PUBLIC VERSION

FINAL REPORT

TECHNICAL ASSISTANCE for the DISASTER EARLY WARNING SYSTEM CAPACITY DEVELOPMENT & SYSTEMS INTEGRATION PROJECT for the DEPARTMENT OF METEOROLOGY of the DEMOCRATIC SOCIALIST REPUBLIC OF SRI LANKA

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Executive Summary

Following the mandates of the Sri Lanka Prime Ministers' Office and by the direct support from the U.S. Trade and Development Agency (USTDA), the Sri Lanka Department of Meteorology (DOM) has been given the responsibility of producing timely and coordinated early warnings for all severe meteorological events affecting the country.

In support of the above effort, Science Applications International Co. (SAIC) conducted a survey of the existing capabilities of the department and performed a Gap Analysis to identify critical deficiencies in analyzing impending meteorological events to understand their impact on the country. SAIC then conceived of an architecture enabling the DOM to improve their production of timely warnings and alerts and implemented a Pilot System to demonstrate this architecture. Critical to this was the development of a digital atlas of Sri Lanka. The pilot system is an integrated set of both hardware and software systems supporting surveillance and response to improve the emergency response and crisis management situations in Sri Lanka. This prototype system is based on the SAIC developed Consequences Assessment Toolset (CATS) software system. CATS is a collection of tools and data management software, which allows for storage of information on resource management, population, and geographical data. Additionally, it provides an emergency-situation early warning system and the tools to analyze a disaster event, forecast consequences, and help with the calamity mitigation efforts.

In addition to the above, SAIC considered the Financial, Environmental, and Regulatory issues that would be impacted by extending the prototype efforts reported on here to full-scale implementation by the Government of Sri Lanka. SAIC also considered the benefits and detriments to Sri Lanka of the implementation of such a system.

The Gap Analysis and Recommended Procedures were previously documented in reports delivered to the Department of Meteorology: *Gap Analysis in Support of the Disaster Management Process and Recommended Operational Procedures – Department of Meteorology (DOM) / Ministry of Disaster Management and Human Rights / Government of Sri Lanka (Dated 21 DEC 2007).* This report focuses on the overall effort and the recommendations for the way forward. This report also provides two appendices that supplement the training materials previously supplied and presents an overview of the CATS capabilities and basic ArcGIS functionality.

1.0 Introduction

The country of Sri Lanka is prone to natural hazards such as tropical cyclones, floods, and landslides. These phenomena have a disastrous impact on the coastal population most susceptible to these hazards and on the whole of the country and its resources in dealing with the aftermaths and in managing the consequences. In addition to the tragic human toll, the effects of these natural phenomena can set back years of progress and have a devastating impact on the regional economy.

Following the tragic 2004 tsunami, it was recognized that a more pro-active system of disaster management and response was necessary to mitigate the effects and identify subsequent health and economic risks. Under the leadership of the Sri Lanka Prime Ministers' Office, guidance from the United Nations Development Program (UNDP), direct support by the U.S. Trade and Development Agency (USTDA), and participation of numerous stakeholders, a course of action was formalized and implemented. This provided a legal and definitive framework for instituting a Disaster Risk Management (DRM) plan and establishing a National Council for Disaster Management (NCDM). Subsequently, the Disaster Management Center (DMC) was established as the lead agency for disaster risk management in Sri Lanka. The Department of Meteorology is responsible for the timely production of all alerts and warnings resulting from meteorological events. The USTDA funded two complimentary projects to establish the framework of activities to respond to current disaster management efforts as well as creating a comprehensive concept of operations to respond to future disaster management tasks.

TheHonorable Prime Minister vice-chair of NCDM has provided the guidance in achieving the goals set forth in the above Disaster Risk Management (DRM) framework. His message states that, "... significant steps have paved the way to launch a Road Map that facilitates us to systematically approach DRM. However, we must realize that we have a long way ahead. Merely having a Road Map is not sufficient ... It would need all stakeholders to get together with a clear vision and to work as a team for a safer Sri Lanka".

Under the above proclamation, the Department of Meteorology (DOM) is responsible for coordinating the production of and issuing timely warnings for all severe meteorological events such as tropical cyclones and flooding. To improve its ability to deal with disasters, however, it is essential that the DOM improve its understanding of the *effect* of the meteorological events on the people and infrastructure of Sri Lanka. In support of the above proclamation and under the auspices of the USTDA funded efforts, the SAIC team proposed and implemented a system of Global Surveillance and Local Response to improve the response to emergency and crisis situations in Sri Lanka. For the Department of Meteorology, the main thrust of this effort was to implement a system that can take the area threatened meteorologically, and determine the magnitude of human impact of this event. This information in turn will improve the ability of other government entities to respond to disasters.

Included in these efforts were the production of a Gap Analysis and Recommended Procedures report, which was previously delivered to the DOM management. This document was the result of both an inward look at the agencies involved in disaster management in Sri Lanka, their roles and responsibilities, but also at the methodologies used around the world. It started with a review of the international efforts, continued with a Stakeholders meeting held in Sri Lanka in January, 2007, followed by one-on-one meetings with various Stakeholders, and concluded with a melding of the international best practices to fit the needs of Sri Lanka. SAIC presented the results of its findings and proposed a comprehensive emergency management system to the Government of Sri Lanka in December 2007.

The Consequence Assessment Toolset (CATS) software system is at the center of the emergency management-system proposed by SAIC. CATS is a collection of tools and data management software, which allows for storage of the essential resource management, population, and geographic data and provides an emergency situation early warning system the tools to analyze a disaster event and forecast consequences and help with the mitigation efforts. Developed by SAIC to improve US disaster response following Hurricane Andrew (1992), CATS represents a critical link in the determination of the most important questions that arise when faced with any potential or actual disaster:

- *How many people will be affected?*
- *For how long will they be affected?*

These questions are important because all disaster response decisions are affected by their answers. A situation affecting a small number of people is not a disaster; nor is one where the impact is too short lived to mount a response. On the other hand, the number of people affected and the number of days they will be affected determines the amount of shelter, water, food, sanitation, and medical care that will be required to support the displaced people and the logistics tail required to *provide* this level of support. For this reason, this final report discusses the requirements to be able to support this level of analysis as it is critical to the DOM mission success.

1.1 Local Subcontractor

In answering these questions, SAIC subcontracted with a local Sri Lanka company:

General Engineers & Suppliers Co.
GE Tower 285
R. A. De Mel Mawatha
Colombo 03
Sri Lanka

The GESCO Program Manager was Mr. Ajit Jayasekera, (+94-77-302-2442). GESCO provided local logistics support and also purchased the hardware and software installed at the Disaster Management Centre as part of the prototype system.

1.2 Sources of Supply

The computer hardware was purchased from Hewlett-Packard. The original plan had been to use Dell computers, however the local support situation made HP equipment a preferred choice. The commercial geographic information system (GIS) software was purchased from Environmental Science Research Institute (ESRI). Sri Lanka contact information for suppliers of both is:

Hewlett-Packard (www.hp.com)
Silicon Data Systems, (PVT) LTD
No 26 / 1 Dickman's Rd
Colombo 05
Sri Lanka
+94 11 250-4037
silicon@dynanet.lk

ESRI (www.esri.com)
EMSO Limited
100 Glennie St.
Colombo 02
Sri Lanka
+94 11 231-6100
emsoesd@slt.lk

2.0 Scope of This Report and the Intended Audience

This report constitutes the Final Report (DOM Task 8 – Final Report) of the work performed under the USTDA funding to assist the Department of Meteorology. This report contains no security or confidential information and therefore it is considered the public version of the Final Report.

3.0 A Waterfall of Requirements

One definition of a crisis is a situation the response to which requires external assets. The primary problem is the while the local assets are insufficient to manage the response, they understand the local infrastructure and "the beat of the street"; on the other hand, the external assets (*e.g.*, national civilian or military assets) have the needed resources and capabilities, but don't know "the lay of the land".

The first step in melding local and non-local assets is for all parties to understand the roles and responsibilities of each organization. This can only be established once the response organizations all understand the capabilities of each other. Thus prior planning, training and exercise are essential elements of disaster planning, management, and response.

From the need to be able to plan, monitor, and respond to unfolding events comes a waterfall of requirements the first element of which is information. Only by having timely access to information can an adequate response be planned and executed. More, the information must be in a format that allows it to be correlated with other information to become actionable intelligence. The creation of a data repository of geospatial data is a critical element in meeting this requirement. This data repository must contain both geographic and demographic data.

The specific geographic data needed is related to the hazards of interest. While every command centre is different, common hazards of interest include airborne releases of toxic material, earthquakes, floods, landslides, hurricanes, tsunamis, and storm surges. The most important geographic data (Table 3.1) for these problems includes the elevation, watershed, geology, vegetation, and land use. In addition, historical information on factors that affect these hazards is important. These include climatological weather information and historical episodes of floods and seismic events. Part of the proposed effort will provide guidance on the collection of geographic data – the specific data and their format – to aid in its fusion into actionable information.

The first step in developing hazard maps is to acquire geographic data. For decades, this data resided in hand-drawn maps. Today, digital geo-coded data can be used to create maps on demand. In addition, multiple layers of geo-coded data can be inter-related to produce new information.

By definition, a disaster involves people and/or property. Thus it is not sufficient to only obtain

Table 3.1. Geographic data required for developing emergency response to natural and anthropogenic hazards.

- **Terrain Data**
  - Digital Elevation Model
  - Watershed (Drainage / Rivers / Estuaries)
  - Geology
  - Vegetation
  - Land Use
- **Historical / Climatological Hazard Data**
  - Climatological Weather Data
    - Surface temperature
    - Dewpoint
    - Precipitation
    - Wind speed / direction
  - Historical Hazard Data
    - Flood history
    - Seismic history

geographic data, demographic data is also required. Table 3.2 outlines many of the different types of demographic data that relate to the development of strategies to respond to emergencies. Obviously, the most important demographic information is the population distribution. The next most important is information on the transportation system that is essential to evacuating affected people and getting emergency responders into the affected area. This is closely followed by information on the utilities (e.g., power, water) that are essential for the responders. Other demographic information that is important for emergency response includes the building assets, personnel assets, supplies, and the location, status, and availability of medical facilities. Under this task, a survey will be conducted to identify existing GIS data that are valuable for disaster management. The data format and the metadata that is essential to the conversion of GIS data into actionable intelligence will be determined. Those data that are readily available will be collected; data gaps will be identified and recommendations for additional efforts to fill them will be made.

A crisis is a local situation that requires non-local emergency response personnel and/or assets to manage. For many types of natural disasters, this entails having a thorough and comprehensive understanding of the unfolding events, including detailed information about the hazardous situations as well as the resources to mitigate their consequences.

The first step in managing a crisis begins with the recognition that a crisis is developing or in fact, does exist. Typically, this involves monitoring for specific types of events that are likely to precipitate a disaster. This includes the Department of Meteorology (DOM) monitoring for

Table 3.2. Demographic data required for developing emergency response to natural and anthropogenic hazards.

- **Demographic Data**
  - Population Data (Day / Night)
- **Transportation Data**
  - Road Network (Highways to Residential Streets)
  - Public Transportation Assets (Rail / Bus / Subway)
  - Airfields & Ports
- **Utilities**
  - Power Generation
  - Water Desalination / Treatment
  - Power lines
  - Pipelines (Water / Oil / Gas)
  - Communications lines
- **Building Data**
  - Building Footprint
  - Building Assets (Shelters, etc.)
- **Physical Assets**
  - Hopital Layer with detailed capability (Services / Beds)
  - Fire / Police / EMS facilities
- **Personnel Assets**
  - First responder assets (Police / Fire / Medical)
  - National / Military disaster response assets
  - Civilian Volunteer / Military skilled personnel
- **Supplies Status**
  - Bottled Water / Food Assets / Sanitary Supplies
  - Portable Restroom Facilities
  - Fuel Resources
  - Medical/Pharmaceutical Supplies
  - Camping Equipment / Shelter / Provisions
  - Portable Generator Assets

severe weather events, such as heavy precipitation and damaging wind storms, the Geological Survey and Mines Bureau (GSMB) monitoring seismic event, the National Aquatic Resources Research and Development Agency (NARA) monitoring of tidal surge and also predicting the potential impact of a tsunami generated by GSMB identified seismic events. As can be seen, this monitoring phase of the disaster management process can be at a global, regional, or local scale.

For meteorologically driven disasters, typical surveillance is on a regional or local scale. This surveillance involves monitoring instruments and sensors, model output, synoptic and mesoscale analyses, forecasts, satellite imagery and sensors and advisories, watches and warnings disseminated by other agencies and countries. The fusion of all this data, information, and knowledge into a coherent picture and understanding of the event unfolding is known as the common operating picture (COP).

A generalized overview of the data, processes, applications, and operator interactions within the context of disaster management operations is presented in Figure 3.1.

Developing a COP was essential to the DOM in improving its ability to provide timely warnings and alerts to the population of Sri Lanka. Going back to the basic questions at the end of the introduction, the key is determining *How many people will be affected and for how long.* This information is essential in allowing the DOM to allocate its resources appropriately and also in determining the level of severity of the impending situation.

"The COP must include the underlying *event(s)*, the resulting *hazards*, the *assets* (including human assets) available to respond, and the state of the *infrastructure*. In understanding the hazards, it is necessary to be able to not only discern the *current* state of affairs, but also to be able to *predict* the future state. Until the [DOM forecasters and DMC] responders are thinking ahead of the crisis, they are just *reacting* to events; once they can predict the unfolding events, then it is possible to try to *respond* to them. Modeling and simulation tools are essential to gaining this upper hand." [1]

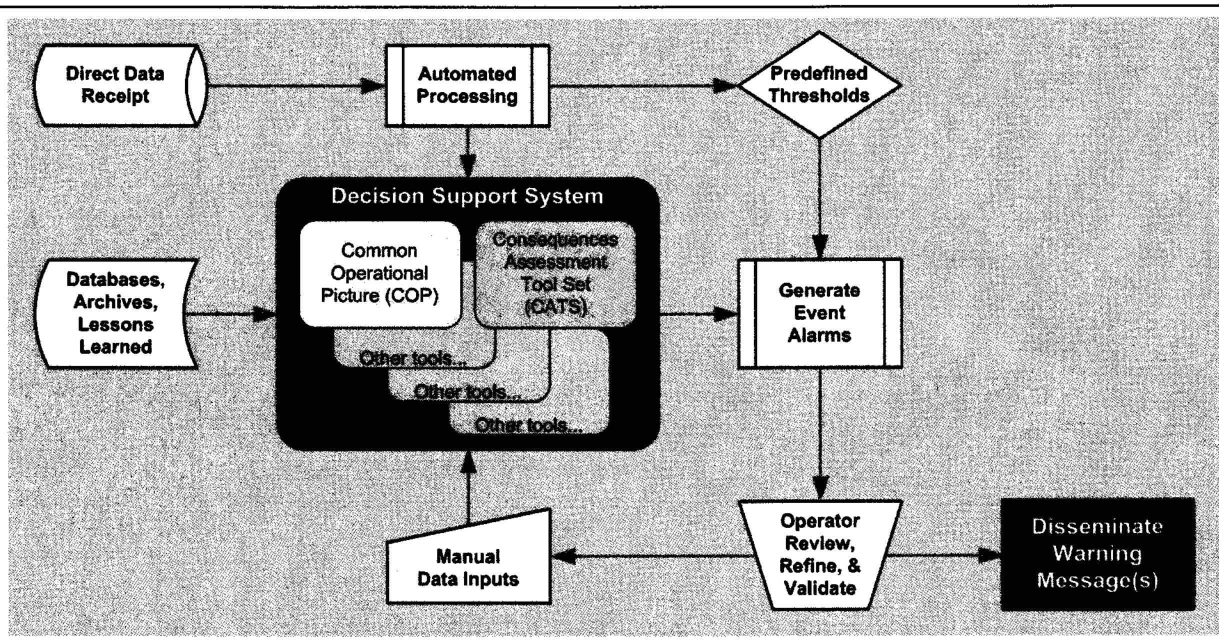


Figure 3.1 Generalized Disaster Management Process Overview

A common operational picture must be maintained to monitor the extent and severity of the event as it develops. The COP must adequately portray the underlying events, the resulting hazards, and the status of population and infrastructure such as utilities and hospitals, and provide the means to respond to the emergency utilizing those resources. This requires a complex system of models, visualization capabilities, and a massive relational database of information. To accommodate these requirements, the Consequence Assessment Tools Set (CATS) software was installed on the Sri Lanka disaster management and response systems.

CATS is a comprehensive package of hazard prediction models, and casualty and assessment tools that provides a linkage between a modeled or observed effect and the attendant consequences for population, infrastructure, and resources. Therefore, CATS provides the engine for the *Common Operational Picture* for emergency response.

Major parts of the CONOPS for Sri Lanka are built around this software, its warning system, and generated outputs which geo-reference the extents of the affected area or the exposed population to risks on a map display.

4.0 Disaster Management

4.1 Preparation

Disaster management and risk mitigation begins with preparation. An adequate response to each type of disaster can only be mounted if the assets exist, personnel are properly trained in their required roles and responsibilities, and all are working from a common frame of reference. This process is inherently a local problem requiring non-local assets to deal with the situation. Local assets implies an understanding of "the beat of the street" but lacking the resources to resolve the crisis. External assets often understand "the big picture" but otherwise have little or no knowledge of the lay of the land. Thus merging the local and non-local assets into a unified team is critical to crisis resolution and recovery.

Adequate training of the staff and familiarity with the various command centers, communications equipment, computing hardware, software, etc, is a requirement for the personnel who will be managing the normal operation of the emergency center. It is advisable to have multiple individuals trained in the same area as a means of avoiding single-point-failures.

After the initial training, routine exercises, evaluations, and fine-tuning the procedure can lead to big payoffs during the actual response situations. This is a critical step in clearly defining the roles and responsibilities of various command centers and agencies at the local and regional level. There is little or no time during the actual emergency to sort through these issues.

4.2 Monitoring

The requirements for managing a crisis start with the situational awareness. It is the recognition that an emergency, in fact, exists. Typically, this involves monitoring for specific types of events that are likely to precipitate a disaster. An example would be to monitoring seismic events with large magnitudes that can cause a tsunami at shallow depths underwater or near population centers. This constant surveillance of activities is always global in extent in that we do not know where an event might take place and hence it is necessary to monitor everywhere to identify the events of interest. In the case of the Department of Meteorology, while serving as the primary source of natural hazard alerts, forecasting severe weather and the resultant flooding, storm surge, and/or wind damage becomes the primary area of responsibility.

The CATS Localized Advanced Warning System (CLAWS) component monitors various natural hazard RSS[2] feeds, processes the feeds, and creates audible, visual, and spatial warnings to the user providing such information as the location, time, and event description. The visible area of the map may be confined to the area of interest, thus *localizing* the information. The warning system is designed to inform and alert an operator on duty. A manual intervention is required to further investigate the consequence of a particular tsunami and its potential impact by launching one of CATS hazard assessment tools. The system may be readily configured to respond to other sources of disasters for which warning messages might be broadcast. For the Department of Meteorology, alerts from the Joint Research Centre in Europe, the Joint Typhoon Warning Center in the US, and other major forecasting centers that support geo-coded RSS data feeds are easily monitored with CLAWS. CLAWS should be used jointly with the other tools provided in CATS such as Hurricane (Cyclone), Manual Hazard, High Explosives, and Toxic Industrial

[2] Really Simple Syndicated (RSS) messages are text-based informative messages which are available over the internet. A *URL* points to the source of the message, which is then extracted as a data stream.

Materials models. These models when used with Consequence Assessment, Roadblocks, and RRS will provide the disaster management teams with means of determining the affected Population at risk, available Resources, and the area of containment.

4.3 Response

Since a crisis, by definition, is a situation in which an adequate response requires the addition of non-local resources to mitigate the risks to life and property, it leads to several issues in rapid succession. This includes determining the extent of needed resources, those complementing the local resources, and multiple events competing for the same resources. Furthermore, it is necessary to both understand the current events as well as be able to predict the future states of potential hazards. This implies that various teams responding and managing to a disaster must be adequately trained and have a unified set of guidelines and procedures to efficiently mitigate the risks and diffuse the situation.

4.4 Concept of Operations (CONOPS)

The ability to respond to the rapid unfolding of these states of crisis in a timely manner is best achieved by following pre-established and carefully customized guidelines. These guidelines are collectively known as the Concept of Operations (CONOPS). CONOPS provides for monitoring instruments and sensors, weather analyses and advisories, forecasts, satellite imagery, and watches and warnings disseminated by other agencies and countries. It also defines ways to monitor the list of resources or assets available to respond, understand the population and infrastructure at risk, how resources might be used and their impacts on the events.

A CONOPS normally entails a textual or graphical broad outline of emergency response procedures and chain of command. The plans will be a series of clearly defined operations allowing response to varying emergencies which may encompass many sequential or simultaneous events. Clearly defined scenarios will assist in preventing emergencies from adversely affecting the livelihood and well-being of the population. CONOPS are usually created by the disaster management team and provide an overall picture of the response to the emergencies. It represents the coordinated effort of all levels of government, local to federal.

The details and implementation of the various CONOPS guidelines are compiled in Standard Operating Procedures (SOPs), tailored for each disaster event. An SOP is a reference document with procedures for performing a single or a series of sequential functions to mitigate the consequences of the disaster event. It may be as simple as providing a checklist for a person on duty at the "watch desk" or more comprehensive for a first responder at the disaster site.

CONOPS are generally created to respond to natural and/or technological (man made) disasters tailored to a regions of interest. The current effort in Sri Lanka was mandated to respond to natural disasters such as tsunami, flooding, and landslides and the corresponding CONOPS attempt to define the steps in the preparation, response, and recovery actions.

The nature of CONOPS and SOPs is that they must be "living" documents. As the capabilities and responsibilities of the underlying organizations evolves, the CONOPS and SOPs must change with them. For this reason, the Recommended Procedures document provided by SAIC was presented not just in paper form, but also electronically so that it can be easily updated and maintained.

5.0 Hazard Prediction and its Consequences

5.1 Early Warning and Notification

The fusion of the above methodologies and knowledge, information, and various pieces of data into a coherent picture and understanding of the unfolding events requires a unique set of tools to help first responders and crisis managers to gain the upper hand in dealing with these situations. Furthermore, these tools must be capable of modeling and simulation of complex, and potentially cascading crisis events for the purposes of training and creating scenarios to understand the consequences of each disaster event and determining the best course of action.

Once a crisis or its potential to develop is recognized and its locality known, then the response to the unfolding events is always local in nature. The activities begin with a prediction of the potential hazard, which will typically trigger one or more alerts and/or warnings. It is then necessary to assess the potential consequences to the people, infrastructure, and assets that need to be preserved or are needed in responding to the unfolding events.

A unique set of tools, the CATS *Localized Advanced Warning System* (CLAWS), in the Consequences Assessment Toolset provide the initial warning, the extent of the perceived concern, and the consequences of the unfolding events. CLAWS can receive global feeds of *RSS* messages, for example of oceanic seismic events, and translate them into warning messages of tsunamis that could affect the locality of interest. CATS visual frame displays the event locations and provides audio-visual warnings. Subsequently, resultant hazard distribution may be computed and displayed over the map of the affected area, provide an analysis of the associated consequences, and identify and locate resources for an effective and sustained response. The resulting data fusion analysis may then be used to support disaster and other emergency management activities or construct planning and mitigation scenarios.

5.2 Population at Risk

There are two metrics that are essential to use by the crisis management teams and the CATS software to handle the emergency response to a situation:

- *How many people are affected and for how long?*
- *What assets are available to mitigate the effects of the disaster?*

These metrics provide estimates of the type and amount of shelter, water, food, and medical care. This information in turn leads to a realistic prediction on the work force, logistical support, and sustainability requirements. It is therefore imperative to generate and assemble this data is a useful format in CATS or any other tools beforehand.

Once the nature of a disaster is determined, the CATS Consequence calculations would provide an estimate of the population at risk of exposure to a particular hazard level within the affected area. Secondary events triggered by the original calamity may also be studied by using the Manual Hazards tools in CATS to assess the extent of cascading crisis. Finally, the CATS Response, Resource, and Sustainability (RRS) tool would provide an inventory of the assets located outside of the impacted area and available for the crisis management. Depending on the severity and magnitude of the event, the analyst may also deduce how long the immediate response to a disaster would last and what the subsequent recovery period might be.

5.3 Crisis Management Architecture

Clearly, an unhindered communication and full cooperation among the different crisis management teams is essential to the success of the risk mitigation and disaster relief efforts. The complete cycle of events from the onset of the disaster to the final recovery phase then implements a successful CONOPS. Figure 5.1 depicts this architecture in terms of the flow of information and the extent of the activities.

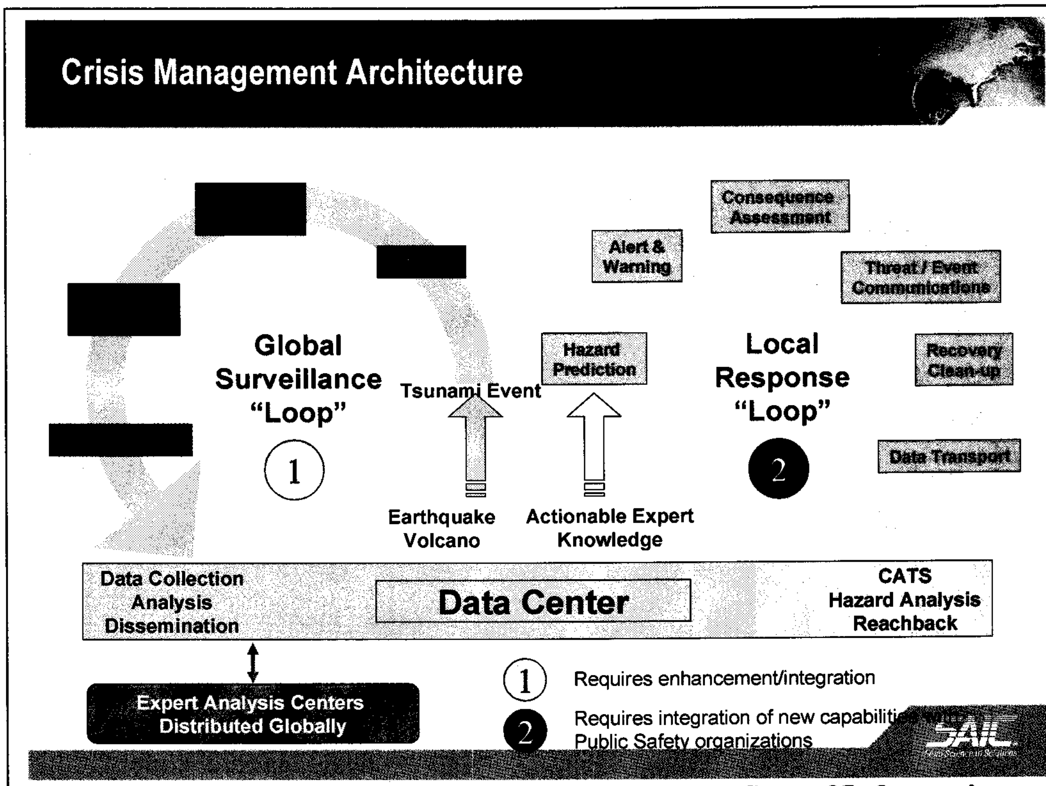


Figure 5.1 Crisis Management Life-cycle and flow of Information

6.0 Resource Management and Sustainability

In the aftermath of an emergency situation, the crisis managers may face numerous escalating problems that are natural by-products of the initial disaster. These situations normally arise after the initial plans are established to identify the available assets to mitigate the effects of the disaster. Typical situations are erosion of access roads, landslides, disease control, and crowd management.

The successful resolution of the above situations invariably highlights the importance of having adequate data and information and be able to respond to the changing landscape. The software tools available under the CATS system allow for establishing buffer zones and identify them as "*keep-out or limited access*" areas on a map of the area. For example, a food and tent storage warehouse would have limited access while a washed out bridge presents a no-access zone. The Roadblock tools may be used to identify on the map the locations of warning signs at road, rail, or waterways. Similarly, the Shapemaker tool in CATS may be used to identify a new safe-zone for sheltering large segments of the population and providing for their basic needs. These maps could then be reproduced and distributed to the local authorities for enforcement and guidance.

This *on-the-fly* capability to data-generation and information-dissemination is the key to sustain a response to the aftermath of a disaster.

7.0 The Role of the Department of Meteorology (DOM)

7.1 DOM Operations

The Department of Meteorology of Sri Lanka has the task of generating routine weather products and also to provide all alerts and warnings for severe meteorological events that threaten the country. In the past, the DOM was severely limited by its bandwidth to the outside world; with support from the US National Oceanographic and Atmospheric Administration (NOAA), this has been alleviated over the past 18 months with the implementation of higher bandwidth data communications to the meteorological data sharing networks. In addition, with support from the French government, the DOM has implemented a MESSIR-VISION workstation that allows for the automated plotting of the newly available larger data feed data. These two developments provide a major improvement in capability of the DOM to develop forecast products for the nation.

