July 4, 2006

Lic. María Guzmán Ortiz, Directora
Secretaría Técnica Nacional Ambiental
Ministerio del Ambiente y Energía
San José, Costa Rica

Dear Sra. Guzmán,

Enclosed is our report entitled Improved Waste Management in Costa Rica's Uruca River Basin. It was written at the Ministerio del Ambiente y Energía during the period March 15, 2006 through July 4, 2006. Preliminary work was completed in Worcester, Massachussetts, prior to our arrival in Costa Rica. Copies of this report are simultaneously being submitted to Professors DiBiasio, Mello and Salazar for evaluation. Upon faculty review, the original copy of this report will be catalogued in the Gordon Library at Worcester Polytechnic Institute. We sincerely appreciate the time that you, Sra. Shirley Soto Montero and Sr. Marco Chinchilla Salazar have devoted to us.

Sincerely,

Jill Goldstein

Evan May

TITLE PAGE

Report Submitted to:

Professor David DiBiasio, Professor Natalie Mello and Professor Guillermo Salazar

Costa Rica, Project Center

By

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In Cooperation With

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Ministerio del Ambiente y Energía, Dirección de Gestión Calidad Ambiental

IMPROVED WASTE MANAGEMENT IN COSTA RICA'S URUCA RIVER BASIN

Date: July 4, 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 MINAE or Worcester Polytechnic Institute.

This report is the product of an education 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

This project, prepared for the Ministerio del Ambiente y Energía (MINAE) in San José, Costa Rica, examined methods to monitor industrial waste management practices while raising community knowledge about cleaner production. The following report describes our development of an online questionnaire, a waste estimation model and a brochure encouraging proper waste management within commercial centers. Through the use of technology, our project aims to enhance MINAE's ability to monitor the waste generation and disposal techniques of Costa Rican businesses.

Authorship

This paper was entirely written by both team members. Jill Goldstein and Evan May both contributed equally to all aspects of the project through teamwork.

Acknowledgements

We would like to thank a number of individuals who have helped us throughout the course of our Interactive Qualifying Project. Their contributions to our work have been invaluable.

We would first like to thank our advisors, Professor David DiBiasio, Professor Natalie Mello and Professor Guillermo Salazar. We are very grateful for their constant guidance and commitment to our project. Thank you also to Professor Susan Vernon-Gerstenfeld, Mr. James Music and Mrs. Marcela Music for coordinating our project.

We would like to thank our liason, María Guzmán Ortiz, outgoing director of the Direccíon de Gestión de Calidad Ambiental (DIGECA) at the Ministerio del Ambiente y Energia (MINAE). Her constant insight and efforts in coordinating visits to industries were vital to our project. We would also like to extend a special thanks to the incoming director of DIGECA, Shirley Soto Montero, for her assistance with our project.

We would like to express our deepest appreciation to Marco Chinchilla Salazar from DIGECA. He was an essential asset during our fieldwork to Santa Ana. Additionally, his kindness, patience and knowledge of databases and mapping software provided us with enormous insight throughout our work.

Thank you to Vera Barrantes for her assistance with translating. Her time and effort contributed to the success of our project.

We would like to thank all of the staff at the DIGECA office for their continual help. Thank you also to Elmer Martínez Arguedas for transporting us to and from Santa Ana for our fieldwork.

Thank you to the following individuals for providing us with detailed tours of their facilities:

- Carlos Rosas and Warren Jimenez from the Compañía Nacional de Fuerza y Luz (CNFL) Natural Resources Department for showing us the Brasil Hydroelectric Facility.
- Francisco Tamez, Gestor Ambiental of Terramix, S.A. at Hultec Industries.
- Eladio Brenes, Gerente de Calidad at Empaques Santa Ana, S.A.
- Román Herrera Castro, Gerente de Exportadora PMT, S.A.

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Executive Summary

Costa Rica is a land rich with natural beauty, in which active volcanoes and tropical beaches contribute to its Central American charm. To help preserve its flourishing environment, Costa Rica has invested in renewable forms of energy that are environmentally sound. In fact, hydroelectricity is Costa Rica's primary source of energy, constituting over 80% of the nation's total generated power. However, a recent boost in the economic activity of small businesses has significantly increased the amount of industrial debris that ends up in the country's rivers, thereby clogging the electricity-generating turbines at the hydroelectric facilities. This illegal dumping of waste by small businesses does not only tarnish the environment, but also reduces the maximum energy output from hydroelectric facilities while increasing dam maintenance costs. The Ministerio del Ambiente y Energía (MINAE), a government sponsored environmental organization in San José, Costa Rica, has shown concern with this problem by investigating various methods to improve industrial waste management.

During industrial production, companies begin with raw materials and manufacture them into a desired product through a specific process, as illustrated in Figure 1. An inevitable byproduct of manufacturing is waste materials, for which companies must find proper sources of disposal.

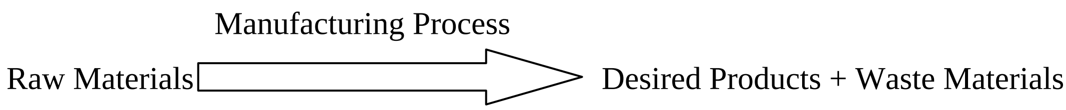


Figure 1: Basic Outline of a Manufacturing Process

Consequently, the fundamental goals of this project were to help MINAE monitor the waste management practices of businesses in Santa Ana while encouraging cleaner production. To accomplish this goal, we recognized the following objectives:

- To determine the economic activity, name and classification of every business along the Uruca River in Santa Ana through an observational study by employing a Global Positioning System (GPS).
- To formulate a protocol for MINAE to obtain information from industries about their manufacturing process and generated waste materials.

- To develop a prediction based model for MINAE to estimate the type and amount of waste produced by any business.
- To promote cleaner production within one type of business in Santa Ana.

The first step we took in completing our project was to perform an observational study of the business sector in Santa Ana. To complete this task, we visited all of the companies along the road parallel to the Uruca River and documented their type of economic activity and their total number of employees. We used a GPS unit to obtain the mapping coordinates of these businesses. Any obtained information was recorded in the chart in Table 1.

Microcuenca del Río Uruca
Levantamiento de información en campo

Nombre del ente generador / Name of the company	Descripción de la actividad / Description of the activity	Longitud	Latitud	Número de empleados / Number of employees

Table 1: Field Work Collection Sheet for Observational Business Study

From this information, we were able to classify the businesses based upon their International Standard of Industrial Classification (ISIC) code, a business classification technique established by the United Nations Statistics Division. We also developed a map of the Uruca River basin highlighting the locations of the 44 businesses we identified. This map can be seen in Figure 2.

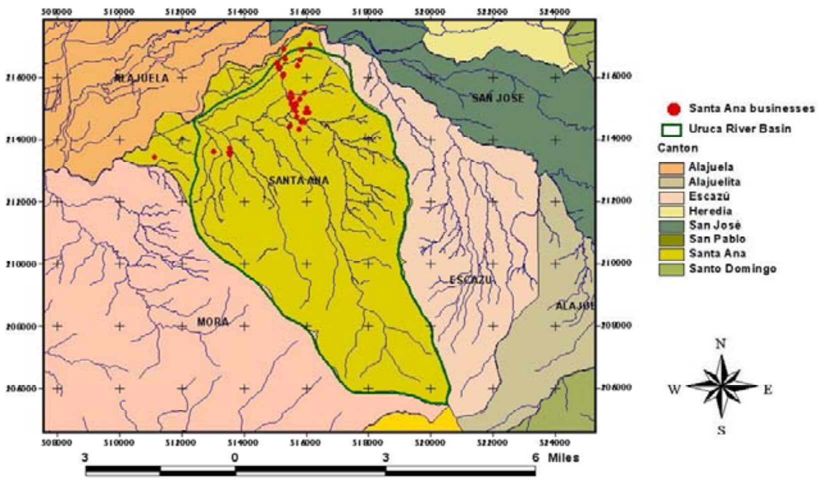


Figure 2: Distribution of the Visited Businesses in Santa Ana

The next aspect of our project was to develop a method for MINAE to monitor the economic activities of any business in Santa Ana without conducting an on-site interview. Consequently, we created an interactive Portable Document Format (PDF) as part of an online protocol. This form contained questions regarding the raw materials, manufacturing process and waste disposal methods that a company employs. We also developed an operating manual containing suggestions to assist MINAE in integrating this form with their existing database.

In addition to the online protocol, we developed a prediction based model for MINAE to estimate the type and amount of waste produced by different companies in Costa Rica. Our project aimed to simplify their current methodology, a popular waste estimation model known as the Industrial Pollution Projection System (IPPS). We based our model on a ratio of the total waste generated by a company per day per number of employees. Using test data, we found this method to provide estimations that were accurate enough for MINAE's requirements, in most cases offering conjectures with better than 70% accuracy.

The final facet of our project was to develop a brochure to promote cleaner production within one type of industry. We selected commercial centers, or a collection of retail vendors, because they were the most prominent type of business found during our observational analysis. Our brochure contained suggestions on how to improve customer satisfaction, to promote environmental awareness and to save money via waste reduction and recycling.

From our work, we have established the following set of recommendations for MINAE to employ in expanding our three deliverables:

- Create a website with a username/password system for businesses to access the online protocol and electronically submit the PDF to MINAE.
- Update the waste estimation model every time an online protocol is received.
- Distribute the cleaner production brochure to local commercial centers, monitor their cost savings and update the brochure with any success stories.

The final products of our project all aim to promote improved waste management practices within Costa Rican businesses. Hopefully, with our deliverables, MINAE can improve communication with companies about proper waste disposal.

1 Introduction

Access to energy is an essential step in the modernization of any developing country. Without energy, many economic activities would be impossible to complete, creating vast difficulties in a country's attempt to modernize and compete in the global market. Despite efforts to bring affordable energy to all of their populations, many countries are still faced with problems that drive the price of energy higher. In Costa Rica, an emphasis has been placed upon renewable forms of energy, especially hydroelectric power. Hydropower has become a valuable resource within Costa Rica, constituting over 80% of the nation's generated electricity. With the development of hydroelectric plants throughout the Virilla River Basin, Costa Rica has made progress in relying on a reusable and cost-efficient source of energy.

Unfortunately, illegal dumping from various sources poses a threat to Costa Rica's hydroelectric facilities. Currently, many rivers in Costa Rica are polluted through illegal dumping. After releasing solid waste into the river, the debris travels along the river and clogs hydroelectric turbines located further downstream. As a result, the flow of water through the dam is decreased, resulting in a lower yield of electricity. With less energy available to the country, the cost of energy is driven higher due to increased expenses associated with unclogging and repairing the dams. In fact, hydroelectric dam companies must budget for increasing cleaning and maintenance costs to fund the replacement of equipment and the removal of unwanted objects.

Much of this problematic debris originates from sources upstream of the dams. With high disposal costs, communities and businesses may be tempted to discard their waste through illegal dumping as a cheaper alternative. To evaluate the current waste management system in Costa Rica, we have conducted a review of the literature on the waste disposal costs and collection programs of different municipalities within the country. This research has provided us with information about the amount of waste generated in various communities, their specific waste management techniques and their efforts to promote recycling.

The Ministerio del Ambiente y Energía (MINAE) has taken a great interest in the problem of industrial and corporate waste management. Within Santa Ana, a canton of the San José province, recent economic growth has left MINAE's records incomplete. As the presence of industries in Santa Ana grows, the need to monitor their amounts of generated waste also rises. We have worked with MINAE to assess various industrial waste management programs in support of overall cleaner production.

Ultimately, the goal of this project was to examine the presence of businesses in Santa Ana, to determine ways for MINAE to monitor waste generation by businesses and to promote cleaner production within one type of industry. We performed fieldwork to determine the distribution of businesses within Santa Ana and to investigate their waste management practices. Our group also created an interactive online protocol for MINAE to obtain information from businesses regarding their economic activity and waste handling methods. Additionally, we generated a prediction based model for MINAE to perform estimates of the type and amount of waste produced by businesses. Lastly, we compiled a brochure highlighting best practices for cleaner production within commercial centers.

2 Background

Hydroelectricity is an important component of Costa Rica's energy production system. Generating over 80% of the nation's energy, hydroelectric plants provide multiple benefits to Costa Rica, including renewable energy, environmental friendliness and cost efficiency. However, recent concerns of small companies dumping unwanted waste into rivers have posed a huge problem to the industry. Due to the clogging of hydroelectric turbines, hydropower corporations produce a lower energy yield and must budget a higher cost for dam maintenance. To discourage illegal dumping, we needed to evaluate the importance of hydroelectricity in Costa Rica and the efficiency of the country's waste management system.

This section discusses:

- The advantages of hydroelectric power;
- The consequences of illegal dumping in relation to the clogging of hydroelectric facilities;
- The current waste management system globally and within Costa Rica; and,
- A description of the Rio Uruca and its surrounding territory.

2.1 Benefits of Hydroelectric Power

Hydroelectric power remains one of the most viable alternatives to fossil fuels in the world today. Fossil fuels, including coal, oil and natural gas, constitute over 60% of the world's energy sources, as seen in Figure 3. Alternatively, approximately 15% of the world's power was generated by hydroelectricity in 1997. The "other" category includes biofuel and geothermal energy generation.

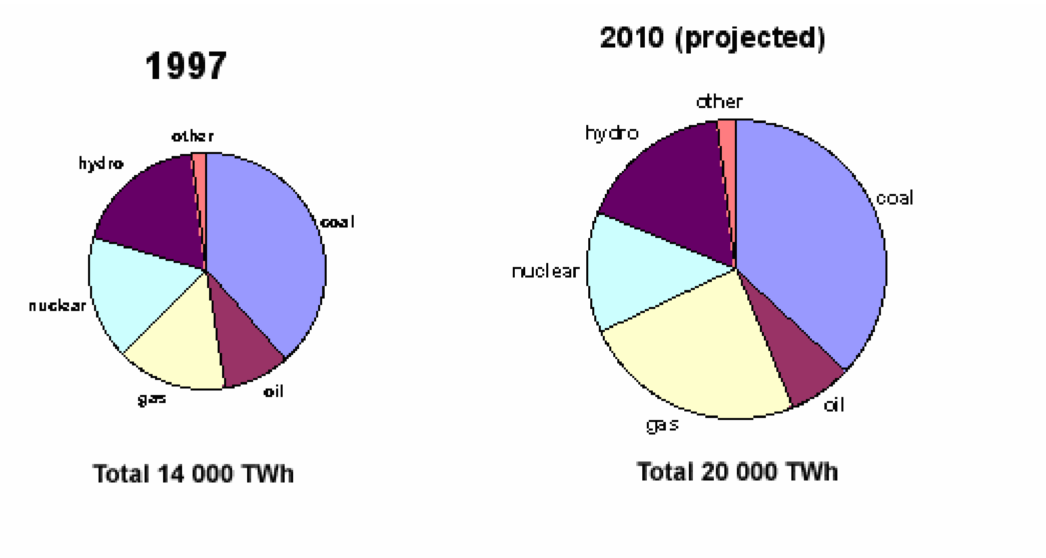


Figure 3: World Electricity Generation in 1997 and 2010 (projected)

Source: http://www.world-nuclear.org/info/inf16.htm

Throughout the many years of using fossil fuels as a primary source of energy, scientists have consistently stated that alternate sources of energy are more sustainable than those currently in use (Fossil Fuel Production and Consumption, 1999). According to many scientists, fossil fuels will run out relatively soon at the current rate of consumption (Fossil Fuel Production and Consumption). In fact, if all of the developing countries were to consume energy at the same rate as the United States, and if the U.S. rate of consumption doubled, then the Earth's fossil fuels would provide the world with energy for only seventeen more years (Fossil Fuel Production and Consumption). However, even if every country were to maintain a constant fossil fuel consumption rate, the Earth will exhaust its resources in about 50 to 70 years (Fossil Fuel Production and Consumption). If the world continues to depend heavily on fossil fuels, a sudden crash in the global economy may occur as the fossil fuels begin to run out (Kasting, 1998).

Since fossil fuels are consumed during energy production, they are considered non-renewable sources of energy. However, wind, solar and hydroelectric power are all examples of renewable sources of energy. In fact, hydroelectric dams have gained popularity in recent years and now represent approximately 20% of the world's total electricity, a 5% increase from 1997 (Coutant & Sale, 2006). Due to its low cost and global environmental appeal, hydropower has become a feasible option for energy generation. The operation and maintenance of a hydroelectric plant costs 0.6 cents per kilowatt-hour (kWh), while nuclear and coal plants cost 2.2 cents/kWh and 2.1 cents/kWh, respectively (Coutant & Sale, 2006). Also, hydroelectricity does not generate as many of the adverse environmental effects that many other forms of energy do, such as the production of various green house gases. The cost savings that hydroelectric plants can offer entice many energy-producing agencies with their affordability.

Currently, Costa Rica is one of the leading countries in the construction and use of hydroelectric dams in the world. In 1999, 72% of Costa Rica's energy came from hydroelectric sources. Since then, with the completion of several new hydroelectric dams, this percentage has increased to approximately 81%, as seen in Figure 2 (Hydropower, n.d.). In fact, 75.2% of this energy stems from the hydroelectric plant located at Arenal (Dutschke, 2005). Figure 4 illustrates a breakdown of the types and amounts of generated electricity in Costa Rica.

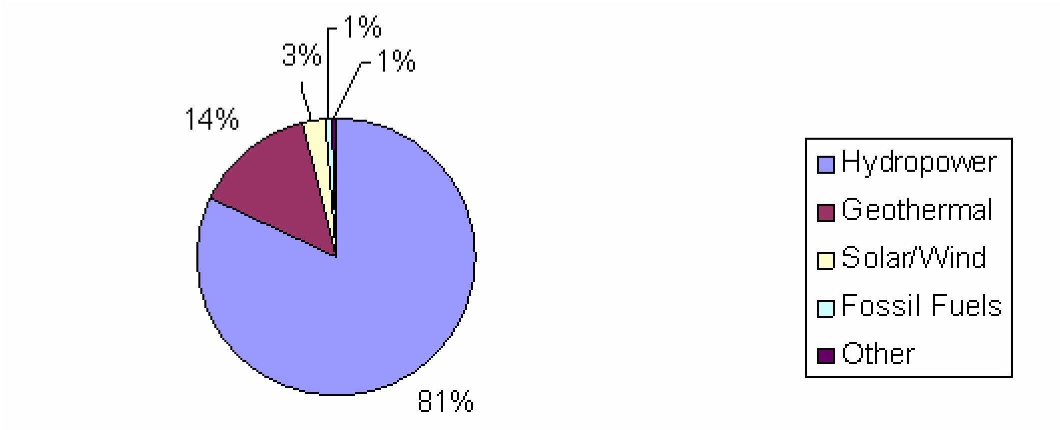


Figure 4: Current Electricity Generation in Costa Rica

Despite the country's emphasis on hydroelectric power, Costa Rica currently utilizes only an estimated 15% of its total hydroelectric potential (Hydropower, n.d.). In the future, Costa Rica can continue to expand upon their current hydropower facilities to meet increased energy demands. Furthermore, strategies to help keep the turbines clear of debris are continually being developed in Costa Rica.

2.1.1 Mechanics of a Hydroelectric Dam

The main principle behind a dam is that gravity will make water flow downriver. As water approaches a dam, it is channeled through turbines which spin as the water passes through. These turbines then move a magnet inside of a copper coil, thus producing electricity. This electricity is oftentimes stored in a powerhouse to be later tapped by the company (Hydroelectric Power: How It Works, 2005).

The most common type of hydroelectric dam in the world is an impoundment facility, seen in Figure 5. In this system, a reservoir is created by building the dam to create a higher water pressure. A gate then allows water to flow through, channeling it into the turbine via the penstock. The gate can then be adjusted to increase or decrease the water flow through the dam in accordance with changing energy demands, or to simply keep the water level of the reservoir above the minimum height necessary to maintain proper water pressure. (Types of Hydropower Plants, 2005).

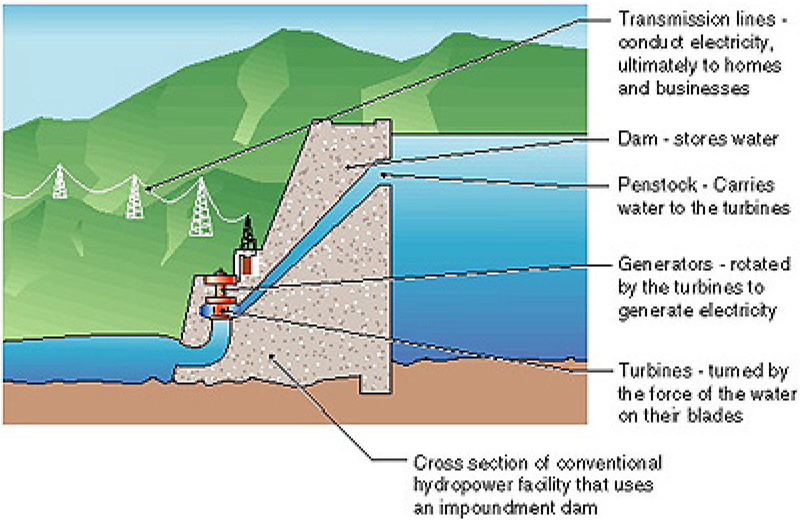


Figure 5: Impoundment Hydroelectric Dam Model

Source: http://eereweb.ee.doe.gov/windandhydro/images/illust_howworks.jpg

Another common way to create hydroelectric power is to simply use the river's natural course via a diversion dam. In this method, rather than building a dam to create water pressure, the system relies upon the river's natural flow to create sufficient pressure to rotate the turbine. The turbine is typically placed outside the natural course of the river, and water is diverted into it. After rotating the turbine, the water can flow back into the river (Hydroelectric Power in California, 2001). This system generally does not yield as much electricity as an impoundment facility since the water pressure is lower and the turbines do not turn as fast.

