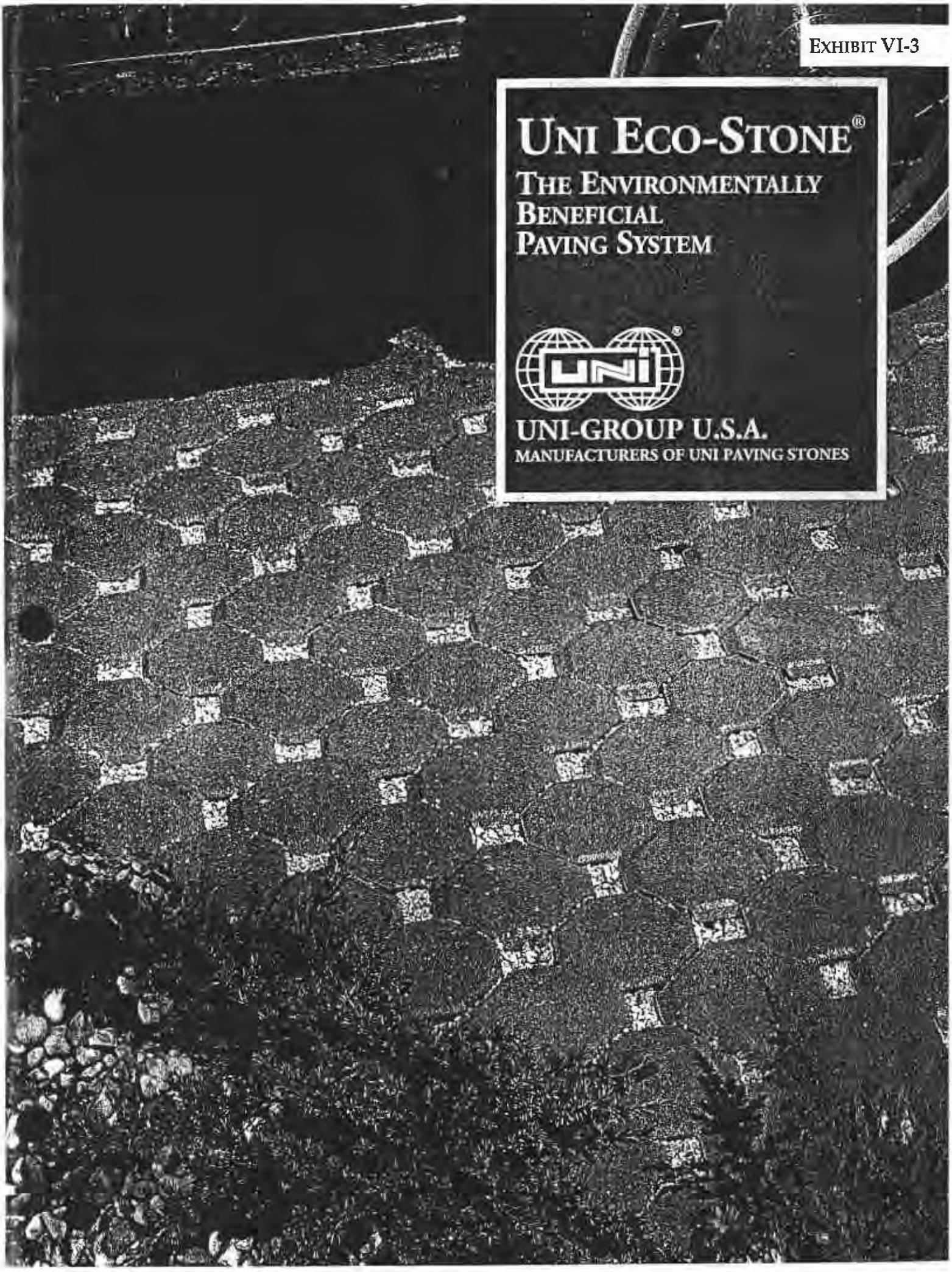
EXHIBIT VI-3

UNI ECO-STONE®

THE ENVIRONMENTALLY BENEFICIAL PAVING SYSTEM

UNI-GROUP U.S.A.

MANUFACTURERS OF UNI PAVING STONES



Environmental Concerns

In nature, a remarkable eco-system of bogs, wetlands, forested areas, and undulating terrain work together to provide a natural means for the infiltration of rainwater back into the earth, for mitigating runoff, and for retention of stormwater.

As we continue to develop our land resources, many of these natural systems have been replaced or altered to the extent that stormwater management and groundwater recharge have become major issues in many areas of the country. A new philosophy of stormwater management is emerging through the combined efforts of governing agencies, which provide policies and guidelines, and the professionals responsible for the design and construction of storm drainage facilities. These facilities must control the detrimental effects of stormwater so that the threat to not only life and property, but also to the environment, can be eliminated.

Public works, engineering professionals, and conservation commissions are now exploring alternative development practices and are working with developers, contractors, and consultants to limit increased impervious surfaces and reduce stormwater runoff. One way of reducing the impact of development on the environment is the use of porous or pervious pavements. Traditional asphalt and concrete surfaces are designed to be virtually impermeable, with stormwater runoff often mitigated through the use of drainage or detention systems. Porous pavements, however, are designed specifically to reduce, or in some cases eliminate, this runoff and direct the replenishing benefits of rainwater naturally into the ground below. Critics of uniform on-site detention emphasize the importance of infiltration into the ground as the logical way of handling stormwater since it would then contribute to groundwater recharge, provide normal basal flow to surrounding streams, and improve the water quality.

The UNI Eco-Stone® Paving System

For over 35 years, segmental concrete unit pavers have been a proven paving material for a wide variety of applications, offering unique advantages such as resistance to severe loads, flexibility of repair, low maintenance, exceptional durability, and consistently high quality. As members of the nation's leading concrete paver producer organization, UNI-GROUP U.S.A. manufacturers are the industry's experts, dedicated to the highest level of quality manufacturing, technical expertise, and ongoing product research and development.

In response to these recent environmental concerns, UNI-GROUP U.S.A. announces the development of the UNI Eco-Stone® Paving System, an innovative, environmentally-beneficial system designed to mitigate stormwater runoff, as well as provide a method for increased groundwater recharge and/or storage for future use. With concern for the environment and the earth's resources at an all-time high, the UNI Eco-Stone® Paving System offers governing agencies, engineers, architects, developers, and land planners an alternative to traditional non-permeable pavements. UNI Eco-Stone® combines the durability, strength, quality, and reliability of UNI® interlocking concrete pavers with a new high-tech design developed for water conservation and runoff control.

Features of the UNI Eco-Stone® Paving System

- *The unique, patented design features funnel-like openings in the pavement surface which facilitate rainwater infiltration, thereby reducing or eliminating stormwater runoff and maximizing groundwater recharge and/or storage*
- *Lessens or eliminates downstream flooding, stream bed and bank erosion, and mitigates pollution impact on surrounding surface waters*
- *Decreases project costs by reducing or eliminating drainage and retention systems required by impermeable pavements and reduces cost of compliance with many stormwater regulatory requirements*
- *Permits better land-use planning, allowing more efficient use of available land for greater economic value*
- *Provides a highly durable, yet permeable pavement surface capable of supporting vehicular loads*

Vienna Stadium

TECHNICAL RESEARCH AND INFORMATION

To provide basic design information on the UNI Eco-Stone® Paving System, UNI-GROUP U.S.A. sponsored preparation of the report *"Design Considerations For The UNI Eco-Stone® Concrete Paver"* by noted U.S. pavement design authorities Raymond S. Rollings, Ph.D., P.E., and Marian P. Rollings, Ph.D., P.E. The report contains basic design considerations, specifications, applications, and references and concludes that the UNI Eco-Stone® Paving System is a highly functional pavement which offers major environmental benefits and, when properly designed, will accommodate virtually any traffic load or design storm.

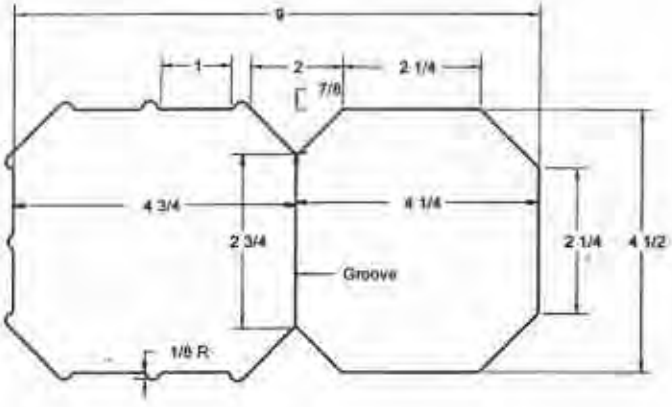
Ft. Lauderdale, Florida Loading Area

The research confirms that UNI Eco-Stone® is a versatile product, providing design professionals, developers, land planners, regulatory agencies, and environmental commissions with new options for stormwater management and water conservation. UNI Eco-Stone® presents new possibilities in pavement surface water control to meet regulatory mandates, potentially reduce the size or need for special stormwater runoff facilities, and reduce or eliminate downstream flooding. In addition, UNI Eco-Stone® is an environmentally-beneficial paving system that utilizes infiltration as a natural way to handle storm runoff, conserve rainwater, recharge groundwater storage, improve water quality, and mitigate pollution impact on surrounding surface waters.

Furthermore, UNI Eco-Stone® will be cost effective, allowing more efficient use of available land that otherwise would not be developed due to requirements for stormwater retention or by limitations on how much impervious area is allowed on a site. Cost of compliance with many regulatory mandates for stormwater management could significantly decrease with the use of UNI Eco-Stone®. This product gives the designer a tool that can be used in a variety of ways to address stormwater management problems and decrease the environmental impact of land development.

UNI Eco-Stone® is manufactured to the same ASTM C-936 specifications as conventional solid concrete unit pavers and possesses the same strength, aesthetics, and durability, yet also has the added feature of permeability. The permeability of UNI Eco-Stone® is achieved by the area of the voids created by its notched design. Measurements of a typical UNI Eco-Stone® paver and basic physical characteristics are shown in Figure 1.

Figure 1



Physical Characteristics

Height/Thickness		3 1/8"	=	80mm
Width	Approx.	4 1/2"	=	115mm
Length	Approx.	9"	=	230mm
Number of stones per sq ft			=	3.55
Percentage of void area per sq ft			=	12.18%

Composition and Manufacture

UNI Eco-Stone® is made from a "no-slump" concrete mix. Made under extreme pressure and high-frequency vibrations, UNI Eco-Stone® has a minimum compressive strength of 8000 psi, a maximum water absorption of 5%, and will meet or exceed ASTM C-936 and freeze-thaw testing per section 8 of ASTM C-67.

The void area of the UNI Eco-Stone® pavement is created when the pavers are installed (Figure 2). To provide a stable pavement surface and facilitate rainwater infiltration, the void area of the UNI Eco-Stone® must be filled with a graded aggregate suitable for the project parameters (Figure 3).

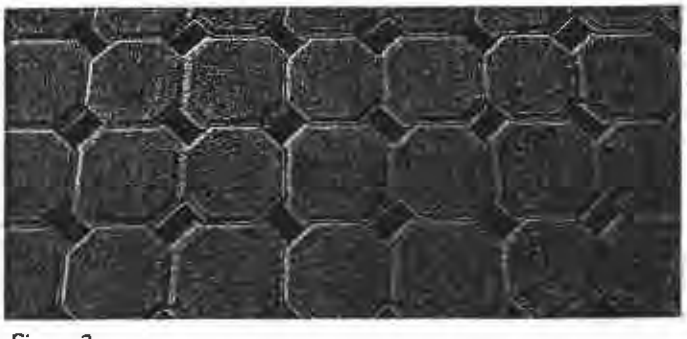


Figure 2

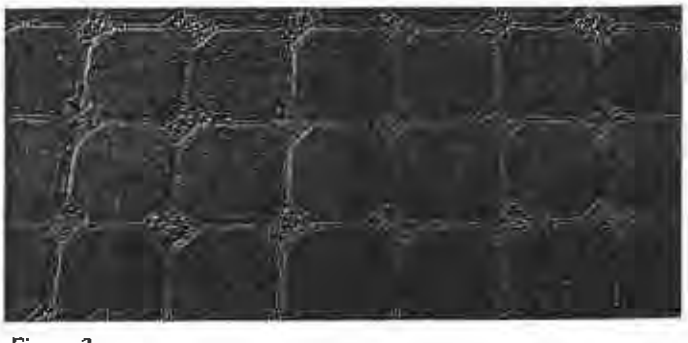


Figure 3

Construction of a UNI Eco-Stone® pavement is similar to that of traditional solid pavers (a flexible pavement with pavers as the wearing course, a bedding layer, base, subbase, and subgrade), with design considerations for water in-flow. More detailed information on designing flexible pavements is available in Rollings and Rollings (1992). *The entire pavement system, including the UNI Eco-Stone® surface, the underlying base, subbase and subgrade, must be designed as a complete system to insure that all project objectives are met.* As with all pavements, the individual material properties, pavement function, traffic load, drainage requirements, environmental conditions, and other special considerations must be addressed by the designer for each application.

Generally, pavement subsurface drainage is designed to accommodate the one-hour/one-year or one-hour/two-year frequency storm. The UNI Eco-Stone® report includes a one-hour/one-year frequency storm map for the U.S. which provides guidance for estimating a typical design storm for a UNI Eco-Stone® pavement to handle common pavement surface drainage conditions. However, if the UNI Eco-Stone® pavement is being designed to meet local stormwater control regulations, the design storm will be specified by the regulatory agency and will normally be more severe (e.g., 100-year storm requirements are common). The research established that a UNI Eco-Stone® pavement can be designed to drain virtually any design storm, including 100-year storms.

The rate at which water will flow through the UNI Eco-Stone® surface will depend on the specific materials used to fill the drainage voids and on the slope of the pavement. *By judicious selection of drainage opening fill and jointing material, the designer can achieve a wide range of permeabilities for the UNI Eco-Stone® surface to attain a specific project's drainage objectives.* The bedding layer is often the same aggregate material that is used in the drainage voids. This simplifies construction and satisfies filter requirements; however, the material selected must also allow for proper seating of the pavers. UNI Eco-Stone® infiltration tests, potential aggregate gradations and flow rates, and other design data are provided in the report and should be referenced for guidance on selecting appropriate materials. Other factors which effect the permeability of the system include the existing subgrade, the type of aggregate materials available for the base and subbase, construction, hydraulic design considerations, environmental conditions, etc. With pervious subgrades, all water may be drained directly into the subgrade, and alternatively, some or all of the water may be diverted to lateral storage or drainage systems. The research provides informative tables and figures for soil infiltration rates, typical friction angles of nonplastic materials, and permeability values for typical pavement materials, as well as a section on hydraulic design.

It is important to note that appropriate gradations of aggregate materials be used to prevent migration of particles from one layer to the next which can cause problems with structural stability and plugging of the drainage system. In some cases, the use of filter layers or geotextiles may be required, and for areas where frost action is a factor, proper specifications must also be considered. Recommended filter criteria and frost design information are also discussed in the UNI Eco-Stone® research report.

St. Andrews Church, Sonoma, California

As a reduction in perviousness of the UNI Eco-Stone® Paving System may occur due to organic growth and fines accumulation over a period of 3-5 years, cleaning with commercial street sweeping/vacuuming equipment is recommended on an approximate 4-year cycle. Additional aggregate fill material can be added to the openings at that time, if necessary.

Ecoloc™ is another UNI® product that possesses the same runoff and permeability characteristics as the UNI Eco-Stone®. Ecoloc™ can be used in conjunction with UNI-Anchorlock,® a solid concrete unit paver, to offer a combination of permeable and impermeable pavements. Both UNI Eco-Stone® and Ecoloc™ can be mechanically installed to speed installation and reduce project costs.

The Rollings' report may be obtained from your local UNI-GROUP U.S.A manufacturer and should be consulted for detailed information to formulate design procedures and specifications. A qualified engineer or design professional should be consulted for applications utilizing the UNI Eco-Stone® and Ecoloc™ Paving Systems to ensure desired results.

For additional information on UNI® interlocking concrete unit pavers, consult the following publication also available from your UNI - GROUP U.S.A. manufacturer: *"Applications For Concrete Paving Block In The United States Market"*, R.S. Rollings and M.P. Rollings, 1992.

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PENTEC ENVIRONMENTAL

Delivering smarter solutions

Stormwater Management Benefits of Porous Pavements

Literature Review

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STORMWATER MANAGEMENT BENEFITS OF POROUS PAVEMENTS LITERATURE REVIEW

INTRODUCTION

This document is a brief review of literature on the application of porous pavements and their potential to provide stormwater detention, filtration, and water quality treatment. The following literature review is provided in support of the proposal to include a best management practice (BMP) section on porous pavements in the draft manual "Stormwater Management in Washington State" (Ecology 1999).

The impacts of urbanization are far reaching both ecologically and economically. The water-retaining characteristics of undisturbed soils (e.g., outwash) provide a natural stormwater runoff reservoir capable of storing tremendous volumes of water. Clearing vegetation, compacting soil, ditching and draining, and covering the land surface with impervious roofs, roads, and parking lots reduces or eliminates the land surface's built-in stormwater management system. Water that would linger for days or weeks before development now, after development, flows rapidly across the land surface and discharges to the nearest stream in concentrated bursts (Booth and Jackson 1997).

With increased stormwater runoff, stream channels can expand catastrophically to consume adjacent land that historically may not have been affected by either flooding or erosion. Sediment may inundate low-lying areas beyond the active channel, stormwater facilities can be overwhelmed by frequent flows far beyond their design capabilities, and populations of aquatic organisms can be adversely affected. In small streams draining lightly to moderately urbanized watersheds, these environmental and ecological consequences of increased water quantity can overwhelm the effects of impaired water quality (i.e., the chemical constituents carried by runoff [e.g., Horner et al. 1996]).

Traditionally, this problem has been addressed by replacing the lost functions of the natural soil reservoir with a costly infrastructure of drains, curbs, ditches, and pipes to collect runoff from paved surfaces into an excavated detention pond. The detention pond is intended to mimic the functions of the soil reservoir by accepting water at whatever rate it flows off the developed

land surface and releasing it at a slower, more "natural" rate. "This approach almost entirely separates the design of the development from the management of stormwater: the runoff displaced by human structures is shunted to a point where 'management' then takes over"(Booth and Leavitt 1999, p. 315).

This strategy has often proven to be ineffective (Booth and Jackson 1997). The primary reason is one of scale—the lost storage capacity in the soil, typically several inches to nearly a foot deep (predevelopment conditions), is replaced by the equivalent of only a few tenths of an inch (postdevelopment conditions). This represents a reduction in "reservoir" volume of potentially 90 percent or more; under these circumstances stream channels are subject to measurable downstream adjustments. According to Booth and Leavitt (1999), most detention ponds are largely or entirely ineffective (e.g., Barker and Nelson 1989, Barker et al. 1991). In addition, a surprisingly high fraction of developed areas may not drain through stormwater facilities, because regulatory thresholds typically allow much of the development in a watershed to occur without any runoff mitigation (Booth and Leavitt 1999).

The limitations of current stormwater management strategies must be addressed in light of the recent listing of salmonids under the Endangered Species Act (ESA). Given previous research (e.g., Barker and Nelson 1989, Barker et al. 1991), stormwater management cannot be successful without integrating infiltration capability into the design of development. When designed and constructed correctly, porous pavement attenuates runoff, improves erosion control, minimizes water quality degradation, reduces the need for curbs and storm sewers, retains natural drainage patterns and vegetation, improves road safety, and allows for groundwater recharge (Shahin 1994). In the context of ESA issues, porous pavement has the potential to reduce or eliminate peak flows associated with urbanization, prevent channel instability, mitigate nonpoint source pollution, and preserve salmonid habitat.

Porous pavement is a viable alternative to traditional stormwater management strategies for providing increased on-site infiltration of stormwater, which decreases the demand for off-site mitigation and decreases the overall costs of stormwater mitigation. Porous pavement is not practical everywhere. However, opportunities for its application are particularly great when growing pressure of urban development threatens high-quality aquatic resources. This report will propose that permeable interlocking concrete pavement (PICP) be adopted as a best

management practice (BMP) for pretreating and/or infiltrating stormwater runoff from large parcels.

TYPES AND CHARACTERISTICS OF POROUS PAVEMENT

Porous pavements are available in both concrete and plastic. Porous concrete paving is available in four forms: poured-in-place concrete slabs, precast concrete grids, modular unit pavers, and PICP. Poured-in-place concrete slabs are massive and are made with reusable forms to create openings for gravel or planted-grass fillings. When reinforced with steel, concrete slabs are suitable for heavy loads and prevent differential settling and the impacts of frost heave. However, the installation is more labor-intensive than that of the precast concrete grids (Booth and Leavitt 1999). Concrete grids are usually precast in a production plant and trucked to a job site for installation. For large jobs these units can be cast at the site. Modular unit pavers are smaller pavers that may be clay bricks, granite sets, or cast concrete of various shapes. These pavers are monolithic units lacking void areas incorporated into their configuration. They are installed in the ground with pervious material placed in the gaps between the units. PICP combines high load-bearing strength with surface permeability through narrow jointing and a built-in pattern of openings. The pavers maintain high side-to-side contact between the units for stability under vehicular loads. The openings are filled with aggregate and are typically placed on an open-graded aggregate base, which serves to store runoff (ICPI Tech Spec 1). Unique to this type of porous pavement, the interlock contributes to the structural performance of the pavement system.

All permeable pavements, regardless of type or brand, accomplish the basic hydrologic goal of infiltration (Booth and Leavitt 1999). Where soil conditions are suitable, porous pavements are successful at managing runoff from small to moderate storms. Effective grain size, percent fine sediment, and porosity affect the permeability of porous pavement (Shahin 1994). Porous pavement functions by allowing stormwater runoff to infiltrate through openings or pore spaces and temporarily retains all or a portion of the inflow until it infiltrates, percolates, or evaporates away. Once the water penetrates through the base material, water can drain vertically into the subgrade. Porous pavement designs have the potential to accommodate subgrades with low permeability by using drain pipes in the permeable base to dispose of runoff. Water quality

concerns can also be addressed by using collection pipes to direct the inflow for further treatment. According to Smith (1984), grid pavements greatly reduce surface runoff volumes and heavy metals with the exception of nitrate/nitrite due to leaching from the soil.

Research conducted by Jackura (1980), Lorant (1992), Thompson (1995), and Shahin (1994) suggests that porous pavement can reduce or eliminate chemical, thermal, and biological pollutants; however, the degree of water quality treatment is highly dependent on the characteristics of the underlying soil and subgrade. The soil material and soil structure bedded in the pavement play a major role in the cation exchange of organic matter and pH. Porous pavement can remove chemical and biological pollutants from stormwater runoff through filtration, adsorption, and decomposition. The natural filtration of runoff by the soil may remove most contaminants. Jackura (1980) found that most pathogenic bacteria and many chemicals are filtered out within 0.9 to 3 m of vertical percolation and 15 to 60 m of lateral movement. Silverman and Strenstrom (1988) noted numerous advantages of porous pavement, particularly its ability to degrade oil and grease captured in the soils surrounding and underlying the pavement and subgrade. The soil and underdraining particles absorbed heavy metals, thereby removing them from stormwater discharge. According to Day et al. (1981), Smith (1984), and Galli (1990), porous pavement lowers water temperature and reduces temperature fluctuations. Galli (1990) reported that pervious pavement is the most effective BMP for reducing urban temperature fluctuations. Though some studies have measured changes of inflow water quality, to date, there have been no studies that design the permeable base of porous pavement specifically for water quality treatment (such as using activated carbon or filter technology).

More recently, plastic products have been introduced to take advantage of their light weight and relative ease of installation. Most are composed of 50 to 100 percent postconsumer recycled materials. Flexible systems can be obtained in long rolls and can be installed quickly; rigid modules, like their concrete counterparts, are laid in a running bond pattern and either interlock or are pinned in place. Plastic pavers, whether rigid or flexible, have less intrinsic strength than concrete pavers. With adequate base and subgrade preparation, any of these systems are fully capable of supporting heavy vehicular traffic loads, even when the ground is fully saturated with water. The compressive strength of a porous pavement system relies in large part on the strength of the underlying soils, particularly in the case of modular plastic units where the "pavement" itself lacks rigidity. Although less intrinsically strong, flexible materials have a compensating advantage of being more easily laid over irregular surfaces. The shape and aggregate area of the

openings (80-100 percent) vary among products; these types of pavers are designed to be completely covered with grass or gravel (Booth and Leavitt 1999).

APPLICATIONS OF POROUS PAVEMENT

Although porous pavement systems have been available for several decades, their use has been expanding slowly. Typical applications have been for light-duty or infrequent-use parking areas or access drives. The load-bearing capabilities, however, allow for a much wider range of uses. Potential applications include the following:

- Vehicular access (residential driveways, service driveways, roadway shoulders, crossovers, and medians, fire lanes, and utility access)
- Parking (church, employee, overflow, event, guest, roof decks)
- Bicycle trails
- Golf courses (cart paths, cart parking)
- Pedestrian access (approaches to monuments, statues, and foundations; areas for outdoor special events; picnic areas and highway waysides; pathways and trails, sidewalks, pedestrian plazas)
- Equestrian trails
- Slope stabilization and erosion control

Design considerations should take into account the potential of the porous pavement to become clogged by fine sediments. According to Lorant (1992), normal maintenance precautions prevent clogging from becoming a major problem; however, street sweeping or flushing can clean a clogged pavement. Schueler (1992) states that porous pavement is best applied to slopes less than 5 percent. At Northeastern University, Boston, Uni Eco-Stone (EC) was tested on slopes ranging from 0 to 10 percent. They found that EC accommodated

infiltration of a 100-year storm with a duration of 5 minutes and an intensity of 300 mm/hr on slopes between 0 to 5 percent (Sargo 1993).

INSTALLATION AND COSTS OF POROUS PAVEMENT

Installation requirements and costs vary with the type of system. Plastic products can be moved and cut easily with hand tools, so they can fit into irregular spaces and around utilities with little or no special preparation or effort. Concrete systems require up to one-third more time to install because of their weight and rigidity. Either type of system is more labor intensive when infilled with grass than with gravel or stone, because of the added attention required for soil preparation, sodding (common for plastic systems) or seeding (generally mandatory for establishing grass in concrete systems), and initial irrigation until the grass is well established. Grass also requires a period of no traffic following installation, typically 1 or 2 months, to allow the root system to become established; even after establishment, the frequency of traffic on a grassed surface must remain low (typical recommendations are one to two trips per day) (Booth and Leavitt 1999).

Previous studies (e.g., Nichols 1992, Sorvig 1993) have suggested that porous pavement is only modestly more expensive than traditional asphalt; however, Booth and Leavitt (1999) do not support this assertion. Based on manufacturers' quotes in early 1997, these systems generally cost more to purchase and install than asphalt. However, total project costs may actually be lower using porous pavement if the expense of associated drainage facilities to manage impervious-surface runoff is included in the comparison. This requires the permitting jurisdiction to fully credit the anticipated stormwater management capabilities of these systems (Booth and Leavitt 1999).

WATER QUALITY TREATMENT BENEFITS OF POROUS PAVEMENT SYSTEMS

The extent of water quality treatment provided by porous pavement systems depends primarily upon the performance of the base and sub-base material as a filter that removes pollutants from stormwater runoff. The main treatment mechanism provided by the system is

physical removal of suspended particulate material as stormwater is filtered through the base and sub-base material. Removal efficiency depends on the length of the flow path and the grain size of the filter material.

Sand filters are commonly used to provide water quality treatment in removing suspended solids and oil from stormwater runoff. Porous pavement systems may provide water quality treatment through filtration similar to the treatment provided by sand filters. The following discussion evaluates potential water quality treatment provided by porous pavement systems by comparison to sand filters.

The King County, Washington Surface Water Design Manual (King County 1998) presents guidelines for the appropriate design and application of sand filters in the treatment of stormwater. The manual also discusses expected performance in reducing total suspended solids (TSS) and oil in runoff. Sand filters treat stormwater by collecting water within a low-lying area and allowing the water to infiltrate vertically through an 18-inch-thick layer of medium sand. An 8-inch-thick layer of coarse gravel placed under the sand layer drains water after it has flowed through the sand layer. The underlying gravel layer must allow free drainage under the sand for the filter to function properly. For the standard design guidelines, water must accumulate above the sand to a depth of 3 ft to provide enough hydraulic head to achieve the necessary flow rate through the sand layer.

Sand filters typically include a pretreatment cell for settling out suspended sediment that would otherwise plug the filter. Without pretreatment, sand filters are prone to clogging as debris, fine sediment, oil, and grease accumulate within the interstices between individual sand grains. Annual or semi-annual inspection and maintenance of the surface of sand filters must occur to maintain sufficient infiltration rates, and replacement of the sand bed may be necessary within 4 to 10 years of installation.

KPFF Engineers presents a case study of a PICP designed to provide stormwater detention and treatment for a 1.70-acre commercial development site in Auburn, Washington (KPFF 2000). The design includes a typical cross section of the pavement system including the surface layer of pavers, pea gravel bedding layer (a few inches thick), open-graded base layer (average thickness of 0.84 ft), and collection drain pipes within the base layer. The proposed design does

not include a sand layer in the cross section. The overall thickness of the pavement system from surface to subgrade is less than 18 inches.

The case study design presented by KPFF provides a measure of water quality treatment through removal of an undetermined portion of the contaminants, including suspended solids as well as oil and grease. The removal efficiency provided by the gravel base cannot be readily quantified because of a lack of relevant data regarding filtration through gravel media. Though the amount of treatment provided cannot be readily determined, it is clearly less than that provided by a sand filter designed to meet water quality treatment standards in King County, Washington. To provide adequate water quality treatment, the porous pavement system design would have to be reconfigured to more closely mimic the configuration of a sand filter.

A porous pavement system configured in the following way would provide water quality treatment performance similar to that of a sand filter that meets water quality treatment standards. The pavers are installed on top of a bedding layer approximately 8 inches thick and composed of pea gravel. The voids between pavers are filled with the same material. Beneath the bedding layer is an 18-inch-thick layer of medium sand that provides filtration. Beneath the sand is an 8-inch (minimum average thickness) layer of coarse graded base material that drains freely through perforated pipe drains. The total average thickness of the proposed section is approximately 3 ft from surface to subgrade. The thickness of the upper gravel layer may vary depending on the required flow-through infiltration rate; a thicker layer provides additional storage above the sand layer and creates a greater hydraulic head to drive more water through the sand layer. The structural integrity and load-bearing capacity of the base is probably diminished by the presence of an 18-inch-thick layer of sand near the surface. An engineer should evaluate the reduction of load bearing capacity and perhaps determine the depth at which the sand layer would not affect the structural strength of the pavement. Irrespective of the results of such an analysis, the 3-ft total depth of excavation is a minimum necessary to provide water quality treatment. The actual required depth may be more than 3 ft as a result of strength considerations.

The previous discussion demonstrates the feasibility of constructing a porous pavement system that provides adequate treatment through sand filtration. The analysis performed by KPFF (KPFF 2000) presents a PICP system that is comparable in cost to a traditional asphalt pavement and drainage collection system. The additional excavation and fill required to meet water quality treatment standards substantially increase the cost of a porous pavement system.

The PICP system as proposed by KPFF provides adequate stormwater detention and flow control. Water quality treatment may be added to such a system by installing treatment facilities downstream of the collection drains.

The treatment efficiency of the PICP system proposed by KPFF could be more precisely determined through additional research combining bench tests and one or more pilot studies that monitor water quality in the runoff from a porous pavement system. Although the treatment efficiency is not equivalent to that of a sand filter, there is an undetermined water quality treatment benefit provided by the porous pavement system. This benefit may be quantified through additional research resulting in credit for water quality treatment in designs that include porous pavement. Although the proposed PICP system does not provide adequate water quality treatment, it clearly provides adequate stormwater detention and flow duration control.

PERMEABLE INTERLOCKING CONCRETE PAVEMENT AS A LARGE-PARCEL BMP

Best management practices include a range of technology and land management practices for reducing the quantity of pollutants in stormwater. They are used in combination at the site, development, and watershed scales to attain the maximum benefits to the stormwater drainage system. BMPs are divided into structural and nonstructural practices. Structural BMPs rely on gravitational settling and/or the infiltration through a porous medium for pollutant reduction. They include dry detention ponds, wet (retention) ponds, infiltration trenches, permeable pavements, and sand filtration systems.

In the draft Stormwater Management in Washington State (Ecology 1999), porous pavement is currently featured as a "Small Parcel BMP." New development or redevelopment projects meeting the following criteria are required to implement large-parcel stormwater treatment:

- Single-family or multifamily residential or subdivision projects in which the total of new and replaced pollution-generating impervious surfaces (PGIS) is 10,000 ft^2 or more in a threshold discharge area of the project.

- Other development projects in which the total of new and replaced PGIS is 5,000 ft^2 or more in a threshold drainage area of the project.

- Projects in which the total of new and modified pollution-generating pervious surfaces (PGPS) is 1 acre or more in a threshold discharge area, and from which there is a surface discharge in a natural or manmade conveyance system from the site.

PGISs are impervious surfaces that undergo vehicular use or store leachable materials, wastes, or chemicals and receive direct rainfall or rainfall runoff. PGPSs are pervious surfaces subject to the use of pesticides, fertilizers, or soil loss; these typically include lawns, landscaped areas, golf courses, parks, cemeteries, and sports fields. Threshold discharge area is defined as an on-site area draining to a single natural discharge location or multiple natural discharge locations that combine within one-quarter-mile downstream (as determined by the shortest flow path). The portion of a project that does not exceed the above criteria can use small-parcel BMPs. The step-by-step selection process for BMPs (Ecology 1999, Figure 1.3, pp 4-5) begins with determining whether or not the project meets the criteria for small or large parcels. This initial determination in the flow chart excludes porous pavement from being considered as a BMP for large parcels, regardless of its applicability to large parcel projects.

The limitation of selecting porous pavement as a large-parcel BMP may be due to restricted examples of its use in the United States. However, interlocking concrete pavement, both permeable and nonpermeable, have been applied to large parcels nationally and internationally. PICP has been applied nationally to sites over 30,000 ft^2 in size. In Florida, PICP was chosen for two renovation projects for municipal parking areas and walkways. After installation in 1995, the PICP continues to infiltrate heavy rainfall experienced in southern Florida, including two tropical storms in October 1995 with 10 inches of rain in a 24-hour period. Also in 1995, over 27,000 ft^2 of PICP was installed in southern California in order to reduce or eliminate stormwater runoff that contributes to flash flooding. In Austria, the City of Vienna installed PICP for two large parking lots. In 1990, 409,015 ft^2 of PICP was installed for the parking lot of the Prater Stadium. Due to the positive results of the first project (the pavement infiltrates water for all storm events), the City of Vienna built a second parking lot for a different project totaling 484,360 ft^2 in continuous area. PICP was used for the second parking lot to avoid construction of a sewer system and to maintain infiltration as part of the hydrologic cycle.

Solid interlocking concrete pavement is based on the same technology as PICP; however, it lacks permeability. The Port of Tampa (Florida) installed 112,620 ft² of solid interlocking concrete pavement for their new 900-ft wharf. After investigating other options over a 40-year cycle, they concluded that the solid interlocking concrete pavement system would be lower in cost than the unreinforced and reinforced concrete pavements and asphalt. The base was designed so that the pavement could accommodate axle loads of 106,000 pounds. The Port of New Orleans (Louisiana) installed nearly 1 million ft² of interlocking pavement. Clearly, interlocking concrete pavers exceed some of the limitations of other permeable pavements (Table 1).

Table 1 Evaluation of applications for precast concrete permeable pavement systems.

	Pavement Types			
	Interlocking Shapes	Widened Joints	Permeable Concrete	Grid Pavers
Low-speed roads	Good	Good	Not Recommended	Not Recommended
Parking lots, driveways	Excellent	Excellent	Not Recommended	Acceptable for Low Use
Overflow parking, access and emergency lanes	Good	Good	Good	Excellent
Revetments, boat ramps	Not Recommended	Not Recommended	Not Recommended	Excellent
Bike paths, sidewalks, pedestrian areas	Good	Good	Excellent	Not Recommended

Source: Borgwardt (1997).

PICP functions as an infiltration and retention area can accommodate pedestrians, and vehicular parking and traffic. This combination of functions offers the following benefits:

- Conservation of space on the site by not using a single-purpose retention/detention pond
- Reduction of runoff by as much as 100 percent (depending on rainfall intensity and duration)

- Reduction of retention requirements in other parts of the drainage system
- Filtration through the base and soil for improvement of water quality
- Reduction of runoff temperature
- Increased recharge of groundwater
- Reduction of downstream flows and bank erosion
- Reduction of overall project development costs due to reduction in storm sewers and drainage appurtenances

PICP is typically built using open-graded, crushed-stone base. The base offers infiltration and partial treatment of stormwater pollution. Unlike other permeable pavements, interlocking concrete pavers are typically constructed as flexible pavements, and when compacted, the pavers interlock and transfer vertical loads from vehicles to surrounding pavers. Sand in the joints enables applied loads to be spread in a manner similar to asphalt, reducing the stresses on the base and subgrade. As interlocking concrete pavements receive traffic, they stiffen and increase their structural capacity over time. The structural contribution of the interlocking pavers and sand layer can exceed that of an equivalent thickness of asphalt (ICPI Tech Spec 10). Dr. Shackel developed the Lockpave Pro™ computer program to assist in the structural design of interlocking concrete block pavements for a variety of applications. The structural design aspects of PICP are included in the program as well as a hydraulic program based on SWMM, EPA's Stormwater Management Model. PICP provides pretreatment for stormwater by settling out the largest particles present in stormwater runoff, and supports the water cycle by retaining and infiltrating stormwater runoff. If infiltration capacity of the soil is exceeded, the pavement base can be designed to filter and slowly release water into a storm sewer or watercourse. By more closely imitating the water cycle, PICP is in some cases the lowest cost means for handling stormwater (KPFF 2000). PICP should be included in the Ecology stormwater manual as a Pretreatment and Infiltration BMP for Large Parcels, given its load-bearing capabilities and versatility compared to other permeable pavers.

CONCLUSIONS AND RECOMMENDATIONS

1. PICP systems can be installed in a way that provides adequate stormwater detention through storage within the base course.

2. PICP systems can be configured to provide water quality treatment by mimicking the performance of a sand filter. The added excavation and fill necessary to achieve effective water quality treatment increase the cost such that traditional water quality treatment facilities are usually more cost-effective.

3. Additional research including bench tests and pilot studies including water quality monitoring may provide a basis for more precisely quantifying the water quality treatment benefits provided by filtration through the gravel base material in a PICP installation.

4. The current Lockpave Pro™ design tool interfaces with the SWMM stormwater model. Expanding Lockpave Pro™ to interface with other commonly used stormwater models including HSPF would probably expand the use of this application.

5. Large-scale successful installations of PICP demonstrate that PICP may be appropriately included in the ecology stormwater manual as a Pretreatment and Infiltration BMP for Large Parcels, given its load-bearing capabilities and versatility compared to other permeable pavers.

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PENTEC ENVIRONMENTAL

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BMP – Permeable Interlocking Concrete Pavement

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BMP – Permeable Interlocking Concrete Pavement

Description

Permeable interlocking concrete pavement (PICP) combines high load-bearing strength with surface permeability through narrow jointing and a built-in pattern of openings (Figures 1A & B and Figure 2). The openings are filled with aggregate and the pavers are typically placed on an open-graded aggregate base for storing runoff. Interlocking concrete pavements are typically constructed as flexible pavements on compacted soil subgrade and compacted aggregate base. The pavers are then placed on a thin layer of bedding sand, compacted, sand swept into the joints, and the units compacted again. When compacted the pavers interlock, transferring vertical loads from vehicles to surrounding pavers by shear forces through the joint sand. The sand in the joints enables applied loads to be spread in a manner similar to asphalt, reducing the stresses on the base and subgrade. PICP has patterns with openings or drainage holes for rainfall to enter, while maintaining high side-to-side contact among units for stability under vehicular loads (Figure 3). BMP T3.40 provides related information on permeable pavements.

Applications and Limitations

Typical applications include:

- Vehicular access (residential driveways, service driveways, roadway shoulders, crossovers, and medians, fire lanes and utility access)
- Parking (church, employee, overflow, event, guest)
- Bicycle trails
- Golf course (cart paths, cart parking)
- Pedestrian access (approaches to monuments, statues, and foundations, areas for outdoor special events, picnic areas and highway waysides, pathways and trails, sidewalks, pedestrian plazas)
- Equestrian trails
- Slope stabilization and erosion control
- Redevelopment projects
- Roof plaza and parking decks
- Ports and industrial pavements

This BMP functions as an infiltration and retention area that can accommodate pedestrians, and vehicular parking and traffic. This combination of functions offers the following benefits:

- Conservation of space on the site by not using a single purpose retention/detention pond
- Reduction of runoff by as much as 100 percent (depending on rainfall intensity and duration)
- Reduction of retention requirements in other parts of the drainage system
- Filtration through the base and soil for improvement of water quality
- Reduction of runoff temperature
- Increased recharge of groundwater
- Reduction of downstream flows and bank erosion
- Reduction of overall project development costs due to reduction in storm sewers and drainage appurtenances
- Elimination of cracking normal to conventional asphalt and concrete pavements
- Accommodation of year-round construction
- Pavement can be opened and closed without using jackhammers, using less construction equipment, and reusing the same pavers ("reinstatement")

PICP is not recommended for the following circumstances:

- When the depth from the bottom of the base to the high level of the water table is less than 3 feet, or when there is insufficient depth of soil to offer adequate filtering and treatment of water pollutants.
- Over solid rock without a loose rock layer above it.
- Over aquifers where there is insufficient depth of soil to filter the pollutants before entering the groundwater. These can include karst, fissured, or cleft aquifers.
- Over fill soils that can become unstable when saturated.

Should any of these conditions apply, an alternative design may incorporate "no infiltration" by using an impermeable liner to capture, store, and release runoff from the base.

Other considerations:

- Total catchment area draining into the permeable pavement cannot be greater than 15 acres.
- The pavement should be upslope from building foundations, and the foundations should have piped drainage at the footers.
- Land surrounding and draining into the pavement cannot exceed 20 percent slope.

Design Criteria

A qualified and experienced geotechnical or civil engineer must complete the design of a PICP project. Zollinger et al (1998) and ICPI Tech Spec No. 4, Structural Design of Interlocking Concrete Pavement for Roads and Parking Lots provide detailed information on designing PICP. Dr. Shackel developed the Lockpave Pro computer program to assist in the structural design of interlocking concrete block pavements for a variety of applications. The structural design aspects of PICP are included in the program, as well as a hydraulic design program based on SWMM, the EPA's Stormwater Management Model.

Key performance factors include:

- Width of joints (0.08 - 0.12 in) between blocks and proper placement of the jointing sand.
- Use of edge restraints to facilitate development of shear between concrete blocks
- Minimal roughness in the initial construction of the longitudinal profile.
- Uniformity of the bedding layer (maintaining a thickness of 1-1.5 in) and proper compaction of pavers. Improperly designed and placed bedded layers may result in premature rutting.
- Quality of materials (gradation, shape, etc.) should be as uniform as possible.
- Incorporate into design the proper balance between void ratio and gradation limits, and material stability and strength to simultaneously meet both the drainage and structural requirements of the design.

Pavement cross-section design options (Figures 4 through 8):

- Full or partial infiltration – A design for full infiltration uses an open-graded base with aggregate-filled joints for maximum infiltration and storage of stormwater. The water infiltrates directly into the base and through the soil. Pipes provide drainage in overflow conditions. Partial infiltration does not rely completely on infiltration through the soil to dispose all of the captured runoff. Some of the water may infiltrate into the soil and the remainder drained by pipes. Excess water is drained from the base by pipes to additional treatment, storm sewers, or natural receiving waters.

- No infiltration – No infiltration is desirable when the soil has low permeability and low strength, or there are other site limitations. An impermeable layer may be used if the pollutant loads are expected to exceed the capacity of the soil and base to treat them. A liner may also be used if the depth to bedrock or to the water table is only a few feet (3 ft). By storing water for a time in the base and then slowly releasing it through pipes, the design behaves like an underground detention pond. In other cases, the soil of the sub-base may be stabilized to render improved support for vehicular loads. This practice reduces infiltration into the soil to nearly zero. The "no infiltration" option requires the use of geotextile and bedding between the pavers and the open-graded base.

- A common error in designing PICP is assuming that the amount or percent of open surface is equal to the percentage of perviousness. The perviousness and amount of infiltration is dependent on the infiltration rate of the joint filling material, bedding layer, and base materials, not the percentage of the open-surface area. A key consideration is the design permeability of the entire pavement cross section, including the soil subgrade. Because of short-term variations in antecedent conditions and long-term reduction in infiltration capacity, a long-term infiltration rate of 10 percent of the initial rate should be used in design.

Site design data:

- Rainfall and traffic data design – The following data will be necessary for designing the pavement:

    1. The total area and percent of impervious surface draining into the permeable pavement.

    2. Design storm – This will vary depending on the project-specific objectives for pretreatment, stormwater volume detention, and/or infiltration.

    3. Keeping management objectives in mind, calculations of the volume of runoff or peak flow to be captured, exfiltrated, or released using the design storm.

4. An estimate of vehicular traffic loads expressed as 18,000 kip (80 kN) equivalent single axle loads (ESALs) over the design life of the pavement, typically 20 years.

- Soil subgrade sampling and analysis:

  1. An experienced civil or geotechnical engineer familiar with local site conditions and stormwater management should be sought to confirm the suitability of soil characteristics and possible treatments for use under all PICP. Evidence of a high water table, impermeable soil layers, rock, or dissimilar layers may preclude the use of full or partial infiltration.

  2. Determine the permeability or k value of the soil. The lowest tested acceptable k value for considering infiltration of water through soils subject to vehicular traffic is 0.14 inch/hour. Typical characteristics of selected soil types are shown in Table 1.

  3. To maximize infiltration, the subgrade should have less than 5% passing the No. 200 sieve, although soils up to 25% passing may drain adequately depending on site conditions and specific characteristics. Soil stability for traffic should be carefully reviewed for each application by a qualified geotechnical or civil engineer.

- Filters and geotextiles. Fine particles suspended in slowly moving water will be deposited in the pores of the next material, which can be another soil, aggregate, or geotextile. The build-up of fines eventually clogs and reduces permeability of these materials. To reduce this action, filter criteria must be met whenever there is a change in materials. While aggregate materials are used for filters, the use of geotextiles is more common and is recommended. Geotextile filter criteria can be obtained in AASHTO specifications.

- Materials for the base, bedding, and openings. The following data are required:

  1. Sieve analysis of crushed stone base, leveling course, and bedded sand (if used). The open-graded base should be composed of crushed stone that is hard, durable rock with 90 percent fractured faces, an LA abrasion of <40, an effective porosity of 0.32, and a design CBR of at least 80 percent. ASTM No. 57 is recommended. The leveling/ choke course should be composed of ASTM No. 8 crushed stone. This layer should have a thickness of 3 inches and should be made of hard material having 90 percent fractured faces, an LA abrasion <40, a CBR greater than 80 percent, and permeability of 1,000 inches/hour. The filter criteria for choke stone is: $D_{15\,base} / D_{50\,choke} < 5$, and $D_{50\,base} / D_{50\,choke} > 2$. No. 8 crushed stone is also recommended for the fill material in the openings. ASTM C33 or CSA A23.1 bedding sand, when used, should conform to he grading requirements of ASTM C33 or CSA A23.1. The sand should

Table 1 Stability of soils (per Unified Soils Classification) for infiltration of stormwater and bearing capacity.

USCS Soil Classification	Typical ranges for permeability coefficient, k (in/hr)	Relative permeability when compacted	Shearing strength when compacted and saturated	Compressibility	Typical CBR Range
GW (well graded gravels)	1.3 to 137	Pervious	Excellent	Negligible	30-80
GP (poorly graded gravels)	6.8 to 137	Very pervious	Good	Negligible	20-60
GM (silty gravels)	1.3×10^{-4} to 13.5	Semi-pervious to impervious	Good	Negligible	20-60
GC (clayey gravel)	1.3×10^{-4} to 1.3×10^{-2}	Impervious	Good to fair	Very low	20-40
SW (well-graded sands)	0.7 to 68	Pervious	Excellent	Negligible	10-40
SP (poorly graded sands)	0.07 to 0.7	Pervious to semi-pervious	Good	Very low	10-40
SM (silty sands)	1.3×10^{-4} to 0.7	Semi-pervious to impervious	Good	Low	10-40
SC (clayey sands	1.3×10^{-5} to 0.7	Impervious	Good to fair	Low	5-20
ML (inorganic silts of low plasticity)	1.3×10^{-5} to 0.07	Impervious	Fair	Medium	2-15
CL (inorganic clays of low permeability)	1.3×10^{-5} to 1.3×10^{-3}	Impervious	Fair	Medium	2-5
OL (organic silts of low plasticity)	1.3×10^{-5} to 1.3×10^{-2}	Impervious	Poor	Medium	2-5
MH (inorganic silts of high plasticity)	1.3×10^{-6} to 1.3×10^{-5}	Very impervious	Fair to poor	High	2-10
CH (inorganic clays of high plasticity)	1.3×10^{-7} to 1.3×10^{-5}	Very impervious	Poor	High	2-5
OH (organic clays of high plasticity)	Not appropriate under PICP	Not appropriate under PICP	Not appropriate under PICP	Not appropriate under PICP	Not appropriate under PICP
PT (Peat, mulch, soils with high organic content)	Not appropriate under PICP	Not appropriate under PICP	Not appropriate under PICP	Not appropriate under PICP	Not appropriate under PICP

Source: Asphalt Institute (1993), Barksdale (1991), Rollings and Rollings (1993), and Cao et al (1998).

be washed, and no material should pass the No. 200 sieve. Limestone screenings and stone dust cannot be used. The permeability of the bedding sand is approximately 1.4 inch/hour.

2. Void space in percent for the open-graded base. The storage capacity should be between 20 to 40 percent.

- Concrete materials for permeable pavement. The PICP units must have a minimum thickness of 3 1/8 inch (80 mm) and test results indicating conformance to ASTM C 936, Standard Specification for Solid Interlocking Concrete Paving Units.

Sizing an open-graded base for stormwater infiltration and/or storage. Methods for sizing the open-graded base can be borrowed from design methods for BMP T5.20 Infiltration Trenches.

Sizing an open-graded base thickness for traffic loads. Table 2 provides information on recommended base thicknesses, assuming that the strength of the soil subgrade is at least 5 percent soaked CBR. All thicknesses are after compaction and apply to all infiltration conditions. Greater thicknesses may be required in soils subject to frost heaving. Pedestrian applications should use a minimum base thickness of 6 inches.

Table 2. Recommended minimum open-graded base thicknesses for PICP in inches.

	Soaked CBR of Subgrade Soil		
ESALs*	> 15 years	10 to 14 years	5 to 9 years
50,000	6	8	10
150,000	8	10	12
600,000	10	12	14

*ESALs = 18 kip equivalent single axle loads.

Other Design Considerations

Inflow and outflow calculations:

- The sources of pavement infiltrating water are rainfall, groundwater, melting ice, and snow. Infiltration of rainfall (the primary concern) depends on five factors: slope of the pavement, the rate at which water is applied to the pavement surface, permeability and overall drainage capability of the underlying layers, the materials used to fill the drainage voids in the pavement surface, and antecedent conditions.

- Once the infiltration rate has been estimated, the inflow of water entering the pavement can be determined using Darcy's Law (described in 5.1.8).

- Outflow occurs from surface evaporation, removal by subgrade percolation (dependent on permeability of soils), and removal by a subsurface drainage system (dependent on installation of a lateral drain and system of collection pipes).

- Inflow and outflow can be estimated using the US Army Corps of Engineers DRAIN program. This can be downloaded from the Internet site http://www.pcase.com. This program was written to design open-graded bases for subsurface drainage under conventional pavements. The formulas are useful for permeable pavement bases as well, especially for conducting sensitivity analysis under various permeability and rainfall scenarios.

- The hydrological performance of PICP should be factored into managing runoff within a larger catchment or watershed. As previously mentioned, Dr. Shackel's Lockpave Pro software includes a hydraulic design program based on SWMM, titled PC-SWMM for Permeable Pavements. PC-SWMM provides a step by step accounting (conservation of mass) of water movement through the permeable pavement installation, including surface detention, overland flow, infiltration, subsurface storage, and subsurface drainage.

- More sophisticated methods for calculating infiltration and exfiltration with a free-draining base or partial exfiltration by drainage pipes, and no infiltration with an impermeable liner and drainpipes are listed in the reference section.

Runoff volumes. A surface drainage system should be designed to remove surface water within certain time limits and physical constraints. The rate of runoff is influenced by the intensity and duration of rainfall, the type and moisture condition of the base and soil at the time of rainfall, the slope of the surface, the permeability of fill material in drainage voids on the pavement surface, and the drainage voids in the pavement surface itself. There are several methods available for calculating the runoff (peak runoff rate), such as the rational method or the SCS curve number method. Acceptable methods for calculating runoff volumes are discussed in Volume III of the Stormwater Manual.

Protection against flooding from extreme storm events: Drainage pipes should be built into the open-graded base to handle overflow conditions from extreme rainfall. An added measure of protection could include an overflow area or drainage swale designed to handle overflows from an adjacent pervious parking lot.

Design for water quality: The type of soil subgrade affects the pollution reduction capabilities of infiltration areas. Unfortunately, many clay soils that are effective pollutant filters do not have sufficiently high infiltration rates or bearing capacity when saturated, and cannot be used under infiltration areas subject to vehicular loads. However, a layer of sand could be placed under the open-graded base to filter and treat pollutants prior to their release into a stream or storm sewer. This would be especially effective with soils that have little treatment capacity. A sand filtering system could also be implemented for filtering runoff from adjacent impervious surfaces.

Collection system:

- A collection system is necessary for collecting water from the drainage layer and conveying it to suitable outlets for further treatment or release. Factors in designing the collection system include the collection system drainage capacity, the location and depth of the collectors and their outlets, the type of collection system to be utilized, and filter protection to provide sufficient drainage capacity and to prevent flushing of the drainage aggregate into the collection system.

- Types of edge drains include the traditional perforated or slotted pipe underdrains, prefabricated geocomposite fin drains, geotextile-wrapped underdrains, and geotextile-socked perforated pipes (Figure 9).

- The selection of the type of collection system depends on soil conditions at the site, the function of the collection system (i.e., to be temporary storage or to be a medium for water to pass through), construction feasibility, and economic considerations. Local geotextile suppliers can provide more information on subdrainage designs.

Permanent deformation characterization and prediction: Zollinger et al. (1998) provide information and graphics based on the results of the FLEXPASS model developed at Texas A & M University.

Construction Guidelines

Experienced contractors who hold a current Basic Level Certificate in the ICPI Contractor Certification Program must perform installation. Contractors holding this certification have been instructed and tested on knowledge of interlocking concrete pavement construction. Construction guidelines are provided in ICPI Tech Spec 2, Construction of Interlocking Concrete Pavements, ICPI Tech Spec No. 9, Guide Specification for the Construction of Interlocking Concrete Pavement, ICPI Tech Spec 10, Application Guide for Interlocking Concrete Pavements, and Zollinger et al. (1998).

PICP typically consists of a soil subgrade, an aggregate base, bedding sand, concrete pavers, edge restraints, and drainage. Geotextiles are sometimes used under the base, over fine, moist subgrade soils to extend the life of the base and reduce the likelihood of deformation.

Reducing clogging. *Preventing and diverting sediment from entering the base and pavement surface during construction must be the highest priority.* Preventing muddy construction equipment from entering the area, installing silt fences, and using temporary drainage swales to divert runoff away from the site make a significant difference in keeping the pavement infiltrating well. Practices intended to prevent clogging should be included in the construction drawings and specifications.

Pedestrian and vehicular circulation. Existing pedestrian paths should be studied and defined before a parking lot or plaza is constructed. Vehicle lands, parking spaces, and pedestrian paths as well as spaces for handicapped persons can be delineated with solid concrete pavers.

Soils, geotextile and drain pipes:

- Prior to placing the base, the soil subgrade should be compacted to at least 95 percent of standard Proctor density (per ASTM D 698) for pedestrian areas and to a minimum of 95 percent modified Proctor density (per ASTM D 1557) for vehicular applications. Compaction will reduce infiltration rates but is necessary in most applications for increased structural stability. Some soils may not achieve these recommended minimum levels of density. These soils may have a low bearing capacity or be continually wet. If they are under a base that will receive constant vehicular traffic, the soils may need to be stabilized or have drainage designed to remove excess water.

- Geotextiles are used in all permeable pavement applications. Specifications and minimum physical requirements for geotextiles suited to separation and drainage can be found in the reference section. For vehicular applications, high-quality fabric should be specified that resists the puncturing by coarse, angular aggregate from compaction during construction and from repeated wheel loads during its service life.

- Bases should have their sides and bottoms wrapped in geotextile. For open-graded bases, there should be a 12-inch length placed over the compacted No. 8 aggregate along the perimeter. Geotextile should be used between bedding sand and the No. 8 aggregate base to prevent loss of bedding sand into the surface of the larger No. 8 material.

- Designs using full infiltration should have pipes to handle emergency overflow conditions. Partial or no infiltration designs require pipes to handle storage and outflow from design storms and those from overflow conditions.

Open-graded aggregate bases:

- A test section is required for monitoring the aggregate during compaction to determine the settlement of the pavement section. After application of the geotextile, No. 57 base material should be spread in 4- to 6-inch lifts and compacted with a vibratory roller at approximately 1,200 times per minute. At least 4 passes should be made with a minimum 10-ton steel drum roller. The crushed stone should be kept moist during compaction, but water should be kept from wetting the soil subgrade.

- When the base has been compacted, a 3-inch thick layer of leveling course (moist No. 8 crushed stone) is applied to the top surface and pressed into the top of the

No. 57 with at least 4 passes of a 10 ton vibratory roller. The No. 8 should be moist in order to facilitate movement into the No. 57.

- After the No. 8 is compacted a 3/4 to 1-in thick layer is loosened evenly across its surface. The pavers are placed on this loosened layer and compacted with a plate compactor. For concrete units 3 1/8 to 4-inch thick, the plate compactor should exert a minimum 5,000 lbf at 75 to 90 Hz. For thicker concrete units, the compactor should exert at least 6,800 lbf.

- The joints or openings are filled with No. 8 material and the paving units are compacted again. Excess stone is removed by sweeping.

- The concrete pavers should be applied immediately after the base and leveling layers have been placed in order to prevent or reduce the chance of construction equipment passing over the base and contaminating it with sediment. Equipment drivers should avoid rapid acceleration, hard braking, or sharp turning on the compacted drainage layer.

Stabilized bases:

- Open-graded bases may be stabilized with asphalt prior to placement. It should be used on the No. 57 layer and not on the No. 8 layer. The use of asphalt will likely reduce the storage capacity of the base, but stabilization may be necessary in weak soils—those subject to frost heave or under high loads.

- To maintain high void space, only enough asphalt to coat the aggregate is required. This is usually 2 to 2 1/2 percent asphalt by weight of the aggregate. The asphalt grade should be AC20 or higher.

- Asphalt-stabilized base will need to be compacted at temperatures lower than normal for asphalt pavement. In most cases, the asphalt should cool to less than 200° F before starting compaction.

Edge restraints: ICPI Tech Spec 3, Edge Restraints for Interlocking Concrete Pavements provides guidance on selection of edge restraints for pavement construction with dense-bases. Recommended edge restraints for permeable interlocking concrete pavements on an open-graded base are cast-in-place and precast concrete. Manufacturers of edge restraints fastened by metal spikes should be consulted as to the suitability of their edge restraint systems on open-graded bases subject to pedestrian or vehicular traffic.

Bedding sand: As with all interlocking pavements, the gradation of the bedding sand should conform to ASTM C 33 or CSA A23.1. Gradations for these are given in the guide specification at the end of this bulletin. As previously mentioned, limestone screenings or stone dust must never be used. The thickness of the bedding sand should be between 1 and 1 1/2 inches and screeded to a consistent thickness.

Paver installation:

- PICP concrete pavers are typically installed level to maximize infiltration. Installation can be done by hand or with mechanical equipment. Mechanized installation may be a cost-efficient means to install the units and will reduce the installation time. ICPI Tech Spec 11, Mechanized Installation of Interlocking Concrete Pavements provides detailed information on mechanical installation.

- Like solid pavers, permeable pavers are vibrated into the bedded material with a high-frequency (75-90 Hz), low-amplitude plate compactor. The machine should have a minimum centrifugal compaction force of at least 5,000 lbf for settling units 3 1/8 to 4 inches thick. Thicker units will require equipment capable of at least 6,800 lbf. Units should be cut to fill any spaces along the edges prior to compaction. All installed units should be compacted into the bedding sand or No. 8 aggregate and joints filled with the appropriate material at the end of the day.

- The pavers are again compacted.

Maintenance

Infiltration areas can become clogged with sediment over time, thereby decreasing storage capacity and slowing their infiltration rate. The rate of sedimentation depends on the amount of traffic and other sources that wash sediment into the joints, base, and soil. Since the pavement is detaining runoff with sediments, there may be a need to remove and replace the base material when the infiltration is reduced to where the pavement is no longer performing its job in storing and exfiltrating water.

Economics may prevent this extent of hydrological rehabilitation to the pavement. The best way to ensure enduring infiltration is to prevent sediment from entering the pavement. A well-designed and maintained pavement can be expected to last from 15 to 25 years. Depending on drainage performance, the base may need to be excavated, sediment removed, and clean aggregate reinstated with the same concrete pavers.

The lifetime of the pavement can be extended by pre-treating runoff that originates off site, such as runoff originating from adjacent impervious surfaces. Filter areas or small basins used to capture sediment in urban runoff will reduce the potential for clogging of the PICP. They will also substantially extend the number of years before removal and replacement with clean sand and aggregate are necessary. The length of years added to the infiltrative performance of the pavement may be worth the additional space and initial expenditure.

Permeability has been successfully restored in some PICP projects using conventional street-sweeper equipment with vacuums, water, and brushes.

All PICP should have an observation well to monitor the amount of sediment in the water held in the base. The well is typically a 4- to 6-inch diameter capped pipe that can be uncovered and water samples drawn from time to time.

Snow can be plowed from pavers as with as other pavement. If a unit cracks from soil or base settlement, it should be removed and replaced. Likewise, the same units can be reinstated after repairs to the base, drainpipes, liners, or to underground utilities.

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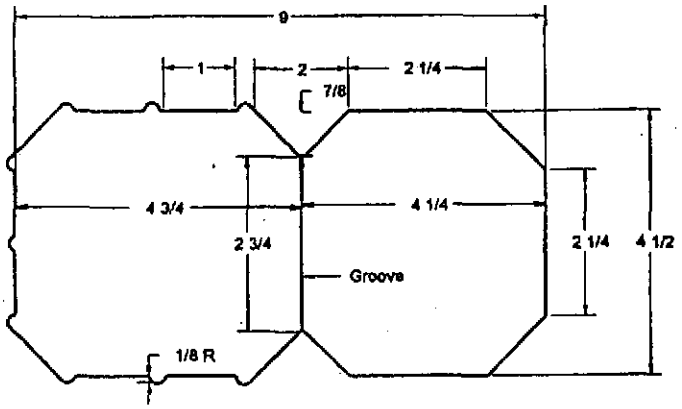
Figures

A.



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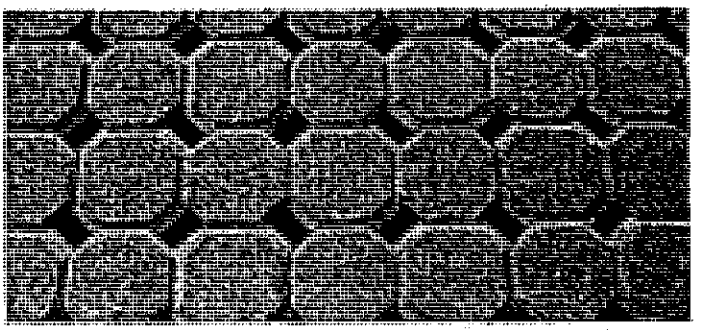

Figures 1A and 1B Example of permeable interlocking porous pavement.

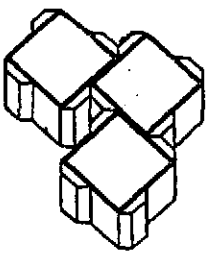

Figure 2 Cross-section drawing of permeable interlocking porous pavement.

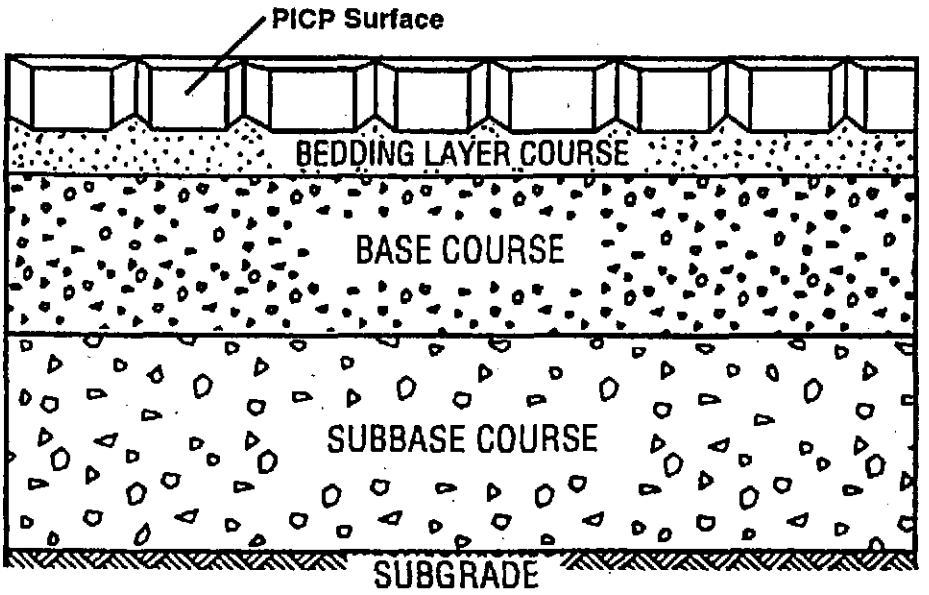

Figure 3 Components of a permeable interlocking concrete pavement.

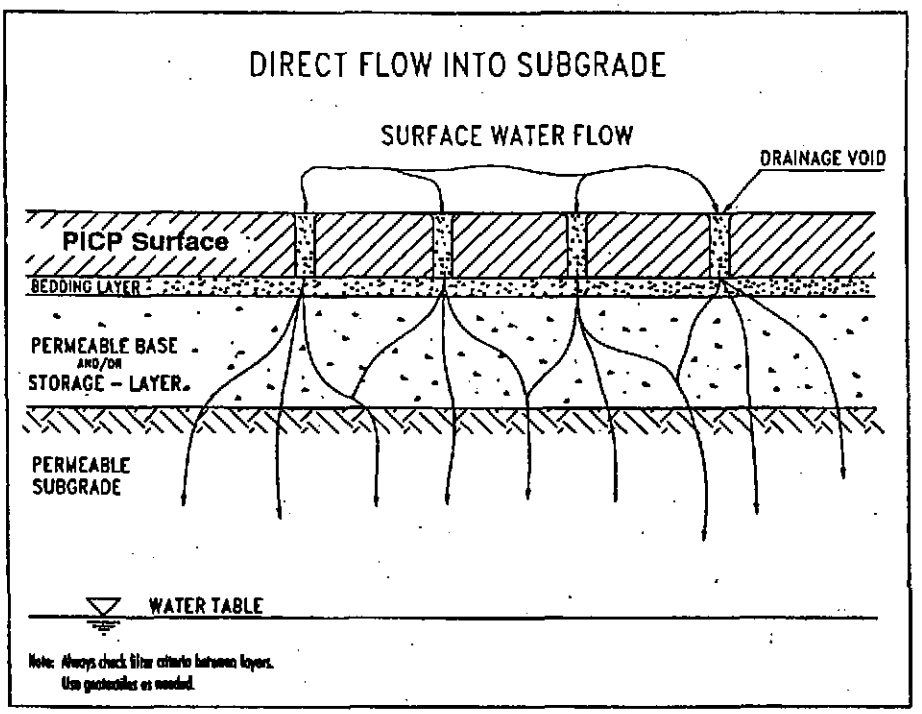

Figure 4 Sample cross-section design drawings.

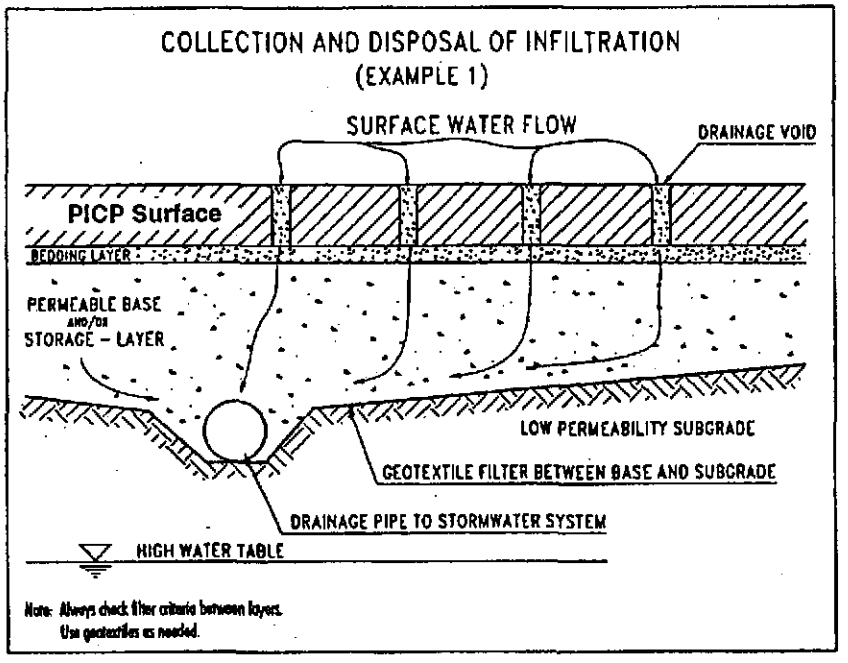

Figure 5 **Sample cross-section design drawings.**

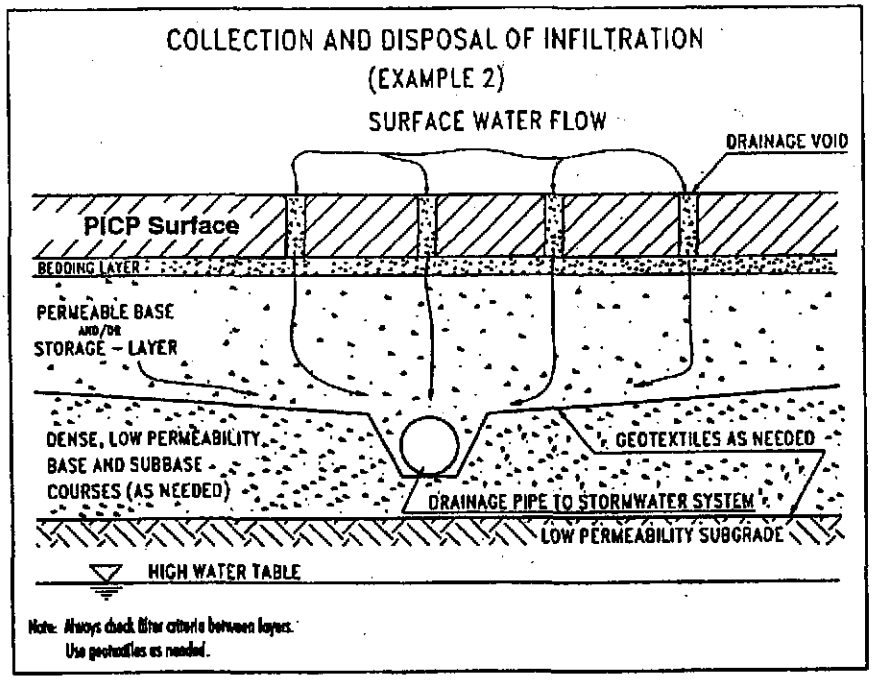

Figure 6 **Sample cross-section design drawings.**

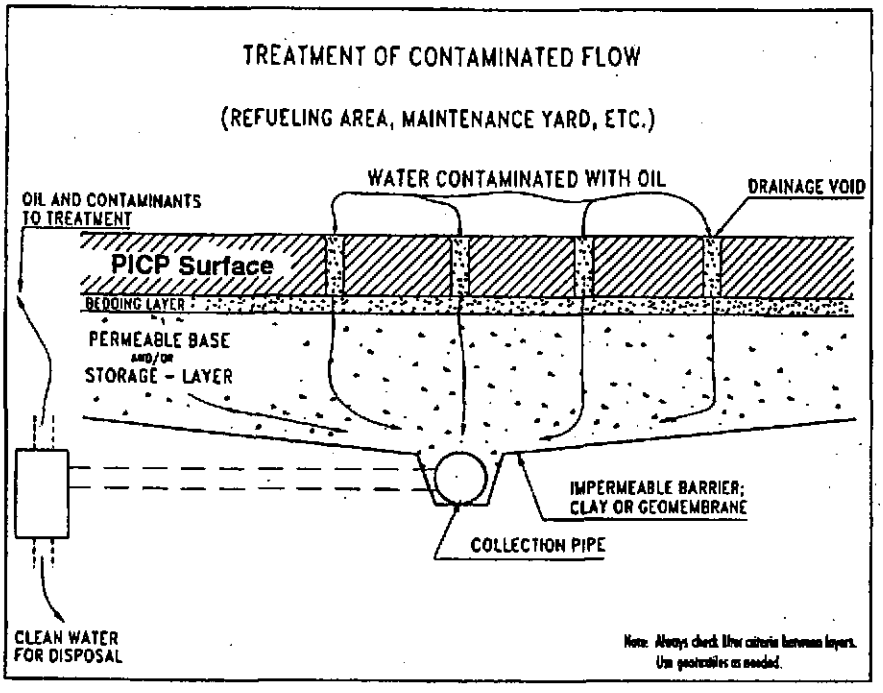

Figure 7 Sample cross-section design drawings.