7.2 Contract Tasks

The SAIC contractual agreements in support of the DOM outlined eight specific tasks to be performed including the delivery of a prototype crisis management decision support system consisting of both hardware and software. Soon after the contract work authorization, a team of SAIC experts carefully reviewed the existing infrastructure and crisis management policy and practices as implied by the responsibilities assigned to the Department of Meteorology. The main objective was to establish what was required to achieve the goals set forth by the Disaster Risk Management Framework of Sri Lanka. The following sections describe the results of the specific contractual tasks in greater detail.

7.2.1 Task 1 - Gap Analysis and System Processes

The Department of Meteorology is responsible for producing timely and coordinated early warnings for a wide variety of meteorologically induced natural disasters such as tropical cyclones, flooding, and all tsunamigenic events that impact Sri Lanka. The timeliness and accuracy of these warnings are extremely important cornerstones to the foundation of the entire Disaster Management Process. It is therefore essential to understand the potential gaps in Information and Communications Technology (ICT) and the infrastructure and resources needed to accomplish this mission.

SAIC conducted a detailed study of the existing capabilities of the Department of Meteorology that support the Disaster Management Process of Sri Lanka. The results have been submitted in a separate volume titled, "*Gap Analysis in Support of the Disaster Management Processes and Recommended Operational Procedures*". The report reviews the existing disaster management processes of the Department of Meteorology, data flow and availability, supporting organizations, agencies, and other data providers. It also includes a survey of the existing DOM Information and Communications Technology capabilities. Various recommendations are provided in that report to assist DOM in improving their current operational posture to better access information and automate the analysis and forecasting process. The ultimate goal is to improve the DOM ICT posture and to improve the speed at which it can assess and monitor a developing threat, provide notification to appropriate national, regional, and local agencies, and support the national Disaster Management Centre.

The recommendations provided represent a concerted effort to integrate recent hardware and software improvements such as the fielding of the CATS pilot architecture and improve operational procedures. It is concluded that the implementation of CATS will provide a more robust capability to achieve real-time visibility of events as they develop and to produce timely and accurate hazard warnings and improve DOM support to the DMC.

One recommendation that was not previously conveyed is a recognition that UNIX systems are important in the forecasting world and the DOM should take steps to develop in-house UNIX expertise as a step towards improving its indigenous forecasting abilities.

7.2.2 Task 2 - System Implementation and Integration for Pilot System

Subsequent to the various studies and in particular the above Gap Analysis, the SAIC team proceeded to design a pilot system that optimized the costs and benefits of responding to the project requirements and establishing a custom disaster management ICT system. The systematic approach was to cost out the various components and allocate the resources in accordance with and to achieve the goals set by the Concept of Operations (COP). This effort also led to define an effective decision support platform that best suited the Sri Lanka disaster management processes.

The culmination of these efforts was to define the COP, acquire, install, and configure hardware and software needed for the disaster management ICT architecture. The completed system was installed as the *Pilot System* at the DOM, which included digitized maps (*c.f.,* the next section) of the country, hazard-specific data sets, and customized integration per user requirements. The prototype system consisted of four workstations – one CATS workstations for analysis and an additional two ArcGIS workstations capable of viewing the CATS analysis. The final system can be used as either a data storage system or as an RSS server. The system qualification tests included both pre-install and post-integration. It should be noted that all equipment and software purchased with the USTDA grants remains the property of the government of Sri Lanka.

To complete the implementation and delivery of the *Pilot System,* the SAIC team created training material and conducted detailed training workshops and technical working sessions with the users to introduce the operational system and hazard management toolsets, gather feedback from the participants, and perform any modifications to the solutions as necessary.

7.2.3 Task 3 - Digital Maping

This was one of the most challenging of the tasks under this contract. While the basic concept was well developed prior to submission of our proposal to the Government of Sri Lanka for evaluation, obtaining the support and cooperation of the various government agencies was the biggest challenge for the current effort.

As discussed in Section 3, disaster management leads to a waterfall of requirements in terms of data availability and these requirements span government agencies. The biggest challenge is that agencies often do not want to share their digital data due to a perception that they will lose control of the data and lose funding for their efforts to other agencies. The key to fostering a climate of collaboration rather than competition among the various agencies is therefore to ensure that agencies that share data will continue to serve as the lead organization in the data development and analysis.

SAIC attempted to collect whatever data could be gathered and has created a 1.5-gigabyte dataset for the purposes of both training and analysis. The various raw data components were provided by the Disaster Management Center, Department of Meteorology, and other sources. The entire collection of various map layers has been packaged for GIS use on a DVD media and labeled "*CATS Auxiliary Data - Sri Lanka*". These datasets were integrated into the SAIC CATS system and a prototype decision support system was installed at the DMC.

Figures 7.1 and 7.2 show samples of data obtained for Sri Lanka. Figure 7.1 shows historic seismic and storm data along with rivers basins and low lying coastal areas that are susceptible to flooding. Figure 7.2 shows a section of the Fort District of Colombo and the more detailed information collected on the road network and public facilities in the area. It is important to understand that much of the digital data is useful not only because of the data itself, but also because of the *metadata* (*e.g.*, street names) that allows the data to be searched and cataloged.

At the same time, it is recommended that the collection / creation of the data layers described in Tables 3.1 and 3.2 be continued. SAIC has recommended to the Disaster Management Centre (DMC) that it take the lead in creating a "Gold Disk" of Sri Lanka data appropriate to disaster

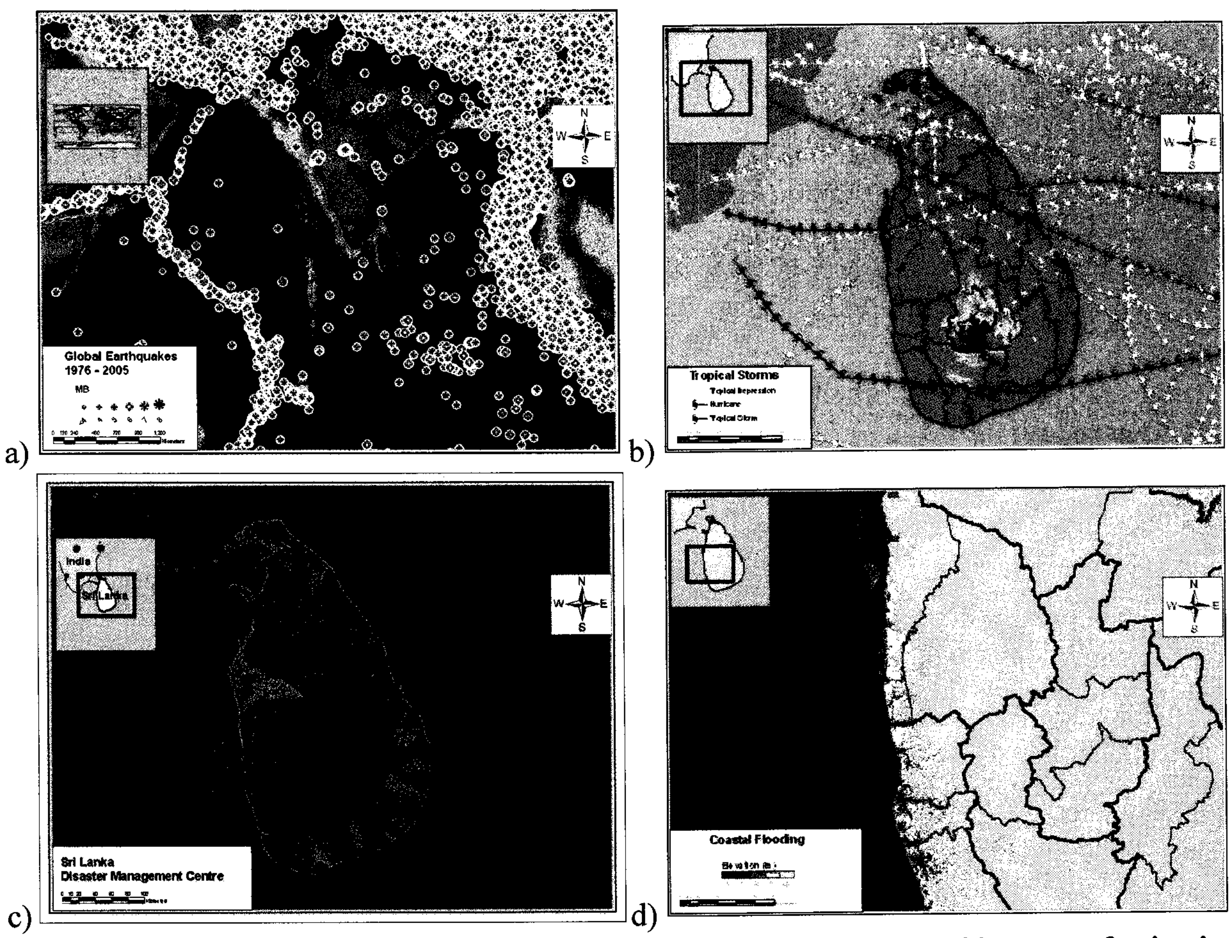


Figure 7.1 Sample datasets produced for Sri Lanka showing (a) 30 years of seismic activity in the region, (b) historic tracks and intensity for tropical storms in the area, (c) the river basins for Sri Lanka, and (d) areas especially susceptible to coastal flooding as their elevation is less than 5m (red) or 10m (orange).

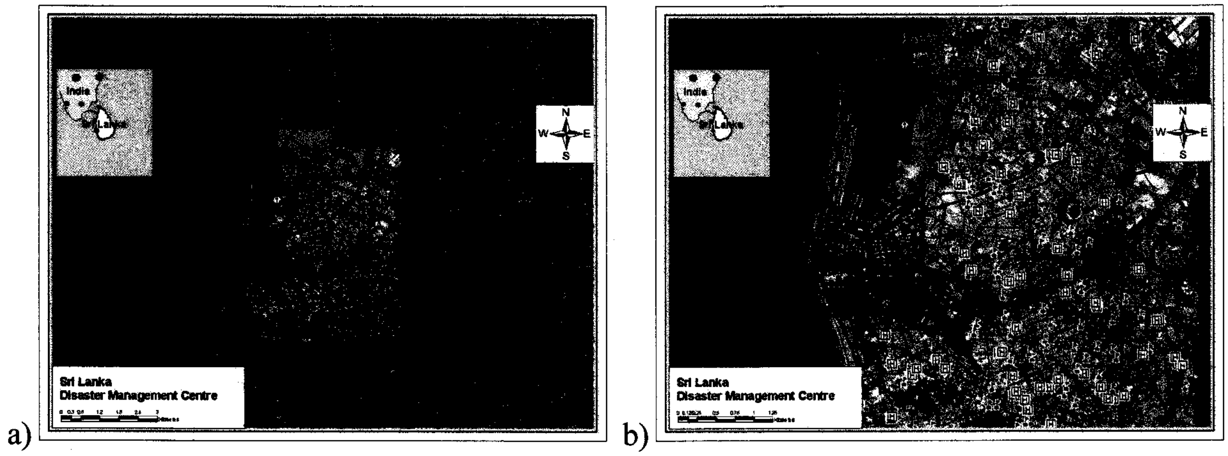


Figure 7.3 Sample maps of Colombo, Sri Lanka showing (a) the transportation network and (b) public facilities (*e.g.*, hospitals, schools) in the Fort District.

management. Table 7.1 contains a list of data sources that should be tapped to create the DMC Gold Disk. While some of the data is available from international sources (*e.g.*, the US Geological Survey data on seismic events is available on the web), it is important that a Sri Lanka agency take the lead in obtaining and verifying all of the input data – in an emergency it will be important to have a point of contact who can speak to the proper interpretation and use of the data. For the Department of Meteorology, this implies the creation of a verified dataset of historic storm tracks, precipitation amounts, coastal and river flood levels, *etc.*

At the same time, it is important to recognize that the private sector is also moving forward and improving the situation. Dialog, the major wireless carrier in Sri Lanka, earlier this year launched SatNav with digital street maps of Colombo and all Class A & B roads throughout Sri Lanka. The base data for the street maps was created by MapMechanics of the UK and is available for purchase.

7.2.4 Task 4 - Financial Analysis

The system installed at the DOM represents a full-fledged capability, but is only the first step in improving its ability to provide improved disaster warnings and alerts. The next set of activities has four thrusts: (1) Develop geospatial datasets of historic conditions; (2) Develop a set of RSS data feeds for notifying other government agencies and the general population; (3) acquire the National Oceanographic and Atmospheric Administration (NOAA) Global Forecast System forecast products, which can be visualized using the MESSIR-VISION system already installed at the DOM to improve the ability to *forecast* severe weather; and (4) (long range) develop a Sri Lanka numerical weather prediction capability.

Geospatial Climatology

The first thrust to improve warning and alerts to severe hydrometeorological events is to create a geospatial climatology. These historic events must, however, be put in context with their effect – for example the amount of watershed flooding associated with a storm and the total storm precipitation. It is the association of the effect with the event that makes the climatology valuable for disaster management as storms of a similar nature can be expected to result in similar effects. Given that most of this information already exists within the DOM, the cost to create the geospatial climatology will likely be less than $200K in terms of labor time.

RSS Data Feeds

Really Simple Syndication provides an excellent methodology for distributing alerts and warnings. RSS readers can typically be set up to check for updates as frequently as 1 minute intervals. Hence, an RSS data server can serve as the primary notification method to both government agencies and the public at large. In the case of government agencies, if they implement CATS and CLAWS, then various alarms can be configured for different types of disasters – tropical storms, coastal flooding, river flooding, *etc.*

The data server provided under this effort can be used to provide the RSS service; the cost to implement automated notification via the implementation of CATS-CLAWS system would be roughly $25-30K per notification site, depending on the need for networking hardware and the level of training provided. Assuming that automated notification is desired to 10 agencies (*e.g.*,

Table 7.1. Recommended initial data sources for a DMC "Gold Disk"

Agency	Data (For All or Any Part of Sri Lanka)
Census Bureau	(1) Any GIS data layers of the most recent census (2) Any tabular data not available in GIS format
Department of Meteorology	Any GIS data layers of historic: (1) Tropical storm tracks (2) Coastal flooding (32) River flooding
Geological Survey & Mines Bureau	(1) Historic seismic event data
Ministry of Education	(1) GIS (preferred) or tabular data of school facilities
Ministry of Health	(1) GIS (preferred) or tabular data of medical facilities and their capabilities
National Aquatics Resources Research and Development Agency	(1) Coastal elevation / bathymetry
National Building Research Organization	(1) GIS data layers of Landslide hazard index
National Police	(1) Concurrence as to the release of the Police station data by the UDA
Survey Department	Any GIS data layers of: (1) Elevation (2) Transportation (Roads / Railroads / Airports / Ports) (3) Land use (4) Public safety facilities (police / fire stations) (5) Medical facilities (hospitals) (6) Schools (7) Buildings / Building footprints (8) Administrative districts
Urban Development Authority	Any GIS data layers of: (1) Elevation (2) Roads (3) Land use (4) Public safety facilities (police / fire stations) (5) Medical facilities (hospitals) (6) Schools (7) Buildings / Building footprints (8) Administrative districts

the GSMB, NARA, NBRO, Sri Lanka Police Headquarters, Sri Lanka Fire Headquarters, Sri Lanka Emergency Medical Service Headquarters, Ministry of Health, Ministry of Disaster Management and Human Rights, Sri Lanka military liaisons), then the total cost to implement this capability would be on the order of $300K (US).

NOAA Global Forecast System

Over the past year, the DOM has improved it connectivity to the meteorological data networks from the order of 300 b to a shared T1 capability. This is sufficient to obtain all of the global observations and a small amount of the global analyses and forecasts. The US National Centers for Environmental Prediction (NCEP) create daily numerical weather prediction products; one product stream is the global analysis and forecast created by the Global Forecast System (GFS). The GFS forecast products are freely available for download; however the volume thereof is too large to pull routinely over a T1 line. An upgrade to a T3 line should be considered in the future.

Sri Lanka Numerical Weather Prediction System

Over the long term, the DOM should aspire to implement its own numerical weather prediction system. Currently, a system based on the Mesoscale Model v. 5 (MM5), implemented by the Korean Meteorological Administration is operating. The lack of local expertise, however, creates a situation where the resolution of problems with the system must await visits from KMA representatives. This is one of the reasons that we have recommended the development of local UNIX expertise.

At the same time, an MM5-based system is not ideal for Sri Lanka. First, Sri Lanka experiences significant topographically forced precipitation and topography influences many other weather events. MM5 uses a terrain smoothing approach to maintain numerical stability and hence the effective terrain resolution is approximately ¼ of the grid resolution. Thus the terrain is likely under-represented in the current operations.

The SAIC developed OMEGA system (http://vortex.saic.com) can resolve terrain features without smoothing. While OMEGA requires more computational resources than MM5, the rapid increase in computing power and decrease in computing cost has resulted in a state where the computing power required is less than $1M – even after accounting for the likely multiplier on US prices to obtain prices in Sri Lanka). Including the costs for the licensing of OMEGA, installation, setup, and training, and a complete turn-key system could be installed for roughly $1.5M.

Training

One of the most overlooked areas is training. A continual interaction with scientific and operational colleagues from the US can provide for cross-pollination of ideas and the development of new concepts to improve both forecasting and disaster management for severe hydrometeorological events in Sri Lanka. While the bulk of this effort would be travel for US scientists to visit Sri Lanka, a ROM cost of $500K is estimated.

Summary

As mentioned in the opening of this section, it is impossible to scope out all activities related to disaster management and many steps have already been taken, or are being taken, by the Government of Sri Lanka and we do not second guess those decisions. The sum of the activities scoped out above, however, is shown in Table 7.2.

Table 7.2. Rough order of magnitude costs for the next steps by the Department of Meteorology.

DOM Thrust	ROM Cost
Geospatial Climatology	< $0.2M
RSS Data Feed	0.3M
NCEP GFS Forecast Access	Not Costed
Sri Lanka NWP System	1.5M
Training	0.5M
Total (of costed items)	**~ $2.5M**

While the total of roughly $2.5M (US) is large compared with the annual budget of the DOM, the efforts can be staged as funds become available. In addition, there are international funding organizations such as the UNDP or private foundations such as the Savers Foundation that may be able to provide part of the funding for efforts.

7.2.5 Task 5 - Environmental Analysis

The installation and operation of the CONOPS and the CATS early warning system and consequence assessment tools should have no adverse impact on the environment. Obviously, the actual operation of the system has no environmental impact. The potential use of the system to determine areas prone to adverse impacts (*e.g.*, coastal or river flooding, landslides) could lead to better land use planning, and hence have a positive effect on the environment.

7.2.6 Task 6 - Political/Regulatory Issues

The policy for disaster management is new and had hardly had time to mature and find its natural placement. Multiple government bodies and/or ministries have some overlapping disaster management responsibilities, whether perceived or legislated. This has led to some bureaucratic confusion at the national level.

However, despite the confusion and growing pains, there is no question that the Government of Sri Lanka is fully committed to strengthening disaster management. Cooperation among various agencies is encouraged. Equally, there is no doubt that the system will improve and smooth out with continued usage and coordination with no or minimal impact on other government services and responsibilities. In the vital area of budgets, the system is normalizing rapidly; at a recent budget meeting, the funding request for the DMC was 1 billion SLR for 2007 (US$10 million)[3].

Moving forward, one of the key regulatory issues that should be addressed includes the assumption of leadership by the DMC in the arena of geospatial data exchange within the Sri Lankan government. The biggest challenge in accumulating all of the data necessary for improved disaster management is that agencies often do not want to share their digital data due to a perception that they will lose control of the data and lose funding for their efforts to other

[3] The statement comes from: "*Sri Lanka Policy and Institutional Capacity Review_Final Draft.doc*", prepared for USAID by IRG & Tetra Tech Joint Ventures.

agencies. The key to fostering a climate of collaboration rather than competition among the various agencies is therefore to ensure that agencies that share data will continue to serve as the lead organization in the data development and analysis. To resolve this inter-agency concern, it is critical that the Disaster Management Centre take the lead in creating an inter-agency data sharing environment that ensures cooperation by all agencies involved. The US equivalent product, the Homeland Infrastructure Foundation Level Database working group *"is a coalition of federal, state, and local government organizations, federally-funded research and development centers (FFRDC), and supporting private industry partners who are involved with geospatial issues related to Homeland Security (HLS), Homeland Defense (HD), Civil Support (CS), and Emergency Preparedness and Response (EP&R)"* (http://www.hifldwg.org). The HIFLD consortium has created a "Gold Disk" of some 300 data layers for use across the government for homeland security purposes. As with HIFLD, the DMC must create a data consortium that fosters the sharing of data by protecting the individual rights of each of the originating agencies. The DMC should take on the role that the HIFLD working group serves in the US and create a formal arrangement for data sharing that fosters collaboration rather than competition.

Another key regulatory issue has to do with import duties on any items procured by the DMC to support its disaster management issue. Obviously with a capital budget exceeding $20M, the addition of duty costs to this could be substantial. Since this is an "internal transfer" in the sense that any collected duties are in fact paid by the Sri Lankan government, it may be beneficial to explore a mechanism that makes the true costs more transparent.

7.2.7 Task 7 - Key Host Country Development Impact

The immediate impact of implementing a viable Concept of Operations with respect to disaster management is to provide a roadmap for interagency cooperation and a focused, effective government response in the event of a disaster. The roadmap outlines a procedure to implement a chain of command, identify shared duties, and place additional responsibilities on the various government bodies and their resources. Implementing a well-rehearsed CONOPS will enable the disaster managers from various departments and agencies to carry out their duties effectively and by extension mitigate the impact on the rest of their duties during the times of crisis.

The primary benefit of improved disaster management is better allocation of resources to protect the population. This occurs at three levels:

- Better understanding of those areas that are prone to disasters (*e.g.*, coastal or river flooding, landslides) will improve the land use planning process. This will limit development in hazard prone areas reducing the potential threat to life and property;
- Better awareness of the impact of a particular event on the populace will lead to improved planning and warning and hence a reduction in the threat to life and property;
- Better awareness of the unfolding events will lead to a cascade of improvements in allocation of resources, response time to the emergency, and minimizing the impact on people.

8.0 Conclusions

A review of the current operation of the Department of Meteorology practices for disaster management was conducted and Gap Analysis and Recommended Procedures were created after a review of industry best-practices. After meeting with the various stakeholders and collecting those datasets that were available for sharing, a prototype disaster management decision support system was implemented at the DOM consisting of three workstations: two loaded with the ArcGIS™ software from ESRI and one loaded with ArcGIS™ and the SAIC developed Consequences Assessment Tool Set. The hardware procured also included uninterruptible power supplies to maintain operations during short power outages.

The SAIC CATS system includes two sub-elements that could prove very useful to the DOM in the future. The CATS Localized Advanced Warning System (CLAWS) can monitor RSS feeds from anywhere in the world – or over a secure network – and will automatically alert the user to events that have a latitude and longitude in their data streams. This is highly useful for monitoring seismic events (which would include events potentially leading to a tsunami), severe storms, *etc.* In the future, the CLAWS system could be the basis upon which the DMC alerts the DDMCUs automatically with geo-coded disaster messages.

The bulk of the deliverables occurred during the installation period in December, 2007. Approximately 20 people from the Department of Meteorology and the Disaster Management Centre took part in the hands-on training that occurred in tandem with the installation. This was followed by the delivery of the Gap Analysis and Recommended Procedures in January, 2008. This report represents the final deliverable.

Appendix-A

A.1 ACRONYMS

CATS	Consequences Assessment Tool Set
CBO	Community-Based Organisation
CLAWS	CATS Localized Advanced Warning System
CONOPS	Concept of Operations
COP	Common Operating Picture
DMC	Disaster Management Centre
DoM	Department of Meteorology
DRM	Disaster Risk Management
EOC	Emergency Operations Centre
ICT	Information and Communications Technology
JTWC	Joint Typhoon Warning Center
MHWC	Multi-Hazard Warning Centre
NARA	National Aquatic Resources, Research and Development Agency
NBRO	National Building Research Organisation
NCDM	National Council for Disaster Management
NEIC	National Earthquake Information Center
NHC	National Hurricane Center
NGO	Non-Governmental Organisation
PTWC	Pacific Tsunami Warning Center
SOP	Standard Operating Procedures

Appendix-B

B.1 Consequence Assessment Toolset (CATS)

SAIC created and designed the CATS toolset in response to the need to predict the hazards from natural or industrial disasters, analyze the consequences on the surrounding environment, and assess the risk to the population. CATS uses the power of GIS to display the hazard footprint on the map, perform the consequence assessment, facilitate the resource management, and create visual results and reports. Conceptually, this defines CATS application domain in the disaster management cycle as:

- *Before: Planning and Training*
- *During: Emergency Management*
- *After: Recovery*

The ESRI Geographic Information System (GIS) software provides the framework and the basic mapping tools for the CATS operation. The CATS software modules collectively operate as an extension to this basic framework and allow for the hazard simulation and resource allocation to mitigate the effects on the affected population. In terms of the logical flow of information, the hazard models in CATS produce spatial output. Their impact on the spatial assets is determined and conversely, other spatial assets are employed to mitigate the effects of a particular hazard.

The current toolset in CATS can analyze hurricanes and typhoons, storm surge, earthquakes, explosions, and chemical and toxic material spills. Other disasters of known geographical extents such as firestorms may be simulated using the manual hazard tools. Additionally, CATS provides an emergency-situation early warning system to warn of the onset of a disaster event such as a tsunami time-of-arrival.

In the normal operational mode, an emergency management center uses CATS to store information on the population, geographical, administrative, and logistical data necessary for response to a disaster. Various tools exist in CATS for this resource management and their allocation during time of crisis. The CATS tools and its collection of customized database are designed to provide a common operating picture for various emergency responders to answer the fundamental disaster management requirements of:

- *"how many people are affected and for how long?",*
- *"what assets are available to mitigate the effects of the disaster?"*

The capabilities of CATS to answer these questions are summarized in Figure B.1.

Why CATS?

- CATS provides the core technology for fusing data and model prediction into a seamless common operational picture
  - Fuse hazard and asset information
  - Rapidly determine affected population
  - Assist in allocation of Shelter / Water / Food / Sanitation
  - Provide the common operational picture to all responders

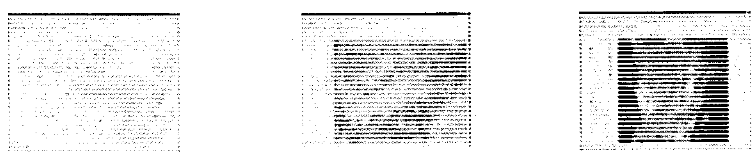


Figure B.1 CATS Core Technology and Data Fusion

B.2 CATS Map View

The CATS installation leaves an icon on the desktop as well as making an entry in the Windows' *start* menu. CATS is normally launched by double clicking the CATS icon and presents a window to select a document to load as shown in Figure B.2.

Starting CATS

- Click the CATS Icon on the desktop
- The CATS Document Loader Screen will appear
- Select the Open an Existing Map Radio Button
- Select the SriLanka-Fort-District.mxd
- The Preview Button can be clicked to preview the map
- Click the OK Button

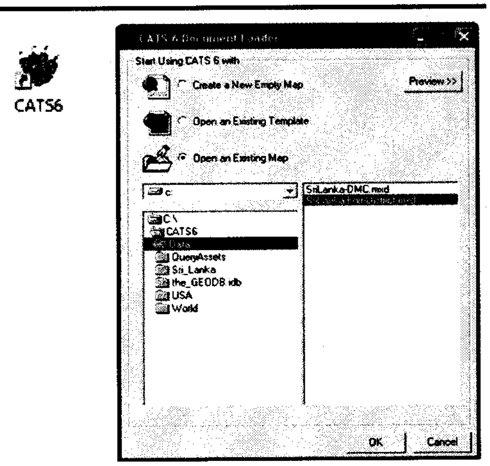


Figure B.2 CATS Application Startup and Document Loader

The *Preview* option allows the user to see the selected map as shown in Figure B.3. In this example, the map of Fort District in Sri Lanka is selected.

CATS 6 Document Loader Preview Window

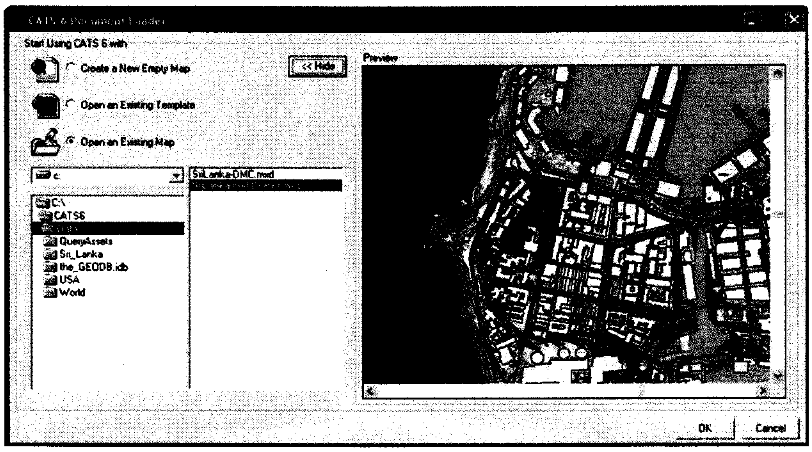


Figure B.3 Document Loader preview window

Once a selection is made, the code proceeds to display its main map view. The only exception is that during the very first CATS startup the user will be asked to navigate to and select a valid CATS license file. Figure B.4 shows a map view of the Fort District. As seen in the figure, CATS *extends* the existing toolbar in ArcMap as well as creating a set of menu items on the top menu banner.