One feature that can enhance any type of hydroelectric dam, but especially in an impoundment dam setup, is an added pump. This pump uses electricity from the dam during off-peak hours to pump the water back upstream. This process occurs mostly in the impoundment facilities, where the pump refills the reservoir. In this manner, the dam increases the water pressure, and consequently boosts electricity production (Bonsor, n.d.).

Although the techniques of creating water pressure differ among hydroelectric facilities, the basic mechanism remains the same. The penstock, a highly pressurized tube, transports water from either the river or reservoir into the turbine. Once the pressurized water reaches the turbine blades, the blades begin to revolve, as seen in Figure 6. This motion rotates the turbine generator shaft, causing the powerful electromagnet, known as the rotor, to spin inside of a tightly wound copper coil, also called the stator, creating an alternating current. This current is then sent to the powerhouse, where it is amplified and distributed along the power lines (Generators and Exciters, n.d.).

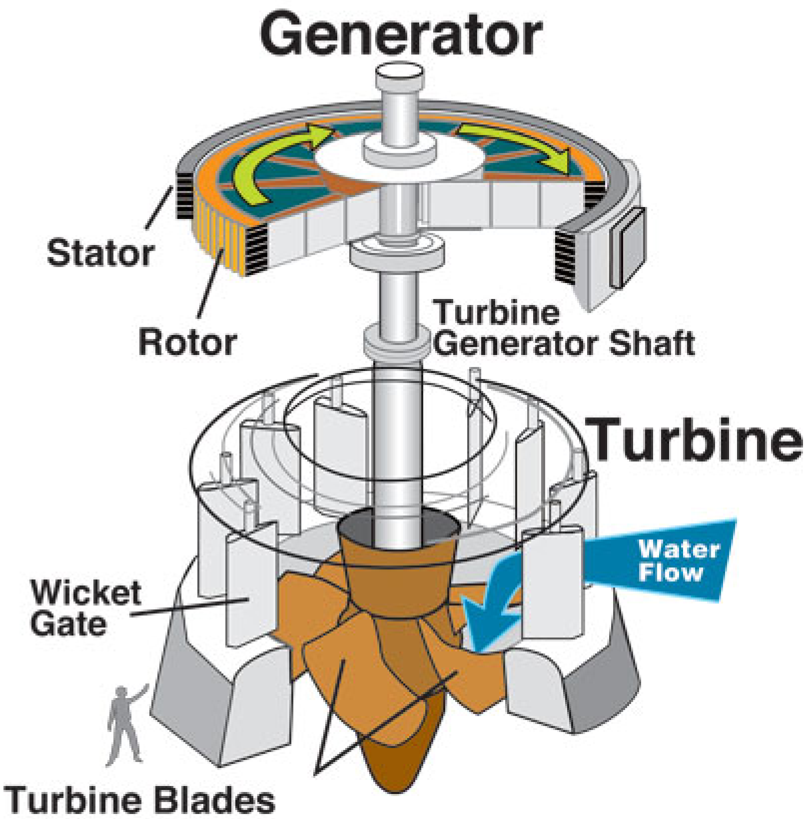


Figure 6: A Hydroelectric Generator

Source: https://www.nwp.usace.army.mil/HDC/edu_genexcit.asp

2.2 How Debris Affects Hydroelectric Dams

As established earlier, hydroelectric dams rely on the water pressure to ensure continuous spinning at a desired rate. Anything that obstructs or restricts this flow decreases the amount of energy produced and removing the debris may require draining the impoundment dam, which necessarily reduces the amount of electricity that may be produced in a given period. Removing the debris may also entail substantial costs.

Many different techniques for dealing with debris clogging the hydroelectric dams currently exist, one of which is a trash rack. These devices prohibit debris, both floating and submerged, from entering a dam and damaging its turbine machinery (Arndt, 1991, p. 10.28). Unfortunately, the build-up of debris impedes the flow of water and requires the regular cleaning of dams. Several methods have been engineered to deal with this problem, including log booms to collect floating trash, heated grates to melt ice, raking by hand, and mechanical rakes (Arndt, 1991, p. 10.28-10.29).

In the Public Meeting on Debris Management in the Susquehanna River Watershed, Marshall Kaiser, a member of the Safe Harbor Water Power Corporation, noted that the company spent approximately $130,000 to remove 9,000 cubic yards of debris from the dam in 1999 (Public Meeting Minutes: Debris Management in the Susquehanna River Watershed, Personal Communication, March, 2006). If a technique to prevent the debris from ever entering the river could be developed, those companies responsible for the maintenance of the dams would enjoy huge savings (Public Meeting Minutes: Debris Management in the Susquehanna River Watershed, Personal Communication).

Since these dams collect trash, companies must also find a location to dump it. Some hydroelectric facilities merely move the debris into a side channel to flow back into the river further downstream. The Environmental Protection Agency (EPA) put a stop to this practice in the U.S. because the dams had become a point source for pollution by dumping the dam’s collected debris further downstream (Arndt, 1991, p. 10.29). Rather than allowing the man-made debris to re-enter the river, dams must dispose of waste properly in an attempt to clean the river downstream. However, natural debris should be released back into the river because of its ecological importance. It has been found that disintegrating wood located on the floor of rivers serves as one of the main sources of organic carbon in the ocean, providing vital resource for the aquatic ecosystems (Bates, et. al, 2004).

2.2.1 Types of Debris

Debris may be divided into two categories: natural and man-made. Different techniques have been developed to deal with the different sized debris and man-made and natural debris, both of which must be disposed of differently

Since it is difficult to prevent natural debris from entering the river basin and making its way down stream, it is generally dealt with after it accumulates in the impoundment dam. Natural debris typically includes limbs from trees, sediment from run off, and ice flow. Smaller debris, such as sediment or silt, can be captured in a silt tank. This tank needs to be emptied frequently, especially after a heavy rain. Construction, deforestation, and other changes in agricultural practices may lead to increased sediment loads (Harvey 327). Small man-made debris will also be captured in sediment tanks, which complicates the task of disposal when the tanks are emptied.

Larger debris, whether man-made or natural, is captured in a trash rack. Hydroelectric dams in cold areas often have problems with ice flow blocking the dam and decreasing the amount of water that can enter the penstock. To help solve this problem, a heated trash rack may be installed. In this instance, as the ice accumulates, it slowly melts and allows the water to proceed through the turbine. However, other objects, such as tree limbs or larger man-made debris, cannot be dealt with as easily. Instead, this debris gets caught by the trash rack and then must be cleared out of the way of the dam. Several methods have been engineered to deal with this problem, including log booms to collect floating trash, mechanical rakes and raking by hand (Arndt, 1991, p. 10.28-10.29). The latter method is the most expensive technique, while the former method remains relatively expensive as well, as the technology has not yet been perfected.

Despite the different methods that are used to help manage debris, the river can not always be tamed. For example, regarding debris management in the Susquehanna River Watershed, John McSparran states that during high flow situations, such as heavy rainfall or floods, it is nearly impossible to capture all of the debris as it flows downstream. He continues to state that due to the increased flow of water, it is impossible to both capture the debris and clear it fast enough to keep the dam functioning. Instead, it usually passes through the flood gates and travels over the dam (Public Meeting Minutes: Debris Management in the Susquehanna River Watershed, Personal Communication, March, 2006).

Since a portion of the debris blocking hydroelectric dams is man-made, an important step in dealing with this type of debris is by eliminating it at its source of entry. To better understand the origins of river debris, we must analyze current waste management strategies to evaluate their effectiveness.

2.3 Solid Waste Management

Waste management has become a growing concern throughout the world, and various methods for disposing of solid waste have evolved over time. According to Clayton and Huie (1973), solid waste is classified as "nongaseous and nonliquid wastes that result from the daily activities of a community's residential, commercial and industrial sectors." Solid waste management systems focus on three aspects of management: generation, collection and disposal (Powell, 1996). A number of methods for solid waste management exist, such as composting, recycling, incineration and land filling. To alleviate illegal dumping and persuade the public to participate in proper waste management practices, a community's sustainable solid waste program must be cheap, effective and efficient.

2.3.1 Waste Generation

To promote effective solid waste management, the amount of generated waste must be reduced and controlled (Curi & Or, 1993). Consequently, the importance of recycling and reduction has grown. Some reduction techniques include minimizing the amount of packaging for goods and a general conservation of materials. Due to the high expenses of waste removal and decrease in available landfills, many communities have opted for waste reduction and reuse instead of landfill usage and open dumping (Noehammer & Byer, 1997).

A place to begin is with the reduction of household waste. Through increased regulation and economic instruments, municipalities can influence the amount of waste generated by households. A case study by Cuthbert (1994) evaluated a direct connection between the cost of waste removal and the amount of household generated waste. With an increased fee for waste disposal, the amount of generated waste decreased while waste reduction efforts increased (Adamowicz, Luckert & Salkie, 2001). This strategy may help to motivate residents in a community to use cleaner alternatives and reduce their waste.

One excellent method of waste reduction is recycling because of its environmental benefits (Ackerman, 1997). Generated waste can be remodeled and converted into new products, thereby diverting refuse away from incinerators, landfills and both legal and illegal dumping sites. According to the Institute for Local Self Reliance (1997), recycling is a cost-effective means of solving the waste management predicament in communities by "reducing energy consumption and water pollution." Recycling offers many benefits to society because objects such as plastics, glass, paper and metals can be reused and regenerated into secondary materials (EPA, 2004). By promoting awareness about the environmental and energy-related benefits of recycling, community involvement in recycling programs can significantly advance. In fact, Figure 7 illustrates how participation in recycling within the U.S. has dramatically increased throughout the 20th century.

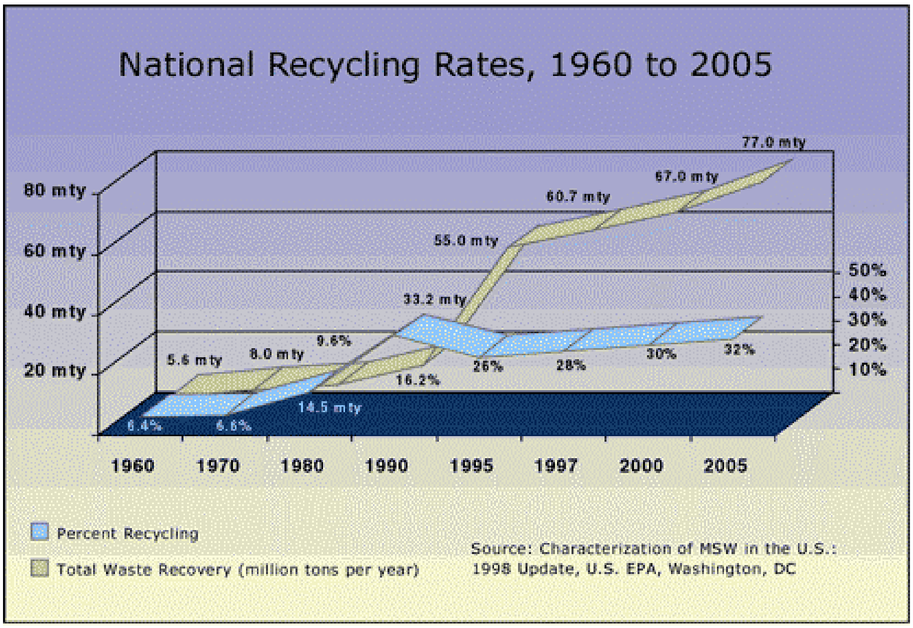


Figure 7: Trends in U.S. Recycling Rates in the 20th Century

Source: http://www.zerowasteamerica.org

The establishment of a municipal recycling program requires community involvement and financial support (Noehammer & Byer, 1997). By evaluating the characteristics and goals of the community, municipalities should be prepared to address any unanticipated problems within the development of the program (Noehammer & Byer). To improve a recycling program, municipalities should promote its awareness through educational means, foster community involvement via financial incentives and enhance legislation and convenience (Evertt & Pierce, 1997).

2.3.2 Collection Services

The next step in the solid waste management process is collection and transportation (Curti & Or, 1993). Three important components of waste collection systems include frequency of collection, location of collection and the method of transportation used. Due to the uniqueness of every community, waste collection is designed for the specific community in accordance with its fiscal capabilities and population density (Korfmacher, 1997).

Korfmacher (1997) describes two types of waste collection methods: House to house collection and site collection. In urban areas, house to house collection consists of a truck that collects and compacts waste from every house on a regular basis. Within poorer cities and towns, trash collectors use pickup trucks or other methods to collect waste. For communities that use site collection, residents must bring their waste to a specific area which will then be transported to a disposal plant. An effective waste collection system is vital because it promotes quality living conditions and a healthy environment.

U.S. solid waste collection practices have remained relatively consistent over the recent decades (Savas, 1977). In fact, almost 60 percent of cities and town with 5,000-10,000 residents conduct garbage collection weekly at homes (Savas, 1977). However, by making improvements to a municipality's collection system, the community can save a significant amount of money (EPA, 2004) In fact, the EPA reported that on average, 50% of a community's waste management budget is devoted to collection costs (EPA). By reducing the frequency of waste collection pickups, increasing the amount of automated waste collection vehicles and improving employee productivity, communities can adopt strategies for a more cost-efficient collection system.

2.3.3 Waste Disposal Methods

The final step in solid waste management is the use of waste disposal methods (Curti & Or, 1993). Various techniques including land filling, incineration and composting can be used to deter the public away from open dumping. In 1989, the U.S. EPA developed a list of the best methods of solid waste disposal, such as recycling, municipality-run composting, incineration with the recovery of energy and sanitary landfills.

The most widely used waste disposal system is landfills, in which waste can be deposited and stored in the earth. Landfills are intended to protect the environment from pollutants in solid waste through a layer of clay and synthetic covers (EPA, 2004). A layer of compacted clay soil is covered with a composite liner to prevent water leaks. By protecting the environment from contamination of landfill waste, municipalities can concentrate their refuse in a well-protected, designated area.

Many factors influence the creation of new landfills, such as increasing populations, trends of urbanization and limited land resources (Charnpratheep, Zhou, Garner, 1997). Since landfills may not be located in environmentally sensitive zones, many communities are faced with a difficult task when planning to establish a new landfill site (Charnpratheep, Zhou, Garner, 1997). To reduce the construction and maintenance costs of landfills, officials suggest creating landfill sites near roads (Charnpratheep, Zhou, Garner, 1997). However, due to strict EPA regulations and environmental concerns, landfills are no longer the most sought-after method of waste disposal.

Incineration is a practical alternative to land filling in today's society because it reduces the volume of waste while generating energy through combustion (Lu, 1996). According to Lu (1996), incinerators produce electricity by generating heat energy while burning waste. After incineration, the residue of burnt waste is deposited into landfills, allowing the landfills to have a prolonged lifetime due to the reduction of waste mass and volume (Lu, 1996). Fiorucci *et al.* (2003) noted that a similar process, called Refuse-Derived Fuel (RDF), allows industries to burn used materials, generating combustibles that can serve as fuel for industries.

Unfortunately, incinerators often contribute to air pollution and may cause potential health problems (Denison and Ruston, 1990). In response, the EPA has instituted a series of regulations and requirements to inspect industrial incinerators constructed before 1999. For example, facilities must accept only materials that do not produce carcinogenic fumes when burned (Denison and Ruston, 1990). Additionally, the EPA requires continuous monitoring of the smoke stacks by the incinerator operators to ensure proper adherence to combustion and pollution control laws.

2.3.4 Waste Management in the United States

According to the EPA, one of the best ways to dispose of solid waste is through reduction (1989). By decreasing the amount of generated waste and promoting recycling programs, cities and towns can find alternative means of waste disposal other than landfills (Noehammer & Byer, 1997). In 2003, the EPA reported that the U.S. has decreased the amount of landfills by 75.8% from 1990-2001 by eliminating over 6,000 landfills. In fact, the amount of land filled solid waste has decreased by 12.4 million tons, an 8.9% decline over the same time period. By emphasizing improved methods for waste management, such as recycling programs and waste reduction, alternatives to open dumping can be promoted.

Throughout the past century, the U.S. has significantly decreased the amount of solid waste through the implementation of recycling programs. According to Figure 8, the percentage of recycled waste in the U.S. has progressively increased while the percentage of waste disposed of in landfills has decreased.

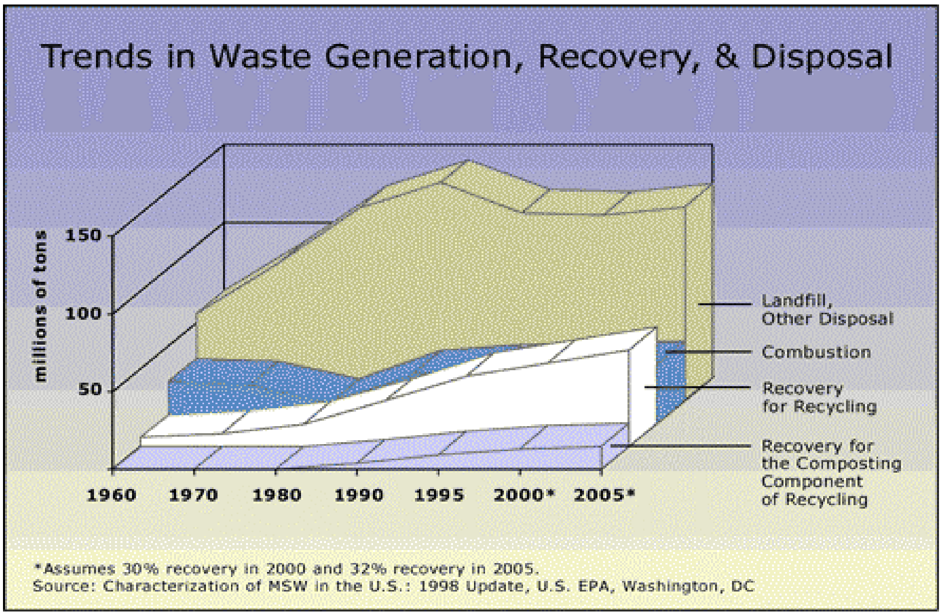


Figure 8: Waste Trends in the U. S. Since 1960

Source: http://www.zerowasteamerica.org

The EPA (2004) confirms that the amount of waste recovered by recycling programs has doubled from 34 million tons in 1990 to 68 million tons in 2001. Additionally, the amount of overall generated waste per capita in the U.S. has risen from 2.7 to 4.4 pounds per person per day since 1960 (EPA). Figure 9 displays a breakdown of the types of solid waste generated within the United States in 2001.

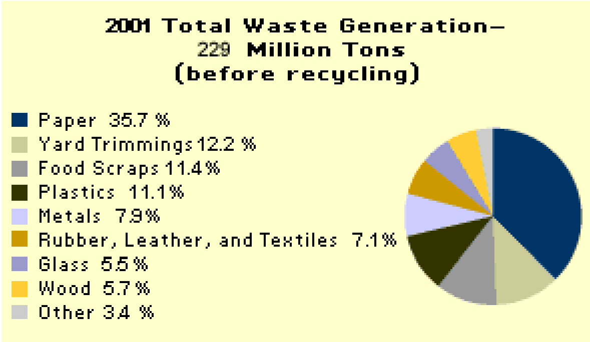


Figure 9: Total Waste Generation in the U. S. in 2001

Source: http://www.epa.gov/epaoswer/non-hw/muncpl/facts-text.htm#chart1

Waste generation is clearly an environmental concern across the globe. The following section analyzes various waste management practices within Costa Rica.

2.3.5 Waste Management in Costa Rica

Holl, Daily and Ehrlich (1995) analyzed the current perceptions of environmental concerns within Costa Rica by interviewing men and women from different neighborhoods and socioeconomic backgrounds. One of their surveys inquired about what pertinent environmental issues need to be addressed both nationally and globally. Figure 10 illustrates the results of this survey, showing that many citizens believe that air and water pollution, deforestation and garbage are of top priority.

