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RECOMMENDATIONS FOR AN IMPROVED RESPONSE TO HAZARDOUS MATERIALS RELEASES

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Estimado Ingeniero Esteban Ramos González,

Adjunto estamos entregando nuestro reporte titulado "Recomendaciones para Procedimientos Mejorados de las Materiales Peligrosos". Fue escrito en el Instituto Nacional de Seguros desde el 15 de mayo al 4 de julio de 2006. El trabajo preliminar fue iniciado en Worcester, Massachusetts, antes de llegar a Costa Rica. Estamos emitiendo simultáneamente una copia de este reporte a Profesor Guillermo Salazar, Profesor David DiBiasio, y Profesora Natalie Mello para su evaluación académica. Después de la revisión hecha por los profesores, la copia original de este reporte se catalogará en la Biblioteca Gordón en Worcester Polytechnic Institute. Leagradecemos el tiempo que usted y el resto de personal en el Departamento de Ingeniería nos han dedicado.

Atentamente,

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Report Submitted to:

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RECOMENDATIONS FOR AN IMPROVED RESPONSE TO HAZARDOUS MATERIAL RELEASES

July 5, 2006

This project report is submitted in partial fulfillment of the degree requirements of Worcester Polytechnic Institute. The views and opinions expressed herein are those of the authors and do not necessarily reflect the positions or opinions of El Cuerpo de Bomberos of Costa Rica or Worcester Polytechnic Institute.

This report is the product of an educational program, and is intended to serve as partial documentation for the evaluation of academic achievement. The report should not be construed as a working document by the reader.

ABSTRACT

The Cuerpo de Bomberos, the National Fire Department of Costa Rica, would like to improve their emergency response and preparedness pertaining to chemical releases. We reviewed their procedures for handling chemical releases and proposed the use of a chemical plume dispersion modeling program, CAMEO®, developed by the Environmental Protection Agency. We then made recommendations in regards to necessary resources for improved emergency response and preparedness plans along with implementation of the CAMEO® software program.

AUTHORSHIP PAGE

As confirmed by the signatures below, every section of this report is comprised of the collaborative effort from Amber Dangelo, Kristen Hodel, and Michael Wood. All three students have actively and equally participated in the creation, development, and editing of each section.

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EXECUTIVE SUMMARY

Tragic chemical release incidents of dramatic proportions took place in the 1970s and 1980s. These included the devastating chemical releases in Seveso, Italy and at the Union Carbide plant in Bhopal, India, which injured over 100,000 people. These incidents have opened the eyes of the public to the dangers of chemical spills to humanity and the environment. The country of Costa Rica has seen a marked increase in the amount of chemical spills per year with 241 releases in 1998 increasing nearly 460% to 1109 releases in 2004.

In June of 2002, there was an accidental release of twenty tons of chlorine gas at the Irex Soap Company in the area of Tres Ríos, Costa Rica. A tanker truck hit a pipe connecting itself with a stationary tank containing the chlorine and broke the connecting valve. The amount of gas that leaked out was so large because the truck owner fled from the scene instead of reporting the leak. By the time citizens began feeling the effects and called local authorities a thick cloud of chlorine had surrounded the tank making it difficult for the fire department to locate the source of the release. The release was not fully contained for over thirteen hours injuring approximately 1,250 citizens and severely damaging the surrounding ecosystem. This release is an example of the need for improved chemical release preparedness and response plans in Costa Rica. Besides chemical facilities, chemical releases can occur in transit. The transportation of chemicals along Costa Rica's narrow, winding roads increases the risk of negative effects that an accidental chemical release can have on any town, farm, or national park with a main road nearby.

The Cuerpo de Bomberos, the national fire department of Costa Rica, is charged with responding to and handling all chemical releases within the country. They also work with other national agencies to evacuate citizens and assist with cleanup. Due to an increased amount of chemical use and releases in Costa Rica, they believe it is important to offer better tools for their Bomberos to respond to these releases. Our mission was to assist them in developing enhanced emergency preparedness and response plans for handling these incidents by recommending

procedures to more efficiently protect citizens in the case of a chemical release as well as ensure the safety of the Bomberos on scene.

We used a variety of methods to complete our mission. To develop a better understanding of the improvements needed for the current system in Costa Rica we compared the procedures of the United States with those currently used in the country. We conducted a needs assessment of what the Bomberos currently have in place for modeling software and what benefits they would like to receive from using a program that models hazardous material releases. We also effected simulations during our interviews at fire stations using the plume dispersion modeling suite of programs named CAMEO, to establish if this software was ideal for the Bomberos. This suite was developed by the Environmental Protection Agency (EPA) in the United States and is freely distributed. Finally, to complete this research, we collected statistics from Bomberos' archives and interviews at seven fire stations in Costa Rica.

Through our interviews, we received input from the Bomberos on how they would use a plume dispersion modeling program. Through these inquiries, we found that the only fire station that uses a plume dispersion modeling program is the Tibás fire station where the country's only hazardous materials (Haz-Mat) team is located, they currently use CAMEO® as a chemical database, but not ALOHA and MARPLOT, the other two programs in the suite. ALOHA uses current weather conditions and the specifications of the release to output a figure showing a toxic threat zone. This zone can then be positioned on a map of local area using MARPLOT.

We also determined that the Bomberos who have not used a plume dispersion modeling program see a need for the CAMEO suite to help improve procedures. At the present time, the program is only available in English from the EPA; therefore from our interviews at the individual fire stations, we determined that in order to use it to the best of its ability the Bomberos need a Spanish version of the software.

Through the completion of these objectives, we reached conclusions in order to make recommendations regarding the needs of the Bomberos to implement the CAMEO suite into their current chemical emergency preparedness and response plans. We concluded that in order for the implementation to be successful the Bomberos would need more resources, including a mobile weather station to provide real-time atmospheric data and an increase in the amount of first response equipment. We recommend that the local fire stations be supplied with more of the equipment needed to properly respond to a chemical incident. This includes, but is not limited to, suits, chemical kits, patches, and absorbent materials. We immediately propose the purchasing of a mobile weather station for the Haz-Mat vehicle in Tibás. The team already possesses a laptop as well as a vehicle, which are both necessary for the use of the program. Since this is the only Haz-Mat team in the country, it is essential they have the proper tools to protect the public.

In lieu of the face that the Bomberos will need to train personnel to run the program, we propose at the current time the creation of a central command center in the Oficina de Comunicaciones[1] (OCO) because all fire stations throughout the country all have the ability to communicate with this office. The overall cost of training for personnel nationwide will be reduced since the use of the program will be centralized in the OCO office. Trained personnel will always be available to receive information and operate the CAMEO suite in the case of an emergency. This also ensures that in the event of a breakdown in the program out in the field, possibly with the Tibás Haz-Mat team, OCO will be trained to communicate with the team to run the program.

We next concluded that the Bomberos would need training in methods to quantify atmospheric conditions visually, if they did not have the use of a mobile weather station. We recommend presently for all other stations the training in visual observations of the weather. The Instituto Meteorológico Nacional[2] (IMN) of Costa Rica has the ability to train all first response Bomberos to use techniques for visual weather observation. Finally we recommend the enhancement of communications between OCO and the IMN. This formation would allow for the conveying of

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[1] Central Communications Office
[2] National Meteorological Institute

atmospheric conditions from one of the 14 weather stations located throughout the country that relay conditions to the IMN headquarters in real-time.

The previous conclusions and recommendations are to be implemented in order to begin the progression towards improved chemical emergency preparedness and response plans. In order for the Bomberos to further improve the procedures of their organization, many larger actions will need to be taken. One recommendation for the future is the creation of more Haz-Mat teams to service the country. These will be located in stations that respond to high amounts of hazardous materials calls, but will have separate jurisdictions. This will alleviate some responsibility from the Tibás team. The next recommendation is the purchasing of laptops in stations that respond to the most hazardous material incidents in the country. This will allow them to be able to use the CAMEO suite to its fullest capabilities. We also recommend for the future that preparedness plans in industry be mandatory so that first response equipment and trained personnel are available at every company in case of emergency. Along with this we propose that companies be mandated document the chemicals and quantities stored at their facilities and the enforcement of regulations on identification for transport. Both of these improvements in regulations will allow the Bomberos to be better prepared when responding to a chemical incident. Our final recommendation for the future is the translation of the CAMEO® database and ALOHA model into Spanish. This will allow the Bomberos across the entire country to use the entire suite efficiently. Through our research, analysis, conclusions, and recommendations we believe that the Bomberos can use the CAMEO suite to improve their chemical emergency preparedness and response plans to better protect Costa Rica and its citizens.

Chapter 1 : INTRODUCTION

A major chemical release[3] in Bhopal, India in 1984, which injured over 100,000 people and killed more than 3,000 in its immediate aftermath, showed the world how chemical releases could have a great impact on society and the environment. The amount of death and destruction caused by this one incident raised the public's awareness around the globe about the possible dangers of chemical releases. This caused many citizens to place pressure on their governments and demand more precautionary measures to be put into place. The development of preventative laws and regulations brought about improvements in emergency preparedness and response planning for chemical releases. These plans allowed the responsible agencies to know how to respond before an accident ever occurs as well as how to react when a situation arises.

In the United States alone there are approximately 5 million cases of chemical releases yearly and almost 20% of these are emissions into the air (Inside the Emergency Response Program, 2006). These releases can occur due to human error, improper handling or mechanical failure. These chemical leaks impact citizens and the environment and, depending on the toxicity and amount of the chemical, it can cause death and extreme devastation to the affected areas. In the United States, companies that manufacture, use and ship chemicals are responsible for having first response plans that include preliminary containment of the release as well as the knowledge of when to call a higher authority. To protect the environment and its inhabitants, laws and regulations, emergency protocols and contingency plans have been created and exercised around the globe. Specifically, in the United States, the Environmental Protection Agency (EPA) is primarily responsible for regulating the use of chemicals and the local fire departments are in charge of protecting the environment and citizens from effects of chemical spills when they are called upon.

[3] We have defined the term chemical release to mean any uncontrolled discharge of a man-made liquid or gaseous substance. In this paper a number of synonyms are used for release including: spill, leak, and accident. They all imply an uncontrolled release of a chemical into the air.

Due to this the United States has developed an extensive emergency preparedness and response system that allows for the best possible management of these accidents.

When creating emergency response and preparedness plans, the relevant authorities in each country need to know an enormous amount of information about the toxic chemicals that are most prevalent in their country, such as the nature, location, quantity, and toxicity of the chemicals. This information is helpful when it comes to responding to a chemical release. This emergency response system starts with the companies that house the chemicals and moves up through local, state, and federal levels based on severity in an attempt to keep impacts minimal. By having a strategy to implement in the instance of a chemical release situation, countries can better protect their homeland and its citizens. One of the tools widely available and used by these agencies in the United States is the CAMEO® modeling application developed jointly by the EPA and National Oceanic Atmospheric Administration (NOAA). The CAMEO suite is able to take in data about current atmospheric conditions and the source of the release to produce a map of where the chemical will travel to. Software programs, like CAMEO, are applied to predict the behavior of the chemical in the environment and finding the appropriate program for each country is important. The CAMEO program suite allows for different scenario inputs that aid in the development of emergency preparedness plans and has the capability for real-time modeling that may be used in an actual emergency response. The organization of its agencies coupled with the implementation of technology, such as modeling programs, allows the United States to serve as a model system for emergency preparedness and response.

Costa Rica is seeking to match the expertise possessed by other countries, like the Unites States, regarding emergency preparedness and response. While formulating a plan, it is beneficial to research the effectiveness of other countries' current protocol and the current legislation that needs to be adhered to. The organization that is responsible for responding to large chemical releases in Costa Rica is the Cuerpo de Bomberos, the national fire department. They would like to know what lessons might be learned from a comparison of emergency response and preparedness in the United States versus Costa Rica, with a particular emphasis on the use of dispersion modeling programs, so that they will be better prepared to handle any type of chemical spill. Ideally, the program would be able to operate in real time, although most programs are used to simulate potential chemical releases. To assist in developing a protocol, evaluators use plume modeling software to conduct a simulation. With the use of a modeling program, the Bomberos hope to be better prepared to handle chemical emissions into the air.

While we worked with the Cuerpo de Bomberos, our goal was to assist them in developing improved procedures to handle hazardous material releases in Costa Rica through the recommendation of a dispersion modeling program. In order to accomplish this goal we implemented a number of strategies:

- We conducted a review of current Costa Rican emergency response and preparedness policies and procedures based on archival data. The findings from this review will be compared with the findings from our review of policies and procedures in the United States. By comparing the policies in both countries, we will be able to identify best practices that might be usefully applied in Costa Rica.
- We interviewed firefighters to determine the procedures they use in handling chemical spills, and to determine where they see a need, if any, for improvements in the existing emergency planning and preparedness policies and implementation strategies. We also used these interviews to determine the level of interest in and need for expanded plume modeling capabilities.
- Using the information gained from interviews with the Bomberos we compared their emergency preparedness and response plans with those of the United States and from this we matched their specifications to the modeling programs and presented our recommendations for a plume dispersion model, the CAMEO suite.
- We determined what, if any Geographic Information Systems (GIS) software and databases the Bomberos use presently, and if these can be used to integrate census data into a dispersion modeling program. This better

allowed us to determine what programs would be the best for the country. Further, we researched their databases and any methods to create, convert, or import their GIS program files into the mapping programs of evaluated software programs.

Through our analysis of the research and interviews we were able to make informed recommendations to the Bomberos regarding a plume dispersion modeling program for their present system of managing chemical releases. The goal of our project is to allow the Bomberos to continue their history of preserving and protecting the environment and citizens of Costa Rica.

This report was prepared by members of Worcester Polytechnic Institute Costa Rica Project Center. The relationship of the Cuerpo de Bomberos and the relevance of the topic to the Cuerpo de Bomberos are presented in Appendix A.

Chapter 2 : BACKGROUND

2.0 Introduction to Background

This chapter contains background information pertaining to our project. Information is presented on chemical releases, current US emergency preparedness and response plans, chemical presence in Costa Rica, and vapor dispersion modeling software. In this literature review an understanding for the need for our project as well as knowledge of necessary background information is introduced.

2.1 Increase in Chemical Releases

As the world has industrialized, the number and extent of uncontrolled chemical releases in the environment has increased (Swift, 1999). Increasingly, these spills have involved toxic releases of great quantity that affect the population and their environment. The impact that these deadly releases have had on the surrounding ecosystem and human life has brought attention to the need to regulate and report the presence of chemicals in industry

Figure 2-1: Devastation in Seveso

A major toxic chemical leak occurred in Seveso, a town in Northern Italy, in July of 1976. A reactor vessel safety plate burst at a chemical plant belonging to the ICMESA firm releasing approximately two kilograms of trichlorophenol into the air. The cloud of toxic gas dispersed over a large area, tainting livestock, people, agriculture, and land in the area. Luckily, a worker noticed the cloud and stopped the release after only twenty minutes.

Precautionary measures were taken including the burning of several inches of topsoil, no agricultural products were allowed to be eaten for several months after the incident and local livestock were killed and incinerated to prevent contamination into the food of the local people. The town of Seveso was very fortunate that there have been no significant long term adverse effects of this release on human health or the environment due to the safeguards taken after the incident. To date only one person has died from liver cancer; and a few people developed skin cancer, although many women had abortions to prevent malformations to their unborn children (The Seveso Incident, 2006).

The deadliest chemical leak thus far in world history occurred in Bhopal, India in 1984. On December 3, at Union Carbide India Limited, a pesticide plant, water leaked into the number 610 tank of methyl isocyanate, which overheated thus releasing twenty-five tons of gas (Michigan State University, 2001). This release immediately killed over 3,000 people and left over 100,000 people injured (Graham, 2001). Later analysis of the incident found that the accident occurred due to a combination of human error and an incorrectly designed safety system that had been non-operational for four months prior to the incident (Sullivan, 1998). The alarm at the plant was not sounded for over an hour after the leak occurred. By this time the damage had been done and the employees could do little to lessen the impact of the leak. This incident has been a key factor for many countries to develop their emergency preparedness and response plans for chemical spills and leaks.

2.2 Development of Emergency Plans in the United States

The Bhopal tragedy and other subsequent chemical leaks, including a domestic incident at a Union Carbide plant in Institute, West Virginia in 1985 (Environmental Quality Control, 2004), raised the public's awareness of the chemical spills occurring in the United States and spurred the United States Congress to make improvements. These improvements occurred in 1986, after the chemical release in West Virginia. These changes were made to the Comprehensive Environmental

Response, Compensation, and Liability Act of 1980 under the Superfund Amendments and Reauthorization Act (SARA). Title III of SARA is known as the Emergency Planning and Community Right-to-Know Act (EPCRA) which is enforced by the Environmental Protection Agency (EPA). This act requires that manufacturers, consumers and keepers of hazardous chemicals maintain detailed records of the amount, use, location and any discharge of these chemicals. Citizens can then be informed of what chemicals are in their neighborhoods, where they are stored, and when they are released. Any company or facility that falls under the EPCRA requirements is also bound by the Hazardous Waste Operations and Emergency Response (HAZWOPER) rule. This means that a company must have personnel on site at their facility that are trained to handle chemical spills or releases of any size and must be able to clean and dispose of the chemical properly and efficiently. This training is required by law and every company that must report to the EPCRA must abide by the HAZWOPER rule (Emergency Planning for Chemical Spills, nd).

The EPA works with state authorities to develop contingency plans and educate the public on prevention of chemical releases. Local Emergency Planning Committees (LEPCs) and State Emergency Response Committees (SERCs) were created to better organize communities in the event of an emergency (South Dakota Department of Environment and Natural Resources, 2006). When a company holds a substance that exceeds a specified threshold level they are then required to work with LEPCs to develop an emergency response plan in order to reduce the risk to citizens in the even of a chemical leak. Threshold levels for reporting to local authorities are listed as over the Threshold Planning Quantity (See Glossary) or 500 pounds for extremely hazardous substances and 10,000 pounds for hazardous substances (Department of Ecology, 2006). The definitions for extremely hazardous substances and hazardous substances are listed under CERCLA section 101(14) (Environmental Protection Agency, 2006).

In 1989, EPCRA was implemented and the first Toxic Release Inventory (TRI) became available to the public. This inventory recorded the nature and location of toxic releases into the atmosphere in different communities. Surprisingly, this was the first time that the public and local officials had any idea about the amounts and kinds of chemicals in use in their communities and the number of releases that occurred. This information has been used effectively by environmental and community groups to raise awareness about toxic chemicals in society, and has been used by local officials to develop emergency preparedness and response plans. It should be noted, however, that the TRI is based on self-reporting by industry, and refers mostly to ‘routine’ and not emergency releases. In 1994 the number of toxic chemicals required to be reported under the law doubled, making the data available to the public more informative and complete. Having this kind of information accessible to the community helps people to be aware of the potential dangers of these chemicals and possible chemical leaks and makes manufacturing companies more aware of the potential damage they could cause to the area.

Twenty-five percent of accidental chemical releases in the United States occur while the substances are in transit (Managing Hazardous Materials Incidents Volume I, 1992). Because of this, regulations and precautions must be taken while transporting chemicals. The Federal Hazardous Materials Transportation Act (Federal HazMat Law), originally passed in 1975, applies to ". . . any person who transports, or causes to be transported or shipped, a hazardous material; or who manufactures, fabricates, marks, maintains, reconditions, repairs, or tests a package or container which is represented, marked, certified, or sold by such person for use in the transportation in commerce of certain hazardous materials" (para. 2, Department of Energy, 2006).

The Hazardous Materials Transportation Uniform Safety Act was passed in 1990 to clarify and supplement local, state, and federal regulations created under the Federal Hazmat Law. This required states to develop uniform policies regarding hazardous material transportation (Department of Energy, 2006). The Federal HazMat Law is enforced by the Research and Special Programs Administration (RSPA) along with the Federal Highway, Railroad, and Aviation Administrations. These agencies govern motor, rail, and air carriers, respectively, while the RSPA has jurisdiction over container manufacturers and shares jurisdiction over maritime shipments with the U.S. Coast Guard (Department of Transportation, 2005).

2.3 Emergency Plans in the United States

Over 20,000 chemical releases occur each year in the United States that are managed under the National Response Plan, which is overseen by the National Response Team, co-chaired by the EPA and U.S. Coast Guard (Inside the Emergency Response Program, 2006). Numerous smaller releases occur in the United States each year that are handled by individual companies and local fire departments. When a release occurs that a company and the local emergency response personnel cannot handle, it is reported directly to the National Response Center (NRC) (National Response Center, 2002). The NRC is staffed 24 hours a day by Coast Guard employees, who then notify a local EPA or U.S. Coast Guard On-Scene Coordinator (OSC). The OSC determines whether the local authorities have the situation under control or if federal assistance is needed. A federal agency that the OSC may summon if assistance is needed is the EPA's Environmental Response Team. Under the Environmental Response Team there are five agencies; one of them, the Chemical Emergency Prevention and Preparedness Office responds specifically to chemical emergencies (Inside the Emergency Response Program, 2006). The structure of the National Response Team is outlined in Appendix C.

The National Response Plan comes into action when an owner or operator of a facility or vessel reports a hazardous chemical spill that has crossed a specified threshold based on the toxicity of the chemical. Thresholds for more toxic chemical are lower therefore even a small spill may trigger an emergency response. These thresholds are stipulated by law and enforced by the EPA. These thresholds for thousands of chemicals used in industry are listed in #40 Code of Federal Regulations 302.4 (Oil & Chemical Spill Reporting, 2005). Spills are reported to the National Response Center where the incident is then passed on to local authorities. Ideally under the EPCRA firefighters would know of every chemical stored or in use in local industries as well as the contents of any containers being transported in the surrounding area. Because of the fact that the EPCRA is based on self-reporting, this is not always the case as many business fail to inform authorities of the chemicals they house. This lack of communication of the type and location of chemicals can have many environmental and biological repercussions when a leak occurs, like the ramifications of the disaster in Bhopal, India, which is why the EPCRA was written into law (Off-site Consequence Analysis, 2006).

In the United States emergency response personnel can be divided into first responders and hazardous materials (HazMat) team members in a network that is outlined in Appendix C. A first responder might be a local firefighter, a police officer patrolling highways, or a trained employee at an industrial site. They do not need to how to control a situation, but must be trained to recognize when a situation needs to be managed by higher authorities. More specifically first responders should understand the potential outcomes and ramifications of hazardous material spills, be able to recognize a hazardous material, realize when there is a need for HazMat teams, and have the ability to isolate an incident site (Cheremisinoff, 1995). Proper training is essential for first responders. They are the citizens most at risk because they are responsible for determining the extent of a situation, which frequently puts them in harm’s way. The information they gather about the incident affects how a HazMat team responds and treats the site.

The roles of Hazardous Materials teams members include establishing a safety plan, understanding chemical terminology, being able to classify and identify materials and chemicals, implementing decontamination measures, keeping records of procedures, and performing hazardous materials operations which consists of control and confinement of a chemical (Cheremisinoff, 1995). Additionally, they consult with LEPCs when a chemical spill occurs to implement the plans that have already been drawn up. In this way the EPCRA is implemented into communities to better protect citizens. These teams work in conjunction with local fire departments so that they have access to the same resources including chemical plume modeling software to aid them in assessing how to treat a chemical spill. This software was created to provide rapid information to while attending to a chemical emergency. Many firefighters, State Emergency Response Commissions, LEPCs, Industry, Schools, Environmental Organizations and Police Departments use this software to help directly aid their emergency preparedness and response plans (Environmental Protection Agency, 2002).

2.4 Characteristics of Modeling Software

Government agencies and private organizations in the United States have developed a variety of plume dispersion modeling programs in the past two decades. To accurately and efficiently predict or plan for the behavior of a toxic cloud, it is advantageous to have a dispersion modeling program to ensure that responders have a complete and effective emergency plan.

Modeling software has been used to help local authorities and emergency responders develop a protocol to handle different conditions and scenarios when faced with a toxic chemical spill. There are many variables that must be taken into consideration when planning for chemical accidents. These variables include, but are not limited to, meteorological, the type of release and the location of the release. Because of this the EPA and other organizations have created modeling software that aids emergency planners and responders in exploring the impact of different releases. Using the information that is obtained from the software they are able to determine what may be the most appropriate response in the situation at hand.

To properly use modeling software and for it to provide meaningful results, the properties of each chemical must be studied and considered in the model. Additionally, how much of the chemical is present and where it is located in the facility, the size of the container they are released from, the rate at which the chemical is being released, and whether the chemical is under pressure determines how much of a hazard the spill could be come. All of these factors are then affected by constantly changing weather conditions including wind speed and direction, humidity, and precipitation which must be included in the model to assess the hazards as accurately as possible (Off-site Consequence Analysis, 2006).

Although various dispersion models are used today, they all have the same goal. “Dispersion models use complex calculations to determine the area affected by a toxic release and the chemical concentrations within the affected area” (Haroz, 2004). In the majority of instances the models are not used for real-time evaluation of chemical releases because of the cost of the required equipment and a mobile weather station to provide accurate and up to date weather conditions. Although, at the present time, a push for real-time use is becoming more prevalent because the advantages are known to be very beneficial to the containment of a chemical spill. Instead, these models are used to map out certain scenarios, such as worst case or best case, in order to better “develop contingency response plans” (Haroz, 2004). Due to the ability to visually map out the effects a chemical release with differing weather, terrain, and wind conditions truly allows for insight as to what may happen in the event of an actual emergency. When this program is used in conjunction with a chemical database and a GIS map of the affected area, it can be a very valuable and effective tool for preparing for chemical releases.

