Implementing a Sustainable Watershed Strategy
in San Cristóbal de las Casas

Matt Elke
Karen Setty
Dayna Yocum
Deborah Glaser
Daniel Sussman

Advisor: Arturo Keller, PhD
Abstract:

The city of San Cristóbal de las Casas, located in the central highlands of Chiapas, Mexico is the cultural and economic center for a predominantly rural population of descendents of the Mayan culture. The city has experienced major population expansion, caused in part by the sociopolitical upheaval of the last two decades. In addition to population growth pressures, the future water supply to San Cristóbal is being compromised by changing land use and an insufficient understanding of sustainable water resource management. An analysis of the San Cristóbal area was performed by a Bren School group project from 2005-2006. This led to a number of specific recommendations including watershed best management practices, or BMPs. The first goal of this year’s project seeks to implement these recommendations. Working with our partners in Mexico, we aim to construct several BMP pilot projects to improve water quality and quantity, while protecting supply. As a second goal, the BMPs will be evaluated under a continuous water monitoring program developed for the San Cristóbal watershed, which tracks both chemical and microbiological parameters. A third goal of our project will be to create and implement an educational campaign to increase awareness of the link between water and health, and the benefits of protecting water resources. Interviews of local residents will serve as a benchmark for the structure and effectiveness of the educational program. Finally, using GIS and remote sensing data, we will conduct an analysis of ideal locations for reforestation within the region, which will be used by our partners to begin a reforestation program. These measures will enhance the sustainable utilization of water resources while improving access to safe water for local communities. This implementation project may serve as a model to extend to other communities in developing regions that face similar water resources issues.

Objectives:

The principal objective of this project is to design and implement sustainable programs for the San Cristóbal de las Casas watershed with regard to the environment and human needs. The main goals are to:

- Design and implement several pilot projects utilizing best management practices for water capture and treatment, as well as protecting the water resources;
- Implement a long-term water quality and quantity monitoring program, with a particular emphasis on increasing the accuracy of pathogen monitoring;
- Create a program to educate community members on the effects of poor sanitation and contaminated drinking water, and the benefits of watershed protection;
- Identify ideal locations for a reforestation program.

Significance:

This project will draw upon research information generated by last year’s Bren School group project “Developing a sustainable water resources management plan for San Cristóbal de las Casas, Chiapas.” This earlier work produced knowledge surrounding the hydrology of the area, water use, and options for improving water quality. Collaborations between UCSB and researchers at an academic institution in Chiapas, Mexico have already been initiated. By proceeding into the second phase of the project, we plan to make those collaborations stronger, and to provide local capacity to carry forward long term implementation of a sustainable plan for managing this watershed.
San Cristóbal’s plight is not unique. Sustainable watershed management is a major issue for many communities, particularly in areas experiencing rapid population growth. Because of inadequate infrastructure, management, and sanitation, over one billion people – nearly 20% of the world’s population – lack access to clean drinking water (UN 2006). The United Nations set a millennium development goal to cut that number in half by 2015. Our research will contribute to progress in this realm, and may serve as an example to other similar communities.

**Background information:**

**Study Area:**

Chiapas trails other Mexican states in many quality of life and economic indicators. Despite being one of the wettest regions in Mexico it also ranks below the national average in access to potable water and sewer development. Although the city is located in a rain forest environment, the water supply for many of the citizens of San Cristóbal and the surrounding villages becomes sporadic during the dry season (from December to May). Sociopolitical upheaval over the last two decades has also brought many peasants into the city, expanding the city’s population by as much as 20%. As a result, the city’s water supply is under increased strain, and is insufficient to meet the needs of the growing population. There is anecdotal evidence that basin storage and recharge have diminished from their previous levels, and will continue to decline if no action is taken to relieve the increased stress on the aquifer. Meanwhile, an incomplete sewage collection system and the lack of wastewater treatment facilities, and the loading of excess nutrients and pesticides from the surrounding fields results in poor water quality in certain parts of the watershed. Adequate protection of water supply is needed, both in terms of quality and quantity. In short, the future of San Cristóbal’s water supply is being compromised by population growth, changing land use, and an insufficient understanding of the water dynamics.