CATS 6 Map View – Fort District, Colombo

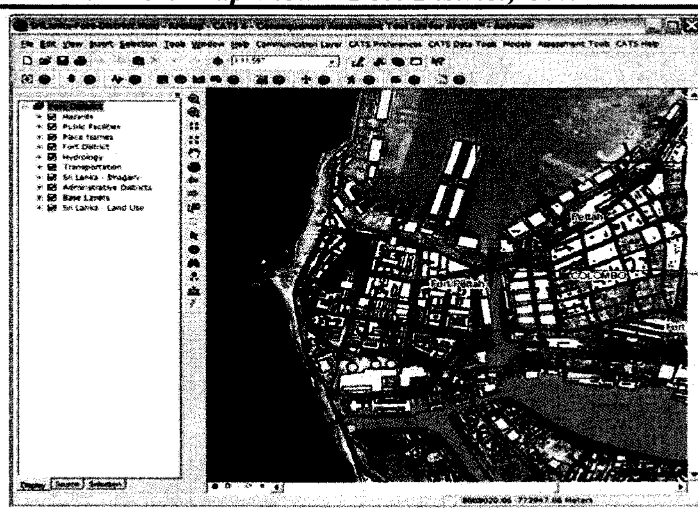


Figure B.4 CATS Map View with a Loaded Document

The CATS toolbar includes all the tool tips, which need to define a single location on the map in order to launch the tool. The procedure is to click on the tool icon, then click on the vicinity of the event on the map. This brings up a screen to make further adjustments to the coordinates of the event before launching that tool. Figure B.5 lists the available tools on the CATS toolbar. A brief description of each tool is also included.

CATS Toolbars

	Rapid Hazard Analysis (RHA)	High Explosives and Toxic Industrial Materials (TIMS)
	ALOHA	Atmospheric Dispersion Model
	Earthquake	Seismic Modeling Tool
	Manual Hazard	Hazard Drawing Tool
	Terraserver-USA	Web-based tool gathering for gathering US Imagery data.
	WX Query Tool	Shows weather as Wind barbs on the map
	Escape	Population Evacuation Model
	Shape Maker	Asset creation tool

Figure B.5 CATS Tools Launched by Clicking on the Map with the Tooltip

The CATS Menu items on the top banner include system settings and preferences, data management tools, and models that perform computation of hazard events or provide assessments tools. In contrast to the toolbar items, these tools do not require the pre-selection of a single map location to begin processing. Figure B.6 summarizes the general rules governing the distinction between the tools and menus.

CATS Toolbars, Menus, and Menu Items

- Why are some things Controls on a toolbar, while others are Menu Items on a Menu?

Controls on Toolbars – These are generally tools which interact with the map through clicking or dragging and shape

Menu Items on Menus – These tools may be spatial, but they do not interact directly with the map

Figure B.6 CATS Toolbar and Menu Items

The following sections are devoted to the detailed discussion of the CATS tools, menus, and relevant examples. In particular, the final sections provide a comprehensive treatment of the hazards, their consequences, and application of CATS specialized models.

B.3 CATS Map View CATS Communication Layer, Preferences, and Weather

As mentioned before, the CATS menu items are appended to the standard ArcMap menu bar. The first menu item is the *Communications Layer*, which provides the interface between the CATS ArcGIS extension and the various CATS tools. There is rarely a need to use this capability and it is only designed to provide a restart capability for the CATS application. Figure B.7 shows the contents of this menu.

Start/Stop Communication Layer

- The Communication Layer provides the means by which the CATS ArcGIS 9 extension communicates with CATS applications. It is designed to restarted automatically, if stopped. However, it may be stopped and started manually.
- Start/Stop ICE is not currently used in the Commercial CATS Product

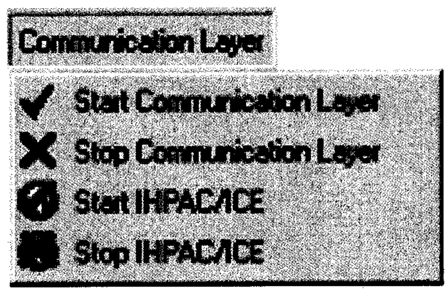
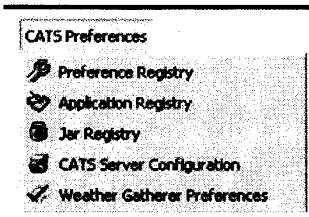


Figure B.7 CATS Communication Layer Manager

Figure B.8 shows the elements of the next menu item, *CATS Preferences*. There are five categories of the preferences, which define the operating environment for the CATS application. A short descriptor follows each menu item in this figure.

Preferences and Configuration Menu and Menu Items



Preference Registry	CATS specific settings
Application Registry	Allows application be registered with CATS.
Jar Registry	Java Jar Registration
CATS Server Configuration	Configures NOAA Weather settings
Weather Gatherer Preferences	Configures Spatial and Temporal weather settings

Figure B.8 CATS Preferences Menu

Clicking on the first menu item labeled the *Preference Registry*, reveals a set of tabs as shown in Figure B.9. These tabs are used to convey system-related data and provide administrative types of information. For example, the CATS version number and the Java RMI communications port settings. The figure guides the user in choosing the appropriate entries in this screen for the normal CATS operation.

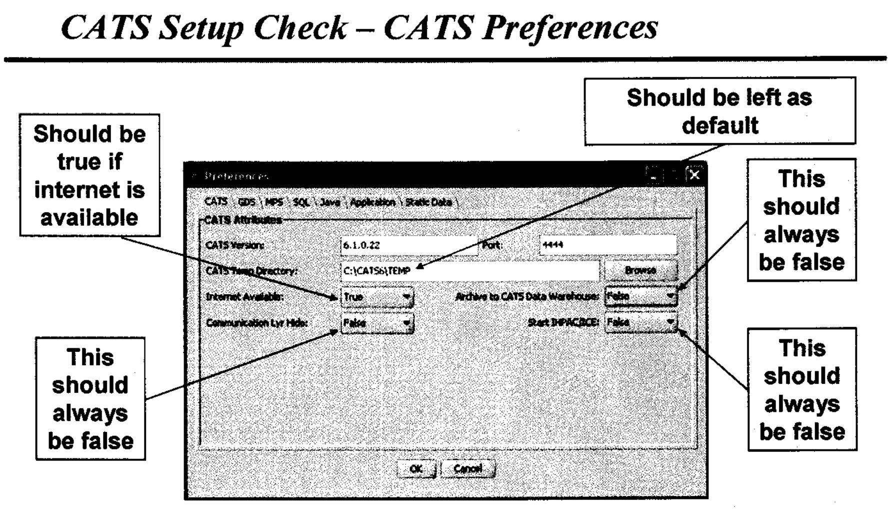


Figure B.9 CATS Preferences – Preference Registry, CATS Tab

The remaining tabs under the *Preference Registry* and their meaning and functionality are displayed in Figures B.10 through B.13. These tabs hold information related to the MYSQL database server, CATS private Java runtime libraries, any external application available to CATS such as ALOHA, and the location of CATS static data files, respectively.

The two tabs labeled *GDS* and *MPS* are intentionally left out as they are designed for the CATS developer use. The next two menu items under CATS Preferences are the *Application Registry*, which allows the user to change the order of the components in the CATS toolbar and the *Jar Registry*, which shows the CATS Java library components. The user normally does not alter these settings.

CATS SQL Settings

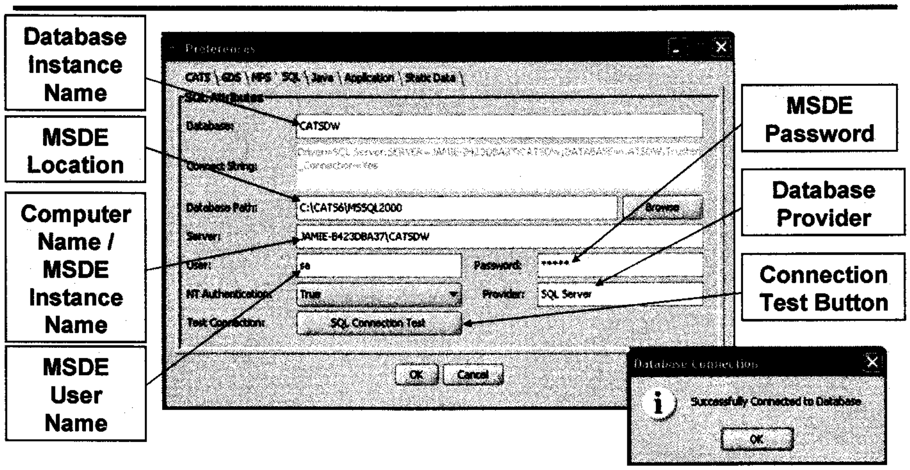


Figure B.10 CATS Preferences – Preference Registry, SQL Tab

Java Preferences

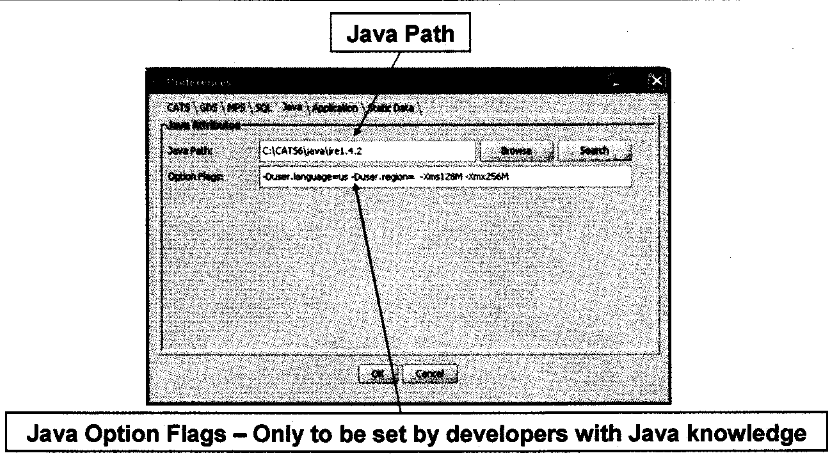


Figure B.11 CATS Preferences – Preference Registry, Java Tab

Application Preferences

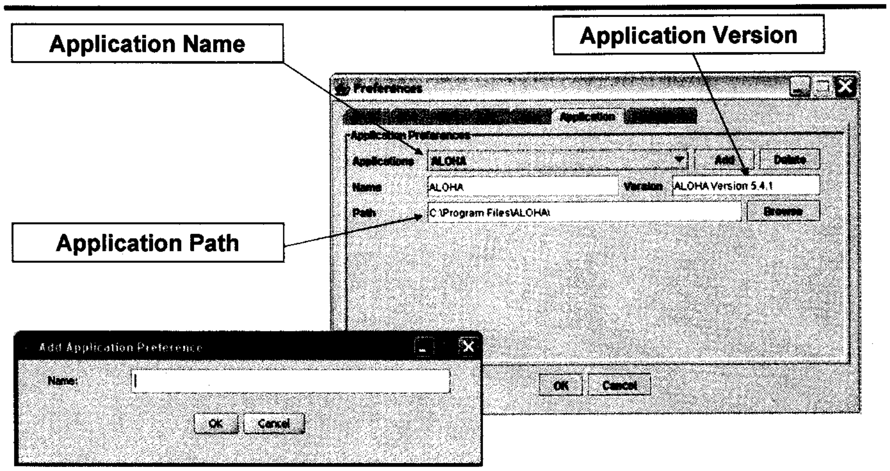


Figure B.12 CATS Preferences – Preference Registry, Application Tab

CATS Static Data

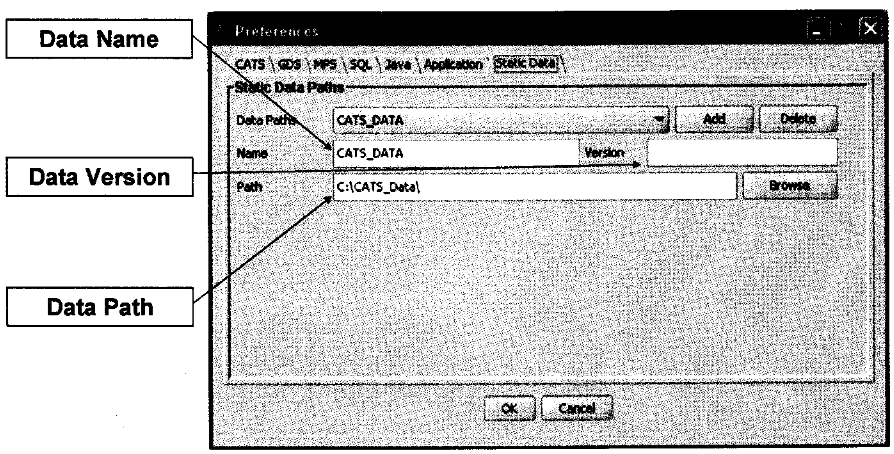


Figure B.13 CATS Preferences – Preference Registry, Static Data Tab

The *CATS Server Configuration* menu item is the next option under the preferences and as shown in Figure B.14 allows for entering the remote weather resources. In the example shown, the NOAA sites have been entered.

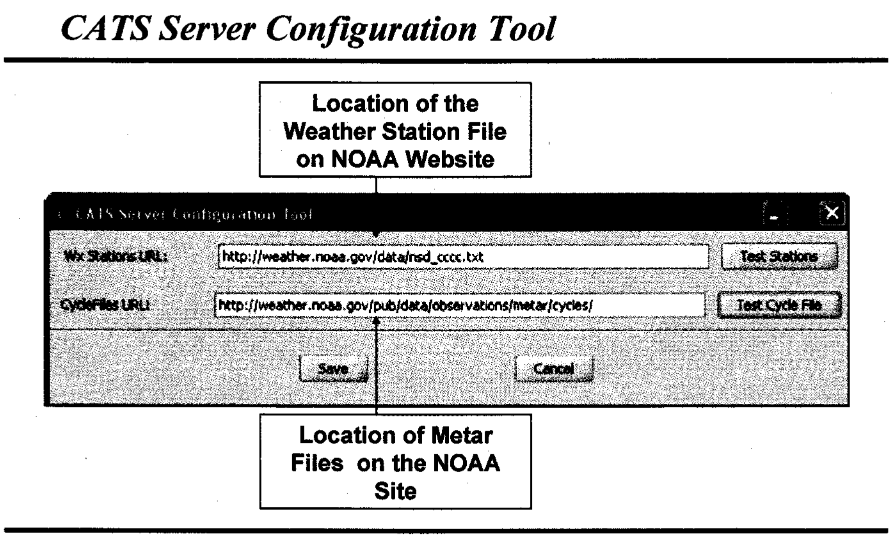


Figure B.14 CATS Preferences – Weather Server Configuration

Figure B.15 shows the result of selecting the last entry under the CATS preferences, *Weather gatherer Preferences* menu item. Also shown are a description of the terms and a map of Sri Lanka and its Latitude-Longitude bounding box. As the name implies, this menu item is used to define a geometric bounding box to retrieve the weather data in the course of the analysis. The CATS weather search engine will confine its data acquisition to this area.

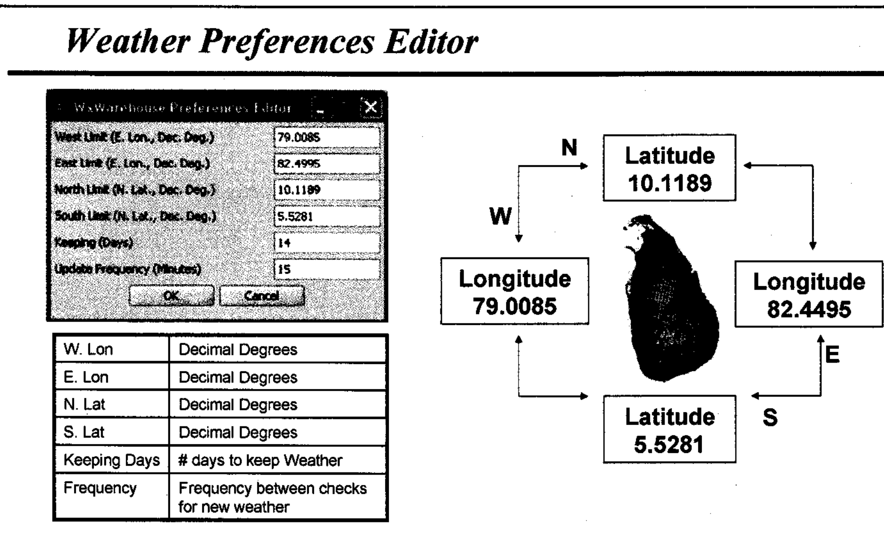


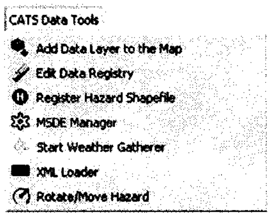
Figure B.15 CATS Preferences – Weather Gatherer Preferences

B.4 CATS Data, Models, and Assessment Tools

We now proceed to discuss the remaining menu items available in CATS. These are *CATS Data Tools*, CATS *Models*, CATS *Assessment Tools*, and *CATS Help*, respectively.

The CATS *Data Tools* is at the heart of the CATS operation. These menu items facilitate the retrieval, display, and organization of the data into various categories and their registration with the CATS database engine. Figure B.16 shows the Data Tools menu and Menu Items as well as a table describing the function of each menu item.

Data Tools Menu and Menu Items



Add Data Layer to the Map	Adds a data layer based on the CATS Registry
Edit Data Registry	Allows the user to edit the CATS Data Registry
Register Hazard Shapefile	Allows a Shapefile generated by other means to be added to CATS as a Hazard
MSDE Manager	Allows user to manage data in the CATS MSDE database – Currently only weather data
Start Weather Gatherer	Starts the CATS Weather Gatherer – NOAA Data
XML Loader	Loads CATS Hazard XML
Rotate/Move Hazard	Allows CATS Generated Hazards to be rotated or moved.

Figure B.16 CATS Data Tools Menu and Menu Items

The next two Figures, B.17 and B.18 show examples of adding a registered layer to the map in two different ways. The user may already know the type and category of an asset layer, for example building footprint. Alternatively, he may wish to search using specific keywords as the examples indicate.

Add a Data Layer to the Map

- Under CATS Data Tools, Select Add Data Layer to the Map
- Click the Asset Radio Button
- Choose Category Buildings
- Choose Category None

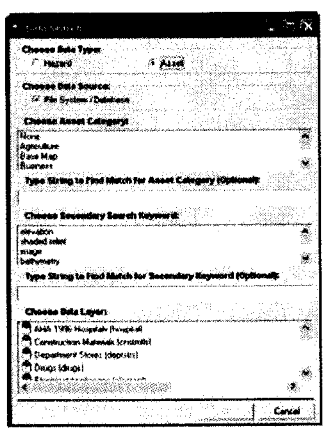


Figure B.17 Adding Registered Layers to the CATS Map Display

Add a Data Layer to the Map

- Type the Sri Lanka into the Text Box Below the Choose Secondary Keyword Listbox
- Type the Fort District into the Text Box Below the Choose Secondary Keyword Listbox
- Click OK Button

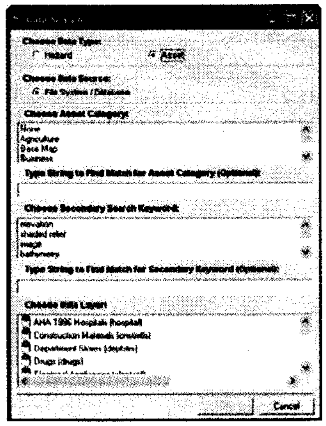


Figure B.18 Adding Registered Layers to the CATS Map Display, Continued

Figure B.19 shows how to edit the *Data Registry*. As shown in the figure, data may be added, modified, or removed. A search option is also available to locate specific data records. There are several tabs within the data registry to perform various tasks. For example, the *Register* tab provides selections for registering hazard and asset layers and edits existing data. The example in the figure corresponds to the hazard registry.

Editing the Data Registry

- **Add, Edit, Delete**
- **Searchable Index**
- **Layers must be registered to be used in RRS and Consequence**
- **Gives the user the ability to easily locate data**

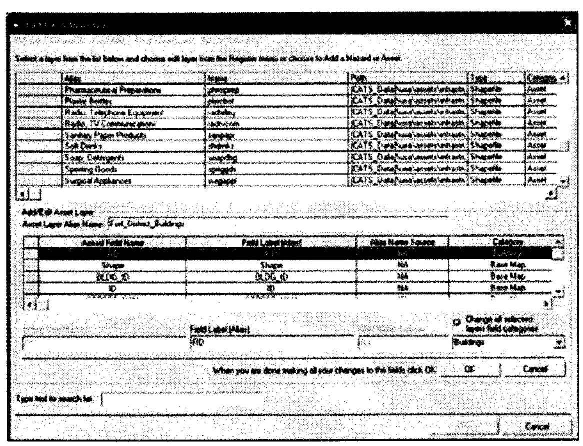


Figure B.19 Registering a Hazard Layer in CATS Registry

The concept of registering an asset layer is demonstrated in Figures B.20 and B.21 where the existing Fort District Buildings layer is first removed, then added back in, and finally modified to represent a new asset layer. Routine application of registering assets is in the course of performing hazard consequences on exposed population where the population data is registered as an asset. Note that any data registry is performed only once and the database will retain the information for the subsequent CATS calculations.

Editing the Data Registry – Add a New Asset Layer

- **In the Table of Contents, Right Click and Remove Fort District Buildings**
- **Under CATS Data Tools, Click Edit Data Registry**
- **On the Edit CATS Registry Screen, Click Register menu and select Add an Asset Layer to the Registry**

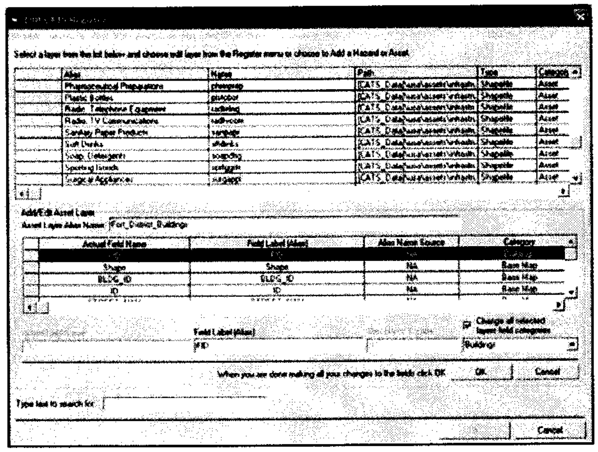


Figure B.20 Editing the Data Registry, Continued

Editing the Data Registry – Add a New Asset Layer 2

- **Browse to the Fort District Buildings Shapefile**
- **In the Categories Textbox, Type Buildings**
- **Click on the Change All Selected Layers Field Categories**
- **Click the OK Button**

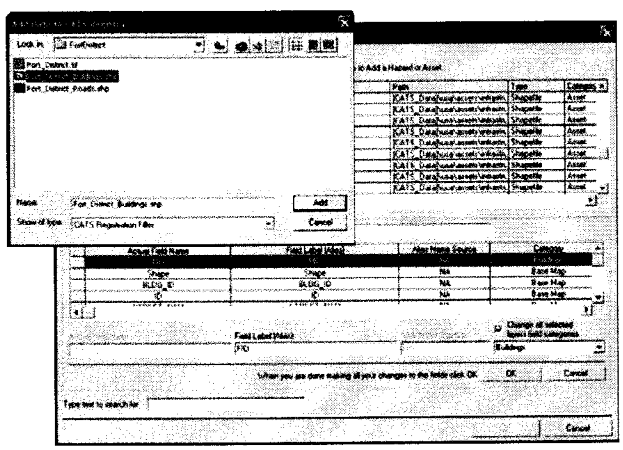
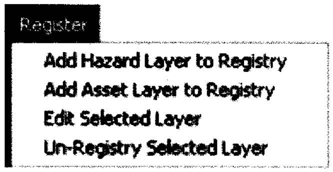


Figure B.21 Editing the Data Registry, Continued

Figures B.22 through Figure B.27 show the remaining options under the data registry. Each figure also demonstrates the utility of the tool.

Data Registry – Register Menu



Add Hazard Layer to Registry	Register a Hazard Layer.
Add Asset Layer to Registry	Register an Asset Layer.
Edit Selected Layer	Edit a Registered Layer.
Un-Registry Selected Layer	Unregister a Registered Layer

Figure B.22 Editing the Data Registry, Continued

Data Registry – Keywords Menu

Edit Keywords for a Selected Layer	Change keywords associated with a Registered Layer – This is extremely helpful in searching for data. It is possible to add too many keywords. They should be used in moderation.

Figure B.23 Editing the Data Registry, Continued

Edit Data Registry - Keywords

- On Keywords Menu, Select Edit Keyword for Selected Layer
- Click the add Button and Type Sri Lanka into the Textbox.
- Click the Add Button and Type Fort District into the Textbox
- Click the OK Button

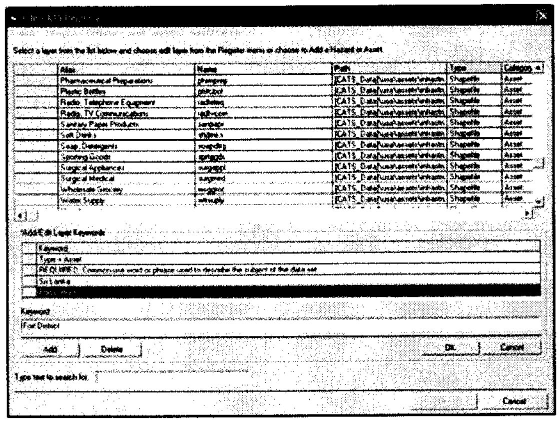


Figure B.24 Editing the Data Registry, Continued

Data Registry – Field Alias Menu

Edit User Specified Field Alias	Change Field Alias

Figure B.25 Editing the Data Registry, Continued

Data Registry – Asset Categories

Edit Asset Categories	Change Categories associated with a Registered Layer

Figure B.26 Editing the Data Registry, Continued

Data Registry – Add to the View

Add Selected Layer to View	Add a Layer to the Map

Figure B.27 Editing the Data Registry, Continued

The final menu item under the CATS Data Tools menu as discussed here is the CATS Weather acquisition system as shown in Figure B.28. The Weather Gatherer normally obtains surface weather observations from the National Oceanographic and Atmospheric Administration (NOAA) website.

Start The CATS Weather Gatherer

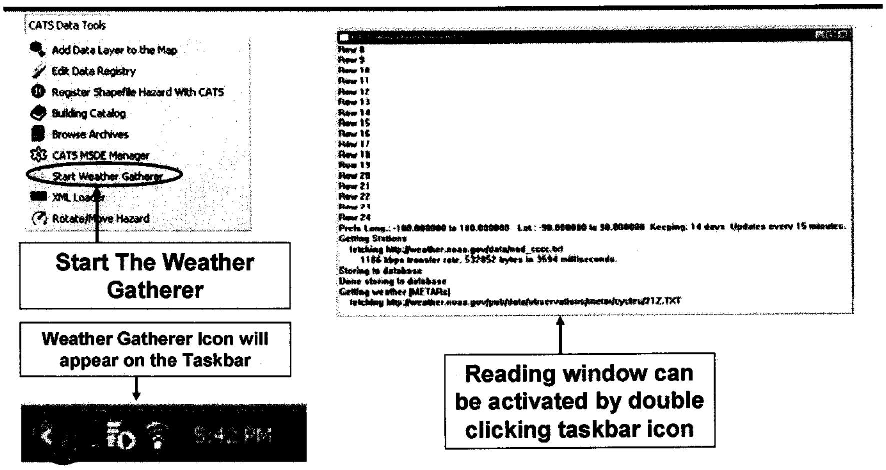
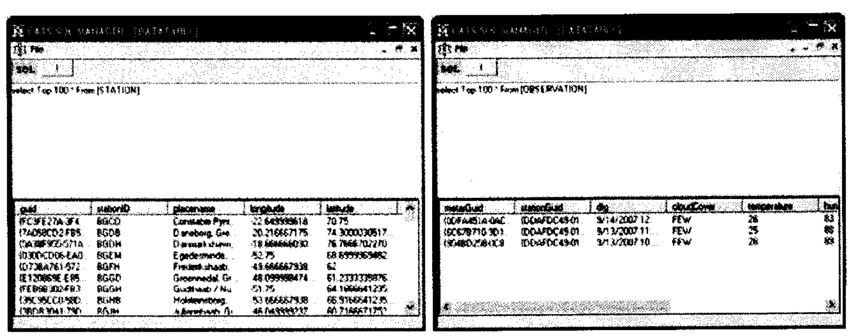


Figure B.28 Gathering Weather Data for CATS

Figure B.29 shows how the WxQuery tool is used to obtain weather data for CATS within a certain radius of the location and at times of interest.