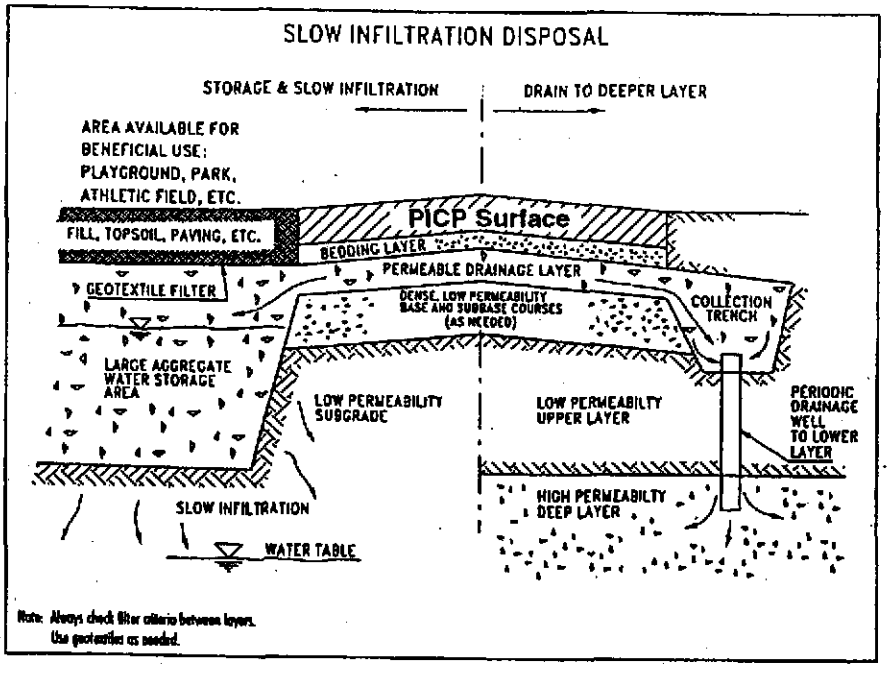

Figure 8 Sample cross-section design drawings.

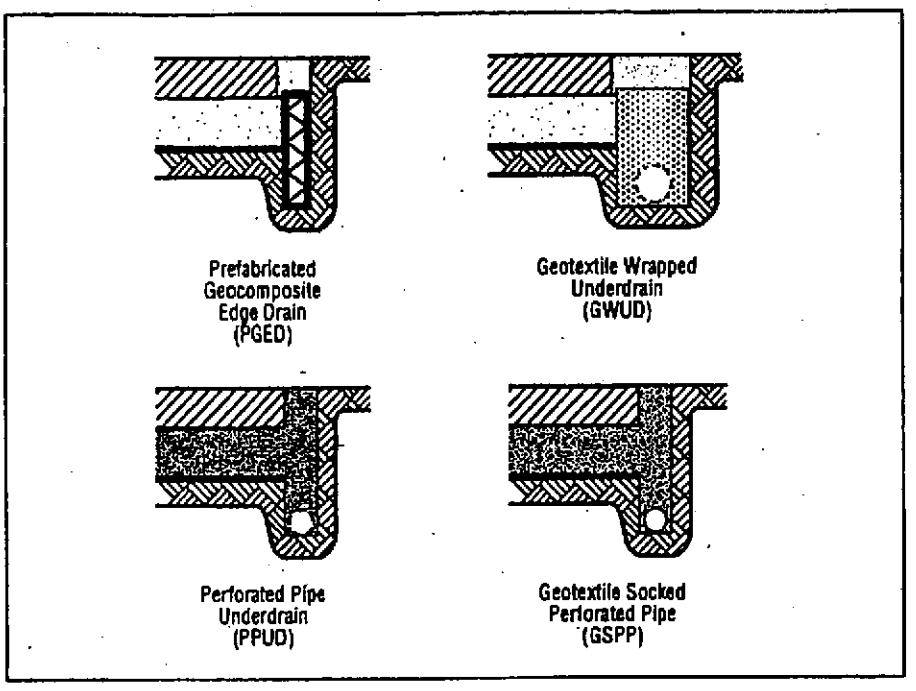

Figure 9 Various types of subdrainage systems using geotextiles.

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Item #	Description	Price	Qty
13406	Pole-Top Mount 2 G51	$95.00	0
41468	M3 Agricultural Pump	$995.00	0

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Comparison Table(s):
M3 Agricultural Pump Performance Chart

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M3 Agricultural Pump Performance Chart

	Meters Lift (feet)	1-75W LIters/Min (gpm)	Approx. daily output in gpm	2-50W Liters/Min	Approx daily output in gpm
1	(3.3)	22.7 (6.0)	1,500	31.8 (8.4)	2,100
2	(6.6)	21.5 (5.7)	1,400	28.6 (7.6)	1,900
3	(9.8)	20.0 (5.3)	1,300	25.4 (6.7)	1,700
4	(13.1)	16.7 (4.4)	1,200	22.0 (5.8)	1,450
5	(16.4)	13.6 (3.6)	1,100	18.3 (4.8)	1,250
6	(19.7)	11.4 (3.0)	900	13.9 (3.7)	950
7	(23.0)	7.6 (2.0)	600	9.9 (2.6)	650

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SOLARPAL®

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  100% Powered by the Sun
- **Unsurpassed Reliability**
  Sold worldwide - with no outstanding warranty claims
- **Unsurpassed Durability**
  Patented design gives the most resistance to wind possible. **Survived hurricanes.**
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  So safe they can be shipped fully charged
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  The **only** UL® listed solar light
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- **Will light even after cloudy days**
  No maintenance battery back-up
- **Meets IES Standards**
  Uses high frequency fired fluorescents with super efficient reflector or low pressure sodium lamps
-

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Environmentally Friendly
Every two solar panels save 800 KWH/year, eliminating over 1000 lbs. of pollution

- **Self-Contained System**
  No wiring! **No** delays!
  No trenches through existing roads, sidewalks or landscaping
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  No electric bill

Twenty one days before opening day, the Atlanta Committee for the Olympic Games (ACOG) ordered 64 lights from Solar Outdoor Lighting, Inc. to illuminate 8 parking lots covering 8,000 parking spaces, comprising over 2 million square feet.

"We asked Solar Outdoor Lighting to do the impossible - to install these lights in 21 days and have them lit for opening day. SOL® did it with their SolarPal® wireless lights which have worked beautifully throughout. No one else could have done this job. SOL® crews did a fantastic job and SOL® kept every promise."

Hank Padgham
Assoc. Director, ACOG Transportation Dept., 1996 Olympic Games in Atlanta
(Press Release)

GENERAL DESCRIPTION

The patented SolarPal® Safety Streetlight is a commercial quality, solar powered lighting system for residential streets, parking lots and area security lighting. Used by city park departments, homeowner's associations, colleges and the military, it is also effective for any "dark spot" - rural areas, farms, or storage facilities.

SYSTEM OPERATION

Solar panels absorb the sun's rays, even on overcast days, converting them to electricity. The electricity is stored in batteries. A small proprietary microprocessor controls the functions of the system; it acts as a photocell, turning the light on at dusk; it is a timer, regulating the hours the light stays on; it regulates the battery, preventing overcharging and protecting against discharging. The system will operate for at least 5 consecutive days without sunlight.

Technical Specifications

TESTING, QUALITY CONTROL, AND WARRANTY

All products are tested in the Solar Outdoor Lighting research facility before delivery. Furthermore, field tests have been performed by universities, Underwriters Laboratory, and by United States National Laboratories. All of these inspections assure customers they are buying the most reliable commercial solar lighting produced. The warranty, including a 20 year solar panel power guarantee by Solarex®, is the strongest in the industry. *SOL, where Safety Goes In Before the Name Goes On.*

SIMPLE PAYBACK ANALYSIS

How long will it take to recoup your investment in solar-powered technology? Here are some points to consider when comparing to the traditional electric

lighting system:

1. Cost to run wire from grid.
2. Cost of street and sidewalk paving to be torn up or tunneled under.
3. Cost of street and sidewalk and landscaping to be replaced.
4. Cost of transformers to be added.
5. Savings from credits for state and federal taxes.
6. Lowest operating cost.

Technical Drawings

EPA GREEN LIGHTS ALLY
SOL® is an appointed member of the Environmental Protection Agency Green Lights program.

A model SL 120, double units totaling ten were chosen for the parking and entrance road to the Federal Building in St. Croix, U.S. Virgin Islands. A flat panel model was selected with a cobrahead fixture and dome lens. The lights were ordered by the General Services Administration and are the same style as used by GSA in Puerto Rico, Hawaii and Atlanta.

To find out more about **Solar Outdoor Lighting** Products and how you can benefit, please use the **Request Information Button**.

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APPLIED POWER CORPORATION

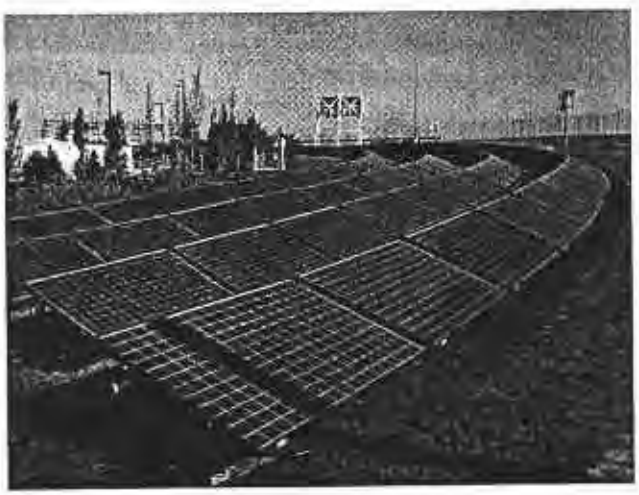
Project Qualifications and Experience
Grid Connected Power Systems

Applied Power is one of the largest and most experienced "systems integrators" in the PV industry, having supplied and installed thousands of photovoltaic power systems operating reliably in the U.S. and around the world.

1. Project Experience

Applied Power's team includes some of the most experienced personnel in the photovoltaic industry. Our engineers have first hand experience installing and maintaining photovoltaic systems. Applied Power's technical capabilities and superior designs have given us a reputation for cost-effective and reliable systems work that is unsurpassed in the industry. Applied Power has installed over 2 megawatts of grid connected photovoltaic systems for the US Government, utilities, and other commercial clients. Applied Power has more experience with the design and integration of grid interconnected systems than any other firm in the United States.

100 kW Grid Connected System at Bentley Mills



30 kW System at the Pentagon, Washington DC

APC has successfully completed projects with costs exceeding $4M and array capacities to 140 kW peak. These projects span a wide range of applications from a weather station in Antarctica, to mountaintop microwave repeaters in Utah, to water pumping systems in the Sahara Desert. The ability to manage projects over such a broad range of locales requires thorough understanding of technical and schedule risks, superior logistical planning, and careful attention to details. These qualities have given APC one of the most successful project records in the business.

2. Engineering and Construction

Applied Power has engineered and constructed some of the most sophisticated projects in the industry. Our engineering abilities draw on years of experience and familiarity with critical component technologies. At the core of all Applied Power designs is a commitment to quality, reliability and ruggedness to meet the "real world" conditions.

The ability to design a quality system is not sufficient, however. Applied Power has also demonstrated outstanding skills in construction management, with a well-established reputation for on time installation and commissioning. This includes a concern for the environmental impact on the site and a strict adherence to safety standards. Applied Power projects are done on time, not because they cut corners, but because they are done right.

3. Utility Project Experience

Applied Power has worked with numerous utility customers and is dedicated to successful partnerships with utility clients. Our satisfied customers for photovoltaic power systems include the following electric power companies:

- Pacific Gas and Electric
- Southern California Edison
- Los Angeles Dept of Water and Power
- PacifiCorp
- Hawaiian Electric Company
- Idaho Power Company
- Nevada Power Company
- Arizona Public Service Company
- Arizona Electric Power Cooperative
- Utah Power and Light
- Public Service Company of Colorado
- Public Service Company of Oklahoma
- Central and Southwest Corporation
- West Texas Utilities
- Central Power and Light
- Houston Power and Light
- Northern States Power
- Wisconsin Public Service
- Duke Power Company
- The Southern Company
- Alabama Power Company
- Florida Power Company
- Reedy Creek Power Company (Disney World)
- General Public Utilities
- Consolidated Edison Company
- New York State Electric and Gas
- Northeast Utilities
- New England Electric System
- Massachusetts Electric Company
- Narragansett Electric Company
- Granite State Electric Company
- Boston Edison Company
- Bonneville Power Administration
- Colton Electric Utility

4. Key Personnel

Applied Power's team includes some of the most experienced personnel in the photovoltaic industry. Our staff has unparalleled experience in system design, materials supply and installation. Below are some of the key personnel responsible for the success of these projects.

Edward C. Kern, Jr.: (Program Director) Dr. Kern has over twenty-two years experience working with photovoltaic systems and their interconnection to electric power systems. He is president of Ascension Technology, Inc. Before founding Ascension Technology, he was a member of the Massachusetts Institute of Technology faculty and research staff. He joined the MIT Lincoln Laboratory Photovoltaic Field-Tests and Applications Project in 1977 and was promoted to Assistant Group Leader in 1980. Beginning In 1979 he planned and then managed the U.S. Department of Energy's Residential Photovoltaic Systems Project. He currently is a MIT Research Affiliate serving as an advisor to the MIT Analysis Group for Regional Electricity Alternatives.

Dr. Kern is a graduate of the Thayer School of Engineering at Dartmouth College and received his Ph.D. from the Massachusetts Institute of Technology.

Michael Daugherty: (Director of Projects) Mr. Daugherty has over nine years of experience in the photovoltaic industry, including responsibilities as a product designer, program manager, project manager and consultant. He has a broad background in project engineering, system integration, and system sizing and training. His work also includes the development of software, algorithms and controls for photovoltaic systems. Mr. Daugherty holds a Bachelor of Science degree in Mathematics.

Miles C. Russell: (Senior Engineer) Mr. Russell has managed the design and installation of over 1 megawatt (ac) of grid-tied, roof-mounted PV systems for projects with the U.S. Environmental Protection Agency and electric utilities through the United States. Mr. Russell is secretary of the IEEE Utility Working Group of Standards Coordinating Council 21, on Photovoltaics, which is re-writing IEEE 929, Recommended Practice for Utility Interface of Photovoltaic (PV) Systems. He is also an elected member of the NFPA CMP-3 Task Group on Article 690 of the NEC. Mr. Russell is a 1976 mechanical engineering honors graduate of Purdue University and holds a Masters degree in mechanical engineering from Stanford University.

James M. Bing: (Manager of Projects and Instrumentation) Mr. Bing is a registered Professional Electrical Engineer. He has nine years of experience in electrical engineering in instrumentation and photovoltaic system design and installation. Prior to becoming an electrical engineer, Mr. Bing was a licensed electrician in the commercial construction industry for approximately ten years. Mr. Bing holds a bachelor's degree in electrical engineering from the University of Massachusetts, Lowell, as well as a bachelor's degree in anthropology from the University of California, Berkeley.

Mike McGoey: (Sr. Field Engineer) Mr. McGoey has 12 years experience as a photovoltaic systems designer, photovoltaic installer, journeyman electrician and energy consultant and trainer. He has installed hundreds of PV systems in the Midwestern U.S. Mr. McGoey is an expert in the installation and commissioning of large PV arrays, circuit protection equipment and utility interactive inverters. He is EMT certified and has a perfect safety record for all work done under his supervision during more than 10 years of remote site installations.

Brad Bassett: (Product Engineer) Mr. Bassett has 15 years experience in designing and specifying photovoltaic systems. He has designed systems for water pumping, telecommunications, lighting, residential and other applications. Mr. Bassett has extensive experience in procuring and specifying a wide range of components, including modules and batteries. He has also provided training, documentation and drawings for photovoltaic systems.

Dale Myers: (Project Engineer) Mr. Myers has a Bachelor of Science Degree in Electrical Engineering. He has 6 years of experience as a field engineer and project engineer in the energy industry. He has served as project engineer for grid connected and hybrid PV applications.

5. Financial Strength

Applied Power is a subsidiary of IDACORP, a holding company for various energy related enterprises. The primary subsidiary is Idaho Power Company, a leading U.S. electrical utility with over $2.5 billion in assets and one of the first U.S. utility companies to offer solar electric service to its customers.

With this corporate backing, Applied Power has financial strength and credibility that few other solar equipment providers can match. Applied Power is able to obtain bonds and insurance for the large-scale construction projects. Applied Power is a reliable project partner that is dedicated to the success of the project.

6. Recent Project List

Applied Power has extensive experience with the design and installation of grid connected photovoltaic power systems. Few other U.S. companies offer as much experience with utility connected PV systems. The following list is just a short selection of some of the more recent projects completed by Applied Power.

GSA Suitland Federal Center (Scheduled Completion in Fall 2000): Design, procure, and install a 100 kW grid connected system at the GSA's Central Heating Plant. Project included remediation of an abandoned cooling pond for the array site. This project is considered one of the largest thin film projects in the United States. Applied Power furnished all materials included modules, inverter and support structure.

Bentley Mills 100 kW Grid Tie System: Design, procure, and install a 100 kW grid connected system at for a carpet manufacturing facility. This project is considered one of the largest commercially owned PV facilities in the United States. Applied Power supplied modules, inverter and a DAS for compliance with UPVG monitoring requirements.

City of Ashland Solar Pioneer Project: Design and install four grid connected systems on facilities within the City of Ashland. Project was done in conjunction with the City of Ashland, Bonneville Environmental Foundation, Bonneville Power Administration and other regional partners. Applied Power provided design, equipment and installation services in response to a demanding project schedule.

Colton Electric Utility Carport: Design and install a 22 kW carport system at the utility yard for the Colton Electric Utility. The system was designed to provide power to reduce afternoon peak demand and provide non-power benefits such as shading and site improvement. Applied Power furnished the design, materials and project management. Installation was coordinated with a local installer with some work supplied by the utility.

Carport System at City of Colton, CA

Pentagon Heating and Refrigeration Plant: Design and installation of a 30 kW PV array. One half of the array is comprised of state of the art SunSine 300 AC modules. The second half of the array is a conventional DC system employing two newly developed Trace Technologies 10 kW three phase inverters. The system includes a data acquisition system that provides real time power and energy data to a publicly viewed billboard.

Interface Flooring Grid Tie System: Design and supply of a 17 kW grid connected system for installation by the customer at their manufacturing facility. Energy from the system provides power to a carpet loom.

Nevada Power Company: Design, and supply a 20 kW grid connected system for installation by the utility. This project included a very aggressive materials schedule that was met by APC.

BJ's Wholesale: Design and provide installation assistance for a 50 kW system using thin film modules.

University of Texas Medical Center: Design and supply of a 25 kW roof mounted system. This project was accomplished on a short schedule to commission the system before a major international energy conference.

Additional project references are available upon request.

About Applied Power

Applied Power Corporation is North America's leading photovoltaic system supplier bringing clean energy to industry, businesses, utilities, homeowners, and government. We have installed thousands of photovoltaic power systems and have installations presently operating in more than 25 states. Applied Power provides a full range of services from design, consulting, manufacturing, installation supervision, complete turnkey packages, instrumentation, monitoring and evaluation services and educational displays.

During 1999, Applied Power was pleased to welcome the staff of Ascension Technology to our team. The acquisition of Ascension Technology brought together two of the outstanding grid connected suppliers in the nation. Ascension Technology is also the nation's premier data monitoring and evaluation specialists for PV systems and was selected by the Utility PhotoVoltaic Group to provide monitoring and evaluation services for all UPVG TEAM-UP installations.

As the largest independent system integrator in the country, Applied Power can offer the best technologies for innovative and dependable solar power systems. Applied Power's team includes some of the most experienced personnel in the photovoltaic industry. Our engineers have first hand experience installing and maintaining grid connected photovoltaic systems.

Applied Power has corporate headquarters in Lacey, Washington with additional offices in California, Colorado and Massachusetts. Applied Power is a subsidiary of IDACORP, an energy-focused holding company that includes Idaho Power Company (NYSE: IDA). News releases and other information about Applied Power Corporation are available on its Web site at www.appliedpower.com.

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Web: www.appliedpower.com

PV System Supplied and Installed by APPLIED POWER CORPORATION...

Ashland Solar Pioneer Program

New Southern Oregon Solar Electric Project Educates People, Generates Green Power

A new solar energy project in sunny southern Oregon promises to spread the message about converting sunlight into electricity--and to create green power as well. Thirty kilowatts of solar photovoltaic capacity are operating on four sites in Ashland, in what is thought to be the Northwest's largest grid-connected solar electric project.

An Ashland solar installation
Photo courtesy of Dick Wanderscheid, city of Ashland

Officially dedicated July 28, the Ashland Solar Pioneer Program involves a host of partners, including hundreds of local residents and businesses voluntarily paying higher electric bills to support the solar venture. The 30-KW installations cost about $290,000, or nearly $10 a watt, according to Ashland project manager Dick Wanderscheid. "This project is a model for other cities because it demonstrates, it educates and it allows the community to participate in clean, renewable energy," said Rachel Shimshak of Renewable Northwest Project. Shimshak also serves on the board of the Bonneville Environmental Foundation, one of the project participants. Others include RNP, the city of Ashland, Bonneville Power Administration, Avista Corp., the Oregon Office of Energy, **Applied Power Corporation**, consultants Tom Starrs and Doug Boleyn, the Oregon Shakespeare Festival and Southern Oregon University. "The idea was to start getting this technology up so people would see it and learn about it," said Wanderscheid--and that's already happening. "A lot more people know about solar electricity than they did when we started this thing," a trend likely to continue given the high-visibility solar locations at the Shakespeare Festival and the Ashland Civic Center.

Convergence of Interests

Ashland's solar initiative reflects a convergence of many interests. Angus Duncan of Bonneville Environmental Foundation described the venture as "not just a community, but a regional project." The Rogue River Valley city has a long history of aggressive energy conservation through its municipal electric utility, along with solar-access and net-metering rules. Ashland wanted to explore solar electric; a 1998 survey found that 68 percent of residents thought Ashland should develop solar power locally, Wanderscheid wrote last year in the *Ashland Daily Tidings*. City officials talked with Duncan, who was then with Columbia/Pacific Institute for Energy and the Environment. He subsequently joined Bonneville Environmental Foundation as executive director, and passed on the idea for the solar project to Renewable Northwest Project, which hired consultant Starrs. "Our contribution was technical expertise and project shepherding," said Shimshak. In July 1999, BEF announced it would provide Ashland up to $62,500 (on a 1:2 matching basis) for solar PV installations, as the foundation's first renewable energy grant. The Shakespeare Festival, Southern Oregon and the Ashland post office subsequently agreed to host systems, although the postal site was later omitted after its roof was deemed structurally insufficient to handle the added weight. "We're getting involved in Ashland's solar project because we think we need to set an example," Shakespeare Festival executive director Paul Nicholson said in a recent Northwest Power Planning Council newsletter. "We want our solar project to be very visible, with information provided to help stimulate discussion. It may pay for itself in the long term, but we're not doing it for financial gain. We see it as an investment in the community." In addition to the BEF grant and about $35,000 from the city, the Shakespeare Festival and Southern Oregon University contributed $15,000 apiece for

their 5-KW systems. Each will receive 25 cents per kilowatt-hour for the power their systems generate, until their investments are fully recouped--an estimated eight to 10 years hence, according to Wanderscheid.
BPA, he said, will pay up to $100,000 for 20 years' output from 15 KW of the city's 20-KW PV installations. This solar electricity will be added to Bonneville's environmentally preferred power portfolio. Avista Corp.--whose Avista Utilities supplies natural gas in the area--will pay close to $100,000, receiving a like amount in a state tax credit.
And as of mid-August 255 Ashland citizens and businesses had pledged to pay an extra $4 per month over two years to help fund the solar project, which will generate nearly $26,000, according to Wanderscheid.

Solar in Ashland
Photo courtesy of Dick Wanderscheid, city of Ashland

BEF's Duncan acknowledged solar electric is not cost-effective, at unsubsidized costs typically exceeding 25 cents per kilowatt-hour. But he noted PV does make economic sense beyond utility distribution lines, and "where people are willing to pay for them, in the same sense that people pay $150 for a pair of Air Jordan's where $25 tennis shoes would keep their feet out of the puddles. The argument in Ashland," according to Duncan, "is that folks are willing to pay for the solar energy if they value the environmental outcomes and the leadership position for their community . . . then by definition it's cost-effective in Ashland. I hope we start thinking about those values . . . not just what's the market price of the electronics." "Obviously we believe and hope solar power will become more cost-effective," Ashland Mayor Cathy Shaw told the *Daily Tidings*. "Part of that happening is more people investing in solar systems to bring the price down."

Four PV Systems

The PV systems are situated atop four local buildings: the festival's administration building, the university's library, the police station (15 KW) and the nearby City Council chambers (5 KW). Each separately metered system includes ASE modules and Trace inverters, installed by **Applied Power Corporation**. Based on solar resource data from nearby Medford, Duncan estimates that from spring through fall Ashland's systems should provide energy output similar to Boise, ID, and Burns, OR. Ashland's solar production, however, is expected to be substantially less than those locales in winter. At a projected capacity factor of around 20 percent, the 30-KW project could generate 52,000-plus kilowatt-hours annually--still considerably less than 1 percent of Ashland's total electric load. "Our program is aimed at educating Ashland's citizens and visitors about how this technology works and that is why a strong educational component and display will be developed at each site," Wanderscheid wrote in the *Daily Tidings*. An interactive kiosk in the city council chambers vestibule features real-time and cumulative solar energy output, a PV video, a kids' page and more, according to Wanderscheid. Other "not as fancy" kiosks will be established at the festival and the university library. The educational opportunities, meanwhile, extend to technicians: Shimshak reported that electricians who installed the PV systems liked the work and want to do more.
They may get the chance. Duncan expects at least one more large-scale solar electric installation in Ashland, at a remodeled federal fish and wildlife forensics lab. And a planned second phase of the Ashland project will promote PV systems atop local roofs, although Wanderscheid said the details are undetermined. "As much as I love Bonneville and Angus and environmentally preferred power, there is some value to buying green electrons from our customers," he said at an April energy services roundtable in Newport, OR. "That money stays in the community." Beyond Ashland, BEF has already awarded funding to Orcas Power & Light in Washington's San Juan Islands for another solar electric installation project. Other locales may follow. "We'll probably be looking for some other opportunities," said Duncan, "particularly out on the east side [of the Cascades]. There's less load but a lot more sun."--***Mark Ohrenschall***

GEOEXCHANGE

GEOEXCHANGE
GEOTHERMAL HEAT PUMP CONSORTIUM

SEARCH

ABOUT RESIDENTIAL COMMERCIAL MEMBERS NEWSROOM CONTACT

The FACTS

- GeoExchange is the most energy-efficient, environmentally clean, and cost-effective space conditioning system available, according to the Environmental Protection Agency.
- EPA found that geoexchange systems can reduce energy consumption--and corresponding emissions--by over 40% compared to air source heat pumps and by over 70% compared to electric resistance heating with standard air-conditioning equipment. Combining GeoExchange with other energy-efficient measures, such as window or insulation upgrades,

Commercial: Schools

how it works > case studies > brochures > schools

Download our HVAC Comparison Tool Software "Energy-Smart For Schools" -
This program has been zipped up. Please download, unzip and "run" on your computer. It may take a while to download.

GeoExchange and School Buildings

School systems face many concerns and challenges. Administrators face the problems of upgrading old schools and constructing new facilities that meet today's standards. And the way that school buildings are used has changed — from single-use facilities closed after classes are finished to year-round use with lots of evening and weekend activities.

The life-cycle cost of the heating and cooling system is an important economic consideration. Schools must plan for long-term efficiency to maximize their resources. GeoExchange systems have been repeatedly shown to have competitive initial investment costs as well as lower operating an maintenance costs than other systems in most every climate. These savings make GeoExchange ideal for schools of all sizes and locations.

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How They Work

Below the frost line, the temperature of the earth is relatively constant.

can increase these savings even further.

- geoexchange systems use the Earth's energy storage capability to heat and cool buildings, and to provide hot water. The earth is a huge energy storage device that absorbs 47% of the sun's energy -- more than 500 times more energy than mankind needs every year -- in the form of clean, renewable energy. geoexchange systems take this heat during the heating season at an efficiency approaching or exceeding 400%, and return it during the cooling season.

GeoExchange systems use geothermal heat pumps to take advantage of this constant temperature to provide efficient comfort conditioning. Since GeoExchange systems operate by moving heat from or to the earth, no fossil fuels are burned. This approach taps an inexhaustible source of renewable energy.

In most school installations, one geothermal heat pump is used for one or two classrooms. The heat pumps may be in the classrooms as consoles, in closets, or above hallway ceilings. Larger heat pumps are used for areas such as cafeterias and gymnasiums. And still others may be used to provide hot water for kitchens and locker rooms.

Generally, all of the heat pumps are attached to the same earth connection by a loop of pipe inside the building. The earth connection is either a series of buried pipes (closed loop) or water wells (open loop) often buried beneath parking lots or playing fields. Closed loop systems circulate water or an environmentally safe antifreeze through plastic pipes buried beneath Earth's surface. The fluid absorbs heat from the ground during the winter and transfers it to the heat pumps inside the building. In the summer, the process is reversed with heat from the building returning to the ground. Open loop systems operate on the same principle, and can be installed where an adequate supply of water is available.

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Advantages of GeoExchange

GeoExchange systems provide cost-efficient, comfort, safety, reliability, and quality learning environment while freeing-up tight budgets for quality educational programs.

Operating costs are substantially lower.

Kentucky Utilities commissioned studies by three engineering firms who modeled the life cycle costs of alternatives including GeoExchange. Even assuming that the GeoExchange system would cost more to install, the enormous operating and maintenance savings yielded 12 to 19 percent life cycle savings over 20 years. The study also compares energy costs for 24

schools with various HVAC designs. The three lowest operating cost schools have GeoExchange. Similarly, a Lincoln Electric System study of new GeoExchange schools in Nebraska showed savings — even though the GeoExchange schools were designed to meet higher ventilation standards than earlier comparison buildings.

Maintenance savings are remarkable.

At one Canadian school, maintenance costs are less than $0.03 per square foot per year. Routine maintenance is primarily replacement of air filters, and can be done by custodial staff. No in-school technicians are needed in GeoExchange schools. Likewise, the Austin (Texas) Independent School District has converted many of its facilities to GeoExchange. One of the advantages they find is that maintaining spare parts is easier than with alternative systems. The heat pumps are modular and interchangeable, and Austin no longer needs to stock parts for multiple boiler and chillers.

Classroom comfort and user satisfaction.

Because GeoExchange systems use many relatively small heat pumps, each teacher has control for his or her classroom. This leads to greater comfort and satisfaction. Larger GeoExchange units are installed in spaces such as auditoriums, allowing cost-effective heating and cooling for after-school events.

Design flexibility / reduction in rooftop repairs.

GeoExchange eliminates the need for outdoor or rooftop equipment. Schools are no longer limited to flat roofs, allowing for better architectural design. And with no roof penetrations for piping or servicemen on the roof, the need for roof repairs is reduced.

Safety.

Some combustion-based systems present an explosion hazard if the storage or delivery of their fuel is not carefully controlled. Since these systems require a flame to operate, failures can result in loss of property or life to fire. Incorrectly installed systems, chimneys that become blocked, or downdrafting can cause carbon monoxide to remain inside of buildings.

GeoExchange systems have no combustion, and thus produce no indoor pollutants like carbon monoxide. And since the earth connection is buried, there is no dangerous outdoor equipment that children might be tempted to play on.

Integration with educational values.

As the most energy efficient systems available, GeoExchange systems prevent pollution. In addition to creating a quality learning environment, GeoExchange communicates the important message of stewardship of the Earth to students.

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Installation Costs are Competitive

GeoExchange installation costs are sometimes higher due to the additional cost of the required earth connection. However, experienced architects and engineers often find that other factors offset that additional cost, specifically:

GeoExchange systems need much smaller mechanical spaces. Leaving out boiler rooms can decrease the size of the building (and its cost) by 3 to 5 percent.

Because large ductwork is not used to distribute energy throughout the building, floor-to-roof (or floor-to-floor) heights can be reduced. For instance, in Toronto, construction cost savings were more than one million dollars for a 180,000 square foot school.

It's important to include these construction savings in any economic analysis. Involvement by one of the many experienced designers who understand schools and GeoExchange systems helps assure success.

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The Educated Choice

Over 300 principals are proud, 45,000 teachers are smiling, and 1,250,000 students are learning in a more comfortable environment thanks to GeoExchange heating and cooling systems.

GeoExchange systems offer many ways for schools to save money, improve safety, and enhance the learning environment while demonstrating stewardship of our natural resources. No wonder school districts around the country are building or converting all of their facilities to GeoExchange after they experience its comfort and cost savings.

For more information on GeoExchange technology and design options for schools, please contact the Geothermal Heat Pump Consortium at 1-888-ALL-4-GEO. Ask about our video for school administrators, case studies from schools throughout the United States and Canada, or the list of hundreds of GeoExchange schools across the continent.

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GeoExchange School Brochures (available in PDF. You must have Adobe Acrobat Reader in order to view it. Download now).

- Energy Smart Solutions For America's Schools
- The Best Course to Energy Saving For Schools and Universities (GB-028)

GeoExchange School Videos

The Neff School Project Video (VT-901)
For information on ordering this video, please E-mail a request to info@ghpc.org. Or call 1-888-ALL-4-GEO.

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GEOEXCHANGE

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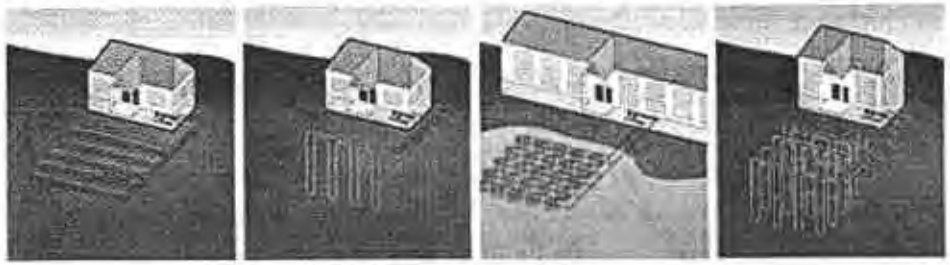

- GeoExchange is the most energy-efficient, environmentally clean, and cost-effective space conditioning system available, according to the Environmental Protection Agency.

- EPA found that geoexchange systems can reduce energy consumption--and corresponding emissions--by over 40% compared to air source heat pumps and by over 70% compared to electric resistance heating with standard air-conditioning equipment. Combining GeoExchange with other energy-efficient measures, such as window or insulation upgrades,

GeoExchange Systems provide space conditioning -- heating, cooling, and humidity control. They may also provide water heating -- either to supplement or replace conventional water heaters. GeoExchange Systems work by moving heat, rather than by converting chemical energy to heat like in a furnace. Every GeoExchange System has three major subsystems or parts: a geothermal heat pump to move heat between the building and the fluid in the earth connection, an earth connection for transferring heat between its fluid and the earth, and a distribution subsystem for delivering heating or cooling to the building. Each system may also have a desuperheater to supplement the building's water heater, or a full-demand water heater to meet all of the building's hot water needs.

In heating mode, heat is extracted from the fluid in the earth connection by the geothermal heat pump and distributed to the home or building -- typically through a system of air ducts. Cooler air from the building is returned to the geothermal heat pump, where it cools the fluid flowing to the earth connection. The fluid is then re-warmed as it flows through the earth connection.

can increase these savings even further.

- geoexchange systems use the Earth's energy storage capability to heat and cool buildings, and to provide hot water. The earth is a huge energy storage device that absorbs 47% of the sun's energy -- more than 500 times more energy than mankind needs every year -- in the form of clean, renewable energy. geoexchange systems take this heat during the heating season at an efficiency approaching or exceeding 400%, and return it during the cooling season.

In cooling mode, the process is reversed. The relatively cool fluid from the earth connection absorbs heat from the building and transfers it to the ground.

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GEOEXCHANGE

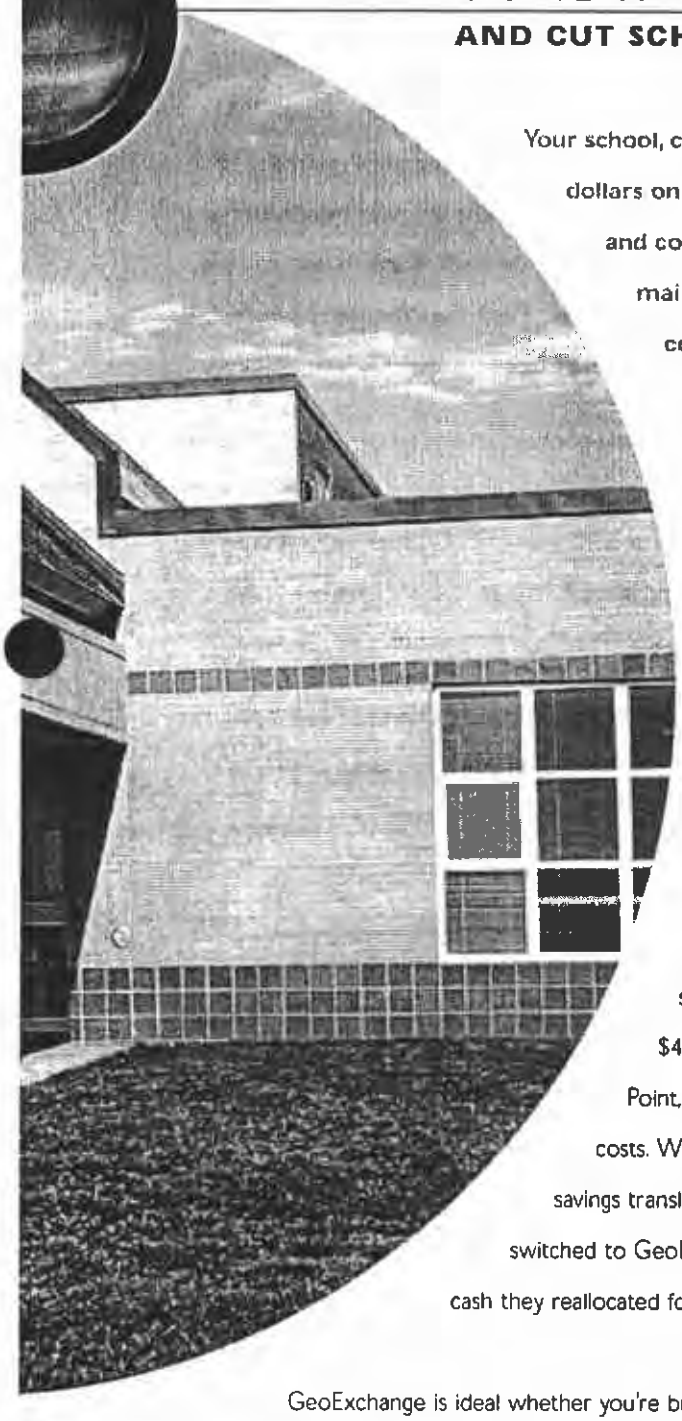
THE BEST COURSE TO ENERGY SAVINGS
FOR SCHOOLS AND UNIVERSITIES

GEOEXCHANGE

CAMPBE
ELEMENTARY SCHOO

BECOME A GEOEXCHANGE STUDENT

AND CUT SCHOOL ENERGY COSTS 25% TO 40%



Your school, college or university can save tens of thousands of dollars on energy bills by learning about GeoExchange heating and cooling. Cost and space savings, greater comfort, lower maintenance, individual room control and environmental conservation are just a few of the benefits that make this earth-friendly HVAC technology worth closer study.

GeoExchange technology has a tremendous future, but it's as old as the earth itself. By tapping into the relatively constant temperature of the earth below the frost line, GeoExchange heats and cools buildings at significant savings — 25%-40% compared to traditional systems. It's the world's most efficient way to heat and cool homes, buildings and institutions.

GeoExchange systems are in operation at more than 500 schools, nationwide. Switching to GeoExchange technology saves Great Bridge Middle School South in Chesapeake, VA, $41,500 annually. And Salem Community College in Carney's Point, NJ, anticipates savings exceeding $60,000 in annual energy costs. With educational institutions facing increasingly tight budgets, these savings translate into financial solutions. In 1995 alone, US schools that switched to GeoExchange heating and cooling saved an estimated $6 million — cash they reallocated for books, computers, teacher salaries and more.

GeoExchange is ideal whether you're building a new school, renovating an existing one or simply replacing your old HVAC system. The more you learn about GeoExchange, the more comfortable, cost-efficient and environmentally conscious your school will be.

← Campbell Elementary School
Lincoln, NE

SIMPLICITY OF DESIGN AND OPERATION

FROM THE GROUND UP

Unlike traditional furnaces that burn fuels for heat and require separate air conditioning or chiller systems, GeoExchange systems transfer heat from one place to another using a simple process to provide both warmth and cooling. There are two types of GeoExchange systems. Each taps the earth's inexhaustible supply of renewable thermal energy, under ground or under water.

"Closed loop" systems use the earth as the heat transfer medium, employing a mixture of water and non-toxic antifreeze pumped through a continuous loop of sealed polyethylene pipes buried beneath the ground, vertically or horizontally. "Open loop" systems draw water directly from a well, lake or pond and pump it through a heat exchanger at the geothermal heat pump; after which, the water is returned to the source.

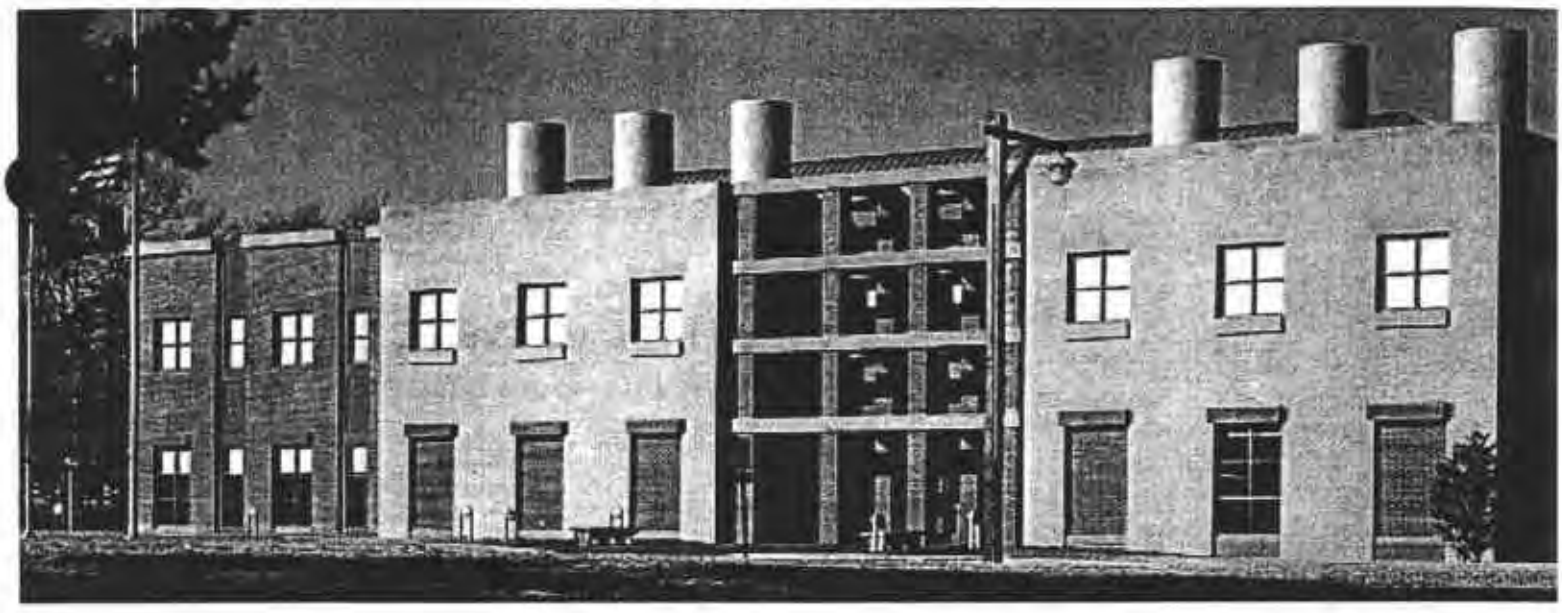
In winter, GeoExchange systems bring the earth's natural warmth up to a building and then transfer it into each room or zone via a heat pump. In summer, they work in reverse to provide air conditioning, absorbing the heat from inside a building and transferring it to the cooler earth below.

Closed Loop Vertical System

Closed Loop Horizontal System

HIGHER EFFICIENCY THAN OTHER SYSTEMS

The Environmental Protection Agency found that, even on a source fuel basis — accounting for all losses in the fuel cycle including electricity generation at power plants — GeoExchange systems average 40% greater efficiency than air source heat pumps, 48% greater efficiency than the best gas furnaces and 75% greater efficiency than oil furnaces. Today's best GeoExchange systems outperform the best gas technology, gas heat pumps, by an average of 36% in heating mode and 43% in cooling mode!



Richard Stockton College, Pomona, NJ

OUTSTANDING COMFORT INSIDE, VIRTUALLY INVISIBLE OUTSIDE

Traditional systems have two major shortcomings. They heat or cool an entire building at once, with little or no ability to control comfort levels in individual rooms or zones. Second, they occupy tremendous space, both inside and outside the building.

A GeoExchange system creates an exceptionally comfortable learning environment by giving educators precise temperature control, room by room. The system can compensate for morning or afternoon shade, heat build-up or temperature variance anywhere in a building. Auditoriums and gyms can also be controlled by separate heat pumps — so there's no need to heat or cool the rest of the school if only these spaces are in use after-hours or on weekends.

GeoExchange systems are much more compact than traditional systems, and out of sight. Mechanical rooms can be smaller. There are no boilers, smoke stacks or fuel tanks.

No massive rooftop chillers requiring added structural support, labor and construction costs.

No holes drilled in roofs to secure them, either, reducing the risk of leaks. No above-ground equipment to be seen at all.

In fact, the surface above a ground loop can be used for athletic fields, parking lots, walking paths or courtyards.

And because GeoExchange equipment is usually underground (wells and piping) and inside (heat pumps), it's not exposed to damage from weather or vandals and not a temptation for children to play on.

† Center. Currently, one of the world's largest GeoExchange systems is at Richard Stockton College in Pomona, NJ

WITH GEOEXCHANGE

THE SKY IS NO LONGER THE LIMIT

MORE DESIGN FLEXIBILITY, MORE AVAILABLE SPACE

Traditional systems limit architects, designers and engineers to traditional thinking. GeoExchange permits them to envision a new world of exterior and interior design possibilities.

A GeoExchange system needs only about one-third the space of a traditional boiler room. Pipes hidden above the ceiling transport warmth to or from individual room heat pumps concealed in small closets. Large blower units and radiators need no longer be a visual detriment in the classroom. And the eyesore of above-ground and rooftop equipment completely disappears from view.

The result? Unlimited architectural creativity. GeoExchange systems permit more attractive exterior and roof designs. They allow historic buildings to be modernized without negatively impacting their appearance. They also permit more room in every classroom, with higher indoor air quality. More overall space available throughout the building. And preservation of the natural beauty surrounding your school.

← Daniel Boone High School, Washington County, TN

"It's not just the simplicity of GeoExchange systems — it's the environmental and economic advantages, and the ease of maintenance and operation."

– David Samokar

Architect, educational facilities

Clotfelter-Samokar

Lexington, Kentucky

"In terms of its efficiency and effectiveness, there's no comparison between GeoExchange and other systems."

– Herman Tester

Principal,

Daniel Boone High School

Washington County, Tennessee

ENVIRONMENTALLY SAFER IN THE AIR AND THE GROUND

Even the most advanced fossil fuel systems release emissions into the air during combustion. The possibility of carbon monoxide fumes in buildings and the possibility of leaks from underground fuel tanks are serious concerns, too.

That's why GeoExchange systems are fully endorsed by the Department of Energy and the Environmental Protection Agency. GeoExchange is environmentally responsible, creating warmth without combustion while drastically reducing greenhouse gas emissions. In fact, GeoExchange systems in use at just 600 schools each year could eliminate some 120 million pounds of carbon dioxide, more than 900,000 pounds of sulfur dioxide and 425,000 pounds of nitric oxide.

Paint Lick Elementary School
Paint Lick, KY

A STUDY IN SAVINGS

DANIEL BOONE HIGH SCHOOL

WASHINGTON COUNTY, TENNESSEE

Original Construction:	1971, 160,000 sq. ft.
Original HVAC:	2-pipe chiller water system, electric resistance heat
Annual Energy Cost:	$238,452
HVAC Retrofit:	1995
Total Area:	160,000 sq. ft.
New HVAC:	GeoExchange, 320 bores, 150 ft. deep, 300 tons capacity
Annual Energy Cost:	$155,513
Annual Savings:	$82,939

White Pine County High School, Wells, NV

If US educational institutions replaced their conventional HVAC systems with GeoExchange technology, they'd do more than demonstrate good stewardship of our earth's resources. They'd have the same effect as planting 8 million acres of trees, or reducing oil imports by 61 million barrels annually, or removing 37 million cars from our roads and saving 2.6 billion gallons of gasoline. All of which help to keep America's blue skies blue.

EXPERTS IN THE KNOW, AS CLOSE AS YOUR PHONE

The GeoExchange industry is growing rapidly, with an expanding infrastructure of knowledgeable experts skilled in the technology. From design engineers and architects to well drillers, pipe fitters, HVAC contractors and equipment specifiers, you can find everyone you need to help design, install and maintain a GeoExchange system precisely tailored to your school's present and future needs.

These people can put you "in the loop" quickly, bring you up to speed on the latest technology, and show you other schools that have benefited, economically and ecologically, from GeoExchange heating and cooling.

SAVINGS AT WORK IN RENOVATION

THE NEFF ELEMENTARY SCHOOL

LANCASTER, PENNSYLVANIA

Original Construction: ..... 1929-1962 (various additions)

Original HVAC: ..... Steam boilers with unit ventilators, no air conditioning

Renovated: 1995-1996

Total Area: ..... 148,530 sq. ft.

New HVAC: ..... GeoExchange, 140 bores, 288 ft. deep, 350 tons capacity

Annual savings $37,140

ADDED ADVANTAGES OF GEOEXCHANGE

HEATING AND COOLING

A CONSTANT SUPPLY OF HOT WATER

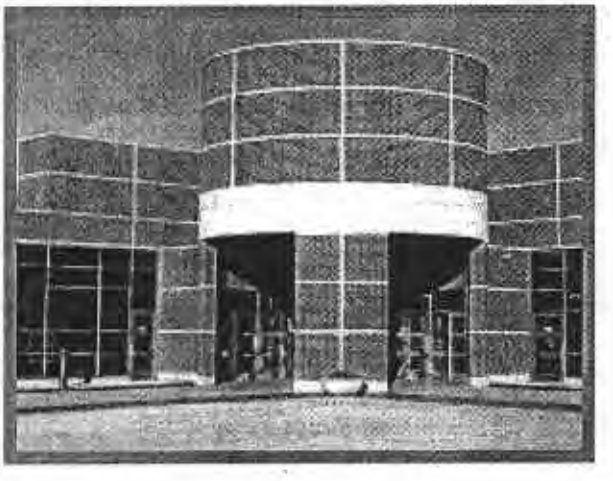
Another GeoExchange extra is plentiful hot water — an added plus for cafeterias, locker rooms, restrooms and dorms. In the summer, hot water is virtually free — produced by the waste heat extracted from interior air during the cooling cycle. Year-round, GeoExchange systems help make hot water abundant and up to 30% less expensive by reducing the amount of electricity or gas consumed by hot water heaters.

LESS MAINTENANCE, FEWER INTERRUPTIONS

It's a fact that traditional HVAC systems can be complex and costly to maintain. Oil and gas-fired boilers demand regular cleanings and component maintenance. Chillers need routine check-ups, fluid testing and replacement. Both systems require the attention of skilled technicians to ensure reliable operation. And should either system fail, the school could shut down with it.

GeoExchange systems, however, are remarkably simple and reliable. They consist of standard pumps, water valves and heat exchange units. The polyethylene pipes underground can last 50 years or longer. Routine maintenance consists primarily of air filter replacement. And in the unlikely event that an individual heat pump, water pump, pipe or valve should fail, that component can be taken off-line and repaired, without affecting the rest of the units in the school.

In recent studies by Kentucky Utilities and Nebraska's Lincoln Electric System, operating and maintenance costs



↑ Discovery Junior High School
Fargo, ND

of GeoExchange systems were estimated to be 12% to 19% lower than traditional systems over a 20-year period. ASHRAE manuals estimate up to 50% savings, with maintenance costs averaging 12¢ to 15¢/sq. ft. versus 30¢/sq. ft. for conventional systems. One school district even reported annual GeoExchange maintenance costs as low as 3¢/sq. ft!

WHY YOUR SCHOOL SHOULD LEARN MORE

GeoExchange is the earth's most efficient, most environmentally responsible heating and cooling technology for your school. For a world of good reasons.

It is unrivaled for economy — comparable to traditional systems on first-installed costs and vastly superior over the long term — with energy cost savings of 25% to 40% annually. It offers precise control of comfort levels in individual classrooms or zones. It affords exciting new architectural possibilities, inside and out. Its simple design and equipment ensure years of reliable performance with much less maintenance than traditional systems.

GeoExchange also enables educators to teach the lessons of global stewardship by example, utilizing a limitless supply of natural heating and cooling energy with no impact on the environment. Or on the world's dwindling supply of fossil fuels.

If you'd like to learn more about the very real benefits of GeoExchange heating and cooling for your school, or receive a list of GeoExchange contractors in your area, contact the Geothermal Heat Pump Consortium toll-free at 1-888-ALL-4-GEO (255-4436) or visit our web site at http://www.geoexchange.org

NEW CONSTRUCTION SOLUTION

CAMERON MIDDLE SCHOOL

CAMERON, MISSOURI

Completed:	December 1992
Total Area:	63,000 sq. ft.
HVAC:	Closed loop GeoExchange, 257 bores, 46 heat pumps
Annual Cost:	$12,876
Comparison:	Traditional HVAC system, similar-sized school. Natural gas heat with electric air conditioning
Annual Cost:	$32,058
Annual Savings:	$19,182

"I really was skeptical...

I couldn't see where the savings to run

the water pumps would be more than...

a boiler or cooling tower. But they've proven it to

me. Without a doubt, this is a lot more efficient

system. Actually, I wouldn't be overstating to say

it's incredible."

Bryan Martin

Maintenance Director

Lake City School District

Coeur d'Alene, Idaho

GEOEXCHANGE ADVANTAGES

- Cuts heating and cooling costs 25%-40%
- Increases comfort and control
- Preserves building aesthetics and beauty of land
- Simpler design, maintenance and operation
- Environmentally friendly technology

Credits: Photos of Campbell Elementary School, Paint *Lick Elementary* School and Discovery Junior High School were provided courtesy of Water Furnace, Ft. Wayne, IN.

The Geothermal Heat Pump Consortium, Inc. (GHPC) is a nonprofit organization whose goal is to advance the use of GeoExchange heating and cooling systems. GHPC is a partnership made up of the nation's electric utilities and trade associations, the geothermal heat pump industry, the US Department of Energy, and the US Environmental Protection Agency.

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GEOTHERMAL HEAT PUMP CONSORTIUM, INC.

$8.00 GB-028

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International Fuel Cells
A United Technologies Company

Fact Sheet

International Fuel Cells, a unit of United Technologies Corp. (NYSE: UTX), is the world leader in fuel cell production and development for commercial, transportation, residential and space applications. IFC is the sole supplier of fuel cells for U.S. manned space missions and is the only company in the world producing a commercial fuel cell system, the PC25™ power plant.

The company's headquarters, research and development, and manufacturing facilities are located in South Windsor, Conn., and cover more than 350,000 square feet. IFC employs some 750 engineers, researchers, managers and production workers.

FUEL CELL DEVELOPMENT PROGRAMS:

SPACE: Since 1966, IFC fuel cells have provided electrical power, as well as drinking water, for astronauts on all U.S. manned space flights, logging more than 90,000 hours in space. Each Space Shuttle is equipped with three IFC fuel cells.

COMMERCIAL: IFC began producing the PC25 fuel cell power plant in 1991. Each unit produces 200 kilowatts of electricity and 900,000 Btu of heat. IFC has delivered more than 200 PC25 systems and installed units in 15 countries on four continents. The PC25 systems provide clean, reliable power at a range of locations, including a New York City police station, a major postal facility in Alaska, a credit card processing system facility in Nebraska and a science center in Japan. The PC25 fleet of fuel cells has accumulated more than 4 million hours of operational experience in a range of operating environments. IFC is also developing a next-generation commercial fuel cell based on Proton Exchange Membrane (PEM) fuel cell technology.

TRANSPORTATION: IFC is aggressively developing quiet, highly efficient ambient-pressure PEM fuel cells and gasoline reformation technology for automotive and bus applications. Fuel reforming technology allows fuel cells to operate on pump gasoline.

IFC is currently working with major automobile manufacturers, including BMW and Hyundai, and the U.S. Department of Energy, on development and demonstration programs for automobiles.

BMW demonstrated a Series-7 vehicle at the Frankfurt Auto Show in 1999 featuring a hydrogen-powered IFC fuel cell to power the on-board electrical systems and air conditioning.

In 2000, IFC successfully integrated its Series 300 75-kilowatt fuel cell into a Hyundai Santa Fe sport utility vehicle. This zero-emission vehicle was unveiled at the California Fuel Cell Partnership in November.

Also in 2000, IFC demonstrated the world's first gasoline reformer system capable of using pump grade gasoline to power a fuel cell for a vehicle.

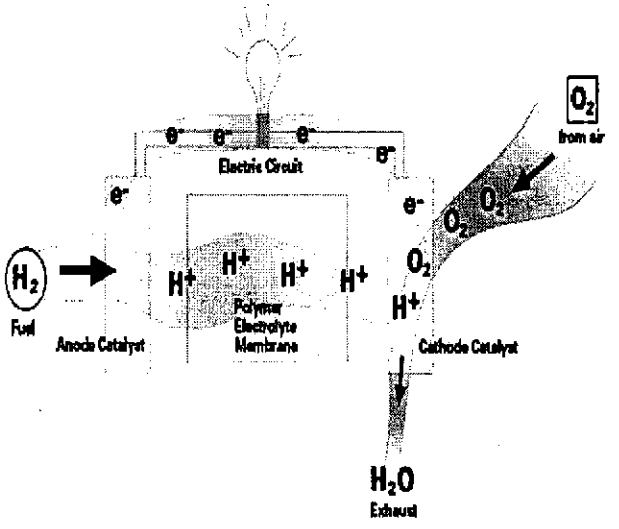
For buses, IFC has teamed with Thor Industries, the largest mid-size bus builder in North America, and Irisbus, one of the largest European bus manufacturers, to build fuel cell powered, zero-emission transit buses. These vehicles will take to the road this year.

RESIDENTIAL/LIGHT COMMERCIAL: IFC is drawing from its experience in both commercial and automotive fuel cell programs to develop a 5 to 10 kilowatt PEM fuel cell suitable for homes and small commercial buildings. IFC is teaming with UTC's Carrier Corp., the world's largest maker of air conditioners, and Toshiba Corp., the global electronics and diversified manufacturer, on the effort. The first residential fuel cells will be available commercially in 2003.

What Is A Fuel Cell?

In principle, a fuel cell operates like a battery. Unlike a battery, a fuel cell does not run down or require recharging. It will produce energy in the form of electricity and heat as long as fuel is supplied.

A fuel cell consists of two electrodes sandwiched around an electrolyte. Oxygen passes over one electrode and hydrogen over the other, generating electricity, water and heat.



Hydrogen fuel is fed into the "anode" of the fuel cell. Oxygen (or air) enters the fuel cell through the cathode. Encouraged by a catalyst, the hydrogen atom splits into a proton and an electron, which take different paths to the cathode. The proton passes through the electrolyte. The electrons create a separate current that can be utilized before they return to the cathode, to be reunited with the hydrogen and oxygen in a molecule of water.

A fuel cell system which includes a "fuel reformer" can utilize the hydrogen from any hydrocarbon fuel - from natural gas to methanol, and even gasoline. Since the fuel cell relies on chemistry and not combustion, emissions from this type of a system would still be much smaller than emissions from the cleanest fuel combustion processes.

FUEL CELLS 2000

TYPES OF FUEL CELLS

Phosphoric Acid
Proton Exchange Membrane or Solid Polymer
Molten Carbonate
Solid Oxide
Alkaline
Direct Methanol Fuel Cells
Regenerative Fuel Cells

Phosphoric Acid. This type of fuel cell is commercially available today. More than 200 fuel cell systems have been installed all over the world - in hospitals, nursing homes, hotels, office buildings, schools, utility power plants, an airport terminal, even a municipal waste dump. Phosphoric acid fuel cells generate electricity at more than 40% efficiency -- and nearly 85% of steam this fuel cell produces is used for cogeneration -- this compares to about 35% for the utility power grid in the United States. Operating temperatures are in the range of 400 degrees F.

Proton Exchange Membrane. These cells operate at relatively low temperatures (about 200 degrees F), have high power density, can vary their output quickly to meet shifts in power demand, and are suited for applications, -- such as in automobiles -- where quick startup is required. According to the U.S. Department of Energy, "they are the primary candidates for light-duty vehicles, for buildings, and potentially for much smaller applications such as replacements for rechargeable batteries." The proton exchange membrane is a thin plastic sheet that allows hydrogen ions to pass through it. The membrane is coated on both sides with highly dispersed metal alloy particles (mostly platinum) that are active catalysts. Hydrogen is fed to the anode side of the fuel cell where the catalyst encourages the hydrogen atoms to release electrons and become hydrogen ions (protons). The electrons travel in the form of an electric current that can be utilized before it returns to the cathode side of the fuel cell where oxygen has been fed. At the same time, the protons diffuse through the membrane to the cathode, where the hydrogen atom is recombined and reacted with oxygen to produce water, thus completing the overall process.

Molten Carbonate. Molten carbonate fuel cells promise high fuel-to-electricity efficiencies and operate at about 1,200 degrees F. To date, molten carbonate fuel cells have been operated on hydrogen, carbon monoxide, natural gas, propane, landfill gas, marine diesel, and simulated coal gasification products. 10 kW to 2 MW molten carbonate fuel cells have been tested on a variety of fuels. Carbonate fuel cells for stationary applications have been sucessfuly demonstrated in Japan and Italy.

Solid Oxide. Another highly promising fuel cell, the solid oxide fuel cell (SOFC) could be used in big, high-power applications including industrial and large-scale central electricity generating stations. Some developers also see solid oxide use in motor vehicles and are developing fuel cell

auxiliary power units (APUs) with SOFCs. A solid oxide system usually uses a hard ceramic material instead of a liquid electrolyte, allowing operating temperatures to reach 1,800 degrees F. Power generating efficiencies could reach 60%. One type of SOFC uses an array of meter-long tubes, and other variations include a compressed disc that resembles the top of a soup can. Tubular SOFC designs are closer to commercialization and are being produced by several companies around the world. Demonstrations of tubular SOFC technology have produced as much as 220 kW.

Alkaline. Long used by NASA on space missions, these cells can achieve power generating efficiencies of up to 70 percent. They use alkaline potassium hydroxide as the electrolyte. Until recently they were too costly for commercial applications, but several companies are examining ways to reduce costs and improve operating flexibility.

Direct Methanol Fuel Cells. These cells are similar to the PEM cells in that they both use a polymer membrane as the electrolyte. However, in the DMFC, the anode catalyst itself draws the hydrogen from the liquid methanol, eliminating the need for a fuel reformer. Efficiencies of about 40% are expected with this type of fuel cell, which would typically operate at a temperature between 120-190 degrees F. Higher efficiencies are achieved at higher temperatures.

Regenerative Fuel Cells. Still a very young member of the fuel cell family, regenerative fuel cells would be attractive as a closed-loop form of power generation. Water is separated into hydrogen and oxygen by a solar-powered electrolyser. The hydrogen and oxygen are fed into the fuel cell which generates electricity, heat and water. The water is then recirculated back to the solar-powered electrolyser and the process begins again. These types of fuel cells are currently being researched by NASA and others worldwide.

To Return to *Fuel Cells 2000's* Homepage

International Fuel Cells
A United Technologies Company

SYSTEM SOLUTIONS

| Power Assurance | Uninterrupted Power | Green Power | Waste Methane |

Power Assurance

To the First National Bank of Omaha just a few milliseconds without electricity can mean hours of headaches and millions of dollars of lost revenues.

IFC's Solution: Four IFC fuel cells now serve as the bank's primary source of power. Heat from the fuel cell installation also provides energy for space heating, increasing the overall efficiency of the fuel cell system to more than 80 percent.

The National Power Laboratory estimates that the typical computer location experiences 289 power disturbances a year. U.S. businesses lose $29 billion annually from computer failures due to power outages.

Today: Reliable, efficient, high quality power for the bank's computer

operations eliminates lost time and revenues, for the bank as well as its customers.

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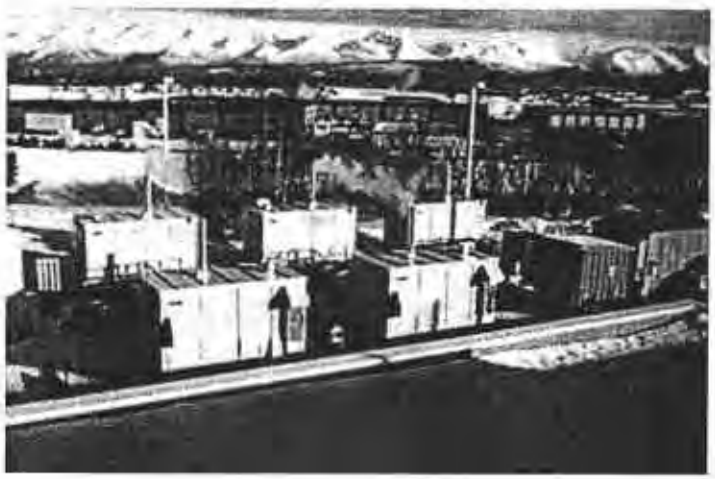
Uninterrupted Power

"Neither rain, nor snow, nor sleet ..." nor power outages should keep the mail from being delivered.



IFC's Solution: The U.S. Postal Service and Alaska's largest electric utility, Chugach Electric, use fuel cells. Five fuel cells, connected in parallel, now produce one megawatt of electricity and are the primary source of power for the Anchorage Mail Processing Center.

This is the largest commercial fuel cell system in the United States and the first to be part of an electric utility's grid. During a grid outage, the fuel cells transition seamlessly, providing uninterrupted operation.

Today: This 24-hour-a-day facility is able to process its average 1.2 million pieces of mail per day without the disruption caused by a power outage.

On December 18, 2000, the local electric grid in Chugach experienced an outage and IFC's fuel cells "saved the day" for the Post Office. The facility's employees were very pleased since that week represents their busiest of the year. Since the PC25™ installation in July 2000, the area has experienced more than 30 outages and each time IFC's fuel cells have kept the facility operational.

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Green Power

A need for reliable, "green" power in the center of New York City's famed Times Square.

IFC's Solution: To help keep its signature building both "green" and reliably powered, the Durst Organization installed two fuel cells at the Conde Nast Building.

Today: Reliable, "green" power from the fuel cells support the building's electrical needs and the thermal energy resulting from operation of these fuel cells is used for the building's perimeter heating.

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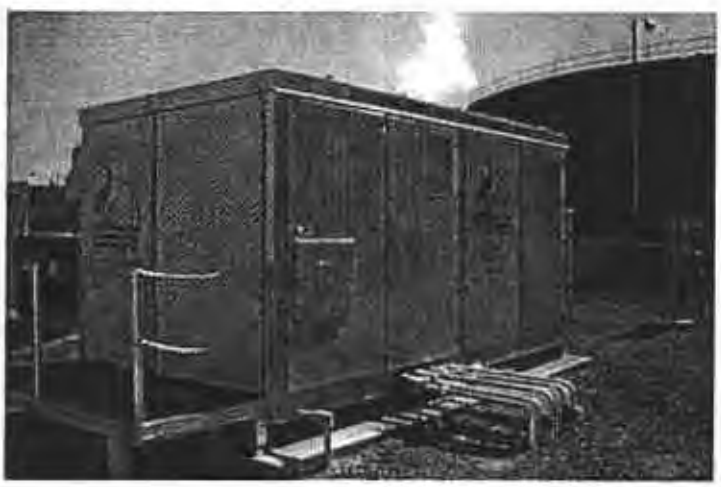
Waste Methane

The city of Portland was looking for an efficient and clean way to power its wastewater treatment facility.



IFC's Solution: The city selected IFC to install one of its 200-kilowatt fuel cells that convert anaerobic digester gas generated by the wastewater treatment facility into usable heat and electricity for the facility. By using waste

gas that might otherwise be flared, the project makes use of a free source of fuel. Additionally, the electricity generated is considered a renewable source of energy.

Today: The use of IFC's fuel cell technology has prevented the annual release of 621 tons of carbon dioxide as well as methane emissions, both of which are potent greenhouse gases. The facility received a Clean Air Excellence Award from the U.S. EPA for its use of fuel cell technology.

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our energy is boundless℠
International Fuel Cells

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Small Turbines

Manufacturers
Residential Applications
Net Billing
Property Values
Wind Resource Evaluation
Wind Resource Maps

Manufacturers of Small Wind Turbines

The American Wind Energy Association (AWEA) has compiled the following list of U.S. manufacturers of wind turbines for use in residential, farm, and commercial/industrial applications. Many have Web sites or are accessible through E-mail links. Links are also provided to the company listings on the **AWEA Industry Member Directory.**

AeroMax Corporation

9250 E. Lorna Lane
Prescott Valley, AZ 86314
(520) 775-0085
E-Mail: aeromag@aeromaxwindenergy.com
Web: www.aeromaxwindenergy.com

Engineering, manufacturing and commercialization of small wind turbine generators and hybrid energy system components.

Atlantic Orient Corporation

P.O. Box 1097
Norwich, VT 05055
(802) 649-5446 Fax: (802) 649-5404
E-mail: aoc@vermontel.com
Web: http://www.aocwind.net
Contact: Peter Hughes
AWEA Directory Listing

Atlantic Orient Corporation (AOC) designs and builds state-of-the-art wind systems. The company is a world leader in wind-diesel research and development for remote and isolated grids. AOC's 50 kW wind turbine is specially designed to withstand arctic environments. Projects under development include a direct-drive, variable-speed 12 kW (rated at 11 m/s) wind turbine, suitable for stand-alone or utility network tie-in, and a larger next-generation wind turbine (the AOC 35/400). In addition, R&D is underway with various partners in commercializing variable-speed, direct-drive reluctance generator technology for hydroelectric turbines as well as AOC's future wind turbines.

Bergey Windpower Company

2001 Priestley Avenue
Norman, OK 73069
(405) 364-4212 Fax: (405) 364-2078

E-mail: sales@bergey.com
Web: http://www.bergey.com
Contact: Steve Wilke
AWEA Directory Listing

Established in 1977, Bergey Windpower manufactures highly reliable wind energy systems with ratings up to 10 kW. They are used for on-grid and off-grid applications such as distributed generation (home, farm, etc.), telecommunications, village electrification, and wind-electric water pumping. Bergey generators are successfully operating in all types of environments from Alaska to Saudi Arabia and more than 90 other countries around the world. They may also be used in hybrid systems with photovoltaic cells and diesel generator sets. Complete systems, systems components, engineering services, installations and training can be provided. A 40-60 kW turbine will be available in late 2000.