To assist first responders and industries in responding to chemical releases in a more efficient manner the EPA has worked with other government agencies to develop a number of plume dispersion modeling programs. The EPA worked in conjunction with the Department of Transportation and Federal Emergency Management Agency to distribute the Automated Resource for Chemical Hazard Incident Evaluation (ARCHIE). A program suite developed jointly by the EPA and NOAA that is distributed freely via the internet is the Computer-Aided Management of Emergency Operations (CAMEO®). It is mainly used as a development tool for emergency preparedness plans for multiple agencies and industry. This suite actually contains three separate software programs. Additionally there is a variety of modeling programs that have been developed by private companies to meet their specific needs. Often times they are used in conjunction with CAMEO®.

CAMEO® is the original program that houses a hazardous chemical database and information regarding industrial facilities that use specific chemicals. CAMEO® "contains a chemical database of over 6,000 hazardous chemicals, 80,000 synonyms, and product trade names. Further, it provides a powerful search engine that allows users to find chemicals instantly" (Environmental Protection Agency, 2006) whether searching by chemical name or brand name. Utilizing a search engine this program allows the user to find chemical-specific information as well as information on facilities that house chemicals and the chemicals specifically contained in each.

The second program in this bundle is the MARPLOT ® (Mapping Applications for Response, Planning, and Local Operational Tasks) GIS-based mapping application. "It allows users to 'see' their data (e.g., roads, facilities, schools, response assets), display this information on computer maps, and print the information on area maps" (Environmental Protection Agency, 2006) in order to better visualize what would be impacted in the case of a release. This device utilizes U.S. Bureau of Census TIGER/Line files for accurate and updated information on populations, locations of high risk areas such as schools and hospitals, and roads.

Finally, ALOHA® (Areal Locations of Hazardous Atmospheres) is an atmospheric dispersion model that calculates the spatial distribution of toxic chemicals following a hypothetical release. The ALOHA® computer model was designed to determine how quickly a chemical will become airborne and then predict how it will move once in the atmosphere. "ALOHA® allows the user to estimate the downwind dispersion of a chemical cloud based on the toxicological/physical characteristics of the released chemical, atmospheric conditions, and specific circumstances of the release" (Environmental Protection Agency, 2006). Using these programs together, the user is able to plot the plume footprint of the specific chemical, knowing its hazardous properties, onto a map containing the information about surrounding communities in order to evaluate the overall level of risk that is posed by the release and hypothesize about the most suitable emergency response.

The differing characteristics of ALOHA and ARCHIE are outlined in Appendix D. From the table it can be seen that ARCHIE has the ability to model fire and explosion hazards, while ALOHA® can output data in both text and graphical form, such as a footprint map. ALOHA® also contains a few more features that allow it to give users a more detailed description of the vapor dispersion.

Although it is useful to have an idea of how a chemical plume is going to behave once in the atmosphere, it is even better to be able to observe what it is doing in real-time. As first response software development companies continue to improve their technology and programs it is possible that there may be a shift to real-time assessment of hazardous plumes. Companies are now beginning to market complete systems that include programs, sensors, and mobile weather stations in order to completely map the movement of a plume in real-time. One example of this type of package is the PlumeRAE system by RAE systems. The components of this system include: PlumeRAE® plume measurement software, AreaRAE GPS® system, and Coastal Environmental systems Weatherpack®. In addition to kits from private companies, weather data may be transferred to CAMEO ® in real-time as well.

Plume modeling software allows Hazardous Materials teams to have a more detailed picture of the spill and the surrounding neighborhoods. With ALOHA®, they can make more informed decisions regarding whether to have citizens shelter-in-place or evacuate and the route evacuees should take before any actual accidents occur. This planning allows for officials to be prepared for a variety of different situations that may arise. The chemical information stored in CAMEO® tells firefighters what characteristics a spill has, possibly what fire or health hazards it can pose so that they can wear the proper equipment to clean up the spill (Off-site Consequence Analysis, 2006). Altogether the CAMEO® suite has become a valuable resource for firefighters in the United States. Appendix E contains a complete illustration of how CAMEO, ALOHA and MARPLOT operate together and what information can be generated through the use of these programs.

2.5 Chemical Presence in Costa Rica

Due to its temperate climate and fertile soil, Costa Rica was a predominately agricultural country throughout the 20th century. Popular produce, such as bananas and coffee beans, were the primary exports of the country (Palmer, 2004). However, over the past 15 years there has been a significant shift in the focus of the economy as Costa Rica has become more developed, including an influx of new high-tech companies. One consequence of this increasing development has been a large increase of the production of chemicals within the country. The gross output of the chemical products industry alone increased from $28.83 million (1995 US dollars) in 1990 to $73.481 million (1995 US dollars) in 2001. The industrial uses of these chemicals include everything from food processing, the creation of textiles and clothing, construction materials, fertilizer, and the production of microprocessors and plastic products. All of these industries are prevalent in the current Costa Rican industrial landscape. Other industrial sectors, such as Basic Industrial Chemicals, Fertilizers and Pesticides, Rubber products, and Plastic products also saw significant gains in output during this same time period (Queri-International LLC, 2006). Costa Rica's Gross Domestic Product (GDP) is approximately $18.4 billion. The division is shown graphically in Figure 3. Agriculture, including products such as bananas, coffee, beef, sugar, rice and dairy products, makes up approximately a tenth of the GDP. Commerce and Tourism, including hotels, restaurants, tourist services, banks and insurance, make up just under two thirds of the GDP. And finally industry, which involves the use of chemicals, makes up almost a third of the GDP (U.S. Department of State, 2005). Currently in Costa Rica the two companies that produce basic chemicals, excluding fertilizers, are INDUSTRIAS LAFUENTE HNOS, S.A. and TRANSMERQUIM DE COSTA RICA S.A. These companies center their production on "basic industrial chemicals and are selling chemicals that are incorporated into a manufactured product or aid in processing" (Swift 1999, para. 7). Furthermore, there are 11 companies that produce assorted chemical products for use by commercial and regular consumers, 12 fertilizer and pesticide companies, as well as numerous paint, plastic, and rubber companies (Costa Rican Digital Exports Directory, 2006).

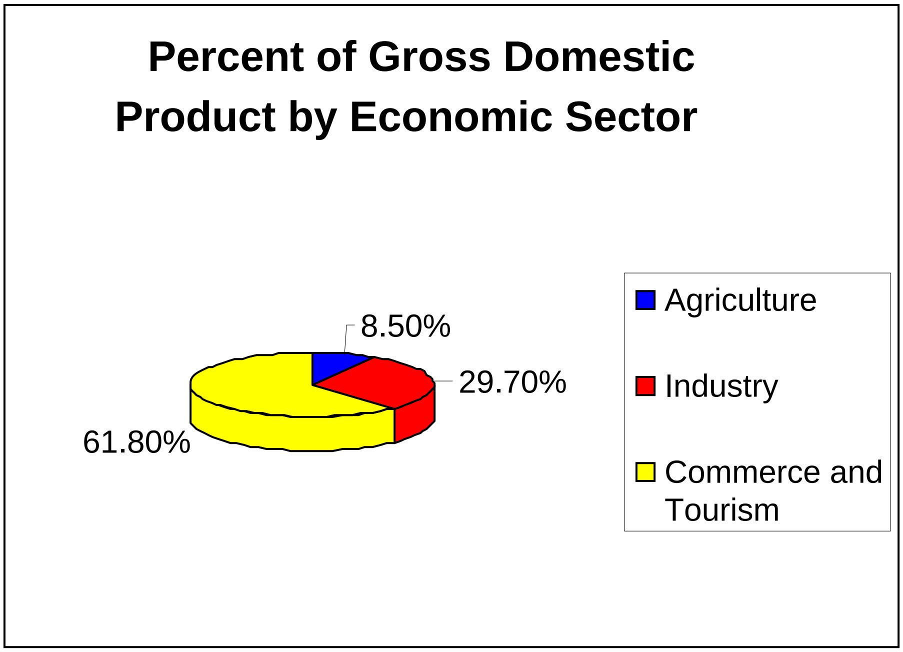


Figure 2-1: Percent Economic Growth by Sector
Adapted from U.S. Department of State, 2005

In Costa Rica there are 730 kilometers of waterways, 278 kilometers of railroad, and 35,303 kilometers of highway, of which only 4,236 are paved (see Figure 4). One hundred and forty-nine airports are located within Costa Rica (Infoplease, 2006). All of these means of transportation help to demonstrate the many ways that chemicals can get from one point to another, and also signify the growing number of possibilities that a toxic chemical spill may occur. In fact, internationally, 25.2% of all dangerous spills occur during transportation of hazardous materials (Suplemento de Cuenca y Technologic, 2004).

Figure 2-2: Major Highways in Costa Rica
Source: Hills of Portal on, 2006

Reflecting the growth in the use of chemicals in the industrial sector, an upward trend is seen in the total number of chemical spills that occurred in Costa Rica in the recent past (See Figure 5). These statistics represent the number of chemical spills involving hazardous materials that were responded to by the Cuerpo de Bomberos.

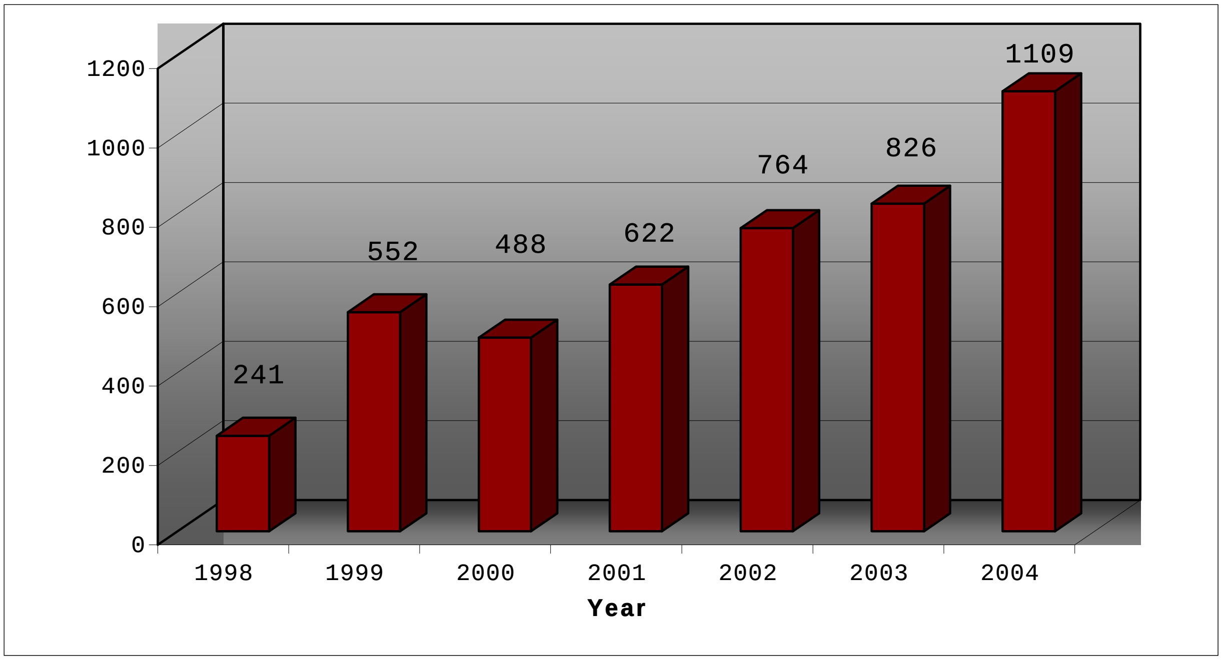


Figure 2-3: Chemical Spills in Costa Rica
Adapted from Suplemento de Ciencia y Tecnología, 2004 and Cuerpo de Bomberos del INS, Informe Estadístico, 2004

The most prevalent chemicals in Costa Rica include liquefied petroleum, ammonia, chlorine, LPG gas, hydrochlorate acid, nitric acid, methane, caustic soda water, and sulfuric acid (Suplemento de Ciencia y Tecnología, 2004). These are all used in different processes of industries located in Costa Rica. Chlorine gas was involved in one devastating accident in Costa Rica similar to the disasters in Seveso and Bhopal. In 2002, the Irex Company had a chlorine gas leak in the area of the Concepción de Tres Ríos. There was a rupture in the transfer pipeline between a stationary tank and a mobile tanker which caused a cloud of

toxic chlorine gas to form over the area.

2.6 The Cuerpo de Bomberos

In Costa Rica there are 61 stations that are divided into four independently operated regions. Fire departments in different regions often times share supplies and aid each other if an emergency requires additional support. In total, the Bomberos employs approximately 400 full-time firefighters, more than 1,000 volunteer firefighters, and 17 engineers to assist in fire prevention. In 1998, a specialized hazardous materials team was created and based in Tibás. In more recent years the Bomberos have looked to provide more first response chemical accident training and equipment to all firefighters and fire stations throughout the country. This is due to the increase in use of chemicals in industries in Costa Rica and the increase in occurrence of hazardous material spills as shown in Figure 4 earlier in this chapter.

The Bomberos are currently concerned with the lack of utilization of a chemical dispersion modeling program in their hazardous material release protocol because they believe that a program like this will help them better predict chemical plumes and better prepare for any chemical emergency. This program would be implemented in the conjunction with their current emergency preparedness and response plans. The organization of trained personnel and the implementation of a revised protocol with the use of a chemical dispersion modeling program will allow the Bomberos to better protect its citizens from the effects of hazardous material vapor dispersion. The program can provide more precise perimeters, allowing for the appropriate evacuations, information regarding specific chemicals and supplies data concerning the way chemicals in the air move with the changing atmospheric conditions. This information is readily accessible and is essential to being fully prepared for any chemical spill. The employment of a plume dispersion modeling program allows the Bomberos to strengthen their current emergency preparedness and response plans regarding chemical spills.

Chapter 3 : METHODOLOGY

3.1 Introduction to Methodology

The main goal of our project was to assist the Cuerpo de Bomberos in developing improved procedures to handle hazardous material releases in Costa Rica through the adoption and implementation of a plume dispersion modeling program. To complete this goal we outlined a number of objectives to complete with the specific methodologies used to carry out the objectives listed below.

Our first objective was to examine the extent of chemical releases in Costa Rica so we could fully understand how our project would benefit the Cuerpo de Bomberos. We then conducted interviews with firefighters at fire stations to gather information regarding their needs for a plume dispersion modeling program to assist them in handling chemical spills. Our third objective consisted of additional interviews with Bomberos and government officials to identify disparities between the resources needed to implement the software program and what the Bomberos currently have. Finally, we conducted a case study and sensitivity analysis to illustrate how the Bomberos can use the CAMEO suite to better prepare for and respond to chemical releases. Through the completing of these objectives we were able to develop a procedure to implement the plume dispersion modeling program into the Bomberos' emergency preparedness and response plans.

3.2 Archival Research

Before we arrived on site in Costa Rica we researched a number of plume dispersion modeling programs. We looked into the required inputs, features within the software, and the value of the outputs to the user as documented in Chapter II and Appendix E. Through this investigation we decided to present the use of the CAMEO suite to the Cuerpo de Bomberos when we arrived in San José. The three programs contained in the suite, CAMEO, ALOHA, and MARPLOT, were well received by our sponsor, as CAMEO was already used by the Hazardous Materials team in Tibás, so we continued with the plan of implementing the program when we conducted our interviews.

To grasp the scope of the chemical releases in Costa Rica we obtained statistics about how many calls the Bomberos responded to in recent years, specifically gas escapes and hazardous material incidents, and researched the Bomberos response to a significant chlorine release near Tres Ríos in 2002. The Cuerpo de Bomberos helped us with this by providing us with files of statistics and legislation from their records. We also traveled to Tres Ríos to review their records of the chlorine release. This research enabled us to have an understanding of the extent of chemical releases in Costa Rica as well as their emergency preparedness and response regulations, policies, and procedures. We analyzed these data before we completed our interviews so that we could have a frame of reference when we were speaking to the firefighters.

3.3 Interviews

We obtained the majority of the vital information for our project through interviews with recommended Bomberos and government officials in their central office and in outlying fire stations. These interviews were very important to our project because they gave us insight into the current state of the Bomberos procedures for handling chemical releases. As a result we were better able to identify and call attention to any disparities and positive features in the Bomberos' practices that would affect the process of implementing a plume dispersion modeling program into their emergency preparedness and response plans. A map of the locations where these interviews took place is in Appendix F.

3.3.1 Interviews with Bomberos and Governmental Officials

Our first interview was conducted to gain an understanding of current emergency preparedness and response regulations, policies, and procedures. We interviewed Luis Salas, Chief of the San José Zone, at the Central fire station in San José. He described to us how and when the chain of command in Costa Rica functions when there is a chemical release and what agencies work together to clean up hazardous chemicals. This information helped us understand the structure in which the Bomberos work.

We conducted more interviews with Alex Solís, Director of Operations for the CNE and Werner Stolz from the IMN. As Director of Operations, Sr. Solis coordinates responses to nation-wide emergencies that involve multiple agencies. He was able to assist us in understand more of what resources Costa Rica currently has for responding to large-scale chemical releases. Werner Stolz assisted us in determining what resources Costa Rica has for transmitting up-to-date weather data and other tools the Bomberos could use to input data into ALOHA. From this information we will be better able to determine if the plume dispersion modeling program should be used for conducting simulations of chemical releases or in real time and how the program should be implemented to best use the Bomberos' resources.

3.3.2 Interviews with Fire Stations

In order to collect data regarding the Bomberos resources, we interviewed personnel at recommended fire stations that included Tibás, Heredia, Alajuela, Puntarenas, and Limón. These interviews are documented in Appendices K through O. The results from the interviews are discussed in Chapter IV. Ing. Esteban Ramos recommended these stations to us because of their active role in responding to hazardous material releases. Limón and Puntarenas are both port cities, lying on the Caribbean and Pacific Coasts respectively. All of these departments were well versed in combating chemical and hazardous material releases thus they were the best source of information on the current and needed equipment, personnel, and technology.

At the fire stations we consulted personnel that had knowledge of their emergency response and preparedness plans. The firefighters discussed with us regarding the limitations of their resources and what equipment and training they would like to have to better handle chemical spills. Through these interviews we discovered in more detail what resources the firefighters in different areas have to handle chemical releases, what types of chemical releases they usually deal with and how they handle these, and what concerns these officials have concerning their ability to manage these incidents. We also conducted a simulation of a chlorine release at each station to show how the CAMEO program works. We chose chlorine because many stations told us that this was one of the most common chemical released. While we carried out the simulation we answered any questions the Bomberos had and then asked for their input pertaining to their thoughts on what resources they would need to implement CAMEO.

As we began developing our recommendations for implementation of CAMEO we visited OCO in Santo Domingo and the Tibás station again in order to present our recommendations. The Bomberos there assisted us in defining how we could implement the modeling program.

3.4 Case Study and Sensitivity Analysis – Irex Chlorine Release

A case study of the chlorine released from the Irex facility near Tres Ríos on June 13, 2002, was conducted as to show how the Bomberos can utilize the ALOHA program to both respond and prepare themselves for future chemical releases. We determined the figures as to the source of the release through speaking with the Bomberos in Tres Ríos. They also provided us with documents of the incident from their log books. We obtained the weather conditions from that day with the help of Juan Carlos Fallas from the IMN. These included: air temperature, humidity, and the velocity and direction of the wind. The dimensions of the truck were determined from researching the specifications for trucks carrying chlorine as well as photos provided to us by Alvaro Sánchez Campos.

With these parameters defined we were able to input them into ALOHA to establish a toxic threat zone of the release. We then imported the zone onto a map of the Tres Ríos area in MARPLOT to determine how far the chemical spread in relation to the surrounding neighborhoods. This zone was compared to a map created by the Bomberos after their investigation of the release to show how ALOHA can be used to predict where a chemical will disperse while it's being released.

For the Bomberos to understand how ALOHA can be used to develop plans for future chemical releases we conducted a sensitivity analysis of the Tres Ríos chlorine release by varying atmospheric conditions to model situations representative of Costa Rica's climate. We outlined all of the conditions that must be inputted into ALOHA. Then we simulated a series of five atmospheric conditions to illustrate how ALOHA is affected by changing wind speed, humidity, cloud cover, and air temperature. Through the analysis of the toxic threat zones outputted by ALOHA we established a worst case scenario for the Irex chemical release. This scenario incorporates the most severe dispersion of the chlorine release. This case study was used to illustrate how the Bomberos can use the CAMEO suite in the future to better protect the citizens of Costa Rica.

Chapter 4 : RESULTS AND ANALYSIS

4.1 Introduction to Results and Analysis

To fully understand the current Bomberos procedures for treating chemical releases and why improvements are needed we investigated

The amount of hazardous materials releases in Costa Rica is on upward trend. This problem is compounded by the fact that laws and regulations are not followed strictly when it comes to the storage and transportation of these materials. Also, the lack of regulations requiring companies to report the chemicals they possess on site is a major problem. Due these factors, it is necessary for the immediate creation of safe, effective, and feasible emergency response and preparedness plans. The current procedures on the local stations levels are adequate at best. These stations lack proper equipment as well as personnel to correctly handle such situations. Most methods for handling these releases are rudimentary and could be improved to better protect the Bomberos themselves, the citizens of Costa Rica, as well as save the Bomberos and ultimately the INS money through the reduction of unnecessary evacuations.

4.2 Statistical Investigation

Our research into the Bomberos statistics regarding hazardous materials allowed for a quantifiable measurement of the current chemical accident situation in Costa Rica. With the help of Bomberos in the central office we obtained data from the year 2000 through 2005. We extracted the data regarding hazardous materials, specifically which types, where they happened, and their severity. From this we constructed a series of graphs so we could visually analyze the trends in recent years. The highest frequency of gas escapes in all of the years investigated was in residences. Because of the propensity of gas escapes occurring in the home the

Bomberos can plan and be prepared for a large number of releases taking place each year. These statistics can be deceiving because it may appear the Bomberos need to be mainly concerned with gas escapes in the home. This is not true because although the frequency is higher in residences, the magnitude of these incidents do not equal the damage caused by accidents that occur in industry or during transportation of chemicals. The amount of chemical that is released is of extreme importance. Residential chemical releases are not significant to our project because most homes store liquefied petroleum gas (LPG) in small tanks for cooking, but industrial companies, such as Irex, have a large amount of chemical stored on site needed to manufacture its product. Any type of chemical release is hazardous to the environment and its citizens, but the extent of the damage is directly related to the amount of chemical released and the location of the discharge point. Small releases, such as LPG, do not carry the significance that greater releases do in our project because they are too small to model with ALOHA. The CAMEO suite is used to effectively predict the toxic threat zone of a large chemical release, such as the Irex incident in 2002, and can be a useful tool to implement for improvement in emergency preparedness and response plans.

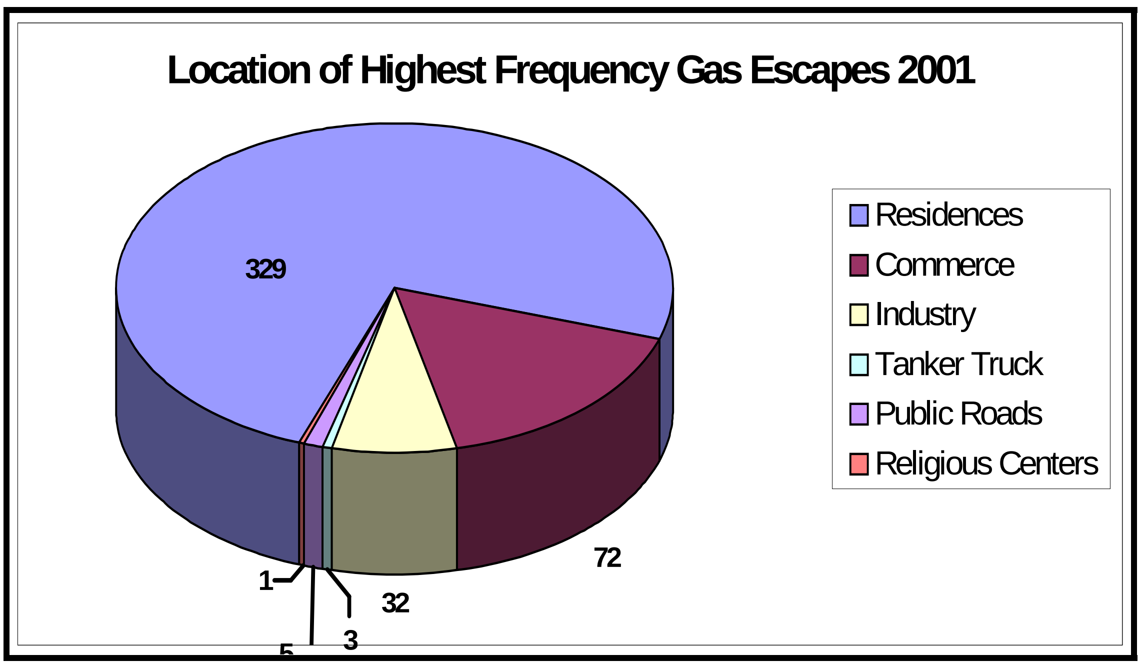


Figure 4-1: Location of Gas Escapes 2001

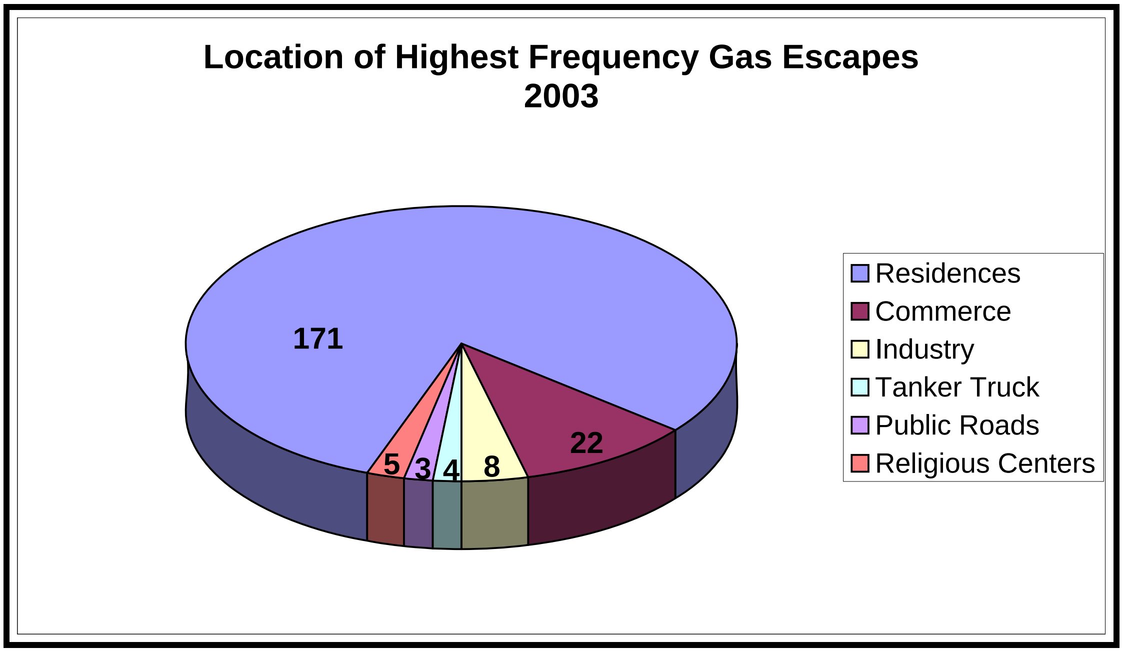


Figure 4-2: Location of Gas Escapes 2003

4.3 Bomberos Resources

Through our interviews we learned that the Cuerpo de Bomberos is a collaborative organization when responding to calls. The presence of OCO in Santo Domingo helps unify the Bomberos throughout the country since all Bomberos are dispatched through that office. In the Alajuela, Puntarenas, Tibás, and Limón stations we visited they spoke of how they can call on their neighboring stations to assist them. One of the more dramatic examples of this collaboration occurred after the chlorine release near Tres Ríos in 2002. Including the hazardous materials team from Tibás, 40 Bomberos from Tres Ríos and the Central Station responded to the incident. The CNE coordinated this response along with the Red Cross, Police Force, and the Ministries of Health and Transportation. Another example of this occurred while we were making an additional visit to the Tibás station. We were not able to speak with the Bomberos because they had been called away to assist with a fire in Alajuelita along with other Bomberos around San José. The cooperative environment throughout the Cuerpo de Bomberos allows them to share resources thereby increasing their effectiveness through a combined response.