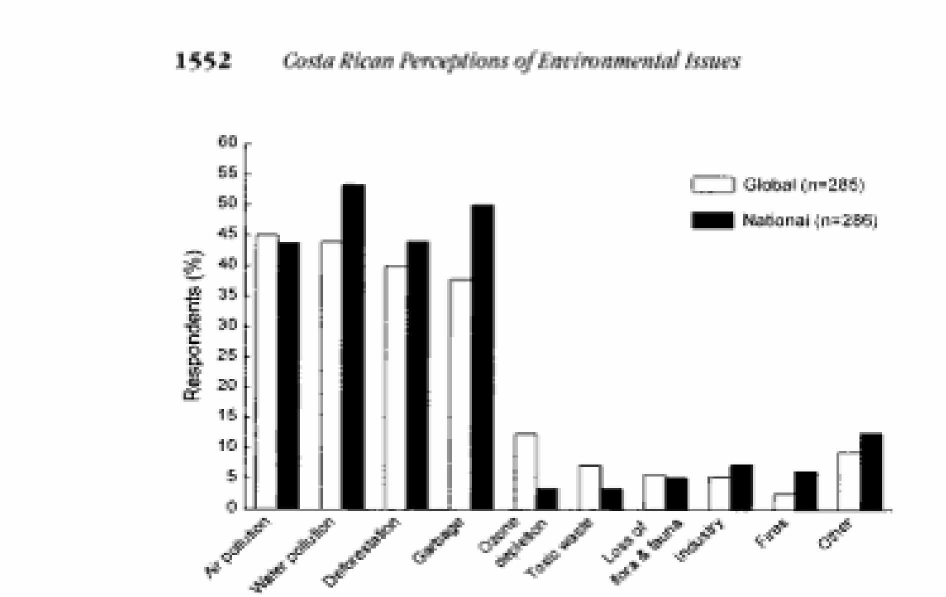


Figure 10: Environmental Perceptions Chart

Source: Holl, Daily, and Ehrlich (1995)

As observed in Figure 10, Costa Ricans believe that garbage is a national concern that should be addressed. To better understand these concerns, an analysis of current waste management strategies in Costa Rican communities follows.

2.3.5.1 Nosara

Nosara, a beachside community on the Northwest Pacific Coast of Costa Rica, rests at the mouth of the Nosara River in a verdant valley (Arnulfo, 2005). The Micro Empresa para el Saneamiento Ambiental de Nosara coordinates the city's garbage collection and recycling program, which operates every Monday and Thursday with certain regulations (Arnulfo, 2005).

Before garbage collection, residents must separate their trash and recyclables into different bins based on their composition (e.g. glass, aluminum, metal, etc.). Nosara ships many of these recyclable items to different areas of the region where they have a higher value. For example, the Nosara sanitation officials send glass to San José, iron to Nicaragua and batteries to Nicoya. Specifically in San José, glass is worth ¢ 1 per kg, batteries are worth ¢ 200 per kg and metals are worth ¢ 500 per kilogram. To help finance the trash collection program, every resident pays a monthly fee of ¢1,000, or $2.20, on the last Sunday of every month. In the town of Nosara and its immediate surroundings, officials collect payments door-to-door; however, residents in outlying suburbs pay these bills at the Super Nosara grocery downtown (Arnulfo, 2005).

2.3.5.2 San José

Currently in San José, the Urban Planning Section and the Environment Sanitation Department handles waste disposal for residential, commercial and industrial communities (Guide for Economic Sustainability and Quality Life of San José, 2003). Every day, 1400 tons of wastes are produced in the San José metropolitan area, of which over 60% ends up in landfills. Additionally, approximately 60% of all residential solid waste originates from food, but composting programs have not gained widespread popularity. Forty seven percent of Costa Rican municipalities dispose of solid wastes in landfills (Costa Rica, n.d.); three common sanitary deposits in the country include Rio Azul, La Carpio and Los Mangos (Guide for Economic Sustainability and Quality Life of San José, 2003). Also, different companies such as INCSA, CEMPASA and

VICESA use incinerators to convert solid waste into energy (Guide for Economic Sustainability and Quality Life of San José, 2003). To ensure that companies cooperate with necessary environmental policies and waste management practices, the Costa Rican Ministry of Environment and Energy (MINAE) has made efforts to educate the community on current environmental legislation.

2.3.5.3 Escazú

Escazú, a canton of San José, is located in the northern section of the province. In 2002, Escazú's 54,000 residents produced 12,700 tons of waste which cost over 213,610,046 colones ($546,317) to collect and dispose of (Levesque et. al. 2003). Through biweekly curbside collection, Escazú accepts both trash and recyclables.

For trash disposal, the Escazú Department of Public Works uses six garbage trucks, five for waste and one for recyclables. In 2003, Escazú employed nineteen workers who follow predetermined waste collection routes and deliver all waste to the Río Azul landfill, which costs the company 3,400 colones, or $8.70 per ton. A recycling collection service is also available to residents of Escazú one day per week. The collection agency accepts paper, plastic, glass and more and delivers these items to a recycling facility for further processing.

2.3.5.4 Santa Ana

Santa Ana, the community of particular interest for this project, is located directly west of the canton of Escazú with a population of 39,476 (Levesque *et al*. 2003). Specific areas of economic production in Santa Ana include farming, the food and industry and structural product manufacturing. In 2002, the municipality produced 10,000 tons of waste, costing 168, 545,698 colones ($431,063) for removal and disposal. However, Santa Ana experienced a 31% shortage in removal costs, obtaining only 117,000,000 colones ($299,233) from the community. The municipality is currently investigating means of improving this deficit via increased costs.

Santa Ana utilizes curbside waste pickup funded by its residents, for which every household pays 1,200 colones ($3.10) monthly. The city utilizes three trucks for garbage collection and one for recyclables, each of which follows a specific route. Fourteen employees operate the waste system biweekly, and they deliver the collected waste daily to a landfill in Alajuela costing 4,600 colones ($11.36) per ton. Two employees are in charge of the recyclable items, which are delivered to Santa Ana's own recycling center.

2.4 The Uruca River

The Uruca River, which runs through Santa Ana, is located within the Rio Grande de Tárcoles as seen in Figure 11.

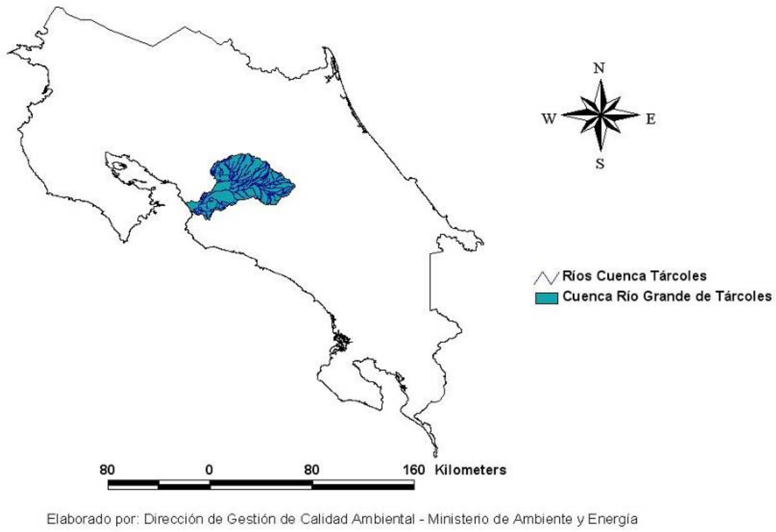


Figure 11: The Rio Grande de Tárcoles in Costa Rica

Source: Microcuenca del Río Uruca: Breve Descripción Geográfica y Biofísica (n.d). Personal Communication, April 19, 2006.

The Tárcoles river basin flows from the central area of the country to the Pacific coast, comprising 4.1% of the nation's territory. Approximately 111 km long, the fluvial system comprises three sub-basins (Figure 12): the Virilla River Basin, the Grande River Basin and the Tárcoles River Basin. The Virilla Basin is located in the high watershed, occupying 83% of the total river area; the Grande River Basin and the Tárcoles River Basin occupy 34% and 23% of the total river area, respectively.

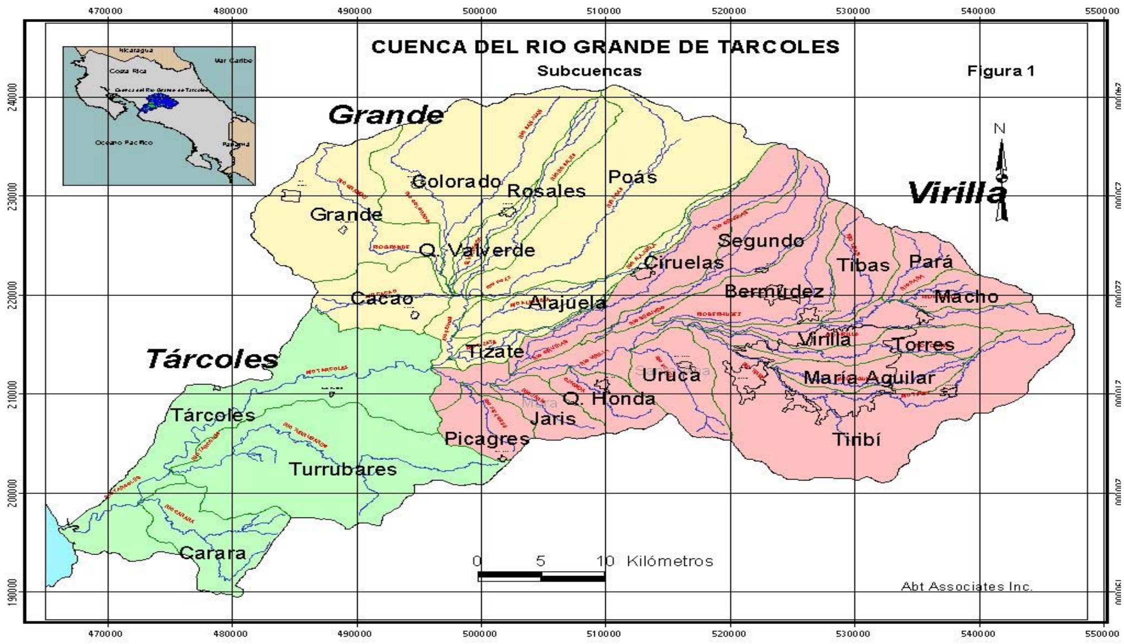


Figure 12: The Three Sub-Basins of the Rio Grande de Tárcoles

Source: ***Microcuenca del Río Uruca: Breve Descripción Geográfica y Biofísica*** **(n.d). Personal Communication, April 19, 2006.**

Our project took place within along the Rio Uruca within Santa Ana, the mid-section of the basin. The territory nearby the Uruca River fosters coffee, sugar, fruit, vegetables, plant and cattle ranches. Figure 13 depicts the location of the Uruca River within the basin, which spans an area of 55.32 sq. km. The Uruca River is one of ten tributaries within the basin.

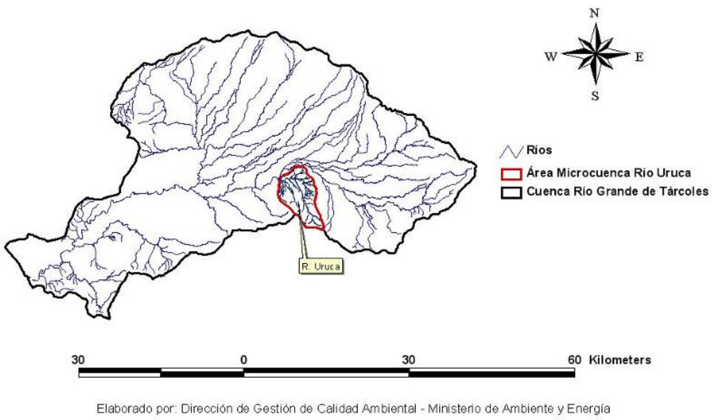


Figure 13: The Uruca River in the Tárcoles River Basin

Source: Microcuenca del Río Uruca: Breve Descripción Geográfica y Biofísica (n.d). Personal Communication, April 19, 2006.

3 Methodology

The goal of this project was to help MINAE identify potential improvements in the waste management practices of small businesses as a means to reduce the amount of debris and solid wastes that enter into streams and rivers and ultimately clog essential hydroelectric turbines. By evaluating the current waste management practices of these firms, we identified the issues of concern and generated potential solutions. Also, by creating a set of suggestions for improved waste management, we encouraged small businesses to implement more environmentally-friendly practices while promoting proper waste disposal and discouraging illegal dumping in rivers. MINAE can then incorporate these strategies within different areas of San José, and ultimately throughout Costa Rica.

This project had four objectives. We:

- Determined the economic activity, distribution and location of businesses along the Uruca River in Santa Ana within an area of less than two square miles; and,
- Developed a protocol for MINAE to obtain information from these businesses about their industrial practices; and
- Produced a prediction based model for MINAE to estimate the type and quantity of waste generated by any industry; and
- Established a method to promote cleaner production within one type of industry.

We utilized the following methods to enhance our data collection:

- We conducted field research using a GPS to track the name and location of businesses parallel to the river in Santa Ana.
- We investigated various International Standard of Industrial Classification (ISIC) codes to attain information about the manufacturing processes of different industries.
- We evaluated existing waste management practices against the ideal practices and the needs of small businesses to identify possible improvements in the waste management system.
- We created a brochure containing pertinent information about recycling and proper waste disposal techniques for a selected business.

By collecting and synthesizing these data, we identified realistic and efficient suggestions for improvements to the waste management practices of various firms along the Uruca River. The timeline for this project can be found in Appendix B.

3.1 Field Research

Throughout this project, assorted methods of field research were conducted to collect information about Santa Ana's industrial sector and its impact on the environment. To obtain this information, we performed an observational study of the local businesses with a GPS unit, visited a local hydroelectric facility and interviewed specific industries in the canton. This fieldwork served as the basis for developing an online protocol and for creating suggestions for cleaner production in companies.

3.1.1 Observational Study with a Global Positioning System (GPS)

One component of our field research consisted of identifying the location and type of economic activity of the businesses found along the Uruca River in Santa Ana. This data allowed MINAE to monitor the industrial presence in Santa Ana and to determine which businesses may be contributing to illegal dumping. To accomplish this goal, we walked along the road parallel to the Uruca River and marked the location of every business located along the road. Table 1 exhibits the form we used during data collection.

Microcuenca del Río Uruca
Levantamiento de información en campo

Nombre del ente generador / Name of the company	Descripción de la actividad / Description of the activity	Longitud	Latitud	Número de empleados / Number of employees

Table 1: Field Work Collection Sheet for Observational Business Study

We collected information about the name, type of economic activity and number of employees of each business. Also, a GPS unit allowed us to determine the approximate longitude and latitude coordinates of the businesses to develop a map of the area. MINAE's map of businesses prior to our research is displayed in Figure 14.

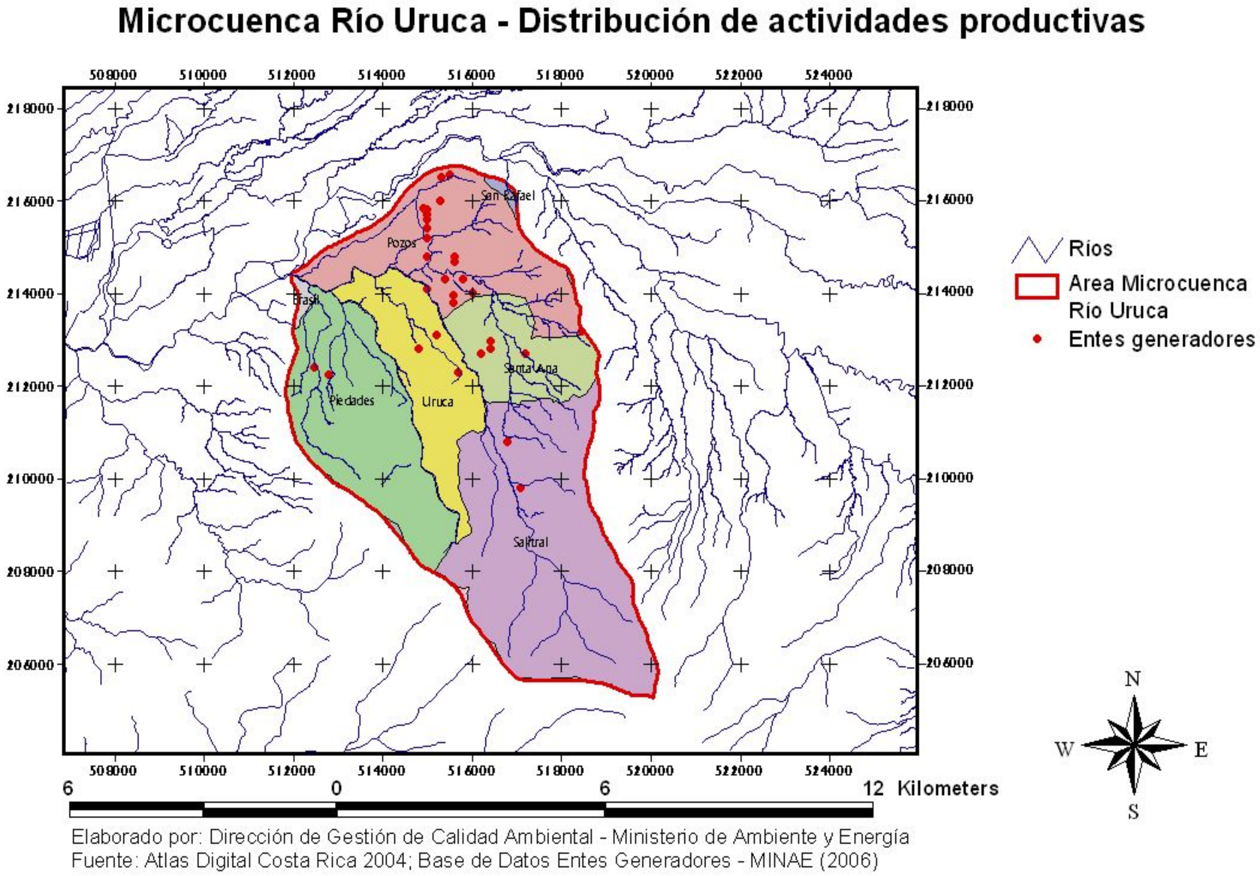


Figure 14: Map of Data Points in the Uruca River Prior to our Field Research

The red dots indicate businesses from which MINAE had already obtained information by conducting visits to the industries. Through our study, we determined the location of the remaining businesses along the Uruca River and updated the database.

To gain an understanding of the environmental impact of these businesses, we visited the Brasil Hydroelectric Facility in the canton of Mora. As seen in Figure 15, which displays all of the cantons of the San José province, Mora is located immediately west of Santa Ana.

Figure 15: Location of the Cantons of the San José Province

Source: http://www.1-costaricalink.com/costa_rica_provinces/san_jose_costa_rica/santa_ana_costa_rica.htm

3.1.2 Visit to the Brasil Hydroelectric Facility

To enhance our knowledge of the severity of illegal dumping in the Uruca River, we visited a hydroelectric dam facility and interviewed members of the Compañía Nacional de Fuerza y Luz (CNFL) who worked there. We asked pertinent questions about the budget for dam maintenance, the amount of daily waste accumulation and their methods for waste removal. We also documented our findings with a digital camera to aid in interpreting our results. By obtaining statistics about the cost and frequency of cleaning the dams, we intended to motivate companies to practice proper waste management and reduce illegal dumping.

3.1.3 Visit to Industries in Santa Ana

The final aspect of our field research was to visit businesses in Santa Ana to gather information about their raw materials, manufacturing process, and generated waste materials. After receiving a tour of the facilities, particularly of their waste management departments, we interviewed the business personnel to obtain specific information about the destination of their waste. This data was later used to finalize our methodology developed for MINAE to estimate the type and amount of waste generated by industries, as described in Section 3.2.4.

3.2 Development of a Protocol

For MINAE to monitor the economic activities and waste materials generated by different industries, we developed an evaluation form to be distributed to businesses. The most appropriate method for collecting this type of information is similar to a self audit. A self audit encourages companies to evaluate their existing practices within the industry in hope of making improvements. To accomplish this objective, we researched various environmental audits currently in use by different global organizations.

3.2.1 Research about Environmental Audits

By analyzing the overall format of a self audit, we determined a method for companies in Costa Rica to accurately and efficiently report their economic activities to MINAE. We also investigated possible incentives to entice companies to participate in an environmental self-auditing program. By promoting the importance of environmentally friendly and cost-efficient manufacturing, we intended to persuade businesses to become involved in cleaner production. After investigating various incentive programs, we proposed an appropriate system to MINAE. Before developing our protocol, a thorough understanding of the International Standard of Industrial Classification (ISIC) codes was necessary.

3.2.2 Investigation of International Standard of Industrial Classification (ISIC) Codes

The main technique that we utilized to help classify the industries within Santa Ana was by researching ISIC codes. These codes, developed by the United Nations Statistics Division, categorize businesses based on the type of materials they manufacture, process or sell within their facility. As a result, we conducted industry-specific research to determine the types of raw materials, the manufacturing process and the waste materials generated by specific types of businesses. A basic formula of this process is exhibited in Figure 16.