Southwest Windpower

P.O. Box 2190
2131 N. First Street
Flagstaff, Arizona 86003-2190
(520)779-9463 Fax (520)779-1485
E-mail: andy@windenergy.com
Web: http://www.windenergy.com
Contact: Andrew Kruse

WindLite Corporation

P.O. Box 1097
Norwich, VT 05055
(802) 649-5446 Fax: (802) 649-5404
e-mail: sales@windlite.com
Web: http://www.windlite.com
Sales Contact: Mark Young

WindLite Corporation is a developer of small wind turbines and integrated power systems for homes, villages, and small businesses. The products can be used where no utility lines exist or they can be connected to the utility transmission system. WindLite's independent (off-grid) hybrid power systems utilize wind, solar, battery, diesel-generator, and controller technologies.

WindTech International, L.L.C.

125 Maple Avenue
Katonah, NY 10536
(914) 232-2354 Fax: (914) 232-2356
E-mail: info@windmillpower.com
Web: http://www.windmillpower.com
Chief Executive Officer: Peter T. Michaelis
U.S./Int'l. Sales Contact: Jeffrey L. Bowden
AWEA Directory Listing

WINDTech™ International manufactures OASIS® high-

performance, low-wind water pumping windmills. Designed primarily for developing countries, OASIS® windmills can be used for providing water to remote villages, supplying irrigation for farming and land reclamation, supplying water to ranches for livestock and aerating shrimp and fish farms. OASIS® windmills combine proven oil-field counterbalance technology with rugged windmill construction for easy installation and minimum maintenance. This design allows OASIS® windmills to begin pumping in winds as low as 5 mph and to depths of several thousand feet. For areas with higher winds, WINDTech™ International also sells the full line of Dempster Industries 6'-14' windmills and hand pumps.

Wind Turbine Industries Corporation

16801 Industrial Circle, SE
Prior Lake, MN 55372
(612) 447-6064 Fax: (612) 447-6050
E-mail: wtic@windturbine.net
Web: http://www.windturbine.net
President: Archie J. Pavek
Manager: Steve T. Turek
AWEA Directory Listing

The exclusive manufacturer of the ***Jacobs***® wind energy systems since 1986, the wind plants range in size from 10kW to 20kW, with rotor sizes ranging from 23 ft. (7 m) to 29 ft. (8.8 m). These systems can provide power for a broad range of applications, which include Grid Intertie (utility bill reduction) or Hybrid battery charging (remote battery charging). The ***Jacobs***® wind energy systems have over 70 years of history providing clean, quality, reliable and efficient power in the USA and around the world.

Wind FAQ | AWEA Home Page

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Small Wind
Questions:

What is Net Metering?

Why Is It Important?

What are the Benefits & Costs?

Can I Use My Present Meter?

What Is the Current Status?

Programs:
Current
Proposed

Bergey Windpower:
Net Billing Web Page

Regulatory policy affecting small power producers

What are "Net Billing" & "Net Metering?"

Q. What Is net metering?

A. "Net-metering" is a simplified method of metering the energy consumed and produced at a home or business that has its own renewable energy generator, such as a wind turbine. Under net metering, excess electricity produced by the wind turbine will spin the existing home or business electricity meter backwards, effectively banking the electricity until it is needed by the customer. This provides the customer with full retail value for all the electricity produced.

Under existing federal law (PURPA, Section 210) utility customers can use the electricity they generate with a wind turbine to supply their own lights and appliances, offsetting electricity they would otherwise have to purchase from the utility at the retail price. But if the customer produces any excess electricity (beyond what is needed to meet the customer's own needs) and net metering is not allowed, the utility purchases that excess electricity at the wholesale or 'avoided cost' price, which is much lower than the retail price. The excess energy is metered using an additional meter that must be installed at the customer's expense. Net metering simplifies this arrangement by allowing the customer to use any excess electricity to offset electricity used at other times during the billing period. In other words, the customer is billed only for the net energy consumed during the billing period.

Q. Why is net metering important?

A. There are three reasons net metering is important. First, because wind energy is an intermittent resource, customers may not be using power as it is being generated, and net metering allows them to receive full value for the electricity they produce without installing expensive battery storage systems. This is important because it directly affects the economics and pay-back period for the investment. Second, net-metering reduces the installation costs for the customer by eliminating the need for a second energy meter. Third, net metering provides a simple, inexpensive, and easily-administered mechanism for encouraging the use of small-scale wind energy systems, which provide important local, national, and global benefits to the environment and the economy.

Q. What are the benefits and costs of net metering?

A. Net metering provides a variety of benefits for both utilities and consumers. Utilities benefit by avoiding the administrative and accounting costs of metering and purchasing the small amounts of excess electricity produced by small-scale wind energy facilities. Consumers benefit by getting greater value for some of the electricity they generate and by being able to interconnect with the utility using their existing meter.

The only cost associated with net metering is indirect: the customer is buying less electricity from the utility, which means the utility is collecting less revenue from the customer. That's because any excess electricity that would have been sold to the utility at the wholesale or 'avoided cost' price is instead being used to offset electricity the customer would have purchased at the retail price. In most cases, the revenue loss is comparable to having the customer reducing electricity use by investing in energy efficiency measures, such as compact fluorescent lighting, efficient heating and cooling equipment, or other highly-efficient appliances.

The bill savings for the customer (and corresponding revenue loss to the utility) will depend on a variety of factors, particularly the amount of excess electricity produced. In most circumstances, however, the difference will be between $10-40 a month for a 10 kilowatt residential wind energy system.

Moreover, any utility revenue losses associated with net metering are at least partially offset by administrative and accounting savings, which are not included in the above figures. These savings can exceed $25 a month because, absent net metering, utilities have to separately process the accounts of customers with wind turbines and issue the monthly checks. In practice, these checks can be for as little as 5 cents.

Q. Can I really use my existing meter to take advantage of net metering?

A. The standard kilowatt-hour meter used for most residential and small commercial customers accurately registers the flow of electricity in either direction. This means the 'netting' process associated with net metering happens automatically — the meter spins forward (in the normal direction) when the customer needs more electricity than is being produced, and spins backward when the customer is producing more electricity than is needed in the home or building. The meter registers the net amount of energy produced or consumed during the billing period.

Q. What is the current status of net metering?

A. Currently, 30 states require at least some utilities to offer net metering for small wind systems, although the requirements vary from state to state. Most state net metering rules were enacted

by state utility regulators, and these rules apply only to utilities whose rates and services are regulated at the state level. In recent years many states have enacted net metering laws legislatively, including California, Connecticut, Delaware, Massachusetts, Montana, Nevada, New Hampshire, New Jersey, Ohio, Oregon, Vermont, Virginia, and Washington. In most of the states with net metering statutes, all utilities are required to offer net metering for some wind systems, although many states limit eligibility to small systems.

To find out whether net metering is or will be available in your location, check the lists of Current Net Metering Programs and Proposed Net Metering Programs.

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Wind Turbine Industries Corp.

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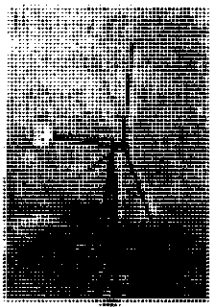
Reps. (INTL.)
Warranty
Site Factors
Brochures & Misc. Data

Wind Turbines, Features, Systems & Purchasing

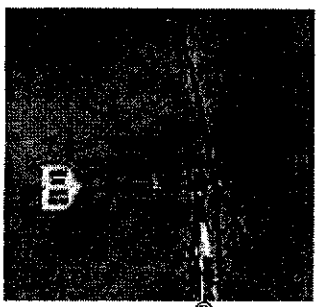
Wind Turbines



20Kw *Jacobs*® Wind Turbine

Model 29-20
29 ft. (8.8 m) Diameter
20,000 watts

Performance
Power Curve
Detailed Specifications
Prices



10 - 17.5Kw *Jacobs*® Wind Tu

Model 23-10 thru 26-17.5
23 - 26 ft. (7 - 7.9 m) Diameter
10,000 - 17,500 watts

Performance
Power Curve
Detailed Specifications
Prices

Features

The *Jacobs*® wind Energy Systems have many features to insure reliability, performance & years of trouble free operation. These features provide protection against high and stormy winds, which could potentially damage the machine. A few of the speed control features are shown at the right.

Features

(click to enlarge p

Systems

All of the above machines can be utilized for Grid Intertie (utility bill reduction) or Hyb charging (remote battery charging).

Grid Intertie System

The Grid Intertie System interconnects with your present utility grid and during demands, the excess power that you do not use is sold back to the power compa low wind periods, the peak power requirements are satisfied by the utility.

Hybrid Power Plant

The Hybrid System is a remote power system that can supply up to 10kW's of p places where utility power is not available, this system is also available in 20kW operates on a 120 volt DC battery system that uses wind as the primary chargin solar maybe added as a secondary source. An engine generator is recommended charging during low wind periods. A wide range of inverters are available to m customers particular AC load requirements.

Purchasing

1. Prices (Domestic only).
   - Grid Intertie System ***Special Discounts Available!***
   - Hybrid System ***Special Discounts Available!***
   - General Price Sheet ***Special Discounts Available!***
   - Installation Cost
     - $5,000.00 to $10,000.00
   - Freight Charges
     - $1.00 to $1.50 per mile (48 states)

2. Siting,
   - Do you have the proper site for a wind system (winds, location & energy p

3. To determine what a Grid Intertie System can do for you.
   1. What is you annual KWH consumption. (contact your Power Company).
   2. Determine your wind speed.
   3. Check output production (KWH) of selected system.

4. Because of Warranty and installation reasons, we recommend that you purchase through one of our factory authorized Dealers.
   - ***Jacobs***® Authorized Dealers provide:
     - Site Planning Assistance
     - Installation
     - Electrical Hook-up
     - Maintenance Service

The Dealer is the key to a successful installation and operation of your win
Your dealer can provide you with information regarding typical wind data
area, a pre-site analysis and the important aspects to consider when purcha
siting a ***Jacobs***® Wind Energy System.

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webmaster@windturbine.net

Wind Turbine Industries Corp.

Performance

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Brochures & Misc. Data

Model No.	23-10	23-12.5	26-15	26-17.5	29-20
Max. Output (Kw)	10	12.5	15	17.5	20
Rotor Diameter (Ft.)	23	23	26	26	29
Rated Wind Speed (mph)	25	27	26	27	26

Wind Speed (MPH)	Estimated Annual Output (KWH)				
10	10486	10521	11363	14729	19727
11	13618	13800	14966	19320	25704
12	17044	17486	19065	24479	32297
13	20648	21472	23558	30060	39289
14	24321	25643	28317	35900	46468
15	27969	29887	33217	41841	53646
16	31515	34103	38135	47744	60665
17	34899	38205	42963	53486	67398
18	38073	42119	47609	58966	73743

All outputs are based on Rayleigh Distribution, outputs will vary depending on tower height.

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webmaster@windturbine.net

Wind Turbine Industries Corp.

Turbine/Tower Spec.

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System, Rotor, Generator, Transmission, Brake & Tower

Turbine Systems:

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Models	23-10	23-12.5	26-15	26-17.5	29-20
Kilowatt Output	10	12.5	15	17.5	20
Cut-In Wind Speed (mph)	---------- 8 mph ----------				
Rated Wind Speed (mph)	25	27	26	27	26
Rated Rotor Speed (rpm)	195	205	205	195	175
Survival Wind Speed	---------- 120 mph ----------				
Weight (lbs.)	1900	1900	1900	1900	2500
Height (ft.) (less Rotor)	---------- 9 feet ----------				

Turbine Rotor:

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Number of Blades	3				
Orientation	Upwind				
Axis (nominal)	Horizontal				
Rotation	Counter Clockwize				
Blade Material	---------- Laminated Sitka Spruce Wood ----------				Fiberglass
Rotor Diameter (ft.)	23	23	26	26	29
Swept Area (ft.)	415	415	530	530	660
Speed Control	1. Centrifugal variable pitch governor (Loaded 25 - 30 mph, Unloaded 15 - 20 mph). 2. Automatic furling - hypoid gear drive (40 - 45 mph) .				
Yaw Control	Passive Tailvane				

Generator:

top of page

Type	Brushless, Synchrous, Three phase AC 12 lead reconnectable with outbound exciter.				
Exciter Field	60 ohm, 2 amps. DC				
Power Rating (kva)	20	20	20	20	23 (Onan) 25 (Winco)
Voltage	40 - 180 VAC				
Speed (rpm)	450-1230	450-1170	450-1170	450-1230	450-1050
Frequency (hz)	0 - 40	0 - 40	0 - 40	0 - 40	0 - 40

Transmission:

top of page

Type	Offset Hypoid Gear Drive
Ratio	1:6.1

Brake System:

top of page

Type	Manual Disc (service/maintenance)

Support Towers:

top of page

Type & Material	Three legged free standing lattice (no welds).
Corrosion Protection	Hot dipped galvanized.
Height & Weight	80 ft. = 4300 lbs. 100 ft. = 6200 lbs. 120 ft. = 8200 lbs.
Base Width	80 ft. = 9 ft. 100 ft. = 11 ft. 120 ft. = 13 ft.
Options	Tilting Hinges

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Wind Turbine Industries Corp.

Performance

Content This Section:

Up
Grid Intertie System
Hybrid Power Plant
Features
10-17 Kw Power Curve
20 Kw Power Curve
Prices
Performance
Turbine/Tower Spec.
Dealers (USA)
Reps. (INTL.)
Warranty
Site Factors
Brochures & Misc. Data

Model No.	23-10	23-12.5	26-15	26-17.5	29-20
Max. Output (Kw)	10	12.5	15	17.5	20
Rotor Diameter (Ft.)	23	23	26	26	29
Rated Wind Speed (mph)	25	27	26	27	26

Wind Speed (MPH)	Estimated Annual Output (KWH)				
10	10486	10521	11363	14729	19727
11	13618	13800	14966	19320	25704
12	17044	17486	19065	24479	32297
13	20648	21472	23558	30060	39289
14	24321	25643	28317	35900	46468
15	27969	29887	33217	41841	53646
16	31515	34103	38135	47744	60665
17	34899	38205	42963	53486	67398
18	38073	42119	47609	58966	73743

All outputs are based on Rayleigh Distribution, outputs will vary depending on tower height.

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Wind Turbine Industries Corp.

20 Kw Power Curve

Content
This Section:

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Grid Intertie System
Hybrid Power Plant
Features
10-17 Kw Power Curve
20 Kw Power Curve
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Performance
Turbine/Tower Spec.
Dealers (USA)
Reps. (INTL.)
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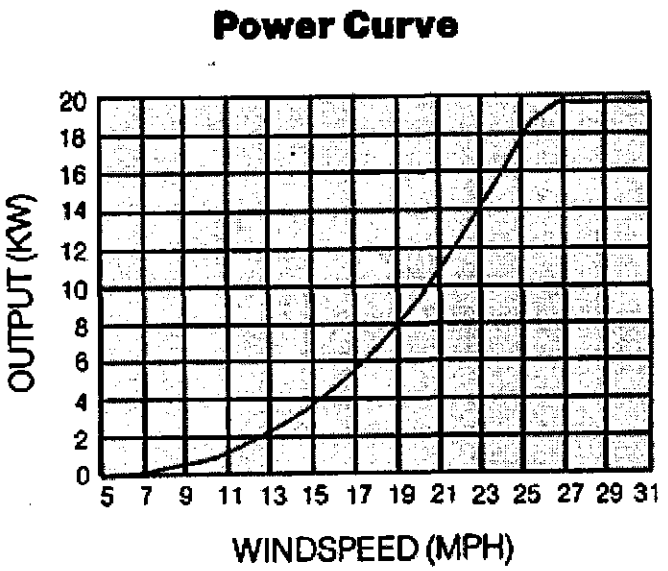

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STORMWATER™
MANAGEMENT

CSF® Stormwater Treatment System

Design Manual

This design manual has been prepared to describe and facilitate the use of the CSF® Stormwater Treatment System. This manual is periodically updated to incorporate additions and refinements. Feedback from those using this manual is invaluable to improving its content and maintaining the highest level of service. If you would like to call us with your comments, please call our toll-free number 1-800-548-4667.

Version 1.2
Released April 21, 1997

Stormwater Management
2035 N.E. Columbia Blvd.
Portland, OR 97211

U.S. Patent No. 5,322,629 and other U.S. and foreign Patents Pending.

© STORMWATER MANAGEMENT

STORMWATER™ MANAGEMENT

INTRODUCTION

Stormwater Management is a progressive, product orientated company whose mission is to develop innovative stormwater treatment solutions for engineers, developers and jurisdictional authorities to help keep our water ways clean.

Since 1991, Stormwater Management's patented signature product, the CSF® Stormwater Treatment System (CSF®), has been treating stormwater runoff from small single retail sites to large urban parking lots, residential streets, urban roadways and freeways.

The CSF® Stormwater Treatment System uses Radial Flow Filter Cartridges housed in standard size pre-cast concrete vaults or cast in place vaults to produce a self-contained stormwater filtering system. The filter systems are installed in-line with storm drains. The filters work by percolating stormwater through the cylindrical cartridges containing CSF® filter media. The filter media traps particulates and adsorbs materials such as dissolved metals and hydrocarbons. Surface scums, floating oil and grease are also removed. After filtering through the filter media, the stormwater flows into a collection pipe or discharges to an open channel drainage way.

CSF® Stormwater Treatment Systems are designed to be very effective for the treatment of first flush flows, particularly those storms early in the rainy season. In general, the CSF®'s efficiency is highest when pollutant concentrations are highest.

FILTER MEDIA CHARACTERISTICS

In the Autumn, deciduous trees begin to drop their leaves in preparation for the winter. In metropolitan areas the leaves accumulate, clog storm drains, and potentially cause local flooding. To prevent this, many cities have leaf collection programs. Leaves are either swept up or brought to drop off points and then transported to landfills, municipal or commercial composting facilities.

Using a feed stock of pure deciduous leaves (i.e. no mixed yard debris such as prunings and grass) Stormwater Management composts leaves collected by

the City of Portland, Oregon, over a period of eight months into a mature stable compost. Stormwater Management then processes the finished compost into a granular media which resembles soil and has no odors. Once complete, the media has physical and chemical characteristics desirable for the filtration of stormwater.

There are three primary pollutant removal mechanisms performed by the CSF® filter media. These mechanisms are: mechanical filtration to remove sediments, chemical processes to remove soluble metals, and adsorption properties to remove oils and greases.

Sediments

The media is contained in a series of radial flow filter cartridges which have a seven inch thick layer of the media through which stormwater passes. Sediments are filtered out on both the surface of the filter and the surfaces of granules throughout the media matrix. As sediments are removed from stormwater runoff and accumulate on the surface of the filter, the permeability will decline thus requiring facility maintenance. Maintenance could include: periodic orifice adjustments, back flushing, or media removal and replacement. Sediment removal will vary with particle size distribution, but removal has been as high as 95%.

Heavy Metals

The media also acts as a chemical filter to remove dissolved ionic pollutants such as heavy metals, including lead, copper, and zinc. The mechanism of cation exchange is provided by humic acids, which are a product of the aerobic biological activity during the composting process. Heavy metal removal rates vary from 65% to 95%.

Oils & Greases

Removal of oils and greases (O&G) and other organic compounds is facilitated by the high organic carbon content of the media. The system performs best when O&G loadings are less than 25 mg/l. Measured removal rates are as high as 85%.

Detailed performance data are available upon request. Removal of other pollutants such as chlorinated hydrocarbons has been demonstrated. However, in the case of specific target pollutants, we recommend a characterization study be performed in our laboratory.

Leaf compost is processed into a pelletized filter media.

SYSTEM HYDRAULICS

CSF® Stormwater Treatment Systems are sized to treat the peak flow of a water quality design storm, as it passes through the filter. The peak flow is determined by calculations based on the contributing watershed hydrology and using a design storm magnitude. The design storm is usually based on the regulatory requirements set by the local stormwater management agency. The particular size of a CSF® is determined by the number of Radial Flow Filter Cartridges required to treat the peak stormwater flow.

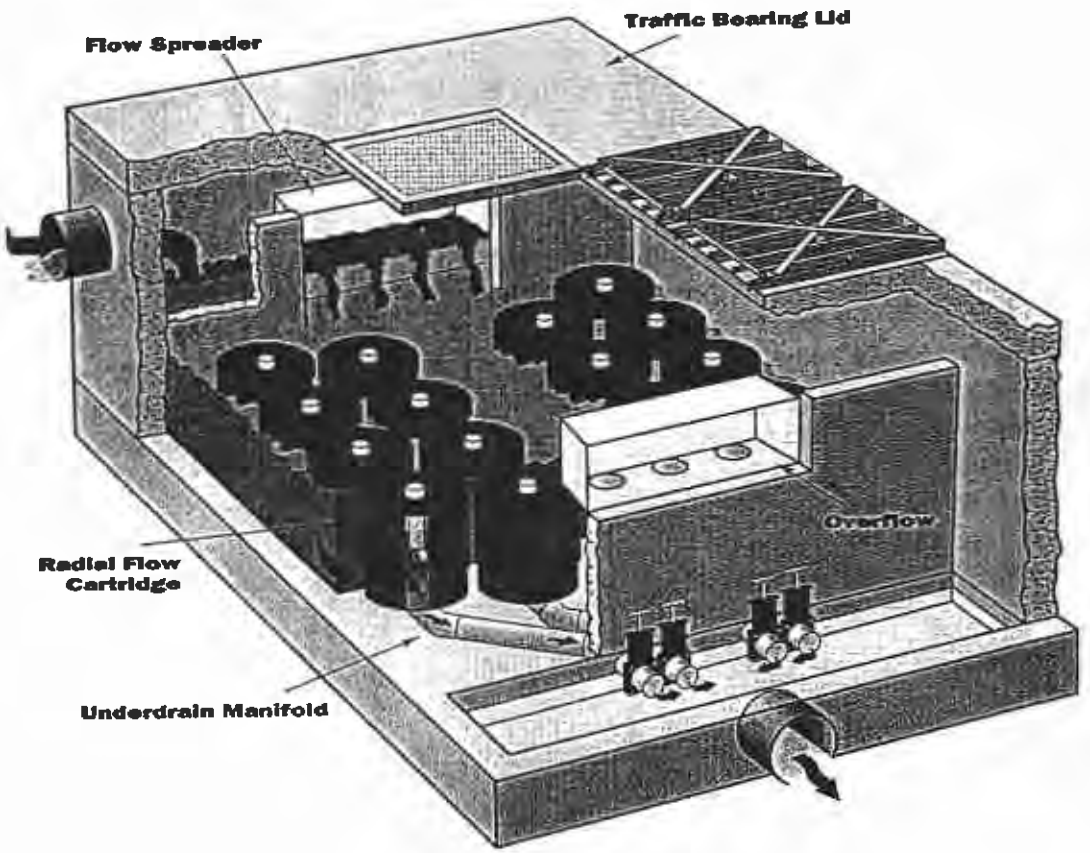


Figure 1.

The typical unit configuration as diagrammed by Figure 1 consists of an inlet bay, baffle, cartridge bay, an overflow baffle, and outlet bay. The inlet bay serves as a grit chamber and provides for flow transition into the cartridge bay. The flow spreader provides for the trapping of floatables, oils, and surface scum. Water enters the cartridge bay through the flow spreader and begins to pond. As shown in Figure 2, the water ponds, infiltrates through the media into the inner drainage tube and begins to raise the float. Once the ponding submerges the cylinders, the float will pull loose the semi buoyant ball and generate a siphon effect which greatly increases the flow potential across the filter media.

The CSF® typically requires 2.3 feet of head differential between the invert of the inlet and the invert of the outlet.

Because of the highly porous nature of the granular compost media, the flow through a newly installed cartridge is restricted to 15 gpm using a flow control valve located at the outlet of each manifold pipe.

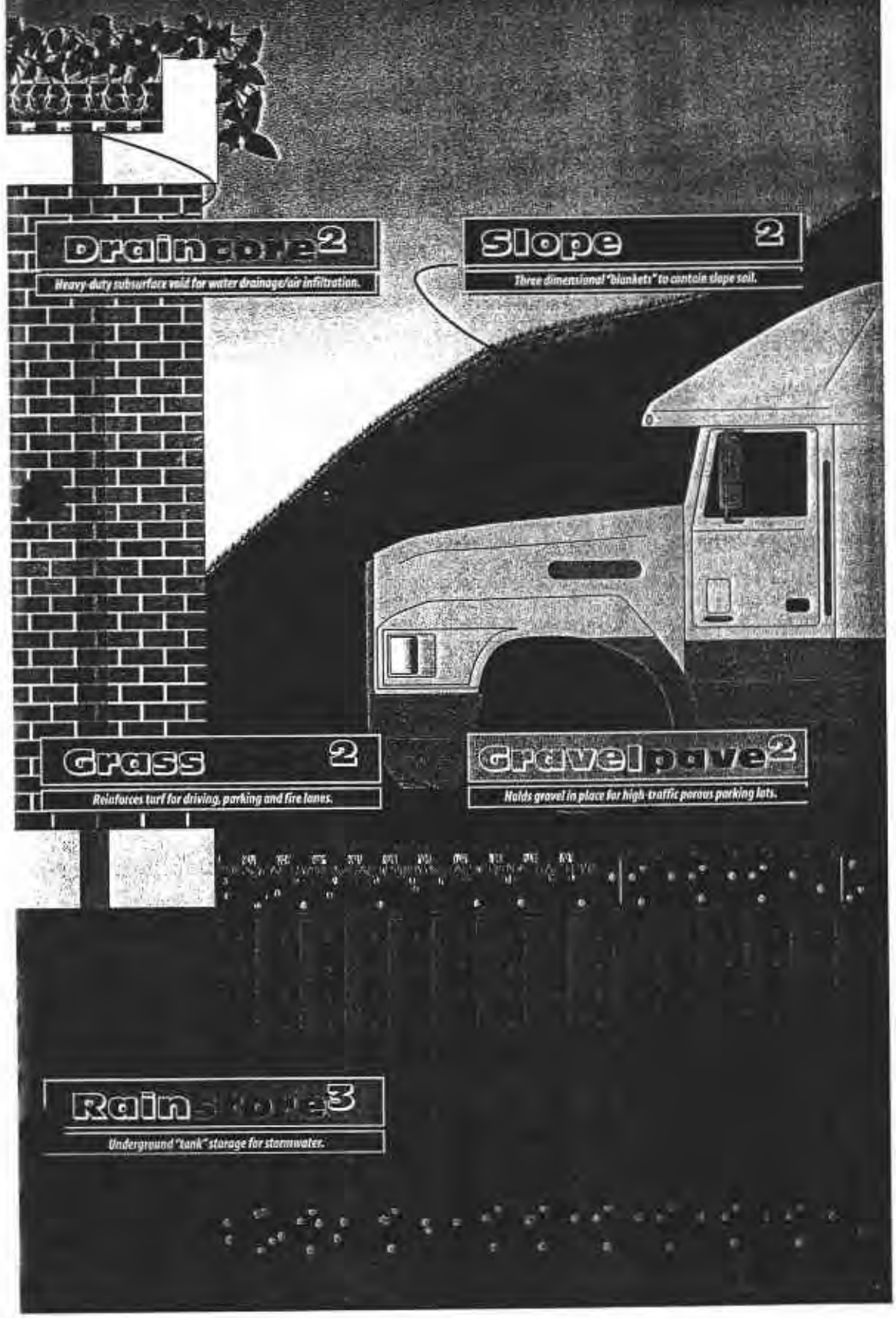
The valve controls the flow from three to eight cylinders (i.e. 45 to 120 gpm). The valve is calibrated and adjusted such that, at design head, the maximum flow is throttled to the number of cylinders on line times 15 gpm per cylinder.

Over a period of time the permeability of the media declines from sediment deposition. When this occurs, the flow control valve can be opened to help restore the system to design flow. This is facilitated by decreasing the head loss across the valve which increases the potential across the filter.

The CSF® is also designed with an inline overflow. The overflow operates when the inflow rate is greater than the infiltration capacity of the filter media

Depending on individual site characteristics, some filters are equipped with high and/or low flow bypasses. High flow bypasses are installed when the calculated peak storm event generates a flow which overcomes the overflow capacity or design capacity of the filter. This is especially important for the pre-cast Drop-In filters. Low flow bypasses are sometimes installed to prevent continuous inflows caused by ground water seepage which usually does not require treatment. For more information on bypassing the CSF®, see System Design.

Total Stormwater Management



Invisible Structures, Inc.

Product Capabilities

- Reduce Runoff Volume and Rate
- Conserve and Protect Natural Areas
- Reduce and Treat Stormwater Pollutants
- Protect Slopes and Channels from Erosion
- Allow Multiple Surface Uses
- Reduce Radiated and Reflected Solar Heat

Manufactured by:
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Aurora, CO 80011-8160
1-800-233-1510
303-373-1234
Fax 303-373-1223
www.invisiblestructures.com

Grass 2

Reinforces turf for driving, parking, and fire lanes.

A Orange Bowl, Miami FL—Stormwater percolates into Grasspave² parking bays.
B Grasspave² System Components—sandy gravel base course at 95% compaction, Grasspave² filled with sand, and grass seed or sod cover.
C Westfarms Mall, West Hartford, CT—multi-use overflow parking.
D Fire Truck Access—emergency access over high strength grass since 1982.

CSI No. 02795

Grasspave² is a structure which provides incredible load bearing strength while protecting vegetation root systems from deadly compaction. High void spaces within the entire cross-section enable excellent root development, and storage capacity for rainfall from storm events. Stormwater is slowed in movement through and across Grasspave² surfaces, which deposits suspended sediment and increases time to discharge. Suspended pollutants and moderate amounts of engine oils are consumed by active soil bacteria, which are aided by the system's excellent oxygen exchange capacity.

Applications Include:
- Overflow Parking
- Driveways
- On-street Parking
- Emergency Access
- Firelanes
- Employee Parking
- Pedestrian Access
- Infiltration Basins
- Event Parking
- Utility Access
- Handicap Parking

Functions Include:
- Pervious Load Bearing Surface
- Stormwater Pollution Filtration and Treatment
- Airborne Dust Capture and Retention
- Heat Energy Reflection Reduction, "Cool" Surface
- Tree Growth within Parking Areas

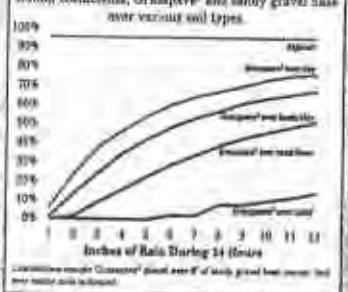
Patent number 5,250,340

Lab Compression Test Results

Load-bearing capacity of sand-filled Grasspave² rings vs concrete, and vehicle loading examples

Runoff Comparison Chart

Runoff coefficients, Grasspave² and sandy gravel base over various soil types.



pave 2

Holds gravel in place for high-traffic porous parking lots.

Grand Canyon Trust, Flagstaff, AZ—30-car parking for employees and visitors.
Gravelpave² System Components—filter fabric backing and rings contain ¼" minus sharp gravel with minimal dust.
Residential Drive and Walk, Savannah, GA—Meets ADA surface criteria.
Frostburg Univ. Dorm Parking, MD—Prevents pollutants from entering adjacent creek.

CSI No. 02795

Gravelpave² is a structure to provide heavy load bearing support and true containment of gravel to create a porous pavement surface with unlimited traffic volume and/or duration time for parking. When used with a proper porous base course material, Gravelpave² can provide a void space of 35% for storage volume of rainfall during rain events. For example, an 8" deep cross-section would store 2.8" of rain. Although bacteria concentrations are lower than with Grasspave², polluted runoff and vehicle drippings are consumed prior to reaching the water table.

Applications Include:
- All Parking Aisles and Bays
- Automobile and Truck Storage Yards
- Loading Dock Areas
- Boat Ramps
- Infiltration Basins
- Handicap Parking Spaces
- All Service and Access Drives
- Trails for Multiple Uses
- Outdoor Bulk Storage Areas (Lumber, Steel, etc.)
- High-use Pedistrian Areas

Functions Include:
- Pervious Load Bearing Surface – Unlimited Traffic
- Stormwater Pollution Filtration and Treatment
- Heat Energy Reflection Reduction, "Cool" Surface
- Tree Growth within Parking Areas

Patent number 5,250,340

Fill	% Passing	Sieve Size
	100	#4 Screen
	80	#8 Screen
	50	#16 Screen
	30	#30 Screen
	15	#50 Screen
	5	#100 Screen

Base	% Passing	Sieve Size
	100	½"
	85	⅜"
	60	#4
	30	#40
	5	#200

Rainstore³

Underground "tank" storage for stormwater.

A *Multnomah Elementary School, Los Angeles, CA—storage basin to irrigate grass play area.*
B *Four Layer Rainstore³ Structure—each unit 0.1 cubic meter (40" × 40" × 4") stackable columns.*
C *LDS Church, Boise, ID—vegetated swale at low end of parking lot to store runoff and exfiltrate to soils below.*
D *2.5m (8.2') Depth Cell—H-25 load capacity allows deep storage under parking lots with up to 94% efficiency.*

CSI No. 02660

Rainstore³ is a modular and stackable structure designed to support heavy loads up to H-25, with 12" minimum road base cover. 94% void space creates an efficient storage Wet Vault below parking or landscaped surfaces with minimal excavation. Detention and retention can be accomplished using geotextile fabrics, or waterproof liners to wrap the structure. Inlets, outlets, pump access, and inspection ports are readily incorporated. Rainstore³ can be installed in layers from 4 inches to 8.2 feet, accommodating high water table or shallow rock conditions.

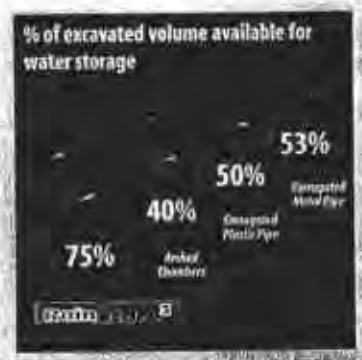
Applications Include:

- Subsurface Water Storage – Detention, Retention
- Water Reuse and Recycling
- Potable (Treated) Water Storage
- Process Water Storage—Heating and Cooling
- Combined Water Conveyance and Storage
- Energy Dissipation at Pipe Outfall
- Septic Leach Fields and Wetlands Treatment
- Dry Wells, Wet Vaults, and Cisterns

Benefits Include:

- Heavy Load Capacity Above Chamber
- Simple and Low Cost Liner Materials
- Maximum Excavation to Storage Efficiency
- Rapid Installation
- Modular for Design Flexibility
- Large Surface Area for Rapid Storage Exfiltration

Rainstore³ U.S. and International Patents Pending



Slope 2

Three-dimensional "blankets" to contain slope soil.

A *Erosion Control and Energy Dissipation—Geotextile pile swale to dissipate energy.*
B *Slopetame² Reinforcement Matrix—an 8" permanent and porous cover.*
C *Merrill Lynch Building Swale, Denver, CO—Vegetated high seed mix at 27 ft/min velocity.*
D *Tahoe Systems, Inc., Chattahoochee River, GA—Slopetame² on Geotextile fabric protects this slope in North Georgia for years.*

CSI No. 02370

Slopetame² is a permanent, three-dimensional, [illegible] matrix for steep vegetated slopes, including [illegible] and [illegible] to contain [illegible] [illegible] and [illegible] and [illegible] Slopetame² is made of [illegible] together forming [illegible] [illegible] by [illegible] slope with [illegible] [illegible] [illegible]

Applications Include:

- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]

Invisible Structures — Standard Product Roll Sizes
Grasspave², Gravelpave², Slopetame², Draincore²

Model	Width m	Width ft	Length m	Length ft	Diameter m	Diameter ft	Area m²	Area ft²	Weight kg	Weight lbs
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1020	1	3.3	20	65.6	0.8	2.7	20	215	37	82
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1520	1.5	4.9	20	65.6	0.8	2.7	30	323	56	123
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2020	2	6.6	20	65.6	0.8	2.7	40	430	75	164
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2520	2.5	8.2	20	65.6	0.8	2.7	50	538	93	205
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

* Roll sizes marked with asterisks should be installed by lifting machines only. All other rolls can be installed manually (2 people advised)

Drain 2

Heavy-duty subsurface void for water drainage/air infiltration.

A *Planter Drainage — [illegible] and moves water while providing insulating air layer from extreme cold weather or hot sun.*

B *Drainscore® Cut-away View — showing "AIRFIELD" sports turf system also effective as landfill cap drainage control.*

C *Infiltration Trench Detail — allows rapid influx of surface and subsurface water.*

D *Hydraulic Lab Test Flows — Colorado State University testing — 50 gpm per foot width.*

CSI No. 02622

Draincore® is a high volume drainage layer capable of withstanding heavy loads in direct contact. This drainage core is wrapped in a geotextile fabric which allows water to enter from any direction, with the ridges placed vertically or horizontally. Water can flow between rings in either vertical or lateral direction, simultaneously. Flow volumes can be matched with multiple layer configurations.

Applications Include:

- Infiltration Basin Collector and Conveyance
- Cutoff Drainage Surface and Subsurface Flow
- Constructed Wetlands
- Foundation and Retaining Wall Drainage
- Roof Pad and Plaza Drainage
- Sports Turf Drainage System
- Landfill Cap and Drainage Construction

[illegible]

www.invisiblestructures.com

Grass 2

[illegible]

Gravel 2

[illegible]

Rain 3

[illegible]

Slope 2

[illegible]

Drain 2

[illegible]

Sure 4

[illegible]

Beach 2

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Sales & Support

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Community Service

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Company Profile

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Media & Tech Specs

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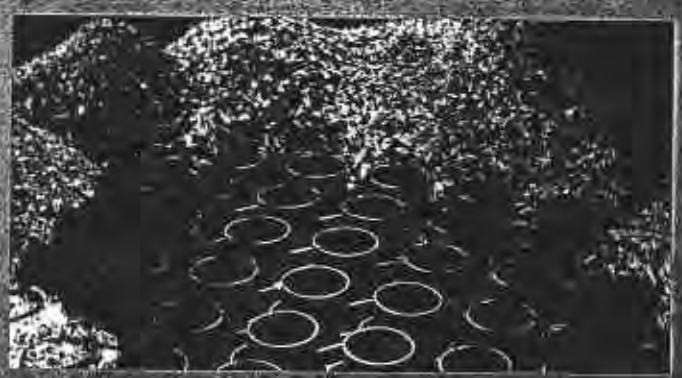

Company Products: 100% Recycled Plastic

[illegible]

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See our nearest dealer

Other Products

Sure 4

Livestock footing and flooring system

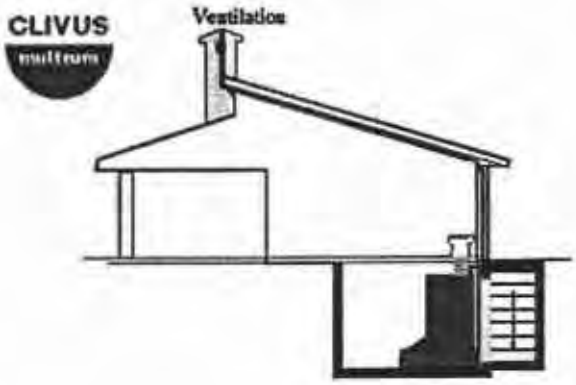
Patent number 5,250,340

Beach 2

Portable mats for wheelchair access on beaches.

Clivus Multrum Public Facilities

The best solution eliminates pollution



- Small foot print - no leach field
- Always odor free & hygenic
- No discharge - no pollution
- Low maintenance - easy cleaning
- Very cost effective

Click here for:

Public Facilty Models	Composter Maintenance

Sample installations

The original Clivus Multrum, built in Sweden 1939, is shown here

http://www.clivusmultrum.com/Public.html

32 years ago (1966) and today (1998) - it is still working fine.

The original Clivus 1939

1998 - New building - same tank

Clivus is used in small installations (pictured here is an **M54 TrailHead**, a self-contained tank and building to be buried or put on the ground),

M54 in Arizona

M54 in Mass.

---

in **medium sized facilities** - 200 visitors per day - such as this park in South Korea,

---

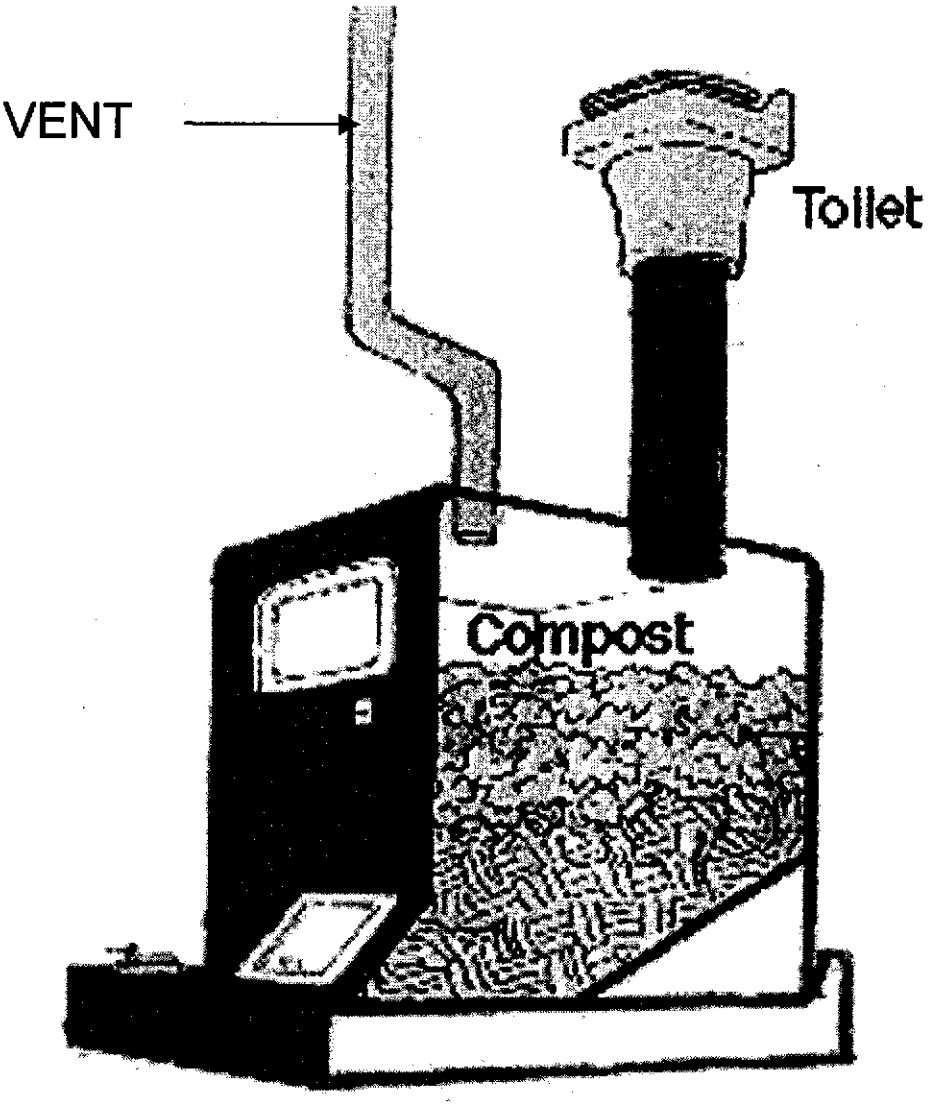
and in very high-use locations like the **Misquamicut State Beach**: 10.000+ per day.

and the worlds largest public composting toilet complex at **Salsbury Beach** in Massachusetts

We provide assistance for site built facilities such as this **US Post office...**

or we provide the whole installation, either **turnkey or prefabricated**.

We have facilities in Frank Lloyd Wright's **Fallingwater** visitor center



Clivus Multrum Composting Toilet

NSF Certified Product Listings

These Listings were Last Updated on **Saturday, July 21, 2001** at 8:00 PM Eastern Standard Time.
Please contact NSF International to confirm the status of any Listing, report errors, or make suggestions.

ANSI/NSF STANDARD 41
Non-Liquid Saturated Treatment Systems

CLIVUS MULTRUM, INC.

Cert-Link (Click here to visit this Company's Website)

15 UNION STREET
LAWRENCE, MA 01840
800-425-4887
978-725-5591

Plant at: LAWRENCE, MA

Clivus Multrum Organic Waste Treatment System

Model M-1	Model M-2
Model M-12	Model M-15
Model M-18	Model M-22
Model M-25	Model M-28
Model M-32	Model M-35
Model M54ADA	

Number of matching Manufacturers is 1
Number of matching Products is 11
Processing time was 0 seconds

Wastewater Treatment Units

Information On:

- Services
- Certified Products
- Certification Programs
- Standards & Publications
- Training & Conferences
- ISO Registration
- Employment

Information For:

- Consumers
- Regulators
- Clients
- International

NSF Wastewater Treatment Units Standards

The four standards against which NSF conducts evaluations include:

ANSI/NSF Standard 40: Residential Wastewater Treatment Systems

ANSI/NSF Standard 41: Non-Liquid Saturated Treatment Systems

ANSI/NSF Standard 46: Evaluation of Components and Devices Used in Wastewater Treatment Systems

NSF Criteria C-9: Evaluation of Special Processes, Components, or Devices used in Treating Wastewater

---

ANSI/NSF Standard 40
Standard 40, relating to residential wastewater treatment systems, requires six months of performance testing, incorporating stress tests to simulate wash day working parent, power outage, and vacation conditions. Although the USEPA permit program does not apply to onsite discharge, "Class I" Listed units have been shown to produce an equivalent quality effluent when tested for six months at their design rated capacities.

ANSI/NSF Standard 41
Standard 41, relating to composting toilets, requires a minimum six months of performance testing, incorporating design loading and stress testing appropriate to the three classes of systems covered: residential, cottage, and day-use park. A minimum of one system is evaluated in a controlled, laboratory setting, and a minimum of three systems are evaluated in a mature, field setting.

ANSI/NSF Standard 46
Standard 46, relating to components of wastewater treatment systems, applies to any wastewater treatment product not covered by Standards 40 and 41. Standard 46 was developed to replace NSF Criteria C-9, which shall be withdrawn in 2000. Standard 46 currently includes performance evaluations for grinder pumps and septic tank effluent filters. A performance evaluation of residential wastewater disinfection devices is currently under development by the NSF Joint Committee on Wastewater Technology. As product users, regulatory officials, and manufacturers identify the need for additional performance evaluations for other classes of wastewater treatment products, the NSF Joint Committee on Wastewater Technology shall develop the evaluations and add them to Standard 46.

NSF Criteria C-9
Criteria C-9, relating to special devices and processes for treating wastewater, is intended for use with products for which specific standards are not available. For a new generic type of product, a special task committee – with

representatives from one or more regulatory agencies, the relevant industry, and other appropriate interest groups – determines the type and frequency of sampling and analyses, the duration of testing, and the level of performance to be achieved. Criteria C-9 Listings may include:

- Package Plants
- Grinder Pumps
- Septic Solids Retainer (SSR)
- Other Wastewater Treatment Devices Not Covered by Specific Standards

Order NSF Standards and Publications

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Contacting Waterless Co.

Español

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Del Mar, CA 92014 USA

Or request information packet via e-mail, please click here.

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Facsimile:	858-793-5661	E-Mail:	klaus@waterless.com

VISA

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Tel: 7074438453
Fax: 707-443-0195

NORTH AND SOUTH CAROLINA
Allied Environmental
601 Eagleton Downs Dr. #A
Pineville, NC 28134
E-Mail: JEM92059@aol.com
Web Site: http://www.phoenixasphalt.com
Tel: 704-375-2525
Fax: 704-529-1996

FLORIDA
TRI COUNTY PLUMBING
211 SE 46th Terrace
Cape Coral, FL 33804
E-mail: tnewman983@aol.com
Tel.: 941-542-5779

INDIANA,
S. ILLINOIS,
W. KY
CiCi Engineering Sales & Service
7811 Baumgart Rd.
Evansville, IN 47725
E-Mail: cici@evansville.net
Tel: 800-848-8197
Fax: 812-867-0760

MARYLAND, W. VA, D.C. & PART VA
N of I-66 and 17
Sierra Co.
8110 Arrowhead Ct.
Frederick, MD 21702
E-mail: sierraco@msn.com
Tel: 888-567-5004
Fax: 888-567-5004

NEW YORK, NEW JERSEY
Ace Supply
170 53rd Street
Brooklyn, NY 11232
Tel: 718-492-7200
Fax: 718-492-3878
E-Mail: a.guttman@worldnet.att.net

1100 Tunnel Rd.
Santa Barbara, CA 93105
Tel: 805-687-1287

DELAWARE
FLANAGAN SALES
12328 Point View Rd.
Bishopville, MD 21813
E-mail: seagull@shore.intercom.net
Tel / Fax: 410-352-5607

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THE SCHILLING GROUP
2512 Hidden Hills Drive
Marietta, GA 30066
E-mail: Drkilawatt@aol.com
Tel: 404-221-3254
Fax: 770-499-9006

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Ron Rumpf
6116 Sharon Circle
Urbandale,IA 50322
Tel: 515-334-5058
Fax: 515-334-5058

MISSOURI
AMS Midlands
8460 Watson Rd. #109
St. Louis, MO 63119
Tel.: 888-889-5426
Fax: 314-729-1351
E-mail: dwheeler@amsmidlands.com

NEVADA
IMT
536 N. Racetrack Rd.
Henderson, NV 89015
E-mail: imtceo@aol.com
Tel: 702-558-2370
Fax: 702-558-2362

NEW ENGLAND
(MA, RI, VT, ME, CT, NH)
R. LEWIS CO. INC.
124 Crescent St.
Needham, MA 02194-0005
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Tel: 781-444-9650
Fax: 781-444-9658

OREGON
Edgewater Environmental
P.O.Box 130
Newport, OR 97365
E-mail: robert@edgewaterenviro.com
Tel: 541-265-8389
Fax: 541-265-9360

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SARCO OF TEXAS (2)
9774 Whithorn Dr.
Houston,TX 77095
Tel: 281-859-0357
Fax: 281-859-7351

TEXAS EL-PASO
Iron Works
6709 Pasco Ct.
El Paso, TX 79905
Tel: 915-779-1086
Fax: 915-779-1086

VIRGINIA
Norm McCall
South of I-66 and 17.

WISCONSIN
BADGERLAND TRADING CO.
2500 S. 170th St.
New Berlin, WI 53151
E-mail: nancy@badgerlandtrading.com
Tel: 262-827-3177
Fax: 414-827-3170

OHIO
TBD

PENNSYLVANIA
JDL EQUIPMENT COMPANY, LLC
107 East Court Street
Doylestown, PA 18901
E-mail: jjdoyle3@hotmail.com
Tel: 215-489-0134
Fax: 215-489-1618

TEXAS
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2992 Oak Hollow Dr.
New Braunfels, TX 78132
E-mail: sarcoct@wireweb,net
Tel: 800-609-0212
Fax: 830-608-0350

UTAH, IDAHO, & WYOMING
Matt Fernandez
7459 South 2700 West
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INTERNATIONAL

BERMUDA

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ENVIRONMENT EQUIPMENT PTY LTD
P.O.Box 988
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CANADA
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331 Trowers Road, Suite # 3
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Fax: 905-850-9100

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Fax: 972-8-9428856

UNITED KINGDOM
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E-mail: mcmaster@wyenet.co.uk
web site: www.waterless.co.uk
Tel: 44-1380-729600
Fax: 44-1380-729888

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Suite #196, #48 Par-la-Ville Road
Hamilton HM 11
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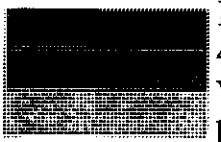
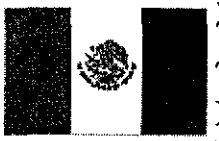
E-mail: a.lewis@ibl.bm
Tel: 441-295-6253
Fax: 441-295-9067



GERMANY
DRL HYGIENE SYSTEMS
Ellerstr. 101
40721 Hilden
Web: http://www.drl.de
E-mail: f.w.@drl.de
Tel: 2103-58790
Fax: 2103-587949



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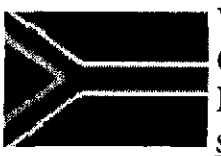
Tijuana, BC 22180
Tel: 52-66-370288
Fax: 52-66-379738
E-mail: asisibi@telnor.net
Web site: http://www.asisibi.com



SOUTH AFRICA
Sannitree LTD
13 Westlake Drive
Westlake Estates, Westlake
Cape Town 7967
E-mail: sannitree@mweb.co.za
Tel: 27-21-7011266
Fax: 27-21-7011299
Web site: www.sannitree.co.za

Thank you for choosing Waterless Co.

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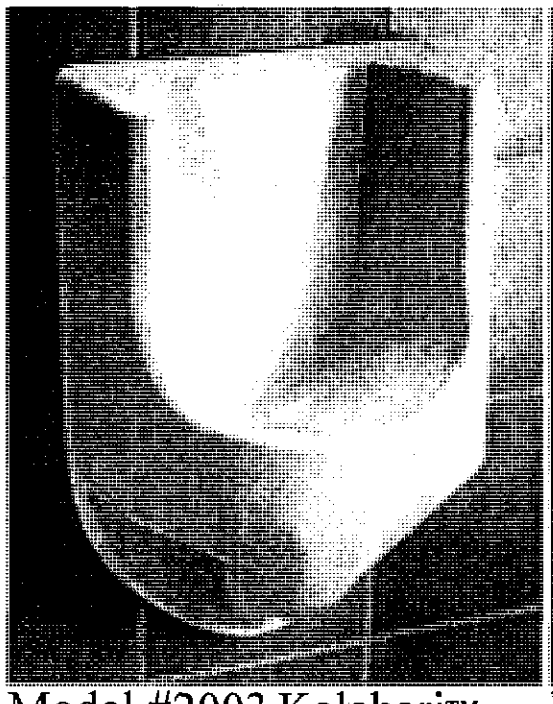
*EcoTrap® * Savings Evaluation * Specifications * Installation * Conservation * Federal Govt. & GSA Info * Contacting Waterless Co. * Rest Room Sanitation * Home * Press Release &*

WATERLESS NO-FLUSH™ URINALS

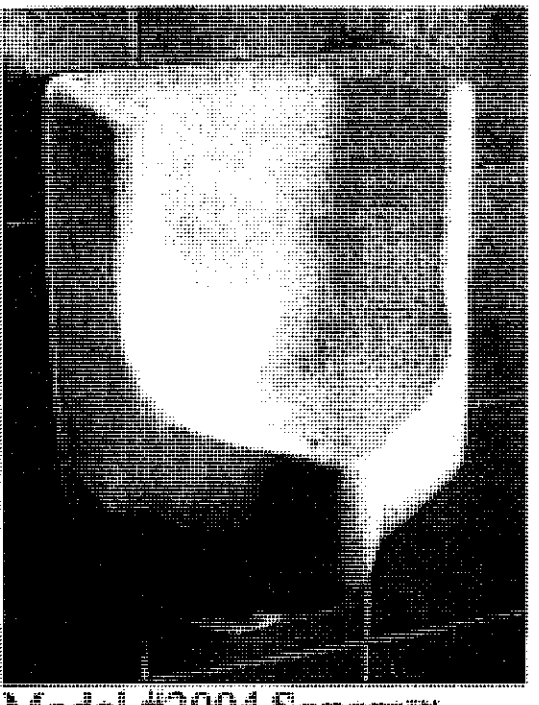
Español

NO-FLUSH™ NO-TOUCH™
THE WATERLESS ADVANTAGE™
SAVING GLOBAL WATER RESOURCES SINCE 1991

Waterless Co. urinals work **completely without water**. Waterless No-Flush™ urinals can be easily installed to **all restroom applications**. This fixture saves up to **45,000 gallons of water and more per year** per fixture. It greatly **reduces** typical urinal **maintenance and improves restroom sanitation.**

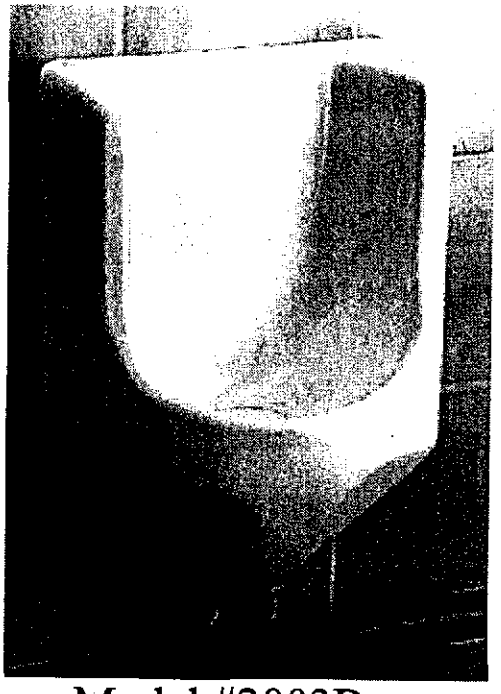


Model #2003 Kalahari™
Our Best Seller. (18"W x 28"L x 10"D)
Covers most urinal footprints.



Model #2004 Sonora™
ADA Compliant
(18"W x 28"L x 14"D)

STATE OF THE ART IN WATER CONSERVATION



Model #2003B
Kalahari™
Bottom Drain, Great for trough conversions. (18"W x 28"L x 10"D)
Also available as #2004B.

This is all our system needs. X-Traptor® Tool #4001, BlueSeal® Trap Liquid #1114 and EcoTrap® #3001.

Winner, *1995 Leadership in Water Conservation Award*
Promising Products Category, U.S. Department of the Interior

Voted ***Hottest Product*** by reader inquiries for 1998, American School and University Magazine

Sole National ANSI Standard ANSI Z124.9 tested Waterless Urinal

Our patented Waterless No-Flush™ urinals eliminate and/or minimize these common problems:

- **Urinal Odors**
- **Flush Valve Repairs**
- **Low Water Pressure**
- **Costly Flush Sensors**
- **Vandalism**
- **Line Encrustations**
- **Leaking Flush Valves**
- **Water & Sewer Costs**

- **Stoppages and Overflows**
- **Rest Room Shut Downs**
- **High Demand On Septic Tanks**
- **Mitigation for Water Usage**

HOW THEY WORK:

No-Flush™ urinals resemble conventional fixtures, and easily replace them. They install to the regular waste lines, but eliminate the flush water supply lines. Flush valves are eliminated as well; there are no handles to touch, no sensors, **no moving parts**! The urinal bowl surfaces are urine repellent; urine is 99% liquid and its drainage is effected without flush water. Daily cleaning procedures are the same as for flushed urinals.

The conventional water-filled urinal's trap drain is replaced by a disposable ***EcoTrap®*** inserted in the urinal outlet. It holds a layer of the immiscible BlueSeal® liquid floating on top of a urine layer. This combination trap seal blocks out sewer gases, and the covering BlueSeal® layer blocks out urine odors from the room. A 3-oz. dose of BlueSeal® lasts over 1500 uses, replacing at least 1500 or up to 4500 gallons of potable quality flush water!!

BlueSeal® is biodegradable and the EcoTrap® is recyclable.

A recent article written by the Energy and Engineering Department of the Secretary of Defense stated, "After a balanced consideration the Waterless urinal seems to be a water conservation fixture who's time has come. It clearly reduces maintenance costs, and may do so dramatically and immediately for some installations. For about the price of a flush urinal, you can automatically save 1.5 - 3 gallons of water per usage, depending on the model of flush urinal you're replacing." "In any new construction, or whenever you plan to replace a flush urinal, Waterless urinals should be given serious consideration."

Check here for more information on our products:

- ***EcoTrap®***
- ***Conservation***
- ***Installation***
- ***Specifications***
- ***Press Release***
- ***Savings Evaluation***
- ***Rest Room Sanitation***
- ***Federal Govt. & GSA Info***
- ***Contacting Waterless Co.***
- ***Request Information Via E-mail***

Thank you for contacting WATERLESS CO. On-line

Waterless Co. is the recognized leader in water conservation for urinal fixtures. This on-

line site contains information on how ***to contact us, locate representatives/showrooms***, and ***what savings to expect.*** For additional questions, problems with this site, or to send us an electronic message, please e-mail klaus@waterless.com.

BlueSeal®, EcoTrap®, X-Traptor®, Waterless™, Sinaqua™, No-Flush™, Kalahari™, Sonora™ and Baja™ are Trademarks of Waterless Co. Patent Pending. Made in USA.

Future Generations Will Appreciate Your Water Conservation Efforts.

Welcome to the WATERLESS CO. On-Line.
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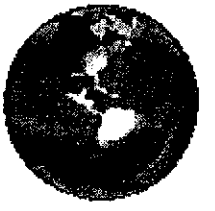
Español

WATER CONSERVATION



Conservation

The conservation of water has become a requirement for many facilities, cities, states and the federal government. This need is driven by three main reasons: the availability of water, current sewer capacity and rising costs or budget cuts.

Toilets and urinals are still flushed with potable water and it is estimated that up to 20% of the available drinking water in the world is flushed down the drain.

Waterless No-Flush™ urinals achieve zero water consumption.

A Waterless urinal saves on average 45,000 gallons of water a year . Twenty-two Waterless urinals save approximately 1,000,000 gallons of water per year. It can be estimated that there are 8 million urinals installed in the US alone with approximately 100 million people using these fixtures. Assuming an average 2 gallon flush, the potable water use of urinals in this country per year is approximately 160 billion gallons.

160 billion gallons of water is equivalent to the water usage of 490,000 homes or 1.9 million people per year. This vast amount of effluent to the sewer and septic systems can be eliminated and will not run into our natural waterways and oceans.

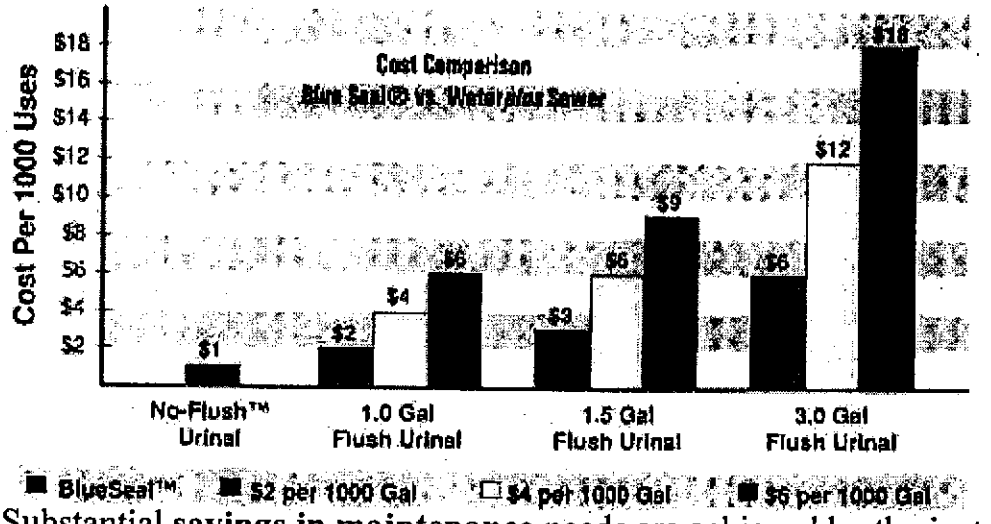
On your local level this could mean: A typical office building rest room with 3 urinals and 120 men equals a yearly water use of 237,000 gallons of potable water flushed down the drain. This assumes 3 uses per person per day and only 220 working days.

EcoTrap® * *Savings Evaluation* * *Specifications* * *Installation* * *Conservation* *

Savings Evaluation

Cost Benefits

The operating costs of No-Flush™ urinals are only about $1.00 per 1000 uses. Drastic operating savings result as shown below, compared with the water plus sewer costs of conventional urinals.



Substantial **savings in maintenance** needs are achieved by the installation of Waterless No-Flush™ urinals. These savings are:

- Flush Valve Repairs
- Waste Line Cleanouts
- Deodorizers
- Blockages
- Overuse of Water
- Overflows
- Urinal Screens
- Water Leaks

Pay back for a Waterless No-Flush™ retrofit is between one and three years, on water/sewer charges alone. The **savings on maintenance are additional.**

In new construction the **savings also include the deletion of a water feed line, flush valves and sensors.**

The cleaning of Waterless urinals is exactly the same as cleaning conventional urinals. Replenishments of BlueSeal® are accurately measured with a Portion Aid. Fill the Portion Aid and simply pour contents into the holes of the ***EcoTrap®***. The measuring device minimizes the waste of BlueSeal®.

Calculate your own savings:

Please ***CLICK HERE*** to go to the Economic Analysis Worksheets. They will help calculate your savings and returns on investment from installing Waterless No-Flush™ fixtures.

Note: The flushing urinals now being used in your facility are costing you for water, sewer and maintenance. These costs, now allocated in your budgets, can be converted to the purchase of Waterless urinals. Our leasing plan is available for municipal state and federal bodies. Your retrofit can pay its own way!

EcoTrap® * ***Savings Evaluation*** * ***Specifications*** * ***Installation*** * ***Conservation*** * ***Federal Govt. & GSA Info*** * ***Contacting Waterless Co.*** * ***Rest Room Sanitation*** * ***Home*** * ***Press Release*** &

Specifications

Español

Sample Specification Model 2003 Kalahari™:

Urinal

General

Waterless Co. No-Flush™ urinal Kalahari™, Model #2003. Wall hung urinal. Complies with ANSI Z124.9, CSA®, UPC®. Supplied vertical EcoTrap® insert required. Mount at 24" above finished floor to lip of urinal or as required by architect,ADAAG. Center drain line to be at 15.5" off finished floor. No carrier needed. Install and maintain as per manufacturer's instructions. Installs and drains to 2" waste. Retrofit or new construction. Color: Sanitary white. To be made of fiberglass reinforced Polyester®. Approx. Weight: 20 Lbs. Use standard sanitation practices to maintain fixture. Adequate BlueSeal® trap liquid to be maintained in EcoTrap® of urinal.

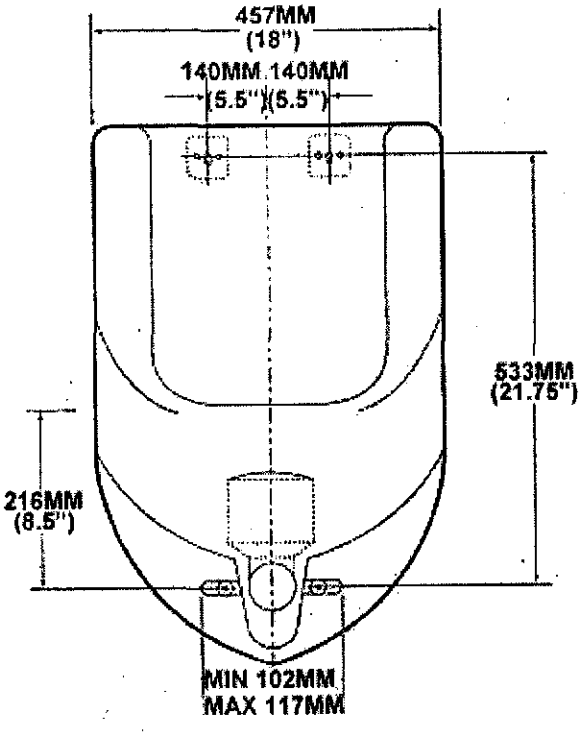
Furnished complete with:

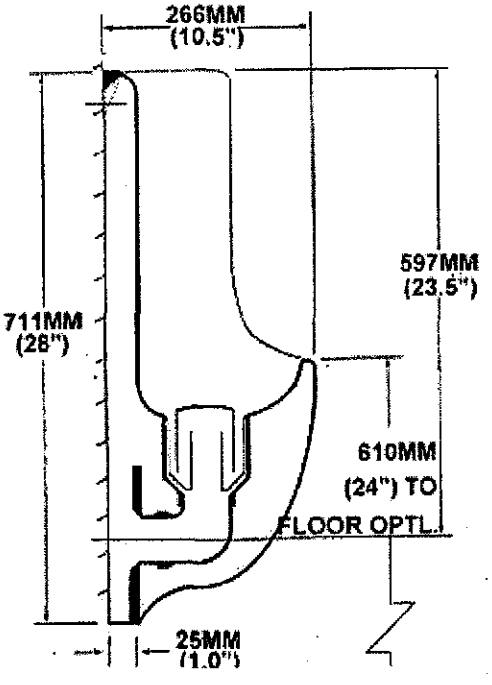
Two unit integrated wall hangers, AllFlange™ slots for flange bolts, fastening hardware, gasket and two EcoTraps®, vertical trap design..

Note:

Urinal is predrilled to accept most 2" brass flanges from other manufacturer's urinals in a retrofit scenario. For new construction specify to include brass flange for 2" waste. (Item #5001).

DIMENSIONS: 18"W x 28" H x 10.5" D





(MIN 4")
(MAX 7")

Model 2003 Kalahari™

Sample Specification Model 2003B, Bottom Drain, Also Model 2004B: General

Waterless Co. No-Flush™ urinal Kalahari™, Model #2003. Wall hung urinal. Complies with ANSI Z124.9, CSA®, UPC®. Supplied vertical EcoTrap® insert required. Mount at 24" above finished floor to lip of urinal or as required by architect,ADAAG. Center drain line to be at 15.5" off finished floor. No carrier needed. Install and maintain as per manufacturer's instructions. Installs and drains to 2" waste. Retrofit or new construction. Color: Sanitary white. To be made of fiberglass reinforced Polyester®. Approx. Weight: 20 Lbs. Use standard sanitation practices to maintain fixture. Adequate BlueSeal® trap liquid to be maintained in EcoTrap® of urinal..

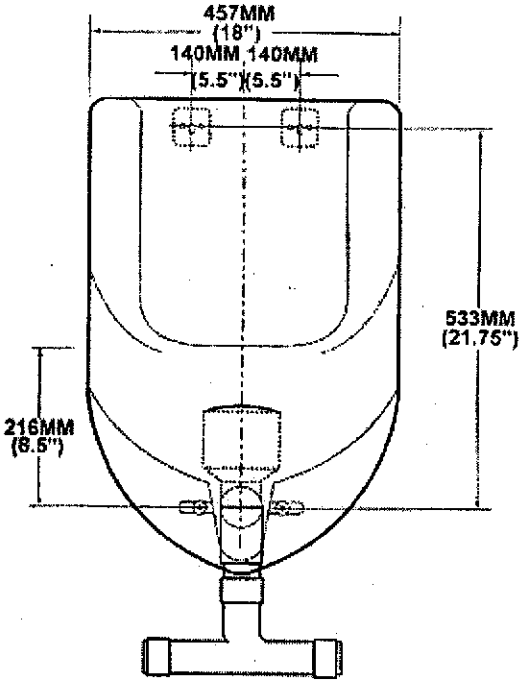
Furnished complete with:

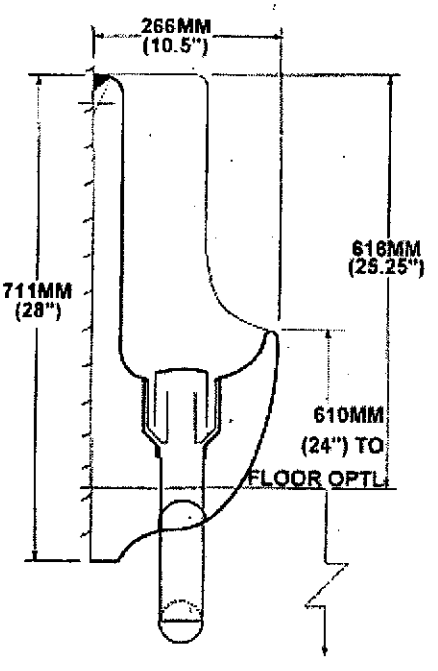
Two unit integrated wall hangers, AllFlange™ slots for flange bolts, fastening hardware, gasket and two EcoTraps®, vertical trap design.

Note:

Urinal is predrilled to accept most 2" brass flanges from other manufacturer's urinals in a retrofit scenario. For new construction specify to include brass flange for 2" waste. (Item #5001).

DIMENSIONS: 18"W X 28" H X 10.5" D





Model 2003C Kalahari™ (with bottom drain)

Sample Specification Model 2004 Sonora™:

Urinal-Handicap:

General

Waterless Co. No-Flush™ urinal Sonora™, Model #2004, elongated rim . Wall hung urinal. Complies with ADA, ANSI Z124.9, CSA®, UPC®. Supplied vertical EcoTrap® insert required. Mount at 17" above finished floor to lip of urinal or as required by architect,ADAAG. Center drain line to be at 8.5" off finished floor. No carrier needed. Install and maintain as per manufacturer's instructions. Installs and drains to 2" waste. Retrofit or new construction. Color: Sanitary white. To be made of fiberglass reinforced Polyester®. Approx. Weight: 20 Lbs. Use standard sanitation practices to maintain fixture. Adequate BlueSeal® trap liquid to be maintained in EcoTrap® of urinal.