Weather Observations



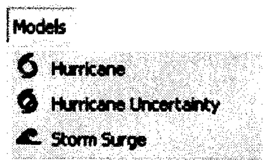
SQL Statement

select Top 100 * From [Station] ,[OBSERVATION] where [Station].guid = [Observation].stationGuid

Figure B.29 Weather Observation Stations and Data

The next drop down CATS Menu is labeled *Models* and as shown in Figure B.30 the Menu Items include Hurricane (Cyclone), Hurricane Uncertainty, and Storm Surge models. The Hurricane Uncertainty uses historical data from a locality to better calibrate the wind and damage patterns. The Storm Surge uses shoreline data from a locality to estimate flood damage, water inundation, and mean heights during the storm. Both of these models currently use US-specific data. The Hurricane model uses the hurricane and typhoon advisories for tracking and wind damage estimation.

Models Menu and Menu Items

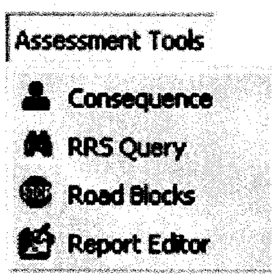


Hurricane	Hurricane Tracking and Wind Damage Estimation Model
Hurricane Uncertainty	Hurricane Probabilistic and Deterministic Damage Model
Storm Surge	Flood model based on high water levels associated with a Hurricane

Figure B.30 CATS Models and Their Descriptions

Figure B.31 shows the CATS Assessment Tools and Menu Items as well as a brief description of each tool. Consequence is generally a measure of the effects within the hazard zone while RRS handles the assets and resources outside the hazard zone. These tools will be explored in greater details in the next sections.

Assessment Tools Menu and Menu Items



Consequence	Creates an output report based on a Hazards effect on a Asset
RRS Query	Response, Resource, and Sustainability Analysis Reports
Road Blocks	Hazard containment analysis reporting
Report Editor	Create reports to be used in Consequence and RRS

Figure B.31 CATS Assessment Tools and Their Descriptions

The last CATS Menu includes the Help files and the CATS software identification as shown in Figure B.32 and Figure B.33.

• ***Help Menu and Menu Items***

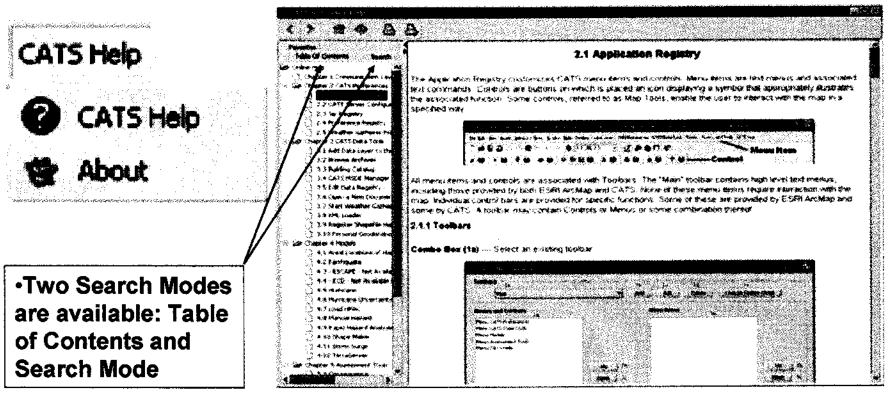


Figure B.32 Accessing the CATS Help Menu

About Menu Item

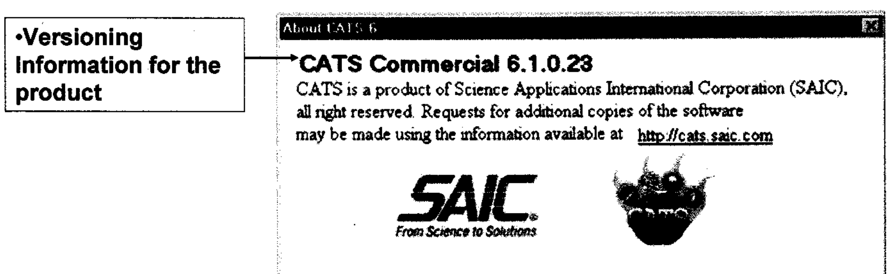


Figure B.33 CATS Software Signature and Identification

B.5 CATS Application - Hazards, and Consequences

The next three sections are a culmination of the previous discussions and are designed to serve as a self-guided tour of the CATS capabilities and may be thought of as CATS Assessment Tools in action. The CATS models are sequentially applied to set up and prepare the data, calculate the hazard footprints, and generate the consequence reports and set up roadblocks when applicable. The commentary will be kept to a minimum and only when necessary to introduce a new concept or call attention to a specific subject. The user may also consult the CATS Help files as an additional resource.

The general strategy in any incident and consequence management situation using CATS is to prepare and manage the available data and employ the appropriate models to estimate the extent of the hazard, assess its impact, and devise mitigation efforts such as providing roadblock information and keep-out zones. The data management normally involves asset registration and report creation. The hazard models may be divided into the two categories of technological and natural hazards. This section will concentrate on the technological hazards, namely damage from high explosives and toxic industrial materials.

Asset Registration was discussed in the previous section. The next data management menu item under the CATS *Assessment Tools* menu is the *Report Editor*. To generate a report of the consequences of the hazard or the available resources, one needs to initially create a template. This is done via the *Report Editor* tool. Figure B.34 through Figure B.38 show the various steps involved in setting up the report template.

Report Editor

- Under Assessment Tools, Select Report Editor
- On the Asset Layer Combobox, Select Sri Lanka Population
- Type Sri Lanka Population in the Report Name Textbox

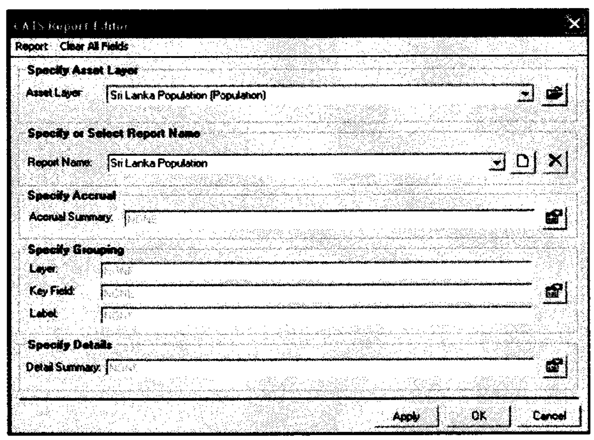


Figure B.34 CATS Assessment Tool – Report Editor

Report Editor - 2

- In the Specify Accrual Groupbox, Click the button
- In the Field Combobox, Select TOTPOP20 and click the add button
- In the Accrual Label Textbox, type Population and click the accept Button

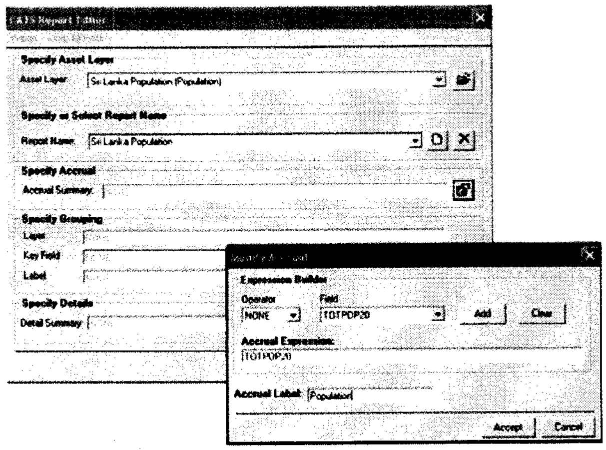


Figure B.35 CATS Assessment Tool – Report Editor, Continued

Report Editor - 3

- In the Specify Grouping Groupbox, Click the button
- In the Select Layer Combobox, Select TOTPOP20
- In the select Key Field Combobox, Select District
- In the Enter Fields Label Textfield, Type District and click the Accept Button

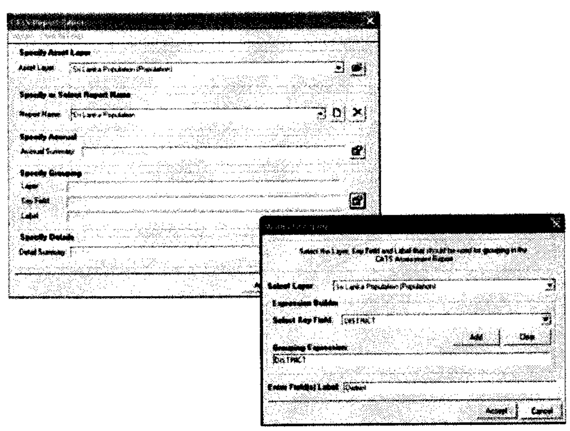


Figure B.36 CATS Assessment Tool – Report Editor, Continued

Report Editor - 4

- In the Specify Details Groupbox, Click the button
- In the Detail Combobox, Select Detail1
- In the field Combobox, select District
- In the Label Textfield type District

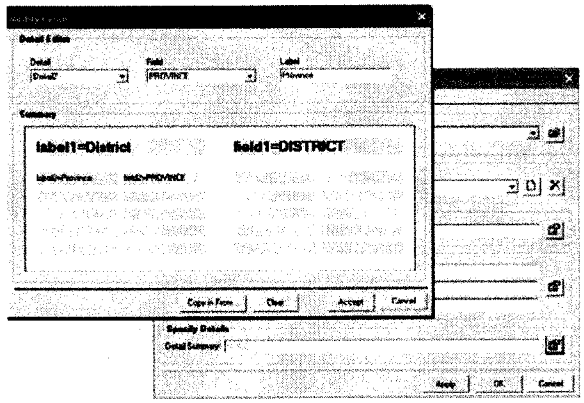


Figure B.37 CATS Assessment Tool – Report Editor, Continued

Report Editor - 5

- In the Detail Combobox, Select Detail2
- In the field Combobox, select Province
- In the Label Textfield, type Province and click the accept button
- Click the OK button on the Report Editor Form

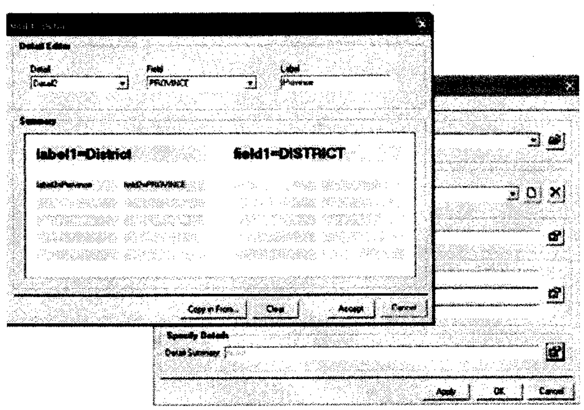


Figure B.38 CATS Assessment Tool – Report Editor, Continued

The first hazard analysis is the damage from a high explosive event. The Rapid Hazard Analysis (RHA) High Explosive (HE) option will be exercised to analyze a hypothetical situation. The RHA Control is selected and a click on the map in the approximate vicinity of the event will display a series of tabs to define the characteristic of the event in terms *Where*, *What, When,* and *Weather* with the aid of selection menus under each tab.

Figure B.39 through Figure B.43 show the succession of setting up the HE problem. Figure B.44 shows the final hazard footprint as well as bands of damage criteria on the map. Figure B.45 depicts the steps in determining the consequences of the population exposed to the explosion while Figure B.46 shows the final Consequence Report generated from the template.

RHA – Rapid Hazard Analysis

- Click the RHA Tool RHA Control
- Click and place the release point at the Hilton Hotel

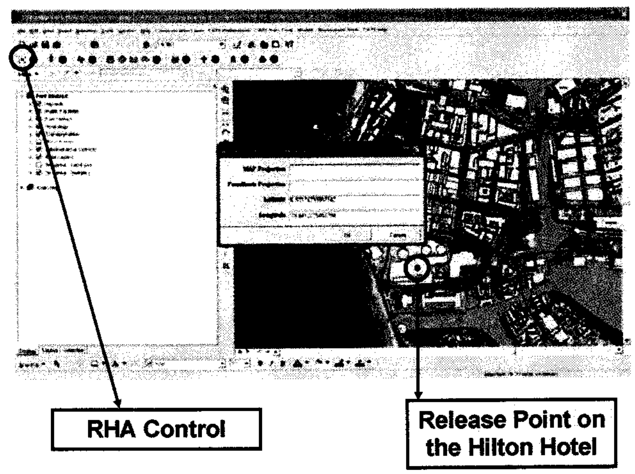


Figure B.39 CATS RHA Tool – HE Event

RHA – Where (HE)

High Explosives (HE)- Simple 2-Dimensional Blast Over-Pressure Model

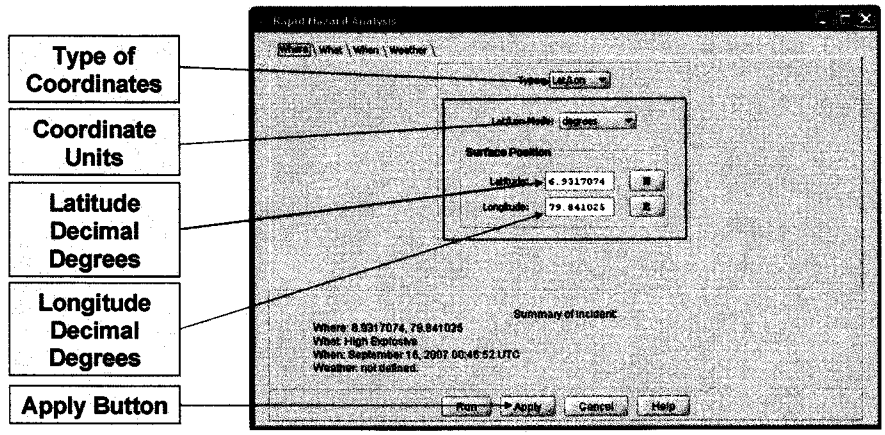


Figure B.40 CATS RHA Tool – HE Event Location

RHA – What (HE)

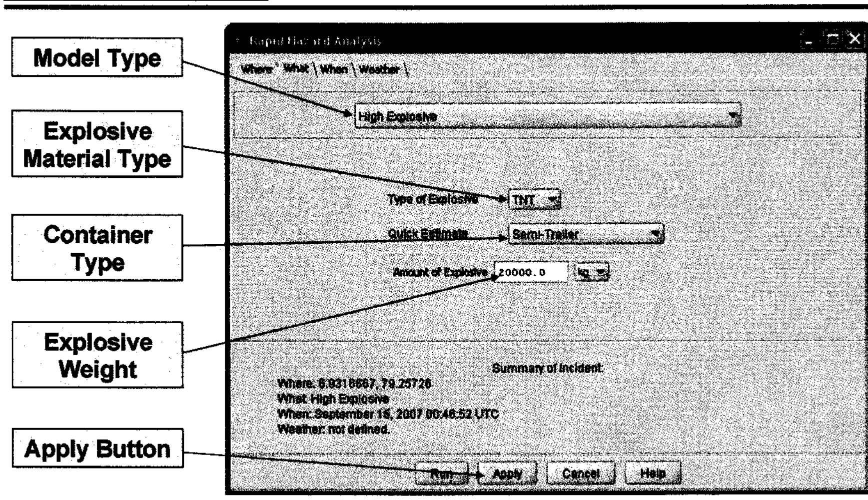


Figure B.41 CATS RHA Tool – HE Event Type

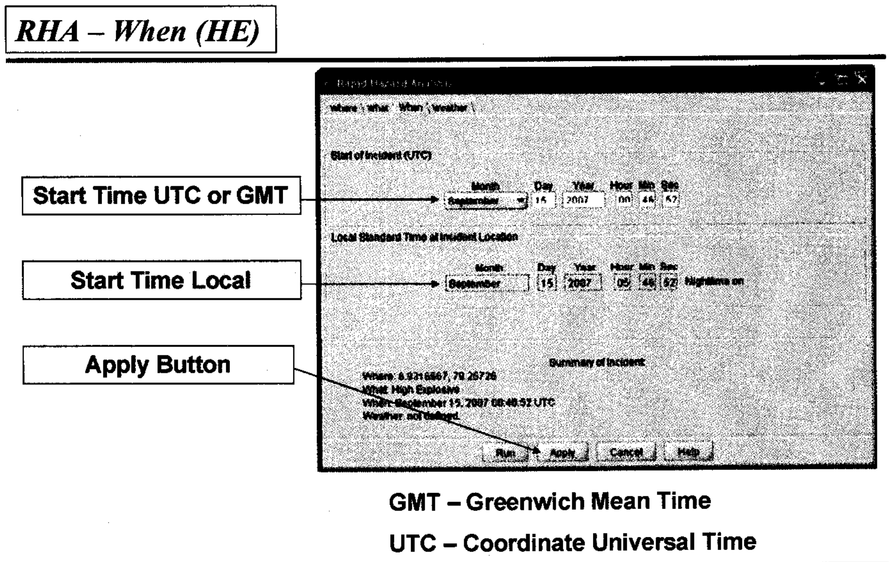


Figure B.42 CATS RHA Tool – HE Event Time

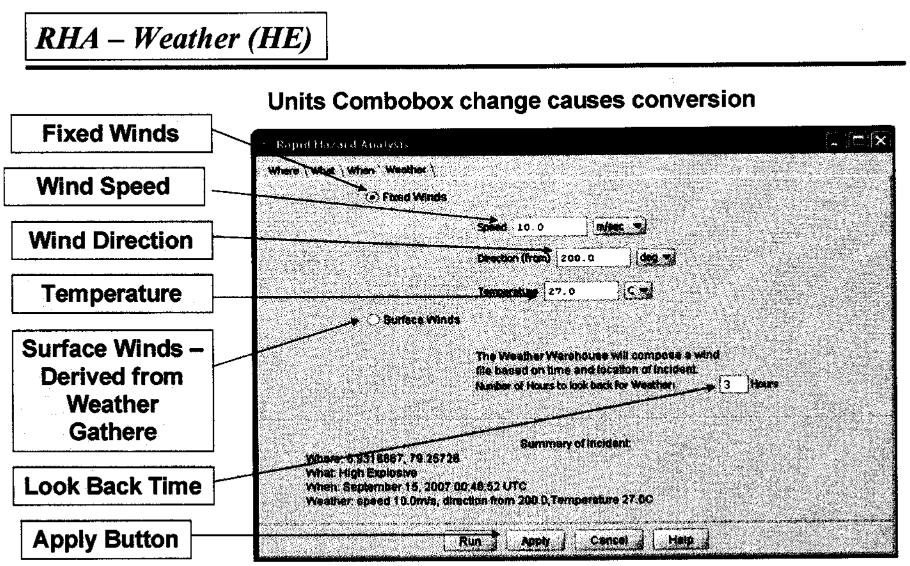


Figure B.43 CATS RHA Tool – HE Event Weather

High Explosive – Results Layers

HE produces damage estimates for infrastructure and population

Figure B.44 CATS RHA Tool – HE Event Shape and Damage Criteria

Consequence

Start Consequence under the Assessment tools Menu

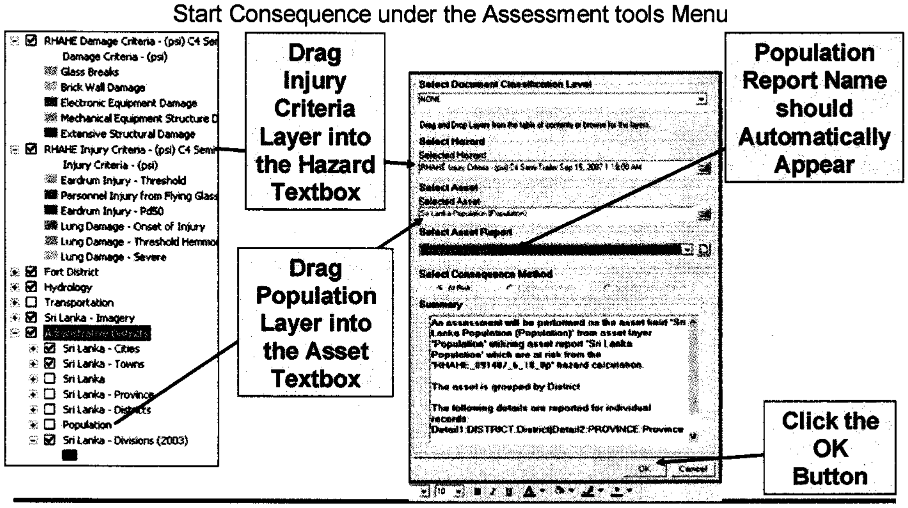


Figure B.45 CATS RHA Tool – HE Event Population Consequence

Consequence Results

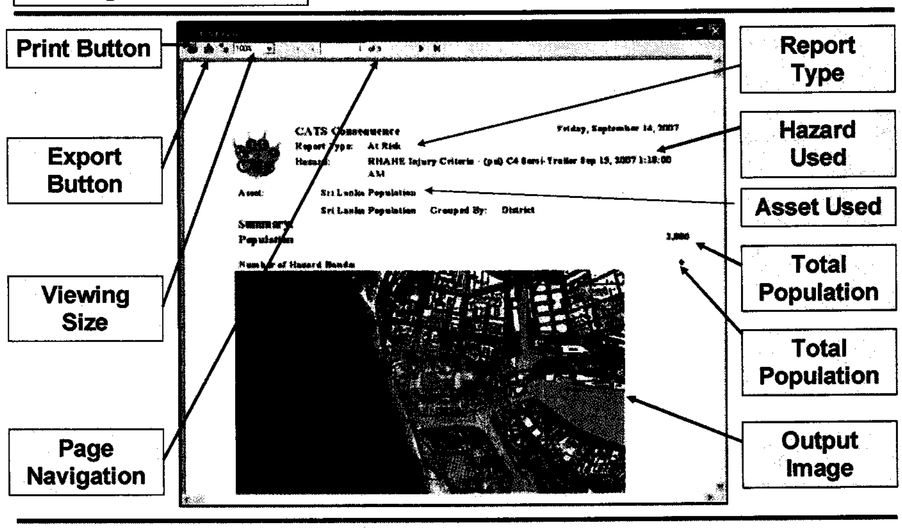


Figure B.46 CATS RHA Tool – HE Event Population Consequence Report

The next type of hazard under the RHA tool is the spillage of Toxic Industrial Materials (TIMS). The TIMS methodology is based on the Emergency Response Guide last published in 2004 and periodically updated jointly by the transportation departments of Canada, U.S., Mexico, and Argentina. The model is primarily designed as an initial response to a railroad or roadway accident. CATS can also handle the spill incidents involving fire.

The mechanics of running the model is the same as HE. Once the event is defined, the calculations proceed and the hazard footprint is placed on the map. Figure B.47 through Figure B.52 show the hypothetical problem set up and execution. With the current incident, the CATS *Roadblocks* model is also invoked to generate roadblocks on the access roads to the hazard area. Figure B.53 through B.55 show the initial setup, the Roadblock Report, and final CATS map display of the hazard and the roadblocks, respectively.

RHA – Rapid Hazard Analysis

- Click the RHA Tool RHA Control
- Click and place the release point at the Hilton Hotel

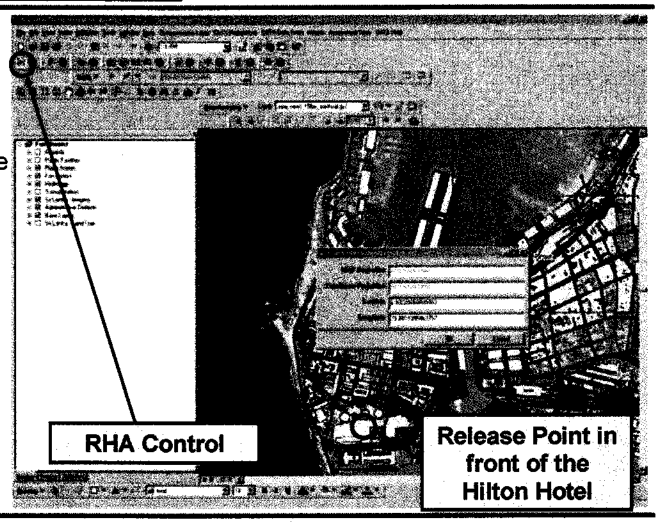


Figure B.47 CATS RHA Tool – TIMS Event

RHA – Where (TIMS)