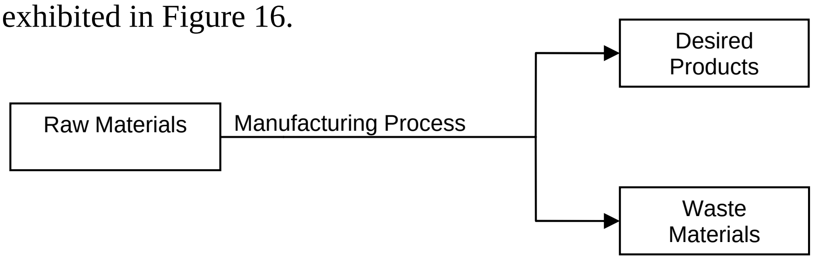


Figure 16: Illustration of Manufacturing Process

Raw materials are the resources that industries start with and modify to create the final product. The manufacturing process illustrates the detailed steps each company employs to transform the raw materials into products. Lastly, the waste materials generated by an industry are any unwanted materials left over after the manufacturing process is complete. By gaining an understanding of this process for different businesses, we were able to develop an efficient protocol applicable to any type of industry. Our research also allowed us to develop pertinent questions for businesses regarding their current techniques of waste disposal.

The online protocol should ultimately enhance communication between Costa Rican businesses and MINAE. If businesses can access this protocol online and report their statistics on a regular basis, MINAE can stay updated on the economic activity of these companies. Since an online-administered questionnaire may not be accessible for all businesses, we also investigated the possibility of distributing a physical copy of this protocol to the companies.

3.2.3 Formulation of a Protocol

To create the checklist, we began with a basic evaluation questionnaire that MINAE has previously employed to collect data from businesses during interviews. Minor additions and expansions were made to include all desired information by MINAE about the businesses.

The next step in implementing this protocol was to create an interactive PDF, so that companies with internet access could download it and submit it to MINAE. For those companies without internet access, the representatives could obtain a hard copy, fill out the form by hand and mail it back to MINAE. Lastly, we created an operating manual containing detailed instructions about how to implement and expand this protocol.

3.3 Formulation of a Waste Estimation Model

Another tenet of our project focused on developing a simple, accurate and easy to use waste estimation model to predict the type and amount of waste generated by a business. To develop our waste estimation model, we researched the Industrial Pollution Projection System (IPPS), a thorough system designed to estimate the amount of waste produced by companies. This method compiles information about the number of employees, the toxicity of any chemicals used, the size of the industry and the amount of profit that the industry earns. By synthesizing all of this information, the IPPS allows a basic estimation for industrial waste to be calculated. We designed a model that produced the same information, but using a different technique.

To create our model, we brainstormed different ways for MINAE to obtain any necessary information to make an accurate waste estimation. From these ideas, we chose one that seemed to be the most realistic while maintaining simplicity: total waste generated per number of employees. Many factors contributed to this selection, including the availability of data, the ease of calculation and its applicability to any type of industry.

During our research, we found a study completed in 1990 with a goal very similar to ours: to develop a methodology to estimate the type and quantity of hazardous waste generated by industries in Naples, Italy (Barnard and Olivetti, 1990). An analysis of this study can be found in Section 4.4.1. This study, entitled *Limiting Environmental Impact by Waste Management*, concluded that basing a waste estimation model upon the number of employees at a business is one of the easiest and most cost efficient methods, especially for developing countries (Barnard and Olivetti). To produce an estimation, MINAE does not need extensive information about a company, only their total generated waste and their number of employees (Barnard and Olivetti). However, for this type of estimation to be accurate, MINAE must already have data for at least one other business of the same ISIC code to serve as a reference point. From this data, MINAE can calculate a ratio of the total waste generated per employee for different types of industries.

After implementing this system, we estimated the type and amount of waste generated by the three businesses we visited during our field research. During these visits, we obtained actual waste production data from the businesses and later compared these values to our estimates to determine any similarities or differences. In this manner, we developed a simple, yet accurate waste estimation tool for MINAE to use in monitoring businesses.

To accompany our waste estimation model, we also created a brochure outlining methods of cleaner production within commercial centers. By promoting awareness of the environmental risks of improper waste management, we encouraged companies to adopt better manufacturing practices and generate less waste.

3.4 Cleaner Production Brochure

To promote cleaner production, we selected one major type of business within Santa Ana and developed a brochure illustrating ideal methods for waste management. We decided to focus on commercial centers based upon their prominence within Santa Ana and the amount of waste that they generate.

To access the necessary information for the brochure, we researched strategies currently in practice to promote cleaner production in commercial centers. By obtaining information about nearby recycling agencies and buy-back organizations, we incorporated a cost savings section into the brochure to serve as a persuasive incentive.

To convey our suggestions for cleaner production, we developed a brochure depicting ways in which commercial centers can improve their current methods of waste disposal. By emphasizing cleaner production, environmental friendliness and cost-efficiency, we proposed realistic alternatives that would both reduce the amount of illegal dumping and increase recycling efforts.

Our brochure contained general information useful for all types of commercial centers. This pamphlet also depicted information about local buy-back centers who would buy used materials from companies and tips for overall waste reduction. After creating this brochure, we provided it to MINAE to print and distribute at a later time.

4 Results and Analysis

We obtained six main results throughout the course of this project: the hydroelectric facility interview, the observational business study results, the online protocol results, the waste estimation model database, the interviews with local industries and the cleaner production fact sheets. The following sections present our findings.

4.1 Brasil Hydroelectric Facility

The Brasil hydroelectric facility, as seen in Figure 17, is located at the junction of the Uruca and Virilla rivers in the canton of Mora and provides electricity to the surrounding metropolitan area of San José. We attended a tour by two employees of the Compañía Nacional de Fuerza y Luz Natural Resources Department: Carlos Rosas, a civil engineer, and Warren Jimenez, a chemical engineer.

Figure 17: Brasil Hydroelectric Facility in Santa Ana, Costa Rica

During the energy harvesting process, the dam creates a small reservoir and transports the river water to a power plant located two meters downstream via an aqueduct, seen in Figure 18.

Figure 18: Aqueduct Used to Transport Water to the Turbine

After a total elevation change of 80 meters, the water spins the turbine, generates electricity and rejoins the river afterwards. At optimum performance, the generator can produce 27 MegaWatts (MW) of electricity while operating on an automated system.

The produced electricity is sent to a general station and distributed throughout the San José province, with a small percentage exported to Nicaragua. Currently, the Brasil dam produces less than half of the required energy for the metropolitan area to function. Consequently, their goal is to build another hydroelectric plant that could provide more energy generation for Costa Rica.

Every year, the Brasil dam encounters 7,000 tons of waste. During its first year in operation, over 10,000 tons of total waste was collected at the dam. A significant amount of the retrieved debris is wood, originating primarily from construction sites. A smaller portion of waste consists of aluminum cans and plastic originating from homes that lack a regular waste removal system. As a result, the Brasil Dam budgets approximately $200,000 annually for debris removal, waste management and maintenance costs. Whenever the dam requires repairs, the aqueduct is closed, completely shutting off all electricity production. This loss of electricity is very costly for the operators of the dam, further increasing the electricity expenses for the metropolitan area. Also of large concern to the dam operators is the liquid waste that they encounter. This waste is oftentimes damaging to the machinery, and much more difficult to prevent from entering the dam.

The dam currently employs two techniques to remove debris that accumulates behind the dam. Both techniques are similar given that they retrieve debris that is of a low enough density to float. The first technique involves a metal clam approximately 5 feet wide which catches debris at the entrance of the dam, as seen in Figure 19. While in use, the clam lowers into the water, collects any debris present and places it into a dumpster.

Figure 19: Clam Used for Debris Removal

The second technique for debris removal involves a giant crane with an attached umbrella shaped metal hook. This scoop can handle a much larger quantity of debris at a time than the clam. During this process, the scoop is lowered into the water and lifted back up to sift out any debris. After removal from the water, the debris is deposited in a large driveway before it is hauled away. This umbrella shaped scoop and pile of debris can be seen in Figure 20. The dam delivers all river waste to the Rio Azúl landfill in Alajuela, yet there is neither the time nor the space necessary to separate this debris before its disposal.

Figure 20: Umbrella Shaped Crane and Debris Pile

Although solid waste is the primary concern of the hydroelectric facility, liquid waste also poses a threat to the machinery. While it is not responsible for clogging the dam, liquids can be corrosive, greatly decreasing the lifespan of the turbine machinery. Every April, the dam performs a water analysis to test for Biochemical Oxygen Demand, phosphate concentration, nitrate concentration and pH.

Most of the waste found at the dam originates from the Virilla River, the most contaminated river in the country. According to Mr. Rosas, a large number of residents and squatters located along the river generate a significant portion of the retrieved waste. Often, this waste is placed onto the curb for a pick up that never arrives. Rather than be forced to live with their waste for a week, many residences dump it into the river instead. Additionally, many companies contribute to river debris through illegal dumping of solid and liquid wastes.

Through various means of capacity building, the Brasil dam has stimulated awareness of the importance of keeping the Virilla River Basin clean. In fact, a local water treatment company has provided funds to establish a treatment plan to improve the quality of the water. For the past ten years, the Brasil facility has provided an ecological class in the local schools for over 24,000 students to encourage learning about the current river debris problem. Due to their efforts to promote a cleaner environment, the Brasil Dam has won many different awards, including one from MINAE.

In support of the Brasil Dam's efforts for a cleaner environment, we evaluated the potential sources of river debris throughout the canton of Santa Ana to educate the community about the harmful effects of illegal dumping. Since MINAE focuses primarily on companies, we performed an analysis of the Santa Ana business sector to evaluate which industries or corporations may be contaminating the Uruca River.

4.2 Observational Business Study with GPS

To determine the origin of debris within the river, it was important to establish what businesses were located in the area of concern. Although all businesses are legally obligated to register with the government, many companies fail to do this. As such, MINAE was unaware of the number, type, and location of many of the businesses along the Uruca River. By walking along a road that parallels the Uruca River, we were able to determine the location, name, and primary economic activity of the different businesses. After we collected this information, we were able to produce a map of the area, as seen in Figure 21. The yellow area indicates the Santa Ana district, the green border specifies the Uruca River Basin and the red dots symbolize the businesses from which we collected data.

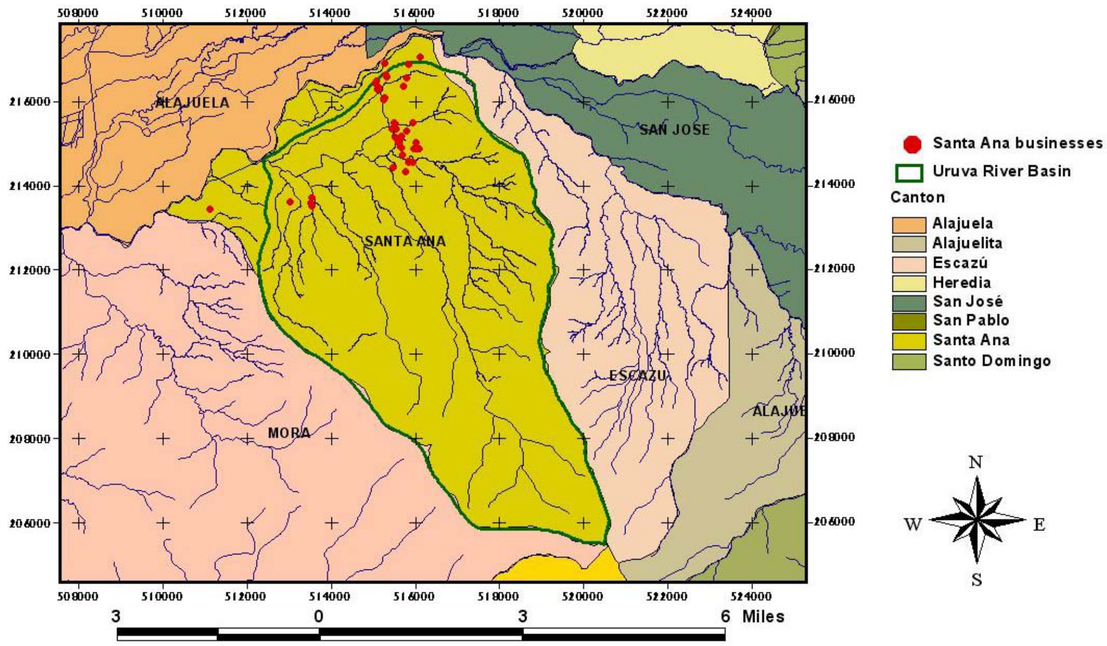


Figure 21: Distribution of the Visited Businesses in Santa Ana

Also, to help with our waste estimations in a later part of the project, we gathered information regarding the number of employees that the business had. The resultant data can be found in Table 1; however, a summary can be found below in Figure 22. Additionally, a breakdown of the average number of employees per type of industry can be found in Figure 23.

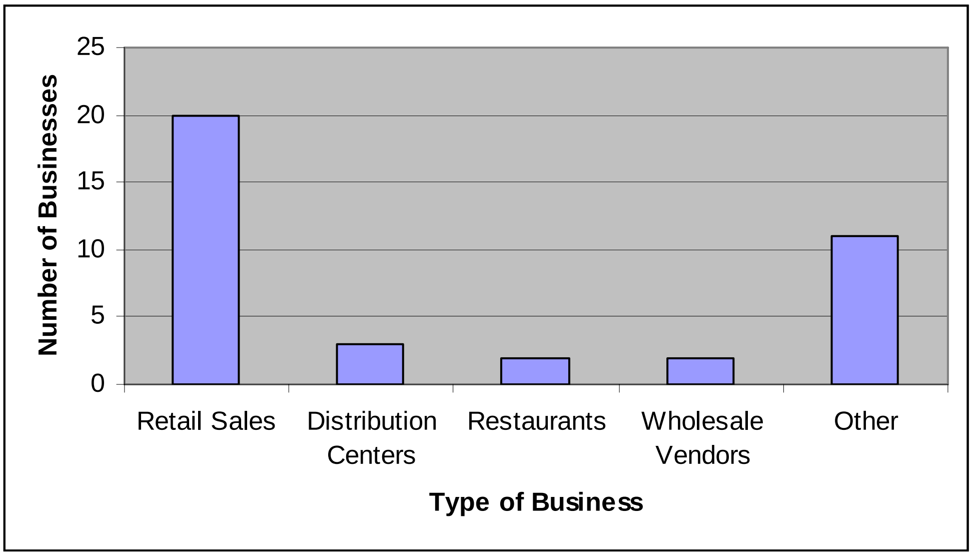


Figure 22: Comparison of Results from Business Survey

As displayed in the graph, a large majority of the businesses found were in retail sales. Three businesses fit the classification of distribution centers, while both restaurants and wholesale vendors had two businesses each. The remaining 11 businesses found were the only business of that type.

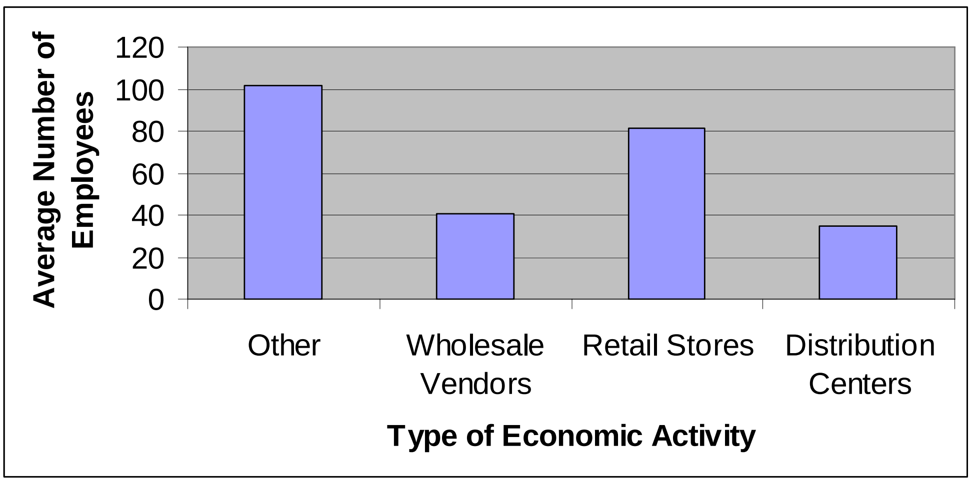


Figure 23: Average Number of Employees per Type of Industry

In analyzing the graph in Figure 23, it can be noted that retail stores generally have a larger number of employees than both wholesale vendors and distribution centers. From our data, retail stores had an average of 81 employees, more than doubling the amount for wholesale vendors, 40, and distribution centers, 38. Commercial centers, which we interpreted as a collection of 7 or more businesses located in the same plaza, were also grouped in the retail stores column. These centers were much larger than individual retail stores, thereby increasing the average number of employees in our calculations. The "other" category consisted of a wide range of the number of employees, ranging from 2 employees at Mesas y Silas Fibro Vidio Santa Ana, S.A. to 315 employees at Empaques Santa Ana, S.A.

As predicted, very few businesses displayed reluctance in sharing information about their number of employees. The only businesses from which we were unable to gather this information were Pizza Hut and RostiPollos, which were closed at the time of our visit. This information was useful to MINAE and ourselves to utilize the prediction based model that we had developed.

4.3 Development of the Online Protocol

The purpose of the online protocol and database was to allow MINAE to obtain information from industries about their economic activities without conducting on-site interviews. This process consisted of creating an interactive PDF and developing recommendations for its implementation. Section 4.3.1 describes the results of the interactive PDF, and section 5.1 illustrates our suggestions for its use.

4.3.1 Creation of an Interactive PDF

To create the online protocol, we obtained the original document used by MINAE in conducting business evaluations. Their questionnaire was modified to include additions regarding permits, water usage and water management. This evaluation contains five sections regarding requesting information specific to each business, as illustrated in the following figures.

1. INFORMACIÓN GENERAL

1.1. Nombre de empresa: ____________________
1.2. Razón social: ____________________ 1.3. Cédula jurídica: ____________
1.4. Ubicación:
Dirección: ____________________
____
Cantón: ____________ Distrito: ____________
Coordenadas: Longitud: ____________ Latitud: ____________
1.5 Otros
Teléfono: ____________ Fax: ____________
Apartado: ____________ E-mail: ____________
1.6. ¿Cuenta con Permiso Sanitario de Funcionamiento al día?
( ) Sí. Indique el número de permiso:____________ ( ) No ( ) En trámite
1.7. ¿Ha realizado trámites ante la SETENA? Año de Establecimiento:_______
( ) Sí. Indique el número de Expediente:_______ ( ) No

Figure 24: General Information Section 1

As seen in Figure 24, section 1 requests general information about the company, including the name, type of business and any contact information.

2. DESCRIPCIÓN DE LA ACTIVIDAD ECONÓMICA QUE DESARROLLA

2.1. Breve descripción de la actividad principal:____________________
____
____
2.2. Actividades secundarias: ____________________
2.3 Consumo de principales materias primas:

Nombre de la(s) principal (es) materia(s) prima(s)	Unidades

2.4. Producto(s) terminado (s)

Nombre del(los) producto(s) terminado(s)	Unidades

2.5. Jornada de producción
Temporada de producción: ( ) Todo el año

( ) Enero	( ) Febrero	( ) Marzo	( ) Abril	( ) Mayo	( ) Junio
( ) Julio	( ) Agosto	( ) Setiembre	( ) Octubre	( ) Noviembre	( ) Diciembre

Horas de trabajo al día: ____________ Días de trabajo al mes: ____________
Mes de mínima producción: ____________ Mes de máxima producción:____________
2.6. Número de empleados: Total: ____________ Proceso: ____________
2.7. Fuente de abastecimiento de agua. Caudal utilizado: ____________ m^3/día. El agua es tomada de:
( ) Cuerpo de agua superficial[1] ( ) Aguas subterráneas[1] ( ) Acueducto ( ) Otro
Nota (1). Indique el número de concesión de aprovechamiento:____________

Figure 25: Description of Economic Activity Section 2

The second section, seen in Figure 25, asks for a description of the economic activities of the business, specifically the amount and type of raw materials, the amount and type of products, and the peak month(s) of production.

3. SOBRE LA GENERACIÓN Y DISPOSICIÓN DE RESIDUOS SÓLIDOS

Breve descripción del desecho	Origen(1)	Cantidad generada	Recibe tratamiento		Frecuencia de recolección para su disposición final	Sitio de disposición final
			Sí (2)	No		

Nota (1): incluir los desechos ordinarios
Nota (2): Especifique: ____________________
Comentarios: ____________________

Figure 26: Generation of Solid Waste Section 3

The third section, displayed in Figure 26, asks for information about the type and amount of any solid waste produced by the business. If this waste receives any treatment, it must be indicated in Nota 2. The company must also specify the final disposal site of this waste and the frequency of its collection.

4. SOBRE LA GENERACIÓN Y DISPOSICIÓN DE RESIDUOS LÍQUIDOS

Tipo de agua residual	Caudal generado	Recibe tratamiento		Disposición final (2)	Presenta Reportes Operacionales
		Sí (1)	No		
Ordinaria					
Especial					
Mezcla					

Nota (1): Especifique: ____________________
Nota (2): Período de vertido: Horas por día: ____________________ Días por mes: __________
En caso de vertido en cuerpo de agua superficial indique el número de Permiso de Vertidos: ____________________
Comentarios: ____________________

Figure 27: Generation of Liquid Waste Section 4

Figure 27 displays the fourth section, which inquires about the type and amounts of generated liquid waste. There are three categories for liquid waste: *Ordinaria* (ordinary), *Especial* (chemically contaminated) and *Mezcla* (a mixture). Similar to section 3, this section asks about the methods of treatment and disposal of the generated waste.