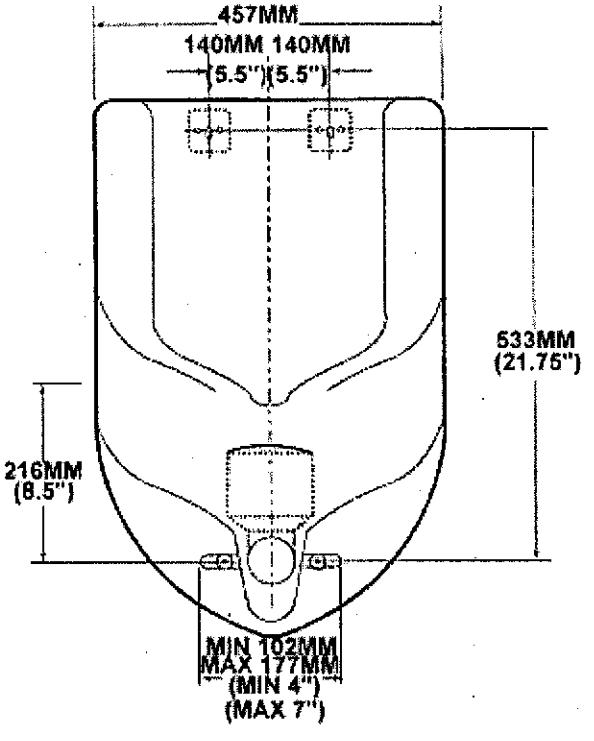
Furnished complete with:

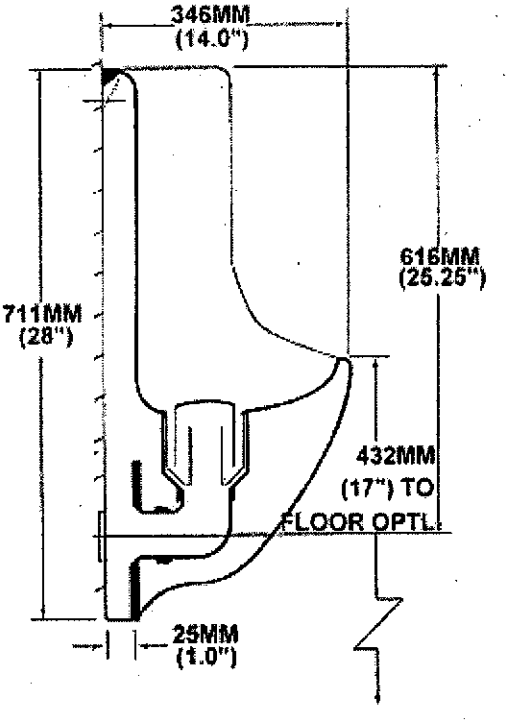
Two unit integrated wall hangers, AllFlange™ slots for flange bolts, fastening hardware, gasket and two EcoTraps®, vertical trap design.

Note:

Urinal is predrilled to accept most 2" brass flanges from other manufacturer's urinals in a retrofit scenario. For new construction specify to include brass flange for 2" waste. (Item #5001).

DIMENSIONS: 18"W x 28" H x 14" D





Model 2004 Sonora™

Waterless Urinals exceed current Federal requirements for urinal flushes of 1 gallon or less per flush.

Colors: Waterless No-Flush™ urinals are available in most colors or color schemes and can be matched to your color chips. Please contact our sales offices for more information and additional pricing for color urinals.

Listing of Standards and Approvals:
UPC®,CSA®,ANSI Z124.9 and others listed. Please call toll-free 888-NO-FLUSH for further information.

High tech is made simple. Why install flush valves or costly approach sensors?

Go NO-FLUSH™. Ideal for schools, parks, restaurants, offices, stadiums, theaters, fairgrounds and military.

Waterless Co. reserves the right to change product specifications without notice. No responsibility is assumed.

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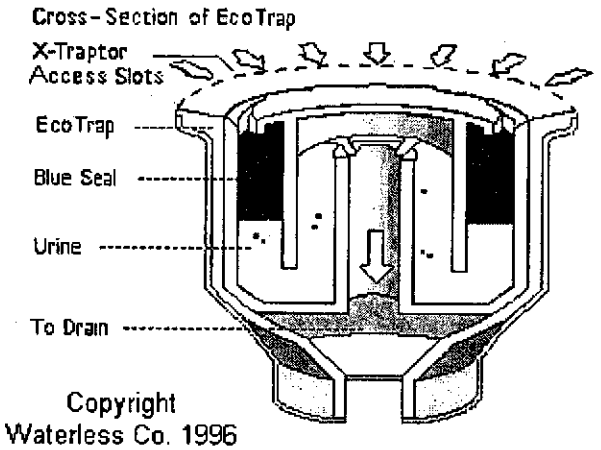
EcoTrap® Principle

Español



The patented EcoTrap® principle relies on the proven vertical trap principle.

1. Urine flows down into the EcoTrap® drain insert.

2. In the EcoTrap® the urine passes through a floating layer of **BlueSeal® liquid**, which forms a barrier that prevents sewer vapors from escaping to the rest room atmosphere.

3. Urine under the barrier layer overflows into the central tube and runs down to the conventional drain line.

4. The layer of approx. **3 ounces of BlueSeal®** will last for a minimum of **1500 sanitary uses**. The liquid is then simply replenished. Task time: 20 seconds. Trap does not need to be touched.

5. The EcoTrap® retains urine sediments and is easily replaced 2-4 times a year according to traffic to the fixture. A special tool, the X-Traptor®, is used to remove the EcoTrap®. This deters vandalism. Task time: 3-4 minutes.

6. Drain lines are free of encrustations. They are easily accessed by removing the EcoTrap® with the special X-Traptor® tool.
© 1996 WATERLESS CO.

The patented vertical EcoTrap® design provides superior efficiencies to other, more complicated trap arrangements.

*SAVES WATER * SEWER * MAINTENANCE CHARGES*

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Living Technologies

"The future lies in the miniaturization of nature and the building of living technologies" Dr. John Todd

Welcome to the Living Technologies web page! Living Technologies designs and builds "Living MachinesTM" – wastewater systems that naturally treat sewage and industrial waste to re-use quality. Our company realizes that fresh water is a limited resource. That is why it is important that we provide sustainable wastewater treatment systems in a cost effective, aesthetically beautiful manner. Living Technologies provides the system, nature does the work.

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431 Pine Street
Burlington, Vermont 05401

Tel: 1+802/865.4460
Fax: 1+802/865.4438
email: livetech@together.net

About Living MachinesTM | About Living Technologies | Representative Projects | Living MachinesTM | In the News | Visit a Living MachineTM | Contact Us! | Extended Family | Employment Opportunities | Education

Site Hosted by and Upcoming Redesign by Burlee Networks

Return to Representative Projects

Municipal Sewage Treatment in South Burlington, Vermont

Background:
Built in late 1995 and supported by the EPA through the Massachusetts Foundation for Excellence in Marine and Polymer Science, the South Burlington Living Machine was ramped up to full design flow by April 1996. Water chemistry data from an EPA certified, independent laboratory demonstrates the excellent performance of the treatment system even at very cold temperatures.

The Waste:
This Living Machine treats 80,000 gpd of municipal sewage, an amount typically generated by approximately 1,600 residential users. Average treatment performance for the year from August 1996 to July 1997:

Parameter	Influent	Target Effluent	Effluent
Chemical Oxygen Demand (mg/l):	454		31.3
Biochemical Oxygen Demand (mg/l):	219		5.9
Total Suspended Solids (mg/l):	174		4.8
Total Nitrogen (mg/l):	23		2.2
Total Kjeldahl Nitrogen (mg/l):	23	5	1.3
Ammonia (mg/l):	14.0	1	0.25
Total Phosphorous (mg/l):	4.8	2.2	
Fecal Coliform (col/100ml):	9,380,833		1177

The Process:
Sewage flows to a greenhouse housing two treatment trains, each with five aerobic reactors, a clarifier and three Ecological Fluidized Beds. The open aerobic reactors have diaphragm aerators and are planted with a variety of aquatic plant species in floating plant racks. BOD and TSS are reduced and ammonia nitrified in this stage of treatment. A clarifier follows the open aerobic reactors to settle solids.

Ecological Fluidized Beds in each train follow the clarifier for final polishing. The beds operate aerobically for BOD and COD polishing, nitrification, and suspended solids digestion. Anoxic denitrification with carbon addition is carried out in the second EFB in each train.

The Benefits:
Designed to achieve stable nutrient removal within a reduced footprint (6,400 sq. ft.), this Living Machine is proving to be a cost-competitive, alternative treatment system. With its aesthetic beauty and lack of offensive odor, this system is also compatible with a residential environment.

Quotes

South Burlington, Vermont Living Machine TM

"It is our hope that by studying human waste recycling in a beautiful, ecologically diverse and dynamic Living Machine, (humans) will begin to comprehend the meaning of natural systems in their lives. Equally important, it may allow them to engage with the natural world in sustaining the communities of tomorrow." *Dr. John Todd, Annals of Earth*

"Unlike anything born of the Industrial Revolution, Living Machines have the potential to organize, repair, and reproduce themselves. They offer a cheaper, cleaner, chemical-free alternative for containing and removing high-strength waste." *Blake Edgar, Pacific Discovery Magazine*

"Natural ecosystems are being developed by a small Vermont company to stimulate the natural purification process that occurs in ponds and marshes as a way to treat wastewater from industrial food processors to municipalities." *Molly Farrell, Biocycle*

"National Audubon contracted the best waste water treatment professionals available to design a new system." *Ed Carlson, National Audubon Society*

"Ecological engineers participate in the ecosystem design by providing choices of initial species as well as the starting physical conditions; nature does the rest." *W.J. Mitsch, Environmental Science and Technology*

"'As we move into the 21st century we all need to be developing ways to manage waste using ecological systems. Supporting projects like the Living Machine is consistent with a progressive and forward-thinking economic development strategy'" *Chuck Hafter, South Burlington City Manager*

"'Everywhere there's a Mars factory, we do our best to be a good neighbor -- providing jobs, not harming the neighborhood, and being sensitive to the environment around us. In 20 years of being a candy maker, [the Living Machine system] is the most interesting thing I've come across. Installing it has turned out to be a tremendous business decision. We've gotten good publicity, the system has never failed to work, and it helps our reputation and image. It's a win-win.'" *Mike Seago, Ethel M Chocolates*

"The congressmen listened incredulously as the ecological wastewater treatment 'living systems' process was described to them. It seemed too good to be true" *Edward Flattau, Burlington Free Press*

"We are moving into the age of living machines, not, as Corbusier noted, 'machines for living in.' The Thomas Edison of the future is not Bill Gates of Microsoft, but John and Nancy Todd" *Utne Reader*

"'We knew because of environmental tightening regulations on sister factories back East, that one day we had to do something. We wanted to be on the front edge of the wave, not on the trailing edge of the wave.'" *Mike Seago, Ethel M Chocolates*

"The real world is not made up of magic bullets, but of symphonies of organisms. There is a new kind of relationship that can turn the tragedy of the twentieth century around." *Dr. John Todd, Bioneers Conference*

National Audubon Society, Florida

"We believe in the wisdom of nature's design. We know that soil, water, plants, and wild creatures depend upon each other and are vital to human life. We recognize that each living thing links to many others in the chain of nature. We believe that persistent research into the intricate patterns of outdoor life will help to assure the wise use of earth's abundance. So we will be vigilant to protect wilderness areas, refuges, and parks and to encourage good use of nature's storehouse of resources." *A Statement of Audubon Philosophy from Corkscrew Swamp Sanctuary, A Self Guided Tour of the Boardwalk*

"'It [the Living Machine] simulates what happens in nature.'" *Ian Yolles, The Body Shop*

"While ultimately it is nature that designs the Living Machine, the human role is that of co-designer, which entails assembling the physical habitat, seeking out and replenishing the various biological forms that are seeded into the ecologically engineered environment and remaining attentive and sensitive to the natural processes." *Erik Ackerson, The Growing EDGE*

"' What is important about the technology is that it is modular in nature, and additions can be made as needed.'" *Shirley Gomes, Town Selectwoman*

"Thank you for letting us visit your plant. I've been on your tour 5 times and still like it! The waste thing was pretty interesting too." *Alisa Leib, age 7*

Ethel M Chocolates, Nevada

Living Technologies

Visit A Living Machine™

One of the most valuable ways you can learn about the Living Machine is to tour one of our treatment systems. We have Living Machines open to the public in four different areas. Please visit us at the following locations:

Ethel M Chocolates cactus garden Nevada

South Burlington, Vermont/EPA
802/660.8094

Ethel M Chocolates, Henderson, Nevada
702/458.8864

Findhorn Foundation, Forres, Scotland

Sonoma Mountain Brewery, Sonoma, California
707/935.4041 ext. 8588

The Body Shop, Toronto, Canada
416/441.4189

National Audubon Society, Florida

Living Technologies

ENN Environmental News Network DAILY NEWS

Plastics RESOURCE

Wastewater treatment innovators honored

Tuesday, June 9, 1998

A couple responsible for the innovation of a wastewater treatment system that utilizes bacteria, bugs and plants to purify industrial and municipal waste received the Lindbergh Award for 1998.

Courtesy Ocean Arks International

Dr. John Todd is famous for his patented onsite wastewater treatment system, the Living Machine.

Dr. John H. Todd and Nancy Jack Todd, the first couple to receive the award, were recognized for their work in the field of environmental engineering.

The Charles A. and Anne Morrow Lindbergh Foundation's Lindbergh Award goes to an individual who has contributed to environmental preservation in the spirit of Charles Lindbergh's life mission to "discern nature's essential wisdom and combine it with our scientific knowledge."

John Todd is famous for his patented onsite wastewater treatment system, the Living Machine. The system uses sunlight, a controlled environment and nature's bounty, including bacteria, zooplankton, plants, snails and fish, to break down organic pollutants in wastewater. The treated water is used for irrigation, recycled back into toilets, or discharged harmlessly back into municipal waste systems.

The Living Machine is sold through the Todd's company, Living Technologies, and has been installed in greenhouses or on bodies of water at a variety of sites in the United States, Australia and the United Kingdom.

One machine treats wastewater at a chocolate factory in Las Vegas, Nev. "By treating our wastewater, we can save 20,000 gallons of this precious commodity each day. The technology is simple, reliable, easy to operate and cheaper to build and run than conventional treatment plants," said Ethel M Chocolates's plant manager Mike Seago.

Todd, speaking about his mission for the Living Machine, has said, "What is needed is a fundamental technological revolution that will integrate advanced societies with the natural world to the mutual benefit of both. Pollution, atmospheric alteration, and the loss of soils and biotic diversity are artifacts of technological cultures estranged from the great natural systems of the planet. Modern cultures exploit the natural world and in so doing threaten their own long-term viability. It is essential that we create a truly symbiotic relationship with nature."

That relationship, in Todd's mind, is embodied by the Living Machine.

Beyond her duties as vice president of the Todd's company Ocean Arks International, Nancy Jack Todd is the editor and publisher of a highly acclaimed journal on ecological engineering.

In nominating the Todds for the Lindbergh Award, the foundation's vice president, Clare Hallward, said, "Nancy Jack Todd is a writer and the editor of Annals of Earth, published three times a year and distributed worldwide. It is a highly intellectual forum for the presentation of leading edge environmental thought -- with an international roster of scholarly, philosophical and ecological writers who deal with planetary issues from a wide range of perspectives."

Previous winners of the Lindberg Award include Neil Armstrong, Dr. Sylvia Earle, Sir Edmund Hillary and Captain Jacques-Yves Cousteau. The award has been given annually since 1978. The Todds were presented with the award on May 20.

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Talk Back!

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- Engineers to test biotrickling filtration unit
- Wetlands remove pathogens from water
- Constructed wetlands help clean up Texas coast

Related sites:

- Living Technologies
- Lindbergh Foundation

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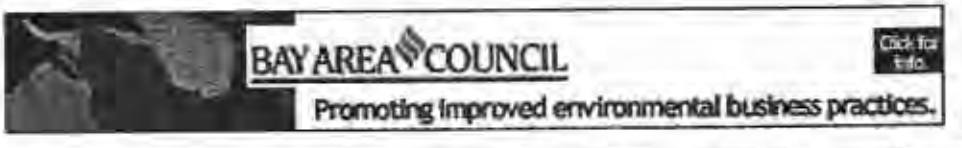

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U.S. ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NORTH CAROLINA
18 JUNE 1997

WASTE MATERIALS MANAGEMENT AND RECYCLING SECTION 01690

PART 1 GENERAL

1.1 RELATED DOCUMENTS:

A. Drawings and general provisions of each prime Contract, including General and Supplementary Conditions and other Division 1 Specification Sections, apply to this Section.

1.2 SUMMARY:

A. This Section includes required salvage and recycling of the following waste materials and applies to all such listed waste materials produced during the course of this Contract:

1. Land Clearing Debris: Solid waste generated solely from land clearing operations, such as stumps and trees.

a. See Division 2 "Site Clearing" section for requirements for salvage and processing of designated materials to produce mulch for use in landscape construction for this project. Material required for production of landscape mulch is not classified as "land clearing debris.

2. Concrete, Masonry, and Other Inert Fill Material: Concrete, brick, rock, clean soil not intended for other on-site use, broken up asphalt pavement containing no ABC stone, clay, concrete, or other contaminents, and other inert material.

3. Metals: Metal scrap including iron, steel, copper, brass, and aluminum.

4. Untreated Wood: Unpainted, untreated dimensional lumber, plywood, oriented strand board, masonite, particleboard, and wood shipping pallets.

5. Gypsum Wallboard Scrap: Excess drywall construction materials including cuttings, other scrap, and excess materials.

6. Salvaged Materials: Reusable lumber, fixtures, and building supplies

7. Cardboard: Clean, corrugated cardboard such as used for packaging, etc.

8. Paper: Discarded office refuse such as unwanted files, correspondence, etc.

9. Plastic Buckets: Containers for various liquid and semi-solid or viscous construction materials and compounds.

10. Beverage Containers: Aluminum, glass, and plastic containers.

11. Other Mixed Construction and Demolition Waste: Solid waste resulting solely from construction, remodeling, repair, or demolition operations on pavement, buildings, or

other structures exclusive of waste materials listed herewith.

B. Non-Recyclable Waste: Collect and segregate non-recyclable waste for delivery to a permitted landfill site.

1. Mixed Solid Waste: Solid waste usually collected as a municiple service, exclusive of waste materials listed above.

C. Hazardous Waste: Control and disposal of hazardous waste is specified in Division 1 "Environmental Protection" section.

1.3 DEFINITIONS:

A. Waste Materials are defined as large and small pieces of the materials indicated which are excess to the contract requirements and generally include materials which are to be salvaged from existing construction and items of trimmings, cuttings and damaged goods resulting from new installations, which can not be effectively used in the Work.

1.4 SUBMITTALS:

A. Construction Waste Management Plan: Before start of construction, submit for the approval of the Contracting Officer's Representative a construction waste management plan indicating how Contractor proposes to collect, segregate, and dispose of all construction wastes and debris produced by the work of this Contract. Show compliance with regulations specified under "Quality Assurance" article below. Include a list of recycling facilities to which indicated recyclable materials will be distributed for disposal. Identify materials that are not recyclable or otherwise conservable that must be disposed of in a landfill or other means acceptable under governing State and local regulations. List permitted landfills and/or other disposal means to be employed. Indicate any instances where compliance with requirements of this specification does not appear to be possible and request resolution from the Contracting Officer through the Contracting Officer's Representative.

B. Delivery Receipts: Provide to the Construction Quality Manager delivery receipts for waste materials salvaged and sent to permitted waste materials processors or recyclers within 48 hours of delivery that indicate the location and name of firm accepting recyclable waste materials, types of materials, net weights of each type, date of delivery and value of materials.

1.5 QUALITY ASSURANCE:

A. Regulatory Requirements: Comply with all applicable requirements of State of North Carolina Department of Environment, Health, and Natural Resources Policy Memorandum #16 Concerning Management of Construction, Demolition, Land Clearing, Inert, and Yard Trash Debris and any and all subsequent modifications and amendments to same.

1. Comply with applicable local ordinances and regulations in addition to the above.

B. Disposal Sites, Recyclers, and Waste Materials Processors: Use only facilities properly permitted by the State of North Carolina, and by local authorities where applicable.

C. Pre-Construction Waste Management Conference: Prior to beginning work at the site, schedule and conduct a conference to review the Construction Waste Management Plan and discuss procedures, schedules and specific requirements for waste materials

recycling and disposal. Discuss coordination and interface between the Contractor and other construction activities. Identify and resolve problems with compliance with requirements. Record minutes of the meeting, identifying all conclusions reached and matters requiring further resolution.

1. Attendees: The Contractor and related Contractor personnel associated with the work of this section, including personnel to be in charge of the waste management program; the Construction Quality Manager; the Contracting Officer; the Contracting officer's Representative; and such additional Government personnel as the Contracting Officer deems appropriate.

2. Plan Revison: Make any revisions to the Construction Waste Management Plan agreed upon during the meeting and incorporate resolutions agreed to be made subsequent to the meeting. Submit the revised plan to the Contracting Officer's Representative for approval.

D. Implementation: Designate an on-site party responsible for instructing workers and implementing the Construction Waste Management Plan. Distribute copies of the Construction Waste Management Plan to the job site foreman and each subcontractor. Include waste management and recycling in worker orientation. Provide on-site instruction on appropriate separation, handling, recycling, and salvaging methods to be used by all parties at the appropriate stages of the work at the site. Include waste management and recycling discussion in pre-fabrication meetings with subcontractors and fabricators. Also include discussion of waste management and recycling in regular job meetings and job safety meetings conducted during the course of work at the site.

E. Resources: The Triangle J Council of Government Guide to Construction and Demolition Waste Recycling and Disposal in the Triangle is available by mail, free of charge (FAX request to Triangle J Construction and Demolition Waste Task Force at 919+549-9390).

The Triangle J Construction and Demolition Waste Task Force and the North Carolina Department of Environment, Health, and Natural Resources Division of Pollution Prevention and Environmental Assistance will also provide technical consultation for developing and implementing the Construction Waste Management Plan.

1.6 STORAGE AND HANDLING:

A. Site Storage: Remove all indicated recyclable materials from the work location to approved containers daily. Failure to remove waste materials will be considered cause for withholding payment and termination of Contract.

B. Position covered containers for recyclable waste materials at a designated location on the Project Site. Select a location for the recyclable materials containers separated from that of general waste and rubbish containers. Provide separate collection containers for minimum of the following materials:

1. Untreated lumber.
2. Gypsum wallboard.
3. Paper, paper products, and cardboard.
4. Plastics.
5. Metals.
6. Glass.
7. Other salvageable materials.

C. Change out loaded containers for empty ones as demand requires, but not less than weekly.

D. Handling: Deposit all indicated recyclable materials in the containers in a clean (no mud, adhesives, solvents, petroleum contamination), debris-free condition. Do not deposit contaminated materials into the containers until such time as such materials have been cleaned.

E. If the contamination chemically combines with the material so that it can not be cleaned, do not deposit into the recycle containers. In such case, request resolution by the Construction Quality Manager as to disposal of the contaminated material. Directions from the Construction Quality Manager do not relieve the Contractor from compliance with all legal and regulatory requirements for disposal, nor shall such directions cause a request for modification of the Contract.

1.7 PROJECT/SITE CONDITIONS:

A. Environmental Requirements: Transport recyclable waste materials from the Work Area to the recycle containers and carefully deposit in the containers without excess noise and interference with other activities, in a manner to minimize noise and dust. Reclose container covers immediately after materials are deposited.

1. Do not place recyclable waste materials on the ground adjacent to a container.

B. Existing Conditions: Coordinate with "Instructions to Bidders" and "Supplementary Conditions".

PART 2 PRODUCTS (Not Used)

PART 3 EXECUTION

3.1 WASTE MANAGEMENT:

A. General: Implement waste management procedures in accordance with approved construction waste management plan. Maintain procedure throughout the life of this Contract.

B. Source Separation: Separate, store, protect, and handle at the project site all identified recyclable and salvageable waste products to prevent contamination of materials and maximize recyclability and salvageability of materials.

C. Arrange for the regular collection, transport from the site, and delivery to respective approved recycling centers of indicated recyclable waste materials. Maintain records accessible to the Contracting Officer's Representative for verification of construction waste materials recycling.

D. Delivery Receipts: Arrange for timely pickups from the site or deliveries to approved recycling facilities of designated waste materials to keep construction site clear and prevent contamination of recyclable materials. Keep and maintain records of all deliveries to recycling facilities and all pickups of waste materials at the site by others as specified above.

3.2 RECYCLABLE WASTE MATERIALS HANDLING:

A. General: The following paragraphs supplement handling requirements for various of the materials identified for classification and recycling listed in Part 1 "Summary" article above.

B. Paper: Classify and handle waste paper goods as follows:

1. Bond Paper: As generally found in the construction offices and used for specifications, correspondence, copiers, PC laser printers and FAX machines. Collect in a separate container at each workstation and deposit loose in the appropriate recycle container daily.

2. Newsprint: Newspapers and tabloid style advertising (slick finish magazines and advertising materials are not typically recyclable). Collect in a single location and deposit daily in the appropriate recycle container.

3. Diazo Prints (drawings): Set up a single location for collection. Roll together to minimize space. Deposit daily in the appropriate recycle container.

C. Packaging materials:

1. Cardboard and paperboard cartons and boxes: Knock-down, fold flat and deposit in the appropriate recycle container.

2. Paper packing materials (separators, stiffeners, etc.) shall be placed in the same container.

3. Newsprint, used as packing (shredded or whole), shall be deposited in the recyclable container for newsprint.

4. Plastic (polystyrene peanuts and other shapes) shall be deposited in the recyclable container for plastics.

5. Metal and plastic banding materials shall be deposited in the appropriate container.

D. Metals: Cut all items to lengths and sizes to fit within the container provided, when necessary. Where there is sufficient quantity of a specific recyclable waste item (for example; salvaged metal roofing or duct work), make special arrangements for items to be bundled, banded or tied, and stack in a designated location for a special pick-up. Coordinate all special arrangements with the Construction Quality Manager.

E. Plastics: Collect recyclable plastics (polystyrene and others specifically marked for recycling) daily from work areas and deposit in designated containers.

F. Glass: Remove waste glass products (sheet, bottles, etc.) daily from the work area and deposit in designated containers. Where glass containers are marked for separation by color or type, segregate glass accordingly. Glass containing imbedded wire (typical in some fire rated doors having glazed lights) is usually not reprocessed; verify with the Construction Quality Manager that wire glass is not recyclable.

G. Gypsum Wallboard: Separate gypsum wallboard from other wastes. Dispose of waste gypsum wallboard off-site at a gypsum reclamation or recycling facility, or on-site as a soil amendment.

1. For on-site application as a soil amendment, incorporate waste gypsum wallboard in landscape areas under construction, at a rate of 50 pounds per 1000 square feet, or

approximately one ton per acre.

a. Material must be unpainted gypsum wallboard from new construction, ground to reduce material to a fine particle size (70% passing a 100 mesh screen), and must be fully incorporated into the soil surface.

b. The above specified application rate may be increased if a soil analysis is reviewed by, and approval granted from the Solid Waste Section, North Carolina Department of Environment, Health, and Natural Resources.

H. Other Items: Where recyclability classification of any given waste material is unclear, verify with the Construction Quality Manager.

END OF SECTION 01690

Feature

May/June 2001 Issue

High Volume Flyash: A Concrete Solution

By Scott Shell

Using high percentages of flyash has been shown to effectively and economically improve the durability of concrete.

Flyash is a byproduct of coal burning power plants — the ash that flies up their smokestacks and gets captured in giant filters. The US produces about 60 million tons of flyash every year, and around 70% of it goes to landfills. This adds up to about 400 pounds per year for every one of us, so as the years tick by, we're all building quite a stockpile.

While efforts are under way to promote cleaner sources of power, coal burning power plants will likely continue to exist for quite a while. Luckily, the flyash they produce doesn't have to end up in a landfill. Instead, it can be used to produce a stronger, more durable and more environmentally friendly concrete.

When used in concrete, flyash acts like cement, and actually replaces a percentage of the Portland cement normally used. Flyash also looks like Portland cement, although on the west coast it's a bit lighter and warmer in color. Concrete with high percentages of flyash looks and finishes the same as regular concrete, with a few minor adjustments. Flyash already replaces around 15% of cement in much of the concrete used today, but we can do much better by using it to replace 50% or more.

Environmental Impacts of Concrete

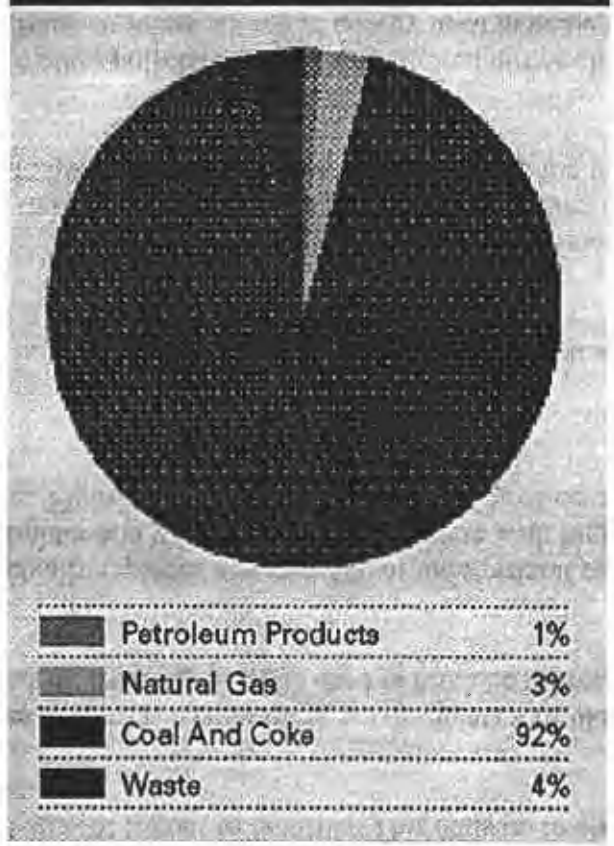
The main ingredients in concrete are gravel and sand, bound together in a paste of Portland cement and water. While cement comprises only around 13% of concrete, it is responsible for most of concrete's environmental impacts.

Cement is made by heating limestone and other minerals to 2700°F in a huge rotary kiln. This process requires enormous amounts of fossil fuels, with all of their associated impacts, including mining, transportation, spills, depletion of natural resources, and emissions of particulates, sulpher and nitrous oxides, and carbon dioxide (CO_2). In this article, we'll focus on carbon dioxide (CO_2), the primary greenhouse gas that causes global warming.

CO_2 is released any time a fossil fuel is burned. Unlike other pollutants, it can't be filtered out or eliminated by burning more cleanly — it is the natural product of perfectly efficient combustion. The most common source of energy used in cement kilns is coal, which produces more CO_2 than other fossil fuels (see Figure 1). For every ton of cement produced, about 1400 pounds of CO_2 are released because of the energy used. Additional CO_2 is produced through the chemical reaction that takes place inside the kiln. The heat in the kiln transforms the limestone ($CaCO_3$) into lime ($CaO + CO_2$), and this reaction releases around 1000 pounds of CO_2 per ton of cement.

Altogether, over one ton of CO2 is released into the atmosphere for every ton of cement produced. It's hard to visualize a ton of CO2 since it is an invisible gas, but if we could separate the two oxygen atoms from the carbon atom, we'd be left with 545 pounds of pure black carbon. Multiply this by the 1.5 billion tons of cement produced every year and you start to get a feel for the size of the problem. In fact, the cement industry alone is responsible for 7 to 8% of all the CO2 we produce in the world — an amount equal to the CO2 emissions of 330 million cars driving 12,500 miles per year.

Figure 1. CO_2 Emissions of Primary Fuels Used for Making Cement



Those of us in the business of designing and building buildings can make a major contribution toward solving the global warming problem by replacing half of the cement we use with a waste product that's currently going to the landfill. It doesn't cost any more, and it works better. All it takes is a little education and very healthy dose of perseverance.

How Flyash Works

The archenemy of concrete is water, which attacks concrete at its weakest point — where the aggregate and the cement meet. Large planar crystals (calcium hydroxide) typically exist next to the aggregate in concrete. These large crystals are very weak and tend to crack. As these cracks interconnect, the concrete becomes permeable, allowing water to seep in. The water carries salt and other elements and begins to corrode the rebar. This causes cracking and spalling, which lets in yet more water, and the cycle gets continually worse.

When flyash is added to the mix, the silica in the flyash reacts with these large crystals and transforms them into more of the very same strong cement paste (calcium silicate hydrate) that binds the concrete together (i.e., the silica in flyash combines with the calcium hydroxide crystals to form more calcium silicate hydrate paste). This eliminates the microcracking and creates concrete that is much less permeable, and therefore much more durable.

Using high percentages of flyash is the most effective and economical way to improve the durability of concrete — more effective and far more economical than epoxy coated rebar or exotic admixtures in the concrete. A potent illustration of the effectiveness of flyash are the Roman structures

that are still standing after 2000 years. The Pantheon and other concrete-roofed structures used volcanic ash similar to flyash for their concrete, and these structures remain strong.

Mix Design

Flyash starts out as impurities in the coal used to fire electric power plants. These impurities can't be burned, so they melt and turn into tiny beads of glass that are carried up the flue and captured. Flyash exists in a number of different chemistries and classes, but it is primarily the particle size that is important. The average particle size of flyash is about 20 microns, which is similar to the average particle size of Portland cement. Particles below 10 microns provide the early strength needed in concrete, while particles between 10 and 45 microns react more slowly. Most flyash supplied to the concrete industry contains less than 15 to 20% of the larger micron particles, and more than 40% of the 10-micron or smaller particles, easily exceeding the standards needed to produce excellent concrete.

The key to successfully using flyash in concrete is in the mix design — how the flyash is combined and proportioned with the other ingredients. The mix design will vary from one supplier to the next since it depends on the mineralology of the materials being used, including the chemical composition and other characteristics of the cement, sand and aggregates. Any mix design should be tested before it is used in a project to see how it performs.

While most concrete incorporates up to 15% flyash, studies have shown that high percentages (50% or more) must be used to obtain the maximum performance benefits (i.e., reduced permeability and increased durability). This results in a product known as "high volume flyash" (HVFA) concrete. In the past, builders have been reluctant to use high percentages of flyash because it reacts slower than Portland cement, providing the potential for slight delays in construction time. However, the mix can be designed to compensate for the different reaction speed by keeping the total amount of water very low.

There are two ways to accomplish this objective. The first, pioneered by CANMET in Canada, uses superplasticizers to get the necessary workability in the concrete while keeping the water content very low (0.32 water-cement ratio). A typical CANMET mix design includes up to 60% flyash, as shown in Table 1. Because the cement content in this mix is less than 300 pounds, the setting time is somewhat longer than that required for a typical concrete mix. However, it generally produces adequate strength (10 Mpa or 1500 psi) within one day, which is acceptable in the building industry. While this mix results in a durable, environmentally friendly concrete, the superplasticizers are expensive.

Table 1. Mix Design Comparison

Mehta HVFA mix design	CANMET HVFA mix design
Water = 240 lbs/CY	Water = 191 lbs/CY
Portland Cement = 300 lbs	Portland Cement = 208 lbs
Flyash = 300 lbs	Flyash = 275 lbs
Coarse Sand = 1,400 lbs	Fine Aggregate = 1333 lbs
3/8" Gravel = 400 lbs	
3/4" Rock = 1,500 lbs	Coarse Aggregate = 1950 lbs
Water Reducer = 5 oz/100 lbs cement (Pozzolith 322-N)	Superplasticizer = 3.0 liters/m3 cement

The second method, pioneered by Dr. P.K. Mehta in San Francisco, CA, uses a slightly higher water-cement ratio (0.45), 50% flyash and a common water-reducing admixture (see Table 1). Mehta found that when used in high percentages, the flyash itself acts like a superplasticizer — no other superplasticizers are required. Mehta also discovered that early strengths are determined only by the amount of water in the concrete and the cement type. As long as the concrete contains at least 300 pounds of high early strength cement and a low enough water content, the HVFA concrete will give reasonably good strengths even at an early stage.

Some building codes haven't kept up with the technology and limit the use of flyash to 15 or 20%. However, using such a low amount of flyash gives only about 6 to 7% reduction in water. Using 50% or greater flyash allows a 20 to 25% reduction in the amount of water used, and the low water content enables the mix to achieve the early strengths, long-term durability and economic value required in construction. Collecting available data on the subject and presenting it to the local building code officials, as well as ensuring that everyone on the construction team — especially the project engineer — is educated and on board, will generally prevent any problems from occurring with the building department.

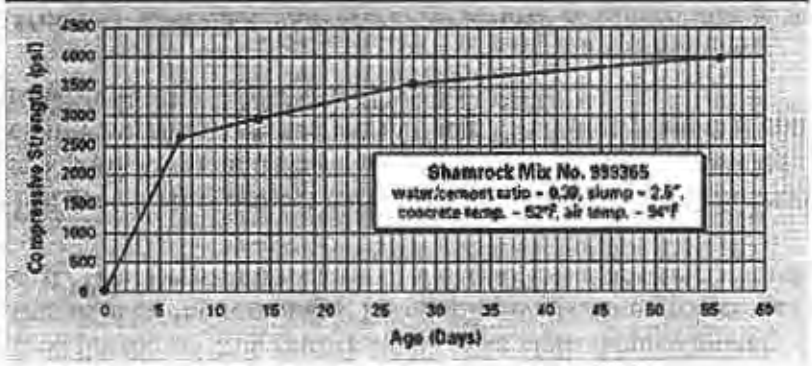
Using Flyash in Your Projects

Once you've decided to use flyash, how do you go about getting it into your projects? First, find a ready mix supplier that is willing to work with you. In the San Francisco area, several ready mix suppliers have experience working with flyash in concrete. If you do not have an experienced supplier nearby, obtaining HVFA concrete may take some effort and perseverance. Some ready mix suppliers don't have the time or resources, while others are wary of something new or just aren't interested. But then there are other people, such as Burt Lockwood at Shamrock Materials, who really get excited about it and do some great pioneering work. It helps if the supplier has some technical expertise and possibly even their own testing lab since tests will be required. (If the cost of testing is an issue, see if your client, a local coal burning utility, or the flyash supplier in your area can pay for that.)

Next, a good mix design is critical. Suppliers, like most of the rest of us, are great believers in their own common sense. But that common sense usually doesn't translate into HVFA mix designs that work very well. This is a new way of designing mixes, and the usual rules don't apply. The mix will vary as the source of materials vary, so the mix designs have to be adjusted for each plant. It is essential that you get a little expert advice from someone who has worked with HVFA mixes before.

We typically identify the local supplier and have them fax us the properties of their raw materials. We forward that to our expert consultant who then designs the mix. The consultant then spends a half-day or so with the supplier's mix designer, explaining how these mixes work, educating them, mixing up a test batch, and tweaking it for workability. A series of test cylinders are cast and then tested at 7, 14, 28, and 56 days (see Figure 4). If the results look good, we move on to the fieldwork. We've been working with Dr. Mehta, who usually needs less than eight hours to complete all of these steps, so it's a very inexpensive investment.

Figure 4. HVFA Mix Test Results



HVFA concrete mixes may gain strength slightly slower than ordinary mixes, but they continue to gain strength for a longer period of time and ultimately end up significantly stronger. It is easy enough to adjust the mix proportions to get whatever early strength is required, but remember that the goal is to keep the total amount of cement to a minimum. Ordinary mix designs typically include 15% or more extra cement just to be certain they will reach the specified strength in 28 days. To reduce this over-design, our structural engineers have in some cases allowed the specified strengths to be met in 56 days, or required that the average of all cylinder breaks meet spec in 28 days, with all cylinders exceeding it in 56 days. These mixes can slow the set a bit as well, so caution should be exercised in cold weather. In slab applications, this can affect how long the finishers have to wait to begin their work. Also, since these mixes are very low in water content, the finishers can't always rely on the amount of bleed water visible on the slab to tell them when they can start finishing. In formed applications, it can slightly delay form strip times or increase hydrostatic pressure on the forms.

A lot of contractors will get nervous upon hearing these caveats, but these are not major issues, and we haven't had a problem with these issues so far. Again, the mix can be designed to set more quickly, but fewer of the performance and environmental benefits are achieved.

Applications

HVFA mixes can be used for most applications. For example, the Lui Center in Vancouver successfully used 50% flyash for all structural elements. (Case studies of this and other projects can be found at www.ecosmart.ca.) We've concentrated on applications that reduce the possible complications. For example, footings and foundations are not usually exposed to view, and concrete in forms does not need to be troweled and finished. This gives everyone on the team a chance to get some experience working with the mix, and also gives us a chance to cast an additional series of test cylinders, without having to worry about too many things at once. We want to gain experience and build confidence, and not have a hastily considered project give high volume flyash a bad name. We do mock-ups or test pours in concealed locations first so the finishers can get a feel for how the HVFA mix works and how fast it cures.

Once on the jobsite there are a couple of things to remember. The key to getting good strengths is to keep the water content very low. This means not adding water at the jobsite. If a higher slump is needed, use more of the water-reducing admixture — do not add more water. Also, curing is very important for all concrete and is rarely done adequately. If you want good quality concrete of any kind, and especially HVFA concrete, good curing is essential, preferably wet curing.

The construction industry always seems to resist change, but this, by definition, prevents improvement. It will take some perseverance to get everyone on the team educated about high volume flyash, but it is perfectly feasible. When we started discussing the idea a couple of years ago, all the engineers, contractors and suppliers we talked to said it wasn't possible. Today, some of those same skeptics have begun specifying HVFA concrete and are now some of its biggest proponents.

References

1. www.epa.gov/globalwarming/index.html
2. www.buildinggreen.com/features/flyash/index.html
3. Fly Ash in Concrete, V. M. Malhotra and A. A. Ramezanianpour, 2nd ed., CANMET.
4. Mehta, P.K., "Role of Flyash in Sustainable Development," Concrete, Flyash and the Environment Proceedings, December 8, 1998, pp. 13-25.
5. Forthcoming guide by Mehta and Malhotra, "High Volume Flyash: Materials and Construction Practice."

Editor's note: A list of projects using HVFA concrete, as well as other supplemental information, can be found with this article online at www.EDCmag.com.

About the Author: Scott Shell is an Associate at EHDD Architects in San Francisco. He has served as project manager on a number of projects that emphasized sustainable design. Recent projects include Croul Hall lab, UC Merced Library programming, Ross Middle School, and Menlo College Library. He can be reached at Scott.Shell@EHDD.com.

Projects Using High Volume Flyash Concrete

Wurster Hall, U.C. Berkeley: Cement is the most expensive ingredient in the concrete, so flyash can lower the cost of the concrete. In other cases, if the supplier isn't interested in trying something new, there may not be any cost savings. At U.C. Berkeley, over 2000 CY of HVFA concrete were used for the seismic retrofit of Wurster Hall. Approximately 600 CY were used at the east tube, another 700 were used at the west tube, and the rest was used on the remaining foundation walls. The project was publicly bid with the 50% flyash concrete as an alternate so we would know what it cost. The alternate bid came in $13,000 less than the standard mix design, so the HVFA was chosen for this project.

The spec on this project required 4,000 psi concrete at 56 days. The supplier had not worked with HVFA concrete before and designed a conservative mix with 330 pounds each of cement and flyash. The test results averaged over 5,000 psi at 28 days, and will likely exceed 7,000 psi at 56 days. The contractor and workmen were brought in on the planning, and placement went very smoothly with good slump and workability. The matt was only roughly finished since it will not be visible.

Architect: EHDD Architecture; Structural Engineer: Rutherford & Chekene, Afshar Jalalian; Concrete Supplier, Berkeley Ready Mix.

* * * * *

Barker Hall, U.C. Berkeley: A seismic upgrade on this six-story 1960s research lab building is just beginning construction. 50% flyash is being used in the foundation and in numerous walls and other locations.

Architect: Anshen & Allen; Structural Engineer: Forell/Elsesser, Mason Walters, 415-837-0700; Concrete Supplier, Berkeley Ready Mix.

* * * * *

GAP Office Building: One of the first projects in the Bay area to use 50% flyash concrete was a new office building for the GAP. It included 50% flyash mixes in pile caps and some additional foundation areas, and 35% flyash in some other locations.

Architect of Record: Genlser; Structural Engineer: Middlebrook &Louie, Ron Middlebrook, 415-546-4900; Concrete Supplier: Bode Gravel Company.

* * * * *

The Liu Centre, University of British Columbia; and The British Columbia Gas Coastal Facilities Office Building: These are two recent projects in a series of pioneering Canadian projects using HVFA flyash.

For information contact tanya.laing@gvrd.bc.ca or call CANMET at 613-992-6127.

* * * * *

San Marga Iraivan Temple, Kaua'i, Hawaii: This first all-stone Hindu temple in the US was designed to last 1000 years. It is constructed atop a 4-foot thick matt slab that used a 60% flyash mix.

For a detailed technical summary, see "Monolith Foundation: Built to Last a 1000 Years" by P.K. Mehta and Wilbert S. Langley, Concrete International, July 2000.

* * * * *

Environmental Technology Building, Sonoma State: This pioneering project is one of the first to use a combination of high volume flyash and rice husk ash (RHA) for a high performance environmentally friendly concrete. RHA is a very promising technology, but as yet is very limited in availability.

Architect, AIM Associates, George Beeler; Structural Engineer, Bruce King, 415-331-7630; Concrete Supplier, Shamrock Materials.

Additional case studies on projects using HVFA can be found at http://www.ecosmart.ca.

For more information on this or any article in Environmental Design & Construction, please contact Kristin Ralff Douglas at (415) 863-2614 or krd@edcmag.com .

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NC STATE UNIVERSITY
Horticulture Information Leaflets

Composting For Home Gardens

Revised 4/99 -- Author Reviewed 4/99 HIL-8100

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Gardeners have used compost for centuries. When materials such as leaves and grass clippings are composted, a microbial process converts plant wastes to a more usable organic amendment. Grass clippings and leaves can be hauled to municipal or county composting facilities as one means of disposal. However, many homeowners may find it more convenient and economical to compost these materials in their own backyards. In either case, the finished compost can be used as a soil amendment or mulch to improve most soils for gardens, landscape beds, lawn preparation or even as 15 % of a potting medium. This leaflet has been written to provide guidelines on how to build and maintain a compost pile.

Decomposition of organic material in the compost pile is dependent on maintaining microbial activity. Any factor which slows or halts microbial growth will also impede the composting process. Efficient decomposition will occur if the following factors are used to fullest advantage.

Aeration: Oxygen is required for microbes to efficiently decompose the organic wastes. Some decomposition will occur in the absence of oxygen (anaerobic conditions); however, the process is slow and foul odors may develop. Because of the odor problem, composting without oxygen is not recommended in a residential setting unless the process is conducted in a fully closed system. Turning the pile once or twice a month will provide the necessary oxygen and significantly hasten the composting process. A pile that is not mixed may take three to four times longer before it can be used. A well mixed compost pile will also reach higher temperatures which will help destroy weed seeds and pathogens.

Moisture: Adequate moisture is essential for microbial activity. A dry compost pile will not decompose efficiently. If rainfall is limited, it will be necessary to water the pile periodically to maintain a steady decomposition rate. Enough water should be added to completely moisten the pile, but overwatering should be avoided. Excess water can lead to anaerobic conditions. Water the pile so that it is damp, but does not remain soggy. The compost will be within the right moisture range if a few drops of water can be squeezed from a handful of material. If no water can be squeezed out, the material is too dry. If water gushes from your hand, it is too wet.

Particle size: The smaller the size of organic wastes, the faster the compost will be ready for use. Smaller particles have much more surface area that can be attacked by microbes. A shredder can be used before putting material in the pile, and is essential if brush or sticks are to be composted. A low cost method of reducing the size of fallen tree leaves is to mow the lawn before raking or run the lawn mower over leaf piles after raking. Raked piles should be checked to insure that they do not contain sticks or rocks which could cause injury during operation of the mower. If the mower has an appropriate bag attachment, the shredded leaves can be collected directly. In addition to speeding up the composting process, shredding will initially reduce the volume of the compost pile.

Fertilizer and Lime: Microbial activity is affected by the carbon to nitrogen ratio of the organic waste.

Because microbes require a certain amount of nitrogen for their own metabolism and growth, a shortage of nitrogen will slow down the composting process considerably. Materials high in carbon relative to nitrogen such as straw or sawdust will decompose very slowly unless nitrogen fertilizer is added. Tree leaves are higher in nitrogen than straw or sawdust but decomposition of leaves would still benefit from an addition of nitrogen fertilizer or components high in nitrogen. Grass clippings are generally high in nitrogen and when mixed properly with leaves will enhance decomposition. Poultry litter, manure or blood meal can be used as organic sources of nitrogen. Otherwise, a fertilizer with a high nitrogen analysis (10-30 %) should be used. Other nutrients such as phosphorus and potassium are usually present in adequate amounts for decomposition.

During the initial states of decomposition organic acids are produced, decreasing the pH. In the past, small amounts of lime have been suggested for maintaining and enhancing microbial activity at this time. However, high rates of lime will convert ammonium nitrogen to ammonia gas which will lead to the loss of nitrogen from the pile. Research indicated that lime additions may hasten decomposition; however, the loss of nitrogen from the pile often offsets the benefits of lime. In general, lime is not necessary for degradation of most yard wastes. The pH of finished compost is usually alkaline (pH= 7.1-7.5) without the addition of lime. If large quantities of pine needles, pine bark, or vegetable and fruit wastes are composted, additional lime may be necessary.

Many organic materials are suitable for composting. Yard wastes, such as leaves, grass clippings, straw, and non woody plant trimmings can be composted. Leaves are the dominant organic waste in most backyard compost piles. Grass clippings can be composted; however, with proper lawn management, clippings do not need to be removed from the lawn (see North Carolina Extension Bulletin Carolina Lawns, AG-69). If clippings are used, it is advisable to mix them with other yard wastes, otherwise the grass clippings may compact and restrict airflow. Branches and twigs greater than $^{1}/_{4}$ inch in diameter should be put through a shredder/chipper. Kitchen wastes such as vegetable scraps, coffee grounds, and eggshells may also be added.

Sawdust may be added in moderate amounts if additional nitrogen is applied. Approximately 1 lb. of actual nitrogen (6 cups of ammonium nitrate) is required for 100 lbs. of dry sawdust. Wood ashes act as a lime source and if used should only be added in small amounts (no more than 1 cup per bushel or 10 pounds per ton of compost). Ordinary black and white newspaper can be composted; however, the nitrogen content is low and will consequently slow down the rate of decomposition. If paper is composted, it should not be more than 10 % of the total weight of the material in the compost pile.

Examples of other organic materials that can be used to add nutrients to the pile include: blood meal, bone meal, livestock manure, non-woody clippings, vegetable and flower garden refuse, hay, straw and lake plants. Livestock manure and poultry litter are nitrogen sources for composting. Approximately 100 pounds of poultry litter will provide 1.8 pounds of nitrogen.

Some materials may pose a health hazard or create a nuisance and therefore should not be used to make compost. Adding human or pet feces cannot be recommended because they may transmit diseases. Meat, bones, grease, whole eggs, and dairy products should not be added because they can attract rodents to the site. Most plant disease organisms and weed seeds are destroyed during the composting process when temperatures in the center of the pile reach 150-160 ^{0}F.

Although plants that have been treated with herbicides or pesticides should be avoided for composting, small amounts of herbicide-treated plants (e.g., grass clippings) may be mixed in the pile as long as one is careful to allow thorough decomposition. Ideally, clippings from lawns recently treated with herbicides should be left on the lawn to decompose.

Use of plastic garbage bags is perhaps the simplest way to make compost. The bags are easy to handle, and require minimal maintenance. To make compost using this method, 30-40 gallon plastic bags should be

alternatively filled with plant wastes, fertilizer and lime. About one tablespoon of a garden fertilizer with a high nitrogen content should be used per bag. Lime (one cup per bag) helps counteract the extra acidity caused by anaerobic composting. After filling, add about a quart of water. Close tightly. Set aside for six months to a year. Bags can be set in a basement or heated garage for better decomposition during winter months. Using garbage bags requires no turning or additional water after closing. The main advantage of composting in garbage bags is that it requires little maintenance; however, because oxygen is limited, the process is slow.

The barrel or drum composter generates compost is a relatively short period of time and provides an easy mechanism for turning (Figure 1). This method requires a barrel of at least 55 gallons with a secure lid. Be sure that the barrel was not used to store toxic chemicals. Drill 6-9 rows of $^{1}/_{2}$ inch holes over the length of the barrel to allow for air circulation and drainage of excess moisture. Place the barrel upright on blocks to allow bottom air circulation. Fill the barrel $^{3}/_{4}$ full with organic waste material and add about $^{1}/_{4}$ cup of high (approximately 30 %N) nitrogen containing fertilizer. Apply water until compost is moist but not soggy.

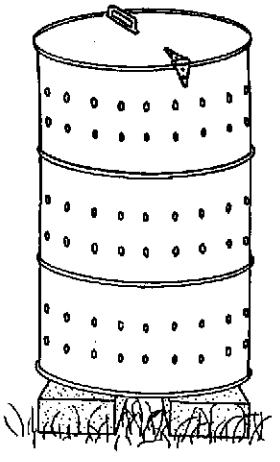

Figure 1.

Every few days, turn the drum on its side and roll it around the yard to mix and aerate the compost. The lid can be removed after turning to allow for air penetration. Ideally, the compost should be ready in two to four months. The barrel composter is an excellent choice for the city dweller with a relatively small yard.

For larger quantities of organic waste, bin type structures are the most practical. As an example, a circular bin can be made by using a length of small spaced woven wire fencing and holding it together with chain snaps (Figure 2). The bin should be about three to five feet in diameter and at least four feet high. A stake may be driven in the middle of the bin before adding material to help maintain the shape of the pile and to facilitate adding water. With this design, it is easiest to turn the composting material by simply unsnapping the wire, moving the wire cylinder a few feet, and turning the compost back into it.

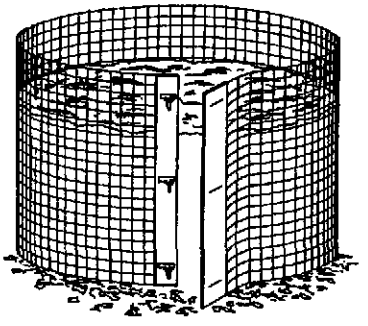

Figure 2.

A very efficient and durable structure for fast composting is a three-chambered bin (Figure 3). It holds a considerable amount of compost, and allows good air circulation. The three chambered bin works on an assembly line idea, having three batches of compost in varying stages of decomposition. The compost material is started in the first bin and allowed to heat up for three to five days. Next, it is turned into the middle bin for another 4-7 days, while a new batch of material is started in the first bin. Finally, the material in the middle bin is turned into the last bin as finished or nearly finished compost.

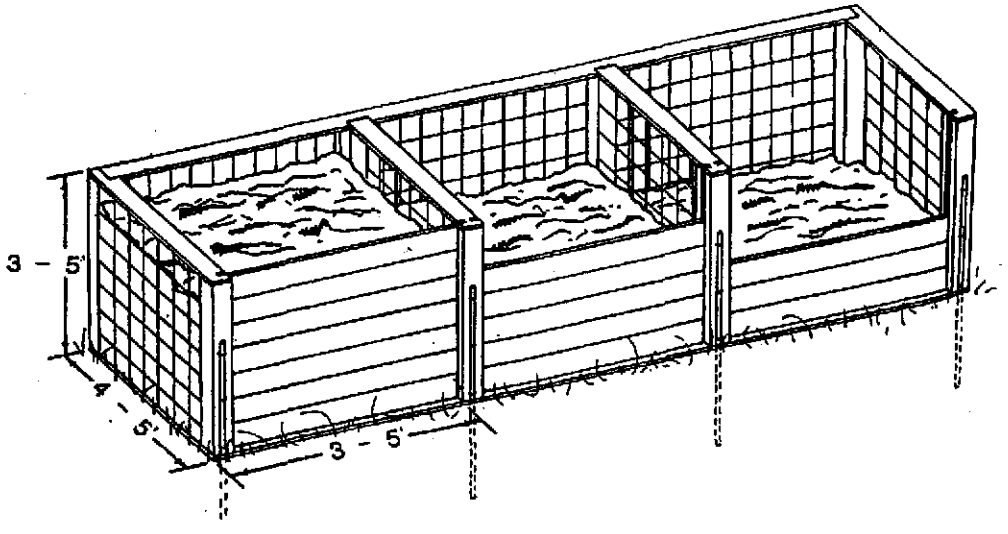

Figure 3.

To make a three-chambered bin, it is best to use rot resistant wood such as redwood, salt treated wood or wood treated with an environmentally safe preservative or a combination of treated wood and metal posts. Unless the wood is treated or rot resistant, it will decompose within a few years. Each bin should be at least three to five feet in each dimension to contain enough volume to compost properly. Using removable slats in the front offers complete access to the contents for turning.

The compost pile should be located close to where it will be used and where it will not interfere with activities in the yard or offend neighbors. From the aesthetic point of view, it is best to compost in a location screened from view of both your property and neighbor s property. Examples of good locations for the pile include: near the garden or between the garage and house. Do not locate the compost pile near a well or on a slope that drains to surface water such as a stream or a pond. The pile will do best where it is protected from drying winds and in partial sunlight to help heat the pile. The more wind and sun the pile is exposed to, the more water it will need. Locating the pile too close to trees may also create problems as roots may grow into the bottom of the pile and make turning and handling the compost difficult.

Organic wastes, such as leaves, grass, and plant trimmings are put down in a layer eight to ten inches deep. Coarser materials will decompose faster if placed in the bottom layer. This layer should be watered until moist, but not soggy. A nitrogen source should be placed on top of this layer. Use one to two inches of livestock manure, or a nitrogen fertilizer such as ammonium nitrate or ammonium sulfate at a rate of one third of a cup for every twenty five square feet of surface area. If these nitrogen sources are not available, one cup of 10-10-10 fertilizer per 25 square feet of surface area will also suffice. Do not use fertilizer that contains herbicide or pesticide.

About a one inch layer of soil or completed compost can be applied on top of the fertilizer layer. One purpose of adding soil is to ensure that the pile is inoculated with decomposing microbes. The use of soil in a compost pile should be considered optional. In most cases, organic yards wastes such as grass clippings or leaves contain enough microorganisms on the surface to effect decomposition. Studies have shown that there is no advantage in purchasing a compost starter or inoculum. One way to insure that activator microbes are present in the new compost is to mix in some old compost as the pile is prepared.

Most compost piles should initially be prepared in layers. This will facilitate decomposition by insuring proper mixing. Each pile ideally should be about 5 feet high. If only tree leaves are to be composted, layering may not be necessary. Fallen leaves can be added as they are collected. Leaves should be moistened if they are dry and since dead leaves lack adequate nitrogen for rapid decomposition, addition of a high-nitrogen fertilizer (10-30 % analysis) should be added to speed up breakdown. Approximately 5 ounces (about $^1/_2$ cup) of 10% nitrogen fertilizer should be added for each 20 gallons of hand compressed leaves.

To prevent odors and hasten decomposition, the pile must be turned occasionally. Turning also exposes seeds, insect larvae, and pathogens to lethal temperatures inside the pile. Odors may arise either from the addition of excessive amounts of wet plant materials like fruits or grass clippings, or from overwatering. A properly mixed and adequately turned compost heap will not have objectionable odors. An actively decomposing pile will reach temperatures of 130-160 ^{0}F in the middle.

Reasons for the pile not heating up may be due to: too small a pile, not enough nitrogen, lack of oxygen, too much or not enough moisture. The pile should be turned when the temperature in the center begins to cool. This will introduce oxygen and undecomposed material into the center and subsequently regenerate heating. The composting process is essentially complete when mixing no longer produces heat in the pile.

Generally, a well managed compost pile with shredded material under warm conditions will be ready in about 2-4 months. A pile left unattended and material not shredded may take over a year to decompose. Piles prepared in the late fall will not be ready for use the following spring. When the compost is finished, the pile will be about half its original size and have an earthy smell to it.

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RESEARCH & ADMINISTRATION FACILITY
U.S. ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NORTH CAROLINA
18 JUNE 1997

ENVIRONMENTAL REQUIREMENTS
SECTION 01100

PART 1 - GENERAL

1.1 RELATED DOCUMENTS:

A. Drawings and general provisions of Contract, including General and Supplementary Conditions and other Division-1 Specification sections, apply to this section, as well as individual specifications.

1.2 WORK INCLUDED:

A. This is an overview of the environmental requirements of this project. It is the goal of EPA to integrate the Agency's mission into this project as much as feasible and practical; i.e., to construct a "green" building.

B. Objectives: Major components of the green effort include pollution prevention and good Indoor Air Quality (IAQ).

1. Pollution prevention is achieved through use of recycled materials and materials from sustainably managed forests, specification of energy efficient equipment and fixtures, waste handling procedures, and limiting the pollutants emitted into the air, soil, and waterways. The specifications included for this project incorporate pollution prevention measures in each section.

2. Maximum indoor air concentrations of certain pollutants have been established. Concentrations must be at or below these standards prior to building acceptance. Baseline testing for these pollutants is outlined in Division 15 "Testing, Adjusting and Balancing".

3. A materials log book is required that includes MSDS sheets and additional information on chemical content of selected materials, including Volatile Organic Compounds (VOC) in terms of grams per liter (g/L). This log book shall be maintained by the contractor throughout the life of the project, shall be updated monthly to include any newly approved products, shall be available at all times to the Contracting Officer's Representative, and shall be submitted at the conclusion of construction.

4. Materials emission testing is required of four finish materials. These materials have been selected based on their volume of use in the facility and potential for impacting IAQ. Other materials may be tested, at the contractor's discretion, in order to assist in meeting the IAQ building acceptance criteria.

C. Research has been performed to ensure that specified building material requirements (e. g., for recycled content, VOC levels) can be met by multiple manufacturers in the respective materials category.

PART 2 - PRODUCTS (Not used)

PART 3 - EXECUTION (Not used)

END OF SECTION 01100

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18 JUNE 1997

ENVIRONMENTAL IMPACT OF MATERIALS
SECTION 01120

PART 1 - GENERAL

1.1 RELATED DOCUMENTS:

A. Drawings and general provisions of Contract, including General and Supplementary Conditions and other Division-1 Specification sections, apply to this section.

1.2 WORK INCLUDED:

A. Objectives: To obtain acceptable Indoor Air Quality (IAQ) for the completed project and minimize the environmental impacts of the construction and operation, the Contractor during the construction phase of this project shall implement the following procedures singly or in combination:

1. Select products that minimize consumption of non-renewable resources, consume reduced amounts of energy and minimize amounts of pollution to produce, and employ recycled and/or recyclable materials. Obtain Contracting Officer's Representative's approval of all materials listed in Part 2 prior to placing the order with the manufacturer of the material.

2. Maintain a materials log book and verification that materials used have been reviewed for environmental considerations as outlined in this section.

3. Control sources of potential IAQ pollutants by controlled selection of materials and processes used in project construction in order to attain acceptable IAQ as defined in this section.

B. Products and processes that achieve the above objectives to the extent currently possible and practical have been selected and shown in the Contract Documents. The Contractor is responsible to maintain and support these objectives in developing means and methods for performing the work of this Contract and in proposing product substitutions and/or changes to specified processes.

1.3 RELATED WORK:

A. Baseline testing for Indoor Air Quality and duct cleaning as specified in Division 15 "Testing, Adjusting and Balancing" section, other Division 1 sections: "Environmental Requirements", "Sequence of Finishes Installation", and "Product Emission Testing for Indoor Air Quality", and "Waste Materials Management and Recycling".

1.4 SUBMITTALS:

A. Submit the following in accordance with Conditions of the Contract and Division 1 specification sections.

1. Materials Log: Maintain a notebook with sectional dividers for each material specification listed in Part 2 of this Section. Each divider shall be labeled with the

specification section number and shall record the VOC content as specified in Table 2.1, the recycled content as specified in Table 2.2, and other environmental specifications of the material such as identified in Part 2 below. The section will also include the Manufacturer's Safety Data Sheet (MSDS), product label and/or manufacturer's data verifying conformance with the environmental specifications, and shall identify in general terms where the product is to be used in the building. This notebook shall be maintained weekly as materials are ordered, shall be accessible to the Contracting Officer's Representative at all times, and submitted in bound form as part of the project requirements specified in Division 1 "Project Closeout Section".

1.5 QUALITY ASSURANCE:

A. General: Perform the work of this Section as a supplement and in accordance with applicable requirements of Division 1 "Contractor Quality Control Program".

B. As part of the Coordination and Mutual Understanding Meeting specified in Division 1 "Contractor Quality Control Program", and prior to the start of construction, discuss the IAQ and environmental impact compliances required by this Contract. The purpose of this agenda item is to develop a mutual understanding of the IAQ and environmental impact program requirements, and coordination of the Contractor's management of the program with the Contracting officer and the Construction Quality Manager.

PART 2 - PRODUCTS

2.1 MATERIALS:

A. General: The following special IAQ and environmental impact requirements apply to materials specified in their respective technical specification sections of this Project Manual. See Tables 2.1 and 2.2 for definitions of low VOC content and recycled content.

B. Division 02 - Sitework:

1. Site Clearing: Topsoil shall be provided by the Contractor from on-site material which has been stockpiled for re-use. Off-site borrow should only be used when on-site sources are exhausted.

2. Aggregate Base Course: Aggregate base course for on-site paved areas shall maximize use of recycled ABC.

3. Asphaltic Concrete Paving: Asphalt paving shall maximize use of recycled asphalt paving.

4. Portland Cement Concrete Paving: Per Federal Acquisition Regulations (FAR) requirements, there will be a minimum of 20% fly ash content in cement.

5. Site Potable Water Lines and Underground Chilled Water (CHW) Piping System: No solder will be used with lead content.

6. Landscaping:

a. All wood fiber or cellulose hydromulch shall be 100% recovered content.

b. All herbicides must be EPA approved and applied per manufacturer's instructions. All herbicide use must be approved by the Contracting Officer's Representative.

C. Division 03 - Concrete:

1. Cast-in-Place Concrete:

a. Per FAR, cement must include 20% fly ash.

b. Reinforcing steel shall maximize recycled scrap steel content.

c. Form release agents shall be low VOC content.

d. Liquid membrane-forming curing and sealing compound shall be low VOC content.

2. Structural Precast Concrete:

a. Cement for all precast with standard finish shall include 20% fly ash content.

b. Form release agent shall be low VOC content.

c. Reinforcing bars shall maximize recycled steel content.

3. Architectural Precast Concrete:

a. Form release agent shall be low VOC content.

b. Reinforcing bars shall maximize recycled steel content.

D. Division 04 - Masonry:

1. Concrete Unit Masonry:

a. Concrete Unit Masonry shall maximize the use of recycled materials.

b. Reinforcing bars shall maximize the use of recycled steel.

E. Division 05 - Metals:

1. Structural Steel: Framing steel shall maximize the use of recycled steel.

2. Ornamental Handrails and Railings: Wood cap originates from a sustainably managed forest certified by Scientific Certification Systems (SCS) or other independent forest management certification agency.

F. Division 06 - Wood and Plastics: Wood products:

1. Each specified solid and veneer wood species must originate from a sustainably managed forest certified by a Forest Stewardship Council (FSC) accredited certification group such as Smartwood or Scientific Certification Systems (SCS).

2. Fiberboard used as blocking, millwork, casework substrate, underlay and door cores must be urea-formaldehyde free, and not exceed ANSI A208.1-1993 emission standard of 0.20 ppm of formaldehyde.

3. Structural fiberboard (OSB, MDF, and particleboard) shall maximize post-consumer waste material.

4. Plastic laminates will be installed with water-based, formaldehyde free, low VOC (volatile organic compound) adhesives.

5. Millwork and casework adhesives will be water-based, formaldehyde free, low VOC adhesives.

6. Transparent wood finish systems shall utilize only waterborne acrylic sealers and finish coats.

7. Use of chromated copper arsenate (CCA) as a wood treating material is not permitted; use of ammonium copper quat (ACQ) is acceptable.

G. Division 06 - Wood and Plastics:

1. Cast Resin Countertops: Silicone sealants shall be water-based low VOC silicone sealant.

H. Division 07 - Thermal and Moisture Protection:

1. Garage Deck Sealer: Silane sealer will be low VOC.

2. Building Insulation:

a. Insulation materials manufactured using chlorofluorocarbons (CFCs) shall not be (CFCs have been completely phased out of U. S. manufactured insulation products.)

b. Extruded polystyrene insulation shall not be manufactured with chlorofluorocarbon (CFC) blowing agent and shall maximize recycled content.

c. Fiberglass batt insulation, fiberglass board insulation, and mineral wool insulation maximize use of recycled material.

d. Mineral wool fire safing insulation shall maximize recycled material.

2. Single-Ply Membrane Roofing: Rigid insulation manufactured with chlorofluorocarbon (CFC) blowing agents shall not be used.

3. Joint Sealants:

a. Interior sealants shall not contain: mercury, butyl rubber, neoprene, SBR (styrene butadiene rubber), or nitrile.

b. Silicone sealants shall be low VOC content.

c. Polyurethane sealants containing mercury shall not be used.

d. Compressible foam joint fillers, polyester polyurethane foam impregnated with neoprene rubber or acrylic ester styrene copolymer used in this facility shall not be manufactured with CFC blowing agents.

e. Sealants formulated with aromatic solvents (organic solvent with a benzene ring in its molecular structure) fibrous talc or asbestos, formaldehyde, halogenated solvents, mercury, lead, cadmium, hexavalent chromium, or their components shall not be used.

I. Division 08 - Doors and Windows:

1. Flush Wood Doors: Fiberboard used as door cores shall meet the requirements of ANSI A208.1-1993 for particleboard, including the requirement to meet a threshold of less than 0.30 ppm of formaldehyde using test method ASTM 1333.

2. Glass and Glazing:

a. Sealants and glazing compounds shall be low VOC content.

b. Sealants and glazing compounds formulated with aromatic solvents (organic solvent with a benzene ring in its molecular structure), fibrous talc or asbestos, formaldehyde, halogenated solvents, mercury, lead, cadmium, hexavalent chromium, or their components will not be used.

J. Division 09 - Finishes:

1. Portland Cement Plaster:

a. Plaster including additives such as epoxy or other resins shall be low VOC content.

b. Steel lath shall maximize recycled steel.

2. Gypsum Drywall:

a. Gypsum board must contain recycled or synthetic gypsum. Facing paper shall be manufactured from recycled newsprint including post-consumer waste.

b. Glass fiber sound attenuation blanket insulation shall maximize recycled material.

c. Joint compound shall be low VOC content.

d. Multi-layer gypsum board applications shall be screw attached and not laminated with adhesives.

e. Provide for thorough cleaning and removal of all silica/gypsum dust upon completion of gypsum drywall installations, including, but not necessarily limited to, all components in plenum spaces, including tops of pipes and sills, and insides and outsides of ducts (as required in Division 15).

f. Only paper joint tape (no fiberglass tape) will be used.

g. Mineral fiber sound attenuation blankets shall maximize recovered material.

h. Steel studs, runners, and channels for framing shall maximize recycled steel content.

3. Terrazzo: Sealers shall be low VOC content.

4. Acoustic Panel Ceilings:

a. Ceiling panels shall maximize use of recycled material, and be finished with water-based low VOC paint.

b. Suspension systems shall maximize recycled material.

5. ResilientTile Flooring:

a. Rubber floor tiles shall maximize recycled materials.

b. Adhesives shall be low VOC content.

6. Sheet Vinyl Floor Covering: Sheet vinyl floor covering shall be installed with water-based, low VOC adhesives per manufacturer's instructions.

7. Carpet/Carpet Tile:

a. Carpet shall be one that is accepted in an operating recycling program which extracts component materials for reuse and/or reclaims inherent energy, and does not contribute significantly to land fill.

b. If an adhesive is required for installation, use low VOC carpet manufacturer recommended adhesive and install per manufacturer's recommended frame or perimeter adhesive pattern method. (Full field glue-down is not acceptable except for carpet with an integral dry film adhesive back.)

c. If a seam sealer is required for installation, use carpet manufacturer recommended low VOC seam sealer or recommend heat welded seaming.