All the Bomberos interviewed expressed that they want to improve their response to hazardous material incidents. They would like an unspecified amount more of first response training and equipment so that they can protect citizens in a more efficient manner. This attitude reflects the Bomberos desire to develop and implement the best plans and procedures possible.

4.3.1 Hazardous Materials Team Resources

Currently there are five trained Haz-Mat technicians that work with the Bomberos in Costa Rica. The technicians on the Haz-Mat team have been trained in Costa Rica to practice offensive procedures to control chemical releases. Two are based out of Tibás, one in El Roble and two more in Siquirres. The Haz-Mat team has a variety of equipment they use to handle hazardous materials incidents

This equipment includes three types of encapsulating protection suits, patches for holes in tanks or tubes, flammable and non-flammable gas detectors, and a variety of containers and kits for different types and sizes of hazardous material spills. Although they do have the most comprehensive set of equipment in Costa Rica they would prefer to have a complete contaminant suit for each man on duty. Further, they would like chemical kits for most commonly dealt with chemicals, which is station specific, and various other accessories. Some examples of equipment the chief of the Tibás station, William Hernández, suggested includes better clothes to wear under the protection suits, communication systems to wear inside the suits that can be activated only when a Bombero is speaking, and heavy machinery to move drums that may contain hazardous materials.

4.3.2 Fire Station Resources

During our interviews we collected data regarding the number of Bomberos that work on duty in each of the station. These numbers ranged from two to ten Bomberos on duty for a 24-hour period at each station as shown in Table 4-1. The number of Bomberos at a station is not reflective of the size of the station. The station in Limón covers a large port city, but only two or three firefighters work on duty there. This is due to a shortage of Bomberos because they are waiting for new Bomberos to finish their training. Limón has only two Bomberos on duty per shift so the work they can do on scene is limited until assistance arrives from volunteer Bomberos or neighboring stations. The amount of Bomberos on duty in each station affects how they work once they are on scene at an incident. During response, Bomberos must work in teams of two to ensure their safety. It is through this sharing of personnel between stations that allows the Bomberos to safely and promptly respond to any incident where extra assistance is needed.

Table 4-1: Amount of Trucks and Firefighters at Interviewed Stations

Station	Number of Trucks	Number of Firefighters on Duty	Total Number of Firefighters
Alajuela	2	5	34
Heredia	3	5	20
Tibás	4	10	34
Puntarenas	3	3	11
Limón	1	3	25

All five stations we visited possessed three basic tools for responding to chemical incidents. Their primary resource is the Emergency Response Guidebook (ERG), which is published and distributed by the United States Department of Transportation, Transport Canada, the Secretariat of Transport and Communications of Mexico along with the Centro de Información Química para Emergencias of Argentina. The guide is updated every four years and is published in French and

Spanish, as it is used throughout North, Central, and Latin America. A copy of the ERG is kept in every fire truck in Costa Rica. Inside the guide there is a wealth of information where a first responder can look up a Hazardous Identification Code from a placard on a tanker truck then obtain a description of a hazardous material. If the chemical is stored by a company on site at a facility where a release has taken place the Bomberos can receive the name of the chemical from an employee on-site then consult the guide for the description. The ERG contains a list of potential hazards, public safety precautions, and emergency response procedures for 61 classifications of chemicals. The Bomberos can also access a table in the guide that describes how far citizens should be evacuated from the point of release for a specified chemical. The information on this table is only of value for the first 30 minutes after a chemical is released. Currently this is the most detailed information first responders have in Costa Rica for handling chemical spills (Cloutier & Cushmac, 2004).

Additional equipment the Bomberos have in all six stations we visited were protective suits and a containment barrel to place the hazardous material in (see Figures 4-3 and 4-4 respectively). The suits were limited in number, usually two or three per station, and the barrel is only used with solid hazardous materials. Only two stations, Heredia and Tibás, possessed chemical specific kits as shown in Table 4-2. These kits contain the necessary tools to contain and handle a particular chemical leak. Stations that lacked these kits communicated a need for them in their station.

Figure 4-4: Barrel for Solid Materials

Table 4-2: Interview Matrix

	Alajuela	Heredia	Tibás	Limón	Puntarenas
Question	**Response**	**Response**	**Response**	**Response**	**Response**
How many firefighters, how many trucks at this station?	There are ten full-time firefighters that work 24 hours on duty then 24 hours off duty, 5 each day There are 24 volunteer firefighters that work 40 hours per month. They have 2 trucks.	There are ten full-time firefighters that work 24 hours on duty then 24 hours off duty, 5 each day. There are 10 volunteer firefighters and 3 trucks: 2 structural and 1 water tanker.	There are 20 full-time firefighters that work 24 hours on duty then 24 hours off duty, 10 each day. 2 MATPEL technicians.	There are 5 full-time firefighters and 20 volunteers. 24 hour shifts, 2/3 a day. Have 3 trucks and 1 is being repaired.	Six permanent firefighters, 3 a day and 5 volunteers. One truck, but it is very versatile.
How many spills does this station respond to a year?	About 5, typical spills include ammonium and chlorine	3-4 as well as occasional assistance to neighboring departments.	Consult Communications Center.	Approximately 50 a year, atleast one a week	about 20 a year
What kind of equipment does this station have for treating chemical spills?	They do not have much equipment except for protective suits and a radio. They have nothing to pick up the chemical or dispose of it with.	We have protective suits but if more help is needed we will ask for assistance from San José or the Hazardous Materials team in Tibás. We also have tools for containing liquids and chemicals.	a. A, B and C level of protection. A is encapsulated, B use duct tape to close the gaps in the suit where the hands are for example, and C is less protective than B and A. They have flammable and non-flammable gas detectors and have containers and kits for different chemicals and sized spills. Also they have a Reactive chemical kit that tests for what type of chemical is present at the spill site.	They have the 2 protective suits and the barrels, only enough for two men.	They have capsule suits, gas masks, containment tanks, and enclosed breathing apparatuses.

What would help you respond better to chemical incidents? Would you like more equipment? Would you like more training?	They would like equipment to be able to contain a spill. Since there is only one HazMat team in the country, often times they are far away and firefighters that are not trained for this type of situation. Yes, definitely. Currently we only have first response training where we use the Emergency Response Guidebook to handle a spill.	Yes, of course. We need more equipment for big spills. Most of the time we call on other stations for help, particularly in San José. Yes, definitely. Currently we only have first response training where we use the Emergency Response Guidebook to handle a spill.	They would like equipment to be able to contain a spill. Since there is only one HazMat team in the country, often times they are far away and firefighters that are not trained for this type of situation. Better undergarments, communication systems, and a practice facility Yes, they would like to have more people trained specially for the MAT-PEL team	More equipment including spill kits, more personnel and more training	Special kits for confinement that are chemical specific such as chlorine. Patches that go over a broken tube/pipe to limit amount of leak, this kit would be very important. Absorbent materials to assist in clean up. Need more first response training, practices scenarios as done in the United States.
Have you looked at using any plume dispersion modeling programs?	N/A	N/A	Have the old version of CAMEO®, know how to use the chemical database somewhat, but don't know how to use the entire program really.	Has been to the United States and Japan and has seen the program in both countries.	N/A
Have you heard of the program CAMEO?	Would prefer it in Spanish.	Would prefer it in Spanish.	Would prefer it in Spanish, but could use it in English.	Preferred in Spanish.	

Do you see a need for the software in your station?	Yes	We would like to use it in our training, but it needs to be in Spanish.	Yes.	Yes.	Yes.
How would you like to use the modeling software (in real time or for simulation)?	Ideally the software would be in every station. We could use it during training when we run simulations of chemical spills. We would also use it in real time.	N/A	They would like to use it to train with and maybe when there is a release they could use it. Right now they are only using it as a means to search for chemicals inside of the chemical database.	Better used for scenarios due to the fact that they lack resources for real-time use.	Real-time if they have laptop, otherwise would use it for scenarios.

It was explained to us that without these kits, if a spill occurred, they must wait for the Haz-Mat team from Tibás to arrive in order for containment and clean-up to occur even on the most basic level.

4.4 Bomberos Training

The single Haz-Mat team for the entire country of Costa Rica is located at the fire station in Tibás. This station certainly has more equipment and training than most, however they also have much more responsibility. If a chemical accident occurs, no matter where in the country, this team is responsible for arriving as quickly as possible and taking the proper steps to control and clean up the area. The Bomberos expressed frustrations with the fact that often time the Haz-Mat team will be assisting a fire department in one region, possibly in Guanacaste, when an incident develops in Limón. It will take hours for the Haz-Mat team to respond thus Bomberos at the local level are entrusted with the task of handling more hazardous material releases when they do not have essential resources.

All Bomberos are required to have 20 hours of first response training for hazardous material incidents, but in speaking with the station chief in Limón, Gilbert Warren Warren, we found that the Bomberos do not always get the training they need since they have to be sent out to stations before they receive all of their training. Often times they learn in the field instead of receiving formal training with instructors at the National Academy in Desamparados.

4.5 CAMEO Implementation

Three of the stations we interviewed had heard of or looked at the CAMEO suite. The chief in Limón had seen the program used in Los Angeles, Houston, and Miami in the United States and also in Japan. In Puntarenas the Bomberos there had just briefly heard of the program. CAMEO is installed on a laptop kept in the Haz-Mat truck and used by the Haz-Mat team in the Tibás station, but currently only as a chemical database. They have not used it to model any chemical releases to date, but would like to know how to fully utilize the program. We were told that they have not used the ALOHA program because they do not know how to use the program and the members of the Haz-Mat team do not know enough English to properly operate the software. This was a repeating difficulty we found through out our interviews.

We conducted an interactive simulation of a chemical release for the Bomberos, where we encouraged the firefighters to suggest inputs and be part of the demonstration in each station we visited using CAMEO®. The examples were very basic and consisted of the selection of an arbitrary chemical determined by a firefighter. Next, a rough estimate of the current weather conditions was suggested. Finally, a mock chemical release situation was developed for use in the demonstration. Through this simulation a judgment on the potential usefulness of the program in their stations was made by the men present. All the Bomberos expressed the opinion that a plume dispersion modeling program would be beneficial in their response to chemical spills in terms of gaining crucial knowledge that they cannot currently obtain.

The most significant drawback the Bomberos found was that CAMEO® is not available in Spanish. Through a series of emails conducted with Tom Bergman, a consultant who conducts CAMEO® training sessions, and Peter Gattuso of the EPA we learned that an older version of CAMEO®, released in 1998, was translated, but the EPA currently has no plans to translate the newest version into Spanish. The EPA has provided a guide, CAMEO Companion en Español, to assist Spanish speakers in understanding data entries and the outputs from the CAMEO suite. There are many improvements in the new version of the suite of the previous version. CAMEO® received information updates on Acute Exposure Guideline Levels (AEGL) levels as well as Reactivity Reports. ALOHA was given the ability to map fire and explosion incidents and MARPLOT made more compatible with ALOHA. When we presented the idea of using the "CAMEO Companion en Español" to assist in entering data into CAMEO®, while simultaneously responding a chemical spill, many Bomberos believed that this would be too much to handle. They believe they would have difficulty sorting through the guide while trying to contain a chemical spill. Additionally this would compound the shortage of Bomberos in some stations. Referring back to the statements previously made regarding the number of Bomberos on duty at stations and how all Bomberos work in teams on site, two Bomberos would have to run CAMEO® possibly leaving no one to actually treat the chemical release situation if the software was being used in real-time.

Our interview with Luis Salas, chief of the San Jose fire zone, consisted mainly of questions dealing with laws, regulations, agencies, and organizational structure of preparedness and response to chemical releases. Much of the preliminary procedures he described to us were discussed in more detail with the Bomberos in their local stations. Costa Rica has regulations that specify that companies that transport goods must mark their contents using Hazardous Identification Placards. These placards allow first responders to identify the contents of a container more quickly. Sr. Salas explained to us that often time's transportation companies do not follow these regulations. The placard on a truck could state that it is carrying a corrosive material, but in reality it is carrying bananas. This example provided by Sr.

Salas demonstrates some of the difficulties first responders have when they arrive on scene. Not only does this obstruct the Bomberos efficiency in handling hazardous material spills, but also could cause bodily harm to the Bomberos if they do not know what chemical they're dealing with.

We also interviewed Werner Stolz from the IMN to discover what tools the Bomberos could use to accurately input atmospheric data into ALOHA. He informed us that the IMN has approximately 300 weather stations in Costa Rica. Fourteen of these stations relay atmospheric information directly to their headquarters in San José via satellite in real time. He expressed that while there would not be a way for the Bomberos to contact the stations directly they could call the NMI to receive up-to-date conditions. We also discussed with Sr. Stolz methods that the Bomberos could use to collect atmospheric data in the field. He provided us with the names of two portable weather stations used by the IMN. A method for collecting data that requires less technology, but is still valuable is Beaufort's Wind Scale that was developed in the 19th Century. This scale allows an observer to survey trees or waves and consult a guide to determine what speed the wind is. This scale could be a simple tool for the Bomberos to use in the field. A copy of this scale in Spanish is shown in Appendix E.

In order to fully implement the CAMEO suite a GIS map was imported into the MARPLOT program, as shown in Figure 4-5. The documentation of the importation process can be found in Appendix F. We worked with Patricia Barrantes to obtain a format that could be changed and utilized in MARPLOT.

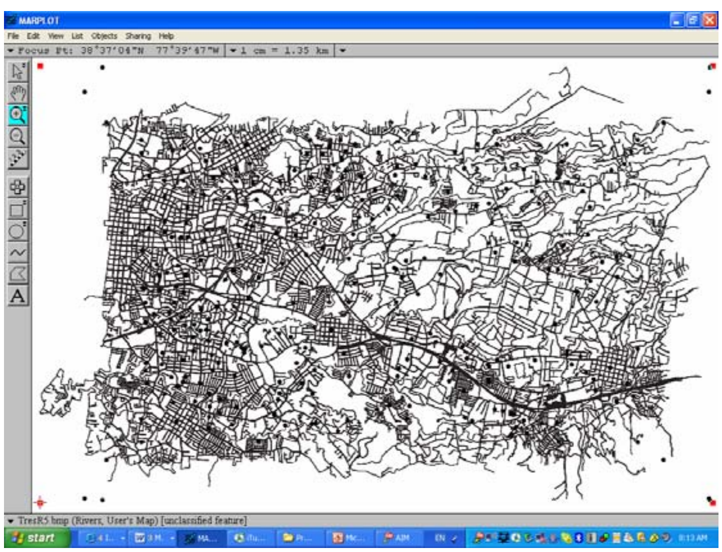


Figure 4-5: Map of Tres Ríos in MARPLOT

4.6 Case Study and Sensitivity Analysis – Irex Chlorine Release

The final task completed by our team was a case study on the Irex incident that occurred in 2002 (a description of this release can be seen in Appendix Q). Due to the massive impact this accident had on the community and the environment it is a prime candidate for scrutiny through the use of the CAMEO software suite. This action allowed for an understanding of what actually happened with the variable set that occurred on that day. This study also afforded the opportunity to clearly demonstrate the effects variables had on the incident. This knowledge was obtained from a sensitivity analysis of the program. Together these studies illustrate how the Bomberos can utilize CAMEO in their response procedures and to prepare for future chemical releases.

We conducted a simulation of the Irex chlorine release using ALOHA. We inputted the weather conditions from 13:00 that day as shown in Table 4-3. The source of the leak was entered including the dimensions of the tank, state of the liquid, and specifications of the release (see Table 4-4).

Table 4-3: Atmospheric Conditions - Tres Ríos - June 13, 2002

Parameters	**13:00**	**15:00**
Wind Speed (m/s)	5.2	4.5
Wind Direction	NORTH	NORTHEAST
Cloud Cover	100%	100%
Humidity	70%	80%
Air Temperature (^oC)	23.9	22
Ground Roughness	Urban/Forest	Urban/Forest
Height of Measurement	Tower - 10m	Tower - 10m
Length (km)	8.5	9.9
Width (km)	0.8	1.0
Confidence Lines (km)	4.0	3.6
Length of Red Zone (km)	1.5	1.7

Table 4-4: Specifications of Irex Chlorine Release

Parameters	**6/13/02 @ 13:00**
Diameter (m)	2
Length (m)	6
Volume (m^3)	18.8
State	Liquid
Temperature (C^o)	Ambient
Mass (tons)	20
Diameter of Leak (cm)	5
Type of Leak	Short Pipe Valve
Location of Leak	Top of Tank

This toxic threat zone (shown in Figure 4-3) measured 8.5 kilometers in length and 3.9 kilometers wide using the confidence lines, with the red zone, the highest threat level to Bomberos and local citizens, measuring 1.5 kilometers.

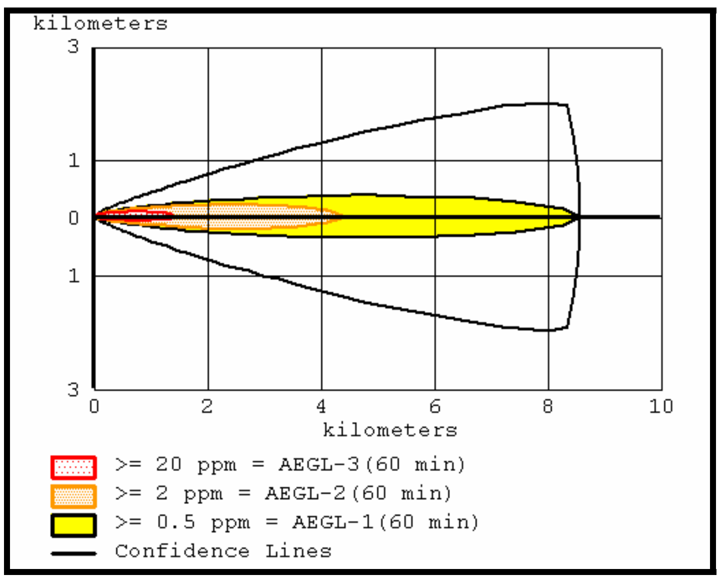


Figure 4-6: Toxic Threat Zone of Irex Chlorine Release at 13:00

The colored zones show the three Acute Exposure Guideline Levels (AEGL) levels with red signifying life-threatening health effects or death, orange signifying possible irreversible, other serious, long-lasting adverse health effects or an impaired ability to escape, and finally yellow signifying notable discomfort or irritation. The confidence lines, shown in black outside the colored plume, might be more useful to the Bomberos instead of the boundaries of the red, orange, and yellow zones because the Bomberos would likely use a broader area to protect both themselves and local citizens. This length and width of this zone can be used by the Bomberos to establish a radius of evacuation distances. This information can also aid them in creating a command center to facilitate the response. Other agencies such as the Red Cross and CNE would find this useful because they assist the Bomberos in evacuating citizens in situations like the Irex chlorine release. Additionally, the dimensions of the red zone can be used by the Bomberos to plan for where they will need more protective equipment, such as Class A encapsulating suits (see Figure 4-3), as well as developing a plan for evacuation. Buildings or houses in the red and orange zones will need to be evacuated prior evacuating the yellow zone.

In the case of Irex release the wind shifted direction from the north to the northeast and decreased slightly in velocity from 5.2 meters per second to 4.5 meters per second. This caused the plume to spread more to southwest of the site than to the south. This information is important for the Bomberos to know when they are on scene so they can modify their response in respect to changing atmospheric conditions. In this case, ALOHA can process the changing conditions to give Bomberos up to the minute weather information. The two differing plumes are shown in Figures 4-6 and 4-7.

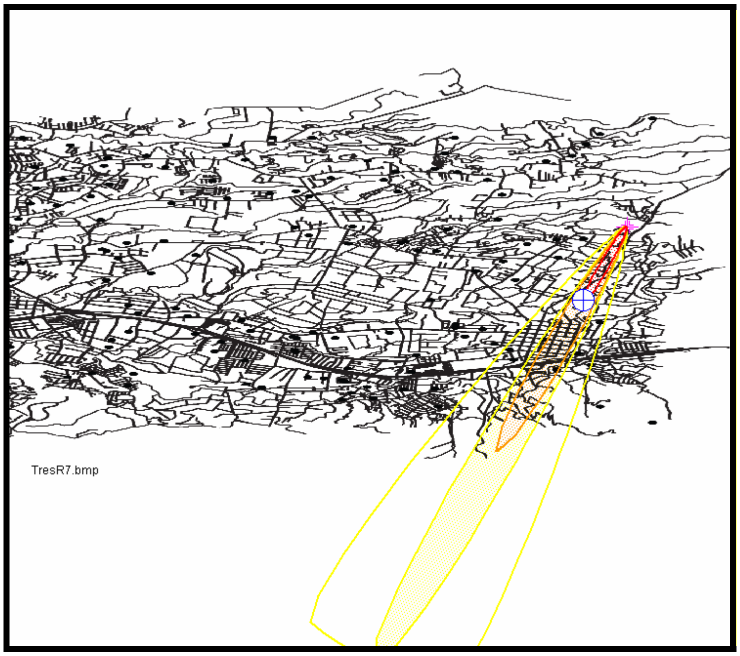


Figure 4-7: Irex Chlorine Release 13:00

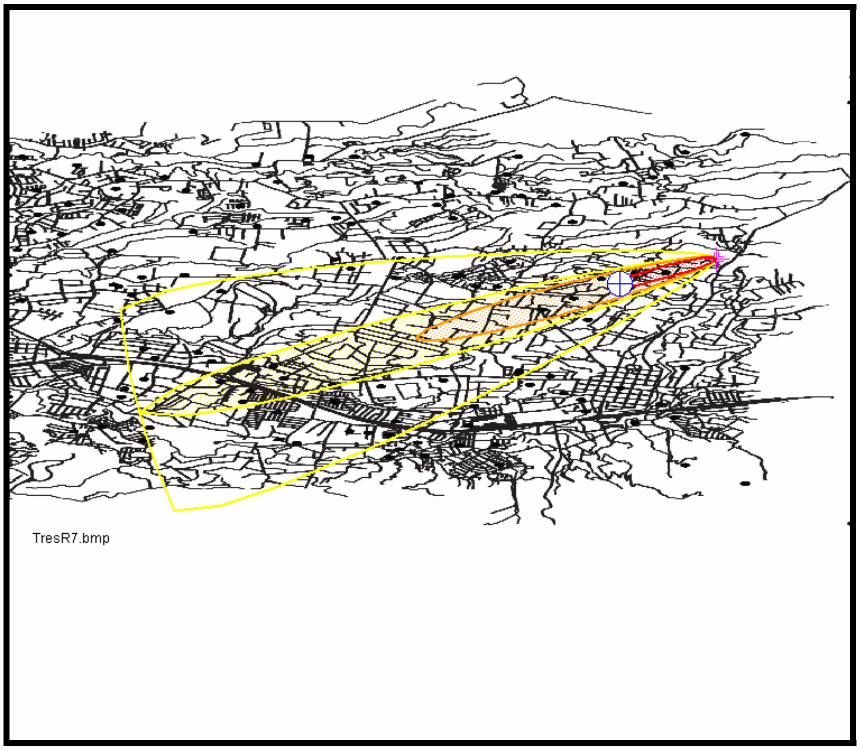


Figure 4-8: Irex Chlorine Release 15:00

Figure 4-8, a map of the dispersion of chlorine from the Irex release was provided to us as part of a presentation prepared by the Bomberos after their investigation of the release. We compared the toxic threat zones outputted by ALOHA to the map in order to examine the accuracy of the ALOHA program. This map shows that the zone calculated by the ALOHA program is similar to the actual dispersion recorded by the Bomberos.