5. ADOPCIÓN DE POLÍTICAS DE PRODUCIÓN MÁS LIMPIA
5.1. Se desarrollan acciones vinculadas con políticas de producción más limpia: ( ) Sí (1) ( )No
(1) Especifique: ____
____

Figure 28: Adoption of Cleaner Production Policies Section 5

Lastly, as seen in Figure 28, the fifth section evaluates whether or not the industry of interest currently employs any techniques for cleaner production.

After finalizing this form, we used Adobe® Acrobat® to make the form interactive. With this dynamic PDF, companies can access the form online and directly type in the requested information. The only program the businesses need is Adobe® Acrobat® Reader®, a free program used to read PDF files. We used a collection of text fields, numeric fields, radio buttons and check boxes to arrange the desired information in an organized manner. Text and numeric fields allow the user to input text and numbers, respectively. Radio buttons enable mutually exclusive responses, and check boxes allow for multiple responses to one question.

We chose to create a PDF because of its cross-platform compatibility, as well as its ease of use for the end user. PDF files are one of the few file types that can be opened on any machine and retain its configuration. Also, PDF files have become very common, increasing the odds that the user will be familiar and comfortable with the format. Yet, in the situation that the industry has never encountered this file type before, the Adobe® Acrobat® Reader® software to view it is freely available and simple to use.

4.4 Waste Estimation Model and Database

Before determining how to develop the waste estimation model, we brainstormed possible methods of how to obtain information from businesses. Some of these methods are illustrated in Table 2 below.

Potential Method	Pros	Cons
Import/Export forms	Provides details about amounts of starting materials and products	Difficult to access
Profit and financial records	Provides detailed information about amount of raw materials and budgets for waste disposal	Difficult to access
Physical size of the business (blueprint, satellite images, etc.)	Will indicate the areas space for manufacturing and waste management/storage	Blueprint does not specify areas; clear satellite images may not be available
Information from branches in other countries	Possible trends between waste budgets and waste disposal techniques	Different economic activity in different countries
Number of employees	Easily accessible information from businesses; indicates the size of the business; data is simple to process	Requires information from other businesses of the same type

Table 2: Summary of Potential Methods for Waste Estimation

Many of the possible methods in Table 2 are difficult to employ considering the resources that MINAE currently has access to. We wanted to create a simple model with easily available information that MINAE could obtain without searching though public records. Based on this criterion, we selected the amount of waste generated per employee for each type of business as an appropriate method. However, to conduct this approximation, information about at least one other company of that type is needed

By obtaining information about one or more businesses of a certain type, including the different amounts, the categories of waste they produce and the number of employees, we created a set of ratios relating the amount of waste to each employee. We also researched a study completed by Richard Barnard and Giancarlo Olivetti in Italy entitled *Limiting Environmental Impact by Waste Management* (Barnard and Olivetti, 1990). We decided to design our model after theirs due to their high success rates. In their report, they discuss how this method is the easiest to gather for which to gather any necessary information, especially when budgets are a main concern. The following section briefly summarizes the Barnard and Olivetti study.

4.4.1 Analysis of Barnard and Olivetti Study

To carry out a waste management analysis of a specific region, it is imperative to determine the type and amount of waste generated by companies. Consequently, Barnard and Olivetti's method of making predictions about the industrial waste materials involved minimum data collection. These estimations were based on the amount of waste generated per employee for a specific industry.

This specific study was executed in Naples, Italy throughout the 1980's. One step of their analysis was to take an inventory of the local industries and noting their genre, location, size and economic activity. For example, Barnard and Olivetti utilized the ISTAT system, or National Census Information, to classify the industries and to group together businesses of the same type to analyze any trends present in their waste production (Barnard and Olivetti, 1990).

Since it is nearly impossible to visit every business in the area, a random sample of one of each type of business was chosen to collect data from. Barnard and Olivetti visited 185 industries in 16 months and collected information about the type and amount of waste from different industries. This data was compiled in a database, as seen in Table 3.

An example of final model of data bank

ISTAT class	Description of waste	Quantity (tonne/ empl./month)	Months/yr
3 01 A	Sludge	0.1125	11
3 01 A	Paper and plastic	0.113	11
3 09 01	Sludge	0.102	11
3 09 01	Refractory bricks	0.023	11
3 09 01	Slag	0.7	11
3 09 03	Oily emulsion	0.24	11
3 10 D	Carbon tetrachloride	0.0043	11
3 10 H40	Toxic sludge	0.007	11
3 10 H40	Phenolic oily residue	0.0001	11
3 10 H42	Aromatic solvent	0.00014	11
3 10 I47	Acid solution	0.15	11

Table 3: Type and Amount of Waste Produced by Businesses in Naples

Source: Barnard and Olivetti, 1990

This study concluded with information about how to conduct a similar study in other locations, especially within developing countries. By obtaining information about the presence of industries in the area of concern, an initial evaluation of the environmental impact of businesses can be performed.

4.4.2 Development of a Computer-Based Waste Estimation Technique

To assist in MINAE's implementation of the waste estimation model, we developed a methodology utilizing the program Microsoft® Excel®. By using the built in functions of this program, the waste estimations can be created quickly and efficiently for a very wide range of businesses. Also, this program is currently in use by MINAE for data storage and viewing purposes, nullifying any need to adjust to or transfer data to a new system.

In the current Excel worksheets, information about the number of employees, the Biochemical Demand of Oxygen (DBO), the Chemical Demand of Oxygen (DQO), and the Total Suspended Solids (SST) are stored, along with a large amount of other information. By setting a formula in one cell of the worksheet where the DBO, the DQO, or the SST is divided by the number of employees, it can then be dragged to the other businesses' rows as well using the Fill Handle in the bottom right corner of the original cell. This will copy the formula from the original cell to the other cells that are highlighted; however, it will also automatically change the formula to reflect the data from the row that it is in. This will create a ratio of the amount of waste produced per employee for each business. From these ratios, the average ratio for each individual type of industry can be computed using functions within Excel. The average can then be multiplied by the number of employees that the business of interest has, thus creating an approximate estimate of the waste.

4.4.3 Testing the Accuracy of the Waste Estimation Technique

By using this technique, estimates of waste were produced for various industries that MINAE had collected data for in the past. The results can be seen in Table 4.

Name of Business	Real DBO	Estimated DBO	Percent Error
Auto Transportes, S.A.	0.5400	0.2825	47.69%
Banco de los Mariscos	8.4130	8.2303	2.17%
Pescarnes, S.A.	11.3000	5.3493	52.66%
Productos del Mar Tico	1.8755	1.5432	17.72%
Tun-Atun Internacional Costa Rica, S.A.	28.2891	21.6047	23.63%
Corrugadota de Costa Rica, S.A. (COCORISA)	0.9450	0.7795	17.51%
Corrugados Belén, S.A. (CORBEL)	0.7830	0.9940	26.94%

Table 4: Comparison of Collected Data to Estimations

To create these estimates, first the ratios for each type of industry were produced utilizing the technique described in section 4.4.2. This ratio was then multiplied by the number of employees that the business had. To find the percent error, we took the absolute value of the real data minus the estimated data, and then divided the resultant difference by the real data. This calculation gave a decimal number which was then multiplied by 100 to obtain the percent.

After the percent error was determined, we found that out of the seven businesses we tested, three of the percent errors were less than 20%, while two more were less than 30%. The remaining two businesses had 47% and 53% errors. This was done for the DQO and SST data as well with similar results found. Based on this information, we believe that our waste estimation technique is close enough to the real data to be of use to MINAE.

4.4.4 Estimating the Amount of Waste Produced Within Santa Ana

After we had confirmed the accuracy of our waste estimation model, we then took the data from our business survey and calculated the estimated kilograms of waste produced each day. This gives MINAE an approximate idea of the amount of waste that can be expected to be produced within the area of Santa Ana that we had visited. The resultant data can be found in Table 5 below.

ISIC Code v. 2	Number of Employees	Estimated DBO (Kg/day)	Estimated DQO (Kg/day)	Estimated SST (Kg/day)
3319	15	0.30000	0.54900	0.30000
3320	2	0.04000	0.07320	0.04000
3411	205	4.10000	7.50300	4.10000
3412	110	0.57200	1.06613	0.31882
3620	6	0.01292	0.02697	0.00787
3692	75	1.50000	2.74500	1.50000
3699	16	0.08799	0.36243	0.10820
3843	115	2.30000	4.20900	2.30000
5000	35	0.70000	1.28100	0.70000
6100	60	3.21879	6.26179	0.35514
6100	21	1.12658	2.19163	0.12430
6200	6	0.01924	0.07970	0.04123
6200	45	0.14428	0.59775	0.30919
6200	115	0.36872	1.52759	0.79015
6200	100	0.32063	1.32834	0.68709
6200	13	0.04168	0.17268	0.08932
6200	76	0.24368	1.00954	0.52219
6200	85	0.27253	1.12909	0.58402
6200	14	0.04489	0.18597	0.09619
6200	100	0.32063	1.32834	0.68709
6200	31	0.09939	0.41179	0.21300
6200	30	0.09619	0.39850	0.20613
6200	120	0.38475	1.59401	0.82450
6200	10	0.03206	0.13283	0.06871
6200	10	0.03206	0.13283	0.06871
6200	25	0.08016	0.33209	0.17177
6200	200	0.64126	2.65669	1.37417
6200	20	0.06413	0.26567	0.13742
7114	25	0.50000	0.91500	0.50000
7114	418	8.36000	15.29880	8.36000
7114	100	2.00000	3.66000	2.00000
7192	15	0.30000	0.54900	0.30000
7192	54	1.08000	1.97640	1.08000
9520	3	0.27474	0.56092	0.34342
9513	160	1.19828	7.85118	2.86572
	Total Estimated Waste:	**135.01782**	**Kg/day**	

Table 5: Estimated Amount of Waste Produced by Visited Companies within Santa Ana

The red ISIC codes indicate businesses that MINAE did not have collected data available for. For these businesses, the estimation technique currently in use by MINAE had to be used instead of our own method numbers. In this method, MINAE uses the same ratio of waste per employee for every type of business. This method is less accurate than our own during our tests, further displaying the need for the implementation of our alternative technique. The total waste produced by the 36 businesses we had information for is approximately 135 kilograms every day, or approximately 298 pounds. MINAE can now apply this technique to the remaining businesses within Santa Ana, San José, and ultimately throughout Costa Rica to determine roughly the amount of waste produced in different regions of the country.

4.5 Waste Management in Santa Ana Industries

To obtain a detailed idea of the economic activities of the industries along the Uruca River, we performed visits to three different industries. From these visits, we obtained data used to verify the effectiveness of the waste estimation model. Since we were neither employees of MINAE nor from Costa Rica, many industries did not grant us access to view their facilities. However, our liaison was able to negotiate with three industries for a tour of their manufacturing plants: Terramix,S.A. Empaques Santa Ana, S.A. and Exportadora PMT, S.A. Before visiting these industries, we researched their ISIC codes used for business classification.

4.5.1 Results from ISIC Code Research

Through our research, we discovered the raw materials necessary for conducting various industrial activities. From this information, we evaluated actual businesses in Santa Ana about their manufacturing process resulting waste materials. The specific industries we investigated included rubber manufacturing (ISIC code 2519), corrugated cardboard manufacturing (ISIC code 2102) and fish processing (ISIC code1512). Detailed information from our research can be seen in Table 6.

ISIC Code	Raw Materials	Process Followed	Waste Materials Produced
2519	1. Natural Rubber 2. Synthetic Rubber 3. Steel cord and beading 4. Reinforcing Fabrics 5. Carbon Black 6. Zinc Oxide 7. Sulphur 8. Recycled Rubber 9. Additives (age resistors, vulcanizing agents, softeners, etc.)	1. Natural or synthetic rubber heated 2. Mixed with additives 3. Cooled in mold, extruded into long tubes, or injected into a mold	1. Excess rubber 2. Waste water 3. Vulcanizing agents 4. Excess metal
2102	1. Trees (usually pine) 2. Sulfate 3. Corn starch glue 4. Waxes or paraffin 5. Ink	1. Tree stripped down the trunk 2. Pulped and treated with sulfate to make Kraft paper 3. Kraft paper glued to two other sheets of Kraft paper with corn starch glue 4. Put together into boxes	1. Excess wood pulp 2. Parts of tree that are not the trunk (e.g. branches, leaves, bark, etc.) 3. Excess chemicals
1512	1. Fish 2. Salt	Canning 1. Fish is de-boned and skinned 2. Placed into a can 3. Cooked in a pressurized cooker Salting 1. Skined, de-boned 2. Excess fat trimmed 3. Placed with layers of salt	1. Skin 2. Bone 3. Salt

Table 6: Results from ISIC code Research

4.5.2 Terramix Visit

We visited the Terramix headquarters in Santa Ana, a manufacturer of rubber gaskets with over 750 employees. The company has three main facilities dealing with waste management: solid waste, waste-water and chemically contaminated waste-water.

All solid waste is separated into containers based upon its composition. Table 7 indicates the destination of the specific types of waste produced during the gasket manufacturing process. Most of the solid waste is transported to a concrete company, either Cemex or Holcim, and burned for fuel. However, Terramix must pay these companies to donate their trash. Although incineration avoids contamination of the Uruca River with debris, the combustion process generates significant air pollution that has other negative environmental impacts.

Type of Waste	Destination of Waste
Rubber	Cemex or Holcim
Resin	Cemex or Holcim
Black Carbon	Cemex
Grease	Cemex or Holcim
Plastic Containers	Cemex
Metal Containers	Recycled in Guatemala
Regular Trash	Landfill
Metal	Recycled in Guatemala
Wood	Reused in Industry

Table 7: Type and Destination of Solid Waste Generated by Terramix

Terramix also has two waste water treatment plants on its property. The non-hazardous waste water is all sent to a facility that purifies the water and sends the clean product to the Uruca River. Additionally, a water treatment plant specifically for chemically contaminated water purifies the water of its chemicals and sends it back to the river.

4.5.3 Empaques Santa Ana Visit

Empaques Santa Ana buys old cardboard from businesses and individuals, creating new cardboard boxes after recycling the old. They receive both clean scrap material from other cardboard manufacturing plants as well as old corrugated cardboard from recycling centers or individuals. Through recycling, Empaques Santa Ana utilizes much fewer raw materials than creating new cardboard, saving over 700,000 trees a year and 46 m^3 of water per ton of produced cardboard.

Although they are proud to be a strong contributor to recycling, currently the methods employed to handle their waste are very poor. As seen in Table 8, they produce only a few different types of waste.

Type of Waste	Destination of Waste
Metal wire	Recycled in Guatemala
Water	Rio Virilla
Unusable Cardboard	Landfill
General waste	Landfill
Wood	Burned in on-site incinerator
Wood with nails	Landfill
Paint	Treated at paint treatment facility

Table 8: Type and Destination of Waste Generated by Empaques Santa Ana

In total, all of the waste sent to the landfill is approximately 5% of the total amount of the final product produced.

While the method of recycling the metal wire and the treatment of paint are excellent, the emissions and treatment of water leave much to be desired. At the time of the interview, Empaques Santa Ana was not in compliance with the guidelines set in place by MINAE. They were, however, in the process of building a waste water treatment plant, and were also attempting to reduce the emission of Carbon Monoxide from their wood burning boilers.

4.5.4 Exportadora PMT Visit

The final industry we visited was Exportadora PMT, a fish processing company located on the border of Santa Ana that exports primarily to the United States. They process fish year-round, yet November and December are their peak months for production. Depending on the yields, Exportadora PMT can ship from 3,000 lbs/day to 20,000 lbs/day of their processed goods.

For raw materials, this company receives seafood imports from 5 ports: Gulfito, Quepos, Puntarenas, Coco and Guaji. In fact, the fish they receive has already been cleaned of blood and innards, thereby significantly reducing their potential waste production. Any water used during the process is obtained from local wells located deep within the ground.

When the imported fish arrive at the plant, they are separated, classified and weighed in the receiving room. Next, they are sent to the storage room, where they are defrosted for four to five days. In the next room, used for processing, the employees cut the fish into filets and different sized portions based on their clients' requests. The fish are then packaged with ice packs in Styrofoam containers and wrapped in plastic wrap.

Table 9 indicates the types of generated waste and their means of disposal. Since they receive their raw materials already cleaned, they only generate skeletal and processed waste, which are sent to an aquaculture plant. At this plant, the fish heads and tails are used as food for tilapia farms. Also, any bone waste is crushed, combined with flour, and also served as food. Any packaging materials and general solid waste are picked up and distributed to a local landfill. The business generates from 1,000-1,500 kg of waste per day and approximately 3 m^3 of liquid waste during every hour of operation.

Type of Waste	Destination of Waste
Bone waste	Aquaculture plant
Fish waste	Aquaculture plant
Packaging materials	Landfill
Water from processing	On-site water treatment plant

Table 9: Type and Destination of Waste Generated by Exportadora PMT

Exportadora PMT had a very elaborate, well-organized waste water treatment facility on their grounds. This treatment plant receives all water used during fish processing and handling, including any leftover water from the employee cafeteria. In fact, 80 m^3 of water is used daily during processing, most of which is used to make ice. Any waste water coming from on-site bathrooms is sent to a septic tank. Throughout the plant, a variety of different sized filters are used to separate solid materials from liquid. An example of this type of filter can be seen in Figure 29. The purpose of these filters is to limit the amount of solids that reach the wastewater treatment plant.

Figure 29: Typical Filter at Exportadora PMT

Before entering the water treatment plant, the liquid waste is sent through a final filter containing 1.5mm wide spaces, as exhibited in Figure 30.

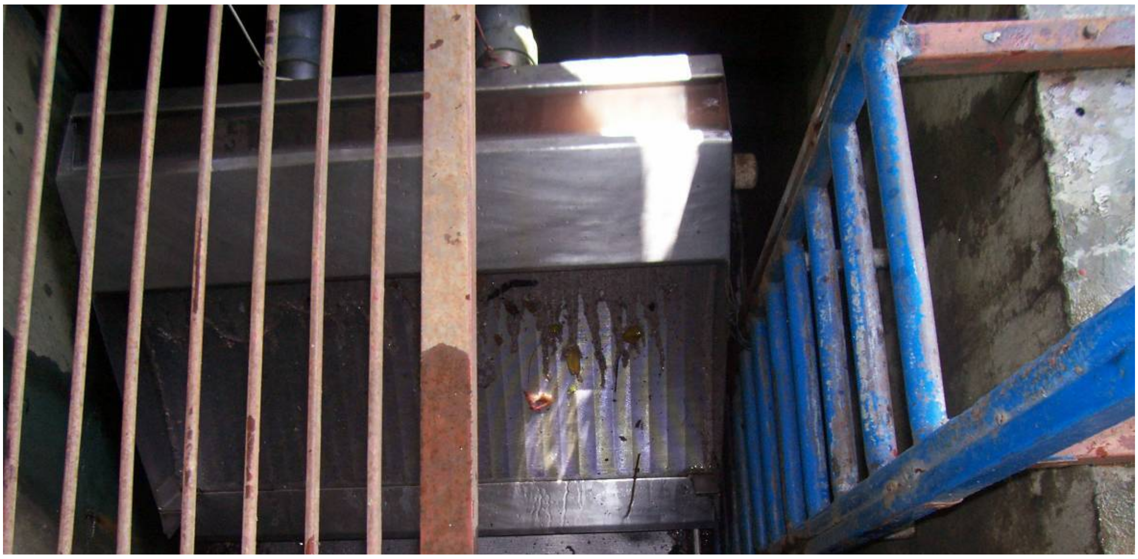


Figure 30: Final Filter Before Wastewater Enters Treatment Pond

The water then passes through a homogenizing tank to maintain a steady level of liquid within the pond. After homogenization, the water travels into the pond, seen in Figure 31.

Figure 31: On-Site Wastewater Treatment Facility

This pond is rich with aerobic bacteria which remove any dissolved solids from the liquid. The red spokes continually revolve to supply the bacteria with sufficient oxygen to decompose the dissolved solids into organic material. Any excess mud, or biomass, is separated from the liquid and continually replaced into the system until it is completely degraded.

The final liquid is distributed to the sewers and liquid waste facilities in the country. After treatment, this water is sent to the Copei River in compliance with the standards set by the Ministry of Health. To promote cleaner production, Exportadora PMT participates in the Hazard Analysis Critical Control Point (HACCP) program. Every six months, the business receives an inspection along with updated certifications for the company and its employees.

4.6 Cleaner Production Brochure

Before selecting which industries to focus on for our cleaner production brochure, we compiled the data from our observational business study to determine which types of companies were most prominent in Santa Ana. We narrowed our selection to several different options, including commercial centers, distribution centers, gas stations, automotive shops, and hotels. According to MINAE, commercial centers are rarely regulated on their environmental practices and often generate significant amounts of waste. Based on these suggestions from MINAE, we chose to focus our efforts for cleaner production specifically on commercial centers.

Our brochure took the form of a trifold pamphlet, which can be seen in Appendix F in English and in Appendix G in Spanish. An outline of the brochure is displayed in Figure 32.