8. Paint and Polychromatic Finish Coating:

a. Do not use water based paints formulated with aromatic hydrocarbons (organic solvent with a benzene ring in its molecular structure), formaldehyde, halogenated solvents, mercury or mercury compounds, or tinted with pigments of lead, cadmium, chromium VI and their oxides. Water based paints shall be low VOC and shall have a flash point of 61 degrees C or greater.

b. Where it is necessary to use solvent-based paints, they shall be formulated for low VOC emissions and shall not be formulated with formaldehyde, halogenated solvents, mercury or mercury compounds, or tinted with pigments of lead, cadmium, chromium VI and their oxides, nor formulated with more than 10% aromatic hydrocarbons by weight.

c. The following shall be low VOC and not be formulated with aromatic hydrocarbons (organic solvent with a benzene ring in its molecular structure) formaldehyde, halogenated solvents, mercury or mercury compounds, or tinted with pigments of lead, cadmium, chromium VI and their oxides.

High performance water based acrylic coatings.
Pigmented acrylic sealers.
Catalyzed epoxy coatings.
High performance silicone grafted epoxy coatings.

J. Division 11 - Equipment:

1. Walk-in-Environmental Rooms:

a. Verify CFC compliance with EPA regulations and the Clean Air Act.

b. Verify that the job site mechanic has received accredited training conforming to EPA and the Clean Air Act of July 1, 1992, in regard to venting of EPA regulated refrigerant gases.

K. Division 12 - Furnishings:

1. Laboratory Casework: Silicone sealant shall be water-based silicone sealant with low VOC content.

L. Division 15 - Mechanical:

1. Basic Mechanical Materials and Methods: Use low VOC joint sealers.

2. Basic Piping Materials and Methods: Use solder that does not contain lead.

3. Underground Utilities - Basic Piping Materials and Methods: Use solder that does not contain lead.

4. Pipes and Pipe Fittings: Use solder that does not contain lead.

5. Mechanical Insulation: Mechanical sound insulation materials within the duct shall include a impervious, non-porous coating that prevents dust from accumulating in the insulating materials.

6. Plumbing Fixtures: Plumbing fixtures must meet water conservation requirements of the Energy Policy Act.

7. Metal Ductwork: Use low VOC joint and seam sealants.

Table 2.1 Definition of Low VOC Content Levels

Material or Product	Low VOC Content
Form Release Agents	350 g/L VOC content
Plastic Laminate Adhesive	20 g/L VOC content
Casework and Millwork Adhesives	20 g/L VOC content
Transparent Wood Finish Systems	350 g/L VOC content
Cast Resin Countertop silicone Sealant	20 g/L VOC content
Garage Deck Sealer	600 g/L VOC content
Water based Joint Sealants	50 g/L VOC content
Non-water based Joint Sealants	350 g/L VOC content
Portland Cement Plaster	20 g/L VOC content
Gypsum Drywall Joint Compound	20 g/L VOC content
Terrazzo Sealer	250 g/L VOC content
Acoustic Panel Ceiling Finish	50 g/L VOC content
Resilient Tile Flooring Adhesive	100 g/L VOC content
Vinyl Flooring Adhesives	100 g/L VOC content
Carpet Adhesive	50 g/L VOC content
Carpet Seam Sealer	50 g/L VOC content
Water-based Paint & Polychromatic finish coatings	150 g/L VOC content
Solvent -based Paint	380 g/L VOC content
High Performance Water-Based Acrylic coatings	250 g/L VOC content
Pigmented Acrylic Sealers	250 g/L VOC content
Catalyzed Epoxy coatings	250 g/L VOC content

High Performance Silicone	250 g/L VOC content
Casework Sealant	50 g/L VOC content
Liquid membrane-forming curing & sealing	350 g/L VOC content

Table 2.2 Required Minimum Recycled Content of Materials

Material or Product	Recommended Recycle Content
Asphaltic Concrete Paving	25% by weight3
Reinforcing Steel in Concrete	60% recycled scrap steel 1
Reinforcing Bars in Precast Concrete	60% recycled steel 1
Concrete Unit Masonry	50% recycled content
Reinforcing Bars in Concrete Unit Masonry	60% recycled steel 1
Framing steel	30% recycled steel 1
Fiberglass batt insulation	20% recycled glass cullet2
Fiberglass board insulation	20% recycled glass cullet2
Mineral wool insulation	75% recycled material (slag)2
Mineral wool fire safing insulation	75% recycled material by weight (slag)2
Gypsum board	10% recycled or synthetic gypsum
Facing paper of Gypsum Board	100% recycled newsprint including post consumer waste2
Mineral Fiber Sound Attenuation Blankets	75% recovered material by weight (slag)2
Steel studs, runners, and channels	60% recycled steel 1
Acoustic Panel Ceilings	60% recycled material by weight
Ceiling Suspension Systems	60% recycled material 1
Rubber floor tiles	90-100% recycled materials2
Hydromulch	100% recovered materials2
Structural fiberboard	80-100% recycled content2

Notes for Table 2.2:

1. 60% represents the average recycled content for the U. S. steel industry. Use of U. S. manufactured steel will meet this requirement.

2. As per EPA Comprehensive Guideline for Procurement of Products Containing Recovered Materials (60 FR 21370, effective May 1, 1996).

3. As per North Carolina Department of Transportation (NCDOT) recommendation.

PART 3 - EXECUTION

3.1 GENERAL:

A. Submit to the Contracting Officer's Representative for review and approval product data such as MSDS and environmental impact data prior to ordering project materials.

B. Prepare and maintain a Materials Log, providing information on content of materials, where specific materials are to be used, MSDS, and environmental specifications of the

material. Maintain the log book weekly as materials are ordered.

3.2 FIELD QUALITY CONTROL:

A. The Government reserves the right to take samples and perform, at random, tests of approved materials delivered to the job site to verify compliance of actual materials with specifications.

END OF SECTION 01120

Table 2: Environmental & Safety Specifications: Enviro Care® Coatings & Miscellaneous Products

Properties of Enviro Care Products	Hand Soap	Liqui Bac	Fragrance Additive	Neutral Disinfectant	Floor Finish Restorer	Resilient Tile Coating	Con Seal	Tech 4 Wood Floor Finish
% Biodegradable [1]	71	61		36	20	7	33	64
Contains Phosphates	No	No		No	No	Yes	Yes	No
Nontoxic (per OSHA Current Criteria)	Yes	Yes		Yes	Yes	Yes	Yes	Yes
LD50 (oral) mg/kg	132083	66007		6490	21417	11296	19047	20396
Contains Hazardous Ingredients (per OSHA 1200.1910 CFR)	No	No		Yes[1]	Yes[2]	Yes[3]	Yes[4]	Yes[5]
Endocrine Disruptors	No	No		No	No	No	No	No
Added Fragrance	Yes	Yes		No	No	No	No	No
Aquatic Toxicity: mg/L [2]	172	29870		46	160	623	218	54841
Flash Point	None	None		None	None	None	None	None
Contains EDTA	No	No		Yes	No	No	No	No
Contains NPE/APE	No	No		No	No	No	No	No
Contains DEA	No	No		No	No	No	No	No
Known or Suspected Carcinogens	No	No		No	No	No	No	No
pH	7.5	8		7	6	8	8	8.5
VOC (% by weight)	0.50	1.90		0.0	2.12	5.14	6.71	12.62
Contains Petrochemical Derivatives	No	No		Yes	Yes	Yes	Yes	Yes
Contains Active Component(s) From Renewable Resources	Yes	Yes		Yes	No	No	No	No
Corrosive	No	No		No	No	No	No	No
Reactive	No	No		No	No	No	No	No
Ozone Depleting Compounds	No	No		No	No	No	No	No
Recyclable Packaging	Yes	Yes		Yes	Yes	Yes	Yes	Yes
Concentrate	Yes	Yes		Yes	Yes	Yes	Yes	Yes

Available Soon

(1) contains a mixture of didecyl dimethyl ammonium chloride and n-alkyl dimethyl dibenzyl ammonium chloride (4.82% by weight)
(2) contains ethylene glycol (0.51% by weight) and diethylene glycol methyl ether (1.61% by weight)
(3) contains diethylene glycol methyl ether (5.14% by weight)
(4) contains ethylene glycol (1.71% by weight) and diethylene glycol butyl ether (5.00% by weight)
(5) contains methyl ethyl ketone (1.7% by weight) and triethylamine (1.9% by weight)

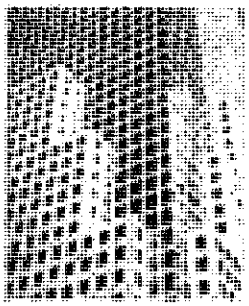
The didecyl dimethyl ammonium chloride and n-alkyl dimethyl dibenzyl ammonium chloride (quat) mixture is the sanitizer component, or active ingredient, that provides the ability to kill pathogenic microorganisms.

The ethylene glycol, diethylene glycol methyl ethers, diethylene glycol butyl ether, methyl ethyl ketone and triethylamine are fugitive plastisizers. The plastisizers are needed to cause the polymer molecules to bond (coalesce) and are a necessary component of hard floor finishes. Following the coalescing process, the plasticizers evaporate during the finish curing process, typically 10 to 30 minutes.

Table 1: Environmental & Safety Specifications: Enviro Care® Cleaners

Properties of Enviro Care Products	Tough Job Cleaner	Washroom Cleaner	Glass Cleaner	Floor Finish Remover	Carpet& Upholstery Cleaner	Carpet Spot Remover	Low Foam All Purpose Cleaner	Food Service Cleaner
% Biodegradable (1)	70	63	99	69	68	66	61	67
Contains Phosphates	No	No	No	No	No	No	No	No
Nontoxic (per OSHA Current Criteria)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
LD50 (oral) mg/kg	10828	27267	17399	15830	171468	115915	194746	61444
Contains Hazardous Ingredients (per OSHA 1200.1910 CFR)	No	No	No	No	No	No	No	No
Endocrine Disruptors	No	No	No	No	No	No	No	No
Added Fragrance	No	No	Yes	No	Yes	No	No	No
Aquatic Toxicity: mg/L (2)	305	7520	691	1859	14750	4212	9963	3965
Flash Point	None	None	None	None	None	None	None	None
Contains EDTA	No	No	No	No	No	No	No	No
Contains NPE/APE	No	No	No	No	No	No	No	No
Contains DEA	No	No	No	No	No	No	No	No
Known or Suspected Carcinogens(3)	No	No	No	No	No	No	No	No
pH	9.95	4.15	6.85	9.9	8	8.5	8.5	9.5
VOC (% by weight)	2.60	0.65	9.25	4.85	0.00	0.00	0.00	0.00
Contains Petrochemical Derivatives	No	No	No	No	No	No	No	No
Contains Active Component(s) From Renewable Resources	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Corrosive	No	No	No	No	No	No	No	No
Reactive	No	No	No	No	No	No	No	No
Ozone Depleting Compouns	No	No	No	No	No	No	No	No
Recycable Packaging	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Concentrate	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

(1) - The standard for biodegradability is % (BOD28/COD) > 60%.
(2) - The Green Seal standard of acceptability with regard to aquatic toxicity is >100 mg/L as neat product
(3) - Carcinogens are defined as those chemicals listed as known, probable, or possible human carcinogens by the International Agency for Research on Cancer (IARC), the National Toxicology Program (NTP), the U.S. Environmental Protection Agency, or the Occupational Health and Safety Administration. Chemicals known to cause reproductive toxicity are defined as those listed by the State of California under the Safe Drinking Water and Toxic Enforcement Act of 1986 (California Code of Regulations, Title 22, Division 2, Subdivision 1, Chapter 3, Sections 1200, et seq.).



Honeywell Honeywell, Inc.

(612) 951-1000
Honeywell Plaza, P.O. Box 524
Minneapolis, MN 55440-0524

About The Company : Honeywell is a manufacturer of energy management controls and systems for automation of building lighting, heating, cooling, energy and security. In addition, Honeywell manufacturers energy saving equipment from lighting to cooling. Also, as an Energy Services Company (ESCO), Honeywell provides energy benefits through comprehensive energy-efficient upgrade packages and performance contracts.

If a section is expandable, a blue triangle will appear beside the section. Click on the triangle to view the section's contents.

Services:

- ▸ **Product Development and Analysis**
- ▸ **Financing/Performance Contracting**
- ▸ **Commissioning and Performance Evaluation**
- ▸ **Equipment Installation**
- ▸ **Equipment Maintenance**
- ▾ **Environmental Systems Control**

Removal Recycling Disposal:
Lamp Recycling, Lamp Disposal, Ballast Recycling, Ballast Disposal, Asbestos Removal

Indoor Air Quality:
IAQ Monitoring (CO and CO2 Sensors), Systems Installation, IAQ Systems Control (Maintenance)

Hazardous Materials Monitoring Handling:
Hazardous Material Transportation, Central Plant Refrigerant Monitoring, Central Plant Ventilation, Controls/Installation

Products:

- ▾ **Stage 1: Lighting Upgrades - Green Lights**

Lamps:
Incandescent/Halogen, Compact Fluorescent, Full-Size Fluorescent, High-Intensity Discharge, Electrodeless Lamps, Exit Sign Sources

Ballasts:
Fluorescent - Hybrid, Fluorescent - Electronic/Fixed Output, Fluorescent -

Electronic/Varible Output, High-Intensity Discharge - Magnetic, High-Intensity Discharge - Electronic

Luminares:

Full-Size Fluorescent - Commercial, Full-Size Fluorescent - Industrial, High-Intensity Discharge - Indoor, High-Intensity Discharge - Outdoor, Task Lights, Downlights - New and Retrofit Kits, Emergency/Exit Signs, Spotlight/Floodlight Track, Sconce/Pendent/Speciality

Luminare Retrofit Components:

Reflectors, Lenses, Louvers, Luminaire Modification Hardware

Lighting Controls:

Occupancy Sensors, Dimming Controls, Daylight Sensors, Scheduling Systems, Manual/Timer Switches

Stage 2: Energy and HVAC System Tune-Up

HVAC Controls Automation Systems:

Computer Hardware, Control Point Equipment Hardware, Direct Digital Control (DDC), Electronic Thermostats, Electronic Timeclocks, Energy Monitoring/Equipment, Utility Software, Metering Equipment, Programmable Controls

Electrical Power Controls:

Sensors, Circuit Breakers, Power Panels, Low Voltage Relays, Regulators, Power Transformers, Generators, Programmable Controllers, Power Conditioning Equipment, Submetering Equipment

HVAC Replacement Components:

Air Filters, Burners, Chemicals, Cleaning Equipment, Coils, Radiators, Steam Traps, Refrigerants, Refrigerant Recovery Systems

Stage 3: Other HVAC Load Reductions

Building Envelope:

Architectural Glass/Windows, Architectural Panels/Siding, Curtain Wall, Insulated/Solar Control Glass, Insulation, Paint, Roof Insulation/Materials, Photovoltaic Modules, Skylights, Window Film

Piping/Duct Insulation:

Piping Insulation, Duct Insulation

Energy Star Office Equipment:

Workspace Presence Sensors

Stage 4: Fan System Upgrades

Air Handling Systems Components:

Air Handling Units, Air Louvers/Diffusers, Air-Side Economizer, Fume Hoods, Ductwork/Variable-Air-Volume Boxes, Variable-Air-Volume Systems

Fan/Damper Controls:

Cog Belts and Pulleys, Dampers, Damper/Vane Controls, Exhaust Fans, Fan Coils, Fan Motors (High Efficiency), Fan Controls, Variable Speed Drives

Indoor Air Quality Technologies:

Air Cleaners, Air Monitoring Equipment, Dehumidification Systems, Desiccant Systems, Energy Recovery Systems, Humidifiers, Indoor Air Quality Controls

Stage 5: Heating and Cooling Plant Upgrades

Cooling Equipment:
Absorption Chillers, Centrifugal Chillers, Reciprocating/Scroll Units, Gas-Fired Chillers, Refrigerant Retrofit Kits, Scroll Compressor Chillers, Water-Side Economizer Systems

Heating Equipment:
Coal/Oil/Multi-Fuel Boilers, Electric Boilers, Forced Air Units, Gas Boilers, Geothermal Heat Pumps, Heat Pumps, Heaters

Pumps, Heat Exchangers, Cooling Towers:
Modular Evap Systems, Built-up/Packaged Evap Systems, Motors (High Efficiency), Plate & Frame Heat Exchangers, Pump Meters/Controls, Shell & Tube Heat Exchangers, Variable Speed Drives, Water Heat Exchangers/Cooling Towers, Hydronic Units

Thermal Energy Storage Systems:
Infrared Heaters, Water Heaters, Ice on Coil, Dynamic Ice, Eutectic, Chiller Water

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or visit our Web Site at www.honeywell.com. EXITING EPA

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Updated 06/05/2001
http://itdomino1.icfconsulting.com/EPA/ESGateway/CPDCaseStudy.nsf/

EXAMPLE
Pest Management Program

Best Practices Landscaping and Pest Control (Santa Monica, California)

Landscaping and garden maintenance activities can be major contributors to ocean pollution. Soils, yard wastes, over watering and garden chemicals become part of the urban runoff mix that winds its way through streets, gutters and storm drains before entering the ocean. Poorly functioning sprinklers and over watering, for example, waste water and increase the number of pollutants flowing into storm drains. Fertilizers, pesticides and herbicides are washed off lawns and landscaped areas. These chemicals not only kill garden invaders, they also harm useful insects, poison fish and contaminate ground and ocean water. Leaves, grass clippings and tree trimmings that are swept or blown into the street and gutter are also ocean polluters. These wastes clog catch basins, increasing the risk of flooding on your street, and carry garden chemicals into the ocean. As they decompose, they also absorb oxygen fish need to survive.

Solutions

General Landscaping Tips

- Protect stockpiles and materials from wind and rain by storing them under tarps or secured plastic sheeting.
- Schedule grading and excavation projects for dry weather.
- Use temporary check dams or ditches to divert runoff away from storm drains.
- Prevent erosion by planting fast-growing annual and perennial grasses. These will shield and bind the soil.

Garden & Lawn Maintenance

- Do not over water. Conserve water by using irrigation practices such as drip irrigation, soaker hoses, or micro-spray systems.
- In communities with curbside yard waste recycling, leave clippings and pruning waste for pickup in approved containers, or, take clippings to a landfill that composts yard waste.
- Do not blow or rake leaves into the street, gutter or storm drains.
- Use organic or non-toxic fertilizers.
- Do not over fertilize and do not fertilize near ditches, streams or other water bodies.
- Store pesticides, fertilizers, and other chemicals in a covered area to prevent runoff.

Pesticide Alternatives

The "chemicals-only" approach to pest control is only a temporary fix. A more common-sense approach is needed for a long-term solution. It's called Integrated Pest Management. Plan your "IPM" strategy in this order:

Physical Controls

- Caulking holes
- Hand picking
- Barriers
- Traps

Biological Controls

- Predatory insects e.g. Green lacewings eat aphids
- Bacterial insecticides
- Bacillus thuringiensis kills caterpillars

Chemical Controls - Your last Resort

Use these least-toxic products:

- Dehydrating dusts (e.g. silica gel)
- Insecticidal soaps
- Boric acid powder
- Horticultural oils
- Pyrethrin-based insecticides

Safe Substitutes for Pest Control

- Garden Aphids and Mites
  Mix 1 tablespoon of liquid soap and 1 cup of vegetable oil. Add 1 teaspoon of this mixture to a cup of water and spray. (Oil may harm vegetable plants in the cabbage family.)
- Caterpillars
  When caterpillars are eating, apply products containing Bacillus thuringiensis to leaves.
- Ants
  Place boric acid dust or hydramethylnon baits in problem areas, cracks and insect walkways. Be sure it is inaccessible to children and pets (it is a mild poison).
- Roaches
  Apply boric acid dust to cracks and entry points (see ants above). Place Bay leaves on pantry shelves.

If You Must use Pesticides

- Use a pesticide that is specifically designed to control your pest. The insect should be listed on the label.
- Approximately 90% of the insects on your lawn and garden are not harmful.
- Read labels! Use only as directed. In their zeal to control the problem, many gardeners use pesticides at over 20 times the rate farmers do.

Pesticide Disposal

Household toxics such as pesticides, cleansers, and motor oil can pollute the ocean and poison groundwater if disposed of in storm drains or gutters.

- Rinse empty pesticide containers and use rinse water as you would the product. Dispose of empty rinsed containers in the trash.
- City of Los Angeles residents can dispose of unused household toxics at the HazMobile instead of dumping them into the sink, street, gutter or storm drain. Call 1-800-98-TOXIC for information.
- Gardeners, landscapers and residents outside the City of Los Angeles can call the reference numbers listed to learn where they can properly dispose of household toxics.

Team Oregon, LLC

Team Oregon, LLC is a consortium of firms organized in Portland, Oregon, USA to provide sustainable development services to public and private clients throughout the world. The City of Portland and the State of Oregon are leaders in North America in sustainable development.

The key services provided by Team Oregon include public policy guidance; strategic, and land use planning; urban design and master planning; landscape architecture; architecture and interior planning; and civil and environmental engineering. Team Oregon, LLC works with multiple firms to bring clients the exact package of services required by individual projects.

Sustainable development addresses the challenges of unhealthy and unattractive cities, inefficient buildings and infrastructure, pollution, habitat reduction and the decline in bio-diversity, and resource and energy constraints.

The solution to these challenges is sustainable development, which meets today's needs without sacrificing the ability of future generations to meet their needs. Sustainable development results in clear policy vision and public commitment; protection and restoration of ecosystems; conservation, recycling, and reduction of natural resource and energy use; reduction of pollution and use of toxic substances; a stable, diverse, and fair economy; and healthy, safe and pleasant communities.

Team Oregon has been selected by the US Trade and Development Agency to provide sustainable development services to Tainan City, Taiwan, R.O.C. The initial $450,000 grant will fund development of a sustainable development policy framework and feasibility studies for the design of an Eco School, sewage treatment systems, and river enhancement and beautification projects in Tainan City.

Team Oregon will work with the International Sustainable Development Foundation (ISDF) in Portland, Oregon USA to provide services to Tainan City. ISDF is host to the Asia Pacific Economic Cooperation (APEC), Sustainable Development Training and Information Network and the China-US Center for Sustainable Development. Team Oregon also will collaborate with the Taipei Office of the Oregon Economic and Community Development Department.

CONTACT INFORMATION

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Team Oregon

Team Oregon, LLC

BOB WISE, COGAN OWENS COGAN

Bob Wise is team leader for Team Oregon, LLC and senior associate with Cogan Owens Cogan, LLC. He advises clients in strategic planning, public policy, and sustainable development. Mr. Wise builds solutions to problems that meet multiple objectives and harmonize competing interests. He is the recipient of the Theodore Roosevelt Award for innovation in public policy from the U.S. Council of Governors' Policy Advisors/National Governors' Association. This is one of the highest honors given in State government, and has been awarded to only a few individuals in the last 25 years. Bob is the chairman of the Sustainable Portland Commission.

J. NED DEMPSEY, CENTURY WEST ENGINEERING

As president of Century West Engineering and Century Testing Laboratories, Mr. Dempsey has spearheaded the firm's growth for more than twenty years. In the two decades that he has serves at its helm, Century West has grown from a small Oregon based company to a major regional corporation, specializing in water and waste water facility design and construction management.

MIKE ABBATÉ, GREENWORKS

Mike Abbaté is the President of GreenWorks, a Landscape Architecture and Environmental Design firm in Oregon. GreenWorks is committed to integrating people and nature through creative and sustainable design. Mike brings over 16 years of professional experience to Team Oregon and has received national certification from the Council of Landscape Architects Review Board. He has received numerous awards for projects with both regional and national significance. Prior to joining GreenWorks, Mike served as Design Coordinator for the USDA Forest Service interdisciplinary design team. As an advocate of the principles of "Sustainable Design", he has contributed to facilities which reflect and protect the natural character and processes of the landscapes in which they are built.

JOHN ECHLIN, SERA ARCHITECTS

John brings more than 20 years of international experience in architecture and urban design to his role as Principal at SERA Architects. With an emphasis on civic institutions and open space design, John has taken lead design responsibility for projects in Italy, Switzerland, Germany and the United States. While a resident in Switzerland, John taught architectural design and urban planning at the Swiss Federal Institute of Technology. With a passion for green architecture, John currently directs sustainable project integration at SERA. John is a member of the Sustainable Portland Commission.

ADVISOR

RICHARD J. SHULBERG, ISDF

Richard Schulberg is Executive Director and Secretary of the Board of Directors for the International Sustainable Development Foundation. In that capacity, he is responsible for the overall administration and management of the ISDF including the APEC Center for Sustainable Development, the China-U.S. Center for Sustainable Development and the Zero Waste Alliance. The International Sustainable Development Foundation has the mission to accelerate the understanding and use of practices that lead to economic, social and environmental sustainability. It achieves this mission by educating and motivating organizations to take action, developing demonstration projects and disseminating information and best practices through international networks. The International Sustainable Development Foundation is a 501 (c) 3 non-profit organization.

Team Oregon

APPENDIX 2

Fact Sheet*

The State of Oregon and Sustainable Development
Team Oregon, LLC

August 15, 2001

The State of Oregon, USA, located in the Pacific Northwest, enjoys an enviable quality of life. This quality of life is based on engaged citizens, a strong economy, clean air and water, livable cities, and open access to natural surroundings for all its citizens. Sustainable development, defined as "meeting the needs of the present while providing for the needs of future generations," is a goal for Oregon government, businesses and communities.

Oregon's reputation as a sustainable development leader is an increasing magnet for new investment. In 1996, Oregon was recognized as a global leader in attracting foreign investment and promoting growth of local industries.[1] In the space of just two years, over $14 billion in investment was attracted from US, Asian and European investors.[2]

Oregon's commitment to sustainable development came about through recognition over the years that a strong economy could only be maintained if the natural environment, agricultural and forest lands and the livability of communities could be nurtured. Oregon did not always have a reputation as a leader in sustainable development. Because of the state's historical reliance on wood products and agriculture, as population grew following the Second World War, the state's rivers and airsheds became increasingly polluted. In fact, at one time, the Willamette River in western Oregon was widely considered to be one of the most polluted rivers in America. For ecological purposes, it was nearly dead. Coupled with the increasing hazards of smoke-filled valleys, the people of Oregon—both the government and business community—began to realize that the environment must be considered in expanding business.

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As a result, Oregon began a process almost sixty years ago that grew until now, when the state is viewed as one of the leaders in the United States in achieving both environmental quality and a high rate of economic development.

Oregon has provided leadership in North America on sustainable development but is now addressing new complex challenges related to non-point source pollution, ecosystem restoration, and improving the quality of urban development.

Some of the key examples of Oregon's leadership include the following:

- Oregon was the first state in the US to adopt a comprehensive statewide land use planning and development program. Known as "Land Conservation and Development", this program has allowed

[1] Coopers & Lybrand and Area Development Publications, 1996 Outstanding Economic Development Organization in North America and the Outstanding Economic Development Organization in the world.

[2] Oregon was asked to share its strategy and to make a special presentation in Geneva to the United Nations Commission on Trade and Development and the founding congress of the World Association of Investment Promotion Agencies.

for the successful integration and management of agricultural, residential, commercial and industrial developments.

- Oregon's Governor, John Kitzhaber, was the first American governor to establish a policy and program, through executive order, to make Oregon a sustainable society.
- Oregon has supported an active international network on sustainable development through the creation of the International Sustainable Development Foundation, which serves as secretariat to the Asia Pacific Economic Cooperation (APEC) Sustainable Development Network, the China-US Center for Sustainable Development, and the Zero Waste Alliance.
- Oregon was the first state government certified to directly administer air quality regulations on behalf of the US Government. Oregon had actually been ahead of the US Government in formulating higher air quality standards.
- Oregon has the first and most comprehensive system of watershed or "ecosystem" councils in the US, comprised of governments, private, and non-governmental organization (NGO) representatives to plan for, manage, and restore to health watersheds in Oregon.
- Oregon was the first state to adopt a comprehensive business-public sector program to clean up point sources of pollution on its rivers. An initial focus of this clean up was the Willamette River. The clean up was successful and the Willamette River is now a popular recreation area and fishing stream for the Pacific Northwest Salmon. Current efforts are addressing non-point source pollution and reestablishing or more natural streambanks.
- Oregon was the first state to adopt innovative recycling programs, including the "bottle bill" and curbside residential recycling, to reduce solid waste in landfills, save money, and stimulate new recycling jobs.
- Oregon was the first, and remains the only state, to preserve the marine shoreline for open access to all citizens through public ownership of beaches.
- Oregon was the first state to develop a private sector volunteer campaign to clean Oregon beaches and coastal areas. This program, known as "SOLV", Stop Oregon Litter and Vandalism, is now a national model and is being used by other US states and countries.
- Oregon was the first state and now leads the US in the establishment of standards, known as "benchmarks", to measure progress in economic and environmental areas. The Oregon Progress Board, which oversees the benchmarks, recently completed the first comprehensive and peer-reviewed State of the Environment report.
- Environmental Technology and Services was targeted as a "key industry" for Oregon's economy.
- The Northwest Environmental Business Council, headquartered in Portland, covers a five-state region representing companies engaged in environmental technology, clean-up, and sustainable development.
- Many leading edge environmental technology and design firms are located in Oregon, such as Team Oregon, CH_2M Hill, Century West Engineering, SERA Architects, and Greenworks landscape architects.
- Oregon is the center of several leading research efforts including the newly established Western US Hazardous Materials Center.
- Oregon has leading multi-disciplinary environmental studies, environmental engineering and management programs at both the undergraduate and graduate levels of higher education. Several

research institutes focus on sustainable development including the Center for Watershed and Community Health at Portland State University.

- Oregon has created the Oregon Climate Trust to buy, sell, trade, and retire carbon credits to address global warming challenges worldwide.
- Portland had the first Climate Change action plan of any city in the US.
- Portland has the only citizen-elected regional government in the US. This seven-member council, Metro, coordinates land use planning, the urban growth boundary, greenspaces, transportation, solid waste, and major cultural facilities planning.
- Portland has the first Sustainable Portland Commission, Office of Sustainable Development, and adopted sustainable development principles in the US. The Sustainable Portland Commission is expanding its coverage to include the surrounding county.
- Portland has design review, and historic and landmarks commissions to review and approve all major projects in the central city.
- Portland has a Green Building Policy and staff to guide public and private development in the city toward complete life-cycle planning for new and renewed buildings and projects. For example, construction waste is recycled as part of the demolition and building process.
- Portland has a comprehensive Urban Forestry Management Plan and Forestry Commission. The goal of the plan is to provide guidance to all sectors of the city on the types, placement, maintenance, and protection of the urban forest, parks, and street trees.
- Portland has a thriving community of almost 100 non-governmental organizations (NGO's) involved in sustainable development and environmental activism. Leading among these is the Portland City Club, a 100-year old NGO which studies and recommends public policy to the city and state. It recently completed a comprehensive study, *Building a Sustainable Future for Portland* (April 2001). Other important NGO's include Sustainable Northwest, Ecotrust, the Oregon Natural Step Network, the Northwest Earth Institute, Oregon Environmental Council, and Friends of Trees.

* This fact sheet is based, in part, on information provided by the Oregon Economic and Community Development Department and the International Sustainable Development Foundation.

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APPENDIX 3

An Annotated Bibliography of Literature Concerning Sustainable Development

1. **Abbaté, G. Michael, *Sustainable Design on National Forests*. 1995. 11 pages. USDA Forest Service, Vancouver, Washington.**

Presented at the Urban National Forest Academy in April 1995, this paper outlines several factors to assist foresters in evaluating proposed or constructed projects in National Forests. Factors include site planning, energy, water, waste, building design, construction materials, construction technologies, and operations and maintenance. Emphasizes site context; carrying capacity; energy and water cycles; conservation of energy, water and materials; and cultural appropriateness.

2. **Abbaté, Mike, *Sustainable Landscapes and Site Design*. 2000. 12 pages. Team Oregon, LLC, Portland.**

A series of photographs and diagrams that illustrate 10 design principles for "Sustainable Landscapes, Beautiful Communities and Healthy Watersheds". These principles are: reduce stormwater runoff; improve fish and wildlife habitat; control erosion; rebuild disturbed soils; reduce use of chemicals; utilize native plants; reduce use of turf; protect streams, rivers and wetlands; support biodiversity; add beauty and art into outdoor environments.

3. ***Agenda 21: National Sustainable Development Strategy Guidelines of Taiwan R.O.C.* 20 pages. Draft, Government of Taiwan.**

Drafted in response to *Agenda 21* and the 1992 Earth Summit, presents Taiwan's strategy for implementing sustainable development. Describes specific environmental challenges Taiwan faces; defines sustainable development; presents a vision for sustainable development that includes a sustainable ecosystem, a comfortable environment, safe society, and open economy; identifies basic principles of sustainable development; outlines a nine-step integrated strategy of sustainable development; and presents strategy guidelines organized around the categories of sustainable environment, sustainable society, sustainable economy, development motivation, and promoting mechanisms.

4. **Alexander, Christopher et al., *A Pattern Language: Towns, Buildings, Construction.* 1977. 1171 pages, Oxford University Press, New York.**

A resource book that describes the detailed patterns for towns and neighborhoods, houses, gardens and rooms, this is a guide to 253 discrete 'patterns' described in detail and in application. Connections among 'patterns', from larger-scale 'independent regions', 'agricultural valleys', the 'lace of country streets', to the 'magic of the city' and 'local transport areas' to specific areas such as the 'house cluster', and the 'industrial ribbon' are explored. Specific architectural elements for pleasant and inviting design are also described—from 'wings of light' and 'positive outdoor space' to 'indoor sunlight', 'communal eating areas' and openings to the street.

5. **Anderson, Ray C., *Mid Course Correction: Toward a Sustainable Enterprise: the Interface Model.* 1998. 207 pages. Peregrinzilla Press, Atlanta.**

A study of *Interface,* a carpet-making company and its revolution toward a closed-system, zero-waste-producing business. A very practical and inspiring documentation of one man and company's efforts toward realizing an environmentally sustainable and socially responsible business. Explores crisis and the challenge of opportunity through personal and corporate experience. Defines the "prototypical company of the 21st century" – where the company and even its supply chain and customers is treated as a system codependent with the earth's lithosphere and biosphere. Presents and explains the closed-loop system using the example of one business, its consumers, inputs, transportation system, and even tax system. In closing, suggests the Power of One and challenges the reader to Love All Children for a more complete and sustainable world.

6. ***APA Policy Guide on Planning for Sustainability.* 2000. 23 pages. American Planning Association, New York.**

States APA's position on sustainability. Defines four aspects of sustainability: sustaining communities as good places to live; sustaining social values such as democracy; sustaining biodiversity; sustaining functions of natural systems. Identifies global indicators of unsustainability, including global warming, soil degradation, deforestation, species extinction, declining fisheries, and economic inequity. Also identifies indicators of unsustainability in the U.S., including suburban sprawl, segregation/unequal opportunity, loss of agricultural land and open space, depletion and degradation of water resources, loss of wetlands, traffic congestion and air pollution, and disproportionate exposure to environmental hazards. Lists factors that contribute to unsustainability, including over-consumption, population growth, dependence on non-renewable resources, pollution, environmentally and socially destructive development patterns, and inequities in resource distribution. Presents four general policy objectives: reduce dependence upon fossil fuels, extracted underground metals and minerals; reduce dependence on chemicals and other manufactured substances that can accumulate in nature; reduce dependence on activities that harm life-sustaining ecosystems; meet the hierarchy of present and future human needs fairly and efficiently. Presents 13 specific policy objectives an outlines possible planning actions toward sustainability.

7. **Architects Council of Europe, et. al. , *A Green Vitruvius.* 1999. 145 pages. James & James, London.**

Excellent overview of the architectural design-delivery process coupled with principles of sustainability. Includes examples and diagrams of strategies primarily for European climates.

8. **Architecture and Building Research Institute, *Evaluation Manual for Green Building in Taiwan.* 1999. 57 pages. Architecture and Building Research Institute, Taipei, Taiwan.**

Discusses the history and evolution of the "Green Building" concept. Presents seven evaluation indices for Green Buildings: Carbon dioxide absorption and fixation; soil water content; water conservation; energy conservation; Carbon dioxide emission; waste reduction; sewer and garbage. For each index, defines the concept, identifies the goal, describes the quantitative index and its basis; describes how the goal can be met, and presents a case study.

9. **Ashworth, William, *The Economy of Nature: Rethinking the Connections Between Ecology and Economics.* 1995. 340 pages. Houghton Mifflin Company, New York.**

Ashworth maintains in *The Economy of Nature* that we do not have to choose between ecology and economics, rather that each is good and essential for the other. Environmental destruction considered as not only morally wrong, but fiscally irresponsible. Begins with a chapter on "Only One Household" with the statement that there is nowhere on our Earth that the environmental crisis has not reached. He reminds the reader that the health of a society's economy depends on their relationship to its environment. He explores the character and role and limits of laws and regulations and nature preserves; and suggests we are operating with the wrong set of incentives and that whatever compromises the environment compromises our economy. With "thinking like a forest" thinking, Ashworth suggests we adhere to a gaia-like principle of stewardship ethics in our daily lives and all our operations. He encourages a serious consideration of our limits, the value of our resources, opportunity costs that we lose when we damage nature, our collective tendency toward selfishness, our definition of national wealth, limits to free and subsidized access to public land, true-value pricing, environmental justice and a new access to nature.

10. **Batie, Sandra S. et al., eds., *Business-led Initiatives in Environmental Management: The Next Generation of Policy?* 1997. 204 pages. American Agricultural Economics Association, Special Report (SR) 92.**

Series of papers on application of business-led initiatives in Environmental Management to agro-environmental problems. Notes that agriculture is the largest source of non point source pollution in the United States. Assesses the need for "agro-environmental" legislation and the adequacy of voluntary business initiatives such as marketing of eco-friendly products. Analyzes business and regulatory aspects of corporate environmental management, economics and effectiveness of environmental management, and implications for the food system.

11. **Benyus, Janine M., *Biomimicry: Innovation Inspired by Nature.* 1997. 308 pages. Quill William Morrow, New York.**

Holds that biomimicry defines: 1) nature as model; 2) nature as measure; and 3) nature as mentor—and that its practice is "a conscious emulation of life's genius." Includes an inspiring "canon" of nature's laws. Explores how we, as a population, are going to continue to feed ourselves functionally with our 'recent' industrial agricultural methods; how we are going to harness energy; how we will make things; how we'll heal ourselves; how we will store what we learn; how we will conduct business; and how we will go from here.

12. **Berke, Philip R. and Maria Manta Conroy, "Are We Planning for Sustainable Development? An Evaluation of 30 Comprehensive Plans," *American Planning Association Journal,* Vol. 66, No. 1, (2000): 21-33.**

Discusses the increasing effort by cities and counties in America to integrate sustainable development into their planning processes. Evaluates 30 comprehensive plans from local jurisdictions in America against six criteria: harmony with nature; livable built environments; place-based economies; equity; polluters pay; responsible regionalism. The study finds that there is not a significant difference in results between jurisdictions that have adopted policies to integrate sustainable development and those that have not. For example, Portland, Oregon, which has adopted sustainable development policies, has the second-highest rating among the 30 jurisdictions,

and Jacksonville, Florida, which had not adopted sustainable development policies, is ranked the highest. It finds that many jurisdictions address one or two of the six criteria much more directly and effectively than others. Concludes that the next step is to "narrow the gap between theory and practice."

13. Botkin, Daniel B., Discordant Harmonies: A New Ecology for the Twenty-First Century. 1990. 241 pages. Oxford University Press, New York.

Argues that many current practices of managing the environment and ecosystems are based on incorrect assumptions about nature, including that nature in a state undisturbed by humans would be static and stable. Describes the conceptual paradox of viewing nature both from a rational and analytical perspective and from an emotional and intuitive one. Shows through a series of case studies how these incorrect assumptions and concepts translate into management decisions that do not reverse environmental destruction and actually harm ecosystems. Explains that environmental management in the twenty-first century will require a conceptual shift and a redefinition of humanity's relationship to nature and humanity's role in managing it.

14. Brand, Stewart, *How Buildings Learn*, 1994. 242 pages. Penguin Books, New York.

Creative, witty analysis of the way buildings change over time due to a variety of factors. Influential in thinking about the usefulness, meaning and longevity of our built environment.

15. Bryant, Steve, et al., *A Template for Local Government Sustainable Development Initiatives*. 2000. 45 pages. PSU Center for Watershed and Community Health/League of Oregon Cities.

A guidebook for local jurisdictions outlining a step-by-step process for adopting sustainable development policies, programs and practices. Focuses on five key questions around which a sustainable development initiative should be organized: What is our commitment to sustainability? How sustainable are we now? How sustainable do we want to be? How do we get there? How do we measure it? Provides numerous examples of existing endeavors by local jurisdictions around the world. Lists "start-up" ideas that a jurisdiction can take as easy first steps to begin its process of moving towards sustainability. Includes exercises to help assess past and present approaches to the five key questions and to assist with developing new programs for sustainability. Also includes the introductory document, *Context and Background for Local Government Sustainable Development Initiatives*.

16. City Club of Portland, *Building a Sustainable Future for Portland*. 2001. 86 pages. City Club of Portland, Portland.

Attempts to define the term "sustainability", particularly as it applies to the Portland metropolitan region. Explores the costs and benefits associated with sustainability. Reviews approaches that assess progress toward sustainability goals. Describes various roles of government, private business, the community, and individuals in promoting sustainability. Notes that because sustainability is such a broad and complex concept, there are not widely agreed-upon criteria to measure sustainability. Concludes that community value judgements and a widespread consensus on sustainability indicators are needed.

17. *City of Portland Green Building Policy*. 2000. 8 pages. City of Portland Web site.

Policy statement for the City's Green Building Initiative. Because buildings consume significant amounts of materials and energy, construction and maintenance of buildings represents a key opportunity for conservation. Policy statement describes integrated design strategies and life cycle analysis and explains the Leadership in Energy and Environmental Design (LEED) rating system that Portland has joined. Outlines four major policy strategies: incorporation of green building practices into all facilities and projects constructed, owned, managed or financed by the City; adoption of the LEED rating system by the Portland Development Commission; development of a rating system of public infrastructure; promotion of voluntary application of green building guidelines in the private sector. Suggests evaluation criteria for measuring architects' and engineers' knowledge of green building design.

18. City of Portland Office of Sustainable Development, *Sustainable City Principles*. 1994. 2 pages. City of Portland Web site.

Presents the overall goal of the City of Portland to promote sustainable development and outlines ten principles to guide elected officials and staff. Principles address the connection between the environment and economy; recognizing cumulative and long term impacts; equity and environmental justice; linking environmental quality to decision making in other sectors; reducing demand for natural resources; pollution prevention; acting locally to help solve global environmental problems; choice of products to purchase; educating and involving the public; and annual reporting.

19. Cogan Owens Cogan, for the Oregon Department of Environmental Quality, *Stakeholder Guidelines*. 1999. 30 pages. Portland.

Provides guidelines for developing, implementing and monitoring a successful stakeholder involvement program. Though designed for the Oregon Department of Environmental Quality's Green Permits Programs, this is also a model for stakeholder involvement. The Green Permits Program encourages facilities to achieve environmental performance that significantly exceeds legal requirements through the use of recognition and rewards. Facilities must engage the public and other stakeholders in dialogue and other forms of involvement to be eligible for the program. The document describes basic elements of stakeholder involvement including objectives, benefits and drawbacks of involvement; stakeholder identification; variety of stakeholder involvement techniques, their objectives, strengths and weaknesses; key factors for successful implementation; measures to evaluate a program's effectiveness; achievement guidelines for the three different "Tiers" of facilities; and how DEQ will evaluate and verify stakeholder involvement.

20. Crites, Ronald W., Sherwood C. Reed, and Robert K. Bastian, *Land Treatment Systems for Municipal and Industrial Wastes*. 2000. 433 pages. McGraw-Hill, New York.

This book, written by three of the field's leading experts, discusses land and other ecologically sound methods for treatment, renovation, reuse, and disposal of wastewater and biosolids.

21. Davis, Gary and Catherine Wilt, *Extended Product Responsibility: A New Principle for Product-Oriented Pollution Prevention*. 1997. 130 pages. University of Tennessee, Knoxville.

Extended Product Responsibility (EPR) is a principle for pollution prevention that focuses on all segments of the product chain, including selection of product materials, production impacts, use and disposal of the products. Report examines EPR in the United States and explores several case studies, including the electronics industry; automotive take-back and recycling programs; recycling of nickel-cadmium batteries; EPR at the Xerox Corporation; and EPR at the Rochester-Midland Corporation.

22. Detail in Building, *Wind Towers: Battle McCarthy Consulting Engineers. 1999.* 96 pages. Academy Editions, London.

Case studies and history of wind towers as an integral element in climatic design of buildings.

23. Durning, Alan Thein and Yoram Bauman, *Tax Shift: How to Help the Economy, Improve the Environment, and Get the Tax Man off Our Backs.* 1998. 115 pages. Northwest Environment Watch, Seattle.

Describes premise that we should not be taxing things we do value, e.g., our paychecks and our businesses, but we should be taxing the things we do not want, e.g., pollution and traffic congestion. Taxing elements that erode rather than support the public good presented as a way to correct our current disconnect between private behavior and ecological sustainability. Briefly describes the "cobbled" system of taxation (including personal income tax, payroll, property, corporate income and sales tax) and offers clues as to how to identify the difference between a "good" tax and "bad." Suggests taxes that would be more in line with obtaining socially desirable results such as carbon taxes, pollution, including both point and non-point pollution. Lists property tax "evaders" (farms, automobiles, mansions, energy, timberlands) and describes the implication of that "evasion." Suggests ways to begin to press for this type of social-environmental correction.

24. EDAW, *Planning the Green Zone.* 1995. 36 pages. U.S. Government Printing Office, Washington D.C.

In the summer of 1994, eleven students converged at an elevation of 8,000 feet in the wilds of the Rocky Mountains of Colorado for a two-week charette-style workshop in order to create a model for sustainable development. Coming from very diverse backgrounds and perspectives, EDAW's summer workshop brought students and professionals together and provided the environment, resources and collaborative format to deal with the planning and design of a sustainable boundary zone between Rocky Mountain National Park and the neighboring Estes Park community. EDAW personal, experts in various fields, the National Park Service and Estes Town officials provided the factual data and direction from which this report was produced. The team brought with them open and creative minds and an ability to question and challenge the role of the NPS and the people of Estes Park in creating a prototype for sustainability which any community could use as a model.

25. Edwards, Brian, *Sustainable Architecture: European Directives & Building Design.* 1999, second ed. 277 pages. Architectural Press, Oxford.

European examples coupled with in-depth discussion of additional subjects that circle around sustainable architecture such as environmental audits, the ecology of materials, and the future of laws governing the environment.

26. Environmental Resources Management, *Sustainable Development in Hong Kong for the 21st Century, Second Stage Consultation*. 2000. 109 pages. Environmental Resources Management, Hong Kong.

The Sustainable Development for Hong Kong in the 21st Century (SUSDEV 21) study program has the goal of operationalizing the concept of sustainable development into the process of government decision making. Two key aspects of the program are to develop sustainability indicators to predict implications of policy decisions and develop a computer-based decision support tool. The "Second Stage Consultation Programme" had the dual goals of obtaining public feedback on the study and raising awareness about sustainability. This document describes SUSDEV 21's public consultation program; summarizes feedback received from the public and the study team's responses; and discusses how the feedback will be incorporated into the outputs of the study. Many of the specific comments relate to the set of indicators that will be used.

27. Frankel, Carl, *In Earth's Company*. 1998. 240 pages. New Society Publishing.

Identifies the key elements of the emerging era of corporate environmentalism. Details the many concepts and technologies for creating a sustainable future that have already been developed and are in use.

28. Gore, Albert, *Earth in the Balance: Ecology and the Human Spirit*. 1993. 407 pages. Plume.

Written by former American Vice President Al Gore, demonstrates that the quality of air, water and soil is at grave risk, not only locally or regionally, but globally. Argues that only a radical rethinking of the human relationship with nature can save the earth's ecology for future generations.

29. *Green@work*. January-February 2000.

A bi-monthly periodical focusing on business and the environment. Articles describe initiatives by major business leaders, new technological innovations, management theories and new policies.

30. Hawkins, Paul; Lovins, Amory and L. Hunter, *Nature Capitalism: Creating the Next Industrial Revolution*. 1999. 396 pages. Little, Brown and Company, Boston.

A biological and social framework to assist with the transformation of commerce to a sustainable end. A win-win situation is described in Paul Hawkins and Amory and L. Hunter's work: "...a place where the environment and humans are vital and well-being." According to the authors, increasing natural capital adds to everyone's present and future prosperity. The authors suggest a capitalistic system "... as if living systems mattered." They forecast more efficient cars and waste system(s), and new processes in corporate culture as well as design and new technologies. True cost and longer range returns show more clearly the result of "green" or conscious investment. Business/ Economic development.

31. Hillary, Ruth, ed., *ISO 14001: Case Studies and Practical Experiences*. 2000. 382 pages. Greenleaf Publishing Limited, Sheffield.

ISO 14001 is the International Organization for Standardization's most prestigious environmental management system (EMS) standard. This book presents 30 case studies from around the world of organizations that have implemented ISO 14001. Case studies discuss implementation techniques to make ISO 14001 operational, maintainable, and beneficial; explores various issues related to certification, including certifying a group of small businesses and global certification; describes tools to either streamline the ISO 14001 process or make it more intensive; discusses training and communication; presents issues related to engaging stakeholders; describes how products, design and technology can be accommodated into the EMS model; discusses environmental and economic benefits; and considers how organizations can use ISO 14001 to meet the broader needs of sustainable development.

32. Hough, Michael, *Cities and Natural Process*, 1995. 326 pages. Routledge Press, London.

Hough's thesis is that traditional design values that have shaped our cities' physical landscapes have contributed little to their environmental health, their success as civilizing, enriching places to live. He explores the concept of urban ecology, an area easily overlooked for its complexity and socio-political challenges. Traditional versus modern urban forms compared, with the division between city and countryside increasingly defined. The role of humans and human development in this context mentioned. Chapters are devoted to elements of our natural world—water (what we've done to it and some examples of restoration), plants (their loss in cities and some examples of restoration), wildlife (natural and urban processes, opportunities, including in planning and management), city farming (context and some examples are given), climate and the urban influence including temperature control, and the connection between these elements. Urban planning and ecosystems.

33. Industrial Technology Research Institute. *Strategic Guidelines for Sustainable Development of the Republic of China, Proposed by National Forum on Sustainable Development.* 1998. 80 pages. Council for Economic Planning and Development, Executive Yuan, Taiwan R.O.C.

Based on National Sustainable Development Forum (NSDF) conferences of over 240 experts in a wide variety of fields, outlines principles proposed by the NSDF to guide Taiwan in promoting sustainable development. Also outlines action plans for the economic, environmental and social sectors. Proposed principles include: promoting generational equity; maintaining a balance between the environment and economic development; internalizing external costs; adopting a precautionary approach; embedding the spirit of sustainable development in society; encouraging public participation in decision-making; emphasizing scientific and technological developments; taking action systematically and integratively; actively pursuing internationalization. Proposed lines of action include: participation of all segments of society in forming national sustainable development policy; guidance to local governments on their role in implementing sustainable development; public education; allocation of administrative resources; and redrafting of basic environmental laws. Sustainable development policy.

34. Jones, David Lloyd, *Architecture and the Environment: bioclimatic building design.* 1998. 256 pages. The Overlook Press, Woodstock, N.Y.

Balanced collection of new projects from the world, coupled with essays on green architecture and bioclimatic design. Green building/landscape design.

35. Lyle, John Tillman, *Design for Human Ecosystems: Landscape, Land Use, and Natural Resources.* 1999. 279 pages. Island Press, Washington, D.C.

This 1999 contribution to the field concerns the principles, methods and techniques for working with and 'shaping' landscape, land use and natural resources so that they operate in more sustainable ways. Beginning with a documentation of public awareness of our growing ecological crisis, a "hierarchy" of scale is described, from the geographic region, with the role of the growth of regional planning, subcontinents, and the whole earth. Plan Units and smaller landscapes also are described; various design/land use layouts also described with a focus on ecological considerations and ecological planning. Residential development projects described. Human and technological processes of design explored as well as the field of planning and modes of ecological order (structure, plants, habitats). Lyle ends by encouraging capacity for adaptive change—creative change.

36. Lyle, John Tillman. *Regenerative Design for Sustainable Development.* 1994. 338 pages. John Wiley & Sons, Inc., New York.

Regenerative Design for Sustainable Development is a practical guide to the theory, design, and construction of regenerative systems. It describes practical applications to the essential system of land development: energy flow, water flow, agriculture and land use, and building design. The book also explores the cultural, social, and economic implications of regenerative systems, and speculates on the global landscape that can result from their application. Many of the systems that Lyle describes have been incorporated into the designs for the Center for Regenerative Studies - a 16-acre on-campus site at the California State Polytechnic University in Pomona designed to integrate regenerative systems of energy, water, shelter, food productions, waste disposal, and other essential functions. A central tenet of this book is that sustainable development relies on the interaction of numerous systems working in harmony with one another.

37. Lynch, Kevin. *Site Planning,* 2nd Edition. 1974. 380 pages. The Colonial Press, Inc., Massachusetts of Technology, Boston.

This classic site planning text has been updated from the 1969 version with increased attention to ecology, psychosocial analyses, design methods, and the concept of environmental design as a continuous process involving many participants. Examples of site planning across the millennia explored—from Mach Piccu in Peru to modern urban landscapes. People in their environments is emphasized as a design tool. Lynch encourages the study of these "behavioral settings." Density and thresholds explored. Chapters include site form and ecology; social and psychological analyses (understanding how people use and value their environment); movement systems; streets and ways; earthwork and utilities; sensuous form; the problems of control; design and site management; design methods; cost; housing; and special types of site planning (shopping centers and commercial strips), industrial districts, institutions, open space and renewal.

38. McDonough, William and Michael Braungart, *The Hannover Principles Design for Sustainability.* 1992. 122 pages. William McDonough Architects, New York.

The City of Hannover, site of the 2000 World's Fair (EXPO 2000), chose "Humanity, Nature, and Technology" as the Fair's theme. The City commissioned sustainability principles to inform design competitions that were part of the Fair. These "Hannover Principles" are also intended for a wider context, both for the City and the rest of the world. Principles include: insist on rights of

humanity and nature to coexist; recognize interdependence; respect relationships between spirit and matter; accept responsibility for the consequences of design; create safe objects of long-term value; eliminate the concept of waste; rely on natural energy flows; understand the limitations of design; seek constant improvement by the sharing of knowledge. Presents a series of design guidelines organized around the concepts of earth, air, fire, water and spirit.

39. McHarg, Ian L., *Design with Nature*. 1969. 197 pages. Doubleday/Natural History Press, Garden City, New York.

One of the classic texts in the fields of environmental planning and urban design, this book contends that development must occur in harmony with the natural landscape and work with ecological functions and processes rather than against them. It discusses its theme at the philosophical, conceptual, policy and implementation levels. Explores urban development at the regional, metropolitan and watershed scales and contrasts uncontrolled growth and its consequences with planned growth.

40. Melet, Ed, *Sustainable Architecture: towards a diverse built environment* . 1999. 189 pages. NAI Publishers, Rotterdam.

Examples of current examples of world architecture built and un-built. Organized by elements of design: glazed thermal buffers, smart buildings, buildings as energy generators, and compact cities.

41. Minnesota Planning, *From Policy to Reality: Model Ordinances for Sustainable Development*. 2000. 313 pages. State of Minnesota Web site, www.mnplan.state.mn.us/SDI/ordinances.html.

This document is the result of Minnesota Statues, Section 4A.07(3) which directs Minnesota Planning to prepare a model ordinance in consultation with appropriate parties to guide sustainable development. It is a first step in pursuit of the goal of creating a package of model ordinances that Minnesota communities can use in charting their futures. This guide offers tools to help make the best choices today for the health of the community tomorrow. Communities can adapt these model ordinances to their own special circumstances as part of a citizen-based community planning process.

42. National Council for Sustainable Development, *1999 Annual Report of National Sustainable Development*. 1999. 92 pages. National Council for Sustainable Development, Taiwan.

Reports on the progress of Taiwan's National Council for Sustainable Development (NCSD). Discusses trend and current status of sustainable development promotions; reviews important NCSD tasks and their implementation status; outlines the accomplishments of the eight working groups; and discusses future work plans and prospects.

43. National Research Council, *Nature's Numbers: Expanding the National Economic Accounts to Include the Environment*. 1999. 250 pages. National Academy Press, Washington, D.C.

To more comprehensively value and evaluate the sustainability of our nation's capital, the Council recommends that the U.S. National Income and Products Account (NIPA) include "assets and

production activities associated with natural resources and the environment." This is put in the context of a "...larger movement to develop broader economic indicators..." that has been growing, at least since the late 1970's. The authors suggest a three-phase work plan: an overall technological and measurement framework; extend these accounts to stocks and water resources; and lastly, to "non-market" assets such as clean water and air. History of NIPA and its application to the environment.

44. Nattrass, Brian and Mary Altomare, *The Natural Step for Business: Wealth, Ecology and the Evolutionary Corporation.* 1999. 222 pages.

Explains how The Natural Step provides a simple yet elegant framework to integrate environmental issues into the frame of business reality. Provides detailed case studies of four leading corporations—IKEA, Scandic Hotels, Interface, and Collins Pine—that are using The Natural Step as a central part of their corporate strategies.

45. The Natural Step, *The Natural Step's Four System Conditions.* The Natural Step U.S. Web site, www.naturalstep.org.

The Natural Step is an international environmental organization that works with businesses, governments and other organizations to promote sustainable development. The organization's sustainable development framework is a set of four scientifically-based principles called "system conditions". The four conditions are: In a sustainable society, nature is not subject to systematically increasing 1) concentrations of substances extracted from the earth's crust, 2) concentrations of substances produced by society, 3) degradation by physical means; and in that society, 4) human needs are met worldwide.

46. Olgyay, Victor, *Design with Climate: Bioclimatic approach to architectural regionalism.* 1963. 190 pages. Princeton University Press, Princeton, N.J.

Classic textbook on the bioclimatic approach to design. Full of diagrams and analysis of strategies regarding solar, thermal, and wind effects on the design of buildings.

47. Oregon Natural Step Construction Industry Group, *Using the Natural Step as a Framework Toward the Construction and Operation of Fully Sustainable Buildings, Draft #8.* 2000. 14 pages. Oregon Natural Step Construction Industry Group.

Applies the Natural Step Framework to constructing a commercial building. Discusses the four Natural Step system conditions. Depicts the "life cycle" of a building.. Assesses current building practices using the four system conditions. Outlines criteria for materials used, energy, air, water, transportation and other factors for a building to meet the system conditions. Describes a goal or "end point" of green building design.

48. Porter, Douglas R., *The Practice of Sustainable Development.* 2000. 162 pages. Urban Land Institute, Washington D.C.

Published by the Urban Land Institute, this collection of articles begins with a brief introduction to sustainable development, its history, struggle for identity and current challenges. Porter's 'dimensions' of sustainability—social equity, economic prosperity and ecological integrity—are explored in the context of modern challenges and cultural behaviors such as consumerism, post-

WWII suburban developments and the American value of privacy. Porter and his co-contributors offer a historical and contextual introduction to various perspectives on sustainable development – urban planning trends such as 'smart growth', 'new urbanism', transit-oriented developments', 'habitat conservation planning' to avoid penalties under the Endangered Species Act and 'green development'—and considers the appropriate scale for incentives to sustainability planning in the U.S. Site-specific examples in terms of urban development also given.

49. President's Council on Sustainable Development, *Eco-Efficiency: Task Force Report.* 1996. 35 pages. U.S. Government Printing Office, Washington D.C.

The premise of this Task Force Report is a self-described "belief that environmental protection and economic growth can, and must be, linked." The mission of the Task Force was to identify the means by which the United States can realize sustainable development. Eco-efficiency, used to describe corporations producing economically viable goods while continuously reducing the ecological impact of those goods, is applied to goals for a eco-efficient economy. Goals include responsibility; economic growth; sustainable resource utilization; environmental quality; government regulatory policy; and social well-being. A context statement, goal and indicators of progress are given for each. Nine policy recommendations given ranging from chemical operations, eco-industrial parks. Information, economics, regulatory, and money and management clusters described.

50. President's Council on Sustainable Development, *Sustainable America: A New Consensus for Prosperity, Opportunity and a Healthy Environment.* 1996. 186 pages. U.S. Government Printing Office, Washington D.C.

This consensus document begins with a 16-point statement of belief regarding sustainability that was collaboratively developed by its American members. National goals toward sustainable development are presented. In addition to implementation indicators, a policy framework is described, strategies to strengthen communities, encourage natural resources stewardship in forestry, fisheries, restoration and biological conservation formed. Population growth and international leadership discussed. National goals including health and the environment; economic property; equity; conservation of nature; stewardship; sustainable communities; civic engagement; population; international responsibility; and education. Specific goals, action items and indicators of progress are also given.

51. President's Council on Sustainable Development, *Toward a Sustainable America: Advancing Prosperity, Opportunity, and a Healthy Environment for the 21st Century.* 1999. 158 pages. U.S. Government Printing Office, Washington D.C.

The Vision Statement and beliefs published in *Sustainable America* are reprinted as an introduction to this collection of policy areas President Clinton asked the Council to consider. Each policy area contains an introduction and context section. Policy arenas include climate change; environmental management; metropolitan and rural strategies on sustainable communities, including economic health; and international leadership in sustainable development. Key findings summarized and action programs recommended for many policy areas.

52. Risser, Dr. Paul G., Chair, State of the Environment Science Panel et al., *Oregon State of the Environment Report 2000: Executive Summary.* 2000. 80 pages. Oregon Progress Board, Salem, Oregon.

This much-needed comprehensive evaluation of the State of Oregon's current environmental status contains broad-scale inventory information gathered to identify future risks to Oregon's economic health and lasting ecosystem vitality. Data is given in the form of background, status and key indicators regarding estuarine, forest, riparian, farmland, wetlands, rangelands urban areas, biodiversity, and other areas. Areas in Oregon described by eco-region: the coast range, the Willamette Valley, the Klamath Mountains, Eastern Cascades, Columbia Plateau, Blue Mountains, and the Northern Basin and Range. A set of findings and conclusions for each area is given, from water quality, to forests, rangelands biological diversity, agriculture, toxic emissions and data collection and management.

53. Rocky Mountain Institute, et. al., *Green Development: Integrating Ecology and Real Estate.* 1998. 522 pages. John Wiley & Sons, Inc., New York.

Covers all aspects of development , beginning with a new view of real estate and continuing through construction. Includes the benefits of marketing a green development as well as case studies. A CD is also available with supplementary information, not included in the book, for each case study.

54. Romm, Joseph, *How the Best Businesses Boost Profits and Productivity by Cutting Greenhouse Gas Emissions.* 1999. 277 pages. Island Press.

Shows how energy efficiency investments improve productivity, yield high return on investment, and mitigate climate change. Key book about the next industrial revolution.

55. Roseland, Mark, *Toward Sustainable Communities: A Resource Book for Municipal and Local Governments.* 1992. 339 pages. National Round Table on the Environment and Economy, Ottawa.

Chronicles examples of practical outcomes of the Healthy Cities, sustainable communities, and eco-cities movements. Looks at the application of sustainable development through an "ecosystem approach to human settlements management." Written for an audience of local government officials and citizens to apply the concept in their communities. Holds that many of the most pressing global environmental challenges are really rooted in local, day-to-day problems of things such as poor planning or lack of consideration of environment and long-term effect. Defines sustainable development according to the Bruntland Commission perspective as published in its 1987 report *Our Common Future*. Gives examples of initiatives in several cities—using the city as a brief case study example. Summarizes a variety of "sustainable community tools": atmospheric change and air quality; transportation planning and traffic management; land use and growth management; energy conservation and efficiency; waste reduction and recycling; water and sewer; greening the city; economic and community development; and investments and purchasing. Presents several planning and administrative tools: leadership (environmental auditing, staff training); environmental administration (operating principles, public involvement) and implementation.

56. Ryan, John C. and Alan Thein Durning, *Stuff: The Secret Lives of Everyday Things.* 1997. 86 pages. Northwest Environment Watch, Seattle.

Describes the full environmental impact of things we use or consume everyday, such as cars, coffee, newspapers, hamburgers, clothing and computers. Outlines the step-by-step production process for these goods in terms of resource inputs, water consumption, energy costs, and pollution byproducts. Explores changes we can make in our daily life, shopping and transportation to reduce our impacts on the environment.

57. Todd, Nancy Jack and John Todd, *From Eco-Cities to Living Machines: Principles of Ecological Design*. 1994. 197 pages. North Atlantic Books, Berkeley, Ca.

Living machines combine intellectual, biological and technical tools to treat water waste to tertiary levels. Includes history and theory behind the systems as well as early examples.

58. United States Department of the Interior, National Park Service. *Guiding Principles of Sustainable Design*. 1993. 117 pages. U.S Government Printing Office, Washington D.C.

Guiding Principles of Sustainable Design is intended to provide a basis for achieving sustainability in facility planning and design, emphasize the importance of biodiversity, and encourage responsible development decisions in parks and other conservation areas, particularly where related to eco-tourism. This merger of sustainable development and eco-tourism provides tremendous opportunities for affecting visitor perceptions of the natural and cultural world, and developing conservation-oriented values. It is a marriage that would clearly distinguish sustainable development from traditional tourist development. Sustainable principles have been developed for nine topics: interpretation, natural resources, cultural resources, site design, building design, energy management, water supply, waste prevention, and facility maintenance and operations. Although material is presented in separate sections, the interconnection of all systems and resources must be recognized; the resulting development should reflect the blending of disciplines to demonstrate respect for local, regional, and global environments.

59. U.S. Environmental Protection Agency, *Constructed Wetlands for Wastewater Treatment and Wildlife Habitat: 17 Case Studies*. 1993. 174 pages. EPA832-R-93-005, U.S. EPA.

This document provides a brief description of 17 wetland treatment systems from around the United States that are providing significant water quality benefits while demonstrating additional benefits such as wildlife habitat. The projects described include systems involving both constructed and natural wetlands, habitat creation and restoration, and the improvement of municipal effluent, urban stormwater and river water quality.

60. Vale, Brenda and Robert Vale, *Green Architecture*. 1991. 192 pages. Thames and Hudson Ltd., London.

Discusses the importance of architectural design as it affects the environment. Proposes "ground rules" for green cities. Well illustrated with examples and tables.

61. Van der Ryn, Sim and Calthorpe, Peter. *Sustainable Communities: A New Design for Cities, Suburbs, and Towns*. 1986. 238 pages. Sierra Club Books, San Francisco.

In this persuasive and evocative book, two authorities on appropriate technology have assembled a practical vision of how different types of American communities can make the transition to a way of life that encourages sustainability, reduces resource waste, balances consumption and

production, and produces a long-term social and ecological health. *Sustainable Communities* presents practical guidelines for urban and suburban renovation as well as new community planning, and offers inspiring commentaries by leading-edge thinkers in the burgeoning field of "sane" redevelopment, including John Todd on the synthesis of biology and design and Paul Hawken on the economics of sustainability.

62. Van Der Ryn and Cowan, *Ecological Design.* 1996. 201 pages. Island Press, Washington D.C.

Van Der Ryn and Cowan contend that the living world and humanity can be reunited by making ecology the basis for design. Describes two approaches as organized by David W. Orr—technological and ecological sustainability. Where technological sustainability does not demand a radical change in the way we related to our environment, ecological sustainability does. The authors contend that ecological design respects species diversity, minimizes natural resource depletion, preserves the integrity of nutrient and water cycles, maintains habitat quality, and responds to all other conditions of human and ecological health. It is described as "adaptation to and integration with nature's processes." Scale and ecological design processes described according to the following principles: solutions grow from place; ecological accounting informs design; design with nature; everyone is a designer; and making nature visible.

63. Wackernagel, Mathis and William Rees, *Our Ecological Footprint.* 1996. 160 pages. New Society Publishers, Canada.

Fascinating analysis of world's various standards of living and how they relate to amounts of natural resources used to support them. Gives perspective to other approaches to the puzzle of sustainability.

64. Wells, Malcolm, *Gentle Architecture.* 1981. 178 pages. McGraw-Hill, Inc., USA.

An early and highly personal approach to green building as seen by one of the first pioneers of sustainable design. Includes "wilderness-based" checklist for design and construction that measures performance against natural systems.

65. *Willamette Riverbank Design Notebook*. 2000. 105 pages. City of Portland.

A key tool for the City of Portland's efforts to promote recovery of endangered fish species through restoration of healthy watersheds. Provides guidance for repair and modification of the banks of the Willamette River, and is intended to be a common frame of reference for landowners, designers, land use planners, and regulators. Describes current conditions of the banks of the river within the City. Presents design objectives for the riverbanks that stem from discussions with the National Marine Fisheries Service about properly functioning conditions for the lower Willamette River. Provides analysis methods to assess conditions for a particular site, implementation measures and design references. Design guidelines oriented around three different elevation zones of the riverbank. As it is titled, it is a design notebook!

66. Williams, Katie, Elizabeth Burton and Mike Jenks, eds., *Achieving Sustainable Urban Form.* 2000. 388 pages. E & FN Spon, London.

Extensive collection of academic studies exploring the relationship between urban form and sustainability. Various studies examine compactness, density, intensification, centralization and decentralization, mixed land uses and other urban forms for their influences on travel demand, traffic congestion, accessibility, energy use, housing costs, social equity and other factors. Editors review the studies collectively to attempt to define sustainable urban form and approaches to achieve it, both at the policy level and the design level.

67. Wilson, E. O., Editor, *Biodiversity* 1988. 521 pages. National Academy Press, Washington D.C.

Developed by the Smithsonian Institute's Directorate of International Activities Board on Basic Biology, this book maintains that biological diversity "is a global resource to be understood, used and preserved." Written in the context of rapid population growth; increasing understanding of and interest in the value of diverse plants and species; and the loss of intact habitat, the authors urge achievement of a basis of understanding from which a well-informed policy of conservation and development can be developed. With impressive breadth, the authors examine the processes that have evolved to evidence our current wealth of diversity and what should be strong, well-adapted species. Ethical questions as to the choices societies collectively make and the role of a wide variety of conservation programs such as cryobiology, embryo transfer and artificial insemination in ex situ animal conservation programs are raised. The causes and consequences of the loss of diversity in forest zones, mediterranean areas, grasslands, coastal zones and other areas, including urban areas, are explored. The importance of information gathering, monitoring systems and the role of science and technology defined. Restoration explored in general and with specifics.

68. Yeang, Ken, *The Skyscraper Bioclimatically Considered: a design primer.* 1996. 269 pages. Academy Editions, London.

Full of information that applies to more than just skyscrapers. Examples from Asia and the Pacific Rim climates.

69. Zeiher, Laura C., *The Ecology of Architecture: A Complete Guide for Creating the Environmentally Conscious Building.* 1996. 269 pages. Whitney Library of Design, New York.

A number of applications fill Dr. Zeiher's book, which begins with a history of ecology in architecture. The history continues into a description of 'socially conscious' architecture and covers renewable resource technologies as well as the necessary public "process" of creating ecologically conscious architecture. Business case studies include The Body Shop, Energy Resources, the National Audubon Society Headquarters and the Women's Humane Society Animal Shelter in Bensalem, Pennsylvania. The book ends with a review of national environmental legislation and case law and culminates in a call to action for environmentally conscious building.

Web sites

General Community Resources:

City of Portland Office of Sustainable Development - www.ci.portland.or.us/energy/peohome.htm

State of Oregon, Governor's Executive Order, Sustainable Solutions – www.oregonsolutions.net

Building Resources:

US Green Building Council – www.usgbc.org

Environmental Building News –www.buildingreen.com/

Sustainable Building Sources - www.greenbuilder.com

Dept. of Energy Center for Sustainable Development – www.sustainable.doe.gov

Green Building Source - www.oikos.com

Certified Forest Products Council – www.certifiedwood.org

NW Ecobuilding Guild – www.ecobuilding.org

Minnesota Sustainable Design Guide – www.sustainabledesignguide.umn.edu

Rocky Mountain Institute – www.rmi.org

American Solar Energy Society – www.ase.org

Energy Star – www.epa.gov/energystar

Solstice- http:// solstice.crest.org/index.shtml

Team Oregon

APPENDIX 4

POTENTIAL FUNDING SOURCES FOR SUSTAINABLE COMMUNITY PROJECTS

Prepared by
The International Sustainable Development Foundation

August 15, 2001

a. World Bank
b. Asian Development Bank
c. Global Environment Facility (GEF)
d. United Nations Environment Programme (UNEP)
e. United Nations Development Programme (UNDP)
f. US-Asia AEP
g. US Trade and Development Agency (TDA)
h. Conservation International
i. Turner Foundation

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a. World Bank

Web site: http://www.worldbank.org

The World Bank is the world's largest source of development assistance, providing nearly $16 billion in loans annually to its client countries. It uses its financial resources, highly trained staff, and extensive knowledge base to help each developing country onto a path of stable, sustainable, and equitable growth in the fight against poverty.