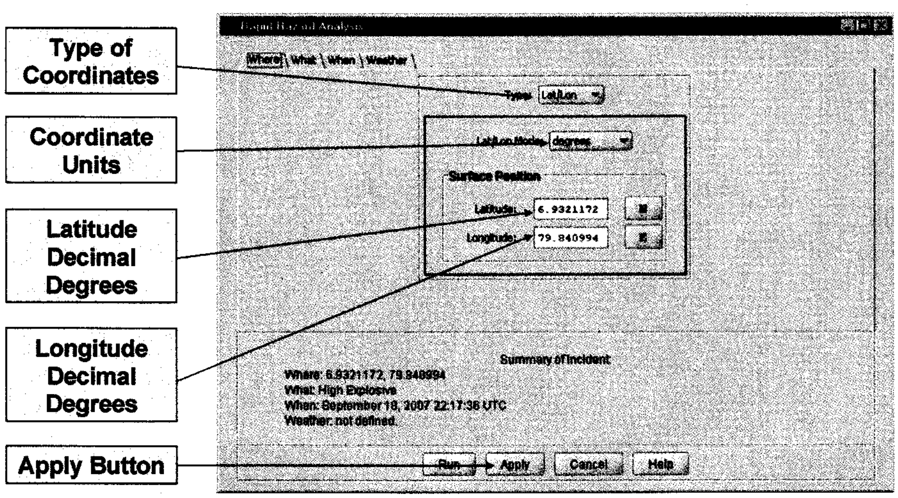


Figure B.48 CATS RHA Tool – TIMS Event Location

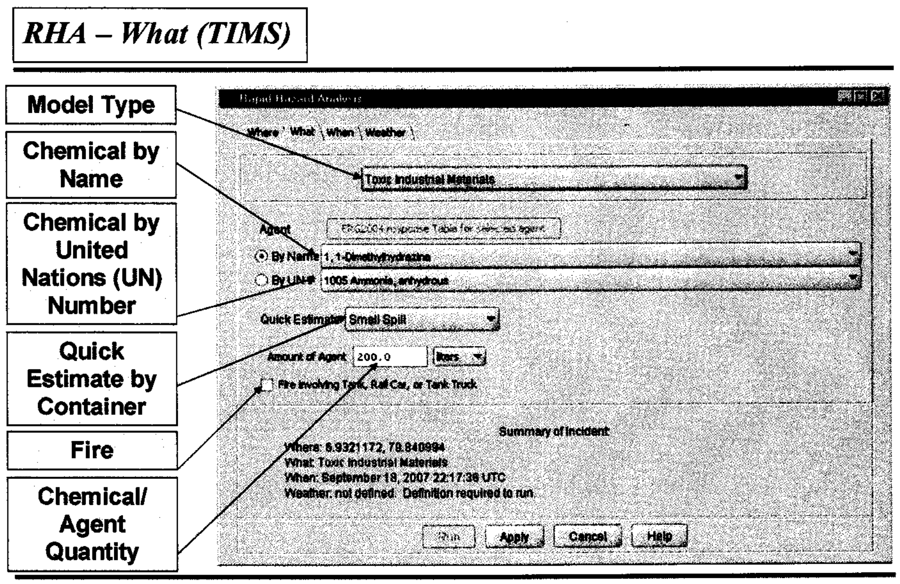


Figure B.49 CATS RHA Tool – TIMS Event Type

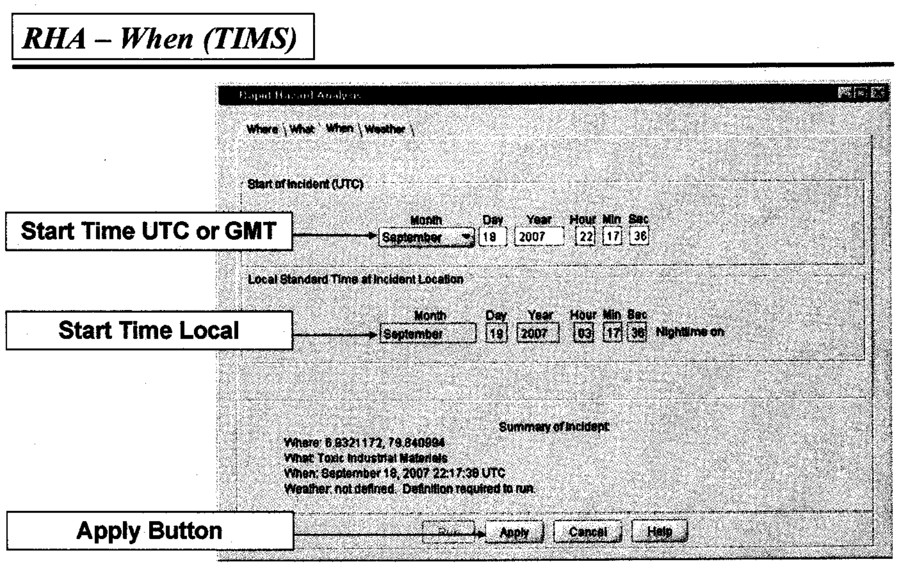


Figure B.50 CATS RHA Tool – TIMS Event Time

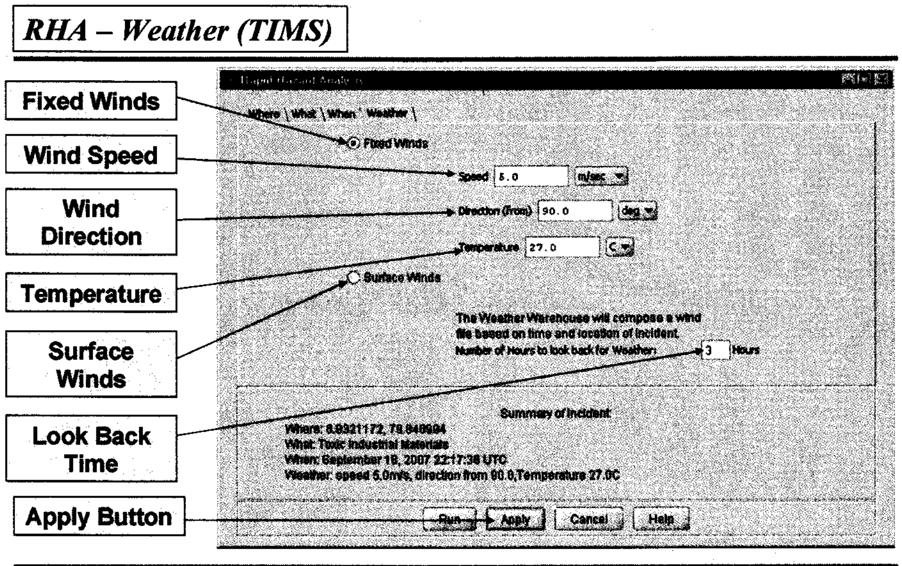


Figure B.51 CATS RHA Tool – TIMS Event Weather

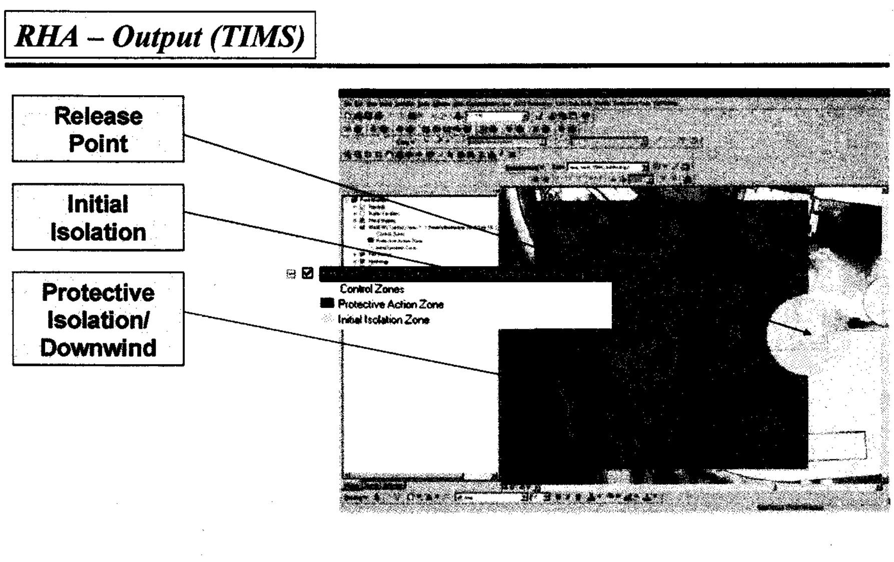


Figure B.52 CATS RHA Tool – TIMS Event Shape and Damage Criteria

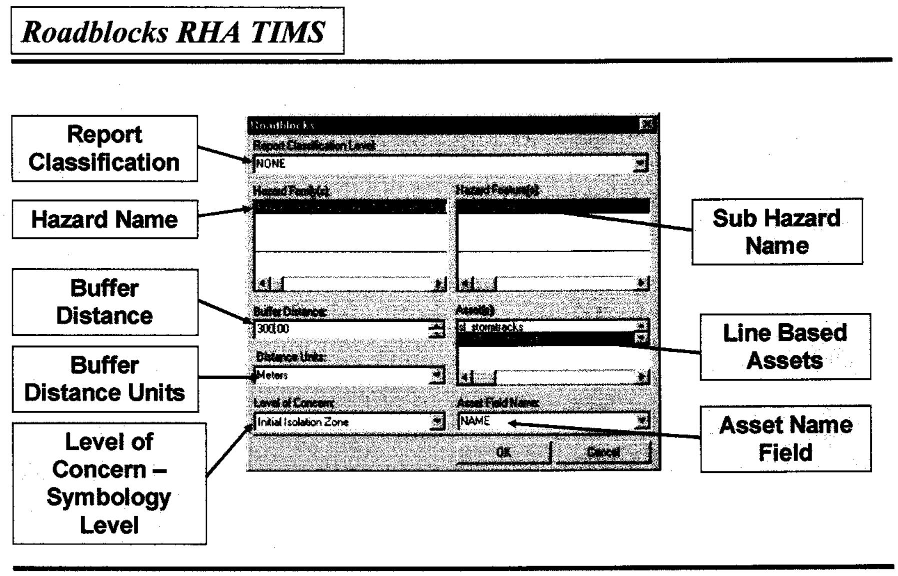


Figure B.53 CATS RHA Tool – TIMS Event Roadblocks Setup

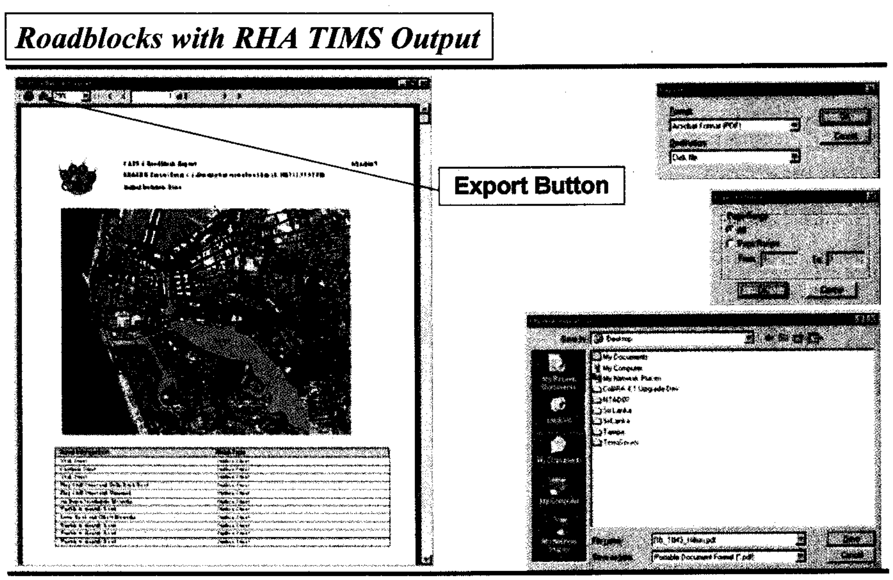


Figure B.54 CATS RHA Tool – TIMS Event Roadblocks Report

Roadblocks on RHA TIMS

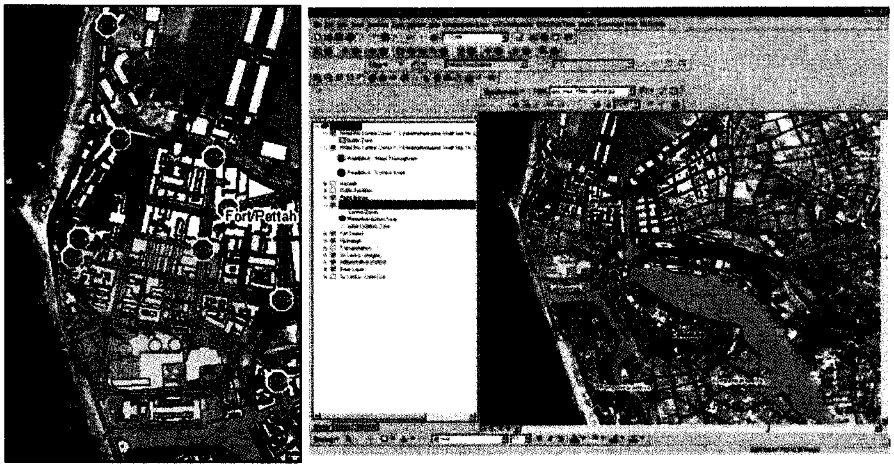


Figure B.55 CATS RHA Tool – TIMS Event Shape and Roadblocks

A more sophisticated model to treat chemical spills and dispersion is ALOHA, which is available on the CATS toolbar. Pertinent information about ALOHA is shown in Figure B.56. The execution of ALOHA requires more detail about the event, container shape, etc, and more expertise to run the model. Figure B.57 shows the various scenarios and hazards handled by the model. Figure B.58 to Figure B.64 show how ALOHA is launched and a problem is set up. Notice the details of the chemical agent and its physical characteristics, its container type and dimensions, and the hazard environment required to define the problem.

Figure B.65 and Figure B.66 show the native ALOHA tabular and graphical displays of the threat zone, respectively. Figure B.67 shows the same information after it has been automatically loaded into the CATS map display.

Areal Locations of Hazardous Atmospheres (ALOHA)

- Developed
  - Office of Emergency Management, EPA
  - Emergency Response Division, NOAA
- Uses
  - Chemicals Escaping from
    - Tanks
    - Puddles
    - Gases and Pipelines
- Can predict release rate changes over time

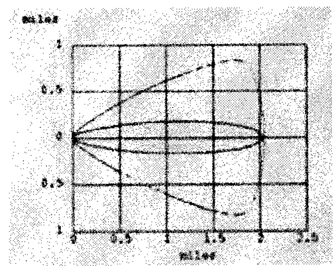


Figure B.56 CATS ALOHA Tool – Model Description

Areal Locations of Hazardous Atmospheres (ALOHA) 2

- Scenarios
  - Toxic Gas Clouds
  - Boiling Liquid Expanding Vapor Explosions (BLEVEs)
  - Jet Fires
  - Vapor Cloud Explosions
  - Pool Fires
- Hazards types Evaluated
  - Toxicity
  - Flammability
  - Thermal Radiation
  - Overpressure

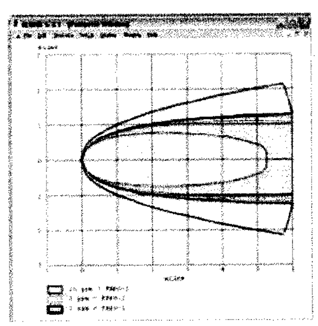


Figure B.57 CATS ALOHA Tool – Model Capabilities

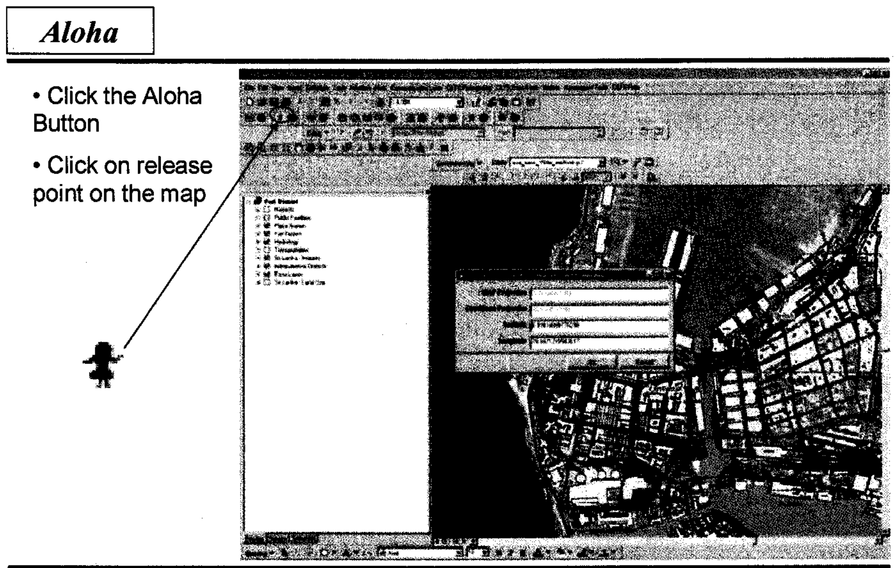


Figure B.58 CATS ALOHA Tool – Launching the Model

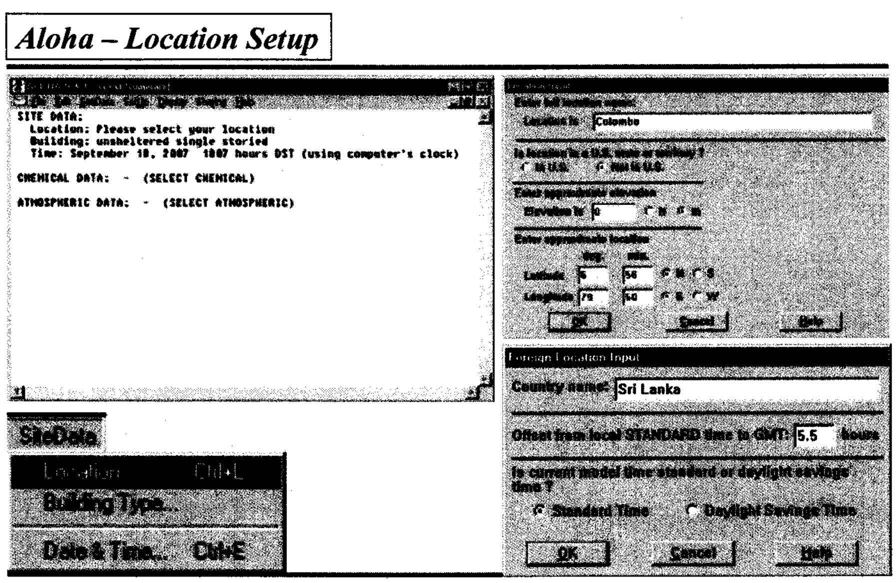


Figure B.59 CATS ALOHA Tool – Event Location

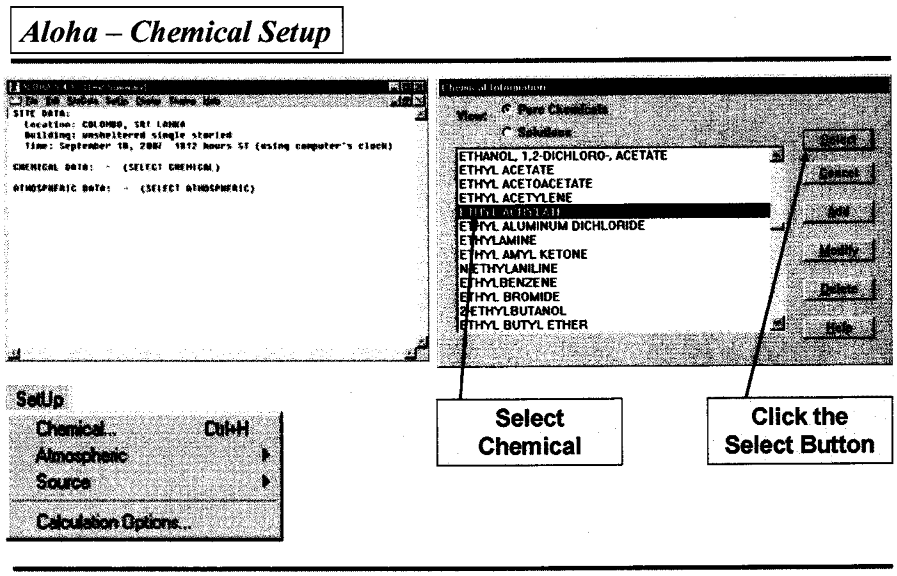


Figure B.60 CATS ALOHA Tool – Agent Type

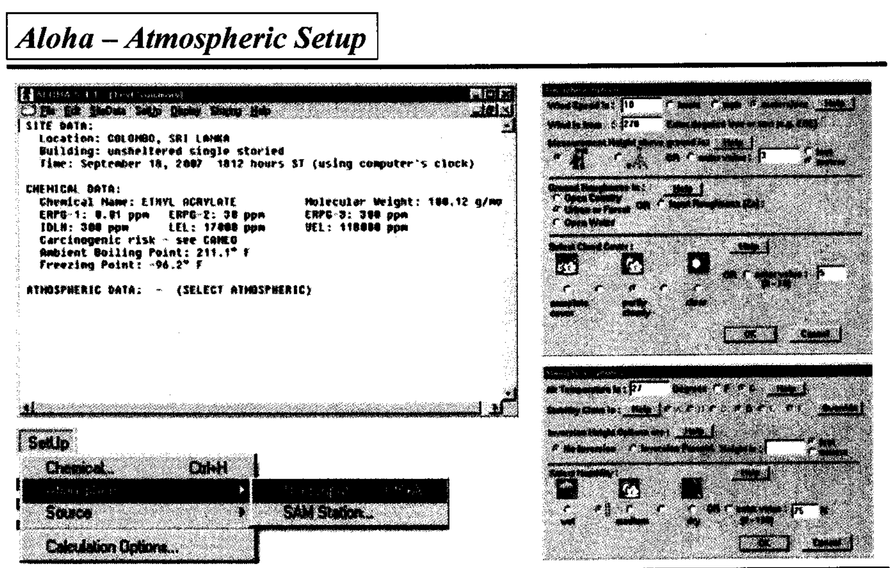


Figure B.61 CATS ALOHA Tool – Atmospheric Specifications

Aloha – Source Setup

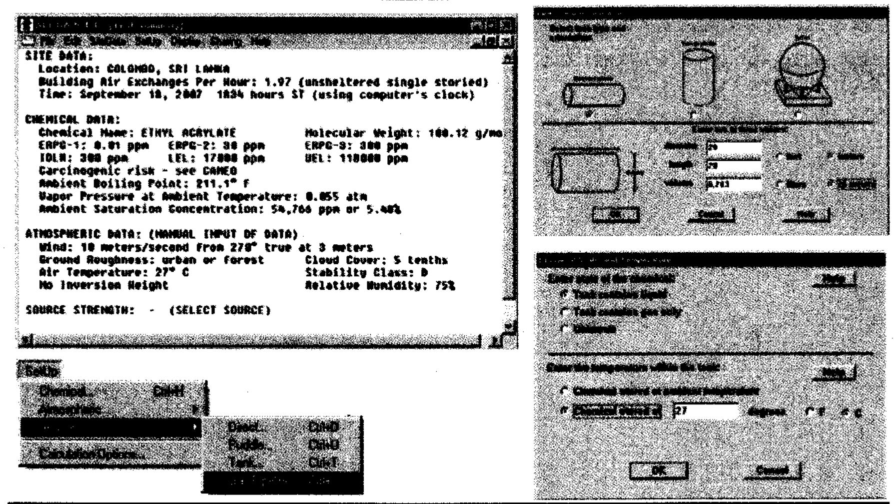


Figure B.62 CATS ALOHA Tool – Agent Container and Quantity

Aloha – Source Setup 2

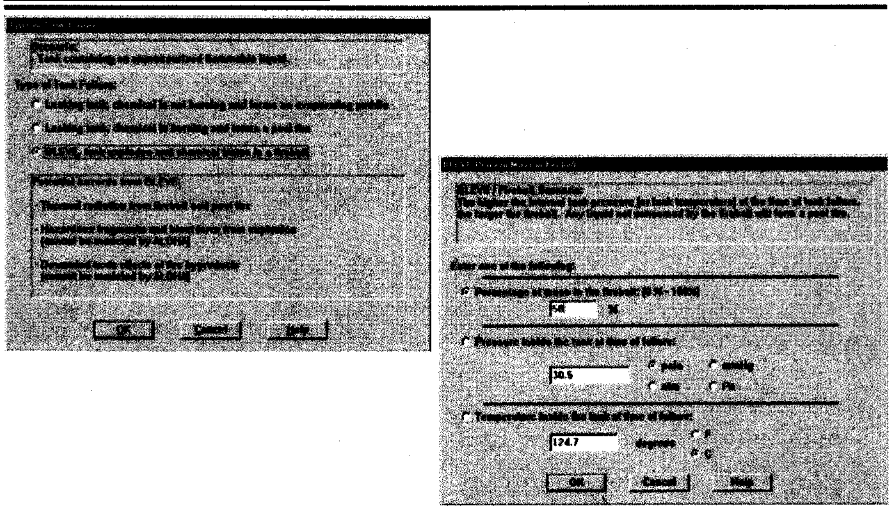


Figure B.63 CATS ALOHA Tool – Agent Specifications

Aloha – Source Setup 3

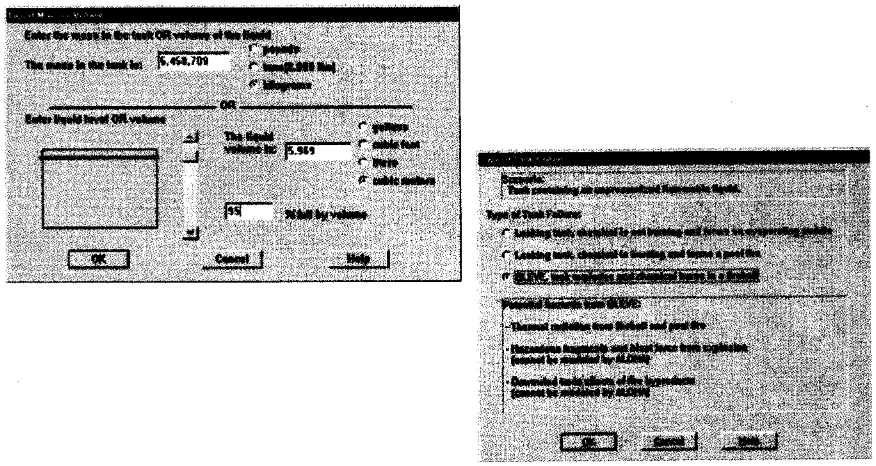


Figure B.64 CATS ALOHA Tool – Agent Container Specifications

Aloha – Threat Zone

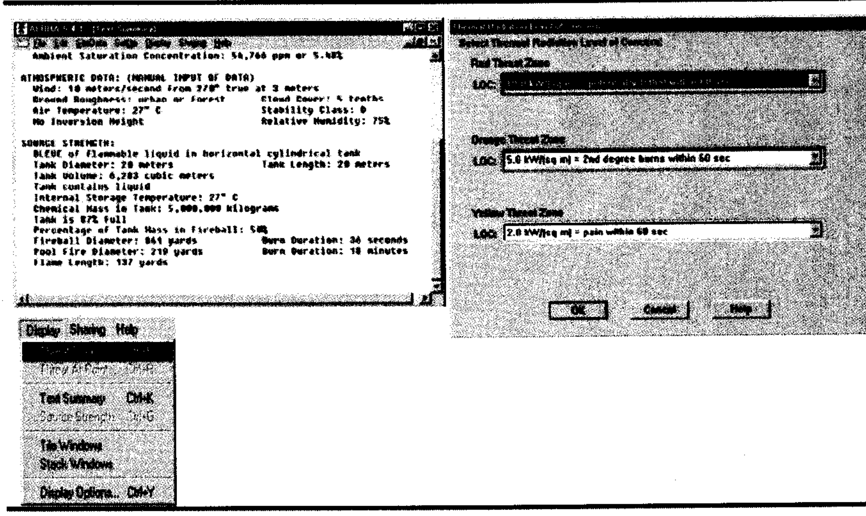


Figure B.65 CATS ALOHA Tool – Area of Concern

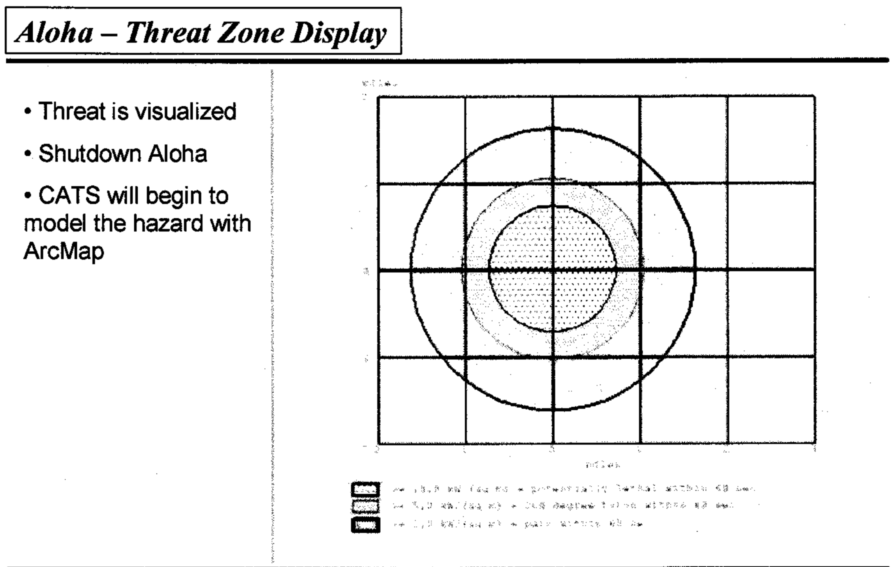


Figure B.66 CATS ALOHA Tool – Area of Concern Display

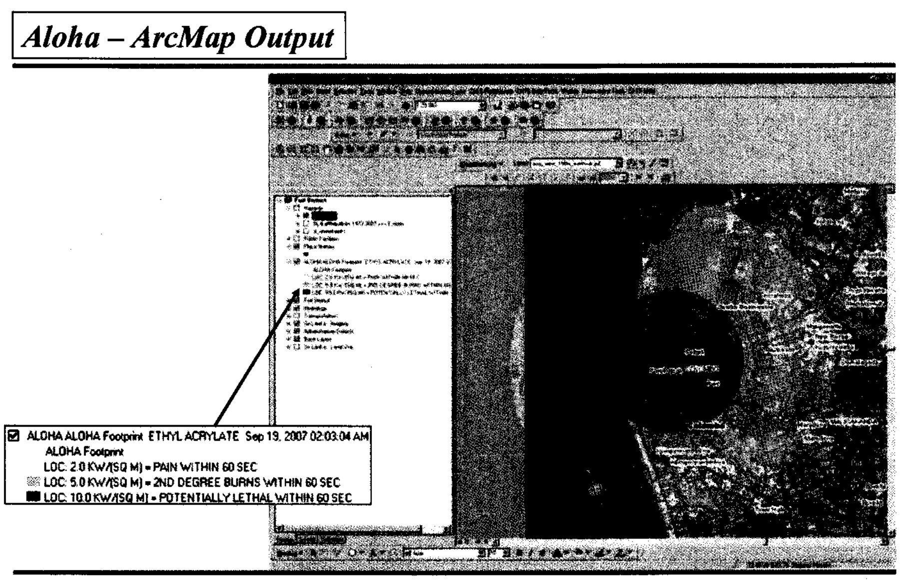


Figure B.67 CATS ALOHA Tool – CATS Display of the ALOHA Footprint

B.6 CATS Application - Manual Hazards, RRS, and Shapemaker

The tools *Manuel Hazards* and *Shapemake*r available as controls on the CATS toolbar, and the *RRS* capability under the CATS *Assessment Tools* menu are considered in this section. It should be noted that the CATS architecture allows for the interaction of a single hazard with multiple assets. The inverse, however, is not true i.e. simultaneous multiple hazards on a single asset or combined injuries are not handled. Therefore, a specific hazard is generated only once but an asset layer may be created multiple times.

Continuing with the self-guided CATS Application scenarios as before, the following three sets of examples will treat each capability in sequence, demonstrating their unique capabilities.

Manual Hazards components are used to draw and define a simple and single geometrical hazard shape on the map for simulation and quick-study scenarios. The geometric hazard shapes allowed under *Manual Hazards* are Rectangular, Circular, Polygon, and Buffer.

Figure B.68 shows a list of the *Manual Hazards* components, their icons, and functionality. The individual tools and their application are explored in Figure B.69 through Figure B.75. The Buffering tool is normally used to rope-in a line feature, thereby emulating a line hazard.