Success stories Client satisfaction	Sponsor contact information	Title
Page 1	*Back Page*	*Front Page*

Cost benefits Goal of the brochure	Waste management options	Waste reduction tips
Page 2	*Page 3*	*Page 4*

Figure 32: Outline of the Cleaner Production Brochure

The front page of the brochure displayed our title for the brochure: Waste Production and Reduction for Commercial Centers.

On page 1, we included a section for MINAE to provide success stories about businesses and their cost savings. We also emphasized client satisfaction to encourage companies to switch to cleaner production.

For page 2, we focused on identifying the current problem: improper waste management can have many environmental consequences. Consequently, the bottom of the page illustrated our goal: to encourage recycling and waste reduction for commercial centers. On page 3, we supplied information of different agencies that buy back used paper, cardboard and plastics bags. We selected these materials because they are common to many vendors. A breakdown of our data can be seen in Table 10.

Recyclable Purchasing Company	Buying Price
Paper	
Amanco Fábrica	¢25/kg
Euroamérica Fábrica	¢10-25/kg
Kimberly Clark	¢10-20/kg
Cardboard	
Intermediario	¢15-50/box
Reutilización	¢15-70/box
Cajas Quirós y Retana Reutilización	¢40/box
Plastic Bags	
Reutilización	¢350/kg
PRODUCOL Fábrica	¢15-40/kg

Table 10: Breakdown of Available Recycling Purchasing Companies

This information allowed us to emphasize the available options for the recycling of used paper, cardboard and plastic bags. We supplied the phone numbers of each of the purchasing agencies for retailers to contact about further information. By presenting information about these buy-back companies in our brochure, we promoted both environmental awareness and cost savings for retailers.

Finally, page 4 contained tips to reduce the amount of overall waste produced. Through our research, we determined that packaging materials and paper are two of the most common materials used by retailers. Therefore, we developed a list of suggestions to encourage vendors to limit their generated waste by conserving their resources. To conserve packaging materials, we suggested that commercial centers:

- Request that shipped materials come in returnable containers
- Reduce packaging layers
- Reuse packaging peanuts, bubble wrap and boxes
- Use shredded paper as packaging material

To conserve paper, we recommended to:

- Make double-sided copies
- Turn used paper into scratch pads
- Set up recycling bins to separate paper waste

Through these tips for waste reduction, we intended to promote awareness to companies about the need to conserve materials. Also, by providing commercial centers with information about recyclable purchasing companies, we aimed to increase their participation in recycling efforts. By providing MINAE with this deliverable, we hoped to improve waste management among industries in Costa Rica.

5 Conclusions and Recommendations

After a thorough analysis of our results, we have determined the following conclusions:

- The interactive PDF is an effective method for MINAE to obtain information from businesses about their economic activities and waste management practices.
- The waste estimation model is a good technique for predicting the type and amount of waste generated by a company with a 70% accuracy rate.
- The cleaner production brochure for commercial centers is an efficient way to communicate with businesses about better environmental practices.

From these conclusions, we have developed a set of recommendations for MINAE to successfully implement these three deliverables. These recommendations consist of three main components: to establish online accessibility of the interactive PDF, to update the waste estimation model and to distribute and expand the cleaner production brochure. The following sections elaborate on these suggestions.

5.1 Make the Interactive PDF Available Online

Based upon our environmental audit research and analysis of the Santa Ana business sector, we have developed recommendations to facilitate MINAE's implementation of our online protocol. By allowing this form to be available on the MINAE website, business representatives can fill out the necessary information and electronically submit their form to MINAE. We suggest that they create a user-friendly website containing a detailed statement of purpose of the protocol, the downloadable PDF form and any other pertinent information that they feel is necessary. The statement of purpose should illustrate the goal of the protocol, along with how the data shall be used and interpreted by MINAE.

Additionally, to obtain feedback from the industries about their economic activities, it is imperative to promote awareness of this protocol. Through various forms of publication and communication with businesses, MINAE can spark an interest in different companies to participate in the use of the protocol. Lastly, by maintaining a database of this information, MINAE can evaluate which companies may be contributing the most to dumping debris in the Uruca River. A detailed description of how to implement the online protocol can be found in Appendix E.

5.1.1 Creation of Incentives

As an incentive for businesses to utilize our form, we suggest that MINAE incorporate various ideas and techniques we have researched from programs currently in place within the United States and in Costa Rica. One current program, known as Bandera Azul, is used to recognize Costa Rican beaches for environmental cleanliness. (Bandera Azul Ecológica, 2005). The Bandera Azul foundation awards beaches that comply with a set of regulations a blue ecological flag. This flag can be displayed on the beach in recognition of their efforts for cleaner production. The success of this program proves that a successful incentives program is possible in Costa Rica.

The practice that we suggest MINAE puts into place involves the creation of a program for recognition of those businesses that are environmentally aware. To join this program, MINAE should set up an application process which should inquire about current and past practices that the industry has utilized for waste management, the amount of waste that they produce and how it is disposed of, and their plans for future improvements in waste management and waste reduction. This application should then be reviewed by a board of judges who will decide if the business has met the qualifications for the program. If they have not, the industry should be informed as to what areas they still need to improve upon, as well as techniques that may be employed to do so. Also, as part of the requirements for participation in the program, the businesses should be required to use the online form.

MINAE should also promote discussions between businesses regarding the processes that various companies utilize to lessen their environmental impact. These discussions could take the form of a regional roundtable, in which all of the businesses in a specific region come together to share and discuss their ideas, or they could be focused more upon the individual types of businesses gathering to discuss their ideas. In both of these methods, potential cost savings and increased customer satisfaction should be promoted to gain interest in attendance.

After a business is accepted into the program, they should be added to a publicly available list that MINAE maintains on their website. Also, an award signifying their participation in the program should be rewarded at a public awards banquet along with any other businesses that may have been accepted into the program. The business should then be given permission to use the program’s logo within their business and their official documents to ensure customer’s knowledge of their achievements. The industry should have to reapply for participation with the program every two years to guarantee continued improvements and adherence to the original goals. At this time, the objectives that they set for themselves on the original application should be evaluated for their progress. Each year, between ten to twenty percent of the participating businesses should be inspected to ensure honesty while completing the forms.

In addition to the publicity and awareness of the form, it is very important to promote the benefits that go along with its use. If businesses are unaware of the incentives that MINAE has put into place for those that utilize the form, than fewer businesses will find it to be worth using, instead relying on paper copies from MINAE.

5.2 Expand the Waste Estimation Model

Although our waste estimation model is fully functioning, it contains limited information regarding the waste per employee ratios for different companies. It is important that in the future, MINAE constantly update and revise this database to reflect any new developments or information that they may gather. This goal will be very simple to accomplish if the Excel sheet used to store information for the individual businesses is the same as the sheet used to create estimations and store the ratios of waste per employee as well. If this is the approach that MINAE uses, then the worksheet could be set up to automatically calculate estimations, ratios and averages of the ratios for each industry. MINAE could also the estimations according to any newly obtained information. Every time a new business submitted their information, and it was uploaded to the database, an estimation could be created to compare the real information. A thorough description of this implementation procedure can be found in Appendix E in the operating manual.

If, when MINAE compares the information that the business reported to the information that the estimation provided, they find that the numbers differ by over 30%, it would be worth MINAE's time to investigate the matter more fully by conducting an on-site visit. During this visit, they could see if the numbers had been reported wrong, or if they actually were as low or as high as originally stated. If the amount of waste produced is much larger than it should be, different techniques for processing could then be suggested to help bring this number down. Conversely, if the numbers are very small, MINAE could gather information about how this was accomplished to later pass this information on to other companies to decrease their waste production as well.

By continually promoting communication between businesses about their best and most environmentally sound practices, MINAE can ensure that the industries are continually becoming aware of all of the possibilities that are available to them for both their manufacturing process and waste disposal.

5.3 Distribute the Cleaner Production Brochure

For our final deliverable, we recommend that MINAE distribute our brochure to several commercial centers in Costa Rica. In doing this, MINAE can obtain information about how much money a commercial center has saved by participating in a recyclable purchasing program. MINAE should then incorporate these statistics into the brochure to provide real data about business savings specific to Costa Rica. To make expansions to this brochure, MINAE can focus on other problematic industries and produce similar brochures containing information about materials specific to the industry of interest. Furthermore, by disseminating this information about environmentally friendly methods of production while promoting customer satisfaction and cost savings, MINAE will entice Costa Rican businesses to adopt better waste management practices.

References

Ackerman, Frank. (1997). *Why do we recycle: markets, values, and public policy*. Washington, D.C.: Island Press.

Adamowicz, W. L. Luckert, M. K., & Salkie, F. J. (2001). Household response to the loss of publicly provided waste removal: A Saskatchewan case study. Resources, Conservation and Recycling, 33(1), 23-36.

An act to strengthen the littering laws. (2002). *General Assembly of North Carolina*. Retrieved March 24, 2006, from http://www.ncdot.org/doh/operations/dp_chief_eng/roadside/beautification/litterlaws/nclitterlaws.html

Arndt, Roger E. A., Gulliver, John S. Hydropower Engineering Handbook. McGraw Hill, Inc. 1991. United States of America.

Arnulfo, D. (2005). *Garbage Collection and Recycling*. Retrieved on April 5, 2006, from http://www.nosaranet.com/nosaragarbagecollectionrecycling.html

Bandera Azul Ecológica (2005). *Instituto Costarricense de Acueductos y Alcantarillados*. Retrieved on June 30, from http://www.aya.go.cr/Dependencias/laboratorio/bandera_azul/playas/ba_playas.htm

Barnard, R. and Olivetti, G., 1990. Limiting Environmental Impact by Waste Management. Eur. Symp. On Integrated Resource Recovery from Municipal Solid Wastes. *Resour. Conserv. Recycl.*, 4:51-62.

Bates, N., Hansell, D., & Kadko, D. (2004). *Degradation of Terrigenous Dissolved Organic Carbon in the Western Arctic Ocean*.

Retrieved April 8, 2006, from http://www.sciencemag.org/cgi/content/full/304/5672/858.

Bonsor, Kevin. *How Hydropower Plants Work.* Retrieved April 8, 2006, from http://people.howstuffworks.com/hydropower-plant2.htm.

Cheremisinoff, N.P. (2003). *Handbook of Solid Waste Management and Waste Minimization Technologies.* New York: Elsevier Science.

Clayton, K., & Huie, J. (1973). Solid Wastes Management. Cambridge, MA: Ballinger Publishing.

Clean Virginia Waterways. (n.d.). *Clean Virginia Waterways.* Retrieved March 22, 2006, from http://www.longwood.edu/cleanva

Costa Rica (n.d). *Pan American Health Organization.* Retrieved on April 7, 2006, from http://www.paho.org/English/DD/AIS/cp_188.htm

Costa Rica Operations. (2006). *Wal-Mart Online.* Retrieved on April 5, 2006, from http://walmartstores.com/GlobalWMStoresWeb/navigate.do?catg=393

Curi, K., Or, I. (1993). Improving the efficiency of the solid waste collection system in Izmir, Turkey, through mathematical programming. Waste Management & Research, 11(4), 297-311.

Cuthbert, R. (1994). Variable Disposal Fee Impact. BioCycle, 35(5), 63-66.

Digeca (n.d.). *Ministerio del Ambiente y Energia*. Retrieved March 22, 2006, from http://digeca.minae.go.cr/

Dutschke, M. (2005). *Host Country Driven Implementation—The Case of Costa Rica.* Retrieved on April 4, 2006, from http://home.wtal.de/dutschke/Publications/chap5.pdf

Environmental Education for the Conservation of Flagship Species in the Osa Peninsula. (2006). *Rainforest Alliance.* Retrieved on April 4, 2006, from http://www.eco-index.org/search/results.cfm?projectID=964

Environment, Health and Safety. (2006). *Intel.* Retrieved on April 4, 2006, from http://www.intel.com/community/costarica/environment.htm

Environmental Protection Agency. (2000). *Biosolids Technology Fact Sheet: Belt Filter Press.* Retrieved April 18, 2005, from http://www.epa.gov/owm/mtb/belt_filter.pdf

Environmental Protection Agency. (2000). *Biosolids Technology Fact Sheet: Centrifuge Thickening and Dewatering.* Retrieved April 14, 2005, from http://www.epa.gov/owm/mtb/centrifuge_thickening.pdf

Environmental Protection Agency. (2003). *Municipal Solid Waste in the United States: 2001 Facts and Figures.* (Report No. EPA530-R-03-011). Retrieved on January 15, 2005. From: http://www.epa.gov

Environmental Protection Agency (www.epa.gov). 2004

Environmental Studies in Costa Rica. (2004). *University of Wisconsin: Center for Latin American and Caribbean Studies.* Retrieved on April 5, 2006, from http://www.uwm.edu/Dept/CLACS/outreach/pdf/bbb4.pdf

Environmentally Sound Waste Management of Solid Wastes and Sewage-Related Issues. (2004). *UN Division of Economic and Social Affairs: Division for Sustainable Development.* Retrieved on April 4, 2006, from http://www.un.org/esa/sustdev/documents/agenda21/english/agenda21chapter21.htm

Everett, J., & Pierce, J. (1993). Curbside Recycling in the USA: Convenience and Mandatory Participation. Waste Management and Research, 11(1), 49-61.

Facts about Litter. (2004). *New South Wales Environmental Protection Authority*. Retrieved March 24, 2006, from http://www.environment.nsw.gov.au/litter/factsaboutlitter.htm

Fossil Fuel Production and Consumption. (1999). *University of Oregon Physics Department*. Retrieved on April 4, 2006, from http://zebu.uoregon.edu/1999/ph161/l10.html

Generators and Exciters. Retrieved April 5, 2006, from https://www.nwp.usace.army.mil/HDC/edu_genexcit.asp.

Guide for Economic Sustainability and Quality Life of San José. (2003). Retrieved on April 5, 2006, from http://www.sanjosemetropolitano.org/ModDocumentacion/Documentos/GuiaSEAM/ELR_GS_ING_Waste.htm

Institute for Local Self-Reliance. (1991). *Beyond 40 percent: record-setting recycling and composting programs*. Washington, D.C.: Island Press.

Holl, K. D., G. C. Daily, and P. R. Ehrlich. 1995. A survey of knowledge and perceptions in Costa Rica regarding environment, population, and biodiversity issues. Conservation Biology 9: 1548-1558.

How Hydroelectric Energy Works. (2005). *Union of Concerned Scientists*. Retrieved on March 24, 2006, from http://www.ucsusa.org/clean_energy/renewable_energy_basics/how-hydroelectric-energy-works.html

Hydroelectric Power: How it works. (2005). *U.S. Department of the Interior*. Retrieved on March 25, 2006, from http://ga.water.usgs.gov/edu/hyhowworks.html

Hydroelectric Power in California. (2001). *California Energy Commission.* Retrieved on April 3, 2006, from http://www.energy.ca.gov/electricity/hydro.html

Hydropower. (n.d) *World Energy Council.* Retrieved on April 4, 2006, from http://www.worldenergy.org/wec-geis/publications/reports/ser/hydro/hydro.asp

Hydropower: Licensed to Protect the Environment. (2006). *Oak Ridge National Library*. Retrieved on March 24, 2006, from http://www.ornl.gov/info/ornlreview/rev26-34/text/hydmain.html

Kasting, J. (1998). *The Carbon Cycle, Climate, and the Long Term Effects of Fossil Fuel Burning*. Consequences. Retrieved on May 16, 2006, from http://www.gcrio.org/CONSEQUENCES/vol4no1/carbcycle.html

Kemper, K., Dinar, A. & Blomquist, W. (n.d.) *Institutional and Policy Analysis of River Basin Management Decentralization.* Retrieved on April 4, 2006, from http://siteresources.worldbank.org/INTSAREGTOPWATRES/Resources/Insti&Pol_Analysis_of_RBMDecent.pdf

Korfmacher, K. (1997). Solid Waste Collection Systems in Developing Urban Areas of South Africa: An overview and Case Study. Waste Management and Research, 15(5), 477-494.

Landau, D., Floyd, S. & DeOssie, D. *Preventative actions to reduce agricultural water contamination in Costa Rica.* Retrieved on April 19, 2006, from http://www.wpi.edu/Pubs/E-project/Available/E-project-070605-150320/

Lardinois, Inge. (1996). Solid Waste Micro and Small Enterprises and Cooperatives in Latin-America. Retrieved on April 4, 2006, from http://www.gdrc.org/uem/waste/swm-waste.html

Levesque, A.P., Pelletier, B.W. & Samuels, E.J (2003). *Solid Waste Management in Costa Rica and the United States.* WPI-Interactive Qualifying Project.

Lu, C. (1996). A model of leaching behavior from MSW incinerator residue landfills. Waste Management & Research, 14(1), 51-70.

Managing Debris in the Susquehanna River Watershed. (1999). *Susquehanna River Basin Commission.* Retrieved March 22, 2006 from the World Wide Web: http://www.srbc.net/docs/debrismangement.pdf

Marais, M., Armitage, N., Wise, C. (2004). The measurement and reduction of urban litter entering storm water drainage systems: Paper 1 – Quantifying the problem using the City of Cape Town as a case study. Retrieved on March 24, 2006, from http://www.wrc.org.za/downloads/watersa/2004/Oct-04/6a.pdf

Microcuenca del Río Uruca: Breve Descripción Geográfica y Biofísica (n.d). Personal Communication, April 19, 2006.

Municipal Solid Waste: Recycling. (2006). U.S. Environmental Protection Agency (2006). Retrieved on March 24, 2006, from http://www.epa.gov/epaoswer/non-hw/muncpl/recycle.htm

Murillo, K, (2006). In Costa Rica, Residents Living Near Popular National Park Find that Their Futures Are Linked to Wildlife Conservation. Retrieved on April 6, 2006, from http://www.rainforest-alliance.org/neotropics/eco-exchange/2006/march_06_02.html

Noehammer, H., & Byer, P. (1997). Effect of Design Variables on Participation in Residential Curbside Recycling Programs. Waste Management and Research, 15(4), 407-427.

NSW Government Litter Protection Program. (2005). *New South Wales Environmental Protection Authority*. Retrieved on March 24, 2006, from http://www.environment.nsw.gov.au/litter/program.htm

Pollution Control. (n.d). *Osa Water Works.* Retrieved on April 4, 2006, from http://www.osawaterworks.com/pollutioncontrol.htm

Powell, J. (1996). _*The Evaluation of Waste Management Options. Waste Management and Research, 14*(6), 515-526.

Public Meeting Minutes: Debris Management in the Susquehanna River Watershed. *Connowingo Hydroelectric Facility*. Personal Communication, March 30, 2006.

Prelini, C. (1911). *Dredges and Dredging*. New York: D. Van Nostrand.

Project for the Improvement of Garbage Collection Equipment in the City of Managua. (2002). *Japan International Cooperation Agency*. Retrieved on April 3, 2006, from http://www.jica.go.jp/english/evaluation/report/pdf/2002_0125.pdf

Rio Tarcoles initiates common Central American policy for water (2003). *International Water Management Institute.* Retrieved on April 3, 2006, from http://www.iwmi.cgiar.org/dialogue/files/Dialogues/America/VERSION%20FINAL%20INGLES%20ENCICLOPEDIA%2001-06-04.doc

River Landscapes: Restoring Rivers and Riparian Lands all over Australia. (2006). Retrieved March 22, 2006 from Australian Government: Land and Water Australia: http://www.rivers.gov.au/index.htm

Savas, E.S. (1977). *The Organization and Efficiency of Solid Waste Collection.* Lexington, Mass: Lexington Books.

Schert, J., Kugler, A., Hilker, E., Rawlins, L., Rogers, R. & Kubinski, D. (1998). The Florida Litter Study: 1998. Available online at http://litterinfo.org/98_florida_litter_study.pdf

Smith, D. (2000). Costa Rica Deals with Environmental Pressures. *National Geographic*. Retrieved on April 2, 2006, from http://news.nationalgeographic.com/news/2000/12/1214_costarica.html

The Impact of the "Beverage Producer Responsibility Act" On Existing Bottle Bill States. (2000). *Container Recycling Institute*. Retrieved on March 24, 2006, from http://www.bottlebill.org/about_bb/home_impact.htm

Types of Hydropower Plants. (2005). *U.S. Department of Energy: Wind & Hydropower Technologies Program*. Retrieved on March 25, 2005, from http://www1.eere.energy.gov/windandhydro/hydro_plant_types.html

Umaña, A. (2002). Capacity 21 Global Evaluation: Costa Rica. *United Nations Development Programme*. Retrieved on April 4, 2006, from http://capacity.undp.org/indexAction.cfm?module=Library&action=GetFile&DocumentID=5325

Van der Werff, M. & Portuguez, J. (2005). A Common Central American Policy for Water, Initiated in the Grande de Tárcoles River Basin in Costa Rica. Retrieved on April 4, 2006, from http://www.fao.org/ag/wfe2005/docs/FUDEU_CostaRica_en.pdf

Woodley, J., Hitch, S., Mosso, D., & Sheavley, S. (2002). Assessing and Monitoring Floatable Debris. Retrieved on March 24, 2006, from http://www.epa.gov/owow/oceans/debris/floatingdebris/debris-final.pdf

Appendix A: Description of MINAE and DIGECA

The Ministerio Del Ambiente y Energía (MINAE), which translates to the Ministry of Environment and Energy, is a governmental agency created in the 1970's to create and enforce Costa Rica's environmental laws, including those pertaining to forestry, hunting, and marine conservation. Similar to other governmental agencies throughout the world, MINAE has many different branches to deal with these various tasks.