**Figure 1.** San Cristóbal watershed, showing the location of major rivers and streams running through the basin (in orange). The area in gray encompasses the SAPAM (Municipal Potable and Waste Water Utility) service area, including downtown San Cristóbal, as well as the communities in the periphery and in the floodplain. Some additional small communities within the watershed are identified (Chamula, La Candelaria, and Piedrecitas).

**Stakeholders:**

The stakeholders involved in this project include researchers from UCSB and El Colegio de la Frontera del Sur (ECOSUR), as well as partners from Skolta’el Yu’un Jlumaltic, A.C. (SYJAC) and the SAPAM Advisory Board. The partners are described below.
UCSB – At the University of California, Santa Barbara, five Master’s students from Bren School of Environmental Science and Management class of 2007 are currently involved in the analysis and implementation of water resources best management programs in San Cristóbal, and will be assisted by researchers from the Bren School and the Department of Geology. An additional six graduate students (class of 2006) from the Bren School MESM program participated in the project previously.

ECOSUR – El Colegio de la Frontera Sur is a publicly chartered research institution providing research and post-graduate education focused primarily on the development and linkage of Mexico’s southern-most states. ECOSUR maintains five campuses, including a campus in San Cristóbal. Jesus Carmona and Alejandro Flamenco are our primary contacts. Collaborators at ECOSUR participate with this project in both a research and logistical capacity. They help to implement water treatment programs, water quality analysis, and long-term monitoring. ECOSUR will be conducting continued water monitoring at points identified by last year’s research group.

SAPAM Advisory Board – Servicio de Agua Potable y Alcantarillado Municipal, or Municipal Potable and Waste Water Utility, is responsible for “implementing potable and waste water services, and conducting studies and improvements for the operation, administration and conservation of the water supply in the municipality of San Cristóbal.” The Advisory Board is a citizen-staffed, citizen-elected board in charge of administrating the actions of SAPAM and ensuring public participation and consensus with the activities of the organism.

SYJAC – Skolta’el Yu’un Jlumaltic, A.C. is a nonprofit organization based in Mexico, whose objective is to support community empowerment and improved quality of life in the indigenous communities around San Cristóbal. SYJAC regularly participates in the execution of sustainable works projects in indigenous communities, including potable water supply and auto-digesting latrines. The director of SYJAC is Sabas Cruz Garcia, who serves as our primary contact.

Results of Previous Group Project:

As part of the initial assessment, the previous research team interviewed many citizens in San Cristóbal, including five distinct Groups: (1) people in the downtown area, which generally have access to SAPAM’s water supply on a regular basis and which are served by SAPAM’s sewer infrastructure; (2) people who live in the 10-15 year-old barrios surrounding the periphery, who have access to intermittent water supply from SAPAM and who are slowly being connected to the sewer infrastructure; (3) people who recently moved to the periphery and low-lying wetland areas, who do not have water supply or sewer infrastructure because they do not own the land and are in “irregular” settlements¹; (4) people in larger communities (e.g. Chamula) who live in the higher elevations within the watershed, and who use some groundwater wells and surface water supplies to meet their needs, but discharge their sewage into the streams that drain down to San Cristóbal; and (5) people in smaller communities that have very small wells, used some surface waters, and generate nutrient, pathogen and pesticide loads in the higher elevations.

The people from Group 1 were mostly concerned with the pricing of water, particularly if a wastewater treatment plant is installed and their rates are increased to recover the cost of operation. They are somewhat concerned with the lack of water at the end of the dry season, but generally can afford bottled water and/or delivery trucks (pipas) that bring in water to their

¹ People in the 10-15 year group have been receiving property rights in part due to the efforts of SYJAC.
storage systems (cisternas). Those in Group 2 were much more concerned with the lack of regular supply, and are actually willing to help pay for the cost of the system(s) if they can receive regular supply and have a working sewer system; they can generally afford to buy some bottled water or sodas, but it represents a significant fraction of their income (up to 20%). People in Group 3 are extremely anxious about the water supply situation; they use contaminated water from the streams and wetlands for most of their needs and can barely afford bottled water for their drinking needs. Individuals in Groups 4 and 5 spend a significant fraction of time obtaining water and have poor sanitation; they only purchase soda drinks sporadically.