Manual Hazard Toolbar

	Rectangular Hazard	Draws Rectangular hazards
	Circular Hazard	Draws Circular Hazards
	Polygon Hazard	Draws Polygon Hazards – Double Click to finish hazard
	Buffered Hazard	Buffers features in other shapefiles
	Model Based Help	Help by Model

Figure B.68 CATS *Manual Hazards* Components

Manual Hazard Rectangle

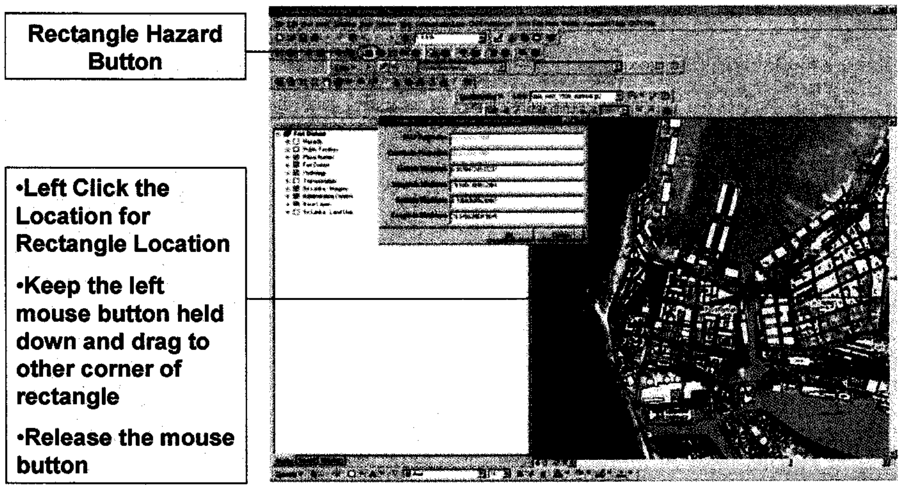


Figure B.69 CATS *Manual Hazards* Rectangle

Manual Hazard Rectangle 2

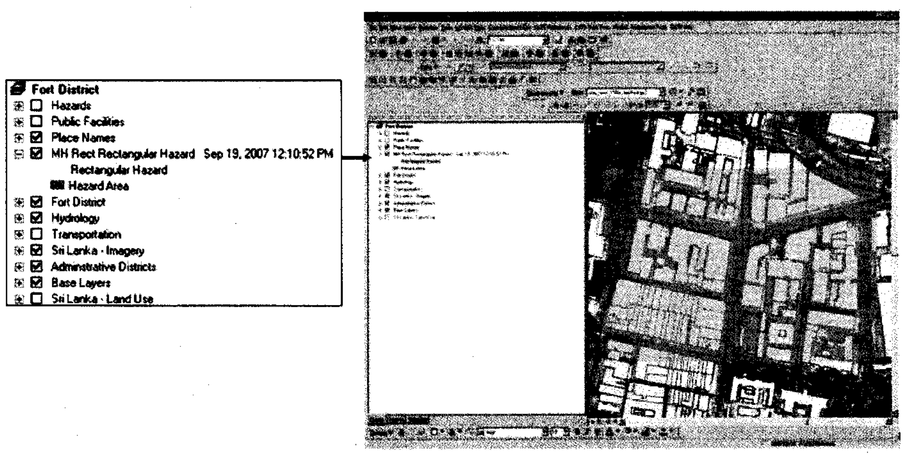


Figure B.70 CATS *Manual Hazards* Rectangle Output

Manual Hazard Circle

Circular Hazard Button

- **Left Click the center of the circle**
- **Keep the left mouse button held down and drag to other outside of the circle.**
- **This is the equivalent of drawing a line measuring the radius of a circle**
- **Release the mouse button**

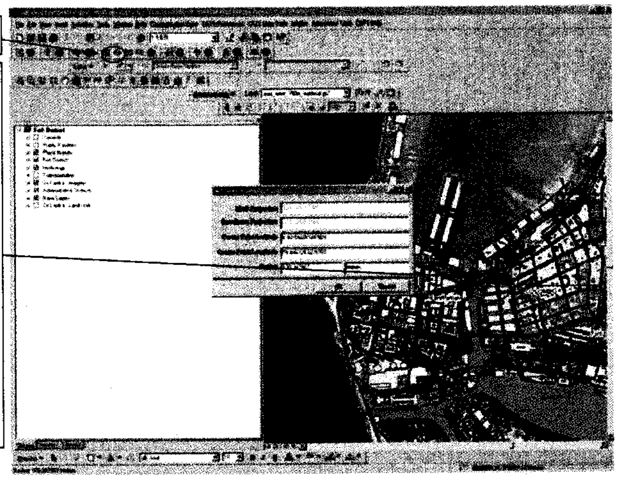


Figure B.71 CATS *Manual Hazards* Circle

Manual Hazard Circle 2

- Fort District
  - Hazards
  - Public Facilities
  - Place Names
  - MH Circle Circular Hazard Sep 19, 2007 1:08:24 PM
    - Circular Hazard
    - Hazard Area
  - Fort District
  - Hydrology
  - Transportation
  - Sri Lanka - Imagery
  - Adminstrative Districts
  - Base Layers
  - Sri Lanka - Land Use

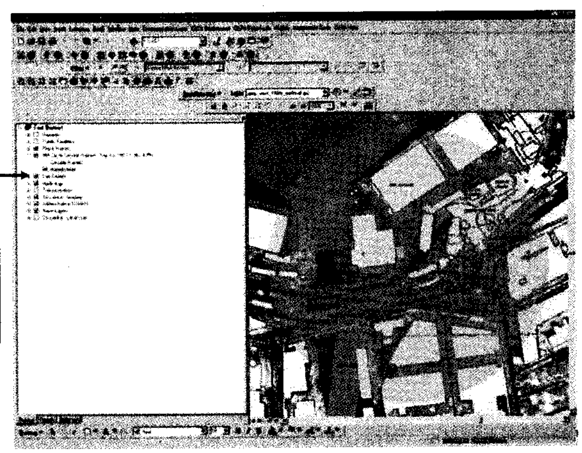


Figure B.72 CATS *Manual Hazards* Circle Output

Manual Hazard Polygon

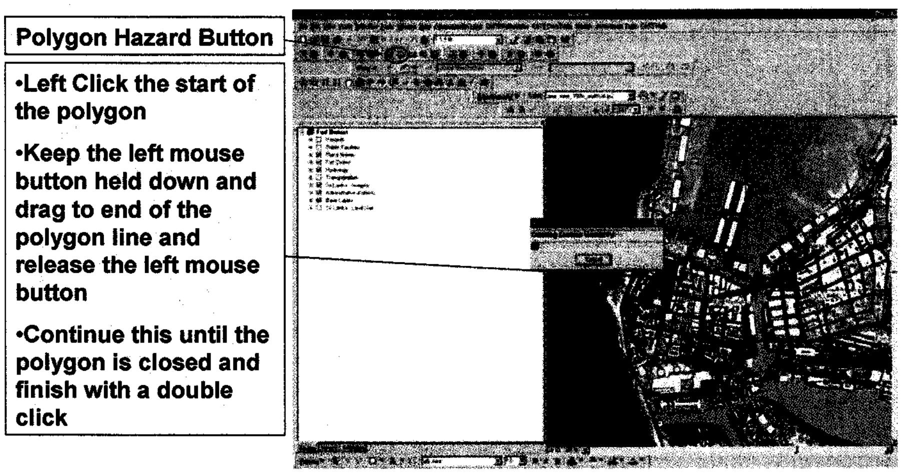


Figure B.73 CATS *Manual Hazards* Polygon

Manual Hazard Polygon 2

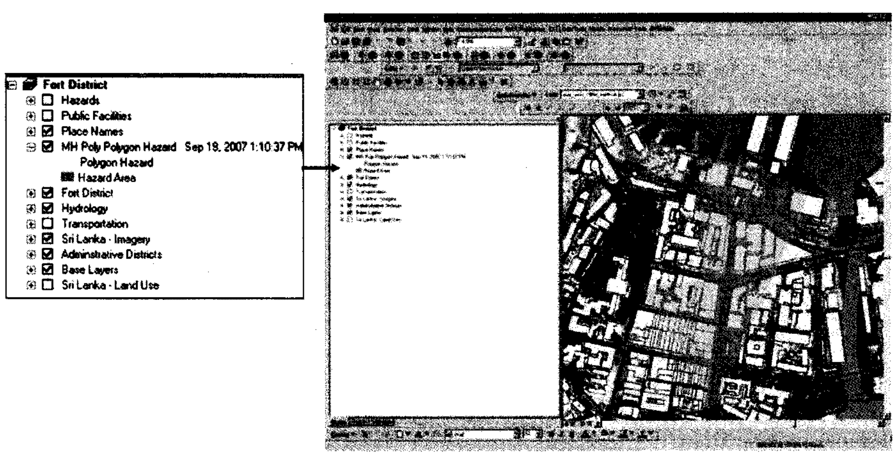


Figure B.74 CATS *Manual Hazards* Polygon Output

Manual Buffer

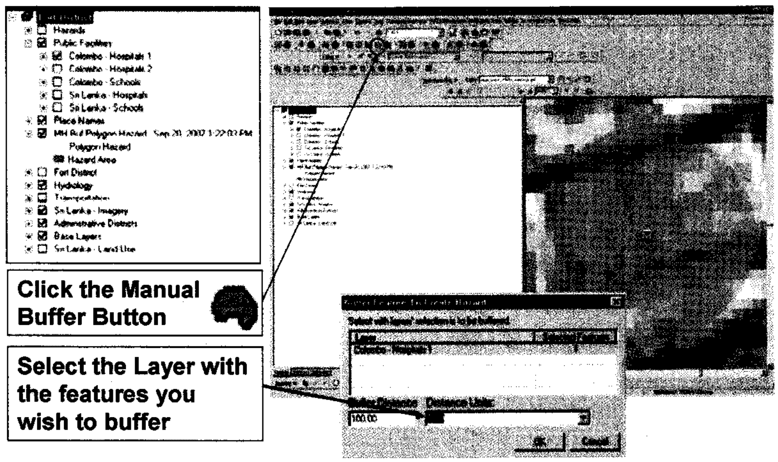


Figure B.75 CATS *Manual Hazards* Buffering tool

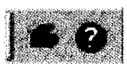
Shapemaker is used to create asset layers of various shapes and its icon expands into a subset of tools to signify the fact that that the same asset shapes may be defined multiple times. Once a certain asset shape is selected, for example a circular asset area, it may be used repeatedly while the other shapes are deactivated and not available for that set of assets. The *Shapemaker* shapes may be Rectangular, Circular, Polygon, Line, and Point. Figure B.76 through Figure B.79 show the creation of a single polygon asset on the map. Note that as the asset is created, its information is registered with CATS so it may be immediately used in other applications.

Shapemaker – The Purpose

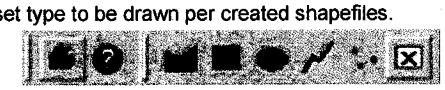
Shapemaker is a tool which allows assets to be drawn using the 5 tools.

	Polygon – allows irregular polygons assets to be drawn
	Rectangle – allows rectangular assets to be drawn
	Circle – Allows Circular assets to be drawn
	Line – Allows Line assets to be drawn
	Point – Allows point assets to be drawn
	Closes the Shapemaker toolbar

Shapemaker tool allows one asset type to be drawn per created shapefiles.



Shapemaker - Closed

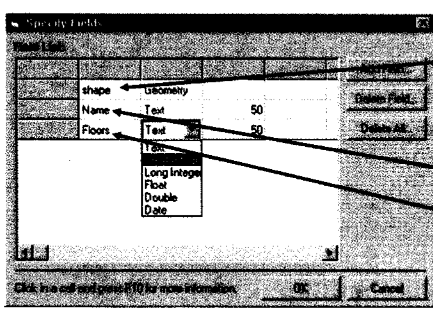


Shapemaker - Open

Figure B.76 CATS *Shapemaker* Components and Description

Drawing an Asset

Select the Irregular Polygon on the Shapemaker toolbar.



Shape is the default field in the new feature class created by Shapemaker

Add two More Fields:

1. **Text field called Name**
2. **Short Integer field called Floors**

Figure B.77 CATS *Shapemaker* Application – Polygon Asset

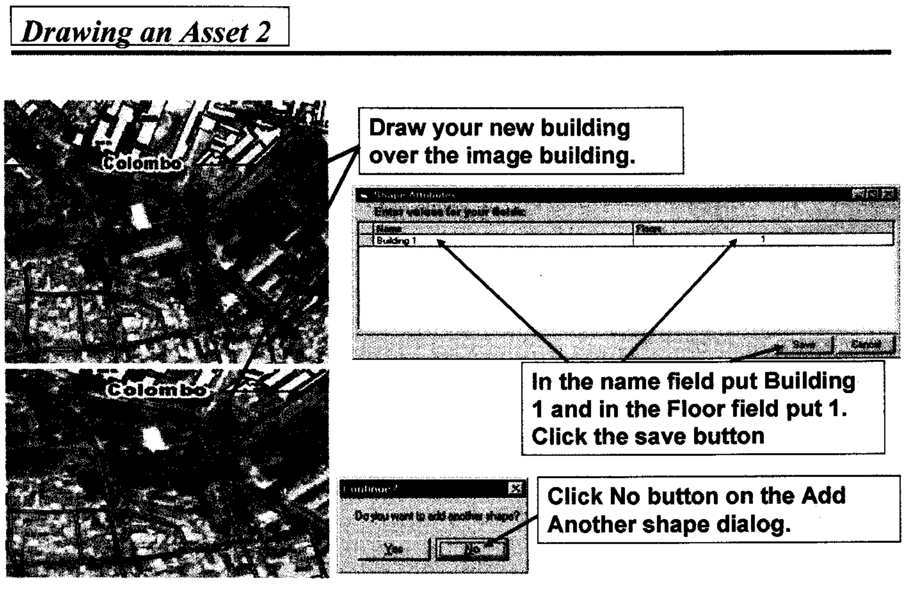


Figure B.78 CATS *Shapemaker* Application – Polygon Asset, Continued

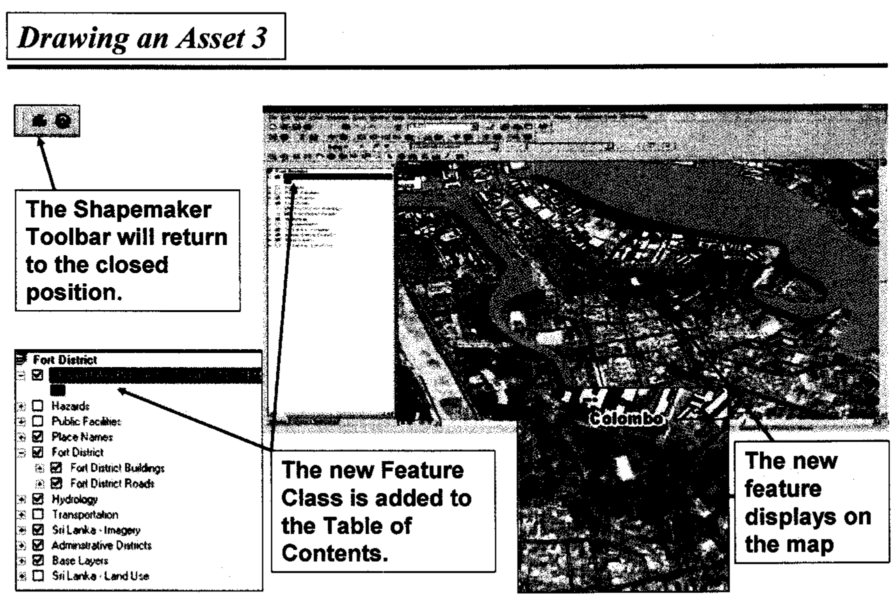


Figure B.79 CATS *Shapemaker* Application – Polygon Asset, Continued

The Response, Resource, and Sustainment (RRS) menu item operates on the registered assets to create reports on the availability of resources within the proximity of a hazard. The RRS tool is therefore used for identification of resources (defined as assets) in the hazard area. To perform an RRS Query, the user normally selects a hazard layer, an asset layer, and an asset report template to generate a list of the resources within a specified distance of the level of concern.

Figure B.80 through Figure B.83 illustrate a use-case for the RRS tool. Note that to exercise RRS, it is assumed that a hazard calculation has already been performed and various asset layers of interest have already been registered with CATS.

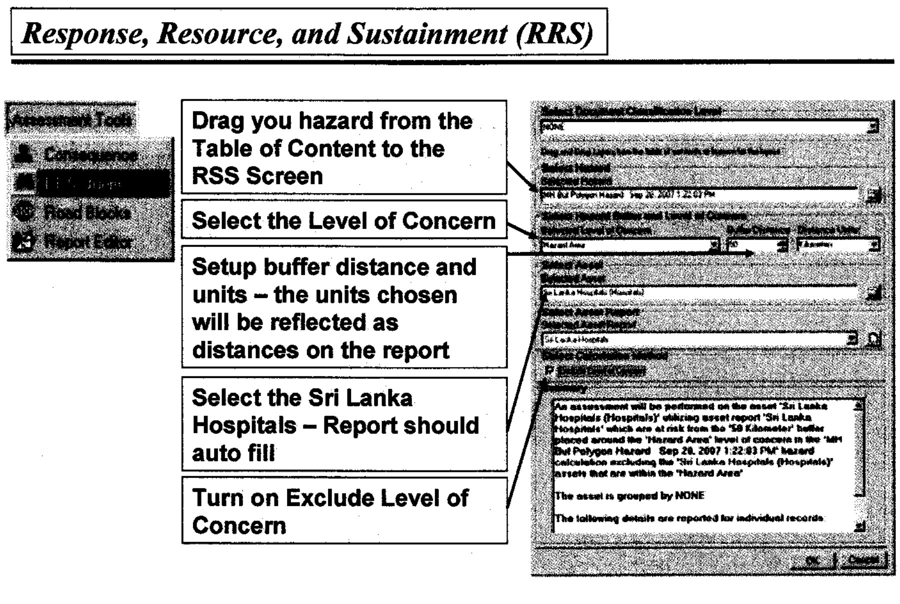


Figure B.80 CATS Assessment Tools - RRS Description

RRS Report – 1st Page

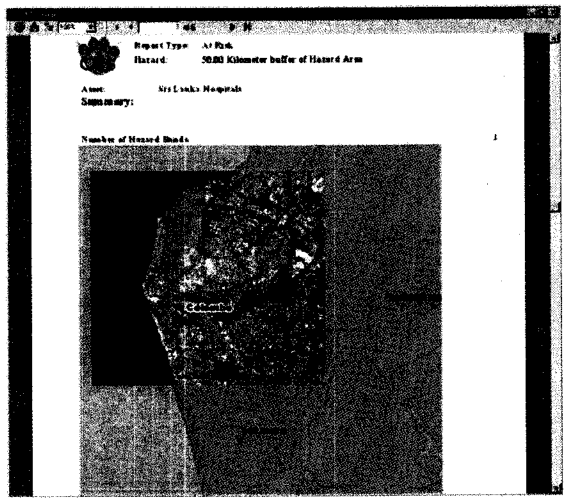


Figure B.81 CATS Assessment Tools - RRS Query Report

RRS Report – Subsequent Pages

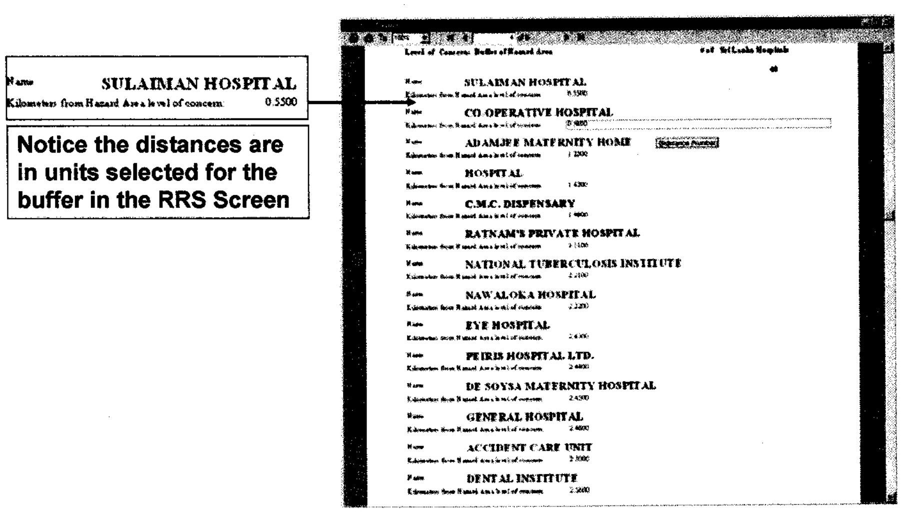


Figure B.82 CATS Assessment Tools - RRS Query Report, Continued

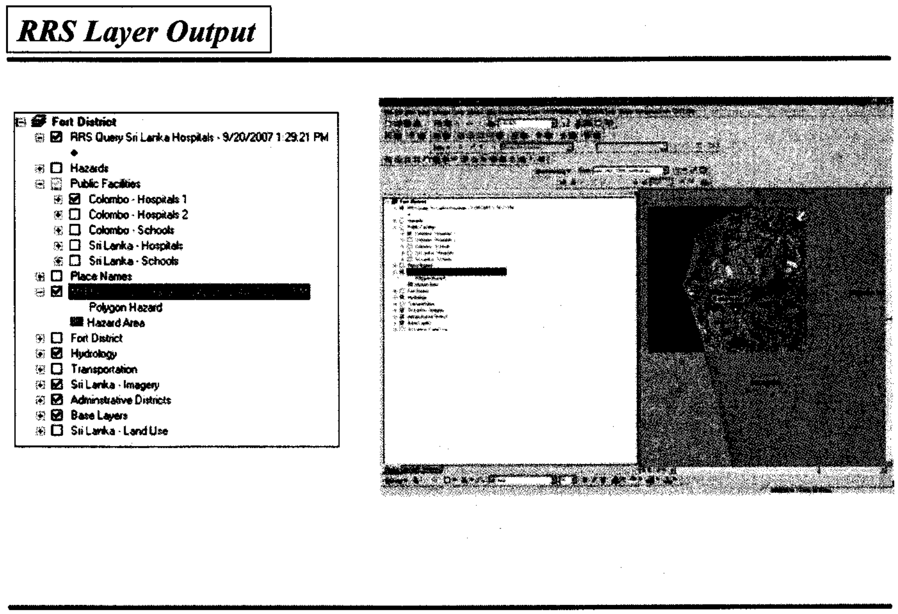


Figure B.83 CATS Assessment Tools - RRS Query Output

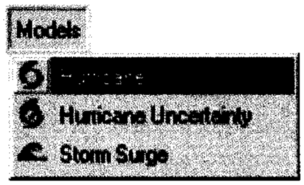
B.7 CATS Application – Hurricanes and Cyclones

The last CATS Model to examine is the *Hurricane* module. The model name is somewhat misleading as it can handle storm advisories issued as hurricanes, cyclones, or typhoons. Closely related models to the *Hurricane* are *Hurricane Uncertainty* and *Storm Surge*. These are depicted in Figure B.84 along with a brief description and limitations of each model. The limitations apply to the last two models and are due to the fact that US-specific data are used in the Wind Uncertainty and Storm Surge calculations.

As before, a CATS Hurricane scenario is calculated except that the map symbology of the output and consequence report are closely examined for a better understanding of the results. Figure B.85 shows the first step in running the model, which is the selection of an advisory. In this example, Typhoon Wipha off the coast of China is selected. Figure B.86 through B.88 show the calculation set up, selection of any structures for wind damage assessment (none in this case), and the final output. Figure B.89 through Figure B.91 show how to isolate a specific symbology and concentrate on the individual feature class.

Consequence calculation and Consequence Report follow in Figures B.92 and B.93. Figure B.94 closely examines the Consequence Report to discover an unusual situation where the category 1 winds strike the town of Jiangsu twice. By further analyzing the data attributes, the reason may be established that the Jiangsu area contains an island by the same name.

Hurricane Models



Hurricane Codes

•**Hurricane** – The Hurricane model produces hurricane/Cyclone tracks and Wind Damage based on Hurricane/Cyclone advisories

•**Hurricane Uncertainty** –The Hurricane Uncertainty Model is similar to the Hurricane Model, but it is US specific as it adds an uncertainty factor to calculations based on past US Hurricane

•**Storm Surge** – Predicts water inundation based on Hurricane/Cyclone advisories. Storm Surge is currently a US specific model as CATS has only inundation data for US sites.

Figure B.84 CATS Hurricane and Wind Damage Models

Selecting a Hurricane/Cyclone Advisories

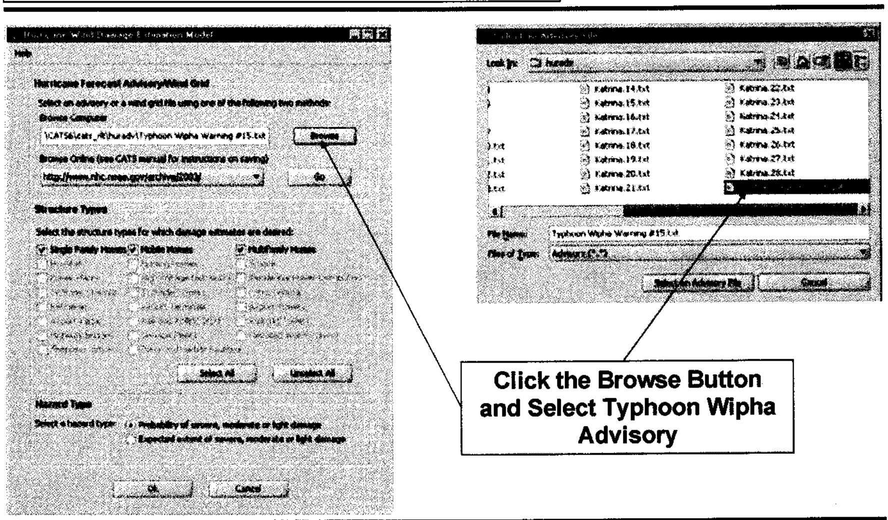
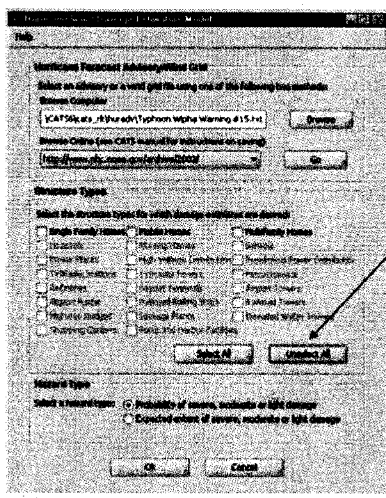


Figure B.85 CATS Hurricane/Cyclone Advisory

Hurricane Structure Types

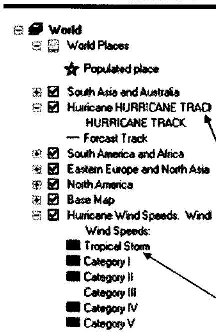


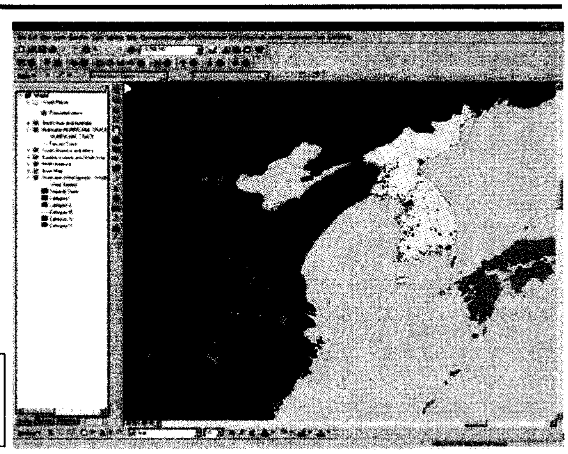
Click the Unselect All Button to deselect all Structures

- **Hurricane Structure Types were estimated using United States Building Codes.**
- **Structures can be used for other countries where building codes are similar, but it is not recommended.**
- **Structures Add significant calculation time to producing model output**