One of the largest and most prominent of these branches is the Sistema Nacional de Areas de Conservacion (SINAC), or the National System of Conservation Areas. This branch is in charge of all of the National parks located within Costa Rica. Currently, SINAC oversees over 160 protected areas, including 26 National Parks. In total, approximately 25% of the country is protected through either National Parks or other protected zones.

One important development by MINAE has been the promotion of "ecotourism." Using this system of tourism, MINAE promotes the viewing of the diverse bio systems Costa Rica has, while creating the least amount of damage to the environment. For example, many National Parks run by MINAE have very few trails leading through them to allow the wildlife to live free from human interference. Overall, ecotourism should satisfy as many of the following conditions as possible: conservation of biological and cultural diversity, sustainable use of the environment, sharing of the economic benefits with the local communities and indigenous people, an increase of environmental and cultural knowledge, and most importantly, that the local plants, animals, and people remain the main attraction to the area. Costa Rica has pulled itself to the forefront in the area of ecotourism, and has served as a model for many different countries.

The branch that is most concerned with our specific project is the Dirección de Gestión de Calidad Ambiental (DIGECA), or the Direction of Management of Environmental Quality. This branch of MINAE was created on October 9, 2003 and is responsible for the establishment of policies and other environmental protections regarding the resources that can be harvested from the air, water, and ground. They are also responsible for preventing the contamination of natural resources, either through the design of new programs or through the enforcement of existing laws. Another goal of DIGECA is to promote the voluntary self-regulation of businesses, and also for businesses to take initiative in promoting cleaner production methods and systems of higher environmental performance. The last two goals in particular explain why DIGECA has sponsored this project. By utilizing our online protocol, DIGECA can promote the self-regulation of businesses much more than before. Also, through our brochure, we encouraged cleaner production within the companies based upon savings both in money and in environmental damage.

Appendix B: Timeline for our Project

Task	Week						
	1	**2**	**3**	**4**	**5**	**6**	**7**
Field Research							
Observational study with GPS			■	■			
Visit to hydroelectric facility			■				
Visit to industries in Santa Ana	■	■	■	■	■	■	
Research and Develop Online Protocol			■	■	■		
Waste Estimation Model							
Research and create a waste estimation methodology			■	■	■		
Make an estimate for specific companies			■	■	■		
Visit companies and gather real data	■	■	■	■	■	■	
Make modifications to the methodology				■	■	■	
Proposal for cleaner production							
Research and create fact sheet					■	■	
Prepare for final presentation						■	■
Present recommendations at final presentation							■

Appendix C: Gathered Data from Business Survey

ISIC Code v.3.1	ISIC Code v.2	Nombre del ente Generador	Descripción de la actividad	Longitud	Latitud	Número de empleados
2610	3319	Valsa	fabrication of doors and windows (bathroom)	515579	214819	15
3610	3320	Mesas y Sillas Fibro Vidio Santa Ana S.A.	furniture construction	515265	214520	2
2102	3411	Empaques de Santa Ana, Division molino	cardboard manufacturing	514687	216140	205
3720	3412	Empaques de Santa Ana, Division corrugadora	cardboard paper and box recycling	514635	216288	110
2610	3620	Mirales y Vitrales S.A.	window construction	515568	214678	6
2694	3692	Concreto Industrial S.A.	concrete manufacture and sales	514891	216395	75
2699	3699	Tajo Meco	construction sand and gravel	515664	216847	16
3120	3839	ITT Industries	computer electronics manufacture	514812	215835	
3410	3843	Daewoo Bus Costa Rica	assemble and sell buses (antes YoungAn)	512581	213411	115
4520	5000	Decisa	construction	515520	214674	35
5234	6100	El Lagar: Marcado de Materiales y Porras	construction material vender	515235	214701	60
7122	6100	Constructora Volio Trejos	construction materials and equipment	514603	216230	21
5233	6200	Indu Muebles Art	furniture vender	515169	214825	
5020	6200	Auto Lavado Chava	car wash	515184	214835	4 (closer to 6)
5219	6200	Vistana este	commercial center	515113	215151	45
5211	6200	Auto Mercado	supermarket	515047	215301	115
5219	6200	Via Lindora	commercial center and offices	514830	215890	100, 450
5050	6200	Texaco	gas station	514684	216079	13
5219	6200	Boulevard Lindora	commercial center	515016	215156	76
5219	6200	Vistana oestre	commercial center	515082	214937	85
5219	6200	Camino a Lindora	Commercial center (7 businesses, one bank)	515168	214825	
5050	6200	Servientro Pozos S.R.L.	gas station	515197	214714	14
5020, 5030	6200	Compañía Mercantil (Grupo Q)	car repair and part sales	515252	214533	20, 80
5211	6200	Comercial Pozos	vendor of food (some wholesale)	515644	214675	31
5020	6200	Reconstructura de Vehiculos (Depozas de Santa Ana S.A.)	reconstruction of past equipment	515496	215300	30
5234	6200	Ronsorcio ferreteros Santa Ana S.A.	importation of articles of hardware	515349	216355	120
5020	6200	Lachuspa	mechanic and paint shop (automobiles)	515289	216155	10
5020	6200	Transportes Ramides Casta	repairing autobuses	514868	216431	10
5020	6200	Gustructora Meco	repairing heavy machinery	514836	216709	25

7499	6200	El Pelon de la Bajura S.A. (Bodegas los Higuerones)	oficinas	515356	215108	50 (175)
5219	6200	Ziruma S.A.	natural marble and stone cutting and selling	513101	213310	20
5239	6200	Mall Santa Ana	commercial center	515336	214144	
5520	6310	Pizza Hut	restaurant	515405	214355	
5520	6310	RostiPollos	restaurant	515402	214386	
5510	6320	Quality Hotel	Hotel	515492	214355	159 hab.
6023	7114	Fhacasa	cookie distribution	514668	216098	14 (?)
6023	7114	Centro Distribucion Wal-Mart Costa Rica	distribution center	515414	216689	418
6023	7114	Distribuidora Comercial Arrozera S.A.	center of distribution of rice	515356	215108	100
6302	7192	Almacén Fiscal Santa Ana	ship materials (agencia de aduanas)	515141	214909	15
6302	7192	Abopac	fertilizer storage and offices	513068	213385	54
9301	9520	DryClean USA Lavandería	dry clean	515073	215271	3
5010, 5020	6200, 9513	Matra	construction machines vender and repair	515221	214985	40, 160
		Parque Empresarial Forum	offices	515035	214221	5500
		Parque Industrial		512095	213525	

Appendix D: English Operating Manuals

Operating Manual for the Implementation of the Online Protocol and the Waste Estimation Model

By Jill Goldstein and Evan May

Online Protocol

With a boost in industries and commercial businesses, it has become necessary for MINAE to stay updated on the economic activities of all companies in Costa Rica. By maintaining an understanding of a company's particular methods of waste disposal, MINAE can evaluate the impact of certain businesses on the environment without conducting on-site interviews. Consequently, an online administered questionnaire has been developed to obtain information directly from companies about their waste management practices.

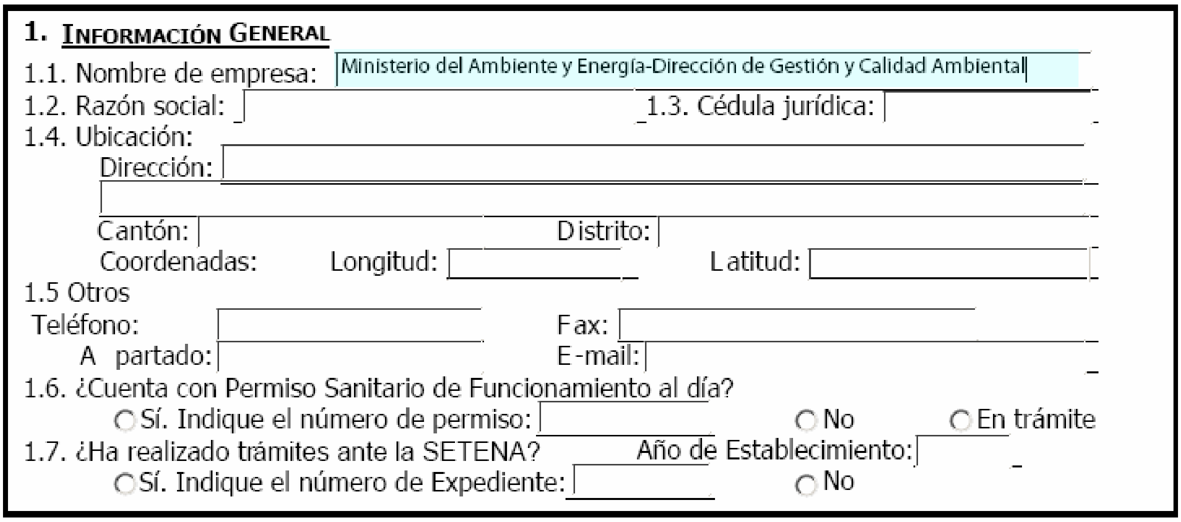
To collect this data from companies in the most optimal way, we have established a set of recommendations, which are outlined below.

Interactive Portable Document Format (PDF)

The first step in the protocol implementation process was to create an interactive PDF. This format allows companies with online access to download the form, fill it out and resubmit it to MINAE on the internet. For companies without internet access, MINAE can use different methods of distributing the form. These options include mailing a hard copy to the companies, sending the form by fax or having printed copies available at the MINAE office for the business representatives to pick up.
. Any data that MINAE obtains can then be uploaded into their existing database.

To use this dynamic form, the end-user must enter the information about his company. We have inserted text fields, numeric fields, check buttons and radio buttons to enhance this data collection. The following figures illustrate this process with more detail.

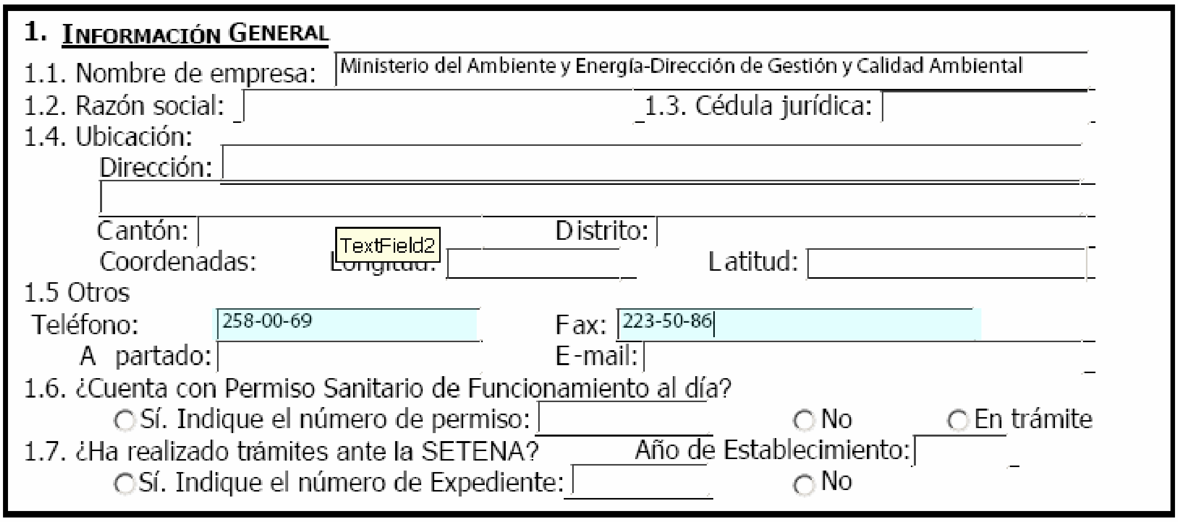
To insert text, the end-user simply clicks on the text field and types in the necessary information, as shown in Figure 1.



1. INFORMACIÓN GENERAL
1.1. Nombre de empresa: Ministerio del Ambiente y Energía-Dirección de Gestión y Calidad Ambiental
1.2. Razón social: 1.3. Cédula jurídica:
1.4. Ubicación:
Dirección:
Cantón: Distrito:
Coordenadas: Longitud: Latitud:
1.5 Otros
Teléfono: Fax:
A partado: E-mail:
1.6. ¿Cuenta con Permiso Sanitario de Funcionamiento al día?
Sí. Indique el número de permiso: No En trámite
1.7. ¿Ha realizado trámites ante la SETENA? Año de Establecimiento:
Sí. Indique el número de Expediente: No

Figure 1: Image of Text Field in Section 1.1

Some fields require a numerical input. For these fields, the end-user simply types in the appropriate numbers, as shown in Figure 2.



1. INFORMACIÓN GENERAL
1.1. Nombre de empresa: Ministerio del Ambiente y Energía-Dirección de Gestión y Calidad Ambiental
1.2. Razón social: 1.3. Cédula jurídica:
1.4. Ubicación:
Dirección:
Cantón: Distrito:
TextField2
Coordenadas: Longitud: Latitud:
1.5 Otros
Teléfono: 258-00-69 Fax: 223-50-86
A partado: E-mail:
1.6. ¿Cuenta con Permiso Sanitario de Funcionamiento al día?
Sí. Indique el número de permiso: No En trámite
1.7. ¿Ha realizado trámites ante la SETENA? Año de Establecimiento:
Sí. Indique el número de Expediente: No

Figure 2: Image of Numerical Field in Section 1.5

We have also inserted check boxes allow the end-user to select any or all of the available options. For example, in Figure 3, question 2.5 asks for the time of peak production during the year. In response, the user can check off a combination of months or ¨todo el año.¨

2.5. Jornada de producción

Temporada de producción: ☐ Todo el año

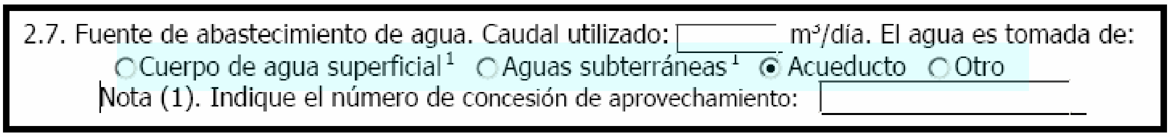
☒ Enero	☒ Febrero	☒ Marzo	☒ Abril	☐ Mayo	☐ Junio
☐ Julio	☐ Agosto	☐ Setiembre	☐ Octubre	☒ Noviembre	☒ Diciembre

Horas de trabajo al día: ____ Días de trabajo al mes: ____

Mes de mínima producción: ____ Mes de máxima producción: ____

Figure 3: Image of Check Boxes in Section 2.5

For questions requiring mutually exclusive responses, we have inserted radio buttons. This option will allow the end-user to select only one response from the group, as displayed in Figure 4.



2.7. Fuente de abastecimiento de agua. Caudal utilizado: ____ m^3/día. El agua es tomada de:

○ Cuerpo de agua superficial [1] ○ Aguas subterráneas [1] ◉ Acueducto ○ Otro

Nota (1). Indique el número de concesión de aprovechamiento: ____

Figure 4: Image of Radio Buttons in Section 2.7

PDF Accessibility Options

Our first suggestion is for MINAE to develop a website made specifically for this protocol. By making the interactive PDF available on their website, business representatives can download the form and resubmit it to MINAE. The only program that the end-user must have is Adobe® Reader®, which allows a PDF to be read. We also suggest that MINAE create a statement of purpose available on the website to illustrate the overall goal of the protocol. This statement should outline how the data will be interpreted and further used. Additional documents about cleaner production and environmental audits can also be added to enrich the content of the website.

Integration with Existing Database

The next step in fully implementing the online protocol is to integrate the protocol with the existing database at MINAE. Currently, MINAE uses a MySQL database on Microsoft Access and imports this data via Microsoft Excel. Therefore, since the data from the PDF can be extracted in Microsoft Excel, we suggest that MINAE integrate the PDF with Excel for easy data transfer. As a result, the end-user should ideally access the PDF from the MINAE website, fill out the form online and submit it to MINAE.

Username/Password System

Our final recommendation is for MINAE to create a username/password system on their website. This system will allow the business representatives to access their submitted information and make any necessary updates as they occur. After resubmitting the form, MINAE can access the updated information and load it into their database.

Waste Estimation Model

To implement the waste estimation model that we have suggested, the following steps will need to be taken. All of these suggestions take place within the main MINAE Excel workbook which contains all of the information for the several thousand businesses MINAE currently has. Several columns will need to be added for the ratios and estimations. To calculate these ratios, the first cell should be selected, and the following formula should be inputted: waste / number of employees, as seen in Figure 1.

SUMA =C2/B2

	A	B	C	D	E
1	**ISIC Code**	**Num. of Employees**	**Actual DBO**	**Ratio DBO/Employees**	**Estimated**
2	3114	20	4,0158	=C2/B2	
3	3114	10	1,9021		
4	3114	15	1,9921		
5	6200	50	4,5892		
6	6200	65	5,6621		
7	6200	20	1,9981		
8	6200	40	5,2210		

Figure 1: Creating Waste to Employee Ratios

The "waste" input can be any type of measurement, whether it is DBO, DQO, SST, or another technique; however, it is important that both of the inputs be to the cells where the information is stored, not the information itself. In this example, we are using the DBO measurement. By selecting the cells, instead of inputting the information, this will allow the next step to function properly. The Fill Handle, the small black box located in the lower right hand corner of the cell, should be clicked on and dragged for the entire column. This will expand the formula to the rest of the cells within the column, while properly reflecting the information specific to each row, as can be seen in Figure 2.

D2 =C2/B2

	A	B	C	D	E
1	ISIC Code	Num. of Employees	Actual DBO	Ratio DBO/Employees	Estimated
2	3114	20	4,0158	0,2008	
3	3114	10	1,9021	0,1902	
4	3114	15	1,9921	0,1328	
5	6200	50	4,5892	0,0918	
6	6200	65	5,6621	0,0871	
7	6200	20	1,9981	0,0999	
8	6200	40	5,2210	0,1305	

Figure 2: Dragged Fill Handle

Once the ratios for the individual businesses have been computed, the average ratio for each industry should be calculated. This should be done in a separate worksheet to allow for easier manipulation and reading, as seen in Figure 3.

B3 =(Hoja1!D5+Hoja1!D6+Hoja1!D7+Hoja1!D8)/4

	A	B	C	D	E
1	ISIC Code	Average Ratio			
2	3114	0,1746			
3	6200	0,1023			

Figure 3: Created Estimates in Separate Worksheet

After this has been done, in the worksheet with the individual business information the user should enter a formula to multiply the industry ratio (matching the type of industry that it is) by the number of employees that the business has. Once again, this should be done by cell identifiers and not the numbers themselves. The Fill Handle should then be dragged down the column to the rest of the businesses within the same CIIU code. This will then have to be repeated for each individual industry type to reflect the different ratios for each. This can be seen below in Figure 4.

E8 | =Hoja2!B3*Hoja1!B8

	A	B	C	D	E
1	ISIC Code	Num. of Employees	Actual DBO	Ratio DBO/Employees	Estimated
2	3114	20	4,0158	0,2008	3,4920
3	3114	10	1,9021	0,1902	1,7460
4	3114	15	1,9921	0,1328	2,6190
5	6200	50	4,5892	0,0918	5,1165
6	6200	65	5,6621	0,0871	6,6515
7	6200	20	1,9981	0,0999	2,0466
8	6200	40	5,2210	0,1305	4,0932

Figure 4: Created Estimations

Each time a new business is added, the fill handle for another business of the same type can simply be dragged down, and the numbers will automatically update themselves. This will be true for the both the individual and the average business ratios as well as the estimations for the businesses. Also, normally the estimations would be done for businesses where the real data is not known; however, the steps would be the same in either case. By utilizing this method, MINAE will be able to easily and quickly compare the information that they have gathered or received to the estimations that the technique produces.

Appendix E: Spanish Operating Manuals

Manual de Instrucción para la Puesta en Práctica del Protocolo en Línea y El Modulo para la Estimación del Volumen de Desechos Industriales

By Jill Goldstein and Evan May

Protocolo en Línea

Conforme se incrementa el número de industrias y empresas en el país, MINAE necesita estar al corriente acerca de las actividades económicas de todas las compañías en Costa Rica. En particular MINAE necesita conocer los métodos de disposición de los deshechos industriales de las empresas para poder determinar el nivel del impacto ambiental derivado de su operación. Esta información se obtiene en general a través de visitas a las empresas conducidas por MINAE. Sin embargo el proceso de adquisición de información se puede agilizar por medio del uso de los medios públicos electrónicos como lo es el INTERNET. Es por esa razón que se desarrollado un cuestionario en línea.

A continuación se describe los procedimientos que se proponen para recabar esta información directamente en forma electrónica.