The World Bank's Board has recently endorsed a new environment strategy that aims to further integrate environmental concerns into the Bank's projects and programs.

The result of two years of consultations across the globe and through the Internet, the strategy will ensure economic growth does not come at the expense of people's health and future opportunities because of pollution and degraded natural resources and

ecosystems. The strategy places emphasis on developing country priorities, spelling out three objectives:

- *Improving the quality of life*--people's health, livelihood and vulnerability—affected by environmental conditions;
- *Improving the quality of growth*–by supporting policy, regulatory and institutional frameworks for sustainable environmental management and by promoting sustainable private development; and
- *Protecting the quality of the regional and global commons* such as climate change, forests, water resources and biodiversity.

In addition to external consultations, the strategy builds on the Bank's own experience. Having moved from a "do-no-harm" approach in the 1970's to targeted, long-term environmental assistance today, the Bank has developed a broad environment portfolio worth some $18 billion. The strategy calls for improvements in the Bank's analytical and advisory work, project design, and safeguards. The Bank will prioritize certain aspects that are particularly urgent, such as integrating environmental considerations into Poverty Reduction Strategy Papers (PRSP's).

Project Area. The World Bank provides funding for multiple sectors, including energy, agriculture, transportation, education, finance, water treatment, etc. The Water Resource Management Group oversees most of water-related projects, including wastewater treatments. For more information on the Water Resource Management group, visit:
http://wbln0018.worldbank.org/essd/essd.nsf/WaterResourcesManagement/Overview.

Taiwan Eligibility Status. It is unclear whether Taiwan is eligible for project funding/financing. A cursory look at the World Bank's database shows that the last project approved was in 1971, which was when the People's Republic of China joined the UN. However, it seems that Taiwan has often been included in multi-country projects. For example, see:
http://www.developmentgateway.org/idml/activity-view.tcl?gdg_id=109339

b. Asian Development Bank

Web site: http://www.adb.org

The Asian Development Bank (ADB) is a multilateral development finance institution dedicated to reducing poverty in Asia and the Pacific.

ADB is committed to promoting environmentally sound development in the region. To fulfill this objective, ADB:

- Reviews the environmental impacts of its projects, programs, and policies;

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- Encourages governments and executing agencies to incorporate environmental protection measures in their project design and implementation procedures, and provides technical assistance for this purpose;
- Promotes projects and programs that will protect, rehabilitate, and enhance the environment and the quality of life; and
- Trains ADB and DMC staff in, and provides documentation on, environmental aspects of economic development.

In addition to targeting interventions to achieve direct environmental benefits in loan projects and programs, ADB continues to mainstream environmental considerations in country operational strategy studies, sector policies, and into its loan and investment projects and programs. It also ensures that environmental impacts of projects and programs are reviewed, and that prevention, abatement, and mitigation measures are incorporated. Where appropriate, environmental impact assessments (EIA's) and summary EIA's are circulated for review by stakeholders, who also are encouraged to participate in implementing environmental management plans. Better ways of reviewing and monitoring projects from identification to post-evaluation have been adopted to ensure quality at entry and quality of supervision.

Project Area. In 1999, ADB approved nine loan projects for nearly $1 billion to improve the environment and conserve natural resources. Two projects in the People's Republic of China had primary environmental objectives, including a rehabilitation project for the Suzhou Creek to improve water quality and flood control and a loan in Shanxi Province to help solve air pollution problems in three cities. A $40 million loan to Sri Lanka will address the problem of coastal erosion and resource degradation. A project in Vietnam will enhance overall environmental conditions in Ho Chi Minh City.

Four projects have secondary environmental objectives and a poverty reduction focus. In Karnataka, India, a $175 million loan addresses urban development and coastal environmental management. In the Maldives, $8 million addresses regional development investment. In the Marshall Islands, a $9.2 million loan addresses health and infrastructure improvements for water supply and sewerage systems. In Pakistan, a $7.8 million loan addresses institutional capacity of farmers for sustainable management of distributary canals.

Areas of projects include:

- Agriculture and Natural Resource Research
- Education, Public Consultation on
- Energy Policy Initiatives
- Energy
- Fisheries
- Forestry
- Health

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- Population
- Social Development
- Water

Taiwan Eligibility Status. Taiwan (officially known as Taipei, China) is the 12th largest shareholder in ADB among its regional members and overall it is the 18th largest shareholder. As a member of the Bank, Taiwan is eligible for funding from the ADB.

c. Global Environment Facility (GEF)

Web site: http://www.gefweb.org

The Global Environment Facility is a financial mechanism providing grant and concessional funds to developing countries for projects and activities to protect the world's environment. Responsibility for implementing the GEF is shared by UNDP, UNEP and the World Bank. UNDP is broadly responsible for capacity-building and technical assistance activities, and for managing the Small Grants Programme (SGP) on behalf of the GEF.

GEF resources are available for projects and other activities that address climate change, biological diversity, international waters, and depletion of the ozone layer. Land degradation -- primarily desertification and deforestation—also is eligible for funding as it relates to each focal area.

A country is eligible to obtain GEF funds if it is (1) a developing country Party to the Convention on Biological Diversity or the UN Framework Convention on Climate Change; and/or (2) if it is eligible to borrow from the World Bank (IBRD and/or IDA) or receive technical assistance grants from UNDP through a country program (formerly, the Indicative Planning Figure).

There are six interrelated GEF funding categories:

Operational Programmes. Operational Programmes are major, long-term GEF projects, which are divided into 10 focal areas.

Project Development Facility (PDF). Project Development Facilities assist in the development of GEF projects from concepts into fully approved documents. PDF's are divided into Block A up to a maximum of $25,000; Block B up to a maximum of $200,000; and Block C up to a maximum of $1 million.

Small Grants Programme. Small Grants Programme provides grants up to $50,000 to local community groups.

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Enabling Activities. Enabling Activities assist countries in preparing strategies, action plans, and reports which fulfill their Convention obligations.

Short-Term Response Measures. Short-term Response Measures are unique opportunities that have a very cost-effective and dramatic impact in the short-term.

Medium-Sized Projects. Medium-sized projects undergo a streamlined project preparation and approval process for grants of up to $1 million. Projects under $750,000 are 'fast-tracked' since Council approval is not required.

Any eligible individual or group may propose a project, which must meet two key criteria: (1) It must reflect national or regional priorities and have the support of the country or countries involved, and (2) it must improve the global environment or advance the prospect of reducing risks to it. GEF project ideas may be proposed directly to UNDP, UNEP, or the World Bank.

Country eligibility to receive funding is determined in two ways. Developing countries that have ratified the relevant treaty are eligible to propose biodiversity and climate change projects. Other countries, primarily those with economies in transition, are eligible if the country is a party to the appropriate treaty and is eligible to borrow from the World Bank or receive technical assistance grants from UNDP.

Project Area. The GEF was initially established for a three-year period known as the Pilot Phase ending in June, 1994 and later extended for three years in what is termed the Operational Phase or GEF I. The GEF provides new and additional grant and concessional funding to meet the incremental costs of measures to achieve global environmental benefits in four focal areas, namely:

- Protection of biological diversity;
- Reduction of greenhouse gases;
- Protection of international waters; and,
- Protection of the ozone layer.

The incremental costs of activities concerning land degradation, primarily desertification and deforestation, as they relate to the four focal areas are also eligible for funding. Currently, more than 150 countries are participating in the Facility.

Taiwan Eligibility Status. Because the UN does not officially recognize Taiwan as a country, GEF funding is not available to any projects in Taiwan.

d. United Nations Environment Programme (UNEP)

Web site: http://www.unep.org

UNEP provides leadership and encourages partnership in caring for the environment by inspiring, informing, and enabling nations and peoples to improve their quality of life

without compromising that of future generations. UNEP does not directly provide funding for projects. Funding for projects are typically done through the GEF, where UNEP closely work with GEF by catalyzing the development of scientific and technical analysis and advancing environmental management in GEF-financed activities. UNEP provides guidance on relating the GEF-financed activities to global, regional and national environmental assessments, policy frameworks and plans, and to international environmental agreements.

Taiwan Eligibility Status. Because Taiwan is not a member of the UN, UNEP assistance is not available to any projects in Taiwan.

e. United Nations Development Programme (UNDP)

Web site: http://www.undp.org

The United Nations Development Programme (UNDP) is the UN's principal provider of development advice, advocacy and grant support. With 132 country offices, it has long enjoyed the trust and confidence of governments and NGOs in many parts of the developing as well as the developed world. It is typically regarded as a partner rather than an adversary, and its commitment to a universal presence has proven especially useful in post-conflict situations and with states that had been otherwise isolated from the international community. UNDP is leading the United Nations effort in building national capacity for environmentally sustainable development, by promoting global best practices and supporting catalytic interventions.

UNDP typically provides funding assistance through GEF. Within GEF, the particular emphasis of UNDP is ensuring the development and management of capacity-building programmes and technical assistance projects. As of June, 2000, the UNDP-GEF portfolio totals $1.045 billion (not including $963.35 billion in co-financing). Over 580 projects—not including Small Grants—are in the current portfolio, ranging in size from $10,000 to $15 million; and they involve constituents at every level from grassroots to high-level decision-makers. UNDP also manages a number of corporate initiatives on behalf of the GEF family. These are: Small Grants Programme, Country Dialogue Workshops, Capacity Development Initiative, National Communications Support Programme and the Biodiversity Planning Support Programme.

Project Area

- Democratic Governance
- Poverty Reduction
- Crisis Prevention and Recovery
- Energy and Environment
- Information and Communications Technology
- HIV/AIDS

Additionally, UNDP provides sustainable development assistance through the Sustainable Energy and Environment Division (SEED). In 1994, in direct response to the Rio Earth Summit, the Administrator of UNDP made a strategic decision to strengthen UNDP's environment and sustainable development capacity by establishing a new division within the Bureau for Policy and Programme Support (BPPS)—the Sustainable Energy and Environment Division (SEED). Since its origin, SEED has worked to support UNDP's overall efforts to help countries successfully design and carry out programmes that integrate the protection and regeneration of the environment and the use of natural resources to reduce poverty, generate sustainable livelihoods, and advance the status of women. (See http://www.undp.org/seed for details).

Taiwan Eligibility Status. Because Taiwan is not a member of the UN, GEF funding is not available to any projects in Taiwan.

f. US-Asia Environmental Partnership (US-AEP)

Web site: http://www.usaep.org

The United States-Asia Environmental Partnership (US-AEP) is a public-private initiative that promotes environmentally sustainable development in Asia. US-AEP is jointly implemented by several U.S. government agencies, under the leadership of the US Agency for International Development (USAID).

In creating US-AEP, the White House recognized Asia's growing commitment to sustainable development and America's increasing eagerness to share its experience, technology, and management practices. Consequently, US-AEP embodies a new model of cooperative development, one that encourages US-Asian partnerships. With the participation of wide range of partners--governments, NGO's, academia, and the private sector—US-AEP has become a flexible, responsive vehicle for delivering timely answers to environmental questions.

US-AEP currently works with governments and industries in 11 target economies: Hong Kong, India, Indonesia, Korea, Malaysia, Philippines, Singapore, Sri Lanka, Taiwan, Thailand, and Vietnam.

US-AEP provides some grants to businesses, US state agencies, and/or NGO's that link American expertise with Asian demands for environmental improvements. Additionally, US-AEP provides in-kind contributions through various programs such as the Environmental Exchange Program.

The types of grants are as follows:

State Environmental Initiative. US-AEP awards matching grants of up to $150,000 to US state agencies to link American expertise with Asian demand for environmental improvements.

NGO-Business Partnerships. US-AEP awards grants of up to $30,000 to Asian nongovernmental organizations to encourage collaborative environmental improvement efforts with industry.

Overseas Program Fund. US-AEP's "OPF" offers up to $25,000 to Asian and U.S. businesses to participate in events in the potential trading partner's home country.

Project Area. US-AEP has three core programs:

Clean Technology and Environmental Management (CTEM). US-AEP's CTEM component supports market pressures and private initiatives that promote industrial environmental performance. US-AEP/CTEM works in areas such as ISO 14000 & EMS, Voluntary Business Standards, Greening the Supply Chain, Environmental Due Diligence, and Industrial Extensions for the Environment.

US-AEP Policy Group. US-AEP's Policy Group promotes and supports policy initiatives to affect an industrial and municipal transformation in Asia. US-AEP's policy initiatives include: Measurement Systems, Framing Papers, Information Disclosure, and Policy Networks.

US-AEP Urban Program. US-AEP's Urban Program assists Asian cities in transforming their management systems to ensure an improved sustainable urban environment. Key elements in this transformation process includes better management techniques, governance, and partnerships with industry and civil society. The Urban Program focuses on four interrelated components: (1) Urban Policy and Management; (2) Business, Citizen and NGO Outreach; (3) Municipal Finance/Privatization; and (4) Water, Wastewater, Air and Waste Management.

It is interesting to note that US-AEP has identified industrial water and wastewater treatment as one of the highest priority markets for US businesses for three reasons (see http://www.usaep.org/export/em-taiwan-ema-v4.htm for more details):

- U.S. manufacturers have some of the most cost-effective technologies for treating water and wastewater in the world and can compete with any foreign producer.
- New water quality regulations with financial enforcement are on the way.
- Industries with high loadings are continuing to expand even through the Asian crisis.

Taiwan Eligibility Status. Taiwan is eligible for US-AEP assistance.

g. US Trade and Development Agency (TDA)

Web site: http://www.tda.gov

The U.S. Trade and Development Agency assists in the creation of jobs for Americans by helping U.S. companies pursue overseas business opportunities. Through the funding of feasibility studies, orientation visits, specialized training grants, business workshops, and various forms of technical assistance, TDA enables American businesses to compete for infrastructure and industrial projects in middle-income and developing countries.

In Fiscal Year 2000, TDA obligated $51.7 million for US firms in more than 63 strategically targeted developing and middle-income countries in the following regions: Africa/Middle East; Asia/Pacific; Central and Eastern Europe; Latin America and the Caribbean; and the New Independent States (NIS).

Because of its focused mission, TDA only considers projects that have potential to mature into significant business opportunities for US companies. To be considered for funding, projects must meet the following criteria:

- The project will have a positive developmental impact on the host country;
- Financing for project implementation is available or likely to be available if the feasibility study confirms project viability;
- The potential for U.S. exports during project implementation is significant; and
- TDA has a facilitative role to play, such as overcoming subsidized foreign competition.

TDA learns of viable public and private sector projects from the U.S. business community and from other government agencies, such as the Commerce Department's U.S. and Foreign Commercial Service (US&FCS) and the State Department's economic officers. TDA also receives project information from the public and private sectors of foreign countries.

Project Area. TDA primarily is involved in these sectors: agriculture; energy; environment; health care; information technology manufacturing; mining and minerals development; telecommunications; transportation; and water resources.

Taiwan Eligibility Status. Taiwan is eligible for TDA assistance.

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h. Conservation International

Web site: http://www.conservation.org/

Conservation International (CI) is a field-based, non-profit organization that protects the earth's biologically richest areas and helps the people who live there improve their quality of life.

CI launched the Conservation Enterprise Fund in 1999 with a $1 million loan from the Small and Medium Enterprise (SME)—Global Environmental Facility program of the International Finance Corporation. CI acts as the financial intermediary to provide debt and equity financing of $25,000 to $250,000 to small and medium-sized enterprises ($5 million or less in assets) that are strategically important to conservation.

Project Area. CEF funds are directed to businesses engaged in one or more of the following activities:

- Agroforestry: Shade-grown and sustainable agriculture that buffers biologically important protected areas.
- Ecotourism: Lodges or other ecotourism products, which link travel and low-impact tourism to communities living in pristine areas.
- Wild-Harvest Products: Development and promotion of oils, nuts, fruit, plants, fibers, or other natural materials sustainably harvested from non-cultivated sources.

Taiwan Eligibility Status. It is unclear whether Taiwan businesses can receive funding from this program since the fund is underwritten by GEF. Aside from the eligibility status, the Fund does not provide grants to government entities and therefore may not be suitable for the Tainan project.

i. Turner Foundation

Web site: http://www.turnerfoundation.org

The Turner Foundation is committed to preventing damage to the natural systems—water, air, and land—on which all life depends.

Project Area. The Foundation makes grants in the areas of the environment and population. The main components of the program are:

- Protection of water and reduction of toxic impacts on the environment
- Improved air quality through promotion of energy efficiency and renewables and improved transportation policies and practices
- Protection of biodiversity through habitat preservation

- Development and implementation of sound, equitable practices and policies designed to reduce population growth rates

Objectives of Water and Toxics Project Area: To protect rivers, lakes, wetlands, aquifers, oceans and other water systems from contamination, degradation, and other abuses. The priorities of this project area are:

- To strengthen the advocacy, outreach and technical capabilities of organizations addressing the protection of water systems.
- To stop the further degradation of water-dependent habitats from new dams, diversions and other large infrastructure projects.
- To reduce wasteful water use via conservation.
- To promote allocation of water specifically for environmental purposes, including habitat restoration and fish and wildlife protection.
- To support efforts to improve public policies affecting water protection, including initiatives to secure pollution prevention and habitat protection.
- To reduce pesticide use.
- To strengthen the advocacy, outreach and technical capabilities of organizations addressing the disproportionate use and locating of toxic materials in poor and rural areas.

Geographic Focus. The Foundation will consider Water and Toxics programs that are national in scope. The Foundation will consider state and local programs, giving priority consideration to programs in New Mexico, Montana, Colorado, Nebraska, South Carolina, Georgia, and Florida. Additionally, consideration will be given to some international programs as well.

Objectives of Air Quality, Energy and Transportation Project Area: To protect the atmosphere and other natural resources by promoting energy efficiency, renewable energy and improved transportation policies and practices. The priorities of this project area are:

- To promote alternatives to increased single-occupancy vehicle use, vehicle miles traveled, and new highway construction.
- To support efforts that limit sprawling development while promoting sustainable community design.
- To support efforts that improve air quality through decreasing pollutants from the production and use of fossil fuels.
- To reduce the overall consumption of fossil fuel-based and nuclear-generated energy by promoting energy efficiency and greater use of solar energy and other renewable sources of energy.

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Geographic Focus. The Foundation will consider Energy and Transportation programs that are national in scope. The Foundation will consider state and local programs, giving priority consideration to programs in New Mexico, Montana, Colorado, Nebraska, South Carolina, Georgia, and Florida. Additionally, consideration will be given to some international programs.

Objectives of Habitat Project Area: To defend biodiversity by protecting habitats. The priorities of this project area are:

- To support ecosystem-wide habitat protection with particular emphasis on locally developed strategies for private and public lands.
- To support efforts that defend wild places from destructive practices such as mining, unsustainable logging, and over-grazing.
- To support efforts that create understanding of the relationship between wildlife, habitat protection and long-term economic stability.
- To protect the world's last remaining vast tracts of relatively undisturbed forestlands. (Please note the special geographic focus of Russia, Brazil and British Columbia, Canada for this funding priority.)
- To protect forest ecosystems through reducing wood consumption, eliminating waste, and promoting safe, sustainable non-wood alternatives.

Geographic Focus. The Foundation will consider Habitat programs that are national in scope. The Foundation will consider state and local programs, giving priority consideration to programs in Alaska, New Mexico, Montana, Colorado, Nebraska, South Carolina, Georgia, and Florida. Additionally, consideration will be given to international programs, with priority consideration given to programs in Mexico, Argentina, Russia, Brazil and British Columbia, Canada.

Objectives of Population Project Area: Worldwide development of policies and practices that will reduce population growth by addressing the relationships between population growth, global resources, the status of women and girls, and access to family planning and reproductive health services. The priorities of this project area are:

- To promote worldwide access to safe, affordable family planning and reproductive health services.
- To support efforts that advocate increased government support for voluntary, affordable family planning and reproductive health services.
- To support activities that address the relationships between population growth, the low status and lack of options for women and girls, consumption of natural resources, and the resulting environmental degradation.
- To support activities that focus on women and girls and provide for their improved status in society through increased access to educational, political and economic opportunities.

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- To support initiatives that address the growing number of teenage pregnancies in the United States, with a particular emphasis on under-served populations. (Priority consideration given to statewide coalitions in New Mexico, Montana, Colorado, Nebraska, South Carolina, Georgia and Florida.)

Geographic Focus. The Foundation will consider Population programs that are national and/or international in scope. The Foundation will consider state and local programs, giving priority consideration to programs in New Mexico, Montana, Colorado, Nebraska, South Carolina, Georgia, and Florida.

Taiwan Eligibility Status. The Turner Foundation funds some international organizations and they do not have any restrictions on funding projects in Taiwan.

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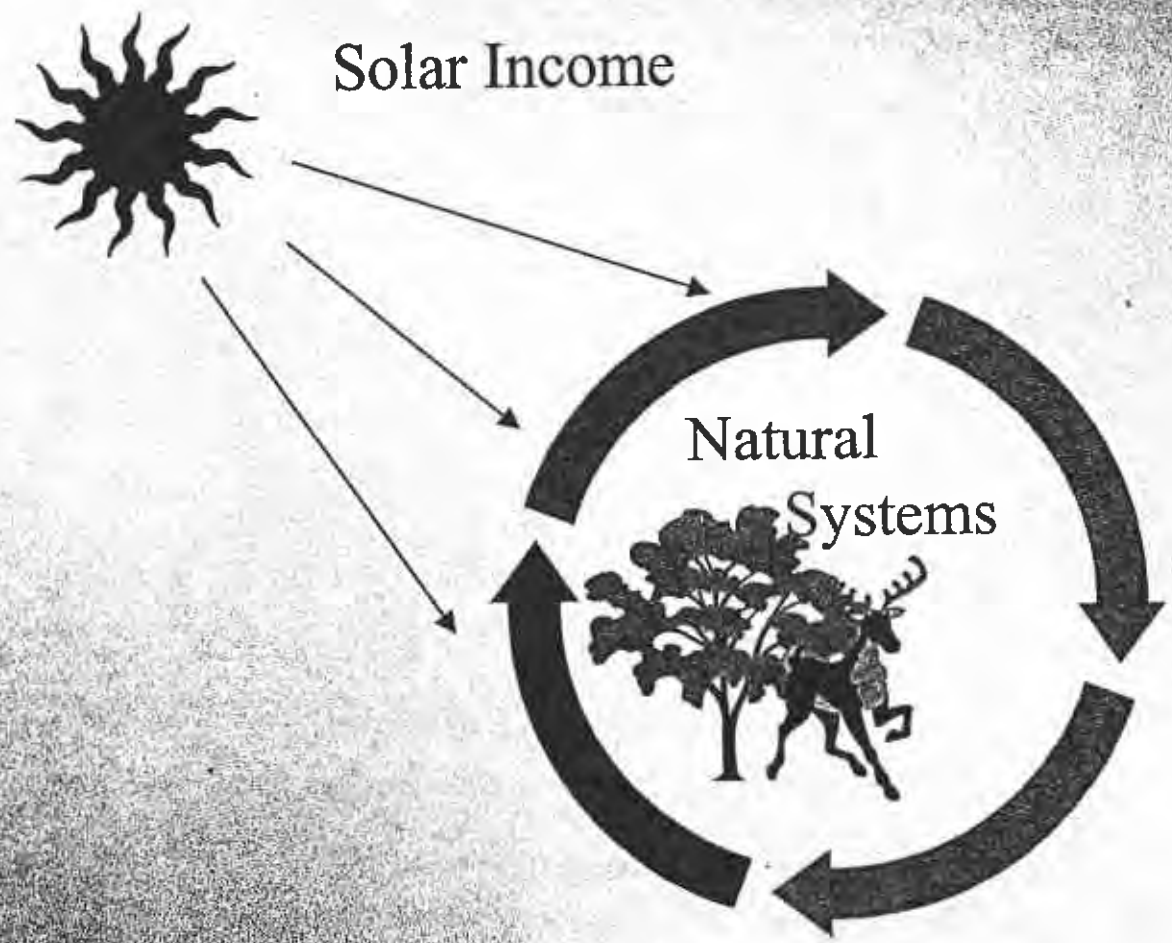
TDA in Tainan

Framework for Sustainability and Case Studies

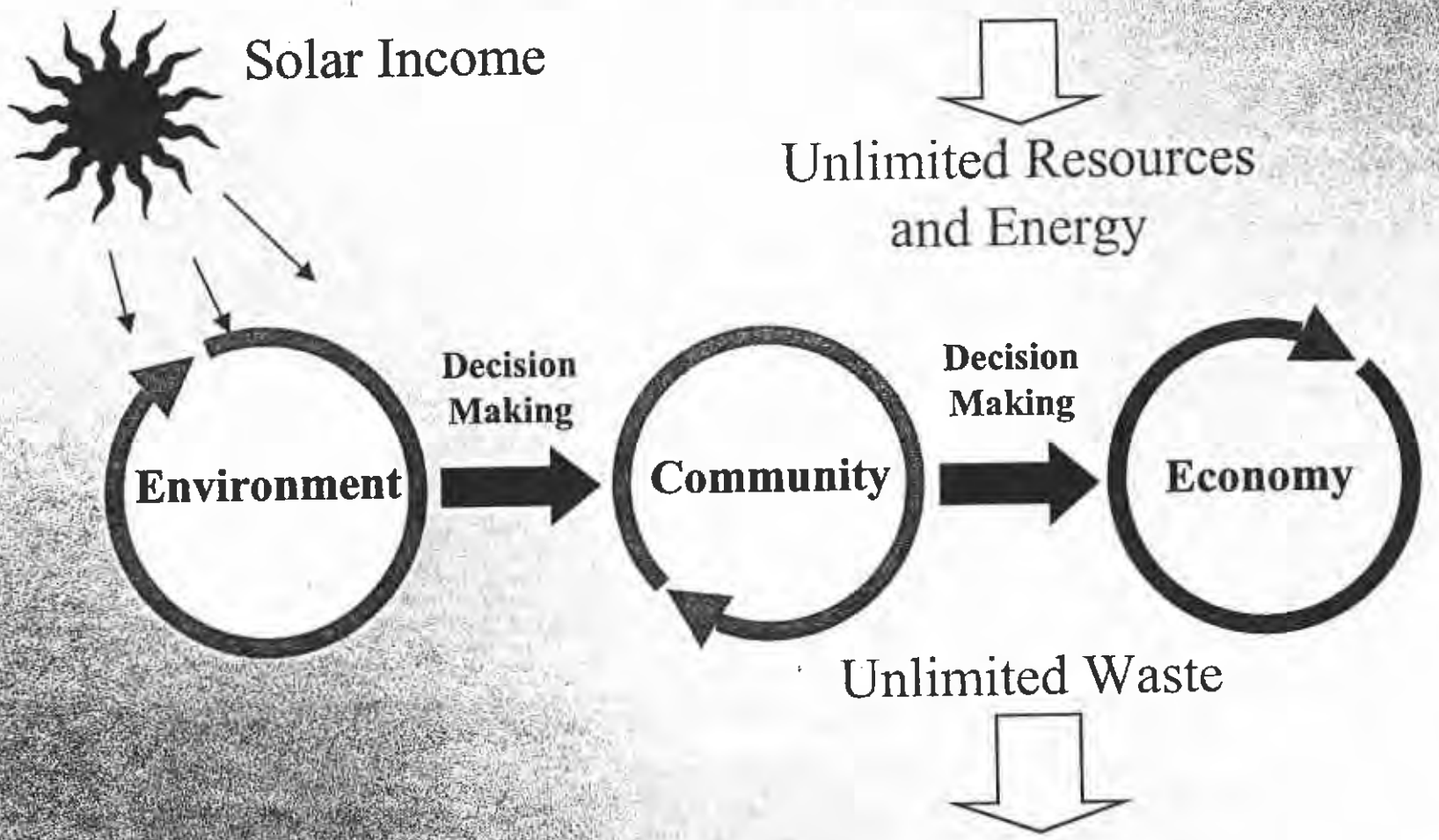
Overview of Presentation

- Sustainable Development Framework
- Case Studies
  - Infrastructure: Waste Water Treatment
  - Stream restoration: Greenways & Greenbelts
  - Architecture: Tainan Eco - School

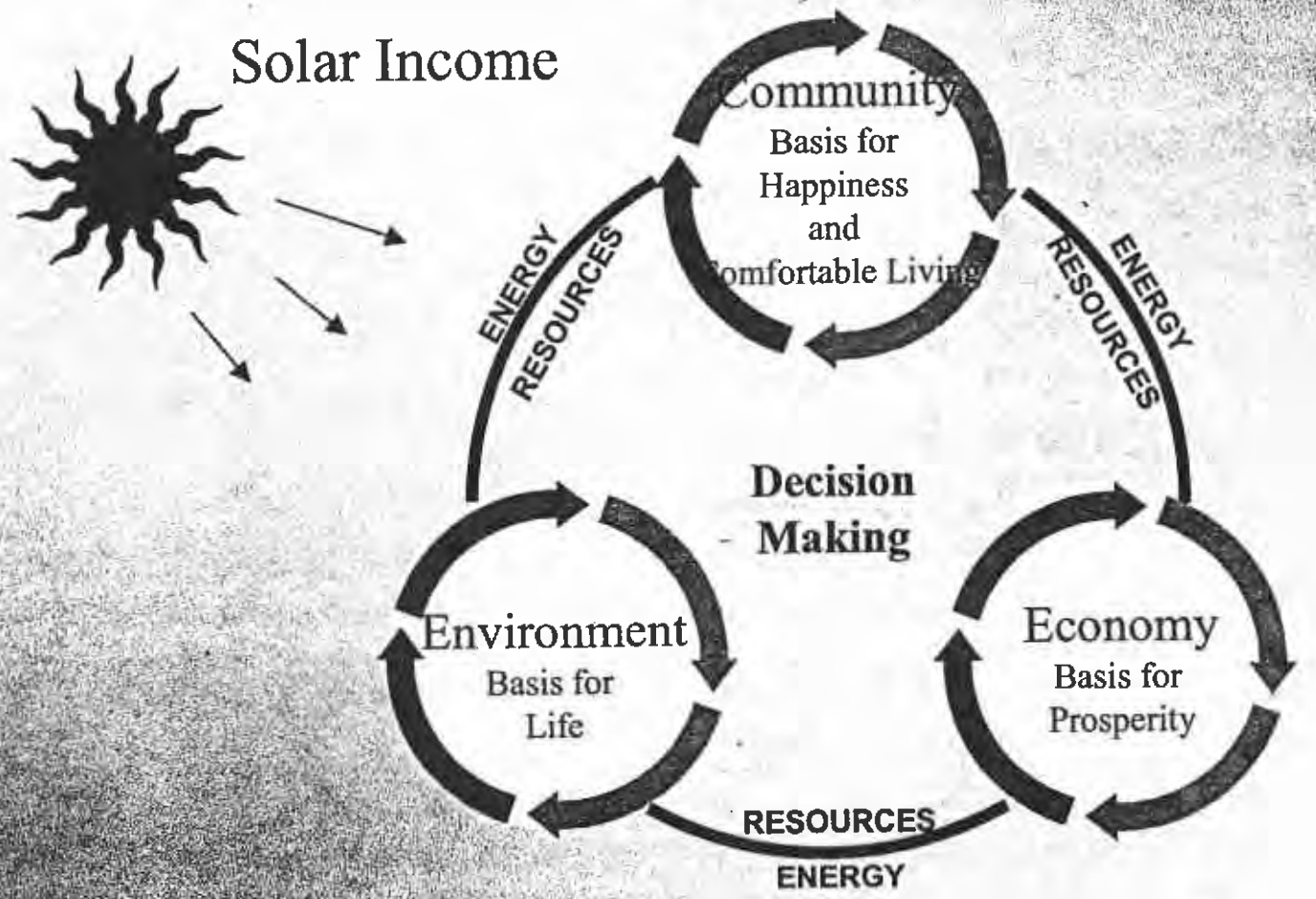
The Natural Cycle



Linear Non-Sustainable Development



Cyclical Model for Sustainable Development



Definition of Sustainable Development

"Sustainable development is that development which meets the needs of the present without compromising the ability of future generations to meet their own needs."

Brundtland Commission: Our Common Future, 1987.

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Sustainable Development Framework

10 Principles

1. Consider Intergenerational equity
2. Prevent environmental overloading
3. Balance environment, economy and community needs
4. Consider impacts of decisions on human health and the environment
5. Promote fairness and justice
6. Involve and educate the public
7. Internalize costs
8. Apply appropriate science and technology to solve problems
9. Integrate public, private and NGO efforts
10. Learn from others globally

Sustainable Development Framework

Guidelines

Environment - Basis of Life

1. Support clean atmosphere, water, land, and marine resources
2. Avoid habitat destruction
3. Protect and restore ecosystems
4. Protect and restore biological diversity
5. Develop environmental protection and restoration programs
6. Develop resources consistent with prevention of natural disasters

Sustainable Development Framework

Guidelines

Economy - Basis for Prosperity

1. Increase the productivity of all forms of capital
2. Increase the quality and durability of goods
3. Reduce, reuse, recycle materials
4. Substitute embodied and solar energy for produced energy
5. Reduce and eliminate all forms of waste and pollution
6. Apply appropriate science and technology to problems

Sustainable Development Framework

Guidelines

Economy - Basis for Prosperity

continued:

7. Develop transportation and energy supply systems consistent with sustainable development
8. Substitute non-toxic and biodegradable substances for toxic substances
9. Review/revise tax, capital investment, and regulatory policies to increase Sustainable Development and eliminate subsidies for non-Sustainable Development
10. Use life cycle cost analysis in procurement decisions

Sustainable Development Framework

Guidelines

Community - Basis for Happiness and Comfortable Living

1. Provide clean air, water, and food for people
2. Provide clean and safe shelter
3. Provide safe, clean, and beautiful community living environments
4. Protect and enhance the arts and cultural & historic resources
5. Provide public education on sustainable development

Sustainable Development Framework

Guidelines

Community - Basis for Comfortable Living

continued...

6. Promote public involvement in decisions
7. Provide collaborative, community-based decision-making with public, private, NGO participants
8. Promote cooperation among levels of government and globally
9. Provide access to information on decisions
10. Undertake social and economic impact analysis of major decisions

Integrated Decision Making

Integrated Decision Making: Levels

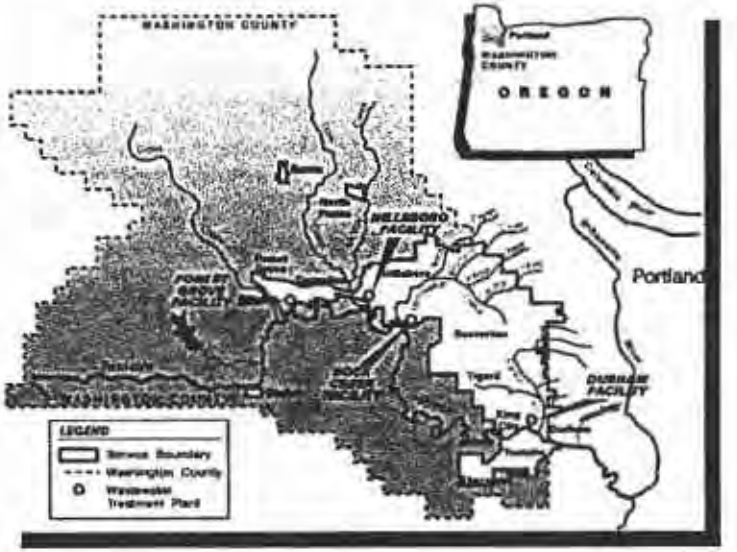
- Policy
- Planning
- Design & Engineering
- Construction
- Facility Management

Case Studies

- Infrastructure: Waste Water Treatment
- Stream restoration: Greenways & Greenbelts
- Architecture: Tainan Eco - School

Infrastructure:

Waste Water Treatment Case Study



Infrastructure:

Waste Water Treatment Case Study

- Regional Governments
- Centralized vs. Decentralized Treatment Systems
- Natural Systems
  - Constructed Wetlands
  - Living Machines™
- Recycle/Reuse Wastes
  - Fuel Cell Technology
  - Microturbine Technology
  - Land Application of Biosolids
  - Composting Biosolids

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What is a Regional Government?

A Regional Government is a governing body that coordinates land use planning and services for a region.

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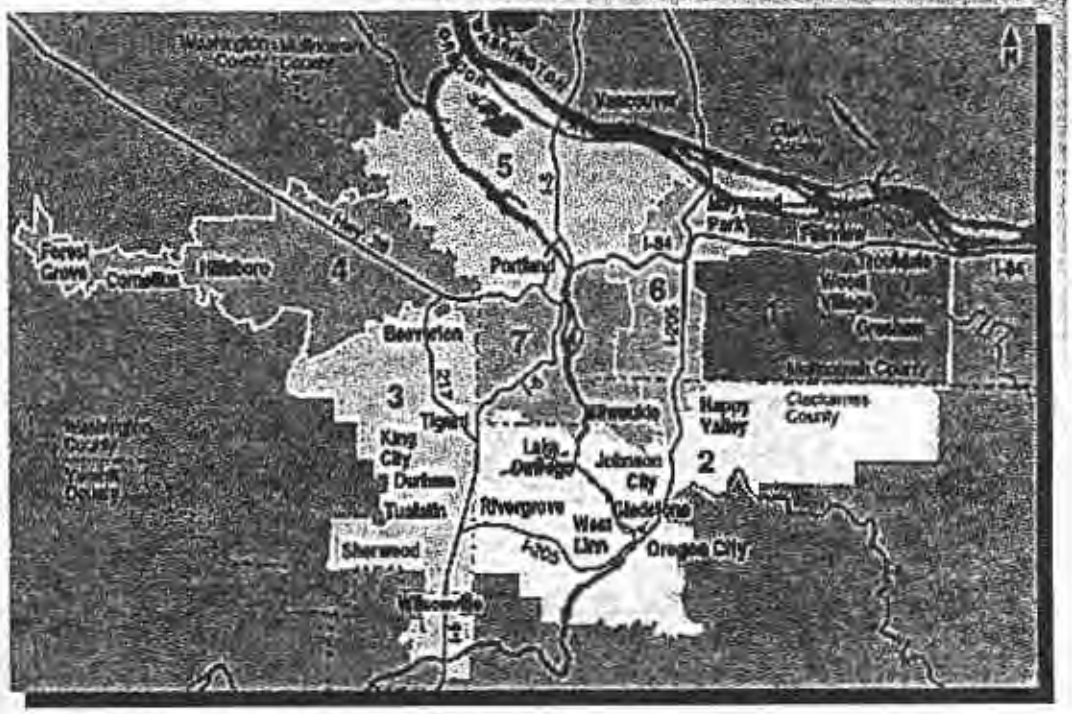
Why are Regional Governments Beneficial?

- Deal with issues that are more efficiently addressed on a large scale.
- Issues are addressed and solutions established region-wide.
- Duplicate efforts for similar services are eliminated.
- Promotes economic efficiency.

METRO

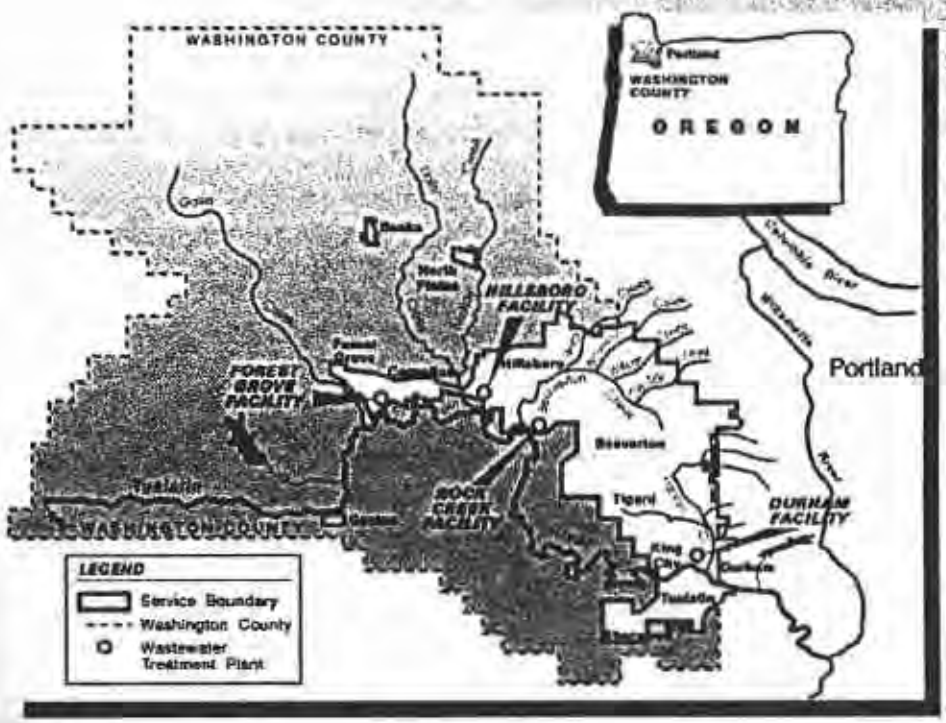
Portland, Oregon Metropolitan Area

- Encompasses 3 counties and 24 cities.
- Responsible for:
  - Transportation Planning
  - Land Use Planning
  - Regional Solid Waste Management
  - Region-wide Recycling & Waste Reduction Programs



CleanWater Services
Tualatin River Watershed, Oregon

- Encompasses parts of 3 counties and 15 cities.
- Responsible for:
  - Managing water pollution problems in Tualatin Watershed.
  - Maintains or controls sanitary sewage collection & treatment system.
  - Flood management.
  - Surface water quality.



Centralized vs. Decentralized Treatment Systems

- Centralized System is one where the collection system directs all wastewater to a central treatment facility.

- Decentralized System (or cluster system) is one where multiple treatment facilities exist (e.g., on-site systems or multiple treatment plants).

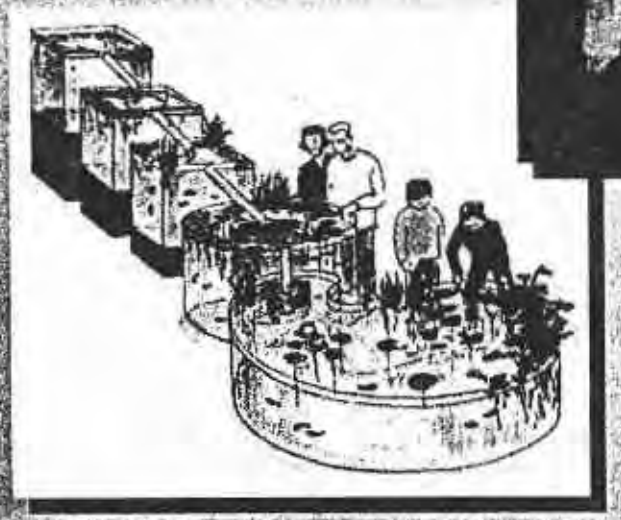
Centralized vs. Decentralized Treatment Systems (cont'd)

	Advantages	Disadvantages
Centralized System **Most appropriate for mixed, high density development.**	• **Easier to monitor treatment effectiveness.** • **Single point for effluent discharge.** • **Single point for bio-solids collection and discharge.** • **Excess capacity included for planning.**	• **Full time, skilled staff needed to operate and maintain facility.** • **High initial capital costs.** • **Mixed bio-solids can result in disposal restrictions.** • **Large blocks of land are needed to site treatment facility.**
Decentralized System **Most appropriate for low density residential and light commercial development.**	• Low initial implementation costs. • Lower collection system costs. • Smaller facilities. • Usually passive treatment systems.	• **Scattered treatment sites.** • **No uniform control of operation and maintenance of treatment facilities.** • **Multiple discharge points.** • **Capacity must be added for new development.**

Natural Systems

Natural Treatment Systems are systems designed to emulate nature's ability to treat itself.

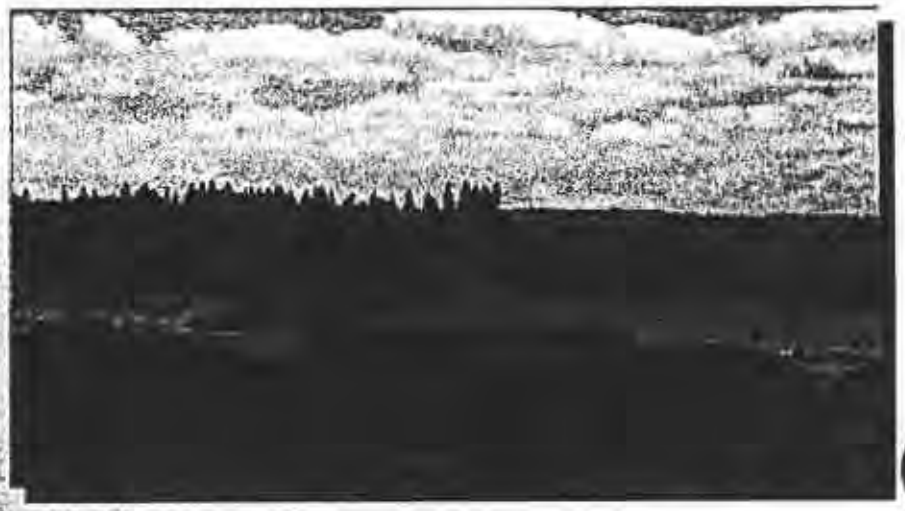
- Constructed Wetlands



- Living Machine™

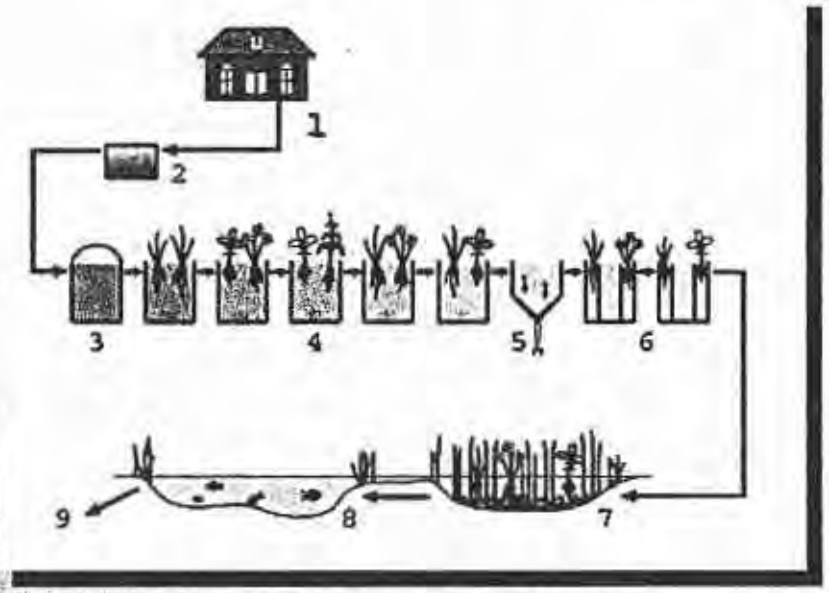
Natural Systems
Constructed Wetlands

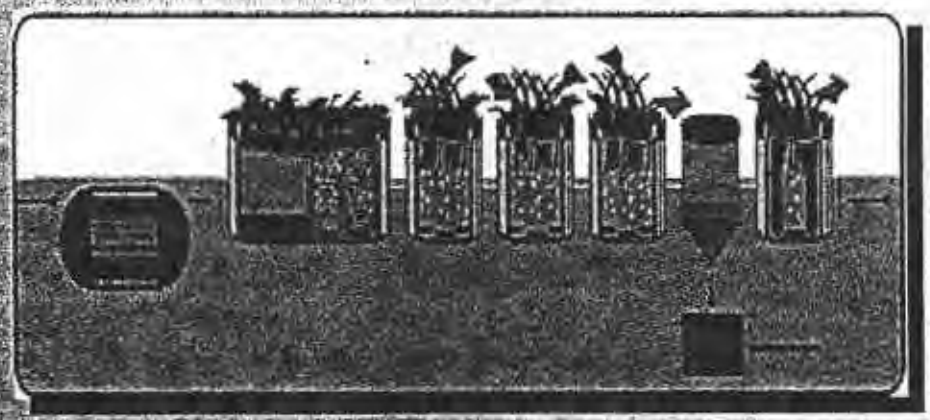
- Engineered system that utilizes natural processes to treat wastewater.
- Designed to mimic a natural wetland system using plants, soil, & microorganisms to remove contaminates from wastewater effluents.
- Systems require large land areas.
- Provide wetland habitat for wildlife and environmental enhancement.



Natural Systems

Living Machine™



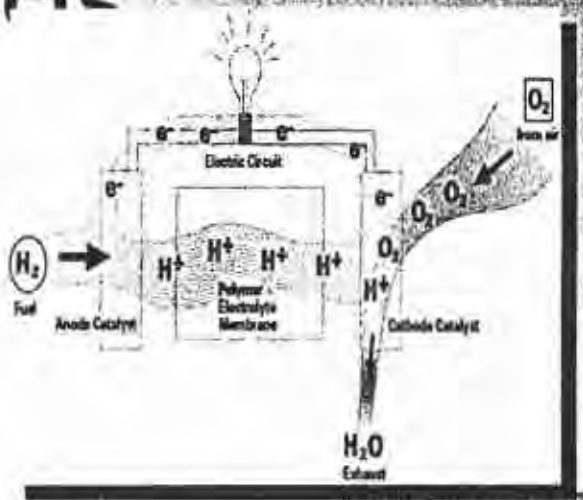


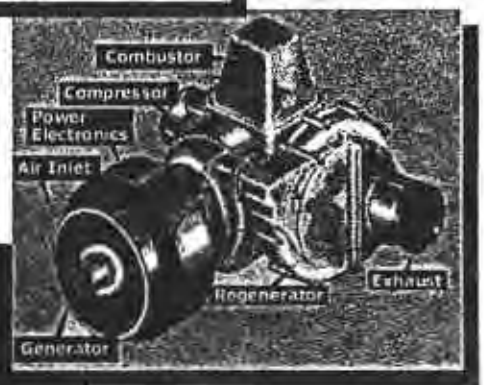
- Technology developed in the 1970s.
- Stresses using natural ecosystems to treat wastes.
- Systems range in size from table top to large treatment facilities.
- Ecologically designed aquatic systems that utilize a diverse community of biological organisms, from bacteria to plants and fish, to treat water to advanced levels.

Recycle/Reuse Wastes

Wastewater Treatment Plant Byproducts

- Reuse/Recycle Methane
  - Fuel Cell Technology
  - Microturbine Technology
- Reuse/Recycle Biosolids
  - Land Application
  - Composting



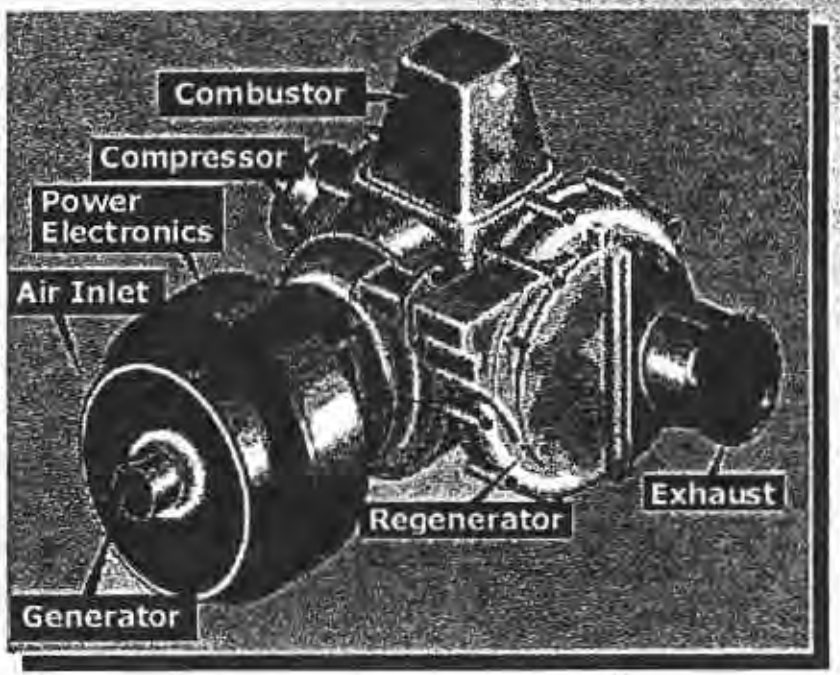


Reuse/Recycle Methane

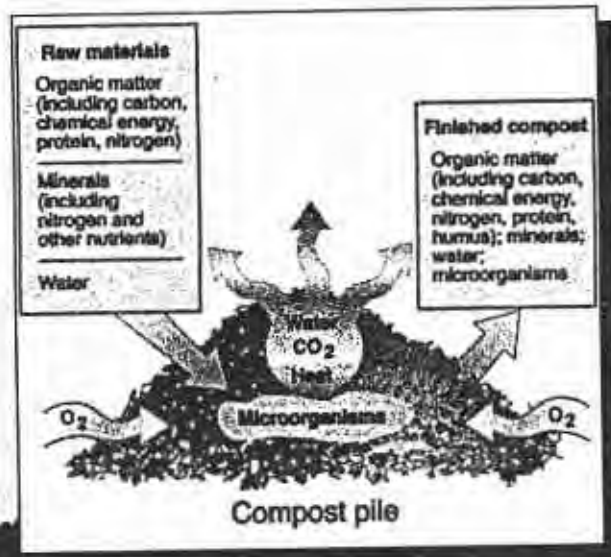
- Fuel Cell Technology
  - A Fuel Cell is an electrochemical device that converts the hydrogen from methane gas produced during the solids digestion process to electricity and heat.
  - *Example: Columbia Boulevard Wastewater Treatment Plant in Portland, Oregon:*
    - *Fuel Cell consumes 1.4 cubic meters per minute of digester gas.*
    - *Produces approximately 175 kW of power (about 1.6 million kW-hr per year which represents US$18,000 per year at $0.05 per kW).*

Reuse/Recycle Methane (cont'd)

- Microturbine Technology
  - Smaller versions of traditional fuel burning, power producing turbines.
  - Cleaner burning than traditional turbines.
  - Use natural gas or methane as fuel source.
  - Less expensive than fuel cells.



Reuse/Recycle Biosolids



- Biosolids are a natural, nutrient-rich byproduct of municipal wastewater treatment.
- Biosolids are rich in nutrients and organic mater that aid the growth of farm crops, gardens, forests, and parks.
- Recycling this nutrient can return useful resources to the land.

Reuse/Recycle Biosolids (cont'd)

- Land Application
  - Application of biosolids directly to the land.
  - Process must be carefully monitored to prevent accumulation of metals and excess nutrient buildup.
  - *Example: The City of Portland land applies more than 56 million kilograms of biosolids annually to farmland in Eastern Oregon.*
- Composting
  - Composting is the breakdown of organic material through biological means under controlled aerobic conditions.
  - Used to stabilize wastewater solids allowing them to be used as a soil amendment or mulch in landscaping, horticulture, and agriculture.

Benefits: Applying Sustainability Framework to Wastewater Treatment

Benefit	Sustainable Tools
• Clean the environment.	• Constructed Wetlands • Living Machine™ • Fuel Cell • Microturbines
• Promote economic efficiency.	• Regional Government • Centralized vs. Decentralized Treatment
• Return resources to the environment.	• Land Application • Composting
• Provide wildlife habitat.	• Constructed Wetlands
• Recover energy from waste.	• Fuel Cell • Microturbines
• Provide educational opportunities.	• Living Machine™

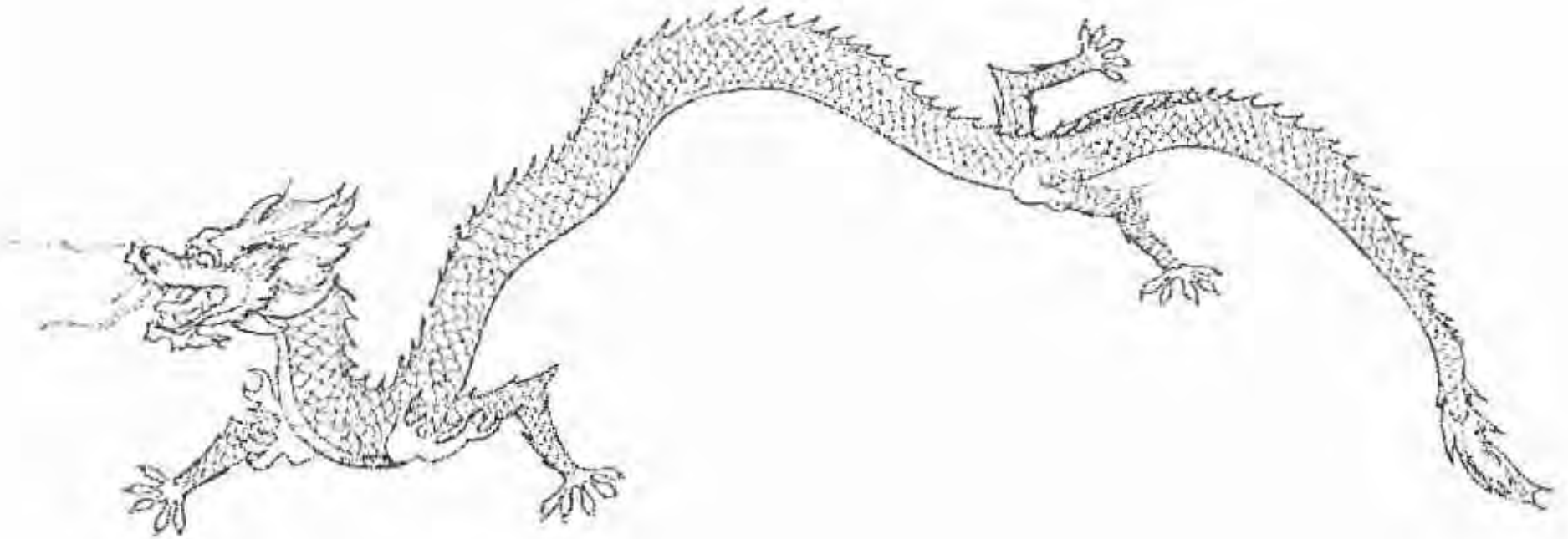
Stream Restoration:

Urban Greenway Case Study

- Benefits
- Actions
  - Remove Sewage and pollution
  - Treat Stormwater runoff
  - Recreate native plant corridor
  - Develop "Greenbelt" beyond top of river bank
  - Protect, preserve, and restore floodplain
  - Develop riverside trail system
  - Use local and recycled construction materials
  - Integrate public art an nature exhibits

Greenways & Greenbelts:

Beautiful Rivers for People That Provide Ecological Function for Nature.



Benefits:

1. **ECONOMIC**
   Greenways are marketable amenities for urban development, increasing property values 6 - 32%.

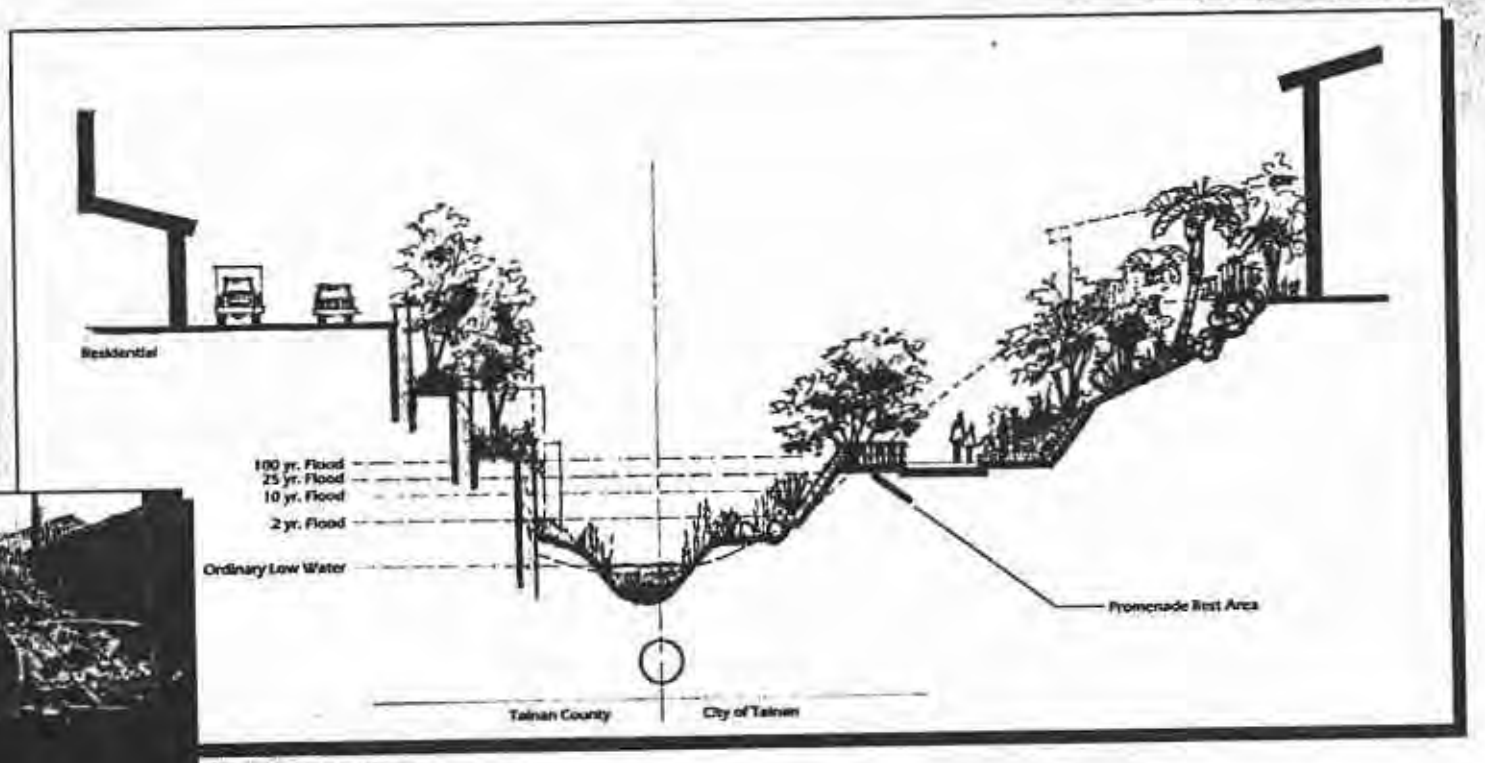
2. **SOCIAL**
   Greenways link communities and provide meeting places.

3. **TRANSPORTATION**
   Greenway Trails can provide alternative transportation opportunities, reducing motorized vehicle use.

4. **ENVIRONMENTAL**
   Greenbelts are natural buffers and filters for adjacent development. They provide a connection between natural areas for wildlife and people.

Action 1:

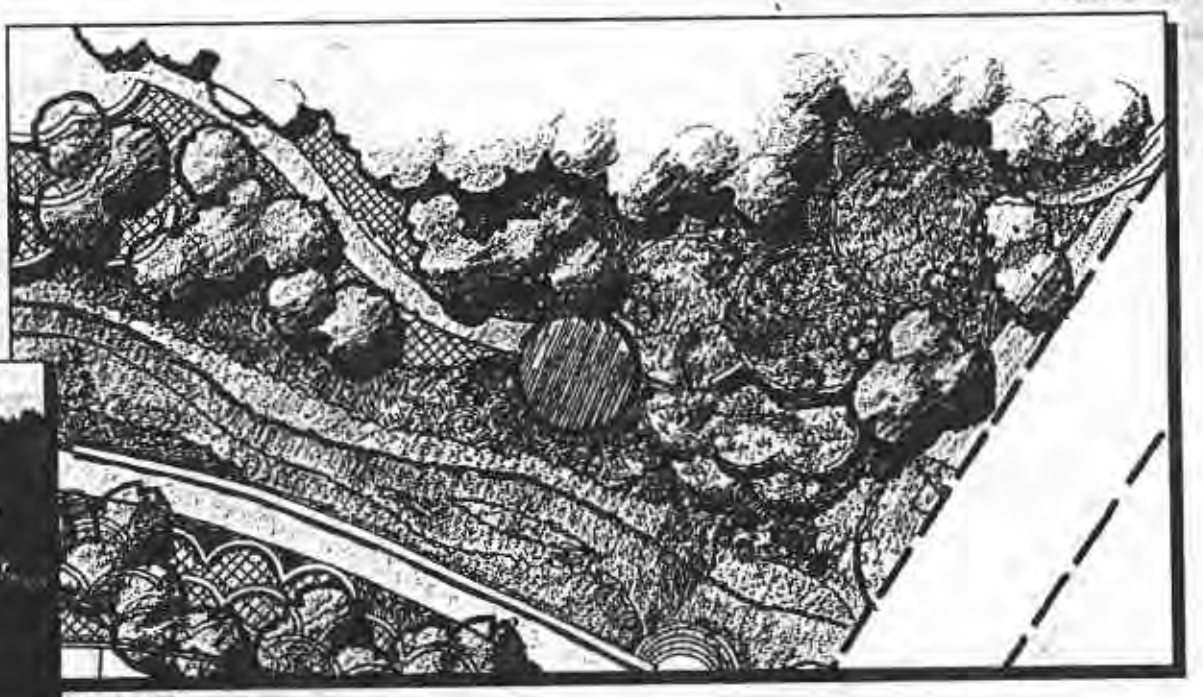
Remove sanitary sewage and other pollution from river flow.



Combined Sewer Overflow

Action 2:

Capture and treat stormwater runoff before it enters the river.

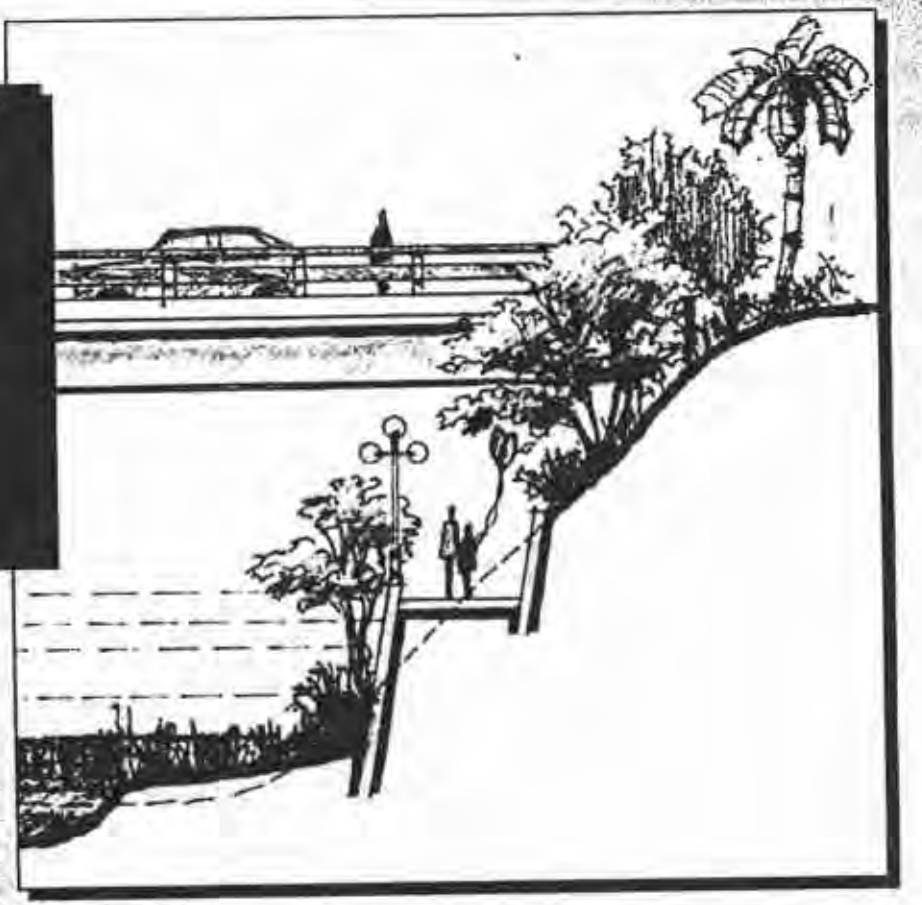


Arala Creek School - Wide Body Biofilter

Action 3:

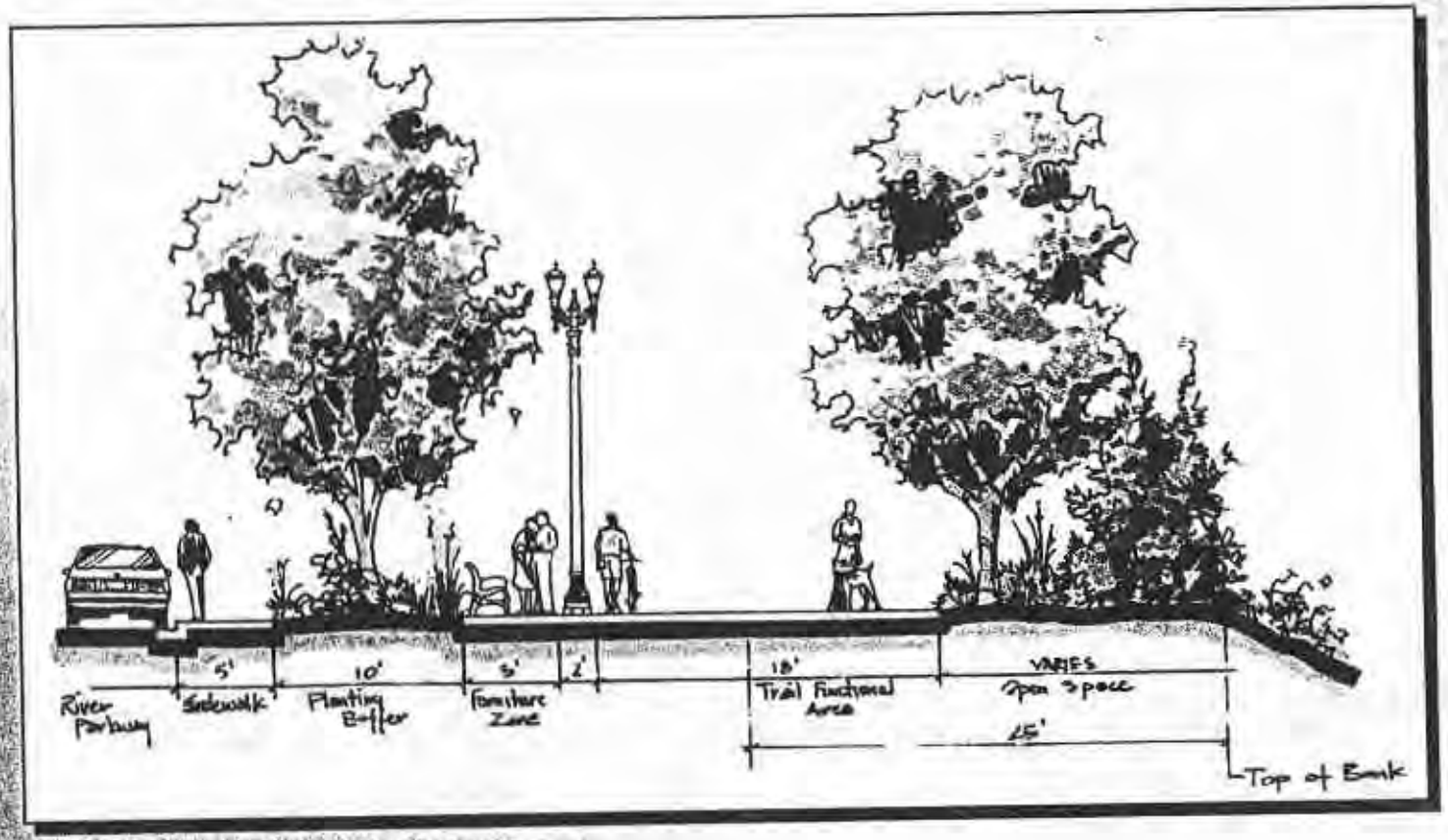
Recreate native riparian plant communities along river corridor.