One important finding of this survey was the lack of understanding regarding the connection between poor water quality and endemic gastrointestinal diseases for all groups. In addition, a large portion of each group was not familiar with what we consider “Best Management Practices” (BMPs) in the US, with regards to water supply, water conservation, sanitation, proper use and disposal of fertilizers and pesticides, etc. In conversations with members of SAPAM’s Advisory Board, we also found out that although the Comisión Nacional del Agua (CNA) has provided options for wastewater treatment, some basic understanding of how each of these options differs in feasibility, land requirements, cost, etc. was needed at the local level.

The initial assessment of the situation thus proceeded along four directions, with the overall objective of developing a management plan for a sustainable watershed. First, biogeophysical information, such as topography, soils, vegetation, river network, demographics, land use, roads, climate, location of drinking wells, current sewer infrastructure, etc. was obtained through interactions with various researchers at ECOSUR, as well as from SAPAM. This information was used to develop a numerical watershed model (using the program WARMF) specific for the watershed of San Cristóbal, which could then be used to understand large scale hydrology, as well as the local hydrological situation near the various water supply wells, temporally and spatially. The model runs at a daily time step, and we currently have 11 years of precipitation data and other meteorological parameters needed for simulation. The model enables the assessment of the effects from additional pumping, decreasing wetlands, changes in land use, installation of the sewer infrastructure, etc. The biogeophysical information is now available electronically to all researchers in ECOSUR and UCSB working on the project, as Geographical Information Systems (GIS) files.

Second, a preliminary water quality and quantity monitoring program was developed and implemented. In this first year, simple analytical methods were first used to establish background concentrations in mostly clean rivers and streams, as well as the levels of contaminants (e.g. nitrogen as ammonia or nitrate, phosphate, pathogens) in areas where human activity generates significant loads. This work also served to verify and pre-calibrate the watershed model with regards to hydrology. Once funding became available, a Hach DR850 Portable Colorimeter was purchased for use by ECOSUR to obtain data on up to 50 chemical parameters at a level of accuracy that would be appropriate for management decisions. Training of ECOSUR personnel by the UCSB researchers was conducted in December 2005 and March 2006 (Figure 2). Based on this preliminary assessment, a more complete water quality and quantity monitoring program was developed, with 14 sites around the entire watershed, to be monitored weekly to monthly for nitrogen compounds, phosphate, dissolved oxygen, pH, temperature, conductivity and pathogens. ECOSUR’s water quality monitoring data collected during the year will be input into the WARMF model to increase its accuracy. At present, ECOSUR has only very simple analytical tools to monitor pathogens, using reagent kits from Hach.
The third part of the analysis dealt with the options for wastewater treatment. A number of alternatives were evaluated including constructed wetlands, intermittent filters, aerated lagoons, and conventional wastewater treatment plants. The evaluation included an analysis of feasibility, cost, land requirements, location(s), sewer infrastructure needed, etc. This information was transmitted in a presentation to personnel from SAPAM and ECOSUR in March 2006. The information is still at a pre-design stage, but allows them to understand better the advantages and disadvantages of the various options. Stakeholders are now able to evaluate their alternatives as they negotiate with CNA for the best way to solve the wastewater treatment problem affecting 80% of the people in the watershed (those in Groups 1-3).

Finally, the fourth component of the analysis involved determining potential solutions to water supply and water quality concerns for Groups 4 and 5, as well as some people in Group 3. These are citizens of the watershed which are unlikely to be served by SAPAM in the next few decades, because they are too far away to be connected to the municipal water supply or the sewer infrastructure. However, as mentioned before, these people are most concerned with their water supply, and have a significant impact on water quality of the rivers entering the city, and can impact the current sources of supply for 80% of the people in the watershed. Several solutions (BMPs) were identified as particularly applicable, chosen for feasibility, low cost, ease of maintenance, acceptability, etc. These include (1) Rainwater capture, filtration and storage at the household to community level; (2) Contour trenches for agriculture, to reduce the migration of fertilizers and pesticides from the fields to the rivers; (3) Riparian zone vegetation buffer zones, to provide filtration of nutrients and sediments that migrate out of the fields towards the rivers; (4) Composting latrines, to reduce the amount of human waste load that impacts the rivers; (5) Retention and/or recharge basins, to capture surface runoff for a short time to allow for reduced flooding and higher groundwater recharge. Other options are still under consideration by the entire research team and SYJAC. In addition, it became clear that an educational campaign at various levels would be extremely useful, as described in more detail below.