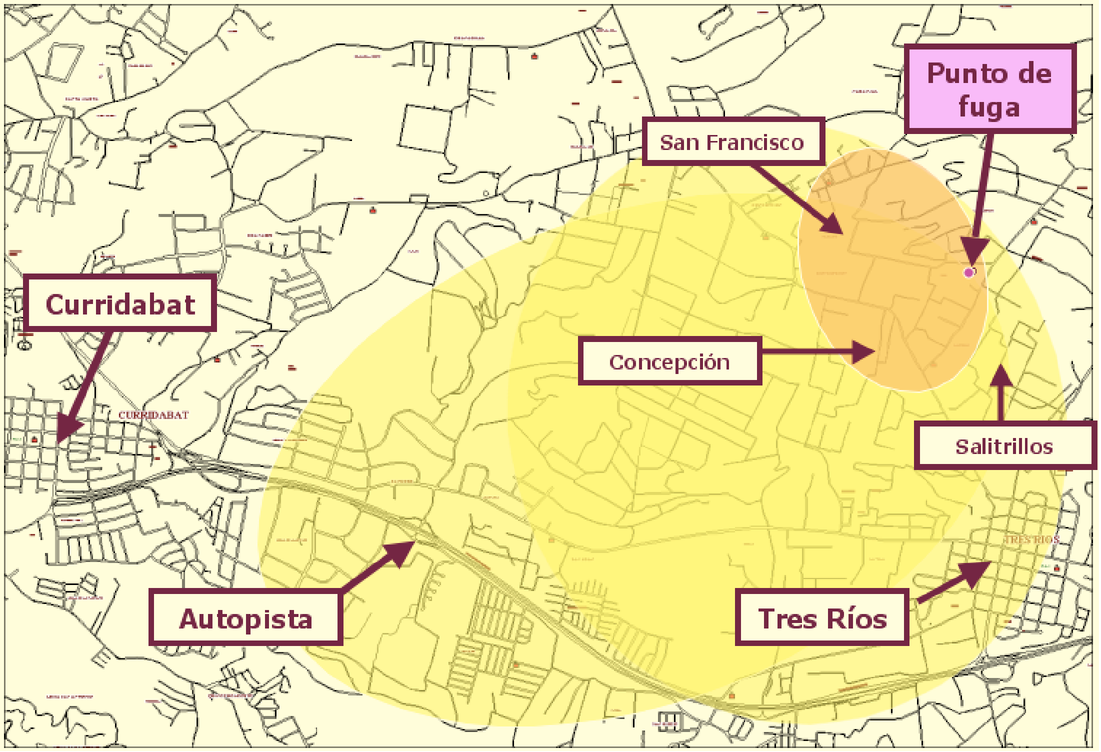


Figure 4-9: Bomberos Map of Irex Chlorine Release

To assist the Bomberos in planning for future chemical releases we analyzed the sensitivity of the program. We carried out a series of simulations in this matter to illustrate this process (shown in Tables 4-7 and 4-8). We first kept the parameters of the chlorine tank and release as constants then varied the atmospheric conditions of that day. We varied the wind speed, cloud cover, humidity, and air temperature. Other conditions such as wind direction were not evaluated because the value of this variable was already demonstrated in the case study of the incident. Ground roughness was not fluctuated because that would not assist us in demonstrating how the Bomberos would have to adapt their procedures to changing atmospheric conditions. If the Bomberos use ALOHA for planning on incidents at a stationary location, like the Irex Company, the ground roughness would only potentially change if there was a dramatic shift in wind direction, which was discussed previously.

Table 4-5: Simulated Atmospheric Conditions I

Atmospheric Conditions	Irex 6/13/02	Windy Day	Hot, Still
Wind Speed (m/s)	5.2	10	1
Wind Direction	NORTH	NORTH	NORTH
Cloud Cover	100%	100%	10%
Humidity	70%	70%	55%
Air Temperature (^oC)	23.9	24	30
Ground Roughness	Urban/Forest	Urban/Forest	Urban/Forest

Height of Measurement	Tower - 10m	Tower - 10m	Tower - 10m
Length (km)	8.5	6.8	7.7
Width (km)	0.8	0.6	1.9
Confidence Lines (km)	3.9	2.0	N/A

Note 1: The confidence lines for the hot, still conditions are equal to a radius around the plume.

Table 4-6: Simulated Atmospheric Conditions II

Parameters	**Clearer Day**	**Cool, Rainy**	**Warm, Partly Cloudy**
Wind Speed (m/s)	5.2	8	3
Wind Direction	NORTH	NORTH	NORTH
Cloud Cover	30%	100%	50%
Humidity	60%	80%	65%
Air Temperature (^{o}C)	24	20	27
Ground Roughness	Urban/Forest	Urban/Forest	Urban/Forest
Height of Measurement	Tower - 10m	Tower - 10m	Tower - 10m
Length (km)	8.6	7.1	8.2
Width (km)	0.8	0.7	1.2
Confidence Lines (km)	4.0	2.1	11.8

These six simulations gave us a variety of weather conditions to assess a worst case scenario in the event of a similar release. The toxic threat zones are pictured in Appendix T. From these we observed that with a clearer and less humid day the chlorine would have spread further, 8.6 kilometers, than it did on June 13, 2002. We choose these conditions as the worst case scenario for the release. The Bomberos can use the same process when planning for a potential chemical release. To rehearse a response to a truck carrying gasoline on the highway they could collect data regarding the typical size of the truck, research what type of gas releases have occurred from trucks in the past, then carry out a series of simulations while varying the atmospheric conditions. These simulations can help the Bomberos improve their response times to chemical release to better protect the citizens in the surrounding area.

To note the simulation for a warm, partly cloudy day has a complete radius for its confidence lines. This situation was not used as a worst case scenario due to the fact that the wind speed was very low in that situation. In that situation the Bomberos could use CAMEO to establish a toxic threat zone, then if there were any changes in the wind they could run CAMEO again in order to establish an updated threat zone.

However, CAMEO explicitly contains a disclaimer that declares its lack of reliability in low wind situations.

The CAMEO suite can assist the Bomberos in improving their understanding of the extent of a chemical release, thereby creating more accurate evacuation perimeters. The toxic threat zone also aids in determining the type of protection they will need when entering a perimeter because of a better knowledge of these areas. This case study and sensitivity analysis allows the Bomberos to understand how the CAMEO suite can be implemented into both their emergency planning and preparedness protocol.

Chapter 5 : CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

From the interviews and sensitivity analysis our team conducted we concluded that the Cuerpo de Bomberos require additional tools to respond chemical releases. These tools include additional first response equipment and a more precise practice for containing these chemical releases. The Bomberos do not currently have the resources to undertake a complete update of their system, but have the ability to begin this process towards a more effective response.

This led us to the conclusion that the implementation of a plume dispersion modeling program, specifically the CAMEO suite, into the Cuerpo de Bomberos' emergency response preparedness and response plans would better ensure the health and safety of Bomberos and Costa Rican citizens. Providentially, the CAMEO software suite is freely distributed by the EPA in the United States via the Internet with no usage restrictions. Further, it is a user-friendly and requires basic inputs in attempt to create the simplest usage possible. The program is accompanied by a companion in Spanish that allows the user to recall certain information concerning the program that might have been forgotten since a training course. However, this program is not appropriate for all stations in Costa Rica. Due to language, personnel, and budgetary restraints not all stations can be equipped with the program, but they can have access to it if implemented appropriately. The use of the CAMEO suite along with the additional first response equipment would allow the Bomberos to create more specific evacuation plans as well as provide them with accurate chemical response data to handle a chemical release.

From these conclusions we developed a system for the Bomberos to implement the CAMEO suite into their current emergency response plans. The Bomberos must take a number of steps in order to implement the CAMEO in Costa Rica. The issues to be addressed include communications, resources, personnel, and training. Due to this, a number of recommendations have been outlined that are necessary for the software to be utilized in Costa Rica. The completion of these tasks will allow the Bomberos to utilize the CAMEO software suite to predict toxic plume dispersion. Thus, it will allow for the improvement of their current emergency response and preparedness plans.

5.2 Outline of Implementation

In order to implement the CAMEO suite we suggest that the Bomberos create a central station staffed with personnel trained in the use of the program. Bomberos throughout Costa Rica will be able to contact the central station in order to transmit data when a chemical release occurs. The personnel in the central station will then enter the data and send back the toxic threat zone to the Bomberos on-scene at a chemical release. To facilitate the transmittal of this data Bomberos at local stations will be provided with a form the outlines all the information necessary to input into ALOHA. This includes current atmospheric conditions and a description of the source of the release. The Bomberos will need to be able to collect the atmospheric information accurately, but do not have access to weather stations, so they will be trained in methods to observe the weather without the use of a weather station.

The Haz-Mat team will be equipped to operate the CAMEO suite independently of the central command. CAMEO® can be used in the laptop they already keep in the Haz-Mat truck. They will also be provided with a mobile weather station to aid in the collection of current weather conditions. The specific resources the Cuerpo de Bomberos will need to follow the implementation design for the CAMEO suite are outlined below.

5.3 Recommendations for Immediate Implementation

1. **Supply Training for Personnel Directly Associated with the CAMEO®**

Necessary training is required in order to properly understand and utilize the program. Training sessions are available in the United States as well as on-site training where the instructor travels to the country. We received a quote for a private CAMEO® instructor, Tom Bergman, to come Costa Rica to work with the Bomberos for $600 per day plus $500 for preparation of materials and any travel and per diem expenses. The EPA does conduct some free training in the United States, but it is not yet known if this is extended to international training.

2. **Establish a Central Command in the Oficina de Comunicaciones**

We advise the creation of a central command center since Bomberos throughout the country all have the ability to communicate with OCO. Trained personnel will always be available to receive information and operate CAMEO® in the case of an emergency. This position can either be filled by the current employees who work as dispatchers. The Bomberos will need to train personnel to operate CAMEO®, but the overall cost of training for personnel nationwide will be reduced since the use of the program will be centralized in the OCO office. This also ensures that in the event of a breakdown in the program out in the field, possibly with the Haz-Mat team, OCO will be trained to communicate with the team to operate the program.

3. **Handheld Weather Units for Tibás and Puntarenas**

This less expensive weather station would be on hand for the two most high-risk regions in the country. This will allow the fire stations in both these port cities to better deal with high number of hazardous materials incidents they respond to annually.

4. **Mobile Weather Station for the Hazardous Materials Team in Tibás**

We recommend the purchasing of a mobile weather station for the Haz-Mat vehicle in Tibás. This mobile station will allow the Bomberos to automatically input current atmospheric conditions, saving them valuable time on-scene. The team already possesses a laptop as well as a vehicle, which are both necessary for the use of the program. Since this is the only Haz-Mat team in the country, it is essential they have the proper tools to protect the public.

5. **Establish Communications between the Oficina de Comunicaciones and the Insituto Meteorológico Nacional**

The establishment of communications between OCO and the IMN would allow for the conveying of pertinent atmospheric conditions from one of the 14 real-time weather stations located throughout the country when the Bomberos are using ALOHA on-scene. During training simulations the Bomberos could draw on data from any of the approximately 300 weather stations in Costa Rica operated by the IMN.

6. **Train Bomberos in Visual Weather Observations**

Visual weather observation training should be incorporated into Bomberos first response training. The IMN is able to provide this training to a group of Bomberos if requested. The Bomberos will then be able to accurately describe conditions to the OCO when a chemical release occurs. One method the Bomberos can use includes the Beaufort Scale for measuring wind speed as shown in Appendix H. This is an example of one practical tool the Bomberos can use in the field to collect atmospheric data to input into ALOHA.

7. **Increase Amount of 1st Response Equipment at Local Stations**

Local fire stations should be supplied with more of the equipment needed to properly respond to the incident. This includes, but is not limited to, suits, chemical kits, patches, and absorbent materials. The Haz-Mat team carries this equipment, but is sometimes hours away from a release. The addition of this equipment will decrease the amount of time a hazardous material is exposed to the air, thereby lessening the effects of the release.

8. **Further Research into Cost Benefit Analysis**

The use of a consultant to perform an in-depth cost benefit analysis would allow the Bomberos much further investigation into the possible options they possess for implementation. This analysis would allow the Bomberos to make the best decisions for them at this time while taking into consideration their current budget and goals of protection for the citizens of Costa Rica.

5.4 Cost Benefit Analysis of Immediate Recommendations

Our immediate recommendations are accompanied by a cost to the Bomberos. However, we feel that some costs may be necessary in order for the increase of protection they provide to the citizens of Costa Rica. Further, it is shown that an increase in money put into safety measure could decrease the overall cost to the organization. To better inform the Bomberos of the options that lay before them we have conducted a cost benefit analysis to assign monetary values to our recommendations.

The cost of the software itself is free as it is distributed by the Environment Protection Agency via the internet. Training of Bomberos in visual observation of meteorological conditions is also free as it has been offered by the National Institute of Meteorology (IMN). A two-day training course with a consultant from the United States would cost approximately $3,500 including airfare, accommodations, and per diem expenses. The cost for handheld weather units for use in Limón and Puntarenas would total approximately $400. The cost for a high-end mobile weather station for direct use with CAMEO for the MATPEL team in Tibás would cost between $5,000 and $10,000. Finally, the allotment of $500 per station in the country would allow for the purchase of chemical kits and absorbent materials needed.

In order to compare the various options available to them, we have utilized a tool for the Bomberos to use. The use of Expected Monetary Value (EMV) allows the Bomberos to compare their various options in financial terms. Before this method could be applied certain variable had to be created. Since the Bomberos do not keep any financial record of accidents it was necessary to find this information elsewhere. Using information developed in a risk analysis by the Department of Transportation the average cost per hazardous materials spills in the United States is $536,000. Due to the large differences in economies between the United States and Costa Rica a reduction factor was created to better apply this number to Costa Rica. This factor was determined as the ratio of Gross Domestic Product (Purchasing Power Parity) per capita for the United States to that of Costa Rica. This number equated to 0.27 and reduced the average cost of a spill to $116,000 in Costa Rica. The second variable created was the probability of a spill happening over the course of a year in Costa Rica. This was defined as the average number of spills per year divided by the number of chemical companies to give the probability of an occurrence and equated to 95%. These are the numbers we based our calculations on (as shown in Appendix U).

Expected Monetary Value is calculated by the sum of the product of the probability of each event times the monetary value of its consequence over all possible mutually exclusive events in the set of possibilities. Using the aforementioned values for calculations an EMV was established for each option (shown in Appendix U). We believe that this method gives the Bomberos an idea of how to weigh the options of their investment with the possible returns they could receive from them.

5.5 Recommendations for Future Implementation

In order for the Bomberos to further improve the emergency response and preparedness plans of their organization, many larger actions will need to be taken. These are recommended for future years because currently the Bomberos do not have the resources to fully enact them, but are necessary to continue the process of improving their emergency procedures.

The first thing to be taken into account is the overhead associated with these recommendations as these are the immediate costs to the Cuerpo de Bomberos.

1. **Laptops in High-Risk stations**

The Cuerpo de Bomberos would benefit greatly by being able to operate the CAMEO suite directly in stations. This will save valuable time in relaying the details of a chemical release to OCO and having that office process that data in ALOHA. High-risk stations would be defined as the five stations that respond to the most chemical releases in a year. The Bomberos will also need to evaluate this investment to ensure that the stations fully utilizing the CAMEO suite do not overlap in their coverage. This resource should be spread around the country to include the port cities of Limón and Puntarenas.

2. **Creation of Additional Hazardous Materials Teams**

Additional Haz-Mat teams will allow the Cuerpo de Bomberos to reduce the effects of chemical releases by providing a quicker response to these incidents. An appropriate location for a Haz-Mat team would be near one of the five stations that responds to the most hazardous materials releases, but also at least two hours from the current team in Tibás. The team will most likely be housed outside of the Central Valley. This ensures that the Haz-Mat team would be properly utilized by not overlapping it’s jurisdiction with the Tibás team.

3. **Translation of CAMEO® in Spanish**

Ideally the CAMEO® chemical database will be available in Spanish as well as all the inputs for ALOHA. This would require much less training for operators of the CAMEO suite and allow the Bomberos to better protect themselves by having critical data readily available while containing a chemical release. Many other Latin American countries can benefit from the use of CAMEO® as Costa Rica will, which makes a translation of the CAMEO suite an important goal.

4. Enforcement of Hazardous Material Transportation Regulations

To reduce the risk to first responders to chemical spills, Costa Rica needs to enforce the use of placards on all trucks carrying hazardous materials. This will decrease the time it takes to properly identify a chemical and begin containing it. Costa Rica needs to communicate with other Central American countries, so that trucks entering from Nicaragua and Panama will carry accurate placards that the Bomberos can identify.

5. Mandated Documentation of Chemicals Housed in Industry

In the future, first responders will be better prepared to handle chemical releases in industry if they have already created contingency plans for each facility. A major component of these plans includes documenting the chemicals housed in each facility prior to a release. This documentation includes name, physical state, and location of each chemical. The Bomberos will then be able to better protect themselves and the citizens of Costa Rica by knowing where a chemical is on-scene and what protective equipment they need to use before entering a building or compound. Again, this process will reduce the amount of time it takes for the Bomberos to begin the treatment of a chemical release.

The Bomberos will require the aid of many other organizations in order to complete all the tasks outlined in this section. However, this cooperation is completely necessary for creation of safe and effective handling of chemical incidents. Through this vane the Bomberos will be able to more effectively protect the citizens of Costa Rica from the dangerous effects of chemical releases through improved emergency response and preparedness plans.

Chapter 6 : APPENDICES

APPENDIX A: MISSION AND ORGANIZATION OF THE CUERPO DE BOMBEROS

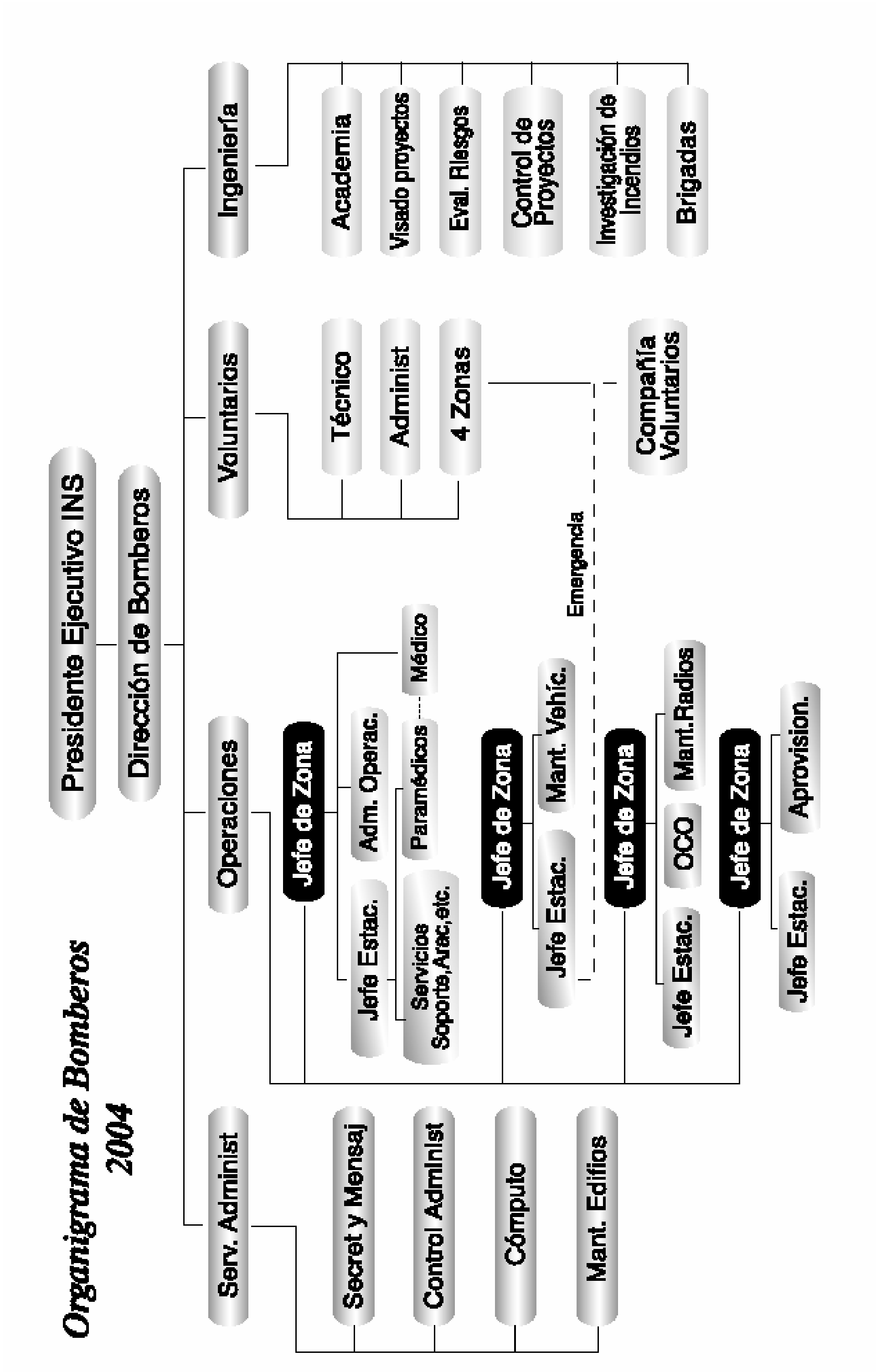
The Cuerpo de Bomberos, the national fire department of Costa Rica, was created on July 27, 1865 by the President of Costa Rica, Jesus Jiménez, after his newly constructed house was set on fire. There is a history of people intentionally setting fires that dates back to the 17th century. Many of these fires were associated with rebellions or invasions. The creation of the Bomberos did not stop the fires, however, and they continued into the 20th century. In 1922, the Law of Insurances was passed and in 1924 a national insurance agency was created, the Instituto Nacional de Seguros (INS), to prevent Costa Rican corporations from insuring their businesses with foreign insurers. "This law made it impossible to become insured by a foreign company without the authorization of a government civil employee, the Superintendent of Insurances" (Instituto Nacional de Seguros). This prevented companies from intentionally setting fire to their businesses and then collecting on the claims. Additionally, the law set aside ten percent of all premiums to fund the fire departments. Since the creation of the INS, it has expanded to fully fund the Bomberos at the federal level.

The Bomberos are headed by the Director of Firemen, who supervises the entire country, and Regional Directors, who supervise the four sub-regions that act independently. There are 61 stations divided among these four regions. Each Regional Director has the authority to distribute materials and personnel as needed in order to increase the effectiveness of the individual fire departments within a given region. Fire departments in different regions often times share supplies and aid each other if an emergency requires additional support. The Bomberos employs approximately 400 full-time Bomberos, more than 1,000 volunteer Bomberos, and 17 engineers to assist in fire prevention. In 2001, the National Academy of Firemen was opened in San Antonio de Desamparados to train Bomberos along with sponsoring programs to help citizens prevent fires. The Paramedic Unit also works closely in conjunction with the Bomberos.