Implementación del Protocolo en Línea

Nuestra primera sugerencia para MINAE es el de crear una pagina web exclusivamente dedicada al manejo de información relacionada con este protocolo. Con esto se facilitaría el acceso a un documento electrónico interactivo en formato PDF en el cual se propone capturar la información relacionada con las empresas. Al tener el documento electrónico interactivo disponible en la página web de MINAE las empresas podrán descargarlo directamente del INTERNET, llenarlo y retransmitirlo en forma electrónica a MINAE. El usuario solamente necesita tener el programa Abobe® Reader® para esta operación. También, se le sugiere a MINAE que el portal de la página web contenga una declaración manifestando el propósito fundamental de esta página web. Esta declaración deberá informar claramente al usuario acerca del uso presente y futuro de la información. Documentos adicionales sobre producción más limpia y otras condiciones ambientes pueden agregarse en un futuro también para enriquecer el contenido de la página web.

Integración con el Baso de Datos Existente

El paso siguiente en la implementación electrónica del protocolo consiste en integrarlo con la baso de datos existente de MINAE. Actualmente, MINAE usa una base de datos MySQL en Microsoft Access a la cual se le puede importar información creada originalmente en Microsoft Excel. La información que las empresas suministraran electrónicamente a MINAE usa el formato PDF el cual permite transferencia electrónica al formato XLS de Microsoft Excel. Por lo tanto nuestra sugerencia es que MINAE integre el protocolo con Excel para que se facilite la transferencia de información a la base de datos.

Sistema de Usuario y Contraseña

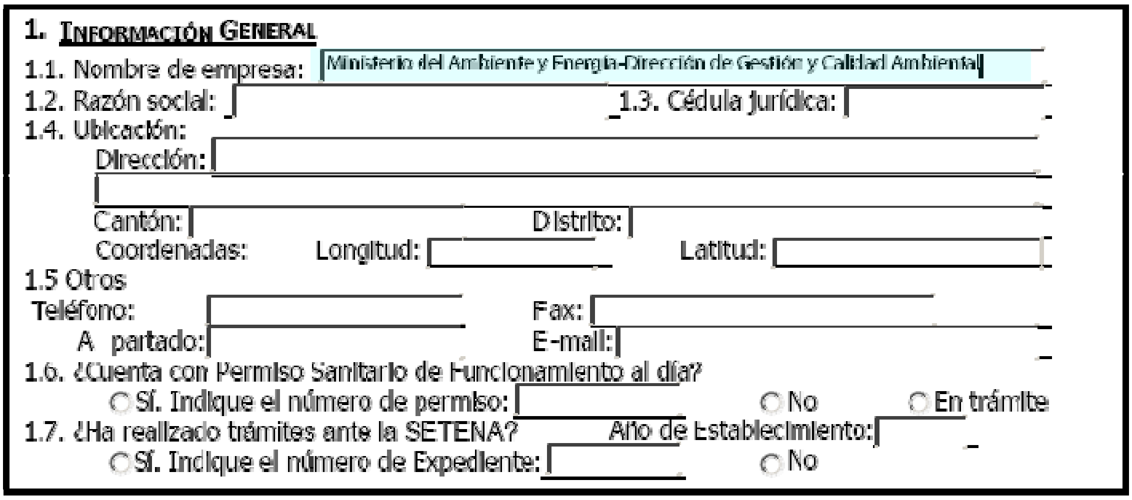
Nuestra recomendación final para MINAE es crear un sistema protección al usuario y a la página web de MINAE a través de contraseña personal. Este sistema permite las representaciones empresas acceso su información y hace actualizaciones cuando necesario. Después de someto la forma, MINAE puede acceso la información nueva y pone en su baso de datos.

Uso de Documento Electrónico Interactivo en Formato PDF (Portable Document Format)

El primer paso para poner en práctica el protocolo consiste en crear un documento electrónico interactivo en formato PDF. Este formato permitirá que las compañías que tienen acceso al INTERNET puedan copiar o descargar el documento en su propio computador, llenar la forma contestando a las preguntas, guardar una copia, y remitirlo directamente en forma electrónica a MINAE. Para aquellas empresas que no tienen acceso al INTERNET, MINAE puede enviar la forma directamente a la empresa por correo tradicional, transmitirla por FAX o tener copias impresas disponibles en sus oficinas para que los representantes de las empresas las puedan obtener. Toda la información que obtenga MINAE en una forma u otra se deberán almacenar en la base de datos que MINAE tiene a creado para este propósito.

El documento electrónico PDF se ha diseñado en tal forma que facilite al usuario la entrada de datos en forma electrónica. La forma cuenta con campos de texto, campos numéricos, botones de verificación y botones de radio. La figura siguiente ilustra el proceso del llenado de la forma en más detalle.

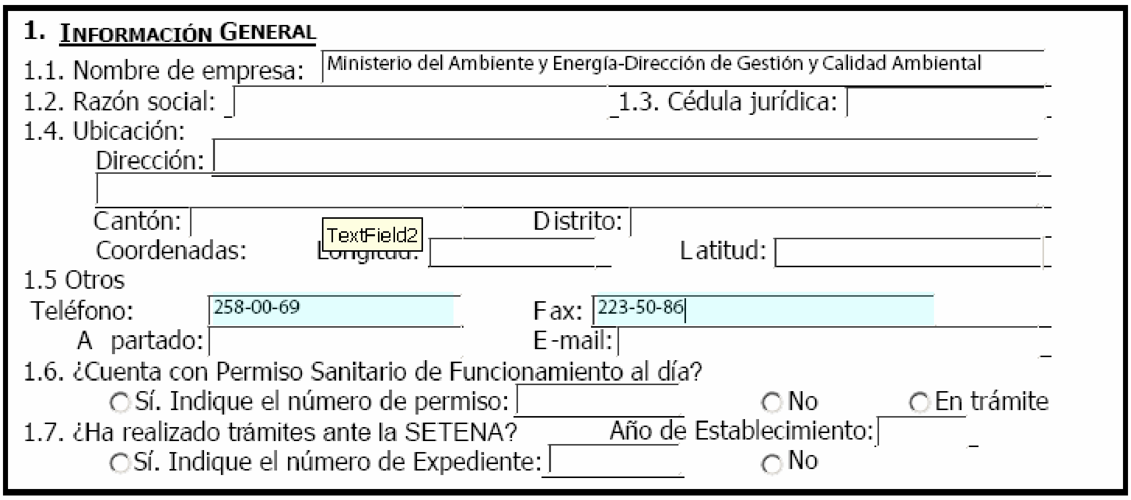
Para insertar texto, el usuario simplemente coloca el cursor sobre el campo correspondiente, aprieta clic y proporciona la información directamente en el teclado del computador. La Figura 1 muestra un ejemplo del llenado del campo correspondiente al "Nombre de la Empresa"



1. INFORMACIÓN GENERAL
1.1. Nombre de empresa: Ministerio del Ambiente y Energía-Dirección de Gestión y Calidad Ambiental
1.2. Razón social: 1.3. Cédula jurídica:
1.4. Ubicación:
Dirección:
Cantón: Distrito:
Coordenadas: Longitud: Latitud:
1.5 Otros
Teléfono: Fax:
A partado: E-mail:
1.6. ¿Cuenta con Permiso Sanitario de Funcionamiento al día?
Sí. Indique el número de permiso: No En trámite
1.7. ¿Ha realizado trámites ante la SETENA? Año de Establecimiento:
Sí. Indique el número de Expediente: No

Figura 1: Ejemplo de un Campo de Texto: "Nombre de la Empresa"

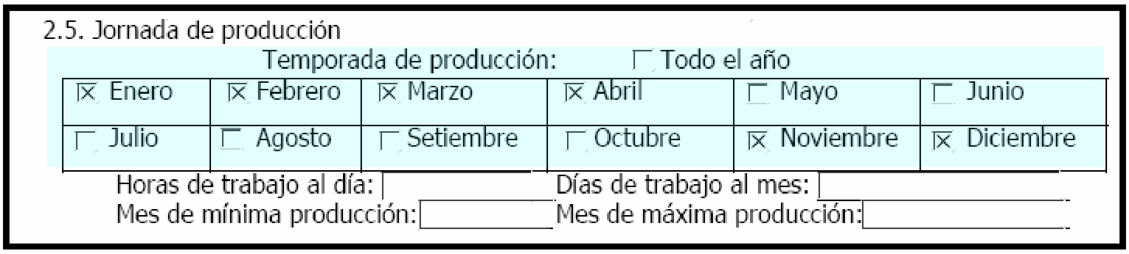
Algunos campos requieren información numérica. Para insertar un número, el usuario simplemente coloca el cursor sobre el campo correspondiente, aprieta clic y proporciona la información directamente en el teclado del computador. La Figura 2 muestra un ejemplo del llenado del campo correspondiente al "Numero de FAX"



1. INFORMACIÓN GENERAL
1.1. Nombre de empresa: Ministerio del Ambiente y Energía-Dirección de Gestión y Calidad Ambiental
1.2. Razón social: 1.3. Cédula jurídica:
1.4. Ubicación:
Dirección:
Cantón: Distrito:
Coordenadas: TextField2 Latitud:
1.5 Otros
Teléfono: 258-00-69 Fax: 223-50-86
A partado: E-mail:
1.6. ¿Cuenta con Permiso Sanitario de Funcionamiento al día?
Sí. Indique el número de permiso: No En trámite
1.7. ¿Ha realizado trámites ante la SETENA? Año de Establecimiento:
Sí. Indique el número de Expediente: No

Figura 2: Ejemplo de un Campo de Números: "FAX"

Cuando existen varias opciones para la entrada de datos, la forma cuenta con botones que le permiten al usuario seleccionar las opciones deseadas. Por ejemplo, la Figura 3, muestra todas las opciones que han sido seleccionadas señalando los meses específicos en los cuales se tienen jornadas de producción. Alternativamente el usuario puede elegir la opción correspondiente a todo el año.



2.5. Jornada de producción

Temporada de producción: ☐ Todo el año

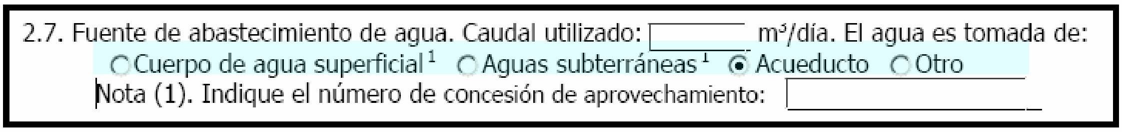
☒ Enero	☒ Febrero	☒ Marzo	☒ Abril	☐ Mayo	☐ Junio
☐ Julio	☐ Agosto	☐ Setiembre	☐ Octubre	☒ Noviembre	☒ Diciembre

Horas de trabajo al día: ____ Días de trabajo al mes: ____

Mes de mínima producción: ____ Mes de máxima producción: ____

Figura 3: Ejemplo del Uso de Botones para Selección de Alternativas: "Jornada de Producción"

Para las preguntas que requieren las repuestas que tengan opciones que son mutuamente exclusivas, se han creado botones de radio. Esta opción permite el usuario seleccionar una repuesta de entre todas las opciones disponibles según lo muestra la Figura 4.



2.7. Fuente de abastecimiento de agua. Caudal utilizado: ____ m³/día. El agua es tomada de:

○ Cuerpo de agua superficial [1] ○ Aguas subterráneas [1] ◉ Acueducto ○ Otro

Nota (1). Indique el número de concesión de aprovechamiento: ____

Figura 4: Ejemplo del Uso de Botones de Radio: "Fuente de Abastecimiento de Agua"

El Modulo para la Estimación del Volumen de Desechos Industriales

Para la implementación del modulo para la estimación del volumen de deshechos industriales generado por las empresas que nosotros hemos desarrollado se sugieren varios pasos a ejecutar. Estos pasos se enmarcan en el contexto del diseño de la hoja de trabajo creada en Excel para MINAE, la cuál contiene información detallada sobre miles de empresas recopilada anteriormente por MINAE. Para lograr esta adaptación se requiere el agregar varias columnas al formato actual de la hoja de trabajo para que se almacenen los cocientes y las valoraciones calculados por el modulo. Para calcular estos cocientes, la nueva celda en la columna agregada debe ser seleccionada, y la formula siguiente debe registrarse: basura / número de empleados (Ratio DBO/Empleados) según se ilustra en la Figura 1

SUMA =C2/B2

	A	B	C	D	E
1	ISIC Code	Num. of Employees	Actual DBO	Ratio DBO/Employees	Estimated
2	3114	20	4,0158	=C2/B2	
3	3114	10	1,9021		
4	3114	15	1,9921		
5	6200	50	4,5892		
6	6200	65	5,6621		
7	6200	20	1,9981		
8	6200	40	5,2210		

Figura 1: Ejemplo: Crear el Cociente "Basura / Numero de Empleados"

La variable "basura" puede ser medida en cualquier tipo de unidades ya sea DBO, BQO, SST, u otra variable técnica (en este caso se ha usado DBO). Sin embargo, es muy importante que en la celda se registre la formula de calculo en función de la información que ya existe en otras columnas y no los valores que resultan del calculo del cociente. De esta manera se incrementa el nivel de automatización de la hoja de calcula y se previenen los errores. Una vez que la formula para calcular el cociente se ha registrado en la primera celda, se deberá de copiar y pegar este registró en el resto de las celdas de la nueva columna. Para esto coloque su cursor en la esquina inferior derecha de la celda hasta que aparezca el signo +, en ese momento apriete el botón izquierdo de su "Mouse" y arrástrelo hacia abajo hasta abarcar el rango de todas las celdas con información. Al finalizar, deje de oprimir el botón del "Mouse". Vera usted aparecer los cocientes calculados correspondientes a todas las hileras de la hoja de trabajo como se ve en la Figura 2.

D2 =C2/B2

	A	B	C	D	E
1	ISIC Code	Num. of Employees	Actual DBO	Ratio DBO/Employees	Estimated
2	3114	20	4,0158	0,2008	
3	3114	10	1,9021	0,1902	
4	3114	15	1,9921	0,1328	
5	6200	50	4,5892	0,0918	
6	6200	65	5,6621	0,0871	
7	6200	20	1,9981	0,0999	
8	6200	40	5,2210	0,1305	

Figura 2: Ejemplo: Copiar y Pegar Formula de Cocientes.

Después de calcular los cocientes correspondientes a cada empresa listada en la hoja de trabajo se puede proceder a calcular el cociente promedio por tipo de empresa. Esto se deberá hacer en una hoja de trabajo separada con el objeto de hacer su lectura más fácil, se como se ilustra en la Figura 3.

B3 | =(Hoja1!D5+Hoja1!D6+Hoja1!D7+Hoja1!D8)/4

	A	B	C	D	E
1	ISIC Code	Average Ratio			
2	3114	0,1746			
3	6200	0,1023			

Figura 3: Ejemplo: Cociente Promedio por Tipo de Empresa

Después de esta operación, el usuario debe regresar a la hoja original y para calcular el volumen de deshecho generado por cada empresa en función del tipo de empresa y del número de empleados. Para esto el usuario deberá registrar la formula que señala el producto del cociente de la empresa (el mismo cociente para el tipo de empresa que se obtuvo en la hoja que se muestra en la Figure 3) con el número de empleados que la empresa tiene. Se recuerda que el registro de la celda se debe hacer con en base a las formulas y no en base a los valores numéricos calculados. Una vez que se ha registrado la formula copie y pegue el resto de la formula en cada una de las celdas correspondientes a las empresas que tiene el mismo código CIIU (ISIC code en la Figura) en la misma forma que se explico anteriormente (ver Figura 2) Esto se tendrá que repetir para cada grupo de empresas del mismo tipo. Como se puede ver en la Figura 4, los valores estimados para cada empresa deberán ser diferentes.

E8 | =Hoja2!B3*Hoja1!B8

	A	B	C	D	E
1	ISIC Code	Num. of Employees	Actual DBO	Ratio DBO/Employees	Estimated
2	3114	20	4,0158	0,2008	3,4920
3	3114	10	1,9021	0,1902	1,7460
4	3114	15	1,9921	0,1328	2,6190
5	6200	50	4,5892	0,0918	5,1165
6	6200	65	5,6621	0,0871	6,6515
7	6200	20	1,9981	0,0999	2,0466
8	6200	40	5,2210	0,1305	4,0932

Figura 4: Valoraciones Creadas

La hoja de cálculo se deberá actualizar cada vez que una nueva empresa se agrega a la lista. Deberá también actualizarse el promedio por empresa y deberá tenerse cuidado de que exista una correspondencia entre el tipo de empresa y su valor promedio. En el caso en que los estimados de volumen de deshechos industriales se hagan para empresas cuya información real no se ha capturado, el procedimiento de cálculo será el mismo. De esta manera MINAE podrá comparar fácilmente la información generada con datos proporcionados por la empresa con aquellos en los cuales se hace solamente una estimación.

Appendix F: English Cleaner Production Brochure

Success Stories

Information about the stores that MINAE implemented our suggestions at, specifically about what they did and how much money they saved, will go here after they have gathered this information.

Client Satisfaction

Clients have become much more environmentally aware in the recent years, choosing to use their money at stores that have shown a concern for the environment as well. Through promotion of your efforts to recycle, you can attract new customers to your store, while maintaining those customers that you already have.

This brochure was made possible by:

Worcester Polytechnic Institute

Ministerio del Ambiente y Energía
Dirección de Gestión y Calidad
Address
Phone: 506-233-4533
Fax: 506-223-50-86
Digeca@minae.go.cr

Waste Prevention and Reduction for Commercial Centers

Problem

Waste management has become a large concern for Costa Rica. Throughout its economic growth, waste practices have grown quickly to respond; however, at the moment, much of the waste that can be recycled is disposed of in other methods, whether it be in landfills or through illegal means.

Goal

Through both waste reduction and proper waste disposal, commercial centers can have a huge impact on the use of landfill space and natural resources.
* For each ton of paper recycled, 17 trees, 7,000 gallons of water, and 60 pounds of pollutants are saved.
* For each ton of plastic recycled, one third of the energy used to produce plastic is saved.

Waste Management

Paper
* Amanco Fábrica
  25/Kg. 551-0886
* Euroaméria Fábrica
  10-25/Kg. 843-0682
* Kimberly Clark
  10-20/Kg. 298-3100

Cardboard
* Intermediario
  15-50/Box 237-6098
* Reutilización
  15-70/Box 380-5959
* Cajas Quirós y Retana Reutilización
  40/Box 233-0210

Plastic Bags
* Reutilización
  350/Kg. 380-5959
* PRODUCOL Fábrica
  15-40/Kg. 848-9412

Waste Reduction

Paper
* Make double sided copies
* Turn used paper into scratch pads
* Set up recycling bins to separate paper waste

Packaging
* Request that shipped materials come in returnable containers
* Reduce packaging layers
* Reuse foam peanuts, bubble wrap, and boxes
* Use shredded paper as packaging material

Appendix F: Spanish Cleaner Production Brochure

Casos del Éxito

Este espacio del folleto se dedicara a dar información sobre las tiendas en las que MINAE a puesto en practica nuestras sugerencias señalando acciones y beneficios económicos una vez que se haya recopilado esa información.

Satisfacción del Cliente

Los clientes han sido mucho más ambientalmente enterados en los años recientes, eligiendo utilizar su dinero en los almacenes que han demonstrado una preocupación por el ambiente también. Con la promoción de sus esfuerzos de reciclar, usted puede atraer a nuevos clientes a su almacén, mientras que mantiene a esos clientes que usted tenga ya.

Este folleto fue elaborado por:

WPI

Worcester Polytechnic Institute

MINISTERIO DEL AMBIENTE Y ENERGIA -MINAE-

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Reducción y Manejo de Desecho para los Centros Comerciales

MINISTERIO DEL AMBIENTE Y ENERGIA -MINAE-

El Problema

La gestión de desechos se ha convertido en una gran preocupación para Costa Rica. A través del desarrollo económico, del pais se han creado prácticas para el manejo de desechos; sin embargo, no se ha logrado el reciclaje total de muchos de los desechos y estos se envian a los tiraderos de basura o se eliminan por medios ilegales.

El Objetivo

A traves de la reducción de desechos y de la disposición apropiada de estos, los centros comerciales pueden tener un impacto significativo en la mejora del ambiente y en la preservación de los recursos naturales.

* Por cada tonelada de papel reciclado, se ahorran: 17 árboles, 1,850 litros de agua, y 27 kilogramos de agentes contaminantes.
* Para cada tonelada de plástico reciclada, se ahorra un tercio de la energía usada para su produccion

Gestión de Desechos

Papel

* Amanco Fábrica
  25/Kg. 551-0886
* Euroaméria Fábrica
  10-25/Kg. 843-0682
* Kimberly Clark
  10-20/Kg. 298-3100

Cartulina

* Intermediario
  15-50/Caja 237-6098
* Reutilización
  15-70/Caja 380-5959
* Cajas Quirós y Retana Reutilización
  40/Caja 233-0210

Bolsos Plásticos

* Reutilización
  350/Kg. 380-5959
* PRODUCOL Fábrica
  15-40/Kg. 848-9412

Reducción de Desechos

Papel

* Haga fotocopias usando ambos lados de la hojas
* Utilize el papel usado como borrador
* Suministre cestos de basura adicionales para disponer del papel usado.

Empaquetado

* Solicite que los materiales enviados vengan en cajas reciclables o retornables.
* Evite el uso innecesario de material de protección
* Reutilice las cajas y materiales de protección como son plásticos con burbujas de aire y espuma de poli estireno
* Utilice el papel de desecho como material de empaquetado