The next phase of the project is to move from the planning stage to on-the-ground implementation, and determining what works, when it works, how well it works, the costs, limitations or barriers for implementation, and solutions to those limitations. In addition, a more complete monitoring program is needed, to assess the effect of the implementation of these projects. Thirdly, an educational campaign to address the human factors and build knowledge about water and sanitation issues is an extremely important component of any solution. Finally, due to the soil type and space limitations in hill slopes, septic systems are not generally feasible.
an analysis on ideal reforestation sites within the watershed will promote protection of the water supply.

**Approach/Methodology:**

Building upon the information collected and analyzed in the first phase of a longer term project, four specific areas have been identified for this project, in order to ensure that the analysis and recommendations are implemented. These four areas involve the implementation of an enhanced water quality and quantity monitoring program, the design and implementation of a number of pilot Best Management Practices, the design and implementation of an educational campaign at several levels, and a site location analysis for a potential reforestation program.

**Water Quality and Quantity Monitoring:**

A specific water quality and quantity monitoring program was developed by the Master’s students in the first Bren School group project. It called for 24 specific monitoring locations to assess the overall hydrology (water flowing through the rivers) and the water quality from the headwaters, integrating the results of the WARMF model (Figure 3). These points cover the communities in Groups 4 and 5, the entrance to the city, and at the exit of the system (Figure 4). Part of the monitoring program also involves monitoring the groundwater elevation over time, to determine the capacity of the various parts of the aquifer to store and supply water for the growing population. The impact of contaminated surface water on the groundwater supplies will also be assessed. The monitoring plan has been provided to researchers at ECOSUR, with flexibility built-in, to take into account changes that may require modification. The information gathered from this enhanced monitoring plan will serve to improve the watershed model, and thus the watershed management plan. As different parts of the watershed management plan are implemented, it is important to monitor the progress made with regards to protecting water supplies.

Although the first project made important advances in providing local capacity to monitor water chemistry, there is a need to improve capacity to monitor pathogens. The current analytical methods are only useful to determine presence or absence, or at best to provide very rough estimates of pathogen concentrations. An IDEXX analytical system will be acquired for use by researchers at ECOSUR in their water quality laboratory. The IDEXX coliform/E. coli tests are the only commercial microbiological methods included in Standard Methods for Examination of Water and Wastewater, 20th Edition. Use of this system will substantially improve the accuracy of pathogen monitoring, allowing a better evaluation of risk from exposure to contaminated supplies. The system allows the determination of the Most Probable Number (MPN) for Total Coliforms, *E. coli*, *Enterococci*, Heterotrophic plate count bacteria, *Cryptosporidium* and *Giardia*. 
Figure 3. Areas which are expected to be at risk of water quality impairment due to proximity of communities to the river, agricultural practices, number of animals and other potential sources of non-point pollution.

Figure 4. Proposed monitoring locations for the five rivers feeding into or out of the San Cristóbal watershed. Note that water now leaves the watershed in the Sumidero through a man-made tunnel. Monitoring points cover headwaters and locations before and after the city.

Each of the current group project members will be trained in the use of water monitoring equipment. We will then transfer this equipment to ECOSUR for use in the project during the September 2006 trip, providing field and laboratory training. During follow-up visits in December 2006 and March 2007, we will provide support if there are any questions in the use of the equipment. We plan to train several people at ECOSUR, in order to ensure that the capacity to conduct these tests will be available for a long time. Meanwhile, ECOSUR is working on developing a budget for the consumable supplies, to make sure they can continue with water quality monitoring on a long-term basis.