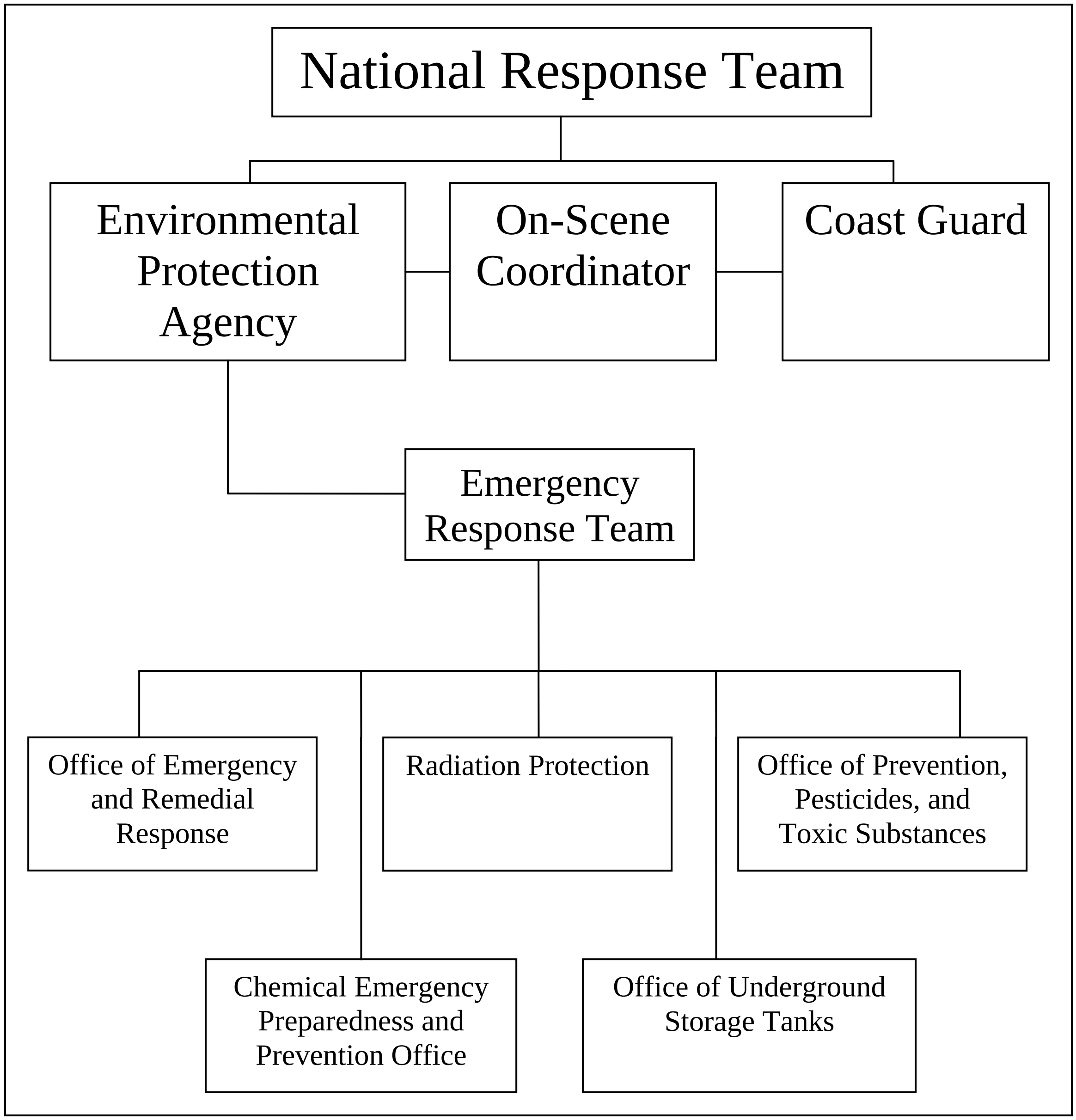
The mission of the Bomberos is to offer protection to society without discrimination when the public or their property is threatened by either nature or man. In more recent years the Bomberos has looked to provide modern training and equipment to all Bomberos throughout the country. Currently they have only one Haz-Mat team which is located in Tibás. The National Commission for Prevention of Risk and Emergencies (NCPRE) “was created to offer an ordered system, in order to mitigate any incidents that involve dangerous materials” (Suplemento de Ciencia y Tecnología). NCPRE responds to high level disasters involving spills, fires, and explosions that result in the release of toxic and dangerous substances from industrial complexes, warehouses, and other facilities. NCPRE also responds to highway and pipeline accidents. The team of ten Bomberos possesses the knowledge, training, and equipment to properly handle a variety of toxic releases. They are trained in accordance with current Costa Rican standards and must service the entire country. “With their main emphasis being on the metropolitan areas, incidents in the countryside are indirectly handled through the furnishing of equipment to the local fire department” (Suplemento de Ciencia y Tecnología). Recent statistics show that the NCPRE responded to approximately a quarter of all “crises” specifically the more severe disasters. While the NCPRE has the ability to take action in these severe situations, there is a need for smaller teams to address less severe accidents throughout the country. The creation of a network of localized Haz-Mat teams would allow the NCPRE to continue to focus on the more severe disasters, while the local teams could address the less severe events.

The Bomberos are concerned with the lack of utilization of a chemical dispersion modeling program in their hazardous material release protocol. This program would be implemented in the creation of Emergency Preparedness Plans. The organization of trained personnel and the implementation of a protocol that is revised with the use of a chemical dispersion modeling program will allow the Bomberos to better protect its citizens from the effects of hazardous material vapor dispersion. It is our task to provide them with adequate information of dispersion modeling programs in order for them to choose a program that best fits their needs. The employment of this program will allow them to strengthen their current protocol.

APPENDIX B: ORGANIZATION OF THE BOMBEROS



APPENDIX C: OUTLINE OF THE U.S. NATIONAL RESPONSE PLAN

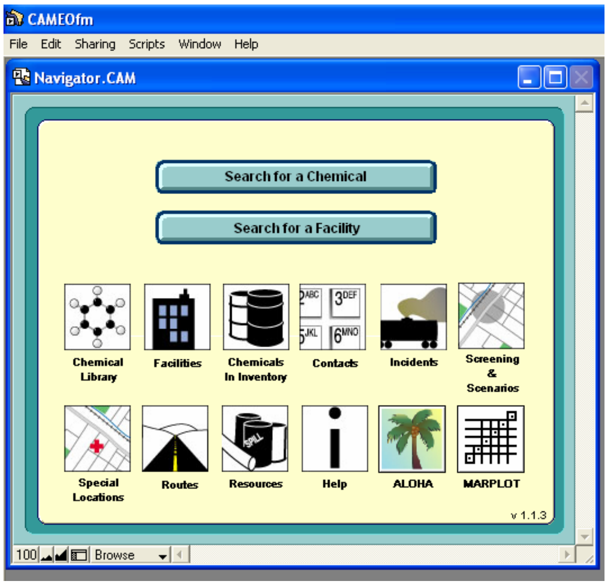

National Response Team
Environmental Protection Agency
On-Scene Coordinator
Coast Guard
Emergency Response Team
Office of Emergency and Remedial Response
Radiation Protection
Office of Prevention, Pesticides, and Toxic Substances
Chemical Emergency Preparedness and Prevention Office
Office of Underground Storage Tanks

APPENDIX D: COMPARISON OF FEATURES OF ALOHA AND ARCHIE

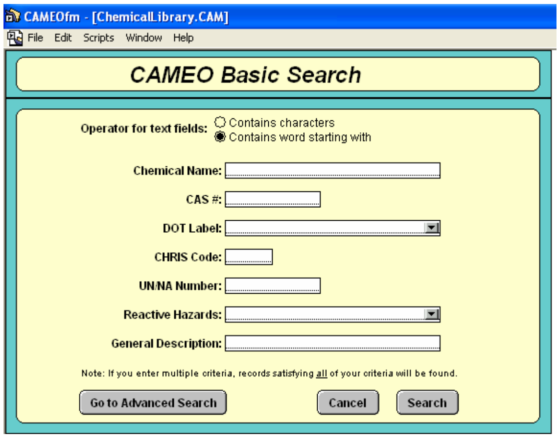
	ALOHA	ARCHIE
Data Handling		
Chemical library		
City library	4	
Data collected by portable weather station	4	
Accident scenario archiving		4
Choice of units for all inputs	4	
Source Strength		
User entry of release rate	4	4
Pressurized liquid tank	4	4
Non-pressurized liquid tank	4	4
Pressurized gas tank	4	4
Pressurized liquid pipeline		4
Pressurized gas pipeline	4	4
Stand-alone non-boiling puddle	4	4
Stand-alone boiling puddle	4	
Vapor Dispersion		
Choice of roughness lengths	4	
Above-ground source heights	4	4
Effects of inversion	4	
Neutral gas driver	4	4
Heavy gas driver	4	
Indoor air infiltration	4	
Concentration at specific location	4	
Dose at specific location	4	
Fire and Explosion Hazards		
Liquid pool fires		4
Flame jets		4
Fireball thermal radiation		4
Vapor cloud fires		4
Vapor cloud explosions		4
Tank overpressurization explosions		4
Condensed-phase explosions		4
Type of Output		
Text summary	4	4
Text tables	4	4
Graphs	4	
Footprint plotted on grid or map	4	

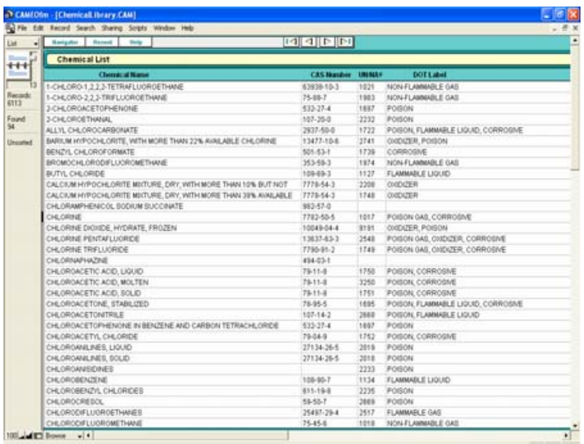
APPENDIX E: DESCRIPTION OF CAMEO SUITE

This outline is intended to be used in order to better understand the technical aspects of our project. It is not a user's manual or a guide to the program. It is simply for the benefit of the readers of our project.



CAMEO® is the chemical database that acts as the launch program for the entire program suite. Upon opening CAMEO® the user will be presented with the "navigator" screen. This screen allows the user to work effortlessly throughout all facets of the program. The user is face with myriad options when looking at the navigator screen, each of which will be explain in the following: **Search for a Chemical-** this option allows the user to search for a specific chemical based on many different criteria, including but not limited to name, synonyms, CAS#, DOT label, and UN number.

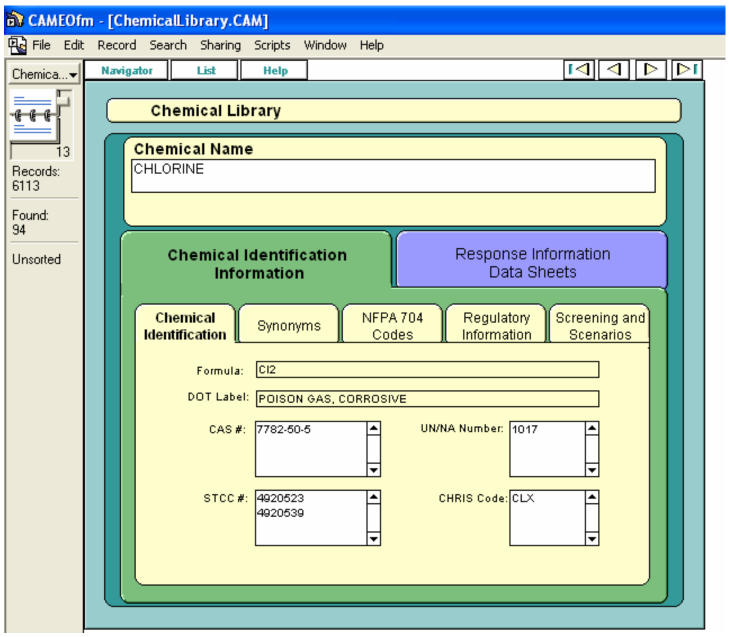




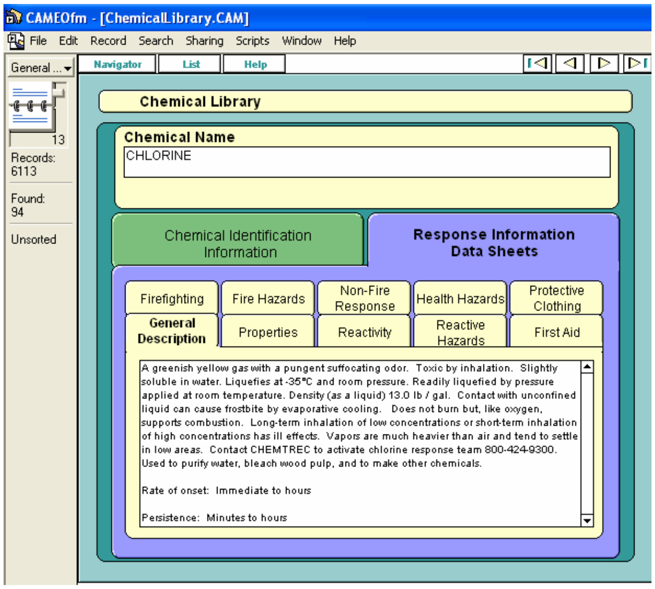
Search for a Facility- allows for the searching of a stored facility by name, location, report year, last modification, etc. **Chemical Library**- allows the user to simply browse through all the chemicals stored in CAMEO®. **Facilities**- Allows the user to simply browse through all stored facilities on CAMEO®. **Chemicals in Inventory-** Gives a list of stored facilities and/or transportation routes and what chemicals they possess. **Contacts-** Provides the user with any and all stored contact information for facilities, special locations such as schools and hospitals, or any other important contacts the user might have. **Incidents-** This is where the user to can stored information of past incidents, including response evaluation, numerical data, dates, location, map data, etc. **Screening & Scenarios-** This option makes it possible to set up a scenario and create a complete circle within in which areas may be affected depending on wind conditions. **Special Locations-** Provides the user with a list of locations of special interest, such as schools, churches, hospitals, or any other locations that may put large quantities of lives at risk in the case of an emergency.

Routes- Provides a list of stored roads and their uses, including amount of usage, main types of usage, type of road, etc. **Resources-** Provides a stored list with contact information of companies, people, and organizations that provide resources to emergency response. **Help-** Brings up the CAMEO® help index that provides answers to many questions the user may have. **ALOHA-** Jumps the user to the ALOHA program. **MARPLOT-** Jumps the user to the MARPLOT program

When a chemical is selected, either through the search or by browsing the library, a new window opens containing information about the specified chemical.

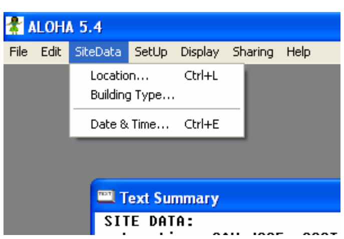


There are two major subsets for each chemical, under which are numerous other subsets. The first is **Chemical Identification Information-** Chemical Identification, synonyms, NFPA codes, regulatory information for the United States, and any stored screening or scenarios involving that chemical.

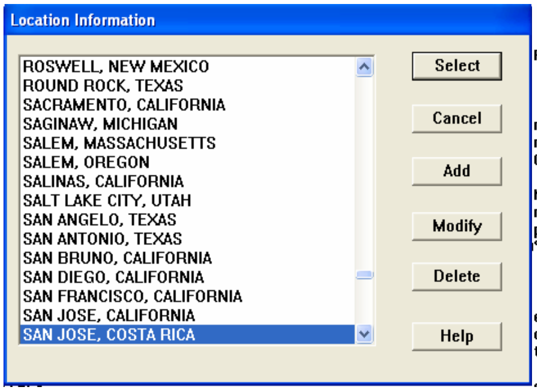


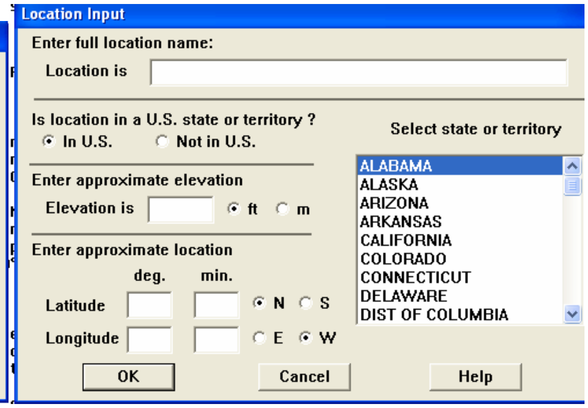
The second major subset is the **Response Information Data Sheets-** this contains all information that is pertinent when responding to an incident involving this chemical. It includes information on firefighting, fire hazards, non-fire response, health hazards, protective clothing necessary, general description of the chemical, properties, reactivity, reactive hazards, and first aid. Under each one this tabs is very detailed, important information that is specific to the selected chemical.

The first set of inputs for the ALOHA® program are grouped under SiteData on the program menu.

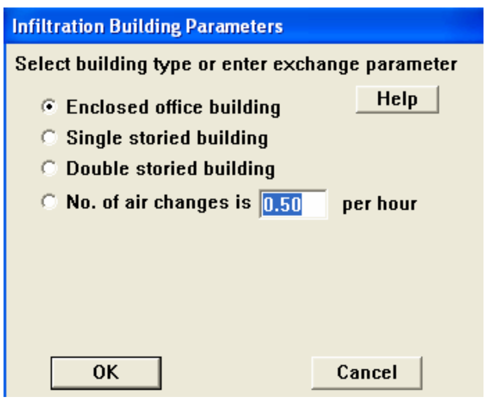


The first option is SiteData→Location. Under this setting you can select your location. The program comes preloaded with many US cities, however anywhere in the world can be input using the add feature as long as the user knows the elevation and coordinates of that place.

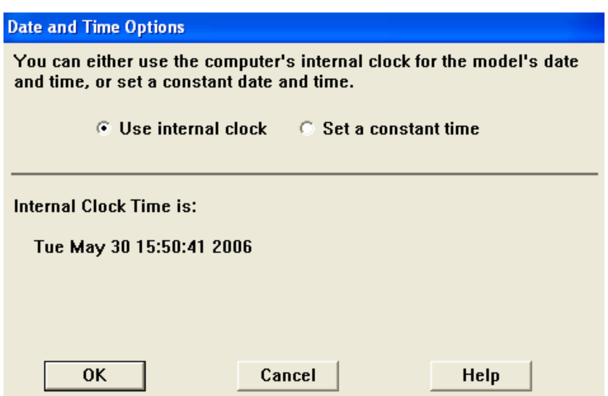




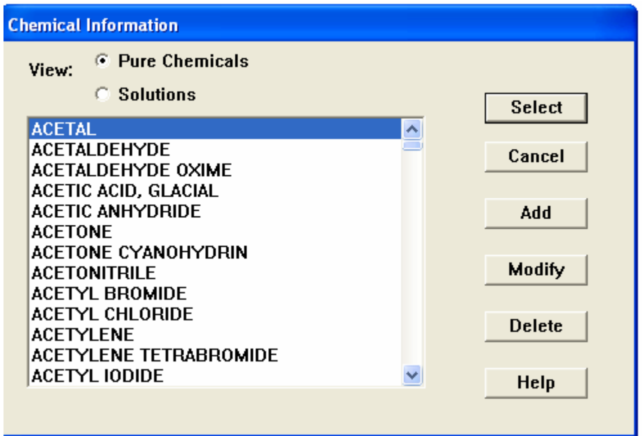
The second option is SiteData→Building Type. In this screen the user selects what type of building they would like to have the ALOHA® model run for the indoor air concentrations.



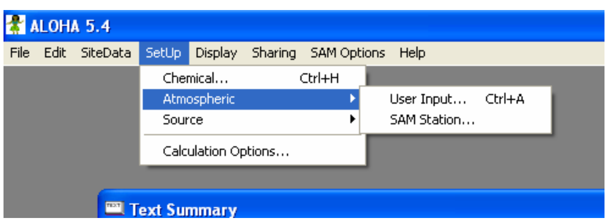
The final option is SiteData→Date&Time. This gives you the option to use your computers current time or set a constant time, mainly beneficial in scenario planning.



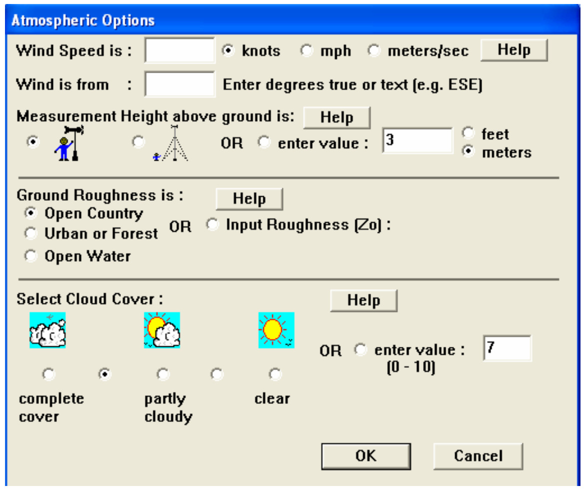
Utilizing the Share option in CAMEO® it is possible for the chemical the user selected to be imported into ALOHA to being the program, however it is just as easy to simply select a chemical from the extensive list ALOHA contains. This is done be going to Setup→Chemical in the program menu, or by using the shortcut Ctrl+H.



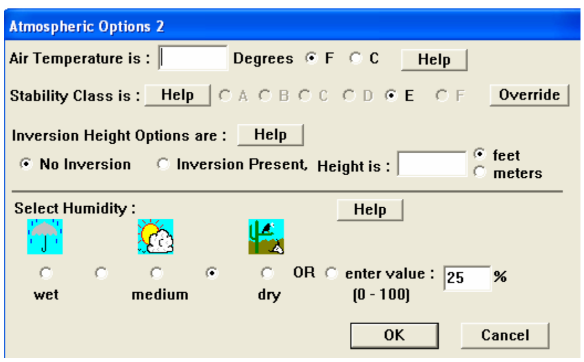
After the chemical has been selected, the next user input is on atmospheric data. The user is presented with two options, SetUp→Atmospheric→User Input, hotkey Ctrl+A, or SetUp→Atmospheric→SAM Station.



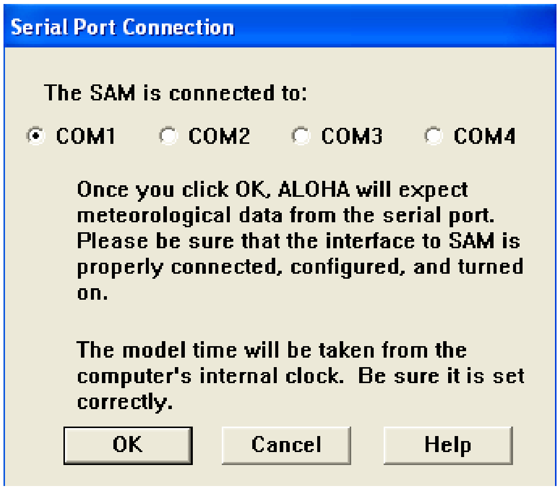
The first option to be discussed is the User Input method. This method assumes that the user does not have access to a mobile weather station that would constantly provide the program with updated information in order to predictions as accurate as possible. The inputs necessary in the first screen of the user input selection are as follows: Wind Speed, Wind Direction, Measurement Height, Ground Roughness, and Cloud Cover.



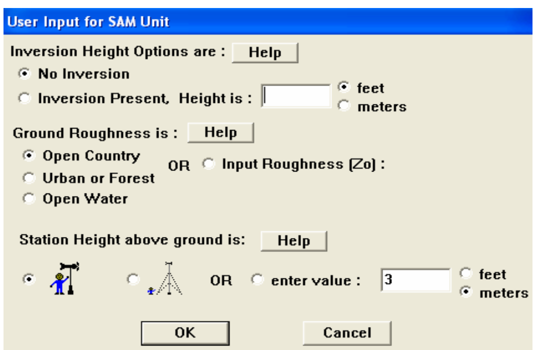
The second screen in the user input method requires Air Temperature, Stability Class, Inversion Height, and Humidity.



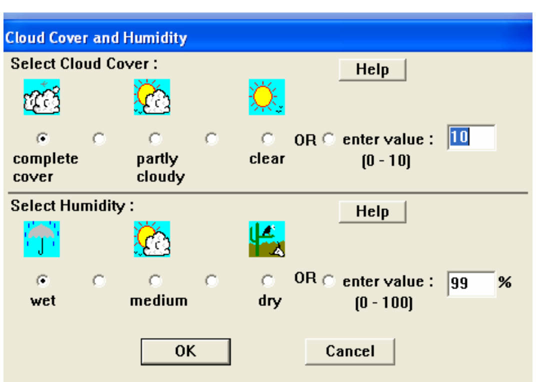
The SAM station method requires a Station for Atmospheric Measurement (SAM). This can either be mobile or stationary, but must have a way to communicate data with the computer the ALOHA® program is running on. The first screen for the SAM station method requires the user to select what communication port on the computer the SAM is connected.



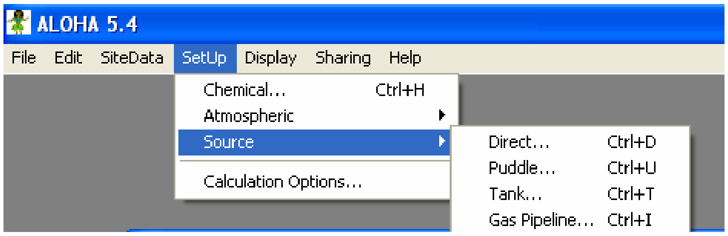
The next screen the user will be presented with is the User Input for SAM Unit. This screen requires the user to input Inversion present and/or height, ground roughness, and station height.



The final screen in the SAM station method is the Cloud Cover and Humidity where the user inputs the cloud cover and humidity.

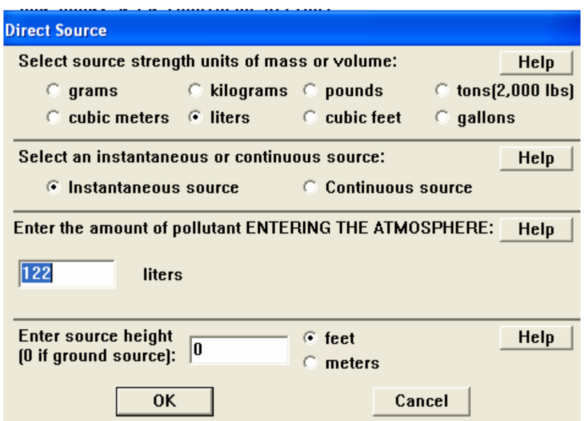


The next set of inputs can be found under Setup→Source. Here the user will be presented with the options Direct; Puddle; Tank; Gas Pipeline.

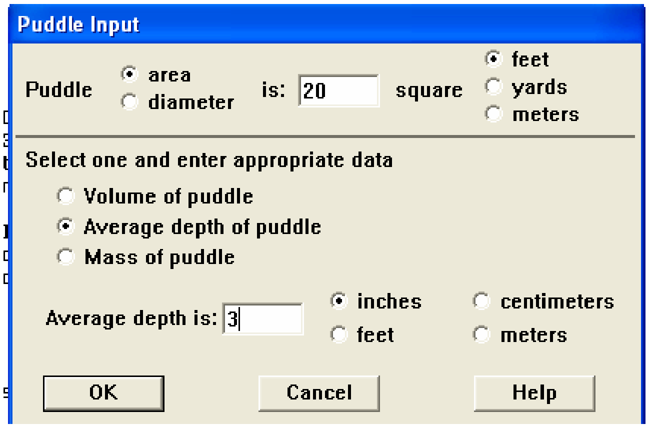


The first option is SetUp→Source→Direct.