Figure B.86 CATS Hurricane Damage Structure Types

Hurricane Output





Output is placed in the Table of contents based on ESRI stacking standards

Figure B.87 CATS Hurricane Wind Category Default Display

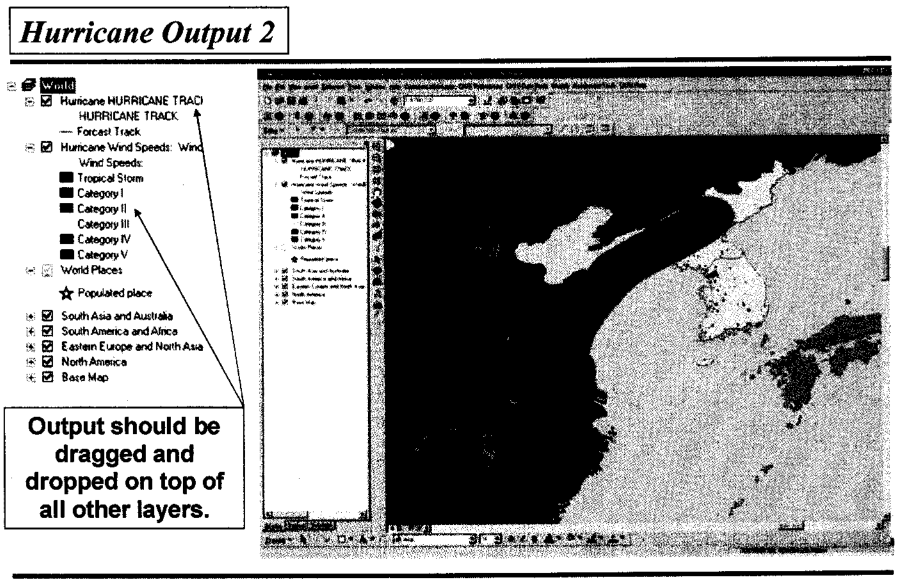


Figure B.88 CATS Hurricane Wind Category Adjusted Display

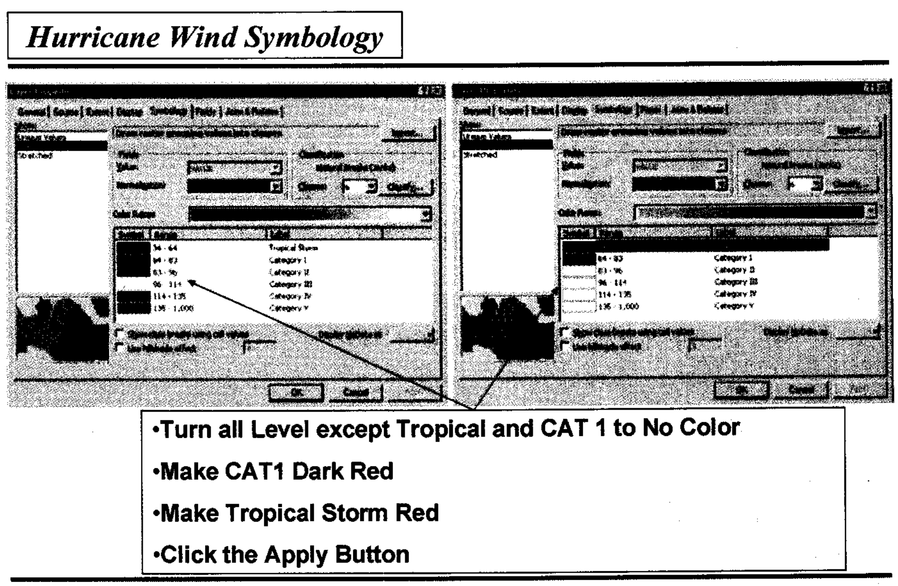


Figure B.89 CATS Hurricane Output Symbology

Hurricane Wind Transparency

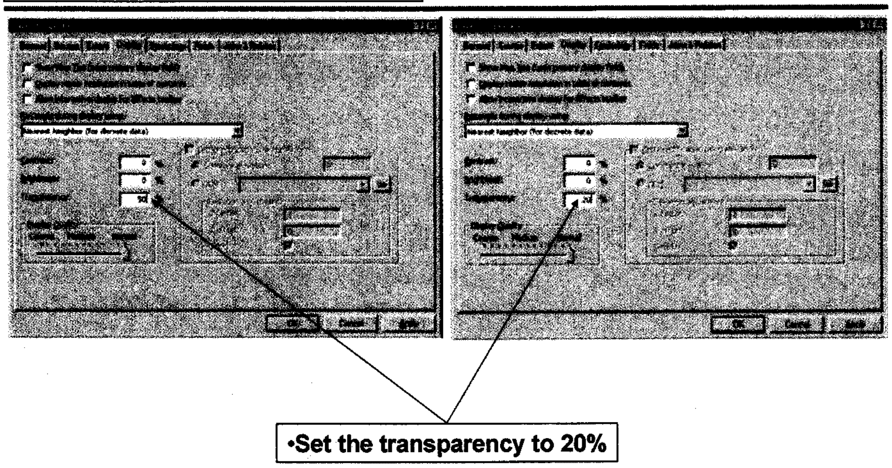


Figure B.90 CATS Hurricane Output Transparency

Symbology Color Comparison

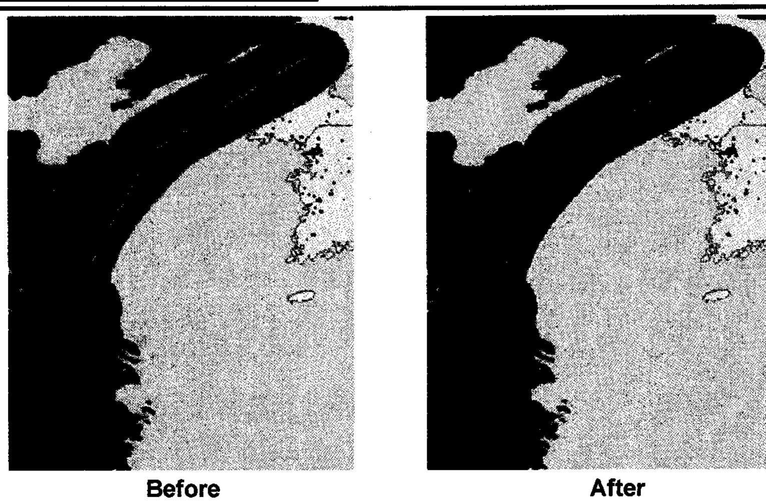


Figure B.91 CATS Hurricane Output Adjusted Symbology

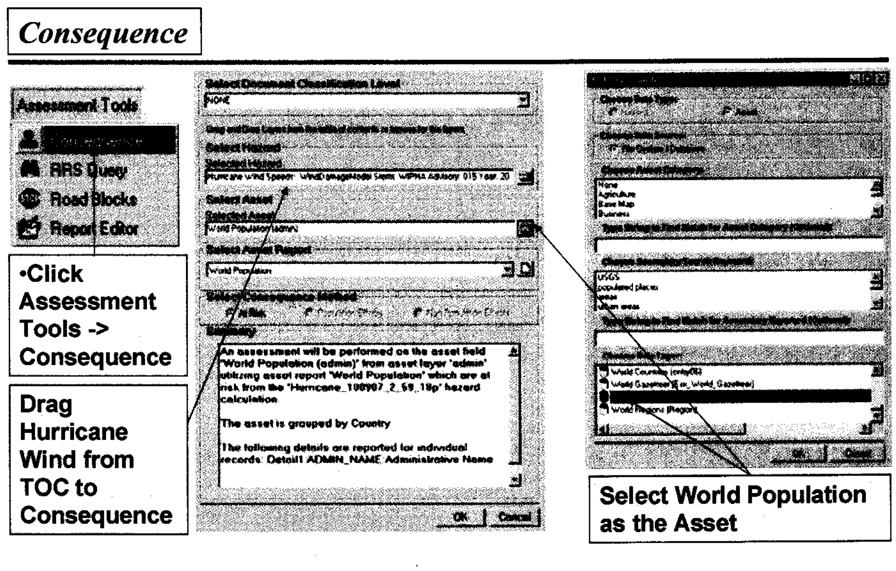


Figure B.92 CATS Hurricane Consequence Calculations

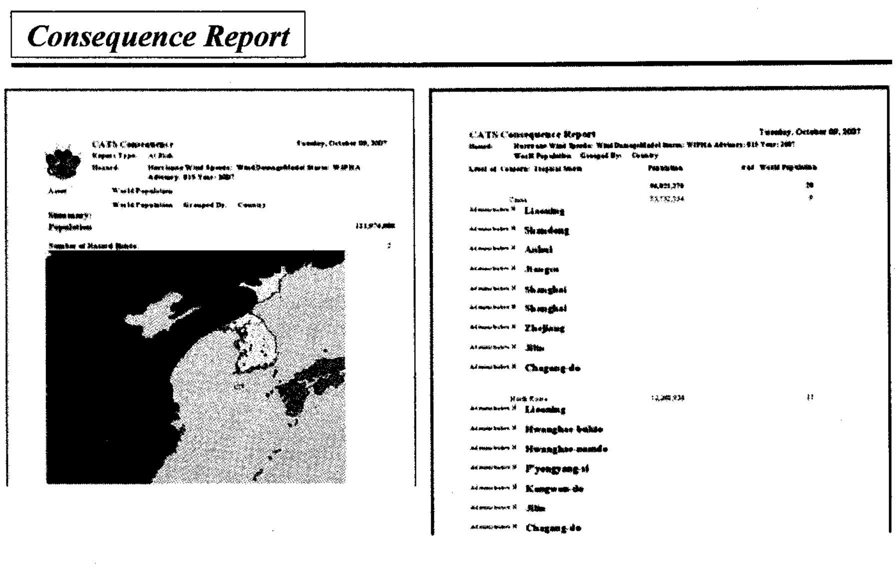


Figure B.93 CATS Hurricane Consequence Report

Consequence Report Analysis

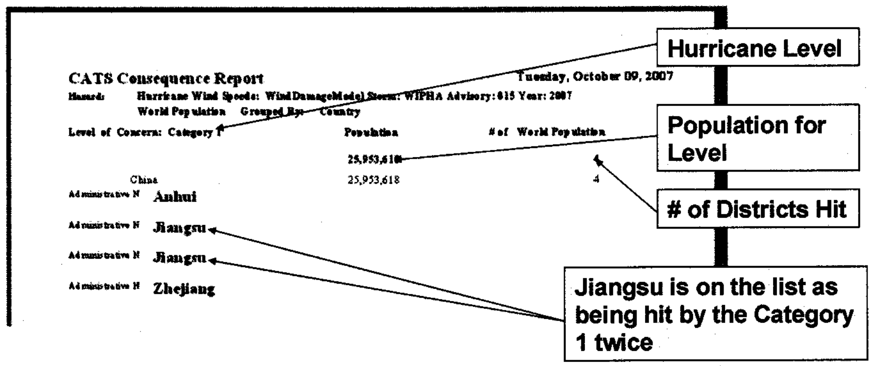
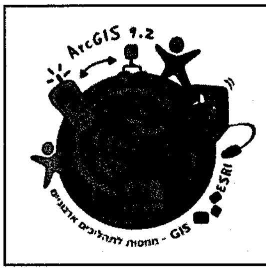


Figure B.94 CATS Hurricane Consequence Report Analysis

Appendix-C



C.1 An Introduction to Esri ArcMap Functionality

A component of the ESRI Geographic Information System (GIS), ArcMap is a MS Windows client software which provides the basic framework to display and analyze maps and which may be thought of as a map-based "operating system". The software is normally "extended" by the addition of user supplied models and functions, which can operate within the ArcMap operating system.

These externally supplied software packages are referred to as Extensions. The CATS software is also created as an ArcMap extension and additionally it makes use of another ESRI extension, Spatial Analyst, to perform more sophisticated operations of the map overlays.

C.2 Table of Contents (TOC), Map Layers, and GIS Terminology

An *Asset* is defined as any physical attribute on the map. It can be buildings, buses, hospitals, ports, electrical lines, or even people. A *Hazard* is anything that can have an effect on an Asset. Hence, hurricanes, tsunamis, chemical spills, landslides, earthquakes can all be a hazard. The physical extent of the damage area is normally referred to as the "*hazard footprint*".

In GIS terminology, anything that represents the class of *assets* or *hazards* is a *Layer* or a *Feature Class.* Often, a single asset within a layer is called a *feature*. Since the operational mode is in the realm of a map, all of the map attributes are defined spatially and they are formed into layers following a certain hierarchy.

A typical example of a complete map following the above prescription and using the corresponding GIS labels is depicted in Figure C.1 in which the individual map layers are also shown.

Think Spatially

- **Think of everything as a map**
- **Highest level**
    - **People - Points**
    - **Building - Polygons**
- **Middle Levels**
    - **Streets - Lines**
    - **Rivers – Line or Polygon**
- **Lowest Levels**
    - **Aerial Imagery - Image**
    - **Terrain - Grid**

Note – A single asset within a layer is called a feature

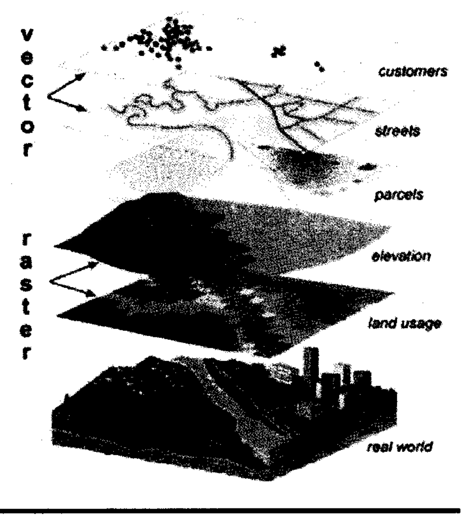


Figure C.1 Spatial Description of the Map Layers

The GIS labels indicate that the underlying software can only manipulate the information that belongs to one of the classes of points, lines, polygons, grids, and imagery. These discussions may be concluded with the following *best GIS practices*, which define the spatial relevance of these components. Points and Lines normally lie above polygons. For instance, Hospital Points should always be on top of Building Polygons. Imagery is normally the lowest level of the map, however, it could be placed on top of a base polygon and its transparency adjusted for better visual effects.

Figure C.2 shows the ArcMap main window without a map display. The map frame has an associated "active legends" area drawn as the left pane, which is called the Table of Contents (TOC). The toolbar in the midsection shows the available generic map tools, while the area on the right is reserved for the display of any map layers that may be loaded into the TOC.

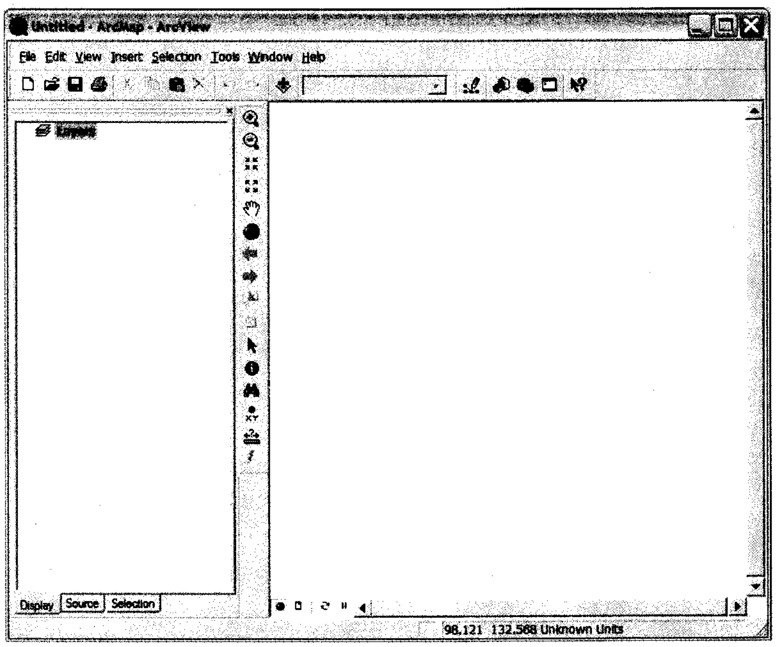
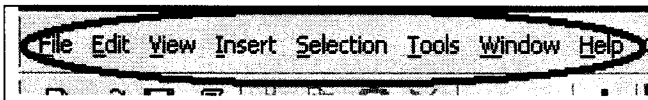


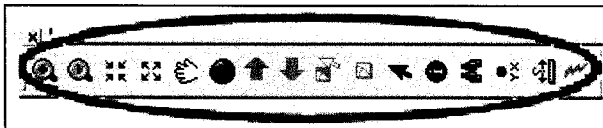
Figure C.2 ArcMap Framework window

The set of Menus on the top row perform the essential data selection, manipulation, and visualization (rendering). Table C.1 describes the basic functionality of the menu items while the standard toolbar components and their applications are summarized in Table C.2.



Menu Item	*Function*
File	gives access to project controls: Close, Save, Print, Export ...
Edit	Graphic Manipulation and Theme Control: Cut, Copy, Paste, Graphic Tools …
View	View Properties and Layout Interface: Add Theme, Zoom, Locate …
Insert	Insert objects into the Data or Layout View Data Frame, Text, Picture, Object…
Selection	Means of Selecting Data Layers from the Map Select by Attribute, Select by Location …
Tools	Data Management: Editor Toolbar, ArcCatalog, Extensions …

Table C.1 ArcMap Menu Items and their Functionality



	Zoom in by clicking a point or dragging a box
	Zoom out by clicking a point or dragging a box
	Zoom in to the Center of the map
	Zoom out from the Center of the map
	Pan: Click and drag to pan the map
	Zooms to full extent of Map
	Go Back to Previous Extent or Forward to Next Extent
	Select Features by click or dragging a box
	Select, resize and move text, graphics and other Features on the map
	Identify the geographic feature or place you click on
	Find: Find Features in the map
	Measure physical extents and distances on the map
	Triggers hyperlinks from features

Table C.2. ArcMap Standard Toolbar Components

There are also equivalent keyboard shortcuts to perform some of these functions. An extensive online Help menu can also be used to provide additional reference.

Most of these are tools common to many windows products and/or are self-explanatory. Some of the more esoteric tools will be further explored in the following sections to demonstrate their usage.

C.3 Interaction with the Map and its Layers

A map is a visual approximation of the world around us. The more the details of an area of interest, the more complex the map structure becomes and hence, more data is required. As an example of map operations, the CATS operation with the Sri Lanka auxiliary map data may be used. Figure C.3 shows the CATS view of the Fort District in Colombo, Sri Lanka.

CATS Main Display – Fort-District, Clomobo, Sri Lanka

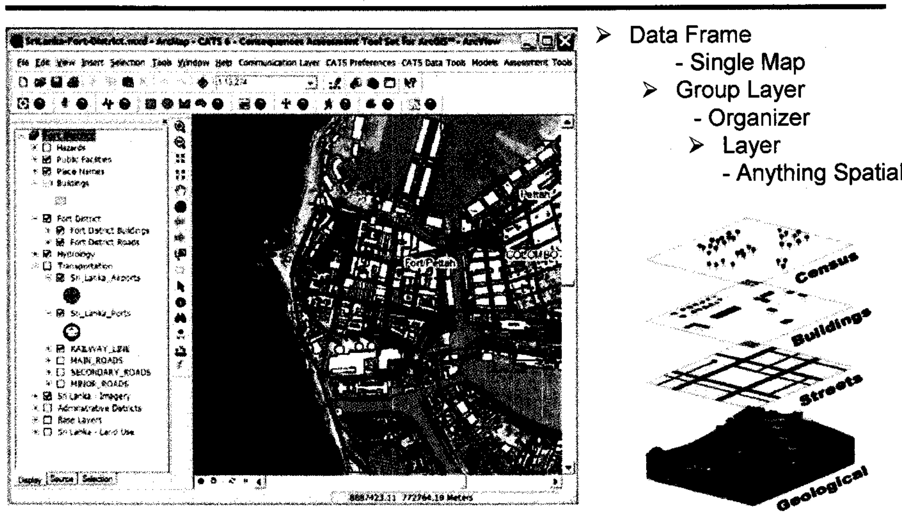


Figure C.3. Map of Fort District, Colombo, Sri Lanka in CATS

The Table of Contents (TOC) in this map has an extensive list of entries organized as expandable lists under various labels. The main heading is called a Data Frame, in this case labeled "Fort District", which identifies a single map with all of its associated layers. A Group Layer is used to organize a subset of individual spatial layers, which correspond to the same GIS "family"; for example, "Fort District" includes "Fort District Buildings" and "Fort District Roads" subcategories. To change the order of the entries in TOC, the layers can be moved by mouse click-and-drag. The check boxes next to the layer names are used to "activate" the layers and make them visible. The layer visibility also depends on whether it is hidden behind another layer or it is out of range of the map scale. These latter points will be explored further in the next section.

There are several generic map tools available to interrogate the map components. The applications of several of these tools are demonstrated below in screen images of interaction with the map, while the accompanying information legends describe the precise functionality of each tool.

Figures C.4 and C.5 explores the Identity tool where information about a specific geographic location is queried. The data attributes include such detail as the number of floors and the street address.

Identify the geographic feature or place you click on

- Click the *Identify* tool
- On the Selection Menu click Set Selectable Layers
- Click Clear All
- Click on the Fort District Buildings
- Select Fort District Buildings using the select features tool
- The tool works in either a point and click mode or a roping mode
- Review its data attributes (Metadata)

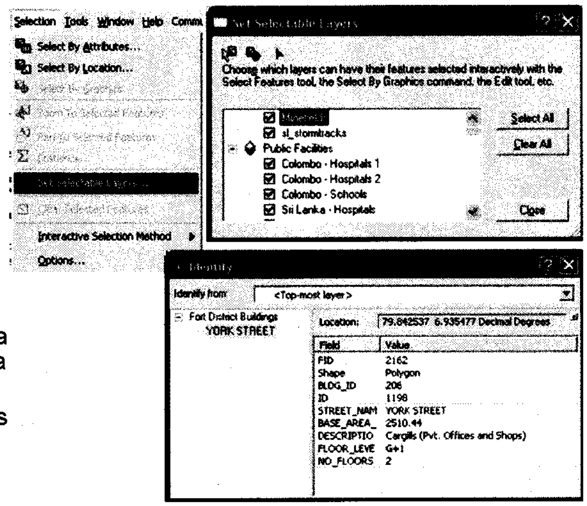


Figure C.4. Identifying the Fort District buildings

Figure C.5 specifically shows an example of using the Find tool to locate the Hilton Hotel in the Fort District Buildings group layer. A search for the word "hilton" will return all occurrences of the word. Selecting the desired name, "Hotel Hilton" in this example, causes the location on the map to Flash on the map. Right clicking on the found object's name reveals a number of other available actions such as Flash, Zoom To, and Identify to pinpoint the location on the map.

Find Features in the map

- Click the *Find* Tool
- Find: Hotel Hilton
- In: Fort District Buildings
- Search All Fields
- Click Find
- Right-Click on Found Object
- Select Action
  - Flash...
  - Zoom...
  - Identify...

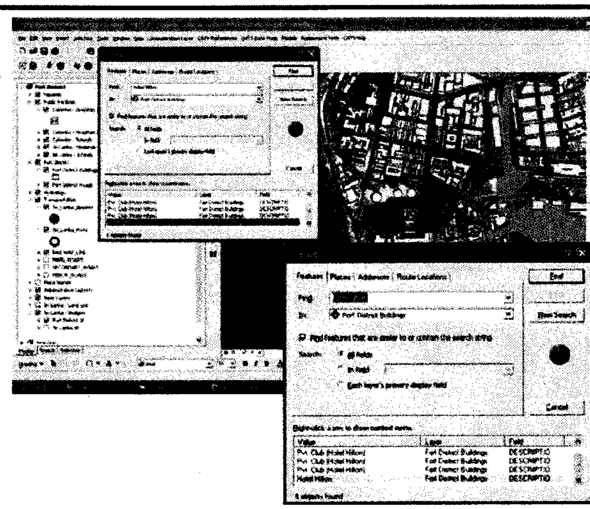


Figure C.5. Searching for the Fort District Buildings with the Find tool.

Using the Measure Distance Tool, various distances and physical extents can be estimated on the map. Figure C.6 shows the available list of options and the corresponding units of measurements.

Measure Distance on the Map

- **Click on the *Measure Distance* Tool**
- **A second window appears labeled Measure**
- **In the Measure Window click on the tool that allows you to change measurement units and select meters.**
- **Use the tool on the map to draw a line of measurement**

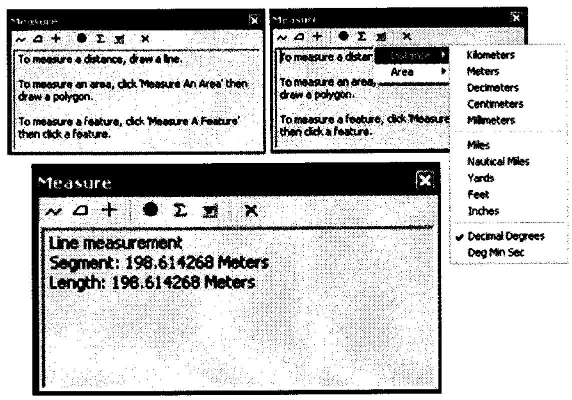


Figure C.6. Measuring Distances and Areas on the Map Projection.

Adding new data to the map is accomplished using the Add Data Tool. This tool is available under both the File menu drop down and the tool icon on the tool bar as shown in Figure C.7.

Dual Controls: Tool Bar and Menu Items

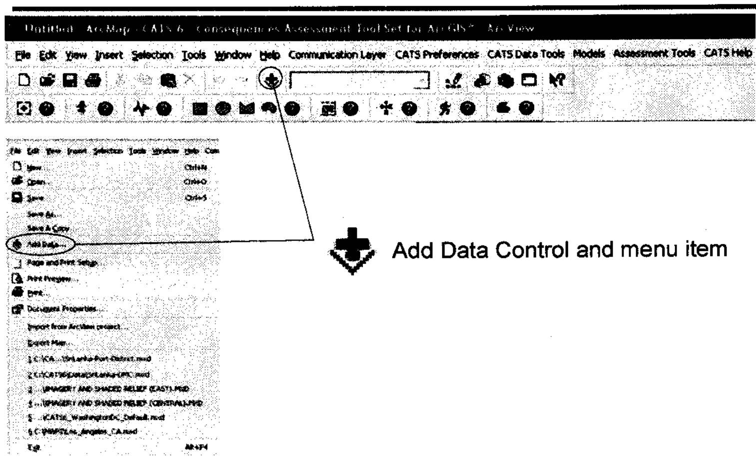


Figure C.7. Accessing the Dual-Control Add Data Tool

To add a data layer, also known as a *shapefile*, this tool is used to navigate the directories to locate and load the desired data to the map as indicated in Figure C.8. In this example, the buildings layer (shapefile) is first removed and then added back in to illustrate the utility of the tool.

Add Data to the Map

- **Right-Click on Fort District Buildings Layer and Select Remove**
- **Click on the *Add Data* Tool**
- **Browse to the Folder Containing Fort District Buildings**
- **Select: *Fort_District_Buildings.shp***
- **Drag the Layer to the Desired Location in the Table of Contents**

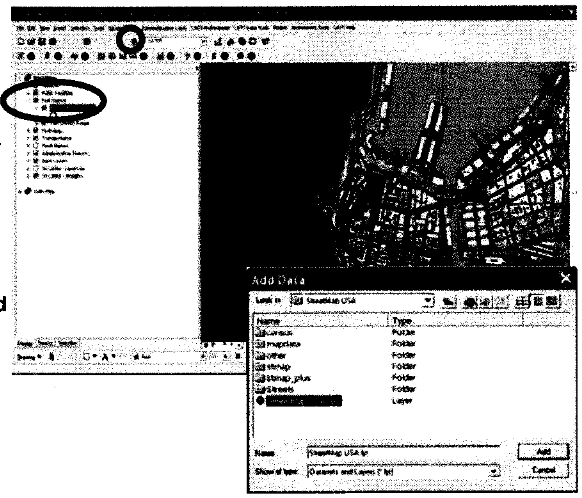


Figure C.8. Using Add Data Tool to add Data Layers (shapefiles) to the Map

C.4 Layer Operations and Properties

The usual method of operating on the individual layers themselves are carried out by right clicking on the particular layer name and choosing from the drop-down menu items, such as zooming to the extent of the layer. Some of these tools are explored in greater detail in the following sections.

Figure C.9 illustrates the menu of commands from the layer operation dropdown. Notice that some of these commands themselves expand into subsets of tools. The check boxes next to the layer names control the layer visibility.

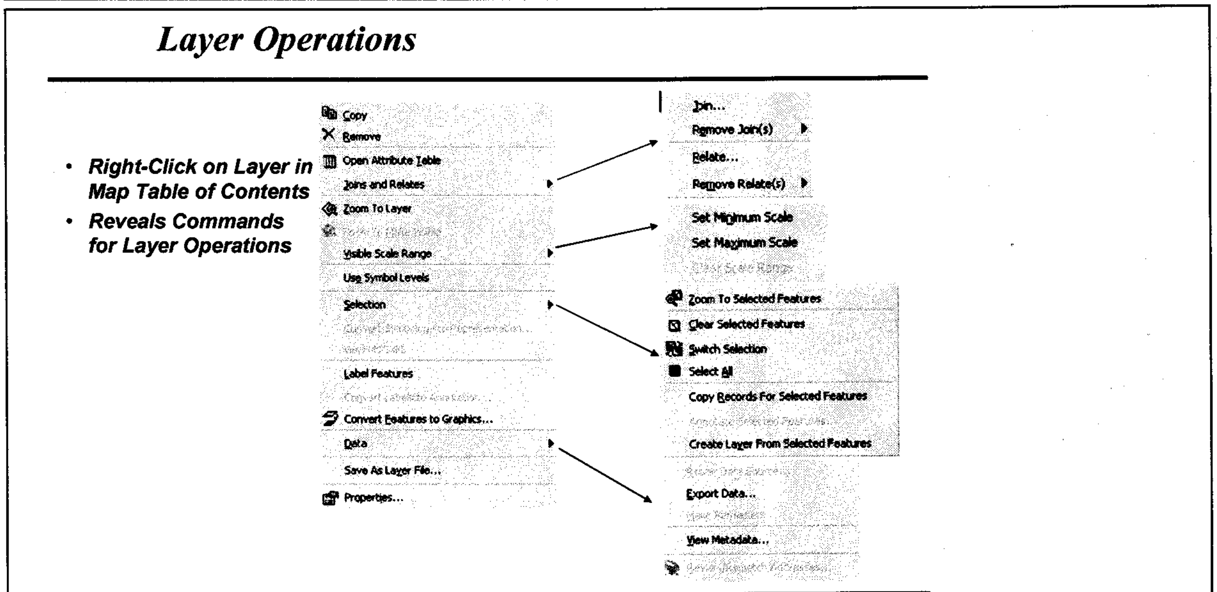


Figure C.9. Layer operations Dropdown Command Menu

As mentioned before, the layer visibility depends on whether it is out of the range of the map scale. Zooming to a layer automatically adjusts the scaling as shown in Figure C.10.