Willamette River : Portland, Oregon



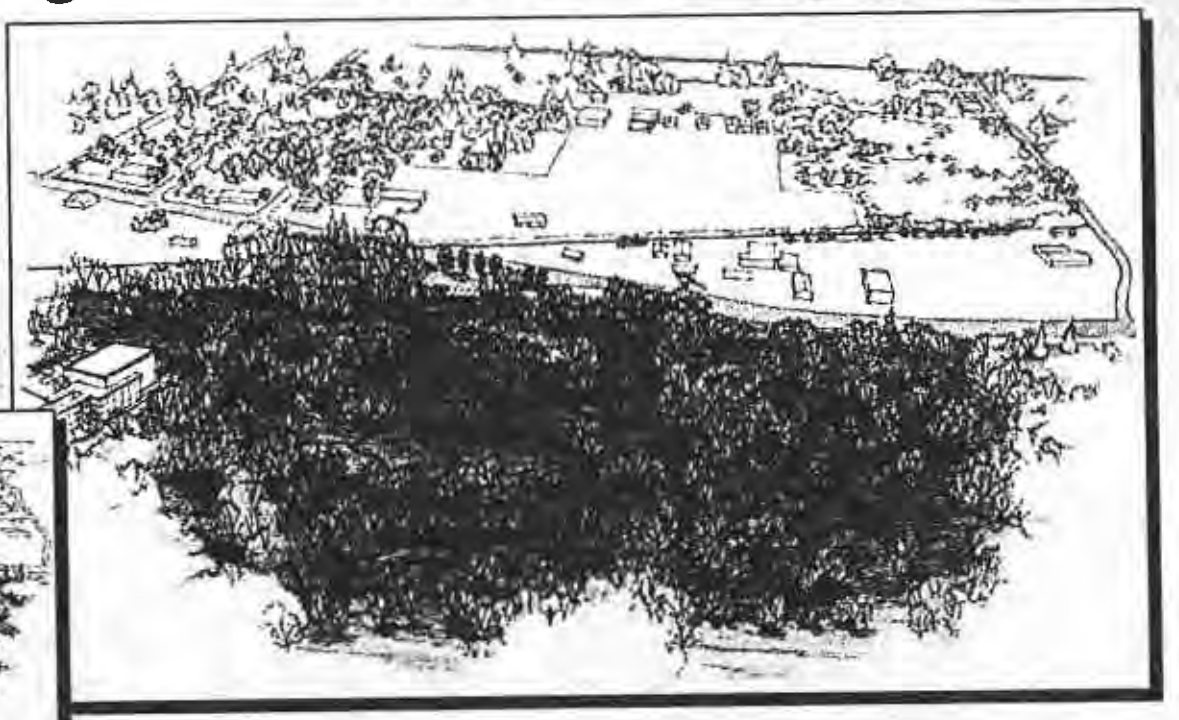
Action 4:

Develop a "Greenbelt" that extends beyond the top of riverbank 20-50 meters.



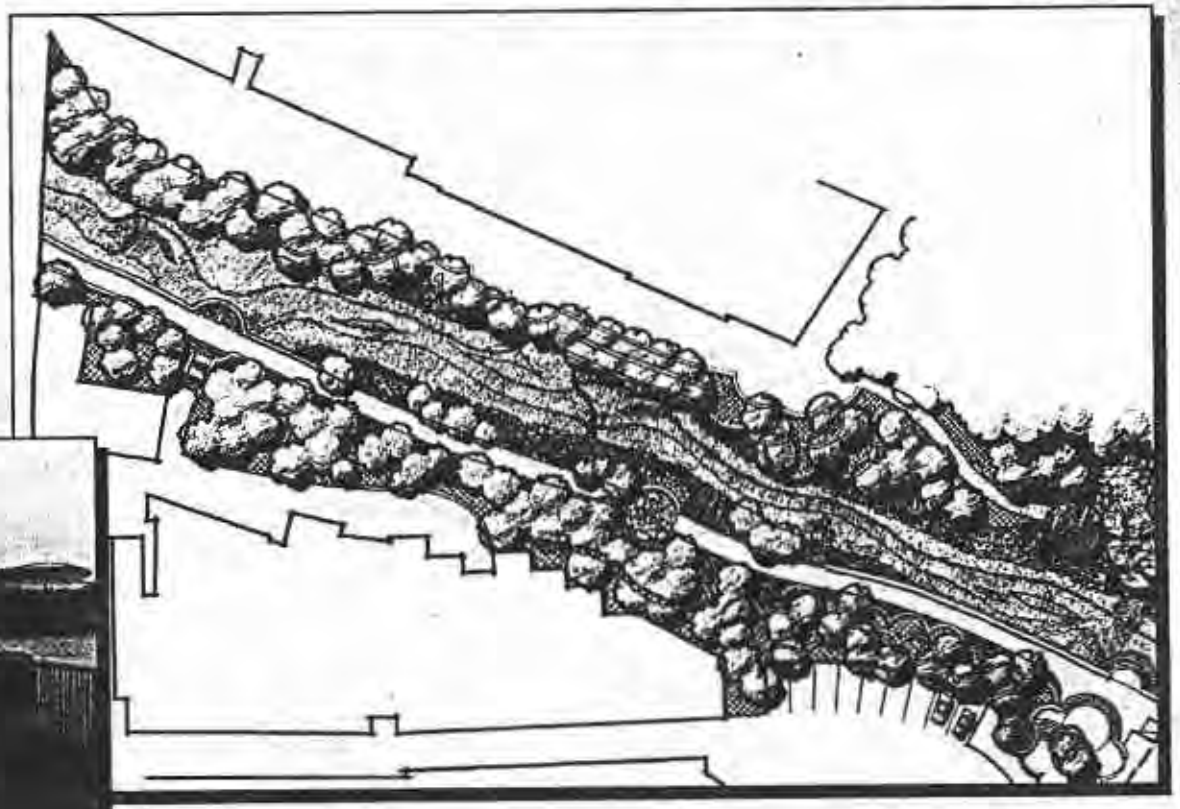
Action 5:

Protect, preserve and restore lowland floodplain areas for agriculture, flood storage, and wildlife habitat.



Action 6:

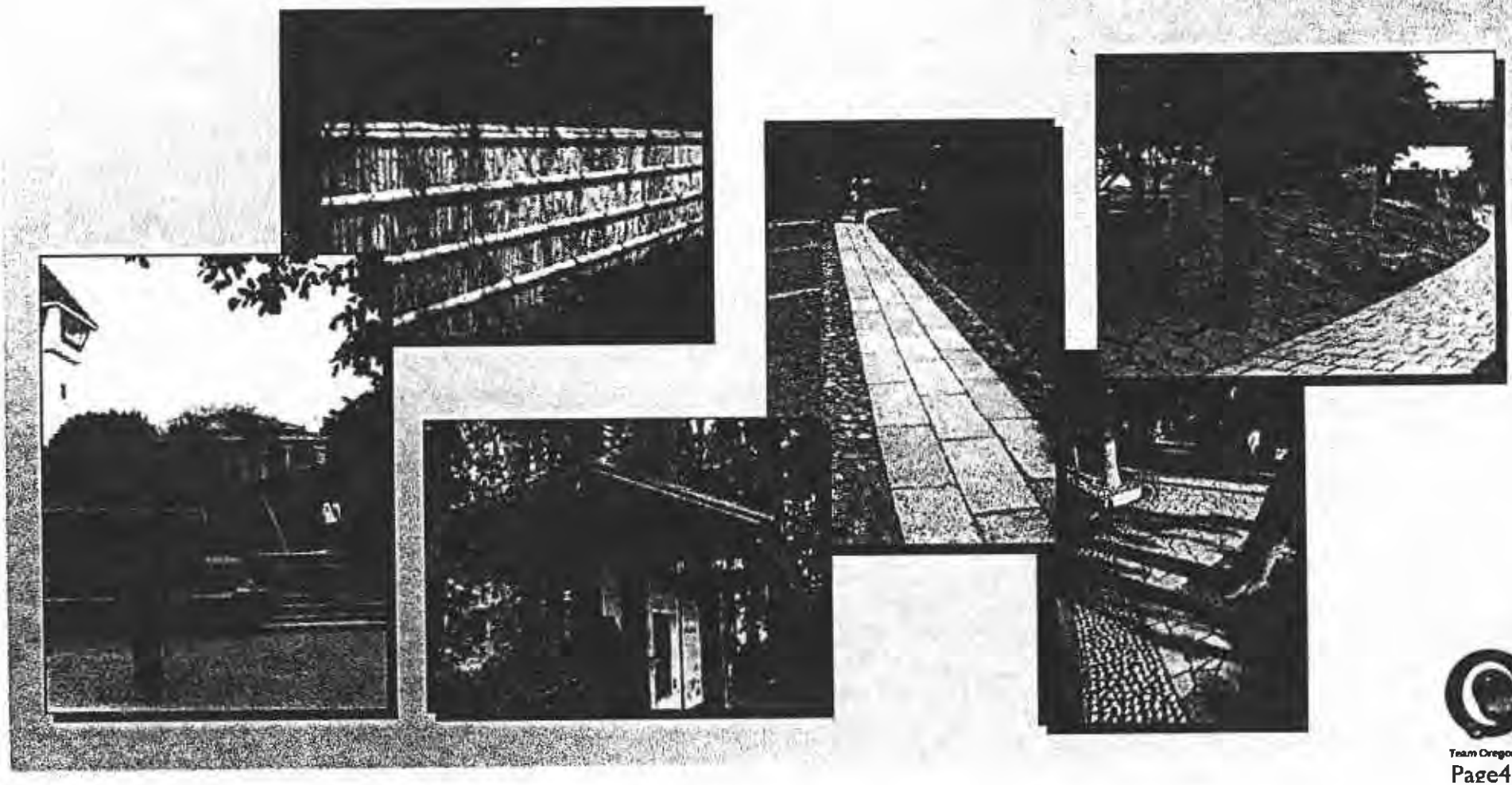
Develop a riverside trail system for use by pedestrians and bicycles.



Gov. Tom McCall Park, Portland, Oregon

Action 7:

Utilize local and recycled construction materials.



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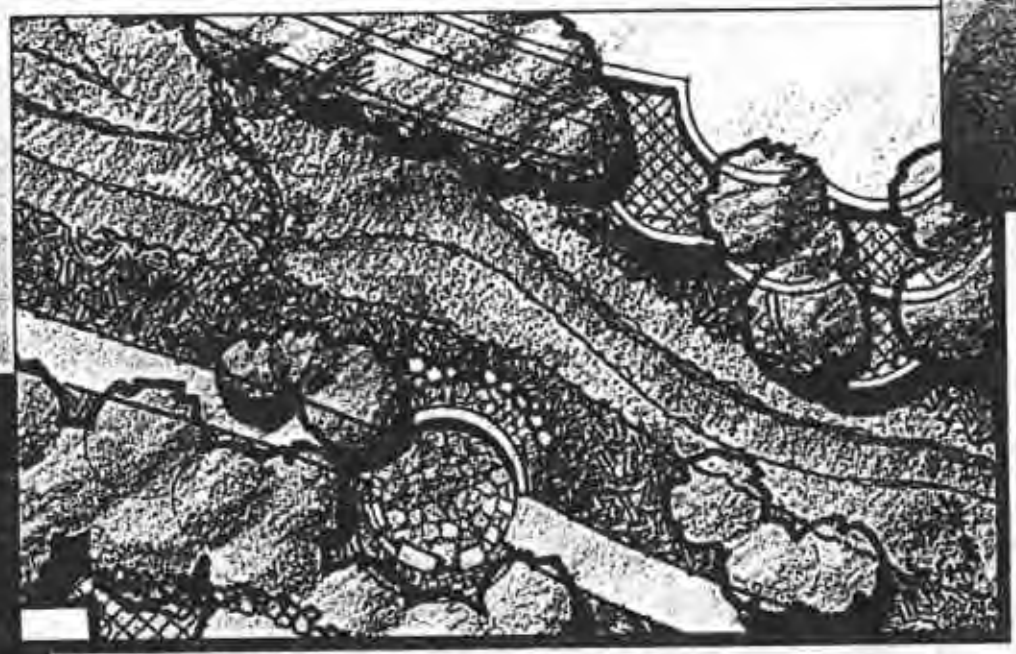
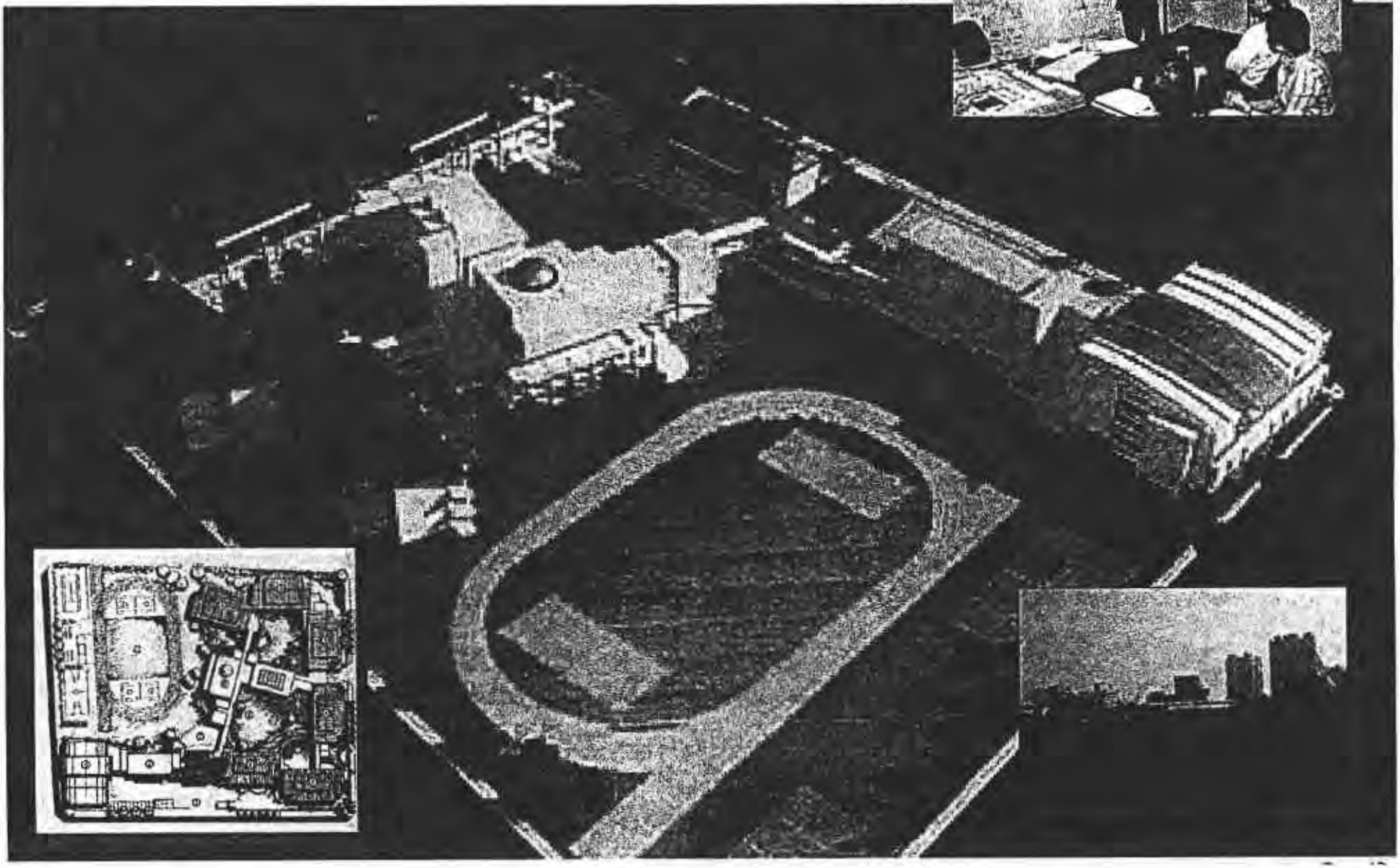
Action 8:

Integrate public art and interpretive exhibits along greenbelt trail.



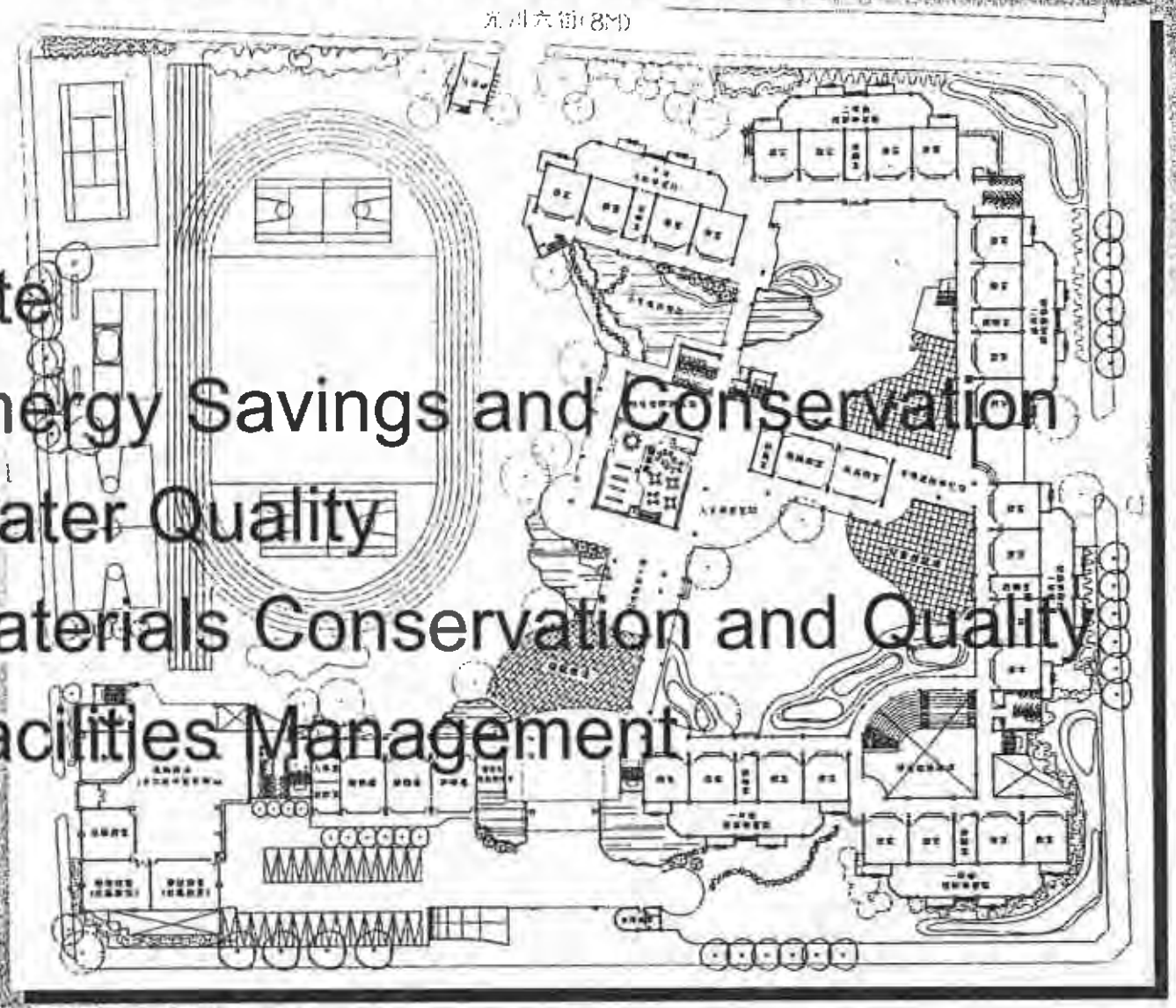
Tainan Eco-School Recommendations

Team Oregon, uc



Tainan Eco-School:

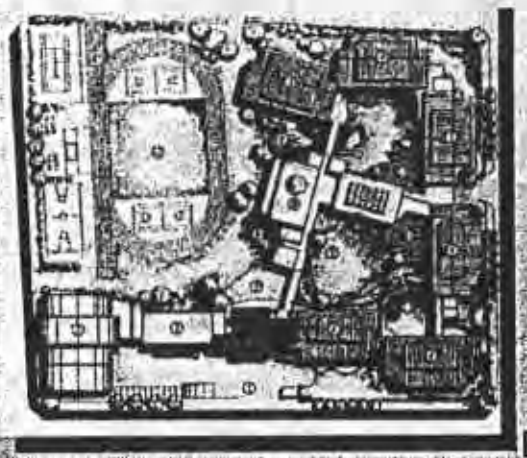
Recommendations & Actions



- Site
- Energy Savings and Conservation
- Water Quality
- Materials Conservation and Quality
- Facilities Management

Tainan Eco-School:
Recommendations

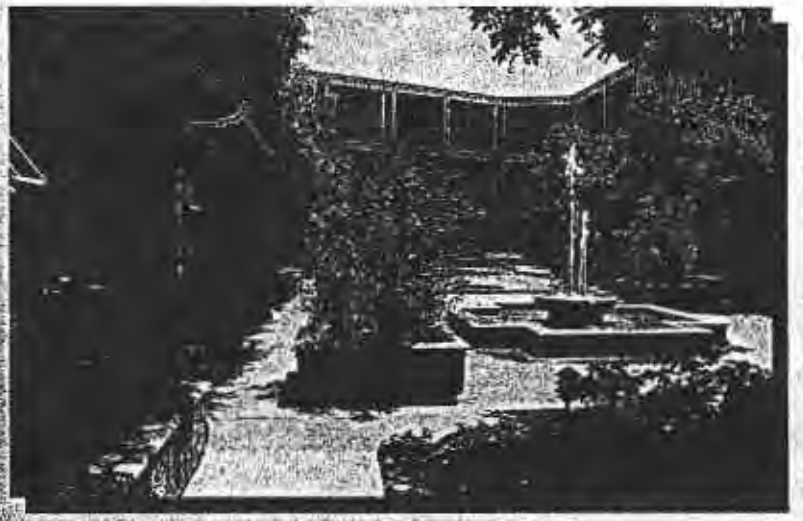
- Site Actions
  - 1. Open Space and Reduced Heat Island Effect
    - Increase plantings to shade 85% of impervious areas and 50% of open space
    - Add eco-roofs to Administrative wing, Gym and Lecture Room



Benefits: Cooler micro-climate, reduced cooling costs, reduced stormwater run-off, increased habitat, beautified environment

Tainan Eco-School:
Recommendations

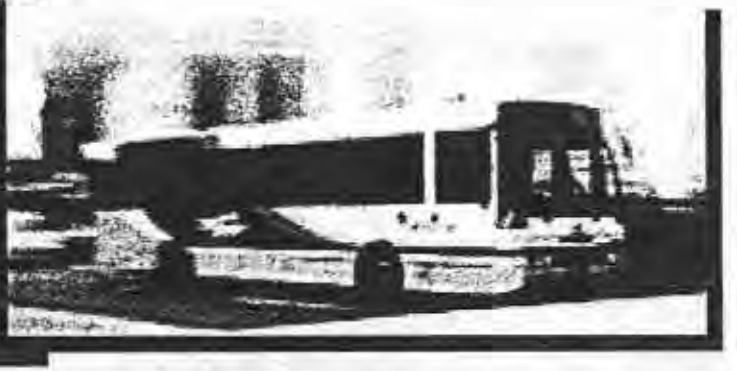
- Site Actions
  - 2. CO_2 Absorption
    - Increase tree plantings on-site to achieve 800 kg/m2 CO_2 absorption average
    - Offset CO_2 emissions off-site through neighborhood and regional tree planting program



- Benefits: Cooler micro-climate, reduced cooling costs, reduced stormwater run-off, increased habitat, beautified environment

Tainan Eco-School:
Recommendations

- Site Actions
  - 3. Reduced Parking
    - Reduce required parking area by 25%
    - Provide alternative transportation such as shuttle bus

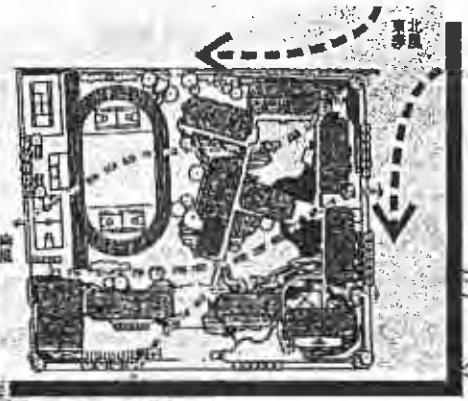


Benefits: Reduced building area requirements, reduced construction costs, reduced CO_2 emissions

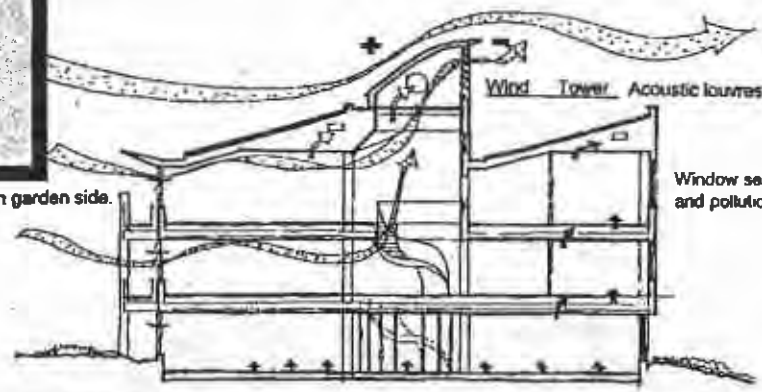
Team Oregon, LLC

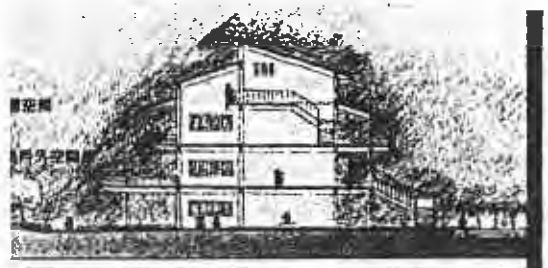
Tainan Eco-School:
Recommendations

- Energy Savings and Conservation Actions
  - 1. Natural ventilation
    - Provide double-skin roof system
    - Utilize stair wells as heat chimneys
    - Provide for natural ventilation stack-effect in assembly areas



Windows openable on garden side.





Benefits: Improved building performance, reduced cooling costs, increased student performance

Tainan Eco-School:
Recommendations

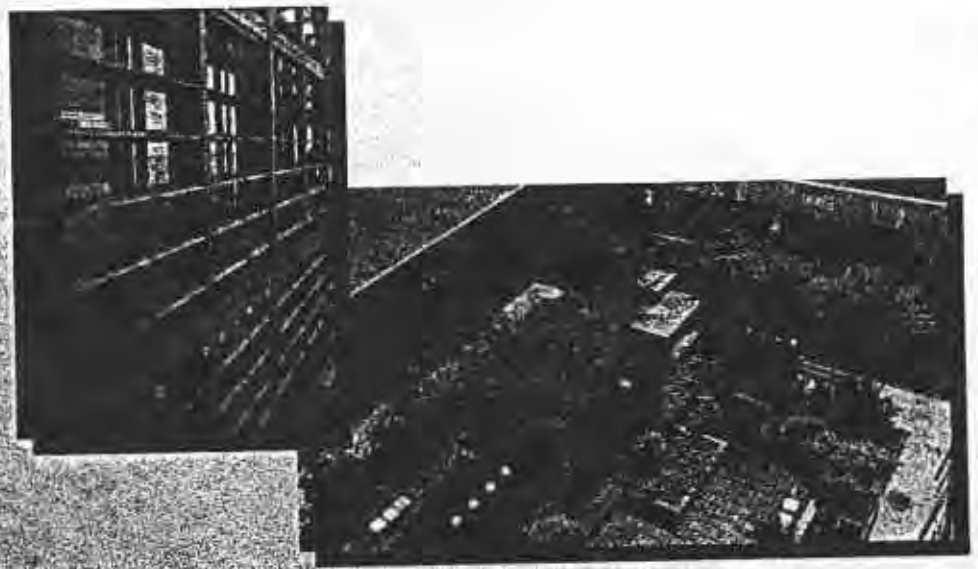
- Energy Savings and Conservation Actions
  - 2. Reduce lighting loads
    - Incorporate energy efficient T-5 (16mm) fixtures
    - Separate control lighting zones adjacent to windows
    - Incorporate light shelves daylighting strategies

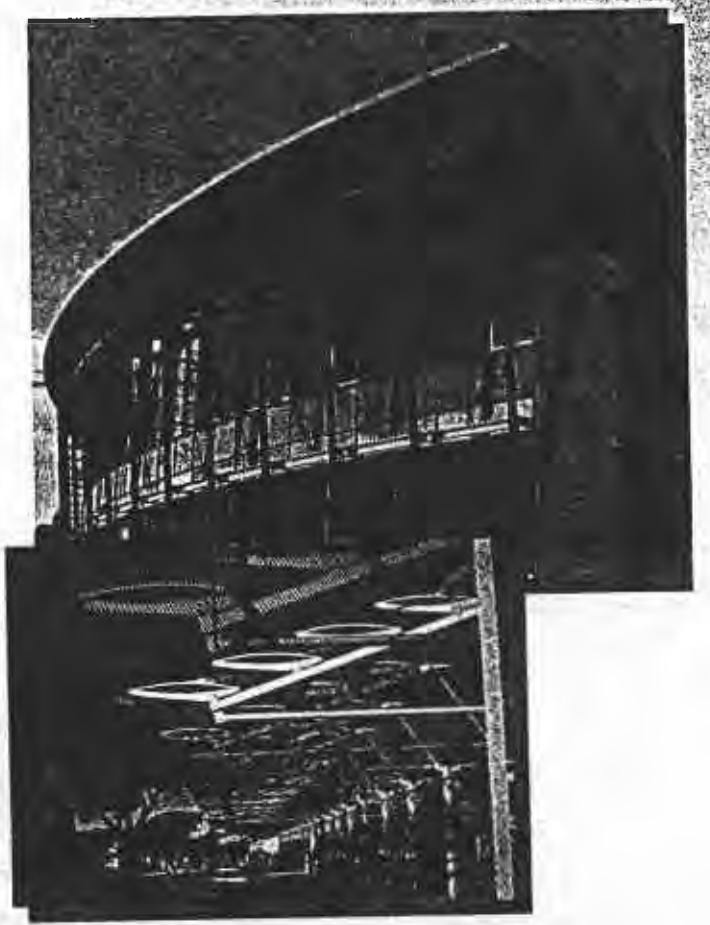
  - Benefits: Improved building performance, reduced cooling costs, increased student performance

Tainan Eco-School:

Recommendations

- Energy Savings and Conservation Actions
  - 3. Exterior sun tempering
    - Sun screens
    - Tree plantings

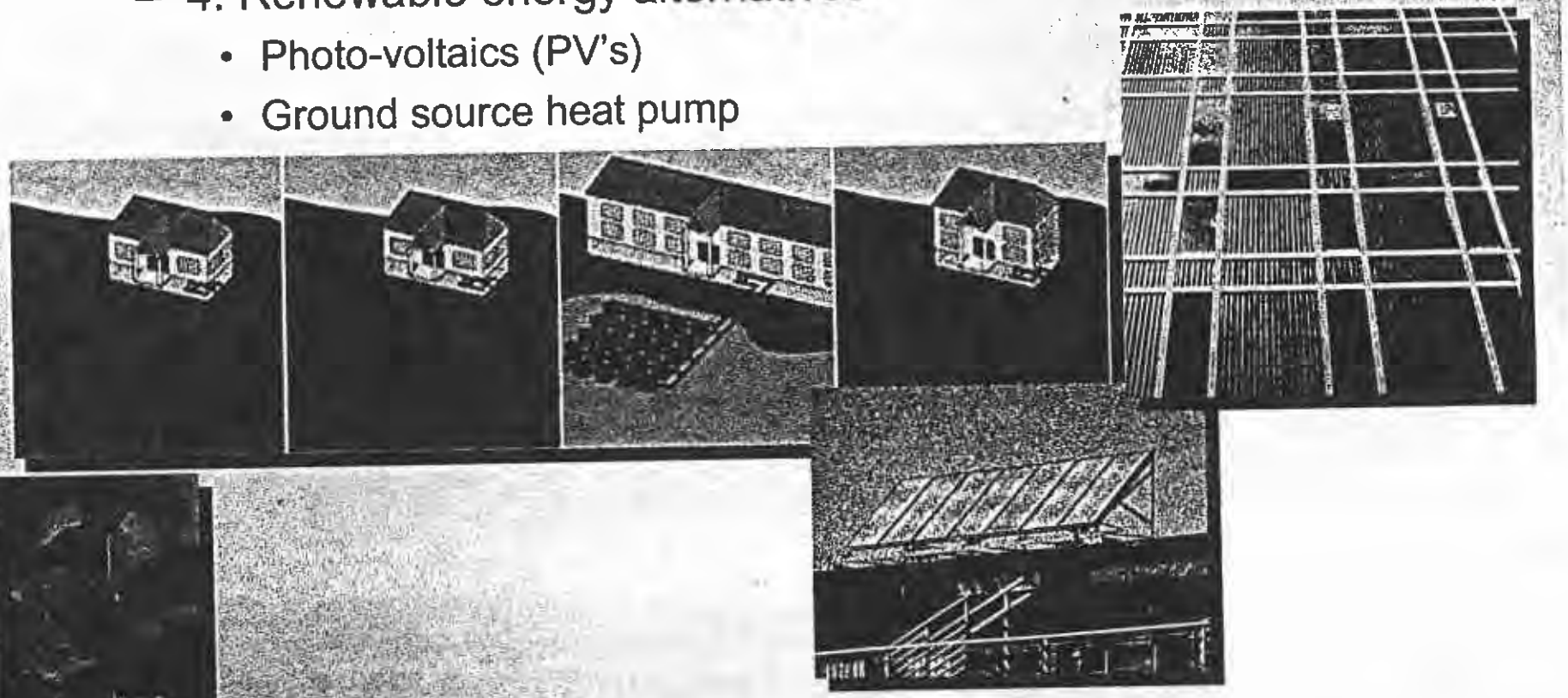




Benefits: Improved building performance, reduced cooling costs, increased student performance

Tainan Eco-School:
Recommendations

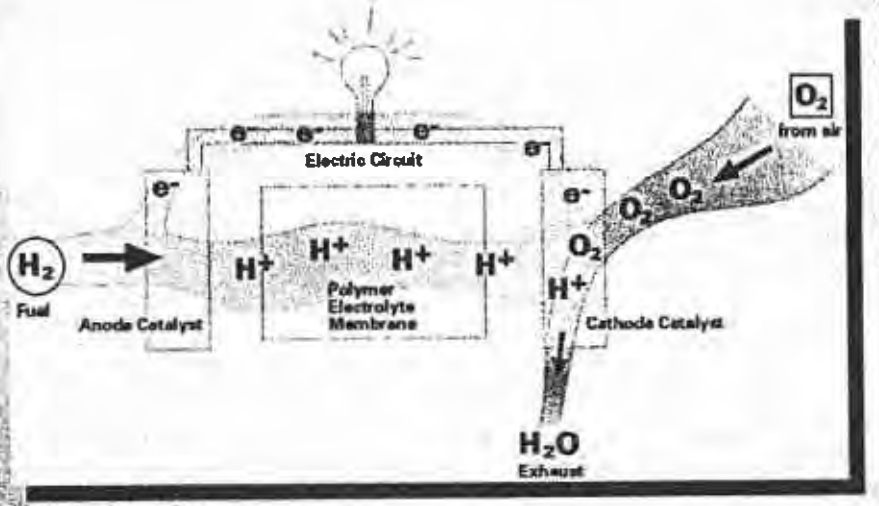
- Energy Savings and Conservation Actions
  - 4. Renewable energy alternatives
    - Photo-voltaics (PV's)
    - Ground source heat pump

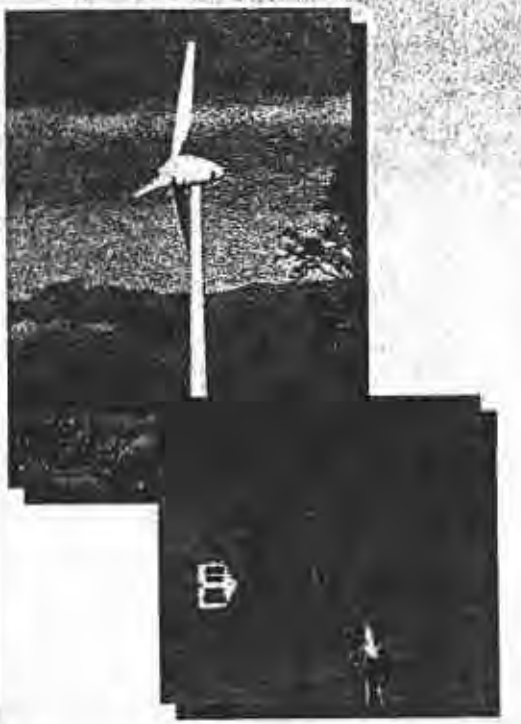


Benefits: Reduced reliance on nuclear and fossil fuels, lower long-term energy costs, reduced green house gases

Tainan Eco-School:
Recommendations

- Energy Savings and Conservation Actions
  - 4. Renewable energy alternatives
    - Fuel cells
    - Wind turbines

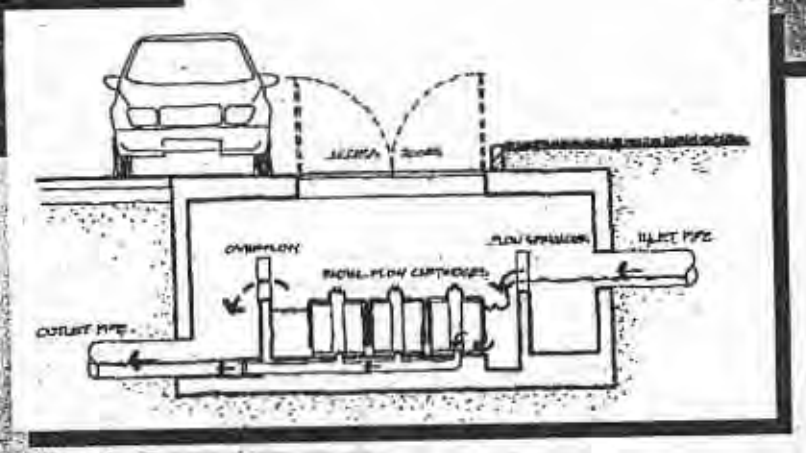


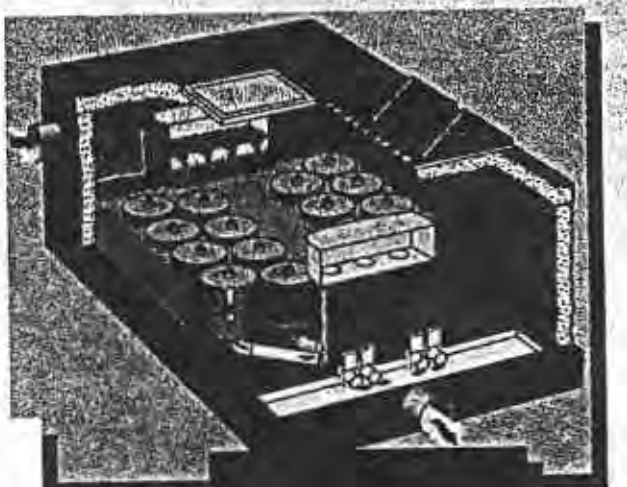


Benefits: Reduced reliance on nuclear and fossil fuels, lower long-term energy costs, reduced green house gases

Tainan Eco-School:
Recommendations

- Water Quality Actions
  - 1. Stormwater filtration
    - Bio-swales and detention ponds
    - Below grade storm vaults

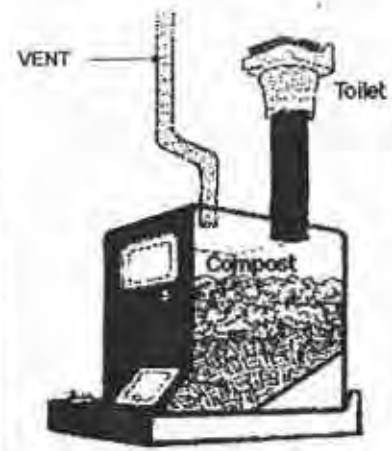




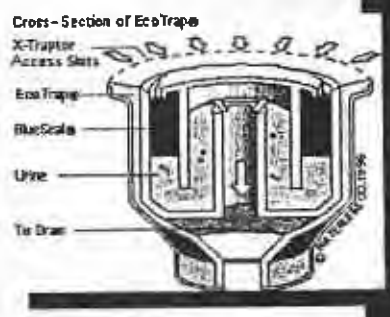
- Benefits: Water pollution reduction and improved watershed quality

Tainan Eco-School:
Recommendations

- Water Quality Actions
  - 2. Reduce toilet water requirements
    - Utilize water conserving fixtures
    - Install demonstration composting toilets
    - Utilize waterless urinal technology



Clivus Multrum Composting Toilet



Benefits: Reduced potable water demand

Tainan Eco-School:
Recommendations

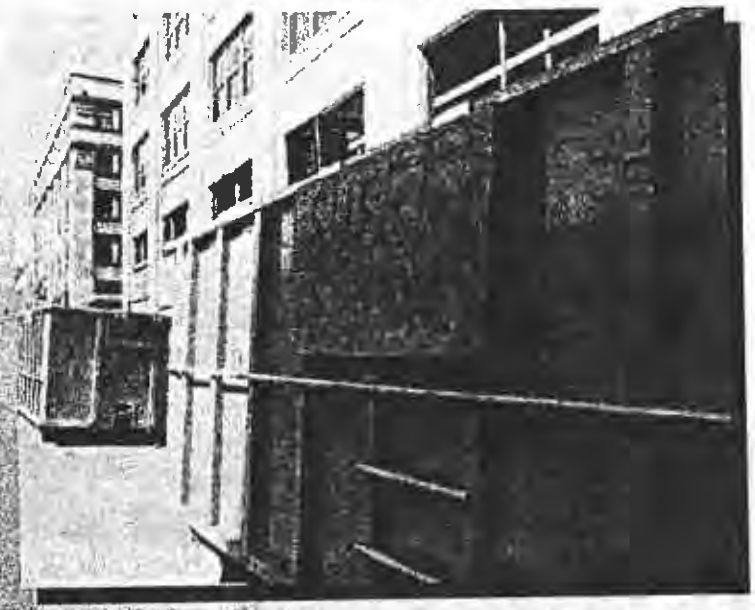
- Water Quality Actions
  - 3. Rainwater collection systems
    - Incorporate cisterns to capture rainwater for irrigation use
  - 4. Incorporate Living Machine technology
    - Treat wastewater biologically on-site

  - Benefits: Reduced potable water demand, educational opportunity

Tainan Eco-School:

Recommendations

- Materials Conservation and Quality Actions
  - 1. Reduce, reuse, recycle
    - Minimize construction waste and packaging by targeting 80% recycling rate
    - Use building materials with a min. 25% recycled content. Examples include steel, ceramic tile, glass, gypsum, paper, and plastic products.

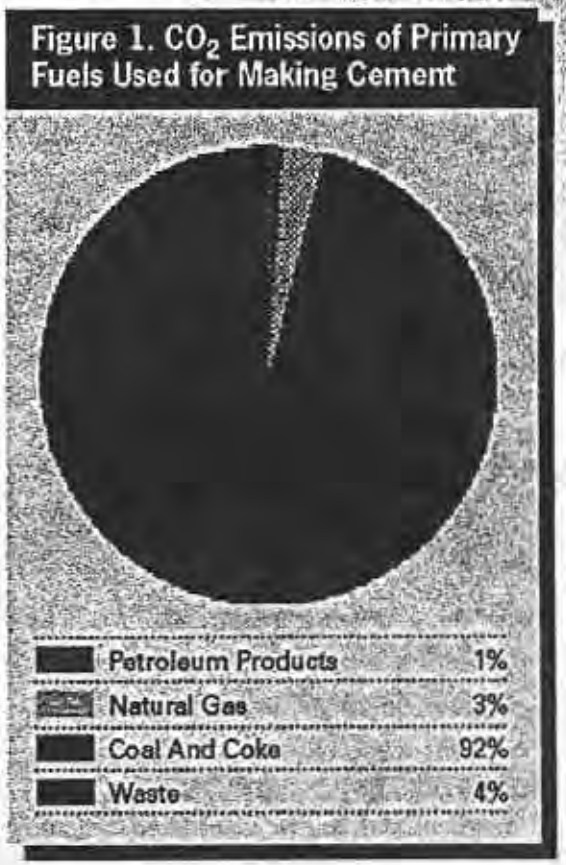


Benefits: Reduce solid waste stream, reduce project costs

Tainan Eco-School:

Recommendations

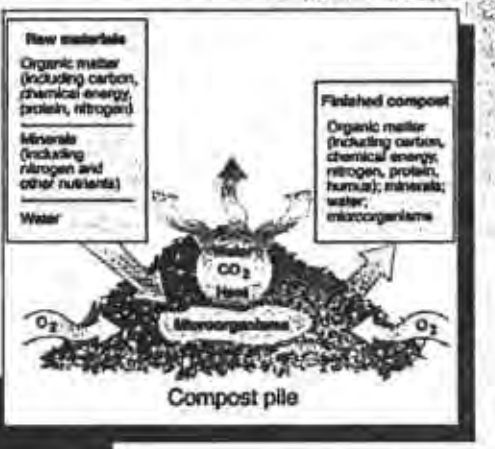
- Materials Conservation and Quality Actions
  - 2. CO2 reduction in construction
    - Utilize steel framing
    - Utilize up to 50% fly-ash content in concrete

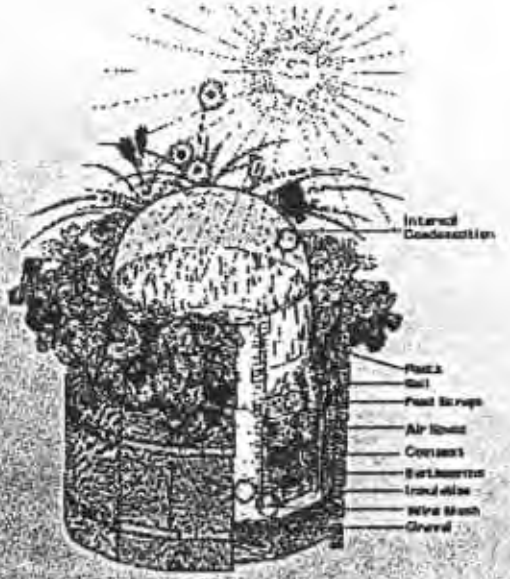


Benefits: Reduced air pollution, green house gas emissions

Tainan Eco-School:
Recommendations

- Materials Conservation and Quality Actions
  - 3. Kitchen waste recycling
    - Compost 100% of food waste on-site
  - 4. Eliminate toxic materials
    - Specify allowable VOC maximums

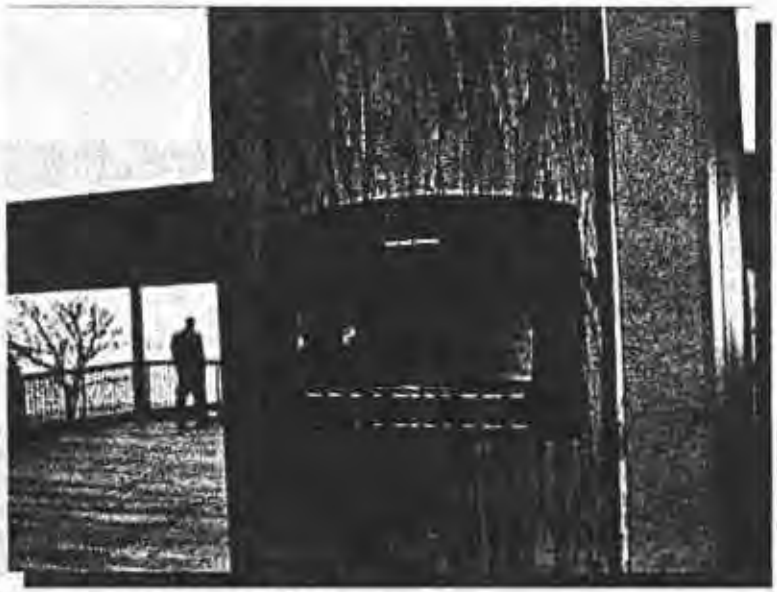




Benefits: Reduced solid waste, educational opportunity, improved indoor environment

Tainan Eco-School:
Recommendations

- Facilities Management Actions
  - 1. Eliminate toxic cleaning materials
    - Choose non toxic bio-degradable cleaning agents
  - 2. Maintain energy performance of building systems
    - Install energy management reporting systems



Benefits: Improved indoor environmental quality, improved energy performance, reduced costs

Tainan Eco-School:
Recommendations

- Facilities Management Actions
  - 3. Landscape maintenance
    - Eliminate pesticide and fertilizer use
  - 4. Building life-cycle
    - Consider expansion, change of use and deconstruction in building design
  - 5. Building waste reuse and recycling
    - Establish and monitor a waste recycling programs

Benefits: Improved environmental quality, increased building life-span, reduced solid waste stream

Team Oregon, LLC

Team Oregon, LLC

TDA in Tainan

Framework for Sustainability and Case Studies

Team Oregon

copy

January 8, 2002

Mr. Lin, Chung-Min
Project Manager
China Engineering Consultants Inc.
21st Floor, No. 185
Hsin Hai Road Sec 2,
Taipei, 10637, Taiwan

Dear Mr. Lin,

It was my pleasure to meet you and your team during the December Team Oregon visit to Tainan City and the review session of the Team Oregon recommendations for the Chai Tou Gang Shi project (CTGS).

As we discussed, Team Oregon has been retained by Tainan City, through the US Trade and Development Agency, to study the feasibility of several projects in the city. I was pleased to provide you a copy of our report on the CTGS. I am enclosing a copy of a report we made to Tainan City on potential products and services for the projects.

Appendix 3 addresses the products and services available for the Chai Tou Gang Shi demonstration project available from US firms. Appendix 2 describes the services available for waste water treatment systems. Should you require further assistance or more detailed information please let me know.

Best wishes for a wonderful New Year.

Sincerely,

Robert N. Wise
Team Leader

813 SW Alder
Suite 320
Portland, OR
U.S.A. 97205
(503) 225-0192

Jennifer Gerard

From: Bob Wise
Sent: Monday, January 07, 2002 8:31 AM
To: Jennifer Gerard
Subject: FW: Please print

-----Original Message-----
From: ks678@ceci.org.tw [mailto:ks678@ceci.org.tw]
Sent: Saturday, January 05, 2002 11:30 PM
To: Bob Wise
Subject: RE: Tainan Project

Dear Mr. Wise:
The project manager of the Chai Tau Gang Chi of CECI is 林崇民(Lin Chung-Min).
The address of him is :21th Floor, No. 185, Hsin Hai Rd. , Sec. 2 ,Taipei, 10637 , Taiwan
(台北市 10637 辛亥路2段185號21F)

Happy New Year.

Best Regards,

Lee Ming-Chung
Kaoshiung Office,CECI

-----Original Message-----
From: Bob Wise [mailto:bwise@coganowens.com]
Sent: 2002/1/5 [星期六] 上午 03:16
To: KS 高辦處 李明忠
Cc:
Subject: Tainan Project

Dear Mr. Lee:

It was my pleasure to meet you in the briefing with former Mayor Chang of Tainan City.
I would like to send your company some more materials from the project of the Chai Tau Gang Shi.
Please provide me the name and address of the project manager for China Engineering
Consultants, Inc for the project so I can send some information.

Please have a happy and prosperous New Year.

Best Regards,

Robert Wise
Team Oregon, LLC

Team Oregon

Team Oregon Report on
Tender Preparations and Potential Products and Services

November 30, 2001

Introduction

This report provides information on Tainan City for Tasks 6 and 7 (Products and Service Recommendations) of the Terms of Reference. These are related to review of tenders and pre-tender activities and recommended products related to the Chai Tou Gang Shi, Wastewater Treatment System plan, and the Tainan Ecological School projects.

The following report develops detailed information on tender status and products and services provided to Tainan City for the three projects.

Team Oregon recommends, for all three projects, that Tainan City consider consultants skilled and knowledgeable in sustainable development related to the Design Teams for each project (Appendix 1). Recommendations include:

813 SW Alder
Suite 320
Portland, OR
U.S.A. 97205
(503) 225-0192

1. Preference should be given to design teams with demonstrated experience in environmentally responsible or Green Building Design.

2. The design team should be able to explain their expertise with environmentally responsible or Green Building Design, and their specific expertise in applying "Integrated Design" concepts and methodologies.

3. The design team should demonstrate experience with completed projects that use less energy than applicable Taiwanese Energy Code.

4. The design team submittal should provide a list of client references for green building design.

5. The design team's submittal should include a résumé of the person or persons who will be in charge of this project, including their experience with green building design projects.

Both the Tainan Wastewater System Plan (Appendix 2) and the Chai Tou Gang Shi Beautification and Restoration Plan (Appendix 3) provide information addressing how to:

1. Review tender documents to best foster competition for bidding for future projects and provide sound and sustainable products at reasonable prices.
2. Respond to questions by the City and local firms (those under direct contact with the city).
3. Review draft designs, review plans/designs, and review other work products.
4. Assist with the preparation of requirements for pre-qualifications.
5. Notify qualified firms of the upcoming tender(s).

The Tainan Wastewater System Plan (Appendix 2) and the Chai Tou Gang Shi Beautification and Restoration Plan (Appendix 3) and the Tainan Eco-School (Appendix 4) provide information on recommended products and services for the project.

Team Oregon Comments on Opportunities for the Future in Tainan City and Taiwan

Team Oregon was well received in Tainan and Taipei. The project is of interest to the City, Tainan County, and the Taiwan Central Government. All levels of authority seem interested in US products and services. We believe there is a special level of interest to develop these projects in a more innovative and sustainable manner other than comparable projects in Taiwan.

In Tainan City, Team Oregon developed an excellent working relationship with Mayor Chang, his staff, and the affected department heads of city government. Team Oregon also has met with Governor Mark Chen of Tainan County as part of the Chai Tou Gang Shi project is located in the county. We also have had excellent meetings in the central government with the President's Office, the Council of Economic Planning and Development, the Environmental Protection Administration, Ministry of Interior, Ministry of Economic Affairs, National Science Council, Ministry of Education and other organizations.

Team Oregon believes there are several related opportunities in Tainan and Taiwan:

- President Chen made two recent announcements that bode well for our project and related US exports. The first is the proposed 25.3 billion US$ this year for a national public works program, including approximately 3.5 billion US$ for wastewater treatment systems. It is estimated that over 93 billion US$ will be

spent on national economic development in the next four years. President Chen also announced that sustainable development is the primary national economic development policy for Taiwan as a "Green Silicon Island." Because Team Oregon is packaging and marketing our projects as "sustainable development", we can distinguish ourselves from the run-of-the-mill Taiwanese, European, Japanese, or Australian consulting firms.

- The Council for Economic Planning and Development, Taiwan's economic planning agency supervising the economic development agenda, has asked for Team Oregon's advice on a national sustainable development action plan, based on Oregon models. This will allow us to carry our Tainan project recommendation to the Central Government.

- Team Oregon projects can generate economic opportunity between Taiwan and the United States.

  Currently the City and County have plans to develop a total of seven wastewater treatment plants and related systems. One treatment plant is complete and the other is under construction. American products in the form of tanks, treatment systems, pumping and monitoring equipment, and other items are already being used in these plants.

  In discussions with the Mayor and the head of the City EPA, Team Oregon was requested to focus recommendations on the entire wastewater treatment system and not just the two original projects. Team Oregon refocused its effort to recommend products and services for the five remaining treatment plants (tanks, pumps, clairifiers, digested sludge tanks, etc.), collection systems, pumping stations, and monitoring and system management products. See Appendix 2 for details.

  Our recommendations affirm the positive direction in which the City is going with the traditional wastewater treatment systems they are constructing, and suggest some additional sustainable development innovations to consider. These innovations, used in Portland and other US cities, include the use of methane gas from sludge digestion to power fuel cells, land disposal of biosolids for agricultural production, the use of a "living machine" as a demonstration project, and the use of constructed wetlands for tertiary treatment.

- Ecoschool recommendations include products and services not originally envisioned in a normal school building including a fuel-cell, solar collectors, a "living machine" to treat wastewater and food wastes, composting toilets, and other items beyond the normal construction materials and services. See Appendix 3 for details.

- The Chai Tou Gang Shi clean-up and beautification project includes recommendations for wastewater collection and treatment and conceptual plans for beautification. At this time, two wastewater treatment plants—one in the county and one in the city—will address the clean-up of the Shi. The Shi divides the city from the county so there is a unique opportunity for city-county cooperation on clean-up and beautification. The City has asked for our recommendation soon so they can issue an RFP for Phase I of the project. At this time it appears the city will follow some elements of the Conceptual Plan of the Shi. See Appendix 4 for details.

The team also discovered that the landscape nursery industry in Taiwan is not well developed, particularly in the Tainan/Kaohsiung region. There is a great deal of nursery expertise in the US, including Oregon, where nurseries form the third largest industry in the state. Propagating, growing and shipping appropriate plants to be used in restoration of the hundreds of miles of degraded riverbanks in Taiwan represents a large business opportunity for US companies. In addition, US firms could work to establish local nurseries in Taiwan using US equipment and procedures. Other US products that likely will be utilized in the Chai Tou Gang Shi project include biotechnical and erosion control fabrics, tackifiers and equipment used in hydroseeding, segmental retaining wall systems, prefabricated bridge systems, concrete coloring systems, and site furnishing and lighting manufacturers. These represent a few of the opportunities for US-Taiwan businesses. These services are presently provided by Oregon companies to many Japanese clients and the opportunity exists for a new large market in Taiwan.

Tender Preparations Report

Appendix 1
Recommended Requirements for Design Teams

November 30, 2001

Prepared by

Team Oregon, LLC

This report was funded by the U. S. Trade and Development Agency (TDA), an export promotion agency of the U. S. Government. The opinions, findings, conclusions or recommendations expressed in this document are those of the author(s) and do not necessarily represent the official position or policies of TDA.

The US Trade and Development Agency
1621 North Kent Street, Suite 200
Arlington, VA 22209-2131 USA

APPENDIX 1

Recommended Requirements for Design Teams
Team Oregon

October 15, 2001

Tainan TDA Grant
Task 6

I. Requirements for Pre-Qualifications for Architects, Engineers and Building Contractors (Design Team)

A. Suggested Evaluation Factors for Determining Design Team's Knowledge and Experience in Green Building Design:

1. Preference should be given to design teams with demonstrated experience in environmentally responsible or "Green Building" design.

2. The design team should be able to explain their expertise with environmentally responsible or "Green Building" design, and their specific expertise in applying "Integrated Design" concepts and methodologies.

3. The design team should demonstrate experience with completed projects that use less energy than applicable Taiwanese Energy Code.

4. The design team submittal should provide a list of client references for green building.

5. The design team's submittal should include a résumé of the person or persons who will be in charge of this project. Include their experience with green building projects.

B. The design team's submittal should detail a sample sustainable project previously designed and completed by the design team. This information should include size and type of project and examples of demonstrated green building measures in, at least, each of the following areas:

1. Energy efficiency and conservation
2. Increased public transportation
3. Increased natural vegetation
4. Reduced stormwater runoff
5. Improved water quality
6. Selection of materials that are low toxic, low environmental impact
7. Waste reduction and recycling
8. Improved human comfort and health
9. Improved natural habitat
10. Inclusion of community process

Tender Preparations Report

Appendix 2
Wastewater Treatment System

November 30, 2001

Prepared by

Team Oregon, LLC

This report was funded by the U. S. Trade and Development Agency (TDA), an export promotion agency of the U. S. Government. The opinions, findings, conclusions or recommendations expressed in this document are those of the author(s) and do not necessarily represent the official position or policies of TDA.

The US Trade and Development Agency
1621 North Kent Street, Suite 200
Arlington, VA 22209-2131 USA

APPENDIX 2

MEMORANDUM

To: Bob Wise
From: Lisa Tamura
Date: November 19, 2001
Subject: Wastewater Treatment System Evaluation - Task 6 Progress
Project #: 41312-001-01 (4030)

As stated in the TOR, Team Oregon is to address the following as part of Task 6:

1. Review tender documents to best foster competition for bidding for future projects and provide the sound and sustainable products at reasonable prices.
2. Respond to questions by the city and local firms (those under direct contact with the city).
3. Review draft designs, review plans/designs, and review other work products.
4. Assist with the preparation of requirements for pre-qualification.
5. Notify qualified firms of the upcoming tender(s).

Team Oregon has made the following progress on these items as related to the City's wastewater treatment system:

1. There were no tender documents available to review for the wastewater treatment facilities in Tainan. However, Team Oregon did review the existing plans for wastewater treatment systems and facilities. In the review we identified potential areas where sustainable processes or designs could be applied.
2. During the visit to Tainan City in August of 2001, Team Oregon met with City officials and the public works department. In these meetings we presented our Interim Report and Sustainable Development Framework, and discussed and answered questions relating to the various technologies (fuel cell and microturbine technology, Living Machines, etc.) available that were described in that report.
3. Team Oregon has reviewed the City's overall plan for wastewater treatment. In our Interim Report and various presentations we have made recommendations for alternative technologies that are available to improve sustainability in treatment plant designs (fuel cells, microtrubines, Living Machines). In addition, we have recommended other procedures that would make the overall system more sustainable. These procedures include combining the 2 interceptors (City and County lines) near the Chai Tou Gang Shi into one, proposing a regional government for regionalizing wastewater treatment, and composting and/or land application of biosolids.
4. Team Oregon is providing a draft of suggested pre-qualification requirements for architects, engineers, and building contractors as part of the Task 6 report document.
5. During the August 2001 trip to Tainan, the Mayor mentioned an upcoming potential release of a treatment plant design. He anticipated possibly releasing this project before the end of 2001. Currently the release of tender data in relationship to the wastewater treatment plant is uncertain, due to the local elections currently taking place in Tainan, and no announced tender date has been set, Team Oregon will send notification to potential interested firms of the possible upcoming tender rather than notification of the actual release of the tender. The letter will be similar in form to that sent out to for the Chai Tou Gang Shi project (dated October 24, 2001).

Century West Engineering
6650 SW Redwood Lane, Suite 300 Portland, OR 97224
Phone: (503) 419-2130 Fax: (503) 639-2710

Team Oregon

November 27, 2001

Mayor George T. Chang, Ph.D.
City of Tainan, Taiwan
6. Yung-Hwa Rd., Sec 2,
Tainan, Taiwan.

Dear Mayor Chang,

As part of our Task 6, Team Oregon, in cooperation with Tainan City, is required to notify you of qualified firms of the upcoming tender(s) in regards to the wastewater treatment plant project(s). It is our understanding that the planning efforts for the wastewater treatment plants are moving forward at a rapid pace and we would like to provide you the name and addresses of qualified firms, both local to Taiwan and from the United States, that may be considered for the next phase of the design and construction. Those firms are:

Blossom
Contact: Owen Hsieh
Email: owen419@m1.is.net.tw
Phone: (03)9310961-9310962-9332045
Address:
Ilan, Taiwan

E Tech
Contact: Alex Tuan
Email:engitech@ms55.hinet.net
Phone: (02)2321-7465
Address: 17F-1, No 83, Chung-Hsiao E. Road, Sec. 1
Taipei, Taiwan

Moh and Associates
Contact: Kai-yao "Kevin" Chang
Email:cky@ms.maa.com.tw
Phone: (886-2)2696-7888
Address: 22FL., No. 112, Hsin Tai Wu Road, Sec. 1
Oriental Technopolises Tower A
Hsichih, Taipei County 221, Taiwan, R.O.C.

813 SW Alder
Suite 320
Portland, OR
U.S.A. 97205-3111
(503) 225-0192

Team Oregon

CTCI Corporation
Contact: Peter, Shou-Chich Kao
Email: ksc@ctci.com.tw
Phone: (886-2)2700-9659 Ext. 2131
Address: 21 Fl., CTCI Corporation, 77, Sec. 2, Tun Hwa South Road
Taipei, 106, Taiwan, R.O.C.

Origin International
Contact: Weija Noble
Email: originwn@ms.13.hinet.net
Phone: 886-2-2708-5018
Address: 65 Hsin-Yi Road, Sec. 4, 6F
City Taipei, Taiwan

Parsons Brinkerhoff, Inc.
Civil Engineers
Phone: 886-2-8919-3616
Address: 10F, No. 190, Chung Hsing Road, Sec. 2
Hsin Tien City, Taipei County,
Taipei, Taiwan ROC

CH2M Hill
Civil Engineers
Phone: 1-503-235-5022
Address: 825 NE Multnomah, Suite 1300
Portland, Oregon 97232
USA

Montgomery Watson
Civil Engineers
Contact: Joseph Glicker, P.E.
Phone: 1-503-226-7377
Address: 111 SW 5th Avenue, Suite 1770
Portland, OR 97204
USA

813 SW Alder
Suite 320
Portland, OR
U.S.A. 97205-3111
(503) 225-0192

Team Oregon

Team Oregon, LLC
Landscape Architecture, Environmental Design, Architecture, Engineering, Public Policy
Contact: J. Ned Dempsey
Email: jndempsey@centurywest.com
Address: 6650 SW Redwood Lane, Suite 300
Portland, OR 97224
USA

HDR Engineering, Inc.
Civil Engineers
Phone: 1-503-768-3700
Address: Lincoln One
10300 SW Greenburg Rd., Suite 500
Portland, OR 97223
USA

Consoer Townsend Envirodyne Engineers, Inc.
Civil Engineers
Contact: John T. Barnes, P.E.
Email: john.barnes@cte-eng.com
Phone: 1-509-994-9361 (cell)
Address: 1145 Broadway Plaza, Suite 800
Tacoma, WA 98402
USA

Tetra Tech, Inc.
Civil Engineers
Phone: 1-626-351-4664
Address: 670 N. Rosemead Blvd.
Pasadena, CA 91107
USA

813 SW Alder
Suite 320
Portland, OR
U.S.A. 97205-3111
(503) 225-0192

Team Oregon

We have included many firms from Taiwan because we believe they have the staff and capabilities to be able to complete the wastewater treatment plant designs. The construction of wastewater treatment facilities is a complex project that requires innovative solutions to the environmental problems and will require the planners have skills in many areas, including an understanding of local codes and regulations, urban design, civil engineering, and an aesthetic understanding and sensitivity to the local area and its residents. The best solution may be to hire a local Taiwan firm to manage the project assisted by a US firm that specializes in sustainable development and design.

Sincerely,

J. Ned Dempsey

J. Ned Dempsey
Principal
Century West Engineering

813 SW Alder
Suite 320
Portland, OR
U.S.A. 97205-3111
(503) 225-0192

Tainan TDA Grant
Task 6 Resources and Services for Wastewater Treatment Facilities

II. Recommended Product Sources

This is a partial list of product and services suppliers from the "2001-2001 Industrial & Municipal Wastewater Technology Buyers' Guide" published by the Water Environment Federation. This information also is available on their Web site, www.wef.org.

PRODUCT FOR WASTEWATER TREATMENT	SUPPLIER/CONTACT	COMMENTS
Wastewater Treatment Equipment	ADS Environmental Services, Inc. 5025 Bradford Blvd. N.W. Huntsville, AL 35805-1952 USA Phone: 1+205-430-3961 Fax: 1+205-430-6633 Web: www.adsenv.com	Data Acquisition & Datalogging, Flow Meters & Controllers
	Aeromix Systems, Inc. 2611 N. Second St. Minneapolis, MN 55411 USA Phone: 1+612-521-8519 Fax: 1+612-521-1455 e-mail: aeromix@aeromix.com Web: www.aeromix.com	Aeration Equipment, Lagoon Equipment
	Ag-Chem Equipment Co., Inc. 5720 Smetana Dr. Minnetonka, MN 55343-9688 USA Phone: 1+952-933-9006 Fax: 1+952-933-7432 Web: www.agchem.com/products/	Biosolids Land Application Equipment
	Aqua Aerobic Systems Inc. 6306 N. Alpine Road P.O. Box 93-0785 Rockford, IL 61130 USA Phone: 1+815-654-2501 Fax: 1+815-654-2508 Web: www.aqua-aerobic.com	Advanced Wastewater Treatment, Aerators, Lagoon Equipment, Water Recycling/Reuse
	AquaShield Inc. 2733 Kanasita Drive, Suite A Hixson, TN 37343 USA Phone: 1+423-870-8888 Fax: 1+423-870-1005 Web: www.aquashieldinc.com	Stormwater Treatment

PRODUCT FOR WASTEWATER TREATMENT	SUPPLIER/CONTACT	COMMENTS
Wastewater Treatment Equipment	Baysaver, Inc. 1010 Deer Hollow Drive Mount Airy, MD 21771 USA Phone: 1+301-829-6119 Fax: 1+301-829-3747 e-mail: BaySaver@BaySaver.com Web: www.baysaver.com	Oil/Water Separators, Stormwater Treatment
	Bio-Microbics, Inc. 8450 Cole Parkway Shawnee, KS 66227 USA Phone: 1+913-422-0707 Fax: 1+913-422-0808 e-mail: onsite@biomicrobics.com Web: www.biomicrobics.com	On-site systems Advanced Wastewater Treatment, Lagoon Equipment, Natural Systems
	CDS Technologies Inc. 16360 South Monterey Road Suite 250 Morgan Hill, CA 95037 USA Phone: 1+408-779-6363 Fax: 1+408-782-0721 e-mail: info@cdstech.com.au Web: www.cdstech.com.au/profile.html	Australian based company w/ offices in US Stormwater Treatment
	Chicago Pump 3905 Enterprise Ct. P.O. Box 6620 Aurora, IL 60598-0620 USA Phone: 1+630-236-5700 Fax: 1+630-236-5779 Web: www.chicagopump.com	Pumps
	Cornell Pump Company 2323 S.E. Harvester Drive Portland, OR 97222 USA Phone: 1+503-653-0330 Fax: 1+503-653-0338 Web: www.cornellpump.com	Pumps
	Eagle Microsystems 266 Circle of Progress Pottstown, PA 19469 USA Phone: 1+610-323-2250 Fax: 1+610-323-0114 Web: www.eaglemicrosystems.com	Chemical Feed Equipment, Chlorination/Dechlorination Equipment

PRODUCT FOR WASTEWATER TREATMENT	SUPPLIER/CONTACT	COMMENTS
Wastewater Treatment Equipment	Ecometrics Inc. 130 W. Main St. Silverdale, PA 18962 USA Phone: 1+215-453-9800 Fax: 1+215-453-1000 Web: www.ecometrics.com	Chlorination/Dechlorination Equipment, UV Disinfection
	Envirodyne Systems, Inc. 50 Utley Drive Camp Hill, PA 17011 USA Phone: 1+717-763-0500 Fax: 1+717-763-9308 E-mail: engineering@envirodynesystems.com Web: www.envirodynesystems.com	Advanced Wastewater Treatment, Aerators, Clarifier Equipment, Dewatering Equipment, Digesters, Grit Handling Equipment, Filter Equipment, Sludge Thickeners, Dissolved Air Flotation Systems, Biological Nutrient Removal
	Envirogen Inc. Princeton Research Center 4100 Quakerbridge Road Lawrenceville, NJ 08648 USA Phone: 1+609-936-0075 Fax: 1+609-936-0085 Web: www.envirogen.com	Advanced Wastewater Treatment, Aerobic & Anaerobic Treatment, Biofilters
	Environmental Dynamics Inc. 5601 Pans Rd. Columbia, MO 65202 USA Phone: 1+573-474-9456 Fax: 1+573-474-6988 e-mail: edi@wastewater.com Web: www.wastewater.com	Biological Treatment Systems, Lagoon Systems, Tanks
	Enviroquip, Inc. 2404 Rutland Drive, Suite 200 Austin, TX 78758 USA Phone: 1+512-834-6000 Fax: 1+512-834-6039 e-mail: Website@enviroquip.com Web: www.enviroquip.com	Advanced Wastewater Treatment Processes, Aerators, Aerobic Treatment, Clarifier Equipment, Digesters, Filters, Dewatering Equipment, Anaerobic Treatment, Biological Nutrient Removal, Sludge Thickeners
	Eutek Systems 1055 NE 25th Ave., Suite N Hillsboro, OR 97124 USA Phone: 1+503-615-8130 Fax: 1+503-615-2906 e-mail: sales@eutek.com Web: www.eutek.com	Advanced Wastewater Treatment, Grit Removal Systems

PRODUCT FOR WASTEWATER TREATMENT	SUPPLIER/CONTACT	COMMENTS
Wastewater Treatment Equipment	Fairbanks Morse Pump 3601 Fairbanks Ave. Kansas City, KS 66106 USA Phone: 1+913-371-5000 Fax: 1+913-371-2272 e-mail: fairbanks_info@pentairpump.com Web: www.fairbanksmorsepump.com	Pumps
	Fluidyne Corporation 2816 West First St. Cedar Falls, IA 50613 USA Phone: 1+319-266-9967 Fax: 1+319-277-6034 e-mail: info@fluidynecorp.com Web: www.fluidynecorp.com	Advanced Wastewater Treatment, Aerators, Aerobic Treatment, Digesters. Package Plants Available.
	Gorman-Rupp Company 305 Bowman St. Mansfield, OH 44902 USA Phone: 1+419-755-1011 Fax: 1+419-755-1404 Web: www.gormanrupp.com	Pumps
	Headworks Inc. 9601 Katy Fwy., Suite 470 Houston, TX 77024 USA Phone: 1+713-647-6667 Fax: 1+713-647-0999 e-mail: hw@headworksusa.com Web: www.headworksusa.com	Conveyors, Dewatering Equipment, Screens
	HIL Technology Inc. 94 Hutchins Drive Portland, ME 04102 USA Phone: 1+207-756-6200 Fax: 1+207-756-6212 e-mail: hiltech@hil-tech.com Web: www.hil-tech.com	Grit Handling Equipment, Screens, Stormwater Treatment
	Hi-Tech Environmental Inc. P.O. Box 360597 Birmingham, AL 35236 USA Phone: 1+800-264-7005 e-mail: jw_hitech@email.msn.com Web: www.hi-techenv.com	Clarifier Equipment, Filtration, Grit Handling, Thickeners

PRODUCT FOR WASTEWATER TREATMENT	SUPPLIER/CONTACT	COMMENTS
Wastewater Treatment Equipment	ONDEO Degremont Inc. P.O. Box 71390 Richmond, VA 23255-1390 USA Phone: 1+804-756-7600 Fax: 1+804-756-7643 e-mail: Schrierj@idi-online.com Web: www.infilcodegremont.com	Advanced Wastewater Treatment, Aerators, Aerobic & Anaerobic Treatment, Clarifiers, Digesters, Screens, Stormwater, UV Disinfection
	ITT Flygt Corporation 35 Nutmeg Drive Trumbull, CT 06611-0943 USA Phone: 1+203-380-4700 Fax: 1+203-380-4705 Web: www.flygt.com	Pumps
	Lakeside Equipment Co. P.O. Box 8448 1022 E. Devon Ave. Bartlett, IL 60103 USA Phone: 1+630-837-5640 Fax: 1+630-837-5647 e-mail: sales@lakeside-equipment.com Web: www.lakeside-equipment.com	Advanced Wastewater Treatment, Aerators, Aerobic Treatment, Clarifier Equipment, Screens
	Nefco Inc. 4362 Northlake Blvd., Suite 204 Palm Beach Gardens, FL 33410 USA Phone: 1+561-775-9303 Fax: 1+561-775-6043 e-mail: info@nefcoinc.com Web: www.nefcoinc.com	Clarifier Equipment, Flumes/Weirs
	Ozonia North America 491 Edward H. Ross Drive Elmwood Park, NJ 07407 USA Phone: 1+201-794-3100 Fax: 1+201-794-3358 Web: www.ozonia.com	Ozone Equipment, UV Disinfection
	Pro-Equipment Inc. 237 Wisconsin Avenue Waukesha, WI 53186 USA Phone: 1+262-513-8801 Fax: 1+262-513-8897 e-mail: sales@proequipment.com Web: www.proequipment.com	Advanced Wastewater Treatment, Aerators, Clarifier Equipment, Dewatering Equipment, Diffusers, Mixers, Odor Control, Pumps, Screens, Sludge Thickeners, Stormwater Treatment. Office in Taipei, Taiwan (Sun Climax).