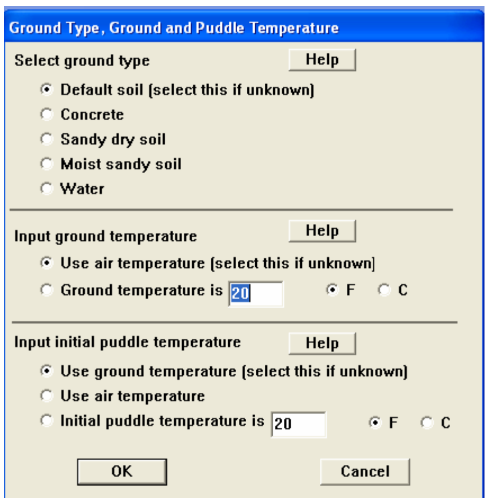
The inputs for the Direct Source screen include the source strength in units of mass or volume; define if it's an instantaneous or continuous source, amount of pollutant entering the atmosphere, and source height.



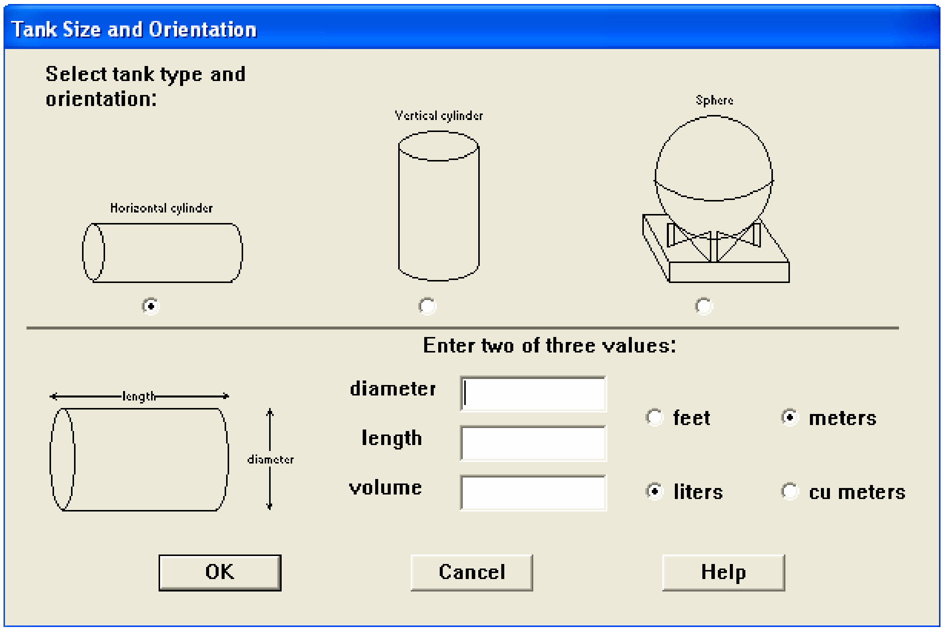
The second option is SetUp→Source→Puddle Input. The first screen for this option is Puddle Input. It requires user inputs of Puddle are or diameter and either volume of puddle, average depth of puddle, or mass of puddle.



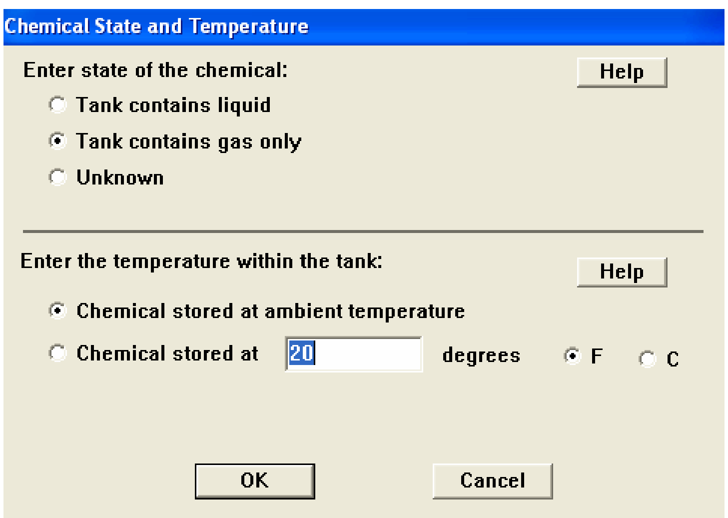
The second screen under the Puddle Input option is Ground Type, Ground and Puddle Temperature. The inputs in this screen are ground type, ground temperature and initial puddle temperature.



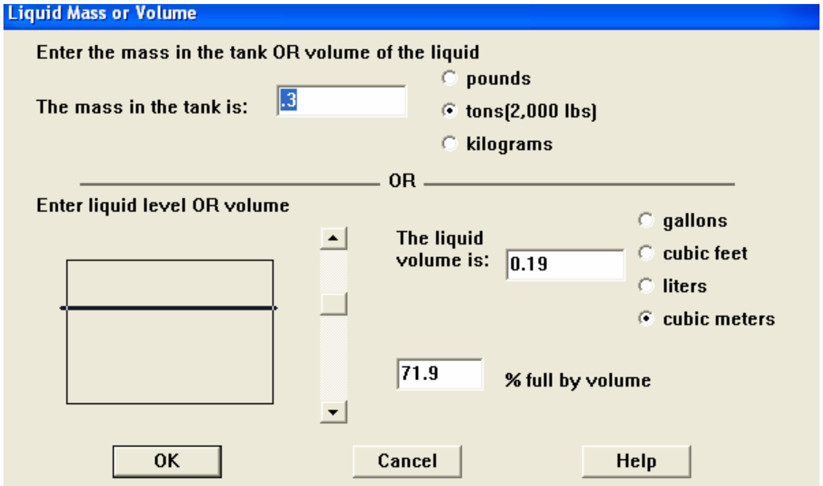
The third selection under the SetUp menu is SetUp→Source→Tank. The first screen under the tank option is Tank Size and Orientation. The inputs for this screen are tank type and orientation, diameter, and length.



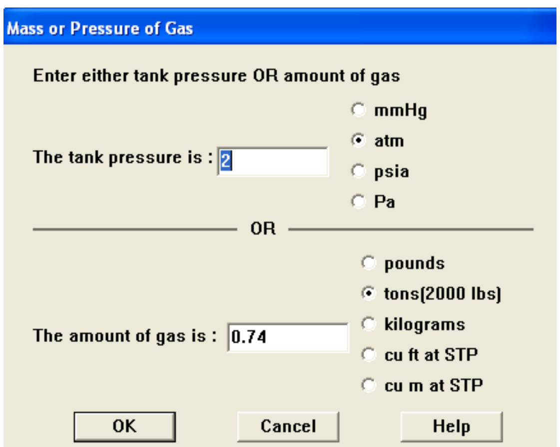
The second screen is Chemical State and Temperature. The inputs include the state of the chemical and the temperature inside the tank.



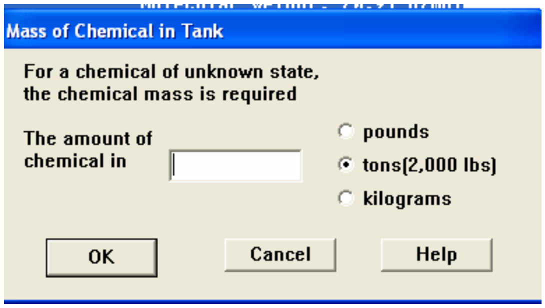
The next screen in this option is dependent upon the inputs from the previous window. If liquid is selected the user will be presented with the Liquid Mass or Volume window where the amount of chemical can be input.

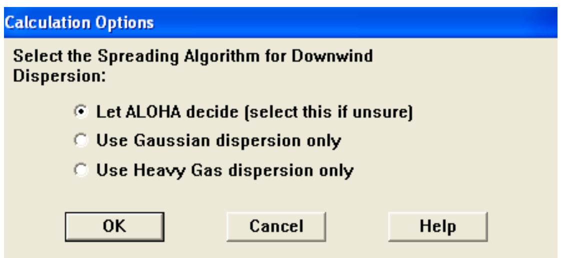


If gas is selected, the first screen is the Mass or Pressure of Gas. The inputs for this screen are either the tank pressure or the amount of gas.

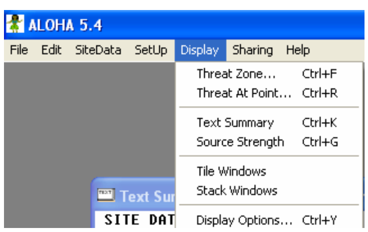


Finally, if the state of chemical is unknown then a Mass of Chemical in Tank screen will appear. The input for this window is simply the amount of chemical in the tank, the program will then decide by this input whether it's solid or gas return the user to the appropriate screen.

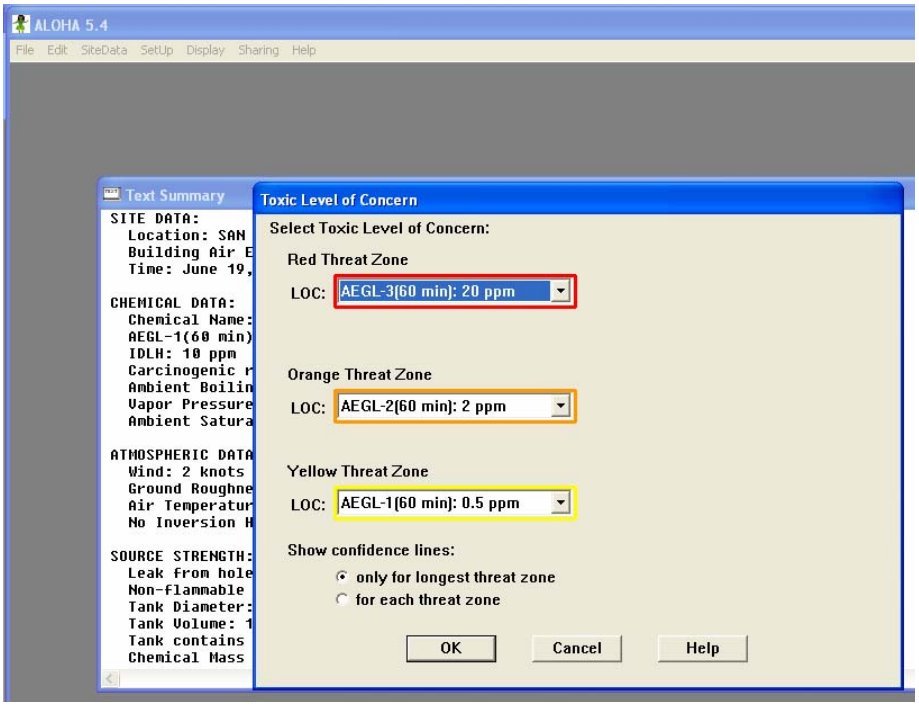




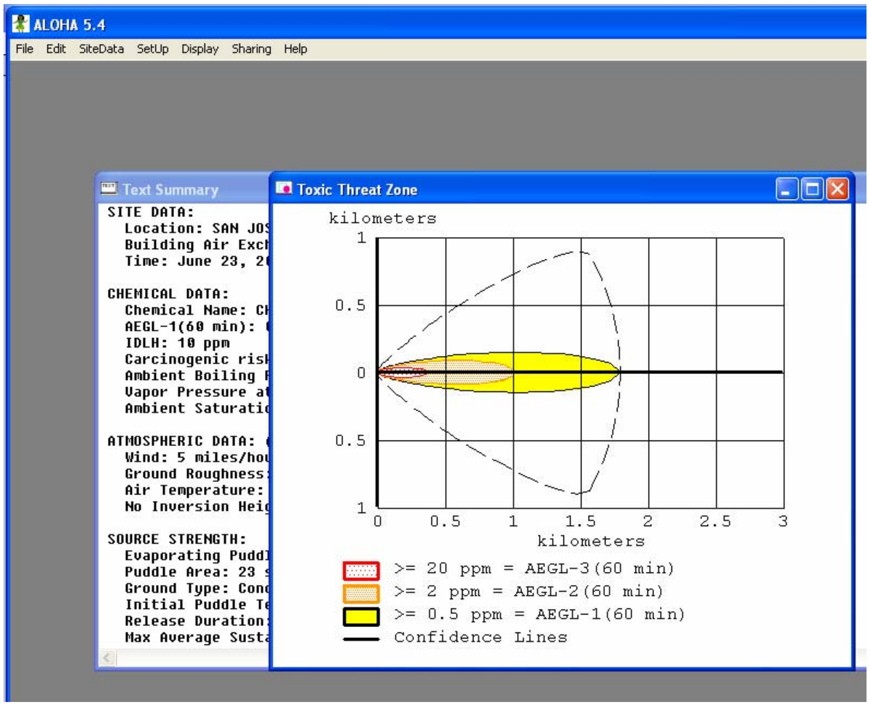
The Calculation Options screen allows the user to choose which dispersion model ALOHA uses or allows the program to make what it believes to be the best decision.



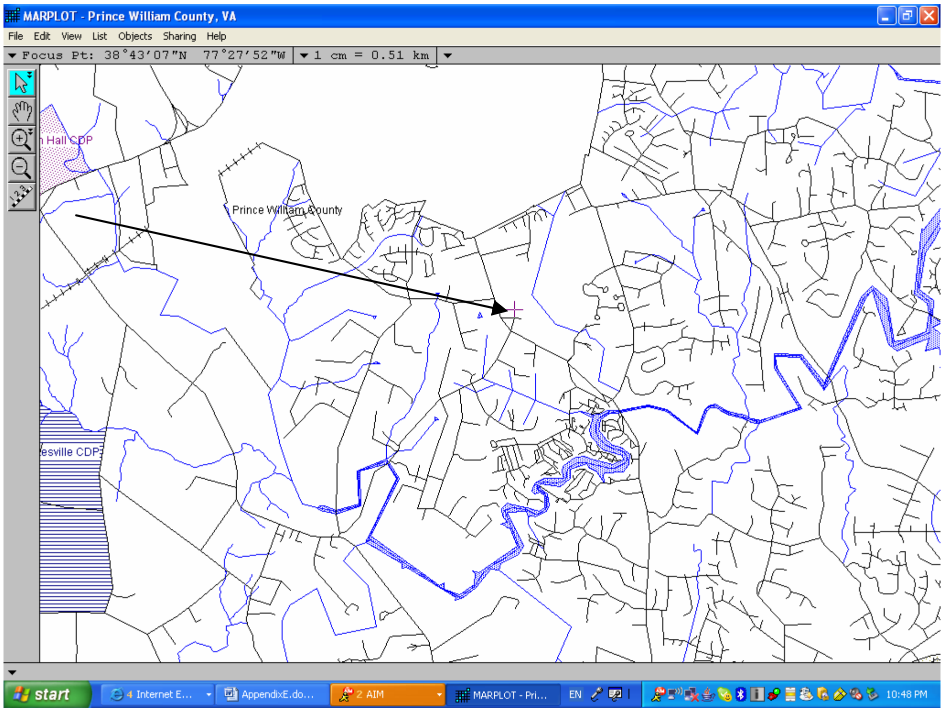
To graph the chemical dispersion, select Display→Threat Zone.



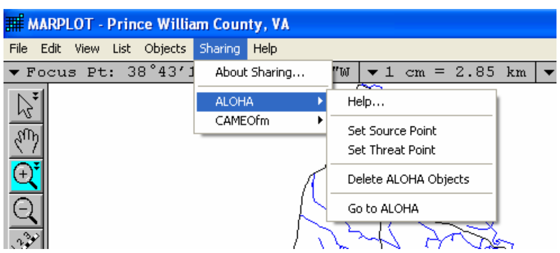
The first screen under the threat zone selection is the Toxic Level of Concern, this allows the user to define the different threat zones according to either their own specifications or those set by other agencies.



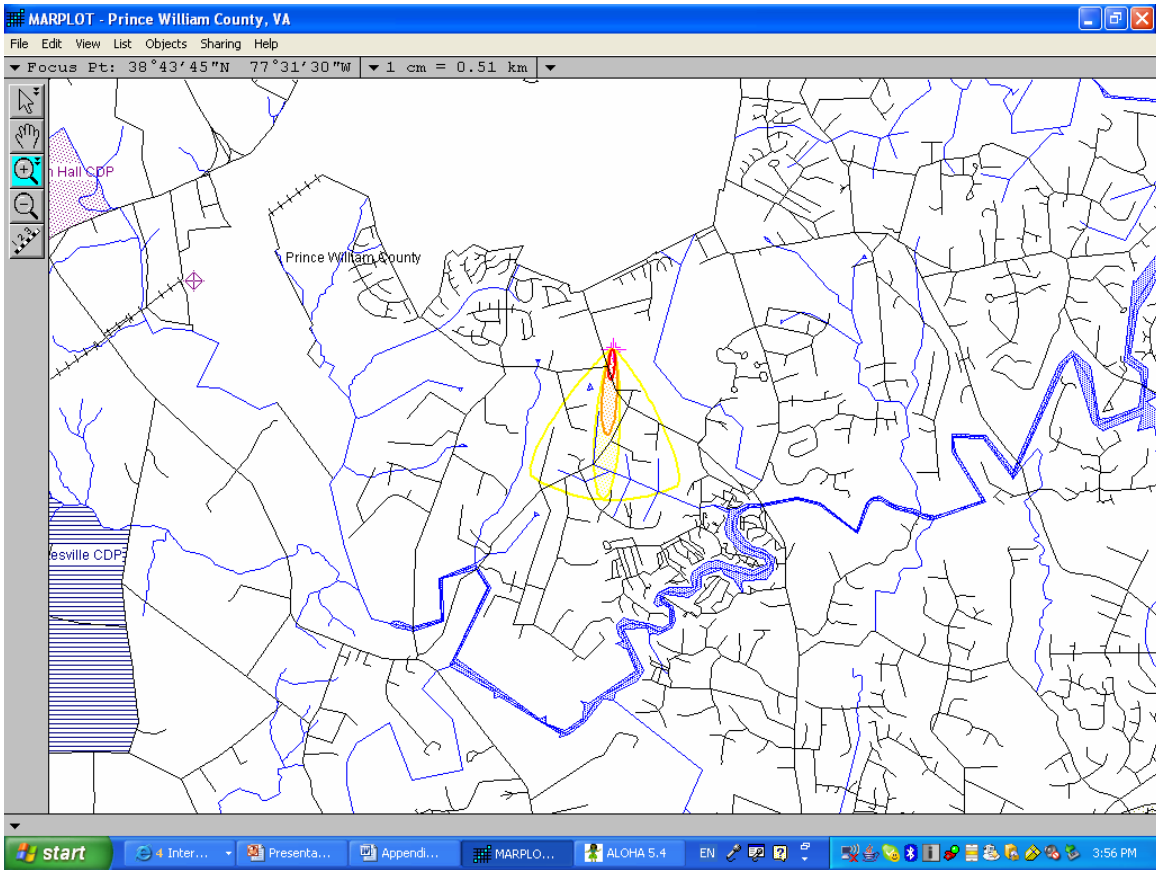
After the selection of the threat zone guidelines, ALOHA® displays the Toxic Threat Zone according to the defined threat zones. Both the X and Y axes are in terms of distance. The three levels of concerned are shown as well as a confidence line that displays the possible variance from the prediction the program calculates for the scenario.



The next step is to select the source point on the map as indicated by the arrow pointing to the purple cross that is the point selector.



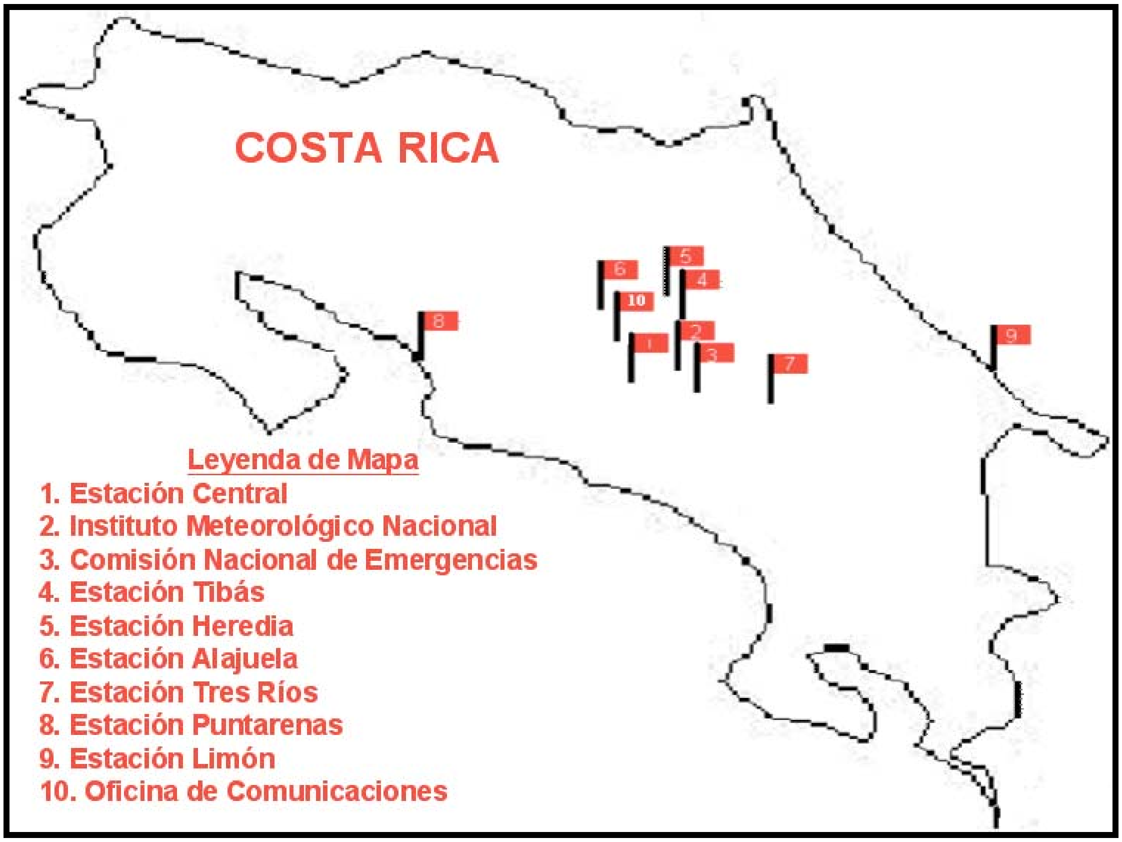
To overlay the toxic threat zone onto a geographic information system map in marplot, select Sharing→ALOHA→Set Source Point.



When completed, a toxic threat zone is overlaid onto the GIS map as shown. This provides information on the area afflicted by the toxic release in order to better act in the case of an emergency.