Best Management Practices:

As mentioned in the introduction, five BMPs were identified as particularly applicable for San Cristóbal’s communities. These will include rainwater collection systems, small scale water treatment units to make sure the water is potable, wastewater treatment via community composting latrines, and BMPs that address pollutants from agricultural activities. Other BMPs
are still under consideration for several reasons. First, the cost factors available for the US are very different for those in Mexico, particularly in Chiapas. There is also a need to determine vendors for the best locally available materials. Finally, a pilot test should make sure the BMPs are acceptable to the users, and that they are easy to operate and/or maintain. To implement several BMPs throughout the watershed, students will work in collaboration with researchers from ECOSUR and volunteers from SYJAC. The goal is to have a number of the tested BMPs throughout the watershed. Once BMPs are implemented, additional water quality monitoring points will be added to the larger monitoring program, to evaluate their performance and the overall impact on the watershed.

The design, costing and small-scale testing of the BMPs will take place in San Cristóbal from June-August 2006. We plan to meet with partners early on for feedback on appropriateness and quality of design, to provide the information so that they can proceed with the implementation, and to address technical and practical questions. After the pilot projects are installed with the help of group project members, additional iterations of the BMPs may be implemented by ECOSUR and SYJAC, depending on the success of the pilot project. Effectiveness and progress will be monitored over the course of the project, and any identified problems will be addressed. We hope to evaluate effectiveness of the BMPs, quantitatively if possible, and thereby make recommendations for future actions. Since the Director of SYJAC is also Director for the local chapter of Habitat for Humanity, there is a high degree of interest in these BMPs for outlying communities, and it is likely that Habitat will be able to raise funds to continue expanding the use of BMPs to other parts of the watershed.

Education:

Educational materials linking water quality and human health will be developed by students at UCSB. These will cover simple hygiene and sanitation measures that can be taken to reduce the risk of waterborne diseases, as well as education regarding the water resources programs implemented by this project to ensure community awareness and involvement. Simple language, diagrams and illustrations will be used in order to promote widespread understanding across communities.

The campaign will be targeted to several audiences, with different concerns and levels of education, from elementary school-aged children to community leaders. However, the content and level of detail will be tailored for each audience. Given the several languages and dialects involved, the information will be very graphical. The message will be the same, explaining the need to protect water resources, and how this improves quality of life. We will utilize the experience of our partners, particularly at SYJAC, to make sure that posters and other educational materials will be understandable for each audience. A draft of worksheets, fact sheets, lesson plans, posters, etc. will be prepared in Spanish and reviewed with local educators.

Once they are finalized, SYJAC staff will be utilizing these materials in community centers rather than as curriculum in the formal education system. Feedback from community members will be important for modifying design of the materials. In the future, materials might also be translated into indigenous dialects and disseminated to additional nearby communities. An assessment of the effectiveness of the educational campaign will be conducted by two sets of interviews, one prior to the campaign and one following its implementation, in collaboration with SYJAC.
Reforestation:

Predominant land use/land cover in San Cristóbal includes urban landscape, forested areas, agriculture, and pasture land. The percentage of existing forests, both in San Cristóbal and Chiapas as a whole, has been in a steady decline since the 1950s. In the most recent analysis, forest cover, ranging from primary and secondary forests to mixed pine and oak forests comprised about 52% of the landscape. Population growth has been the main driver of changing land use. As the urban center of San Cristóbal expands, more of the forested areas are cleared to obtain forest resources and increase alternative land uses, especially subsistence agriculture. As a result, many of the remaining forests suffer from fragmentation. Fragmented forests, and secondary forests that have re-grown after clearing, suffer a reduced capacity to provide ecosystem services that will in turn impact water resources dynamics.

Although land within the watershed has traditionally supported a variety of uses, deforestation can impact the ecosystem in terms of surface water quality, increasing storm water runoff, nutrient loading, and groundwater contamination. Identifying areas where deforestation has occurred can help us to understand what impacts might be seen on the watershed as a whole. Our partners at ECOSUR are especially interested in beginning a reforestation program. Analysis using GIS layers and remotely sensed images can be performed at UCSB to identify prime areas in which to target reforestation efforts. Modeling will utilize a variety of input parameters including land use change, soil type, slope, and land ownership. Following ground truthing confirmation of the model output, the recommendations of this analysis will be delivered to stakeholders so that the reforestation program can be planned successfully.