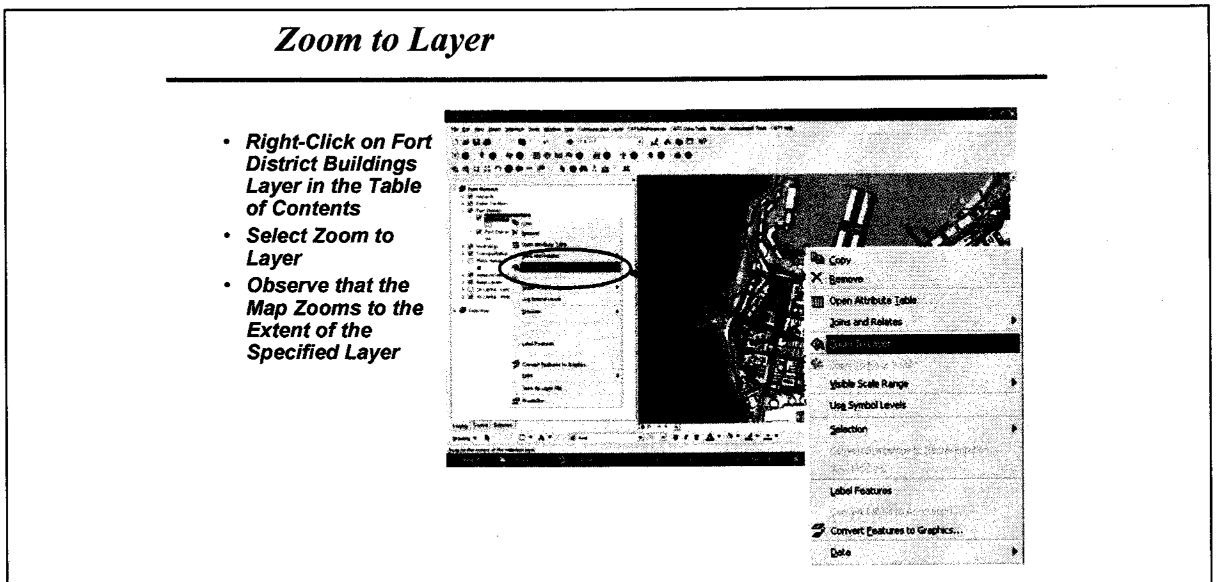
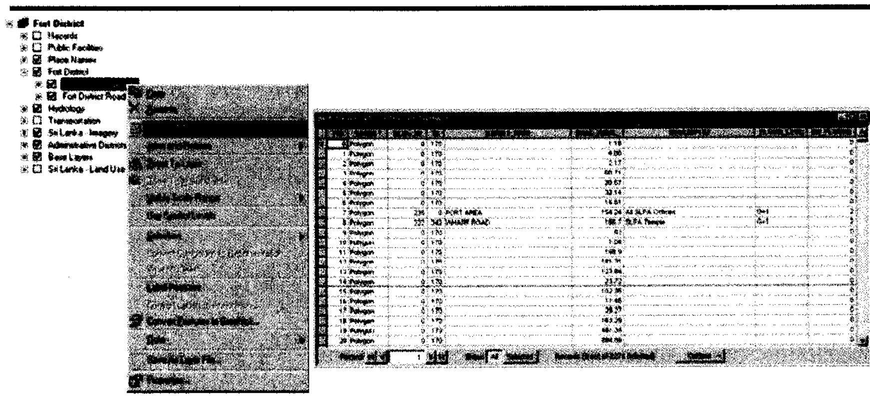


Figure C.10. Zooming to a Specific Layer and Resetting the Spatial Extent.

The attributes of a layer refer to the features that comprise the layer and their associated data. For example, the layer named "Fort District Buildings" contains description and details about the buildings in the Fort District. The map-builder has gathered this information from many resources, packaged them as a relational database, and formed the final product into a layer or a shapefile. Clearly, the complexity of the layer attributes depends on the extent of the underlying data. Figure C.11 shows the attribute table for the Fort District Buildings layer. There are over two thousand entries in the list of buildings. The list of attributes appears as column headings and includes such things as the shape, street name, and number of floors of the building.

Layer Operations – Open Attribute Table



The Attribute table contains data about features within a layer

Figure C.11. Table of Attributes for the Fort District Buildings Layer.

The *Properties* option available as the last selection on the menu, lists the details assigned to a layer and can be as simple as an identification label. In general, much more detail accompanies a particular layer. Launching the *Properties* will present a menu of Tabs as shown in Figure C.12, in which the information under the *General* tab for the Fort District Buildings layer is displayed. Also, note that the layer visibility may be controlled by the map scale settings.

Layer Properties - General

- ***Edit Layer Name***
- ***Reset Layer Visibility***
- ***Annotate Layer Name***
- ***Set Scale Range***
  - ***Show layer at all scales***
  - ***Limit scale***
    - ***Out***
    - ***In***

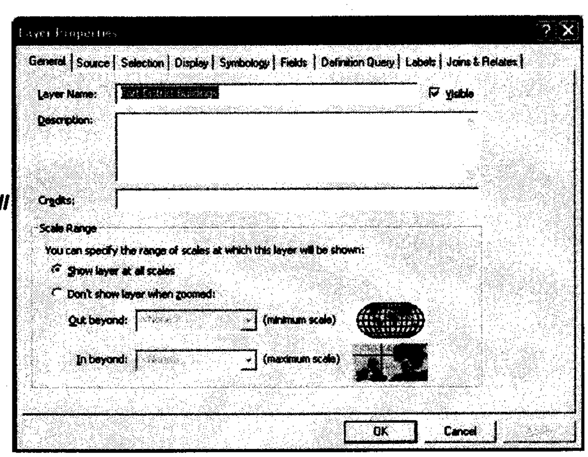


Figure C.12. Fort District Buildings Layer *General* Properties

The next tab in the properties list, Source, describes the pedigree of the data. It contains the extent, the map projection, and the physical location of the data. The data projection is one of the most important attributes of the layer since it has to match the projection of the underlying map. The map projection will be discussed in more details later. This is shown in Figure C.13.

Layer Properties - Source

- ***Review Extent***
- ***Review Data Source***
- ***Set Data Source Using Browser***

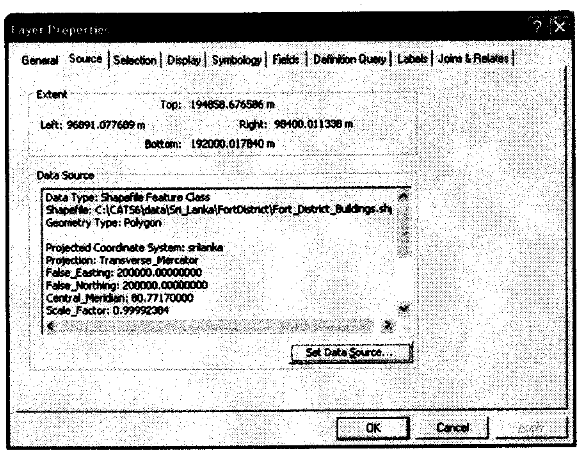


Figure C.13. Fort District Buildings Layer *Source* Property

The Selection property allows customizing the symbol and color of the layer members as shown in Figure C.14. Notice, however, that in order to see the results on the map, the layer has to be selected via the select tool.

Layer Properties - Selection

- ***Options for Showing Selected Features***
  - ***From Selection Options***
  - ***Custom Symbol***
  - ***Custom Color***

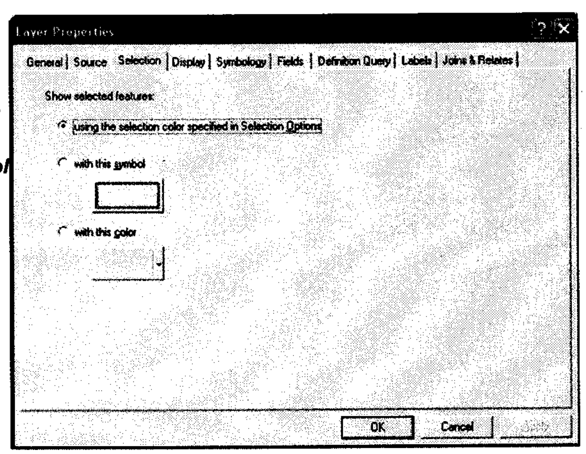


Figure C.14. Fort District Buildings Layer Selection Property

The *Display* allows customization of the symbol scaling and layer transparency. This is shown in Figure C.15. The symbols on the map can be scaled with the changes in the map display or retain a rigid size. Also adjustable is the transparency of the map layer. This is an important attribute as it allows two overlapping layers to be viewed simultaneously, for example, a plume above a landscape.

Layer Properties – Display

- ***Scale Symbols with Map Scale***
- ***Transparent – Set for Translucent Layer***

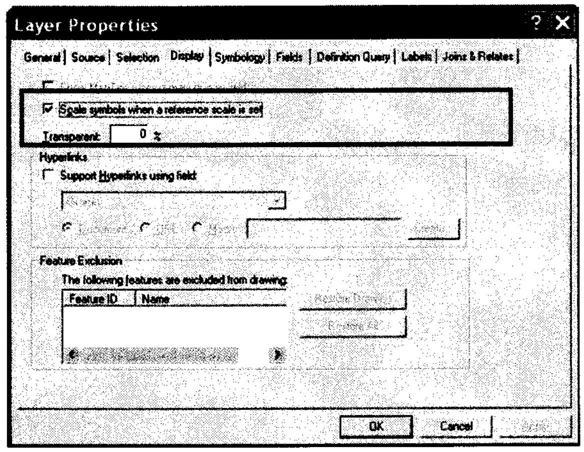


Figure C.15. Fort District Buildings Layer *Display* Property

The next tab is the *Symbology*, which controls a host of visualization settings for the symbols portrayed on the map layer. A routine use of this option is displayed in Figure C.16, where the symbol coloring scheme for a single symbol (for example airports) is being depicted. Note that the layer must be selected in order to see the modifications.

Layer Properties – Symbology – Features - Single Symbol

- ***Single Symbol***
  - ***One Symbol per Record***
  - ***All the Same***
- ***Double Click on Symbol Button to See Selector***
- ***Edit Label***

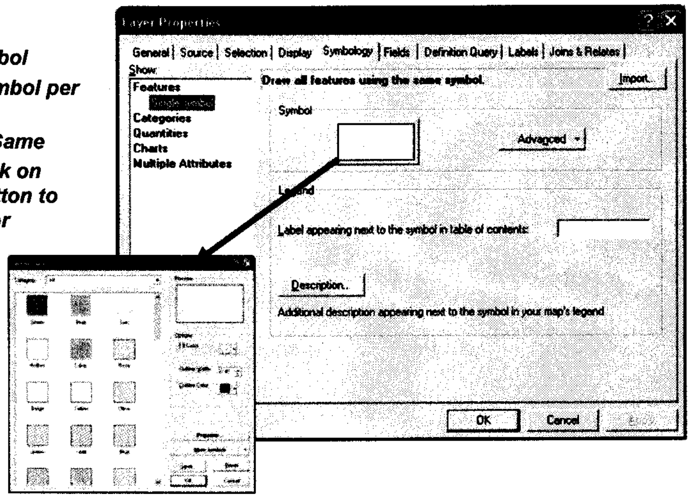


Figure C.16. Fort District Buildings Layer *Symbology* Property

A multi-symbol layer symbology is more complex as shown in Figure C.17. In this case, various buildings are colorized by their street addresses. This assignment is made under the *Categories* option.

Layer Properties – Symbology – Categories – Unique Values

- ***Multiple Symbols***
  - ***One Symbol per Unique Field Entry***
  - ***Default Auto-Color Scheme***
- ***Symbolize All or Some Values***
- ***Double Click on Symbol to See Selector***
- ***Edit Labels***

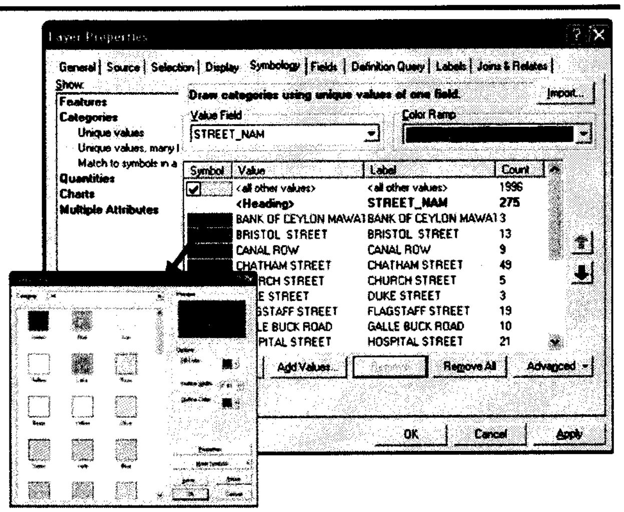


Figure C.17. Fort District Buildings Symbology by *Categories*

It is often desirable to quantify the visual effects assigned to a map symbol by a range of values. This is accomplished using the Quantities settings under symbology. Figure C.18 shows the selection menu for the coloring of the Fort District buildings according to their base areas. A color ramp controls the intensity/shading of the various ranges. Another example would be to show buildings with 10-20 stories in red.

Layer Properties – Symbology – Quantities

- ***Polygon Layers***
  - ***Grad. Colors***
  - ***Graduated Symbols***
  - ***Proportional Symbols***
  - ***Dot density***
- ***Based on Single Field***
- ***Based on Field and Normalization (Quotient)***
- ***Color Ramp Selection***
- ***Edit Labels***

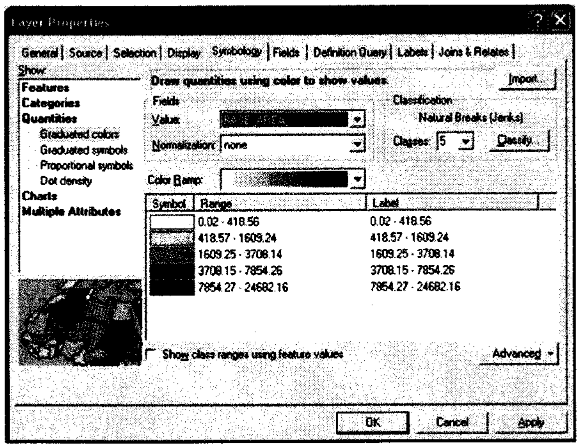


Figure C.18. Fort District Buildings Symbology by *Quantities*

The next tab under layer properties is Fields. This menu is used to make the fields in the attribute table visible. It is also used for the labeling of the map layer features in the table of contents. This is shown in Figure C.19 where all the fields for the Street Names have been activated.

Layer Properties – Fields

- ***Primary Display Field – Used for Labels***
- ***Set Fields Visible in Attribute Table***

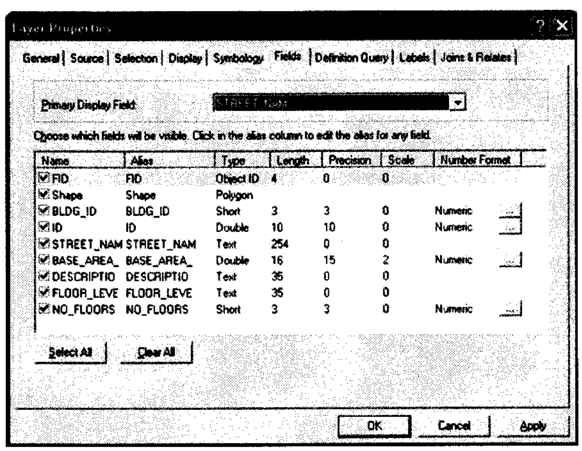


Figure C.19. Fort District Buildings Layer *Fields* Property

The layer properties tab, Definition Query, facilitates map element queries according to some basic relational database commands. These commands are found under the Query Builder button and are shown in Figure C.20. A typical search would be to double click the query type, e.g. "STREET_NAM", double click the operation, e.g. "=", and enter the search value. Normally, a list of available values is generated by clicking on the Get Unique Values button and then one is selected from that list by double clicking its value. In the current example, 'LOTUS ROAD' has been selected and as shown in the figure, all character sets must be enclosed in single quotes.

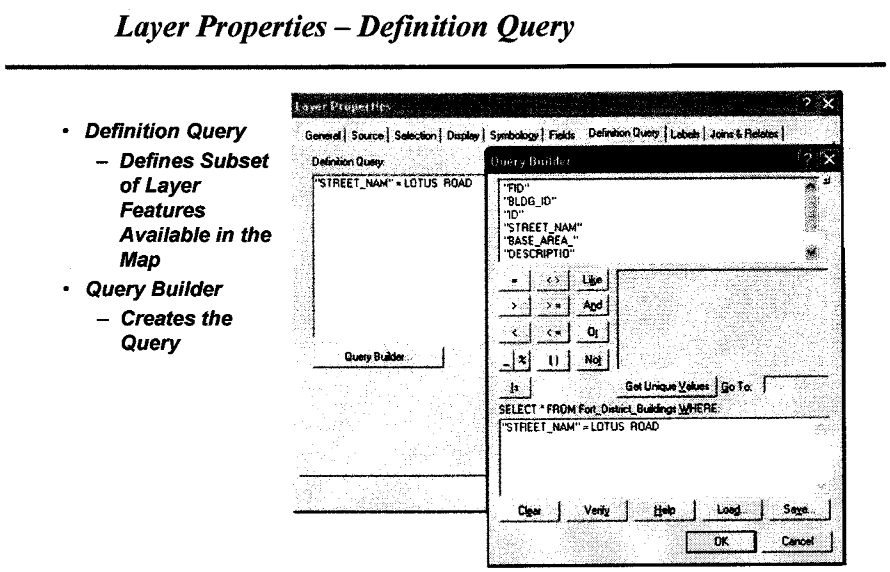


Figure C.20. Fort District Buildings Layer *Definition Query* Property

One last tab under properties to consider is the *Labels*. The various settings under this tab may be used to control the display of the feature labels with different fonts, according to their classifications, and by the scale-range of the map. An example of this tab is shown in Figure C.21.

Layer Properties – Labels

- Label Features Check Box
- Method
  - One Label Specification
  - Label Specification by Class
- Labels by
  - Single Field
  - Multiple Field Expression
- Placement Properties
  - Relative to Symbol
  - Deconflict Labels
- Scale Range for Labels
- Once Label Properties are Set, Turn them on and Off from Layer Operations Drop-Down

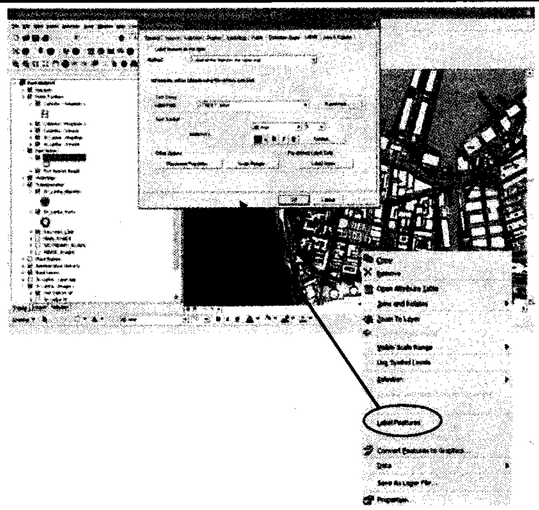


Figure C.21. Fort District Buildings Layer *Labels* Property

The final tab in the layer properties, *Joins & Relates*, is beyond the scope of this introductory tutorial and hence not discussed here.

C.5 Map Frame Operations and Properties

As discussed in the previous sections, a map is a collection of many layers with interacting properties and individual attributes. This collection of data has to be displayed in an organized fashion to render the map useful. The Map Frame therefore has certain properties that are applied collectively across all its layers to set a uniform stage for the map display.

Figure C.22 shows the Map Frame *Operations* that are available by right clicking on the Map Frame name, *Fort District* in this example.

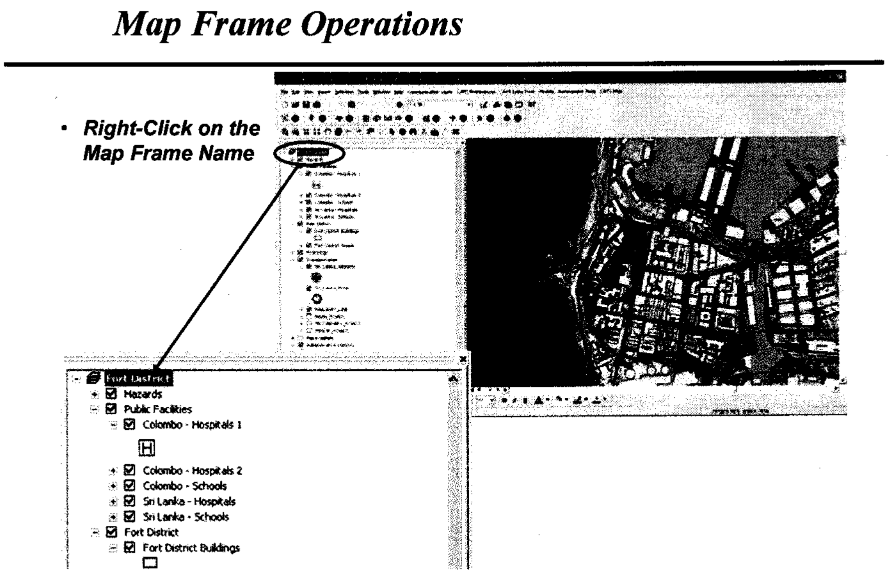


Figure C.22. Fort District Map Frame Operations Available via a Right-Click

The complete view of the menu is shown in Figure C.23 where the arrow-head icons indicating secondary commands have also been expanded. The more routine operations include the addition of Data Layers and Group Layers to the map, Copying and Removing Layers, controlling the display of the layers, and labeling schemes of the features.

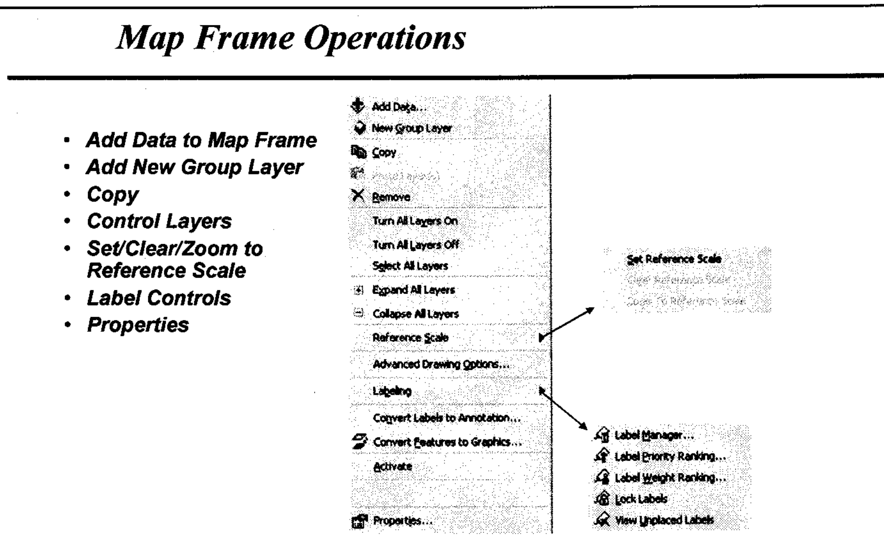


Figure C.23. Fort District Map Frame Available *Operations*

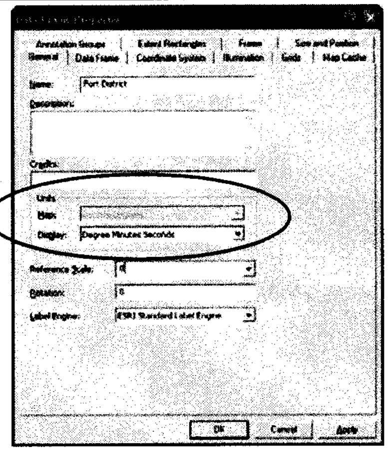
The last operation is viewing and/or setting of the *Properties* of the Map Frame which is a multi-tabbed menu. The Properties *General* tab yields the display shown in Figure C.24. Perhaps the most important item is the Units definition. *Map* refers to the stored units of the underlying data that cannot be modified, in this example Decimal Degrees. The Display units are the metrics for viewing and measurement purposes used on the computer screen or printed material. This is a user-defined attribute and in general, the Map and Display units may be different.

It is important to note that the Map Units must be specified for the proper operation of the CATS analytical tools and data manipulation.

Map Frame Properties - General

- ***Edit Name***
- ***Description Comments***
- ***Units***
  - ***Map - Ground units of measurement– Example, Decimal Degrees the coordinates of spatial data are stored.***
  - ***Display - The units rendered on a computer screen or on a printed map.***

  **** Map / Display can differ.****



*** Map Units Must Be Specified for CATS Analysis Tools To Work ***

Figure C.24. Fort District Map Frame *General* Property

Another important property of the Map Frame is its *Coordinate System*, which may or may not be the same as its layers. The available options are shown in Figure C.25. In general, the layers are specified in their native coordinates while the map frame is expressed in a predefined system, *Geographic* for Latitude/Longitude and *Projected* for Linear measurements on the map. Modifications to the coordinate systems of existing maps must be done cautiously. The software will detect a conflicting choice and generally issue a warning message which is also shown in Figure C.25.

Map Frame Properties – Coordinate System

- ***Current Coordinate System***
- ***Select a Coordinate System***
  - ***Custom***
  - ***Predefined***
    - ***Geographic: Lat/Lon Measure***
    - ***Projected: Linear Measure***
  - ***Layers: Native Coordinate System***
  - ***Beware of Limits!***

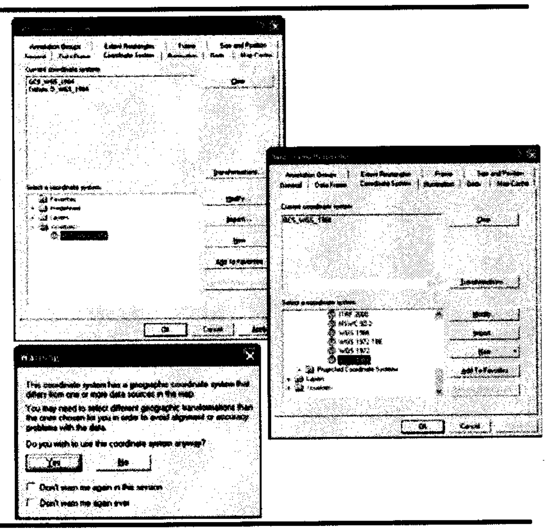


Figure C.25. Fort District Map Frame *Coordinate System* Property

The topic of map *Projection* was briefly alluded to in the previous discussion. A more detailed treatment is well beyond the scope of this write up. Suffice it to note, however, that map projections are a way of visualizing a three dimensional world in a two-dimensional, flat perceptions. Naturally, these projections have spatial limitations and can cause distortions at their boundaries. Figure C.26 summarizes some unique aspects of map projections while Figure C.27 shows an example of using the incorrect projection where the worldview is greatly distorted when the Sri Lanka projection is applied to the globe.

Map Projections

- Map projections were created to allow a round Earth to be portrayed on a Flat Surface
- Different projections cause different map distortions.
- The more localized a projection the less local distortion.
- Localized projections cause greater distortion on non-local maps.
- Coordinate Systems come in two varieties:
  - Geographic – Decimal Degree based
  - Projected – Cartesian based

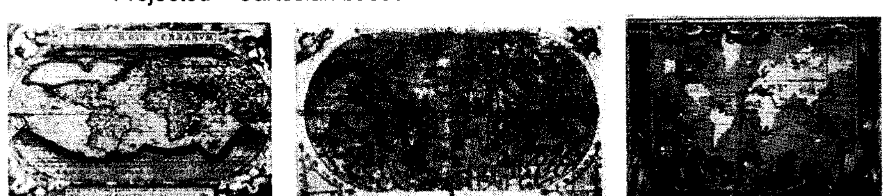


Figure C.26. Map Projections and Coordinate Systems

Projection Differences

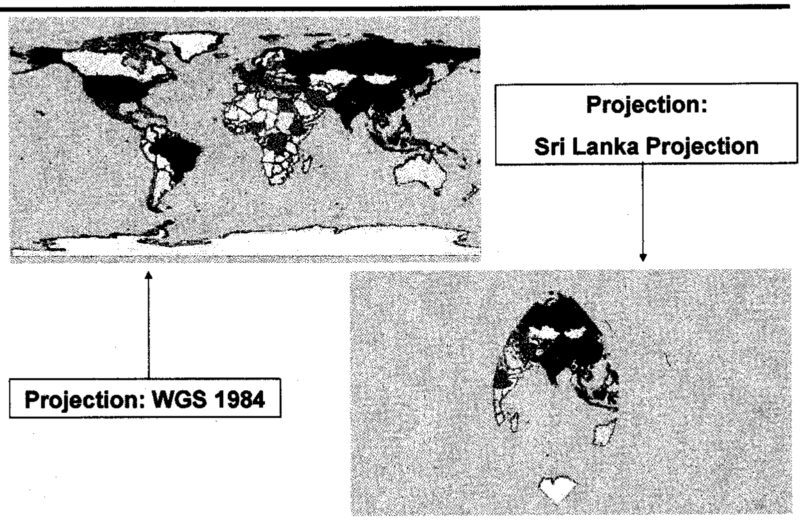


Figure C.27. Map of the World Using Two Different Projections