For further information and instruction on the CAMEO® suite including ALOHA® and MARPLOT® please use the following link:
http://www.epa.gov/ceppo/cameo/

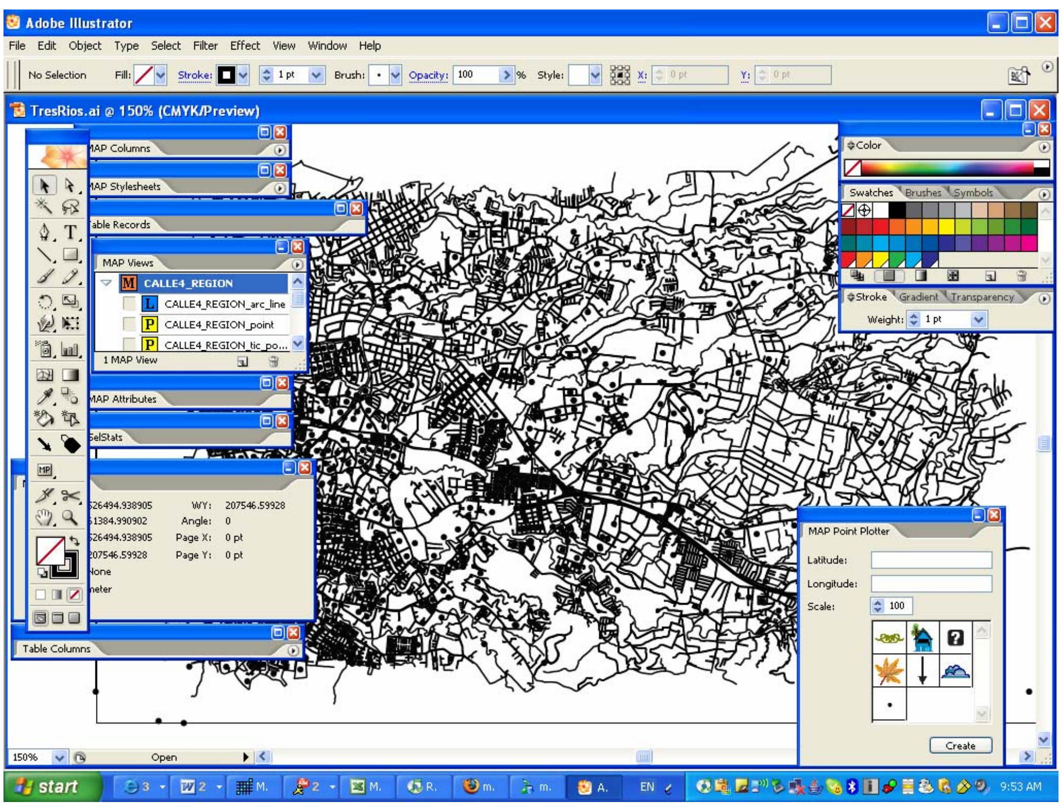
APPENDIX F: MAP OF INTERVIEWS



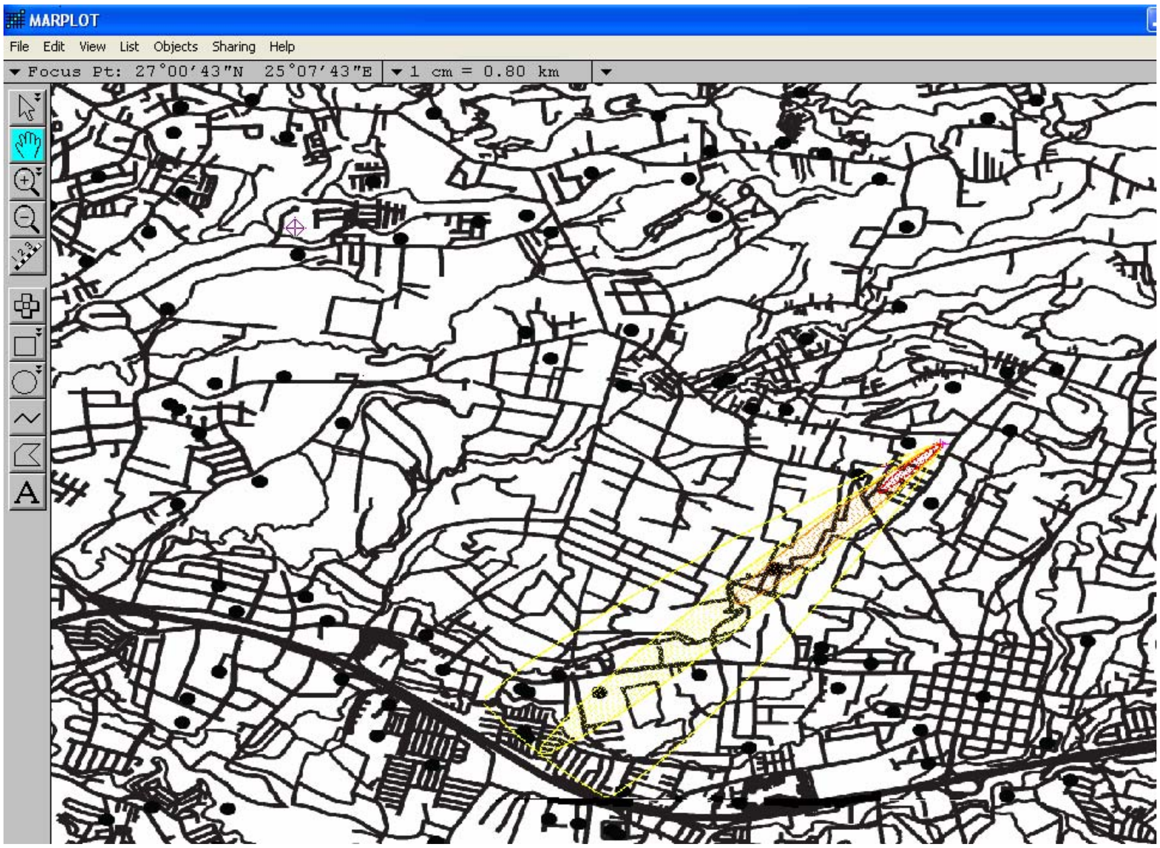
APPENDIX G: IMPORTATION OF GIS MAP INTO MARPLOT

In order to fully utilize the MARPLOT® program, it is necessary for the Cuerpo de Bomberos to import a GIS map of Costa Rica. For our project this was done on a small scale as the area of Tres Rios surrounding the Irex Soap Company was imported. In the following text, the methods followed to import this information will be documented.

The Bomberos currently use the ArcView GIS software program. This program allows for the export of map files in multiple formats. The one chosen for use in our situation was the Arc export format with file extensions of *.e00. In order for MARPLOT® to use the maps they need to be in one of two formats, either MARPLOT® import export format (*.mie) or Arc Generate format (.gen). Due to the fact that the Bomberos only had the ArcView program and not the full ArcInfo program, it was not possible to simply export the maps in this format from the current program. In order to complete this tasks it was necessary to download the Adobe Illustrator CS2 program with the MAPublish® plug-in (pictured below).



With this software it was possible to import the maps in *.e00 format and then export the files in the *.gen format that is compatible with MARPLOT®. By importing each file created by the export in *.gen format as separate layers, it allows MARPLOT® to make a map of the area of interest, in our case Tres Ríos (as shown here).



Through a process similar to this, or through the purchase of the ArcInfo software, the Bomberos will be able to do a similar process with their entire GIS mapping of Costa Rica.

APPENDIX H: BEAUFORT SCALE IN SPANISH

Velocidad del Viento (m/s)	Denominación	Efectos en Tierra
0-0.2	Calma	Calma, el humo asciende verticalmente
0.3-1.5	Ventolina	El humo indica la dirección del viento
1.6-3.3	Flojito (Brisa muy débil)	Se mueven las hojas de los árboles empiezan a moverse los molinos
3.4-5.4	Flojo (Brisa débil)	Se agitan las hojas, ondulan las banderas
5.5-7.9	Bonancible (Brisa moderada)	Se levanta polvo y papeles, se agitan las copas de los árboles
8.0-10.7	Fresquito (Brisa fresca)	Pequeños movimientos de los árboles, superficie de los lagos ondulada
10.8-13.8	Fresco (Brisa fuerte)	Se mueven las ramas de los árboles, dificultad para mantener abierto el paraguas
13.9-17.1	Frescachón (Viento fuerte)	Se mueven los árboles grandes, dificultad para andar contra el viento
17.2-20.7	Temporal (Veinto fuerte)	Se quiebran las copas de los árboles, circulación de personas dificultosa
20.8-24.4	Temporal fuerte (Muy duro)	Daños en árboles, imposible andar contra el viento
24.5-28.4	Temporal duro (Temporal)	Árboles arrancados, daños en la estructura de las construcciones
28.5-32.6	Temporal muy duro (Borrasca)	Estragos abundantes en construcciones, tejados y árboles
>32.6	Temporal huracanado (Huracán)	Destrucción total

APPENDIX I: INTERVIEW – TRES RIOS FIRE STATION

Date: May 29, 2006
Interviewee: Guido Mora Vargas, Station Chief

How did they decide how to make the "hot zones"?

The Bomberos use the Emergency Response Guidebook to see which distances are appropriate and then set up a perimeter in accordance with the direction of the wind. An inner perimeter, which is called the "zona caliente" and is labeled with red, the next perimeter is labeled with orange and is called "zona tibia" and the final outer perimeter is labeled with green, "zona verde".

Who decides what the perimeter of the site is?

The Bomberos decided the appropriate perimeter in accordance with the Emergency Response Guidebook and the police enforced it.

How did the leak occur and why did it release so much gas?

The leak occurred in the tube between a stationary tank and a mobile tanker truck as it was transferring the chlorine gas. The break occurred in the cistern and was thought to be caused by the error of the driver of the truck because he moved the truck too soon. It released about 20 tons of gas into the air because the shut off valve was not the standard valve and its closing mechanism was different than what the Bomberos were expecting. Therefore it took longer to shut off because it was not immediately known that the valve was different.

Do the companies have to self report the chemicals they store and use?

No, there are no laws that regulate how to report or if the companies have to report but the Tres Ríos Bomberos visit companies in the area and recommend procedures for them to use in case of emergency and to keep records of the chemicals they use and store. Many companies keep MSDS sheets on hand for the chemicals that they store and use. Even at night, the guards have access to the MSDS sheets.

Where is Irex located in relation to the fire station?

Irex is 2 kilometers away from the Tres Ríos fire station.

How long did it take the Bomberos to respond to the incident?

It took the Bomberos 9 minutes to respond to the incident. The call was received at 1:30pm and they were on scene at 1:39pm. The Haz-Mat team from Tibás took an hour to get there.

How many stations responded to the incident?

3 stations responded: Central, Tibás and Tres Ríos

How many personnel responded?

40 Bomberos, 1 Haz-Mat team consisting of 4 members

What were the weather conditions at the time of the incident?

Rainy and cold which caused a hydrochlorate acid rain to form

How many people were affected and what kind of damage was caused to the environment?

Over 1,000 people were treated for chlorine gas inhalation and injuries related to the chlorine gas and 8 Bomberos were affected during the response

APPENDIX J: INTERVIEW – CENTRAL FIRE STATION, SAN JOSÉ

Date: May 30, 2006
Interviewee: Sr. Luis Salas, Chief of San José Zone

Chief of the San José Zone, Luis Salas has been with the Cuerpo de Bomberos for 23 years and has served as the head of the San José Zone for a little over three years.

Can you give us a brief explanation of the process when a chemical release occurs?

First the Bomberos must determine what chemical they are dealing with. Is it a solid, liquid, or gas? Gases are the most dangerous because of their ability to spread more quickly. They also must find out how much of the chemical is present on site. The Bomberos then set up a perimeter and evacuate citizens around the incident site. After the type of material is determined they look up whether it is flammable or not. This information affects how they treat the spill. If the chemical is not flammable, but still hazardous, firefighters might need to use protective clothing and not their regular suit. If the chemical is flammable they must be dressed in their suits as well as protective clothing. They use Emergency Response Guidebook to determine how large the perimeter should be as well as how to treat the spill or any fires fueled by the chemical.

Often times Bomberos have no way to tell what is inside a container, although they use standards set by the United States Department of Transportation, they are not enforced. Trucks are required to place placards if they're transporting hazardous materials, but they're often mislabeled. For example, it might be marked with an "8" signifying corrosives, but the container really contains bananas. Also, these placards cannot be relied on since they are not used properly in bordering countries like Nicaragua.

The Bomberos have a chemical detecting instrument that identifies 0_2, CO, and three other common chemicals.

If the Bomberos are dealing with a tank they first shut off the valve to stop the leak.

Who is responsible for coordinating the response to a chemical emergency?

The National Communications Center dispatches first and second responders to a chemical incident. First responders rely mostly on the Emergency Response Guidebook for their response. Second responders include the Hazardous Materials teams in Tibás, and the Limón and Guanacaste provinces. They have more materials and resources to deal with the chemical releases.
The Office of United States Foreign Disaster Assistance (see glossary), which is a governed by the United States Agency for International Development (USAID)

(see glossary), aids all of Latin America if there are large disasters, like chemical releases. It has been around for about 30 years.
The Bomberos also work with OSHA and have done so for the past 25 years.

Are there any regulatory agencies that govern the use and transportation of chemicals in Costa Rica?
Did not ask, previously answered

Do companies that use chemicals and hazardous materials have to report the chemicals that they have and the spills that occur on site?
They are not required too but many companies tell the Bomberos what chemicals they use. Many companies in San José also have teams of first responders on site.

How do the companies know what chemicals to report and whom do they report the data to?
Did not ask, not pertinent

Are those companies required to have first responders on-site?
Companies are not required to have first responder training for their personnel, but if a company is interested the Bomberos will provide training classes. All Bomberos are required to take 20 hours of first response training.

It was recommended that if we have questions regarding specific procedures that we talk to Jorge Barrios or Maynard Zumbado with the Hazardous Materials team in Tibás.

APPENDIX K: INTERIVEW – ALAJUELA FIRE STATION

Date: May 31, 2006
Interviewee: Esteban Rodriguez, Volunteer Firefighter

How many firefighters work here?

There are five full-time firefighters that work 24 hours on duty then 24 hours off duty.

There are 24 volunteer firefighters that work 40 hours per month.

How many trucks do you have in this station?

2 trucks

How many chemical spills does this station respond to in a year?

About 5, typical spills include ammonium and chlorine

We have handled structural fires with chemicals which are dangerous because we don't know where the chemicals are or whether they will react with water. We dealt with a fire four years ago that began at 9:00 PM and took until 3:00 AM to contain. The HazMat team wasn't there. It might have been easier to contain if we had been able to have their help.

What kind of equipment does this station have for treating chemical spills?

They do not have much equipment except for protective suits and a radio. They have nothing to pick up the chemical or dispose of it with.

Would you like more equipment to better respond to chemical spills? If yes, what type?

They would like equipment to be able to contain a spill. Since there is only one Haz-Mat team in the country, often times they are far away and firefighters that are not trained for

Would you like more training to better respond to chemical spills?

Yes, definitely. Currently we only have first response training where we use the Emergency Response Guidebook to handle a spill.

What are your thoughts on the program?

The program needs to be in Spanish. The information in it is very complete in the chemical database. The map could help us with structural fires when we need to find sources of water. We take water from swimming pools and usually someone will ride around on a bike to find a pool. It would be beneficial if we could mark them on the GIS map.

How would you like to use the modeling software (in real time or for simulations)?

Ideally the software would be in every station. We could use it during training when we run simulations of chemical spills. We would also use it in real time.

APPENDIX L: INTERIVEW – HEREDIA FIRE STATION

Date: May 31, 2006
Interviewee: Federico Covballo Ramirez, Station Sub-Chief

How many firefighters work here?

There are 10 full-time, with five on duty each day. There are also 10 volunteer firefighters.

How many trucks do you have in this station?

We have three trucks: two structural trucks and one water truck

How many chemical spills does this station respond to in a year?

This station responds to three to four chemical spills per year. We also ask for assistance and assist other neighboring stations.

What kind of equipment does this station have for treating chemical spills?

We have protective suits but if more help is needed we will ask for assistance from San José or the Hazardous Materials team in Tibás. We also have tools for containing liquids and chemicals.

Would you like more equipment to better respond to chemical spills? If yes, what type?

Yes, of course. We need more equipment for big spills. Most of the time we call on other stations for help, particularly in San José.

Do you see a need for the software in your station?

Yes, of course. We would like to use it in our training, but it needs to be in Spanish.

APPENDIX M: INTERIVEW – TIBÁS FIRE STATION

Date: June 2, 2006
Interviewee: William Hernández, Chief of Station

We spent three hours in Tibás. We first interviewed William Hernández, who speaks English, in regards to the equipment and training of the Haz-Mat team. Then Mike conducted a simulation with the on-duty firefighters with Chief Hernández translating. They were very interested in the simulation we showed them and had many questions. They are interested in learning much more about the CAMEO suite, since they have it in the Haz-Mat truck, but only use it for its chemical database.

How many firefighters work at this station?

20 permanent firefighters, 10 for each day

How many firefighters work on the MAT-PEL team?

2 technicians specially trained for MAT-PEL, but all of the firefighters have first response training. There is an "offensive" practice. There are courses that they can take that teaches them how to stop leaks and control them after the fact, but there has only been once class in Costa Rica to teach the technicians.

How many chemical spills does this station respond to in a year?

We should consult the communications center in order to receive this information. On May there was a factory that produces beer, tropical juice, and bottles water that had an ammonia leak the Haz-Mat team responded too.

How many trucks do you have at this station?

We have one truck to respond to Haz-Mat emergencies.

What kind of equipment does this station have for treating chemical spills? Would you describe it to us? Would you show us?

A, B and C level of protection. A is fully encapsulated, B uses duct tape to close the gaps in the suit where the hands are for example, and C is less protective than B and A. They have flammable and non-flammable gas detectors and have containers and kits for different chemicals and sized spills. Also they have a reactive chemical kit that tests for what type of chemical is present at the spill site.

Would you like more equipment to better respond to the chemical spills? If yes, what type?

They would like better undergarments for under the protective suits because it gets very hot in the suits and the sweat makes mobility very difficult.

They would like a communication system inside the suit because you cannot hear anything once you are encapsulated in the suit and it should be able to be activated through vibrations in the head, not just when you talk.
They would like a tent so that they are able to be shaded from the sun and protected from the rain when they are on site at the chemical spill so that they can set up communications in it.

They would like a field where they can practice their emergency response.

They would like equipment that would allow them to move large drums. This would come in handy when a container at the back end of a trailer is leaking and there are many containers in the way.

Are there areas where you believe you need more training for handling chemical spills?

Yes, they would like to have more people trained specially for the MAT-PEL team.

Do you see a need for the modeling software in your station?

YES!

How would you like to use the modeling software? (Maybe as part of your training exercises for chemical releases or in the field where there is a release)

They would like to use it to train with and maybe when there is a release they could use it. Right now they are only using it as a means to search for chemicals inside of the chemical database.

Extra Notes:

They have an Emergency Response Guide book in every truck and the first responders use it. Start to relay information by radio to the truck from the first responders. They currently have procedures for chlorine and ammonia. Most emergencies do not happen in Tibás, but because they have the only true MAT-PEL team, they are responsible for responding for almost all off the chemical emergencies. They would really like to know more about the program, but most Bomberos do not know English very well. The metrological institute could give information about weather conditions for the program.

APPENDIX N: PUNTARENAS FIRE STATION

Date: June 8, 2006
Interviewee: Alexander Araya Micó, Station Chief

How many firefighters work in this station?
Three permanent firefighters per day and five volunteers.

How many chemical spills does this station respond to in a year?
We've had seven incidents in the past 2 months and average approximately 20 a year. Ammonium and chlorine are the most common chemicals released.

How many trucks do you have in this station?
We only have one truck, but it is versatile enough to handle all the types of incidents we respond to.

What kind of equipment does this station have for treating chemical spills? Would you describe it to us? Would you show us?
We have capsule suits, gas masks, containment tanks, and enclosed breathing apparatuses.

Would you like more equipment to better respond to chemical spills? If yes, what type?
We would like special kits for confinement that are chemical specific such as chlorine, patches that go over a broken tube/pipe to limit amount of leak, this kit would be very important and absorbent materials to assist in clean up.

Are there any areas where you believe you need more training for handling chemical spills?
Need more practice dealing with Hazardous Materials. It would be beneficial to practice scenarios as is done in the United States.

Do you see a need for the software in your station?
Yes.

If the program was not available in Spanish, but you could use a guide that is in Spanish to help with inputs, do you believe it could be used by the fire fighters in this station?
We would still be able to use the program, but we don't have a laptop to use it on so we'd need it.

How would you like to use the modeling software? (Maybe as part of your training exercises for chemical releases or in the field when there is a release)
Many stations don't handle Hazardous Materials, but this one does. Guanacaste has one technician and is closer than Tibás.

If a program like CAMEO was available, but only in a central location such as San José, would your station be able to use it? What kind of communication systems do you have set up for that?

It would be hard to use in a situation because there's lots to sort through. They would use the program for simulations.

APPENDIX O: INTERIVEW – LIMÓN FIRE STATION

Date: June 10, 2006
Interviewee: Gilbert Warren Warren, Station Chief

Station Chief Gilbert Warren Warren has seen CAMEO used in the United States and in Japan. He has visited fire station in Los Angeles, Houston, and Miami in the U.S.

How many firefighters work in this station?

There are 5 full-time firefighters here. Three work on one shift and two work on the other 24 hour shift. There are also 20 volunteer firefighters.

How many chemical spills does this station respond to in a year?

This stations responds to about 50 chemical spills. Most of the time they occur around the port. They probably respond to one once a week.

How many trucks do you have in this station?

This stations has 3 fire trucks with one being repaired right now.

What kind of equipment does this station have for treating chemical spills? Would you describe it to us? Would you show us?

The station has two of the orange protective suits. These give full protection. They have barrels for hazardous liquids and solids. This is only enough equipment for two men.

Would you like more equipment to better respond to chemical spills? If yes, what type?

They would like more first response equipment including protective suits, chemical spill kits, and more personnel. 85% of all imports and exports in Costa Rica pass though Limón so it is important that they have lots of training.

Are there any areas where you believe you need more training for handling chemical spills?

They would like more first response training. The closest Hazardous Material team is in Tibás, so often times it takes a while for them to respond.

Do you see a need for the software in your station?

He likes the computer program a lot and sees the benefit of it, but this station would need many things to implement the program. Right now a firefighter picks up some dirt and tosses it in the air in order to determine where they should set up their headquarters.

The firefighters would need training in many areas in order to run the program including:

- How to enter current weather conditions
- How to operate CAMEO in the different regions of the country like Guanacaste, Limón, and San José
- The definition of the AEGLs on the footprint

This training would be hard to get. Most firefighters here receive training in the field instead of in a classroom. They don't have a lot of time for the classroom training, so they work with a more experienced partner who tells them what to do. Many people would have to be trained in order to implement it since the firefighters work in two shifts. That means that at least two firefighters in every station would need to be trained.

If the program was not available in Spanish, but you could use a guide to help with inputs, do you believe it could be used by the fire fighters in this station?

The program would be very difficult for us to use without the proper training even with the guide. It wastes a lot of time to have to flip through a guide. We only have a staff of 2 or 3 firefighters per shift right now, and they must work together when handling a situation. If one is going into a building the other follows. If one had to be operating the program his partner would have to work with him. These firefighters might be better employed in containing the spill then running the program. We are short on personnel right now, so running the program would tighten the resources we already have.

How would you like to use the modeling software?
(Maybe as part of your training exercises for chemical releases or in the field when there is a release)

Since it would be difficult to implement in real-time we could use it in our training exercises. There are some places in the port where we respond to incidents frequently.

If a program like CAMEO was available, but only in a central location such as San José would your station be able to use it? What kind of communication systems would you need for that?

That would work as long as there was a way to get accurate atmospheric information.

APPENDIX P: INTERVIEW – NATIONAL METEOROLOGICAL INSTITUTE

Location: Nacional Meteorological Institute, San José
Date: June 15, 2006
Interviewee: Sr. Werner Stolz

What agencies does the National Meteorological Institute (NMI) work with?

- World Weather Organization, (a UN agency)
- NOAA
- Meteorological Agency in Japan
- IRI in the United States
- National Hurricane Center in Miami, USA
- The NMI does not work directly with the Bomberos

Will you describe to us what kind of weather stations Costa Rica has and where they are?

Costa Rica has about 300 weather stations around the country. Fourteen of these relay their information by satellite to the central NMI office in San José in real time. They others have a personal manually enter the data that is sent to the central NMI office.

Is there a communication system set up that can relay weather information around the country to fire stations?

There isn't a way for the Bomberos to contact the individual weather stations, but they could call the central office and receive current weather information from the NMI.

Could you recommend any hand-held weather equipment that the Bomberos could use in the field?

There are hand-held weather stations that the NMI uses. They can measure temperature, humidity, and wind speed. Two of the instruments used by our agency are made by Vaisala and Cambell.

Do you know of any techniques for visual observation of weather conditions that the Bomberos can use?

Our agency can train the Bomberos in techniques so that they can learn how to observe weather conditions visually. If a group of Bomberos wanted to be trained they could come as a group and we would teach them.

APPENDIX Q: IREX SOAP COMPANY, TRES RÍOS

Date: June 23, 2006
Interviewee: Alvaro Sánchez Campos

Our team along with two Bomberos, William Vega Mora and Fire Investigator, Alvaro Sánchez Campos visited the site of the Irex chlorine gas release which occurred on June 12, 2002. Alvaro is one of the two fire investigators in Costa Rica. He studied the cause and effects of the chlorine release.

The chlorine tank that was being filled by the tanker truck has now been replaced by a parking lot. Now Irex only holds the chlorine that they use on a daily basis. The other chemical tanks, some containing diesel, water, and caustic soda, were present at the time of the leak. They are used in other processes.

That day the driver backed in next to the stationary tank, connected the pipe to his truck, and began filling the stationary tank. The tanker truck was full at the time of the release. At one point the truck moved causing the pipe to break where it was attached to the truck's tank at the cistern. The driver, who was sick with the flu, ran away from the leak. He returned the next day to the scene. The Irex company and citizens in the surrounding area called the Bomberos when they began noticing they had trouble breathing. It took half an hour from the time the release started at 1:00pm for the Bomberos to arrive on scene. The Bomberos along with paramedics set up their headquarters at the bus station on the road leading to the factory. The Bomberos could not contain the release until 3:00am the next day because the cloud was so thick they could not see whether they needed to shut off a valve or seal a whole in the pipe.

The Irex facility sits on a hill over the town of Tres Ríos. The wind was blowing towards the southwest down the hill and towards the town. The combination of hill and downward slope sent the chlorine cloud towards a populated area. Approximately 1,250 people were affected in the area southwest of the release. The cloud eventually spread 10-12 kilometers to the Autopista.

The evacuation was coordinated by Alex Solís of the CNE. The CNE organized the efforts of the Cuerpo de Bomberos, Red Cross, Ministries of Health and Transit, Police, and Rescate. Citizens that did not immediately feel the effects of the chlorine were notified by the Bomberos who communicated by radio to evacuate the citizens. The affected citizens gathered at the bus station where they were taken by the Red Cross to either the hospital in Cartago or the health clinic in Tres Ríos west of the release. All citizens were evacuated west to another sector of Tres Ríos.

The Bomberos never calculated a total cost of the release to them or other agencies.

APPENDIX R: INTERVIEW – CNE COMISIÓN NACIONAL DE PREVENCIÓN DE RIESGOS Y ATENCIÓN DE EMERGENCIAS

Location: Comision Nacional de Emergencia (CNE) Headquarters, Pavas
Date: June 26, 2006
Interviewee: Sr. Alex Solís, Director of Operations

We interviewed Sr. Alex Solís in the Emergency Operation Center at the National

The central government must declare a state of emergency, and then the CNE can work with other national agencies to help citizens affected by a disaster.

What agencies does the CNE work with?

The CNE works with most of the national agencies, some of these include the Red Cross, Bomberos, MINAE, and the Health and Treasury Ministries.

What types of emergencies does it handle?