PRODUCT FOR WASTEWATER TREATMENT	SUPPLIER/CONTACT	COMMENTS
Wastewater Treatment Equipment	Purestream, Inc. 10584 Dixie Highway Walton, KY 41094 USA Phone: 1+859-371-9898 Fax: 1+859-371-3577 e-mail: purestream@aol.com Web: www.purestreaminc.com	Advanced Wastewater Treatment Processes, Advanced Oxication Systems, Aerators, Clarifier Equipment, Digesters, Filter Equipment, Sludge Collectors, Lift Station Pumps, Lagoon Equipment, Aerobic Treatment, Anaerobic Treatment, Screens
	RDP Technologies Inc. 2495 Boulevard of the Generals Norristown, PA 19403 USA Phone: 1+610-650-9900 Fax: 1+610-650-9070 e-mail: sales@rdptech.com Web: www.rdptech.com	Biosolids Processing, Composting
	Smith & Loveless Inc. 14040 Santa Fe Trail Dr. Lenexa, KS 66215 USA Phone: 1+913-888-5201 Fax: 1+913-888-2173 Web: www.smithandloveless.com	Advanced Wastewater Treatment, Aerobic Treatment, Clarifier Treatment, Water Recycling/Reuse
	Stormceptor Inc. 712 N. Broadway, Suite 600 Kansas City, MO 64105 USA Phone: 1+800-909-7763 Fax: 1+816-802-3871 Web: www.stormceptor.com	Stormwater Treatment
	StormTreat Systems, Inc. 124 Route 6A Sandwich, MA 02563 USA Phone: 1+877-787-6426 Fax: 1+877-787-6426 e-mail: info@stormtreat.com Web: www.stormtreat.com	Stormwater Treatment
	Stormwater Management 12021-B N.E. Airport Way Portland, OR 97220 USA Phone: 1+800-548-4667 Fax: 1+800-561-1271 Web: www.stormwaterinc.com	Catch Basins, Stormwater Treatment

PRODUCT FOR WASTEWATER TREATMENT	SUPPLIER/CONTACT	COMMENTS
Wastewater Treatment Equipment	Trojan Technologies Inc. 2050 Peabody Road, Suite 200 Vacaville, California 95687 USA Phone: 1+707-469-2680 Fax: 1+707-469-2688 e-mail: trojanca@trojanuv.com Web: www.trojanuv.com	Advanced Wastewater Treatment, UV Disinfection Canadian Based Firm
	USFilter 181 Thornhill Road Warrendale, PA 15086 USA Phone: 1+800-547-1202 Web: www.usfilter.com	Advanced Wastewater Treatment, Filter Products, Screens, Sludge Handling, Stormwater Treatment, UV Disinfection, Water Recycling/Reuse
	US Peroxide 23 Morningwood Drive Laguna Niguel, CA 92677-2859 USA Phone: 1+949-661-6713 Fax: 1+949-661-6649 Web: www.h2o2.com	Corrosion Control, Odor Control
	Vortechnics, Inc. 41 Evergreen Drive Portland, ME 04103 USA Phone: 1+207-878-3662 Fax: 1+207-878-8507 e-mail: vortechnics@vortechnics.com Web: www.vortechnics.com	Stormwater Treatment
	W.E.S. Inc. 6389 Tower Lane Sarasota, FL 34240 USA Phone: 1+941-371-7617 Fax: 1+941-378-5218 e-mail: wesinc@packet.net Web: www.wesinc.com	Aerators, Clarifier Equipment, Odor Control Equipment, Ozone Generators, Screens
	Waste-Tech Inc. 1931 Industrial Drive Libertyville, IL 60048 USA Phone: 1+847-367-5150 Fax: 1+847-367-1787	Centrifuges, Conveyors, Dewatering Equipment, Digesters, Grit Handling Equipment, Screens, Sludge Thickeners, Stormwater Treatment

PRODUCT FOR WASTEWATER TREATMENT	SUPPLIER/CONTACT	COMMENTS
Wastewater Treatment Equipment	WEMCO, A Weir Group Product 740 W. 800 S. P.O. Box 209 Salt Lake City, UT 84110-0209 USA Phone: 1+801-359-8731 Fax: 1+801-355-9303 e-mail: info@wemcopump.com Web: www.wemcopump.com	Pumps
	Westech Engineering Inc. 3625 South West Temple Salt Lake City, UT 84115 USA Phone: 1+801-265-1000 Fax: 1+801-265-1080 e-mail: info@westech-inc.com Web: www.westech-inc.com	Advanced Wastewater Treatment, Aerators, Aerobic Treatment, Clarifier Equipment, Digesters, Grit Handling Equipment, Sludge Equipment
Living Machines	Living Machines, Inc. 125 La Posta Road 8018 NDCBU Taos, NM 87571 USA Phone: 1+ 505-751-4448 Fax: 1+ 505-751-9483 e-mail: info@livingmachines.com Web: www.livingmachines.com	
Fuel Cells	International Fuel Cells 195 Governors Highway P.O. Box 739 South Windsor, CT 06074 USA Phone: 1+ 860-727-2200 Fax: 1+ 860-727-2319 e-mail: ifcinte@ifc.utc.com Web: www.ifc.com	Residential, commercial/industrial, & transportation systems
	H Power Corporation 60 Montgomery Street Belleville, NJ 07109 USA Phone: 1+ 973-450-440 Fax: 1+ 973-450-9850 Web: www.hpower.com	Residential systems
	IdaTech P.O. Box 5339 Bend, OR 97708 USA Phone: 1+ 541-383-3390 Fax: 1+ 541-383-3439 e-mail: info@idatech.com Web: www.idatech.com	Residential systems

PRODUCT FOR WASTEWATER TREATMENT	SUPPLIER/CONTACT	COMMENTS
Fuel Cells	Ballard Power Systems 9000 Glenlyon Parkway Burnaby, BC V5J5J9 Canada Phone: 1+ 604-454-0900 Fax: 1+ 604-412-4700 e-mail: marketing@ballard.com Web: www.ballard.com	Residential, commercial/industrial, & transportation systems
Microturbines	Capstone Turbine Corporation 21211 Nordhoff Street Chatsworth, CA 91311 USA Phone: 1+ 818-734-5300 Fax: 1+ 818-734-5320 Web: www.capstoneturbine.com	
	GE Power Systems 1 River Road/Building 37-6 Schenectady, NY 12345 USA Phone: 1+ 518-385-1300 e-mail: GEDistributedPower@ps.ge.com Web: www.gepower.com/dhtml/distributed_power/en_us/index.jsp	
	Ingersoll-Rand 200 Chestnut Ridge Road Woodcliff Lake, NJ 07675 USA Phone: 1+ 201-573-0123 Fax: 1+ 201-573-3168 e-mail: seekinfo@irco.com Web: www.irco.com/energysystems/powerworks.html	
	Honeywell 101 Columbia Road Morristown, NJ 07962 USA Phone: 1+ 973-455-2000 Fax: 1+ 973-455-4807 Web: www.honeywell.com/en/power/index.jsp	

III. Recommended Service Sources

DESIGN	SERVICE /QUALIFICATIONS	PROVIDER/CONTACT	COMMENTS
	Landscape Architecture	Greenworks 24 NW 2nd Ave., Suite 100 Portland, Oregon 97209 USA Attn: Mike Abbaté	
	Architecture, Interiors, Urban Planning	SERA Architects 123 NW 2nd Ave. Portland, Oregon 97209 USA Attn: John Echlin	Sustainable Design in Architecture, Interiors, Urban Planning, Preservation. Seismic Consultants Sustainability Consultants
	Civil Engineering	Century West Corporation 6650 SW Redwood Lane, Suite 300 Portland, OR 97224 USA Attn: Ned Dempsey	Major infrastructure projects Wastewater treatment Environmental Impact Studies
ASSOCIATIONS/ ORGANIZATIONS			
Living Machines	Ocean Arks International	176 Battery Street Burlington, VT 05401 USA Phone: 1+ 802-860-0011 Fax: 1+ 802-860-0022 e-mail: info@oceanarks.org Web: www.oceanarks.org	Non-profit organization providing information and education on Living Machine Technology
Water & Wastewater Technology	Water Environment Federation	601 Wythe Street Alexandria, VA 22314-1994 USA Phone: 1+ 703-684-2452 Fax: 1+ 703-684-2492 Web: www.wef.org	Non-profit organization providing information and educational materials for water quality professional. On-line Buyer's Guide of equipment suppliers available.
Regulatory Agency	United States Environmental Protection Agency	Web: www.epa.gov	US EPA Website provides information and manuals on various treatment procedures, legislation, and programs.
On-Line Resources	Water and Wastewater.Com	Web: www.waterandwastewater.com	Web site containing information on water and wastewater treatment. Includes buyers guide, industry news, newsletter, publications, etc.
	WaterInfo Center	Web: www.waterinfocenter.com/wic	Web site containing information on water and wastewater treatment. Includes buyers guide, industry news, newsletter, publications, etc.
	WaterWorld	Web: www.pennnet.com/home.cfm	On-line magazine for municipal water and wastewater industry covering pollution, wastewater treatment, products, stormwater management, etc. Site includes product guide and many articles.

Tender Preparations Report

Appendix 3
Chai Tou Gang Shi

November 30, 2001

Prepared by

Team Oregon, LLC

This report was funded by the U. S. Trade and Development Agency (TDA), an export promotion agency of the U. S. Government. The opinions, findings, conclusions or recommendations expressed in this document are those of the author(s) and do not necessarily represent the official position or policies of TDA.

The US Trade and Development Agency
1621 North Kent Street, Suite 200
Arlington, VA 22209-2131 USA

APPENDIX 3

MEMORANDUM

DATE: November 1, 2001

TO: Bob Wise

FROM: Brian Wethington

PROJECT: Team Oregon – Tainan, Chi Tou Gang Shi

RE: Task 6

Team Oregon Task 6 responses:

1. *Review tender documents to best foster competition for bidding for future projects and provide the sound and sustainable products at reasonable prices.*
   Team Oregon visited Tainan on Friday, August 24, 2001. During our visit we had the opportunity to present our report "Conceptual Design Report on Environmental Improvement Projects and Sustainable Development for Tainan City, Taiwan" to Mayor Chang and his staff. After our meeting with the Mayor we met with his staff and some employees of the public works department to discuss the current status of the Chi Tou Gang Shi project. During this meeting we had many fruitful discussions about the project and we reviewed the Request for Proposal (RFP) that was released to the public recently. The document was very general in nature and we discussed more specific requirements, many of which are outlined in the Team Oregon document, "Requirements for Pre-Qualifications for Architects, Landscape Architects, Engineers, and Construction Contractors". We also discussed the status of the latest plan and how our concepts of stormwater management from a sustainable perspective could be integrated with the engineering solutions proposed by Moh and Associates. The public works staff assured us that they would take our plans under advisement during the next phase of design and bid documentation.

2. *Respond to questions by the city and local firm (those under direct contract with the city).*
   Team Oregon responded to both the Mayor's staff and the Public Works staff in regards to the Chi Tou Gang Shi during our August 24,2001 meetings. We will be happy to respond to any further questions from Tainan City, or the firm that eventually wins the contract for the next phase of Chi Tou Gang Shi planning.

3. *Review draft design, review plans/designs, and review other work products.*
   Team Oregon reviewed the April 2000 first draft of the Moh and Associates report on the design scheme for the Chi Tou Gang Shi. This report became the basis for much of our work in an effort to mold their plan into a more sustainable design approach. We also took a larger view, beyond the banks of the Shi, and looked at stormwater management, native habitat restoration, and adjacent economic redevelopment opportunities. The overall plan will be part of the final document to be delivered as part of Task 7. During our August visit we also received a copy of the Final Moh and Associates report, which we have since reviewed.

4. *Assist with the preparation of requirements for pre-qualification.*
   See the Team Oregon document, "Requirements for Pre-Qualifications for Architects, Landscape Architect, Engineers and Construction Contractors".

5. *Notify qualified firms of the upcoming tender (s).*
   We have sent a letter to Mayor Chang outlining a list of both U.S. and local Taiwan firms.

End of Memo

cc: File

Copy

October 24, 2001

Mayor George T. Chang, Ph.D.
City of Tainan, Taiwan
6. Yung-Hwa Rd., Sec 2,
Tainan, Taiwan.

Dear Mayor Chang:

As part of our Task 6, Team Oregon, in cooperation with Tainan City, is required to notify you of qualified firms of the upcoming tender(s) in regards to the Chi Tou Gang Shi project. It is our understanding that the planning efforts for the Chi Tou Gang Shi are moving forward at a rapid pace and we would like to provide you the name and addresses of qualified firms, both local to Taiwan and from the United States, that may be considered for the next phase of the design and construction. Those firms are:

Blossom
Contact: Owen Hsieh
Email: owen419@m1.is.net.tw
Phone: (03)9310961-9310962-9332045
Address
Ilan, Taiwan

E Tech
Contact: Alex Tuan
Email:engitech@ms55.hinet.net
Phone: (02)2321-7465
Address: 17F-1, No 83, Chung-Hsiao E. Road, Sec. 1
Taipei, Taiwan

Complex – Development Management Company
Contact: Albert Y. Chang, President/CEO
Phone: (886-2) 2508-2322 ext. 700
Email: albertc@complex.com.tw
10F, 96 Chien-Kuo N. Rd. Sec 1
Taipei, Taiwan

Moh and Associates
Contact: Kai-yao "Kevin" Chang
Email:cky@ms.maa.com.tw
Phone: (886-2)2696-7888
22FL., No. 112, Hsin Tai Wu Road, Sec. 1
Oriental Technopolises Tower A
Hsichih, Taipei County 221, Taiwan, R.O.C.

CTCI Corporation
Contact: Peter, Shou-Chich Kao
Email: ksc@ctci.com.tw
Phone: (886-2)2700-9659 Ext. 2131
21 Fl., CTCI Corporation, 77, Sec. 2, Tun Hwa South Road
Taipei, 106, Taiwan, R.O.C.

Origin International
Contact: Weija Noble
Email: originwn@ms.13.hinet.net
Phone: 886-2-2708-5018
Address: 65 Hsin-Yi Road, Sec. 4, 6F
City Taipei, Taiwan

Phillip Williams & Associates
Hydrologists & Biologists
Contact: Philip _____
322 NW 5th Avenue, Suite 234
Portland, Oregon 97209
USA

Inter-fluve, Inc.
Hydrologists, Engineers, and Biologists
Contact: Greg Koonce
1020 Wasco Street, Suite 1
Hood River, Oregon 97031
USA

Team Oregon, LLC
Landscape Architecture, Environmental Design, Architecture, Engineering, Public Policy
Contact: Mike Abbaté
Email: mikea@greenworkspc.com
24 NW 2nd Ave., Suite 100
Portland, Oregon 97209
USA

Peratrovich, Nottingham, & Drage, Inc.
Marine Engineers
Contact: David Pierce, PE
Email: dpierce@pndsea.com
811 1st Ave., Suite 260
Seattle, Washington 98104

OBEC Engineering, Inc.
Civil Engineers
Contact: Bill Hall
Email: whh@obec.com
920 Country Club Road, Suite 1008
Eugene, Oregon 97401-2208

We have included many firms from Taiwan because we believe they have the staff and capabilities to be able to complete the Chi Tou Gang Shi plans. The restoration of the Chi Tou Gang Shi is a complex project that requires innovative solutions to the environmental problems and will require the planners have skills in many areas, including an understanding of local codes and regulations, urban design, civil engineering, stream channel and riverbank restoration, riparian habitat restoration, wetland creation, extensive native planting knowledge, and an aesthetic understanding and sensitivity to the local area and its residents. The best solution may be to hire a local Taiwan firm to manage the project assisted by a US firm that specializes in sustainable development and design.

Sincerely,

Mike Abbaté
Principle
GreenWorks, P.C.

II. Recommended Product Sources

Products for the CTGC	Supplier/ Contact	CSI Section	Cost / Unit	Comments
Geotextiles and Erosion Control		02370, 02342		
	Tensar Earth Technologies, Inc. 5884 Glenridge Dr., Suite 200 Atlanta, GA 30328-5363 www.tensarcorp.com			Sierra Slope Retention System; Mesa and ARES Retaining Wall Systems
	Synthetic Industries 355 W Chestnut Street Genesee, ID 83832 www.sind.com			Earthscape series of woven and non-woven environmentally friendly fabrics for weed control, erosion control, synthetic mulches, and seed germination
	Belton Industries P.O. Box 127 1205 Hamby Rd. Belton, SC 29627 www.beltonindustries.com			Erosion and sedimentation control fabrics woven from polypropylene yarns.
	Colbond Geosynthetics P.O. Box 1057, Sand Hill Road Enka, NC 28728 www.colbond-usa.com			Dutch owned parent company (Acordis Group) with manufacturing and distribution facilities in the U.S.
	Amoco Fabrics and Fibers Co. 900 Circle 75 Parkway, Suite 550 Atlanta, GA 30339 www.amoco.com			Manufacturers of a complete line of stabilization and high modulus fabrics and geotextiles.
	North American Green 14649 Highway 41 North Evansville, IN. 47711 www.nagreen.com			Manufacturers of erosion control blankets
	American Excelsior Company P.O. Box 5067 Arlington, TX. 76011 www.amerexcel.com			Manufacturers of Curlex erosion control blankets, fiber mulch and woven and non-woven fabrics.
Outdoor Furnishings		02870		
	Columbia Cascade 1975 S.W. 5th Ave. Portland, OR 97201-5293 www.timberform.com			Outdoor furniture, including benches, bicycle racks, and play equipment.
	Dura Art Stone 11010 Live Oak Fontana, CA 92337 www.duraartstone.com			Manufacturers of architectural precast products in Cast Stone, GFRC and Glascrete. Products include planters, bollards, trash receptacles, treegrates, and benches.
	Landscape Forms, Inc. 431 Lawndale Ave. Kalamazoo, MI 49048 www.landscapeforms.com			Modern design outdoor furniture.
	Urban Accessories P.O. Box 310 20004 144th Ave. N.E. Woodinville, WA. 98072 www.urbanaccessories.net			Cast metal outdoor furniture. Specialize in tree grates, tree guards, and modern styles of trash receptacles, and benches.
Solar Powered Systems				
	Kyocera Solar, Inc. 7812 East Acoma Scottsdale, AZ 85260 www.kyocerasolar.com			Water pumps and lighting systems
	Shurflow Pump Manufacturing Company, Inc. 12650 Westminster Ave.			Water pumps

	Santa Ana, CA 92706 www.shurflow.com			
	Solar Outdoor Lighting, Inc. 3210 S.W. 42nd Avenue Palm City, FL 34990 www.solarlighting.com			Lighting systems
Irrigation		02810		
	Hunter Industries, Inc. 1940 Diamond Street San Marcos, CA. 92069 www.hunterindustries.com			Irrigation products for residential and small commercial applications
	Irritrol Systems www.irritrol.com			Now a division of Toro. They specialize in smaller scale irrigation such as residential and smaller scale commercial applications.
	Rainbird 145 N. Grand Ave. Glendora, CA. 91741-2469 www.rainbird.com			Irrigation products for both typical irrigation applications as well as drip and other low flow applications. Makers of the Maxicom central control system.
	The Toro Company Irrigation Division P.O. Box 489 Riverside, CA 92502 www.toro-1.com/irrigation.htm			Multi faceted company with an irrigation system division. Typically they specialize in golf course irrigation and other large-scale applications.
Paving Materials		02752, 02780		
	Mutual Materials 605 119th Ave. N.E. Bellvue, WA 98005 www.mutualmaterials.com			Unit Pavers and modular retaining wall systems.
	Westcon 1821 Mayes Road SE Olympia, WA 98503-3472 www.westonpavers.com			Concrete unit pavers
	Willamette Greystone 2405 NE 244th Ave. Wood Village, OR 97060 www.willamettegraystone.com			Concrete unit pavers
	Uni-Group U.S.A 4362 Northlake Blvd., Suite 207 Palm Beach, FL 33410 www.uni-groupusa.org/uni-eco-.htm			Uni Eco-Stone is a concrete paver specifically designed for stormwater runoff reduction through infiltration.
Soil Stabalizers		02340		
	Invisible Structures, Inc. 20100 East 35th Drive Aroura, CO. 80011 www.invisiblestructures.com			Products lines for stabilizing soils for loads such as; Fire Truck access,

	Mountain Grout 235 Pigeon Street Waynesville, NC. 28786 www.mountaingrout.com			MG Soil Stabilizer – 30 centipoise single component pre-polymer designed to bind together loose soils topically and below grade. Does not contain solvents or petroleum products and is environmentally safe.
	NDS, Inc. 851 N. Harvard Ave. Lindsay, CA 93247 www.ndspro.com			Grass Pavers – honeycomb cell paver that is backfilled with soil that allows light to heavy vehicular traffic in turf areas.
	Soil Stabilization Products Company, Inc. P.O. Box 2779 Merced, CA 95344-0779 www.sspco.org/roadoyl.html			Road Oyl – High strength, non-petroleum binder for loose soils.
Subsurface Drainage		02622		
	NDS, Inc. 851 N. Harvard Ave. Lindsay, CA 93247 www.ndspro.com			Manufacturer of polyethylene drainage products.
	Advance Drainage Systems, Inc. 3300 Riverside Drive Columbus, OH 43221 www.ads-pipe.com			The world's largest manufacturer of polyethylene drainage produts.
	American Wick Drain Corp. 1209 Airport Road Monroe, NC 28110 www.americanwick.com			Drainage structures for flat surfaces, vertical and retaining walls, and plazas or roof gardens.
Nurseries				
	J. Frank Schmidt & Son Co. 9500 S.E. 327th Ave. Boring, OR 97009 1.503.663.4128 www.jfschmidt.com			A local nursery with a wide variety of plant material.
	Monrovia Nursery 18331 E Foothill Boulevard Azusa, CA 91702-2638 1-800-999-9321 www.monrovia.com			One of the larges nurseries in the U.S.
	Northwest Shade Trees 12973 SE 352nd Ave. Boring, Oregon 97009-70000 1.503.663-3520 www.shadetrees.com			Local nursery specializing in trees.
	Oregon Turf and Tree 18381 Boones Ferry Rd. NE Hubbard, OR 97032 1.800.426.1335 www.oregonturfandtree.com			A large local nursery specializing in turf and trees.
	Teufel Nursery, Inc. 12345 NW Barnes Road Portland, OR 97229 1.503.646.1111 www.teufel.com			One of the largest local nurseries and also has an installation division.

III. Recommended Service Sources

DESIGN	Service / Qualifications	Provider/ Contact	Comments
See references for Tainan Eco-School			
CONSTRUCTION			
Landscape Contractors			
	Cascadian Nurseries, Inc.	Cascadian Nurseries, Inc. 13495 NW Thompson Rd. Portland, OR 97229 1.503.645.3350 www.cascadiannurseries.com	
	Kurisu International, Inc.	Kurisu International, Inc. 11125 SW Barbur Blvd. Portland, OR 97219 503.224.5137 www.kurisu.com	International landscape installation and design capabilities.
	Dennis's Seven Dees	Dennis's Seven Dees 7355 S.E. Johnson Creek Blvd. Portland, OR. 97206 503.777.7777 www.dennis7dees.com	
	Teufel Nursery, Inc.	Teufel Nursery, Inc. 12345 NW Barnes Road Portland, OR 97229 1.503.646.1111 www.teufel.com	
	Valley Crest	Valley Crest 24121 Ventura Boulevard Calabasas, CA 91302 1.818.223.8500 www.valleycrest.com	One of the largest contractors in the U.S.
OPERATIONS & MAINTENANCE			
See references for Tainan Eco-School			
ASSOCIATIONS / ORGANIZATIONS			
	International Erosion Control Association (IECA) P.O. Box 774904 1355 S. Lincoln Ave. Steamboat Springs, CO 80477	www.ieca.org	Source for erosion control standards and practices, as well as industry professionals and certification standards.
	American Nusery and Landscape Association 1250 I Street, NW, Suite 500 Washington, D.C. 20005-3922	www.anla.org	Author of the "American Standard for Nursery Stock" which is the primary reference in the nursery industry for the standardization of plant terminology and standards.
	Oregon Association of Nurserymen 2780 S.E. Harrison, Suite 102 Milwaukie, OR 97222	www.nurseryguide.com	See their website for lists of available wholesale plantings

Tender Preparations Report

Appendix 4
Tainan Ecological School

November 30, 2001

Prepared by

Team Oregon, LLC

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The US Trade and Development Agency
1621 North Kent Street, Suite 200
Arlington, VA 22209-2131 USA

II. Recommended Product Sources

Products for the Eco-School	Supplier/ Contact	CSI Section	Cost (US)/ Unit	Comments
Photo voltaics	See **Operations and Maintenance** section of **Recommended Service Sources**			
Wind Turbines	Southwest Windpower P.O. Box 2190 2131 n. First Street Flagstaff, Arizona 8600-2190 USA Phone:1+520-779-9463 Fax: 1+520-779-1485 e-mail: andy@windenergy.com Web: www.windenergy.com		$845	AIR403 MARINE – corrosion proof for coastal areas. Rotor Diameter: 46" (1.14 meters) Weight: 13 lbs (6 kg) Mount: 1.5" (1.9" O.D.) SCD 40 pipe (47 mm O.D.) Start up wind speed: 6 knots (2.7 m/s) Voltage: 12, 24 and 48 volts (Inquire for others.) Output: 400 watts at 24 knots (12.5 m/s)
	Wind Turbine Industries Corporation 16801 Industrial Circle, SE Prior Lake, Minnesota 55372 USA Phone: 1+612-447-6064 Fax: 1+612-447-6050 e-mail: wtic@windturbine.net Web: www.windturbine.net/		$24,000 to $26,000	Models 23-10 & 26-17.5Rotor Diameter: 23 ft. Diameter Output:10-17.5 Kw output at 25-27 mph Weight: 1900 lbs. 80 ft. Tower Grid Intertie System
	Bergey Windpower Company 2001 Priestley Avenue Norman, Oklahoma 73069 Phone: 1+405-364-4212 Fax: 1+405364-2078 e-mail: sales@bergey.com Web: www.bergey.com			Model: Excel-S Rotor Diameter: 23 ft. Output: 6000 Watts at 24 mph Weight: 1060 lbs. 30 ' Tubular Tilt-up tower design requires guy wires Requires GridTek – 10 to tie with power grid
Low-E Glazing Hurricane Resistant Glazing	Viracon 800 Park Drive Owatonna, MN 55060 USA 1.800.533.2080 www.viracon.com			VE1-85, insulating glass units, 76% visible transmittance, U-value = 0.31 HRG2 – hurricane resistant laminate
	PPG Industries One PPG Place Pittsburgh, PA 15272 1.412.434.3131 www.ppg.com			Sungate 500, insulating glass units, 74% visible transmittance, U-value= 0.35

Fuel Cells	See product references for **Waste Water Treatment Plant**			
Living Machines	See product references for **Waste Water Treatment Plant**			
Products for the Eco-School	Supplier/ Contact	CSI Section	Cost (US)/ Unit	Comments
Certified Woods	Collins Pine Company 1618 SW First Avenue, Suite 300 Portland, Oregon 97201 1.800.329.1219 www.collinswood.com	Division 6		Certified Pine, Fir, Cedar, Hardwoods FSC Certification SCS-COC-00023, Chain-of-Custody SCS-FM-00006, Forest Management
	Endura Wood Products, LLC 1301 SE 6th Avenue Portland OR 97214 USA Attn: Mr. Ed Mays 1.503.233.7090 edm@endurawood.com www.endurawood.com	Division 6		Certified lumber, flooring, decking Plywoods, 100% certified FSC Certification: SW-COC-025, Chain-of-Custody
	Harwood Products P.O. Box 224 Branscomb, Ca 95417 1.707.984.6181 harwood@harwoodp.com www.harwoodp.com	Division 6		Harwood produces FSC certified and non-certified Redwood, Douglas-Fir and Hem-Fir lumber. FSC Certification: SW-COC-013, Chain-of-Custody
	EcoTimber 1020 Heinz Ave. Berkeley, CA, 94710 USA 1.510.549.3000 cael@ecotimber.com www.ecotimber.com	Division 6		Wide variety of certified woods and wood products FSC Certification: SW-COC-07, Chain-of-Custody
Wheat and Straw board	Endura Wood Products, LLC 1301 SE 6th Avenue Portland OR 97214 USA Attn: Mr. Ed Mays 1.503.233.7090 edm@endurawood.com www.endurawood.com	06200		Distributor urea Formaldehyde-free wheatboard
	J.E. Higgins Lumber Company 25653 Gateway Blvd. Tracy CA 95376 USA Attn: Lloyd Peverell peverell@higlum.com 1.209.833.8833 www.higlum.com	06200		Distributor urea Formaldehyde-free wheatboard

Source: Construction Specification Institute (USA) www.csinet.org

Products for the Eco-School	Supplier/ Contact	CSI Section	Cost (US)/ Unit	Comments
	PrimeBoard, Inc. 2441 North 15th Street Wahpeton, ND 58075 USA 1.701.642.1152 sales@primeboard.com	06200		Industrial grade particleboard (highest quality) made from agricultural residue fiber and an emission free binder. Product name: PrimeBoard™ No urea-formaldehyde Also available for high moisture applications
Agricultural Fiber Products	Phenix Biocomposites, LLC P.O. Box 609 Mankato, MN 56002-0609 USA 1.800.324.8187 www.phenixbiocomposites.com	06200		Multiple products from wheat, soy, and sunflower seed hulls
Natural fiber acoustic products	TECTUM Inc. PO Box 3002 Newark, OH 43058 USA 1.888.977.9691 waynec@tectum.com www.tectum.com	09510		Manufacturing cementitious wood fiber acoustical products for over 50 years.
	FABRI-TRAK 11 Russell Avenue South River, New Jersey 08882 USA 1.732.432-5860 info@fabritrak.com www.fabrotrak.com	09840		Manufacturers of Sound Control Board- Semi rigid cotton batting and acoustic panel systems
Recycled steel framing		05400		See North American Steel Framing Alliance information in **II. Recommended Service Sources** for multiple listings of steel framing manufacturers
Low VOC Paints Low biocide Paints	Sherwin – Williams www.sherwin-williams.com	*09900*		Includes specification section and discussion on low odor low VOC paints MSDS information
	Miller Paint Company 317 SE Grand Ave Portland, Oregon 97214 USA 1.800.852.3254 www.millerpaint.com	09900		Low Biocide and low solvent paints MSDS information
	ICI – Dulux Paints 925 Euclid Ave. Cleveland, OH 44115 USA 1.800.984.5444 www.iciduluxpaints.com	09900		VOC & MSDS information

Source: Construction Specification Institute (USA) www.csinet.org

III. Recommended Service Sources

DESIGN	Service / Qualifications	Provider/ Contact	Comments
	Landscape Architecture	Greenworks 24 NW 2nd Ave., Suite 100 Portland, Oregon 97209 USA Attn: Mike Abbaté	
	Architecture, Interiors, Urban Planning	SERA Architects 123 NW 2nd Ave. Portland, Oregon 97209 USA Attn: John Echlin	Sustainable Design in Architecture, Interiors, Urban Planning, Preservation. Seismic Consultants Sustainability Consultants
	Civil Engineering	Century West Corporation 6650 SW Redwood Lane, Suite 300 Portland, OR 97224 USA Attn: Ned Dempsey	Major infrastructure projects Waste water treatment Environmental Impact Studies
	Structural Engineering		
	Mechanical / Electrical Engineering	Ove Arup Associates	Large commercial, infrastructure, and public works
		PAE Consulting Engineers 808 SW Third Ave, Suite 300 Portland, Oregon 97204 USA 1.503.226.2921 Attn: Paul Schwer pauls@paemail.com	Appropriate technologies, alternative energy systems
		Keen Engineering Inc. 1932 First Avenue, Suite 307 Seattle, WA 98101 USA Attn: Paul Anseeuw, Principal 1.206.770.7779	Double glazed wall systems, natural ventilation
CONSTRUCTION			
	Turner Construction	Turner Construction Company 830 Fourth Avenue, South, Suite 400 Seattle, WA 98134-1301 USA 1.206.505.6601 Attn: James Goldman jgoldman@tcco.com www.turnernw.com	Member US Green Building Council

Source: Construction Specification Institute (USA) www.csinet.org

	Baugh Construction	2555 SW 153rd Drive Beaverton, OR 97006 503-641-2500 Attn: Ken Mersereau kmersereau@baughpdx.com www.baughent.com	Member US Green Building Council ISO 14001 certification
OPERATIONS & MAINTENANCE			
	Building Controls	Johnson Controls Inc. www.johnsoncontrols.com/cg/	
		Honeywell 101 Columbia Road Morristown, NJ 07962 USA 1.973.455.2000	
		Siemens Building Technologies, Inc. 1000 Deerfield Parkway Buffalo Grove, IL 60089 USA 1.847.215.1000 webmaster@sbt.siemens.com	
	Cleaning Products	Rochester Midland Corporation 333 Hollenbeck Street PO Box 31515 Rochester, NY 14603-1515 USA www.rochestermidland.com	Enviro Care Product Line Environmentally safe cleaning products for all types of building materials
		NEX Systems 235 Frank West Circle Stockton, CA 95206 1.800.982.0602 www.nexsystems.com	Natural extract cleaner for textiles, fabrics and carpet
	Photo voltaics	Schott Applied Power 1210 Homann Drive SE Lacey, WA 98503 USA 1.800.777.7075 Attn: Douglas Broach Dbroach@appliedpower.com www.appliedpower.com	Over 20 years experience supplying and installing P-V systems worldwide. Siemens Solar Panels
		Lightwave Solar No 320 2Sec Chongder Rd. Taizhong Attn: Liao Tai tyl8lsp8@ms27.hinet.net www.siemenssolar.com	Turnkey P-V systems for residential and commercial, varying in size from 4KW to 100KW Siemens Solar Panels

Source: Construction Specification Institute (USA) www.csinet.org

	Solar Energy Consulting	Cascadia Solar Consulting, LLC 17610 Springhill Place Gladstone, OR 97207 1.503.655.1617 cascadiasolar@home.com	Design of Solar panel systems and Photo-voltaic power systems
ASSOCIATIONS / ORGANIZATIONS			
Wood and Forestry	Certified Wood Products	Certified Forest Products Council 14780 SW Osprey, suite 285 Beaverton, Or. 97007-8424 USA Attn: Jeff Wartelle www.certifiedwood.org	Includes searchable listings for certified wood products and suppliers
	International Forestry Standards	Forest Stewardship Council (FSC)	
	Evaluation and Certification of FSC standards	Smart Wood 61 Millet Street Richmond, VT 05477 1.802.435.5491	
Green Building Standards	U.S. Green Building Council	1015 18th Street, NW, Suite 805 Washington, D.C. 20036 USA Attn: Donna McIntire, LEED™ Program Director 1.202.828.7422 www.usgbc.org	Leadership in Energy and Environmental Design Green Building Rating System (LEED)
Recycled Materials	Steel Recycling Institute	680 Andersen Drive Pittsburgh PA 15220-2700 USA Attn: Greg Crawford Craw67ford@aol.com 800.876.7274 www.recycle-steel.org	SRI is a unit of the American Iron and Steel Institute, is an industry association that promotes and sustains the recycling of all steel products
	North American Steel Framing Alliance	www.steelframingalliance.com/	The North American Steel Framing Alliance (NASFA) is an organization that was established by the American Iron and Steel Institute in 1998 to rapidly accelerate the use of light gauge steel framing in residential construction.

Source: Construction Specification Institute (USA) www.csinet.org

Fly Ash Concrete

ISG Resources, Inc.
Morris (Skip) Huffman
P.O. Box 70
Oregon City, OR 97045-0070
Phone: (503) 657-5159
Fax: (503) 657-5087
email: isgskip@earthlink.net

Wood Framing, Sheathing, Finished Carpentry
FSC Certified by SCS, Natural Step Company

The Collins Company
1618 SW First Avenue, Suite 500
Portland, OR 97201-5708
Phone: (503) 417-7755
Fax: (503) 417-1441
sales@collinsco.com
http://www.CollinsWood.com

Recycled, reclaimed, and salvaged wood

Endura Wood Products, LLC
524 SE Main Street
Portland, OR 97214
Phone: (503) 233-7090

Lumber Products
19855 SW 124th Avenue
Tualatin, OR 97062
Phone: (503) 692-3322
Fax: (800) 926-7103

Straw paneling Products

Isobord Enterprises, Inc.
Sales and Marketing Office
1300 SW Fifth Ave., Suite 3030
Portland, OR 97201
Phone: (503) 242-7345
Fax: (503) 721-0940
www.isoboard.com

Composite board – formaldehyde free – FSC Certified
SierraPine Medex, Medite II, Medite FR

Architectural Woods, Inc.
Fax: (253) 627-7546
SierraPine Limited
Phone: (800) 676-3339
www.sierrapine.com

Flooring
Millwork from FSC Certified forest. Second growth firs, redwood, Giant Sequoia, and Western Red Cedar

Cascadia Forest Goods, LLC
2844 Adams Street
Eugene, OR 97405
Phone/Fax: (541) 485-4477
email: cfg@teleport.com
www.uidaho.edu/~witt731/cfg.html

Finished Carpentry

Columbia Trading Company
0547 SW Gaines Street
Portland, OR 97201
Phone: (503) 279-8165
Fax: (503) 279-8793
email: ecofloor@teleport.com

Hardwood Plywood – FSC Certified Cores

Columbia Forest Products
222 SW Columbia, Suite 1575
Portland, OR 97201
Phone: (800) 547-1791
www.ColumbiaForestProducts.com

Wood Ceilings

Pacific Wood Systems, Inc.
32928 Roberts Court
Coburg, OR 97408
Phone: (541) 342-7662
Fax: (541) 342-4716
pws@pacificwoodsystems.com

Strip Flooring
Second growth, Smart Wood program

Green Mountain Woodworks
500 A Street, Suite 2
Ashland, OR 97520
Phone: (541) 482-6031
Fax: (541) 482-8581
email: mstella@mind.net

Finishes – Paint, sealers, stains

Timber –Tek UV
Enviro-Safe Finishes
2232 E Burnside
Portland, OR 97214
Phone: (503) 232-1705
Fax: (503) 235-8794

Cabinets with wheatboard

Neil Kelly
804 N. Alberta
Portland, OR 97217
Phone: (503) 288-NEIL
Fax: (503) 282-7932
email: kathleen@neilkelly.com
rick@neilkelly.com
www.neilkelly.com

RB Rubber Products

RB Rubber Products, Inc.
904 East 10th Avenue
McMinnville, OR 97128
Phone: (503) 472-4691
Fax: (503) 434-4455
ag@rbrubber.com

SECTION 09900 - PAINTING

PART 1 - GENERAL

1.01 ENVIRONMENTAL CONSIDERATIONS

A. Qualities:

1. Protects and preserves materials (conserves resources).
2. Can provide light-colored surfaces that help reduce the need for electrical lighting.

B. Problems:

1. Volatile organic compounds (VOC's) (contributes to indoor air quality problems and photochemical smog).
2. Pigments may contain toxic heavy metals such as titanium and chromium.
3. Additives may include fungicides and bactericides (contributes to indoor air quality problems).

C. Recommendations:

1. Select low-VOC products (improves indoor air quality).
2. Select durable products (conserves resources).
3. Select least toxic alternative (improves indoor air quality, reduces pollution).
4. Select recycled-content product - see 1.03 below (conserves resources).
5. Select products made from natural, renewable resources (conserves limited resources).

1.02 SUBMITTALS

A. Product Data: Submit a complete list of paint materials proposed for use, together with manufacturer's technical information, including paint label analysis and application instructions.

1.03 INDOOR AIR QUALITY (IAQ)

A. Test proposed products (including recycled paint) with individuals with chemical sensitivities before application.

B. Removing or reducing odor does not necessarily reduce toxins and may only serve to reduce natural warning systems to toxins.

C. Plant-based paint products are not necessarily better for IAQ. Test on individuals with chemical sensitivities before installation.

Source: Construction Specification Institute (USA) www.csinet.org

1.04 ENVIRONMENTAL QUALITY ASSURANCE

A. Paint shall comply, at a minimum, with the regulations of the California Air Resources Board for the Bay Area.

PART 2 - PRODUCTS

2.01 MATERIALS **[EDIT TO SUIT PROJECT]**

A. Waterborne Latex Emulsion Paint: Shall not be formulated or manufactured with formaldehyde, halogenated solvents, aromatic hydrocarbons, mercury, or mercury compounds, or tinted with pigments of lead, cadmium, chromium VI, and their oxides

1. Zero-VOC paint: Flat and eggshell, VOC content less than 10 g/l
2. Low-VOC paint: Semi-gloss and gloss, VOC content less than 100 g/l

B. Oil-Based Paint: Low-VOC paint; VOC content shall not exceed 380 g/l. Shall not contain halogenated solvents. Shall not be formulated or manufactured with formaldehyde, mercury, or mercury compounds, or tinted with pigments of lead, cadmium, chromium VI, and their oxides. Shall not be formulated or manufactured with aromatic hydrocarbons in excess of 10%. For increased resistance to yellowing, specify high quality, soya-based oil paints.

C. Recycled Latex Paint: Minimum 90% post-consumer recycled content (50% for whites), VOC content unknown, available in pastel colors only

D. Low-Biocide Paint: Interior use. Shall not contain formaldehyde. Shall not contain fungicides or bactericides that are classified as mercury acetates, phenol phenates, or phenol formaldehyde. **[Reduced shelf life. Paints are made to order; lead-time may be 1 to 2 months.]**

E. Natural Plant- and Mineral-Based Finishes: Contain extracts from plant sources and minimally processed earth minerals, such as chalk or iron oxides. Solvents include citrus oils and small amounts of low-odor petroleum solvents (de-aromaticized isoparaffinics.) Contains natural VOC's; test paint with chemically sensitive individuals prior to installation.

F. Milk-Based Paint: Contains lime, milk protein, clay, and earth pigments. Interior use only; not suitable for damp conditions. **[Most common paint prior to this century]**

G. Epoxy: Waterborne epoxy, durable finish suitable for floor, VOC content less than 200 g/l

H. Urethane finishes: Water emulsion urethane

I. Penetrating oil finishes: Interior use only. Shall not contain lead acetate or cobalt manganese (drying agents).

J. Stain: Vegetable oil-based, waterborne stain for exterior use with UV Protection

Source: Construction Specification Institute (USA) www.csinet.org

K. Paint Strippers - Low-Emitting: Shall not contain methylene chloride (illegal). Avoid products containing methanol and trichloroethane.

L. Clay- and Mineral-Based Pigments:

1. Native earths: Ochre, raw umber, raw sienna
2. Calcined earths: Burnt umber, burnt sienna
3. Iron oxides: Mars black, Mars yellow, Mars Violet

M. Conventional Pigments: Pigments used in conventional paints contain the following toxic compounds: **[Their use should be avoided. If used, avoid heavily pigmented paints.]**

1. White: Antimony oxide, rutile titanium dioxide
2. Yellow-orange-red: Cadmium, cadmium lithopone, chrome yellow, molybdate orange, strontium chromate, zinc chromate
3. Blue: Phthalocyanine blue
4. Green: Chrome green, chromium oxide, hydrated chromium oxide, phthalocyanine green

N. Biocides: Specify levels below 0.025%.

PART 3 - EXECUTION

3.01 EXAMINATION AND PREPARATION

A. Test old paint for lead before sanding, scraping, or removing. If lead is present, conform to procedures applicable when hazardous or contaminated materials are discovered.

B. Verify that substrates are completely dry, free of harmful substances, and in satisfactory condition to receive painting materials.

C. Conform to procedures applicable when hazardous or contaminated materials are discovered.

D. Select formaldehyde-free substrate such as Medex particleboard or exterior grade plywood.

E. Extinguish pilot lights before painting with any paint.

3.02 APPLICATION **[EDIT TO SUIT PROJECT]**

A. Water-Based Latex paint - Low-VOC: Comply with manufacturer's recommendations for application; may be applied by brush, roller, or sprayer.

B. Oil-Based Paint - Low-VOC: Comply with manufacturer's recommendations for application; sand lightly between coats and apply by brush or roller.

C. Recycled Latex Paint: Comply with manufacturer's recommendations for application; may be applied by brush, roller, or sprayer.

Source: Construction Specification Institute (USA) www.csinet.org

D Low-Biocide Paint: Because of reduced shelf life, these products should be carefully evaluated for spoilage before applying at the job site. Comply with manufacturer's recommendations for application; may be applied by brush, roller, or sprayer.

E. Natural Plant- and Mineral-Based Finishes: These products do not necessarily perform or behave the same as conventional paints. They may require more coats or longer drying time. Comply with manufacturer's recommendations for application.

F. Milk-Based Paint (Casein): Available in powdered form. Add water and stir well. Transparency may be controlled by the amount of water added. In powder form it has an indefinite shelf life. May be applied by brush, roller, or sprayer. Do not use beyond expiration date for shelf life.

G. Urethanes - Water Emulsion: May be applied by brush, roller, or sprayer. Sand between coats; raises grain significantly.

H. Penetrating Oil Finishes: Apply three coats, one per day with a brush or cloth. Allow to set, wipe dry, and buff. Comply with manufacturer's recommendations for application. Do not apply when temperature is below 65°F.

I. Paint Strippers - Low-Emitting: Paint strippers that do not contain methylene chloride tend to be slower acting than conventional paint strippers and may take from one hour to overnight to work. Comply with manufacturer's recommendations for application. Use appropriate protection: impermeable gloves, respirators, goggles.

J Heat Guns: Danger of fire, volatilizes chemicals; never use with lead-based paints.

3.03 INDOOR AIR QUALITY

A. Applicators shall wear protective clothing and respirators when applying oil-based paints or using spray equipment with any paints.

B. Maximize ventilation during application and drying.

C. Isolate area of application from rest of building.

D. Vacate space for as long as possible after application. Wait a minimum of 48 hours before occupying freshly painted rooms.

3.04 WASTE MANAGEMENT

A. Separate waste in accordance with the Waste Management Plan. Set aside extra paint for future color matches, or reuse by Owner, Habitat for Humanity, etc. Where paint recycling is available, collect all waste paint by type and provide for delivery to recycling or collection facility.

B. Close and seal tightly all partly used paint and finish containers and store protected in well-ventilated, fire-safe area at moderate temperature.

Source: Construction Specification Institute (USA) www.csinet.org

C. Place empty containers of solvent-based paints in areas designated for hazardous materials.

D. Do not dispose of paints or solvents by pouring on the ground. Place in designated containers for proper disposal.

END OF SECTION 09900

Source: Construction Specification Institute (USA) www.csinet.org

SECTION 07900 - SEALANTS

PART 1 - GENERAL

1.01 ENVIRONMENTAL CONSIDERATIONS

A. Qualities:

1. Reduces air infiltration (improves thermal performance of building)
2. Seals against moisture (extends life of material being protected)
3. Allows for movement (extends life of material)

B. Problems:

1. Some sealants contribute to indoor air quality problems.
2. Most sealants contribute to pollution during manufacturing.
3. Sealants fail.

C. Recommendations:

1. Limit use of sealants through proper detailing. Do not rely on sealants only; use mechanical methods to protect joints.
2. Avoid use of sealants indoors that may contribute to indoor air quality problems.

1.02 CHEMICAL SENSITIVITY

A. Test proposed products with occupants with known chemical sensitivities before installation.

1.03 ENVIRONMENTAL QUALITY ASSURANCE

A. Do not use products containing methylene chloride or chlorinated hydrocarbons.

B. Avoid products containing bactericides and fungicides that are classified as phenol mercury acetates, phenol phenates, or phenol formaldehyde.

C. Avoid products containing aromatic and aliphatic solvents.

D. Avoid products containing styrene butadiene.

1.04 INDOOR AIR QUALITY

A. The following sealants are considered safe for indoor use:

1. Oleoresinous (small amounts of aliphatic hydrocarbons)
2. Acrylic emulsion latex (water-based)
3. Polysulfide (small amounts of toluene vapors)

Source: Construction Specification Institute (USA) www.csinet.org

4. Polyurethane (small amounts of xylene and other solvents)
5. Silicone (small amounts of xylene and other solvents)

B. The use of the following sealants should be avoided indoors:

1. Butyl rubber (aliphatic hydrocarbons)
2. Solvent-based acrylic (xylene)
3. Neoprene (xylene)
4. Styrene butadiene rubber (various VOC's: hexane, toluene, and xylene, depending on type)
5. Nitrile (various VOC's: hexane, toluene, and xylene, depending on type)

PART 2 - PRODUCTS [EDIT TO SUIT PROJECT]

2.01 SEALANT MATERIALS

A. Exterior general use: Single-component polyurethane conforming to ASTM C 920, Type S, Class 25, Grade NS

B. Exterior concealed joints and under thresholds: One-part butyl rubber caulk conforming to FS TT-S-001657, Type I

C. Exterior concealed joints between two assembled rigid surfaces in compression: Polyisobutylene sealant tape conforming to AAMA 804.1

D. Exterior and interior horizontal joints subject to pedestrian traffic: Two-part polyurethane conforming to ASTM C 920, Class 25, Type M, self-leveling

E. Interior non-wet areas: One-component acrylic latex water-based sealant conforming to ASTM C 834

F. Interior wet areas: One-part mildew-resistant silicone rubber conforming to ASTM C 920, Type S, Class 25, Grade NS

G. Sealant backer rod: Compressible rod-stock polyethylene foam, polyethylene-jacketed polyurethane foam, butyl-rubber foam, neoprene foam, or other flexible, permanent, durable, non-absorptive material as recommended for compatibility with sealant by sealant manufacturer

H. Joint cleaner, primer, and bond breaker: As recommended by sealant manufacturer

I. Fiber expansion joint material: Preformed, cellular fiber complying with ASTM D 1751

J. Acoustical sealant: Non-skinning, non-hardening, permanently flexible sealant specifically designed for sealing gypsum wallboard

K. Electrical box sealant: Sheet caulking

Source: Construction Specification Institute (USA) www.csinet.org

L. Tamp-in sealants:

1. Oakum
2. Caulking cord: Fine fiber yarn saturated with wax., contains linseed oil and talcum

M. Low-toxic caulk

N. Additional sealant materials: As specified in the respective Specification Sections

PART 3 - EXECUTION

3.01 INSTALLATION

A. Minimize use of sealants, caulks, and adhesives through proper detailing, including adequate overhangs and eaves, flashing, and proper lapping of building paper and trim.

B. Use oakum to seal around penetrations where feasible.

C. Use dry adhesive sealant tape instead of wet sealants where feasible.

3.02 WASTE MANAGEMENT

A. Separate waste in accordance with the Waste Management Plan.

B. Close and seal tightly all partly used sealant containers and store protected in well-ventilated fire-safe area at moderate temperature.

C. Place used sealant tubes and containers in areas designated for hazardous materials.

END OF SECTION 07900

Source: Construction Specification Institute (USA) www.csinet.org

SECTION 03200 - CONCRETE REINFORCEMENT
SECTION 03300 - CAST-IN-PLACE CONCRETE

PART 1 - GENERAL

1.01 ENVIRONMENTAL CONSIDERATIONS

A. Qualities:

1. Durable: moisture- and insect-resistant (conserves resources, low-maintenance).
2. Thermal mass (conserves energy).

B. Problems:

1. Production of Portland cement is energy-intensive, and emissions contribute significant amounts of carbon dioxide to the atmosphere.
2. Mining of gravel can cause local pollution and damage to natural habitats.

C. Recommendations:

1. Replace >25% of Portland cement with fly ash (conserves energy, reduces emissions, diverts waste material from landfill, increases long-term durability).
2. Use recycled sub-base and aggregate (minimizes mining of gravel, diverts waste material from landfill).
3. Use less concrete by utilizing efficient section, e.g., waffle forms for deck slabs.
4. Reduce the amount of cement needed by specifying longer set times and allowing 56 days, rather than 28, to reach minimum strength.

1.02 RELATED SECTIONS

A. Section 03100 - Concrete Formwork

1.03 CODES AND STANDARDS

A. Comply with applicable requirements of the Uniform Building Code, Chapter 26, and the following: ACI 301-89, 302.1R-89, and 318-89.

1.04 SUBMITTALS

A. Mix design for review by Structural Engineer

B. Test reports for recycled aggregate

C. Test results for any non-standard mix

Source: Construction Specification Institute (USA) www.csinet.org

D. Supplier shall certify that no hazardous waste is used in the cement kiln fuel mix or raw materials. **[OR:]** Supplier shall certify that the hazardous waste is neutralized by the manufacturing process.

1.05 QUALITY ASSURANCE

A. Structural Engineer: Review mix designs, certificates of compliance, and test reports for recycled aggregate.

PART 2 - PRODUCTS

2.01 CONCRETE

A. Strength: As specified by Structural Engineer. Minimum compressive strength in psi after 28 days or as specified by Structural Engineer, when tested in accordance with ASTM C 39. Note: Concrete containing less cement, with or without coal fly ash, may take longer than 28 days to reach minimum specified compressive strength.

2.02 MATERIALS

A. Cements: ASTM C150, Type I, II, or III as specified. Use one brand of cement throughout Project. Portland cement has an embodied energy of 2,401 to 4,060 Btus/lb.

B. Mineral Admixtures: **[EDIT TO SUIT PROJECT]**

1. Coal fly ash: ASTM C 618. [Can replace up to 50% of Portland cement by weight: Subject to requirements of mix design, approval by Structural Engineer, results of tests with actual materials to be used, and applicable codes.]

   a. Class F: Alkaline reducing, resistant to sulfate attack.
   b. Class C: Can be used with very little Portland cement.

2. Blast furnace slag: ASTM C 989
3. Silica fume: Used to reduce permeability and increase strength
4. Rice hull ash: Behaves similar to silica fume

C. Aggregates: Shall conform to ASTM C 33, except local aggregates of proven durability may be used when acceptable to Structural Engineer. **[EDIT TO SUIT PROJECT]**

1. Recycled, crushed concrete aggregate subject to approval by Structural Engineer.
2. Lightweight structural aggregate: 45% sludge, fly ash clay; 40% municipal waste; 15% moisture, liquid waste

D. Water: Clean and potable, free from impurities detrimental to concrete

E. Admixtures: **[EDIT TO SUIT PROJECT]**

1. Water reducing/retarding: ASTM C 494 Type A and D and not containing more chloride ions than allowed in municipal drinking water. Cement content may be reduced through use of a water reducer.
2. Air Entraining: ASTM C 260
3. Coloring: ASTM C 494. Extracts from plant sources and minimally processed earth minerals, such as chalk or iron oxides. Solvents may include citrus oils and small amounts of low odor petroleum solvents (de-aromaticized isoparaffinics). Clay- or mineral-based pigments include:

   a. Native earths: Ochre, raw umber
   b. Calcined earths: Burnt umber, burnt sienna
   c. Iron oxides
   d. Avoid artificially prepared mineral colors.

F. Synthetic Fibers: Monofilament polypropylene fibers for secondary reinforcing of concrete members. Recycled content preferred. Product shall have a UL rating.

G. Reinforcement:

1. Bars: Deformed steel, ASTM C150, Type 1
2. Mesh: Welded steel wire fabric, ASTM C 33

2.03 RELATED MATERIALS

A. Form Release Agents:

1. Form release agents shall be delivered in manufacturer's sealed and trademarked containers and shall be guaranteed to provide clean, stain-free concrete release and not to interfere with future-applied coatings and finishes.
2. Form release agents: Vegetable-based form release only. Do not use petroleum solvents such as creosote or diesel oil. Paraffin and waxes shall not be used when a concrete finish is required.

B. Sub-base Material: Crushed concrete or masonry materials meeting the requirements of the Structural Engineer

C. Sealers:

1. Water emulsion acrylic
2. Sodium silicate
3. Penetrating sealer: Low-VOC

D. Foundation Vents: 100% post-consumer plastic

Source: Construction Specification Institute (USA) www.csinet.org

PART 3 - EXECUTION

3.01 INSTALLATION

A. High-Volume Fly Ash Concrete:

1. Concrete mixes containing high-volume fly ash generally take longer to reach full strength. Specify 56-day strength compliance instead of 28-day strength.
2. Keep total water content very low.
3. Provide protection against drying during curing.
4. Avoid installing in cold conditions.
5. Slabs are more difficult to finish due to less bleed water.
6. In freeze-thaw conditions, increase air-entraining admixture for fly ash with high carbon content.

3.02 WASTE MANAGEMENT

A. Before concrete pours, designate locations or uses for excess concrete. Options include: **[EDIT TO SUIT PROJECT]**

1. Additional paving
2. Post footing anchorage
3. Swale, rip-rap reinforcing
4. Flowable fill
5. Footing bottom, retaining wall footing ballast
6. Storm structure covers
7. Underground utility pipe kickers
8. Storm pipe flared end section
9. Toe wash protection, and shoulder and toe outfall restraints for temporary erosion pipes

B. Before concrete pours, designate a location for cleaning out concrete trucks. Options include:

1. Company-owned site for that purpose (meeting environmental standards)
2. On-site area to be paved later in Project

C. Collect reinforcing steel and place in designated area for recycling.

D. See Section 03100 - Concrete Formwork, 3.01 - Waste Management.

END OF SECTION 03200 / 03300

Source: Construction Specification Institute (USA) www.csinet.org

SECTION 01505 - CONSTRUCTION WASTE MANAGEMENT

PART 1 - GENERAL

1.01 WASTE MANAGEMENT GOALS FOR THE PROJECT

A. The Owner has established that this Project shall minimize the creation of construction and demolition waste on the job site. Factors that contribute to waste, such as over packaging, improper storage, ordering error, poor planning, breakage, mishandling, and contamination, shall be minimized. Of the inevitable waste that is generated, as many of the waste materials as economically feasible shall be reused, salvaged, or recycled. Waste disposal in landfills shall be minimized.

B. Diversion Goals: A minimum _____% **[70% suggested]** of total Project waste shall be diverted from landfill. The following waste categories, at a minimum, shall be diverted from landfill: **[EDIT TO SUIT PROJECT]**

1. Land-clearing debris
2. Clean dimensional wood, pallet wood
3. Plywood, OSB, and particleboard
4. Concrete
5. Bricks
6. Concrete Masonry Units (CMU)
7. Asphaltic concrete
8. Cardboard, paper, packaging
9. Asphalt roofing shingles
10. Metals
11. Gypsum drywall (unpainted)
12. Paint
13. Glass
14. Plastics
15. Carpet and pad
16. Beverage containers

1.02 RELATED SECTIONS

A. Section 02050 - Demolition/Dismantling/Salvage

1.03 REFERENCES, RESOURCES

A. *WasteSpec*, Triangle J Council of Governments, PO Box 12276, Research Triangle Park, NC 27709

B. California Integrated Waste Management Board, 916/255-2296, e-mail: opa@ciwmb.ca.gov

Source: Construction Specification Institute (USA) www.csinet.org

1.04 WASTE MANAGEMENT PLAN

A. Within 10 calendar days after receipt of Notice of Award of Bid, or prior to any waste removal, whichever occurs sooner, the Contractor shall submit to the Owner and Architect a Waste Management Plan. The Plan shall contain the following: **[EDIT TO SUIT PROJECT]**

1. Estimate of total Project waste to be generated, name of the landfill(s) where Project waste would normally be disposed of, tipping fees, and estimated cost of disposing of Project waste in landfill(s)

2. Estimate of total tons of the following waste category to be diverted from landfill: **[EDIT TO SUIT PROJECT]**

   a. Concrete
   b. Asphaltic Concrete
   c. Brick
   d. Other

3. Estimate of total cubic yards of the following waste categories to be diverted from landfill: **[EDIT TO SUIT PROJECT]**

   a. Clean dimensional wood, pallet wood
   b. Plywood, OSB, and particleboard
   c. Cardboard, paper, packaging
   d. Other

4. Estimate of amounts (weight, feet, square yards, gallons, etc.) of the following waste categories: **[EDIT TO SUIT PROJECT]**

   a. Metals
   b. Carpet
   c. Paint
   d. Other

5. Estimate of net cost savings or additional costs resulting from separating and recycling (versus landfilling) each material. "Net" means that the following have been subtracted from the cost of separating and recycling:

   a. Revenue from the sale of recycled or salvaged materials
   b. Landfill tipping fees saved due to diversion of materials from the landfill

1.05 WASTE MANAGEMENT PLAN IMPLEMENTATION **[EDIT TO SUIT PROJECT]**

A. Plan Distribution: The Contractor shall provide copies of the Waste Management Plan to the Job-Site Foreman, each Subcontractor, the Owner, and the Architect.

B. Instruction: The Contractor shall provide on-site instruction of appropriate separation, handling, and recycling, salvage, reuse, and return methods to be used by all parties at the appropriate stages of the Project.

C. Meetings: Contractor shall conduct Construction Waste Management meetings. Meetings shall include subcontractors affected by the Waste Management Plan. At a minimum, waste management goals and issues shall be discussed at the following meetings:

1. Pre-bid meetings
2. Pre-construction meeting
3. Regularly scheduled job-site meetings

D. Separation Facilities: The Contractor shall designate a specific area or areas to facilitate separation of materials for potential reuse, salvage, recycling, and return. Recycling and waste bin areas are to be kept neat and clean and clearly marked in order to avoid commingling of materials. Bins shall be protected during non-working hours from off-site contamination.

E. Materials Handling Procedures: Materials to be recycled shall be protected from contamination and shall be handled, stored, and transported in a manner that meets the requirements set by the designated facilities for acceptance.

F. Transportation: A description of the means of transportation of the recyclable materials (whether materials will be site-separated and self-hauled to designated centers, or whether mixed materials will be collected by a waste hauler and removed from the site) and destination of materials. Provide an estimate of how often bins will need to be emptied.

G. Hazardous Wastes: Hazardous wastes shall be separated, stored, and disposed of according to local regulations.

H. Application for Progress Payments: The Contractor shall submit with each Application for Progress Payment a Summary of the Project waste generated. Failure to submit this information shall render the Application for Payment incomplete and shall delay Progress Payment. The Summary shall contain the following information:

1. The amount (in tons or cubic yards) of material landfilled from the Project, the identity of the landfill, the total amount of tipping fees paid at the landfill, and the total disposal cost. Include manifests, weight tickets, receipt, and invoices.
2. For each material recycled, reused, or salvaged from the Project, include the amount (in tons or cubic yards, pounds, feet, square yards, gallons, etc.), the date removed from the job site, the receiving party, the transportation cost, the amount of any money paid or received for the recycled or salvaged material, and the net total cost or savings of salvage or recycling each material. Attach manifests, weight tickets, receipts, and/or invoices.

END OF SECTION 01505

Source: Construction Specification Institute (USA) www.csinet.org

EXCERPTS FROM:

ENVIRONMENTAL PROTECTION AGENCY 40 CFR Part 51 [FRL-5880-9] RIN 2060-AG70 Air Quality: Revision to Definition of Volatile Organic Compounds--Exclusion of 16 Compounds

II. Comments on the Proposal and EPA Response The EPA received written comments on the proposal from four organizations. The comments were from the petitioner and three manufacturing companies. All four comment letters supported the exclusion of the 16 compounds as VOC. Copies of these comments have been added to the docket (A-96-36) for this action. In the proposal for today's action, EPA indicated that interested persons could request that EPA hold a public hearing on the proposed action (see section 307(d)(5)(ii) of the Act). During the comment period, no one requested a public hearing so none was held. Based on the information presented in the proposal notice and on the comments received during the public comment period, *EPA has decided to list the compounds in Table 2 as negligibly reactive.*

Table 2.--Compounds Added to the List of Negligibly Reactive Compounds

Compound	Chemical name
HFC-32.....	difluoromethane.
HFC-161.....	ethylfluoride.
HFC-236fa.....	1,1,1,3,3,3-hexafluoropropane.
HFC-245ca.....	1,1,2,2,3-pentafluoropropane.
HFC-245ea.....	1,1,2,3,3-pentafluoropropane.
HFC-245eb.....	1,1,1,2,3-pentafluoropropane.
HFC-245fa.....	1,1,1,3,3-pentafluoropropane.
HFC-236ea.....	1,1,1,2,3,3-hexafluoropropane.
HFC-365mfc.....	1,1,1,3,3-pentafluorobutane.
HCFC-31.....	chlorofluoromethane.
HCFC-123a.....	1,2-dichloro-1,1,2-trifluoroethane.
HCFC-151a.....	1-chloro-1-fluoroethane.
C4F9OCH3.....	1,1,1,2,2,3,3,4,4-nonafluoro-4- methoxybutane.
(CF3)2CFCF2OCH3.....	.2-(difluoromethoxymethyl)-1,1,1,2,3,3,3- heptafluoropropane.
C4F9OC2H5.....	1-ethoxy-1,1,2,2,3,3,4,4,4- nonafluorobutane. [[Page 44902]]
(CF3)2CFCF2OC2H5.....	2-(ethoxydifluoromethyl)-1,1,1,2,3,3,3- heptafluoropropane.

Table 3 gives Chemical Abstract Service (CAS) numbers for the compounds in Table 2.

Table 3.--Chemical Abstract Service (CAS) Numbers for Compounds

Compound	CAS number
HFC-32.....	75-10-5
HFC-161.....	353-36-6
HFC-236fa.....	690-39-1
HFC-245ca.....	679-86-7
HFC-245ea.....	24270-66-4
HFC-245eb.....	431-31-2
HFC-245fa.....	460-73-1

Source: Construction Specification Institute (USA) www.csinet.org

HFC-236ea.....	431-63-0
HFC-365mfc.....	406-58-6
HCFC-31.....	593-70-4
HCFC-123a.....	354-23-4
HCFC-151a.....	1615-75-4
C4F9OCH3.....	163702-07-6
(CF3)2CFCF2OCH3	163702-08-7
C4F9OC2H5.....	163702-05-4
(CF3)2CFCF2OC2H5.....	163702-06-5

III. Final Action Today's action is based on EPA's review of the material in Docket No. A-96-36. The EPA hereby amends its definition of VOC at 40 CFR 51.100(s) to exclude the compounds in Table 2 as VOC for ozone SIP's and ozone control strategies for purposes of attaining the ozone NAAQS. The revised definition will also apply for purposes of any FIP's for ozone nonattainment areas (e.g. 40 CFR 52.741(a)(3)). States are not obligated to exclude from control as a VOC those compounds that EPA has found to be negligibly reactive. However, States should not include these compounds in their VOC emissions inventories for determining reasonable further progress under the Act (e.g., section 182(b)(1)) and may not take credit for controlling these compounds in their ozone control strategy.

Sec. 51.100 Definitions.

(s) Volatile organic compounds (VOC) means any compound of carbon, excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate, which participates in atmospheric photochemical reactions. (1) This includes any such organic compound other than the following, which have been determined to have negligible photochemical reactivity:

methane; ethane;
methylene chloride (dichloromethane);
1,1,1-trichloroethane (methyl chloroform);
1,1,2-trichloro-1,2,2- trifluoroethane (CFC-113);
trichlorofluoromethane (CFC-11);
dichlorodifluoromethane (CFC-12);
chlorodifluoromethane (HCFC-22);
trifluoromethane (HFC-23);
1,2-dichloro 1,1,2,2-tetrafluoroethane (CFC- 114);
chloropentafluoroethane (CFC-115);
1,1,1-trifluoro 2,2- dichloroethane (HCFC-123);
1,1,1,2-tetrafluoroethane (HFC-134a);
1,1- dichloro 1-fluoroethane (HCFC-141b);
1-chloro 1,1-difluoroethane (HCFC- 142b);

2-chloro-1,1,1,2-tetrafluoroethane (HCFC-124);
pentafluoroethane (HFC-125);
1,1,2,2-tetrafluoroethane (HFC-134);
1,1,1-trifluoroethane (HFC-143a);
1,1-difluoroethane (HFC-152a);
parachlorobenzotrifluoride (PCBTF);
cyclic, branched, or linear completely methylated siloxanes;
acetone;
perchloroethylene (tetrachloroethylene);
3,3-dichloro- 1,1,1,2,2-pentafluoropropane (HCFC-225ca);
1,3-dichloro-1,1,2,2,3- pentafluoropropane (HCFC-225cb);
1,1,1,2,3,4,4,5,5,5-decafluoropentane (HFC-43-10mee);
difluoromethane (HFC-32);
ethylfluoride (HFC-161);
1,1,1,3,3,3-hexafluoropropane (HFC-236fa);
1,1,2,2,3-pentafluoropropane (HFC-245ca);
1,1,2,3,3-pentafluoropropane (HFC-245ea);
1,1,1,2,3- pentafluoropropane (HFC-245eb);
1,1,1,3,3-pentafluoropropane (HFC- 245fa);
1,1,1,2,3,3-hexafluoropropane (HFC-236ea);
1,1,1,3,3- pentafluorobutane (HFC-365mfc);
chlorofluoromethane (HCFC-31);
1- chloro-1-fluoroethane (HCFC-151a);
1,2-dichloro-1,1,2-trifluoroethane (HCFC-123a);
1,1,1,2,2,3,3,4,4-nonafluoro-4-methoxy-butane (C4F9OCH3);
2-(difluoromethoxymethyl)- 1,1,1,2,3,3,3-heptafluoropropane ((CF3)2CFCF2OCH3);
1- ethoxy-1,1,2,2,3,3,4,4,4-nonafluorobutane (C4F9OC2H5);
2- (ethoxydifluoromethyl)-1,1,1,2,3,3,3-heptafluoropropane ((CF3)2CFCF2OC2H5);

and perfluorocarbon compounds which fall into these classes:

(i) Cyclic, branched, or linear, completely fluorinated alkanes;
(ii) Cyclic, branched, or linear, completely fluorinated ethers with no unsaturations;
(iii) Cyclic, branched, or linear, completely fluorinated tertiary amines with no unsaturations; and
(iv) Sulfur containing perfluorocarbons with no unsaturations and with sulfur bonds only to carbon and fluorine.

Source: Construction Specification Institute (USA) www.csinet.org

Additional Information to Supplement Tainan Eco School Conceptual Design

Exhibits

Volatile Organic Compounds	Excerpts from EPA 40 CFR Part 51 VOC Definitions and EPA Listings
Construction Waste Management	Example Specification Section 01505
Flyash content in Cast-in-Place Concrete	Example Specification Section 03300
Sealants	Example Specification Section 07900
Painting	Example Specification Section 09900
Building Products List	Sustainable Oregon Products – Building Materials

Source: Construction Specification Institute (USA) www.csinet.org