The CNE assists with floods, hurricanes, tornados, landslides, fires, and earthquakes.

They leave first responders to the appropriate agencies, but will assist in evacuating citizens or helping rebuild a damaged area. The CNE has a rescue team that assists with many disasters.

What procedures does the CNE follow when handling a chemical release?

If the Bomberos request help the CNE can assist in coordinating a national response. An example of this was the Irex incident in 2002, when the CNE was called to assist with the chlorine release.

We presented our recommendations for the implementation of the CAMEO suite to Sr. Solís and he gave us input regarding the likelihood of implementation and how the CNE could work with the Bomberos to implement the recommendations.

1. **Training for personnel directly associated with the use of CAMEO®**
   This is very necessary.

2. **Establish a central command in OCO for CAMEO® with trained personnel that can input data regarding a release from Bomberos around the country**

3. **Establish communication between OCO and the IMN so the Bomberos will have access to current, accurate weather conditions**
   Both of these agencies have radios with the same frequency as the CNE, so a communication system is already there.

4. **Train Bomberos in techniques for visual weather observation**

5. **Purchase a mobile weather station for the Haz-Mat team in Tibás**
   Who is going to pay for this?
   We explained that we are currently looking into the cost of a station that is compatible with ALOHA.

6. **Improve and expand the first response equipment in local stations**
   This is always needed.

   Overall these recommendations are very good. The CNE has lots of information about flood areas, topography, fault zones as well as buildings, streets, and schools in their GIS database. The CNE takes part in a Haz-Mat Advisory Committee nationwide.

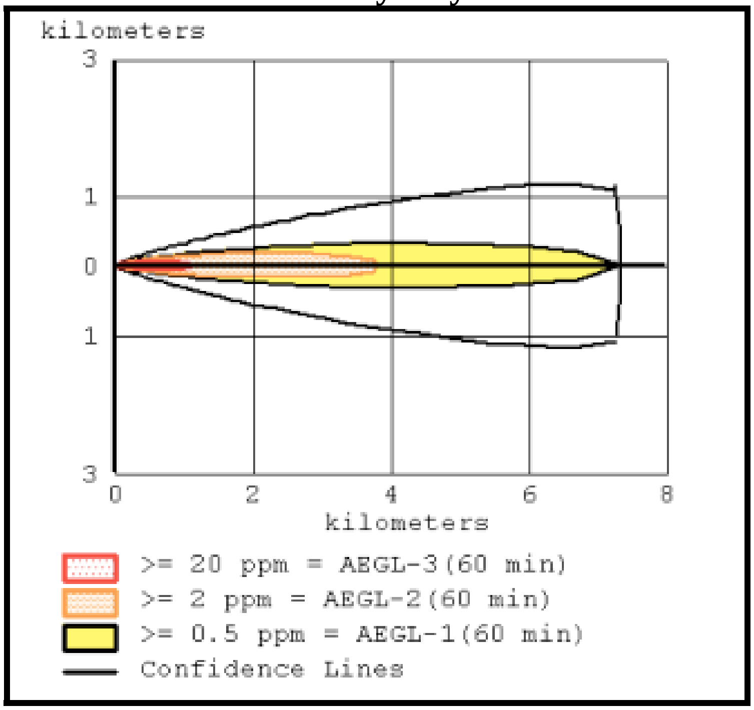
APPENDIX S: INTERVIEW – OFICINA DE COMUNICACIONES

Location: Santo Domingo Fire Station
Date: June 28, 2006
Interviewee: Rodrigo Leandro Quesada, Chief of Bomberos Communications

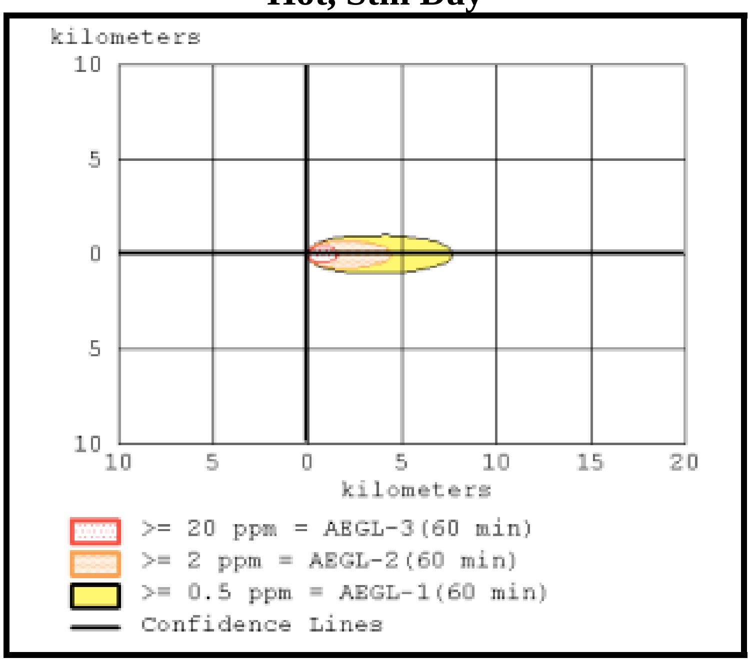
We met with the Bomberos in the Santo Domingo Station as well as the dispatchers from the OCO office including the Chief of OCO, Rodrigo Leandro Quesada. During this meeting we gave them an overview of what the CAMEO suite entails and our recommendations for its implementation. Concerning our recommendations that OCO be the central station to utilize CAMEO in Costa Rica they were very receptive. They stated that with proper training that they were capable of using the program in their daily tasks and would not require additional personnel to run the program. At this point in time they do receive daily faxes from the Instituto Meteorológico Nacional on forecasted weather information. They could develop this link between the two agencies.

APPENDIX T: SENSITIVITY ANALYSIS OF TOXIC THREAT ZONES

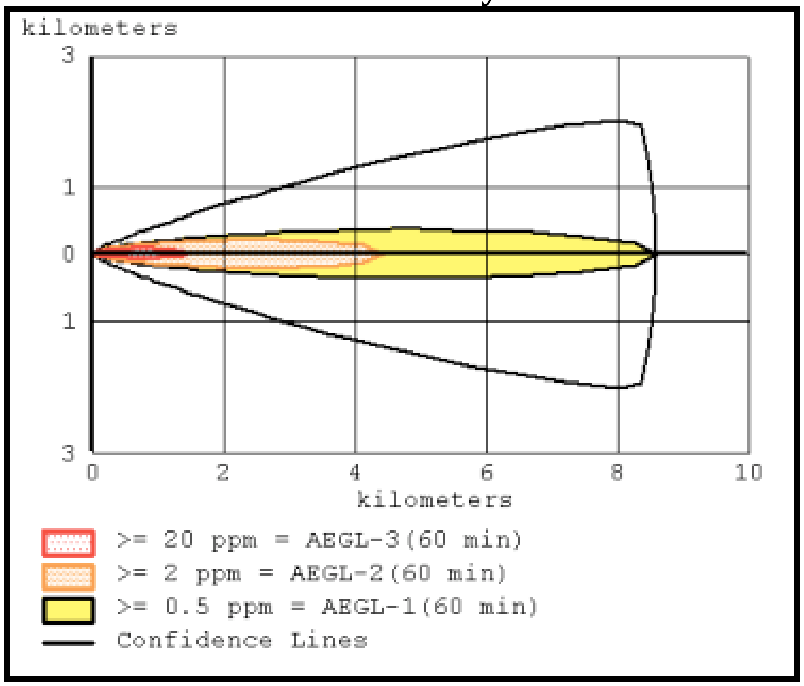
Windy Day



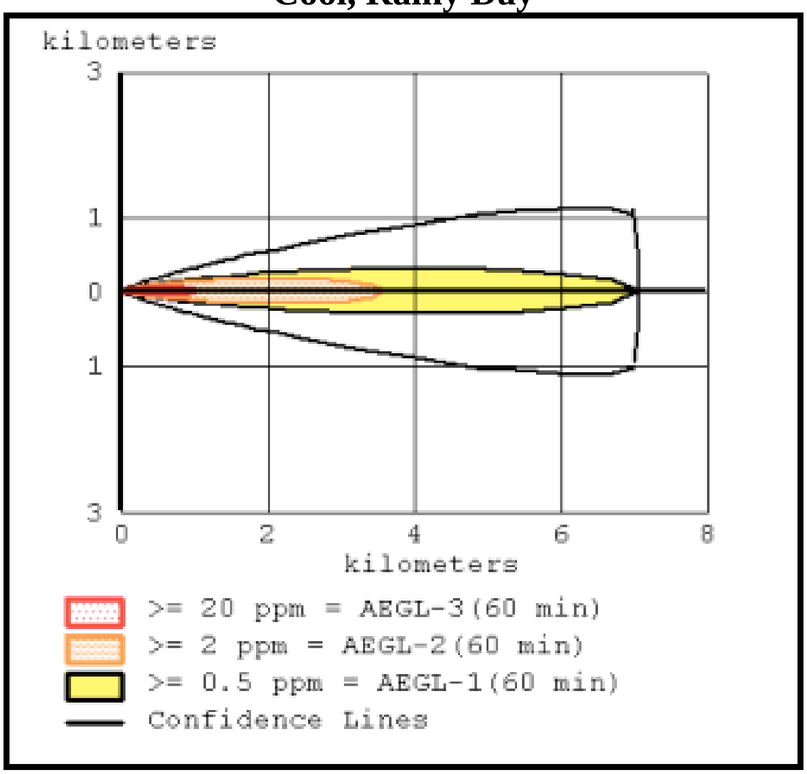
Hot, Still Day



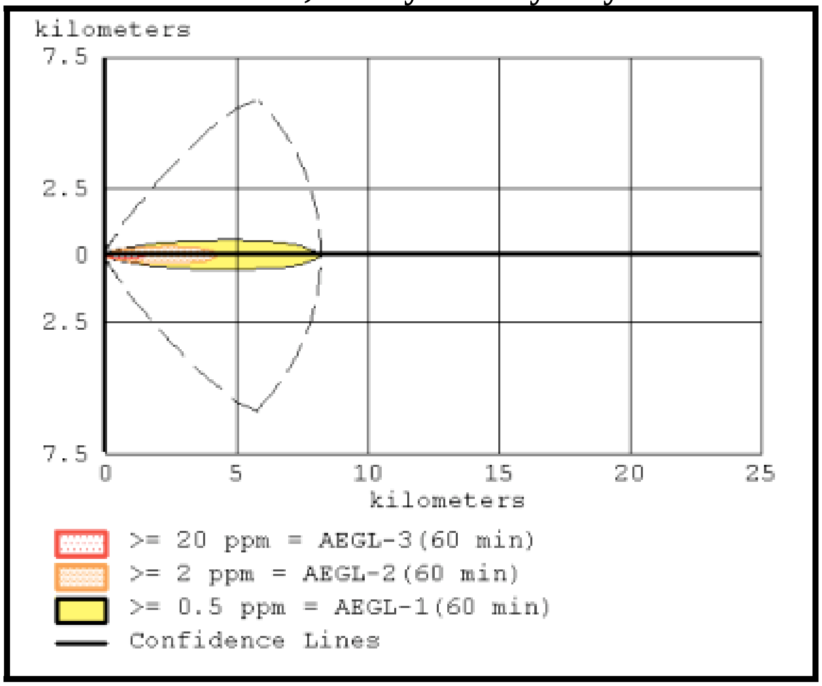
Clearer Day



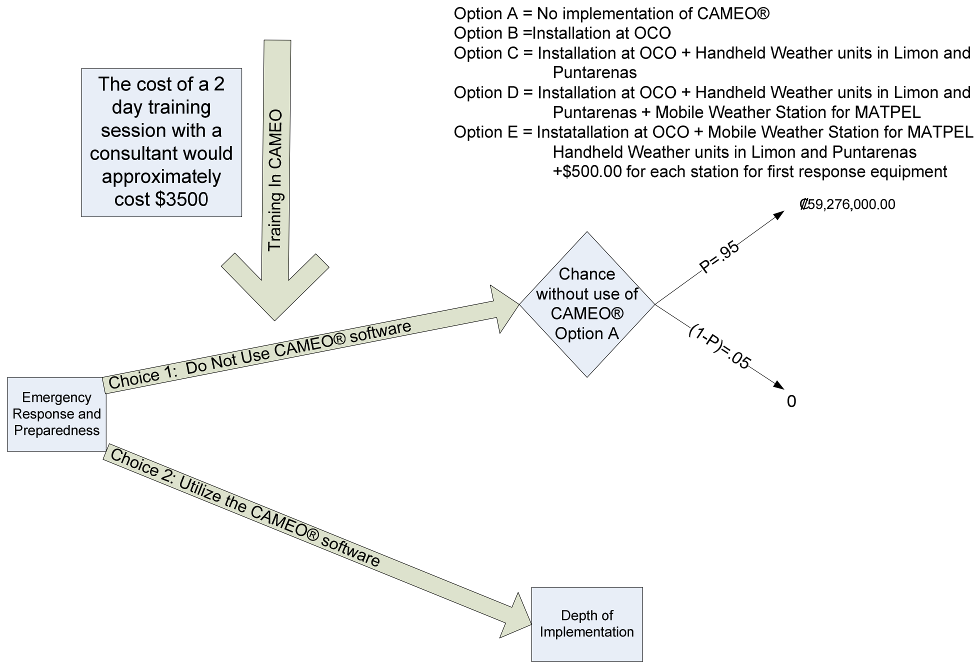
Cool, Rainy Day

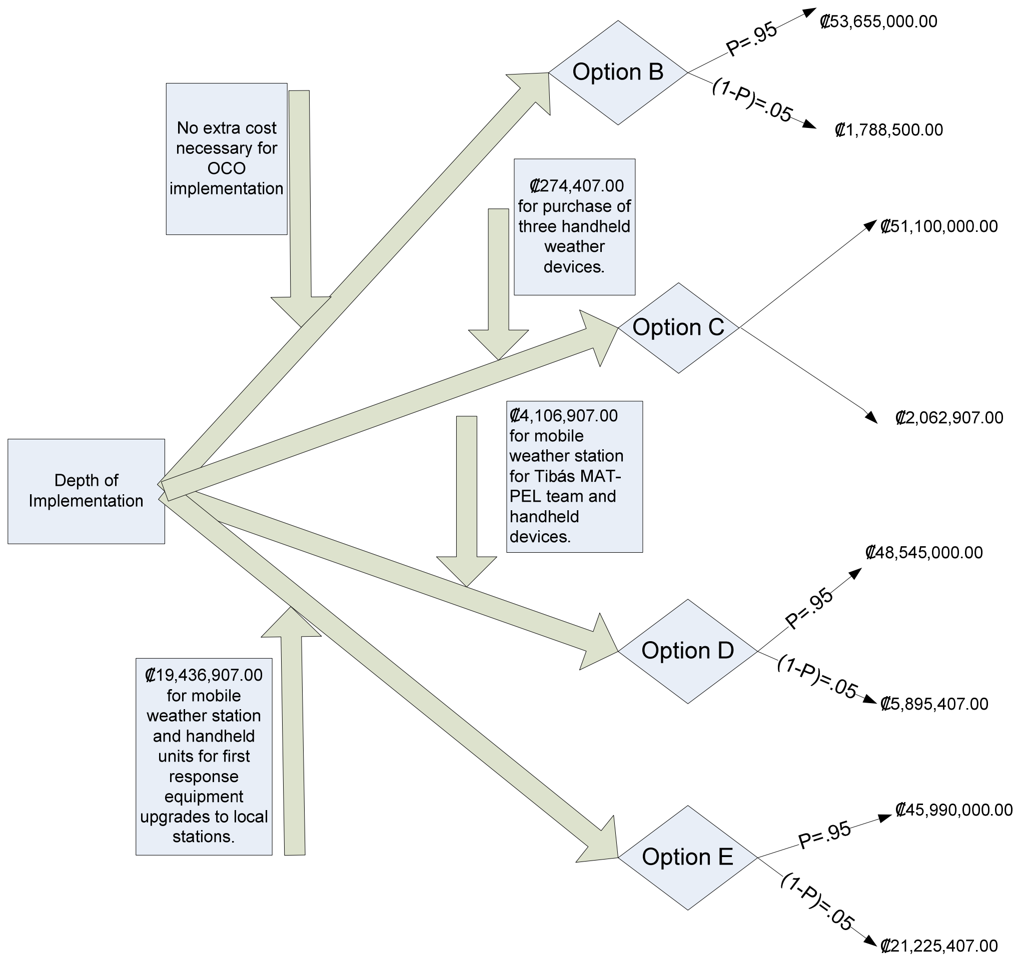


Warm, Partly Cloudy Day



APPENDIX U: Cost Benefit Analysis Tree





Calculations

Reduction Factor = GDP(PPP) per capita US/ GDP(PPP) per Capita CR
Reduction Factor = $41,800/$11,100 = 0.27
Average Cost of Hazardous Materials Spill with release in the United States = ₡273896000
(Source: http://www.fmcsa.dot.gov/facts-research/research-technology/tech/Hazmat-TechBrief.pdf)
Average Cost of Hazardous Materials Spill with release adjusted for Costa Rica = ₡59276000
EMVa = No use of CAMEO® = ₡28,775,534,200.00
EMVb = OCO = ₡26,092,515,925.00
EMVc = OCO + Handheld Weather Unit = ₡24,859,202,273.85
EMVd = OCO + Handheld Weather Unit + Weather Station = ₡23,716,797,898.85
EMVe = OCO + Handheld Weather Unit + Weather Station + First Response Equipment = ₡22,868,154,648.85

GLOSSARY

Organization of Foreign Disaster Aid (OFDA) – office within USAID responsible for facilitating and coordinating U.S. Government emergency assistance overseas (USAID).

Threshold Planning Quantity (TPQ) – toxic chemicals listed by the EPA based on their potential to cause significant health effects in a single exposure, such as an air release (Department of Ecology).

United States Agency for International Development (USAID) – an independent federal government agency that receives overall foreign policy guidance from the Secretary of State. USAID supports long-term and equitable economic growth and advances U.S. foreign policy objectives by supporting economic growth, agriculture, trade, global health, democracy, conflict prevention and humanitarian assistance (USAID).

REFERENCES

Cheremisinoff, Nicholas P. (1995). Handbook of Emergency Response to Toxic Chemical Releases: A Guide to Compliance. Park Ridge, New Jersey: Noyes Publications.

Cloutier, Michael & Cushmac, George. (2004). Emergency Response Guidebook. United States Department of Transportation.

Costa Rican Digital Exports Directory. N.d. Costa Rica: Costa Rica Bruncas. Retrieved March 22, 2006, from http://www.bruncas.com/crexport/chemicals.html

Department of Ecology. (2006). Emergency Release Planning – Section 302. Retrieved April 25, 2006, from http://www.ecy.wa.gov/epcra/section302.html

Department of Energy. (2006). Hazardous Materials Transportation Act. Retrieved March 25, 2006, from http://www.eh.doe.gov/oepa/laws/hmta.html

Department of Environmental Equality. (2006). SARA Title III: The Emergency Planning and Community Right-to-Know Act (EPCRA). Retrieved March 25, 2006, from http://www.michigan.gov/deq/0,1607,7-135-3307_3667_4137-11426--,00.html

Department of Transportation. (2005). An Overview of the Federal Hazardous Materials Transportation Law. Retrieved March 25, 2006, from http://hazmat.dot.gov/regs/overhml.pdf

Emergency Planning for Chemical Spills. (n.d). EPCRA Facilities. Retrieved May 26, 2006, from http://www.chemicalspill.org/EPCRA-facilities/other1.html

Environmental Quality Control. (2004). South Carolina Department of Health and Environmental Control. Retreived May 25, 2006, from http://www.scdhec.gov/eqc/baq/html/112r_gen.html

Environmental Protection Agency. (March 2, 2006). Clean Air Act. Retrieved March 25, 2006, from http://www.epa.gov/oar/caa/

Environmental Protection Agency. (March 3rd, 2006). The Development of Acute Exposure Guideline Levels (AEGLs). Retrieved April 8, 2006, from http://www.epa.gov/opptintr/aegl/

Environmental Protection Agency. (March 1, 2006). CERCLA Overview. Retrieved March 25, 2006 from http://www.epa.gov/superfund/action/law/cercla.htm

Environmental Protection Agency (March 1, 2006). Inside the Emergency Response Program. Retrieved March 25, 2006, from http://www.epa.gov/superfund/programs/er/inside.htm

Environmental Protection Agency (May 24, 2002). What is CAMEO?. Retrieved March 22, 2006 from http://www.epa.gov/ceppo/cameo/what.htm

EPRCA for Firefighters. (N.d.). Emergency Planning for Chemical Spills. Retrieved March 30, 2006, from http://www.chemicalspill.org/FireFighters/epcra.html

Graham, Mary & Miller, Catherine. (October 2001). Disclosure Of Toxic Releases In The United States. Environment. Retrieved March 29, 2006, from http://www.findarticles.com/p/articles/mi_m1076/is_8_43/ai_79381948

Haroz, P.H. (Dec 2004). Minimizing the impact of accidental chemical releases: dispersion modeling to predict plume behavior is key for contingency planning--in advance of any incident. (Environmental Manager). In Chemical Engineering, 111, p57(3). Retrieved March 28, 2006, from CPSN via Thomson Gale: http://find.galegroup.com/ips/infomark.do?&contentSet=IAC-Documents&type=retrieve&tabID=T002&prodId=IPS&docId=A126750680&source=gale&userGroupName=mlin_c_worpoly&version=1.0

Hills of Portalon. (N. d.) Map of Major Highways. Retrieved March 28, 2006, from http://www.hillsofportalon.com/highway_map.htm

Infoplease. "Costa Rica." (2006). Pearson Education, publishing as Infoplease.Retrieved March 25, 2006, from http://www.infoplease.com/ipa/A0107430.html

Instituto Nacional de Seguros. (2006). Historia. Retrieved March 18, 2006, from http://portal.ins-cr.com/Social/Bomberos/Organización/Historia.htm

Lara, Silvia. (1995). Inside Costa Rica. New Mexico: Resource Center Press Managing Hazardous Materials Incidents Volume I. (January 1, 1992). U.S. Department of Human Services, Public Health Service, Agency for Toxic Substance and Disease Registry. Retrieved April 12, 2006, from http://www.floridadisaster.org/bpr/EMTOOLS/Hazmat/p0000018.htm

Michigan State University. (2001-2002) Bhopal Incident Review. Union Carbide Corporation. Retrieved April 2, 2006, from http://msu.edu/course/aec/810/clippings/Bhopal%20India%20chemical%20leak.htm

National Oceanic and Atmospheric Administration. (1993). ALOHA™ and ARCHIE: A Comparison. Retrieved April 15, 2006, from http://archive.orr.noaa.gov/cameo/AlohArch.pdf

National Response Center. (2002). NRC Background. Retrieved March 25, 2006, from http://www.nrc.uscg.mil/nrcback.html

Off-site Consequence Analysis. (N.d). Emergency Planning for Chemical Spills. Retrieved March 30, 2006, from http://www.chemicalspill.org/Offsite/aloha

Oil & Chemical Spill Reporting. (July 14th, 2005). Environmental Health and Safety. Retrieved March 29th, 2006 from http://www.usg.edu/ehs/topics/index.phtml?topic=33

Palmer, Steven & Molina, Ivan. (2004) The Costa Rica Reader: History Culture, Politics.

Peterson, David F. (July 8th,2005). HAZMAT Response. Retrieved April 2, 2006, from http://www.firehouse.com/training/hazmat/training/2002/7_exposure.html

Program in Geographic Information Systems. University of Texas at Dallas. (2004) Fall 2004 Student Reports. Retrieved April 3, 2006, from http://charlotte.utdallas.edu/mgis/ClassFiles/gisc6383/techassess_2004/GIS%20Applications%20in%20Emergency%20Response.doc

Queri-International LLC. N.d. Santa Fe, New Mexico: QuERI-Internatonal. Retrieved March 23, 2006, from http://www.queriinternational.com/new_page_34.htm

RAE Systems. (2006). PlumeRAE. Retrieved March 26, 2006, from http://www.raesystems.com/products/plumerae

Reglamento a la Ley de Bomberos. (2002). Law of the Cuerpo de Bomberos of the Instituto Nacional de Seguros. Received on May 22, 2006 from Francisco Bermudez, Risk Evaluator of the Cuerpo de Bomberos.

The Seveso Incident. University of Bristol. Retrieved April 5, 2006, from http://www.chm.bris.ac.uk/motm/245t/245th/seveso.htm

South Dakota Department of Environment and Natural Resources. (January 4th, 2006). Emergency Planning and Community Right-to-Know Act of 1986. Retrieved March 25, 2006, from http://www.state.sd.us/denr/DES/Ground/SARATitleIII/emergenc.htm

Sullivan, Dale. (May 19th, 1998). Bhopal Gas Tragedy: An Analysis. Retrieved March 27, 2006, from http://www.hu.mtu.edu/hu_dept/tc@mtu/papers/bhopal.htm

Suplemento de Ciencia y Tecnología. (2004). Accidentes tecnológicos, un peligro latente en el país. Retrieved March 23, 2006, from http://www.odi.ucr.ac.cr/crisol/acctec.html

Swift, Kevin T. (1999). Where's the Chemical Industry Going?. Business Economics. Retrieved March 25, 2006, from http://www.findarticles.com/p/articles/mi_m1094/is_4_34/ai_56973856

USAID. (June 26, 2006). USAID: From the American People. Retreived June 26, 2006, from http://www.usaid.gov/

U.S. Department of State. (October 2005). Background Note: Costa Rica. Retrieved April 1st, 2006, from http://www.state.gov/r/pa/ei/bgn/2019.htm