Approach – Specific Tasks and Milestones:

Our approach to this project can be separated into two areas of focus. The first area is the work that will be performed in California, based out of the Bren School at UCSB. It is here that most of our data analysis, modeling, and planning will occur. The second area comprises the work that we will perform down in San Cristóbal. It is during these periods that we will construct and implement our projects, collect data, and evaluate the status of our projects. The two areas are heavily interrelated and the information collected in both locations can be applied to four primary projects:

- Planning, construction, and status review of BMPs;
- Continued monitoring of water quality, modification of the model if appropriate, and formulating a plan for the community to continue the monitoring;
- Organization and establishment of an educational program that teaches local residents about basic sanitation and water quality issues;
- Reforestation analysis focusing on the prioritization of reforestation site locations.

Specific tasks for each of these projects will take place on the following timeline:

April-June 2006
- Visit BMP sites near Santa Barbara to get a better understanding of engineering requirements and the how to apply them for our project.
• Write complete, detailed, “how-to” BMP manuals in both Spanish and English. Each manual will consist of 5-10 detailed pages describing the BMP purpose and design in depth, as well as a single laminated sheet with pictures and diagrams for quick reference.
• Transfer GIS data/spreadsheet from Chiapas I group to Chiapas II group.
• Analyze LandSat images and GIS files for potential reforestation area identification.
• Become trained in water quality sampling techniques that will be used in San Cristóbal.
• Create survey that will be used to gauge the educational level and BMP preferences of residents in the various communities of San Cristóbal.
• Develop teaching materials to be used in our educational campaign that are conducive to a continuation of the program by SYJAC.

June-July 2006 (travel to San Cristóbal)
• Establish contact with stakeholders and the individuals we will be working with directly.
• Through discussion with stakeholders, determine the following:
  o Community selection
    ▪ Which areas and communities are the most appropriate for us to work with
  o BMP selection
    ▪ Which BMPs are most practical, and which ones community members support or favor the most
  o Monitoring program
    ▪ Determine the current situation of the monitoring program, and what we can do to improve its durability and reliability
  o Educational plan
    ▪ Make contact with Hilda at SYJAC to begin formulating an educational plan
  o Cost determination
    ▪ Locate dealers and the associated costs of supplies and materials needed to construct BMPs
• Produce Summary Report to be reviewed by partners and external advisors

August-September 2006 (travel to San Cristóbal)
• Begin BMP construction in the selected communities, with input and assistance from local stakeholders.
• Train local stakeholders in the use of monitoring equipment and the monitoring process.
• Initiate the educational program.
• Collect water quality and quantity monitoring data (both ECOSUR and Bren students).
• Evaluate effectiveness of water quality monitoring program as it contributes to the WARMF model.
• Confirm correct GPS locations for model input parameters, especially water sampling points.
• Access aerial photographs to apply to the reforestation problem modeling.
• Collect further data on land ownership, land use and access, and topographical features, and interpret information as it pertains to reforestation.
• Produce Summary Report to be reviewed by partners and external advisors
October-December 2006
- Update the WARMF model with additional monitoring data.
- Conduct multi-criteria analysis of watershed reforestation possibilities using the GIS.
- Continue developing educational materials and refining the scope of teaching materials and training program.
- Review interview results to integrate into educational program.

December 2006 (travel to San Cristóbal)
- Ground truth reforestation analysis results
- Check the status of the BMPs and perform any necessary modifications
- Continue with the educational program and evaluate what needs to be done to sustain it.
- Continue water quality monitoring and determine effectiveness of small scale BMP projects

January-March 2007
- Evaluate BMPs and use WARMF model to evaluate large-scale impact of adoption scenarios
- Continue developing education materials
- Write final report
- Determine feasibility of Chiapas III project

March 2007 (travel to San Cristóbal)
- Determine the status of the implemented BMPs.
- Make any final recommendations for the sustainability and continuation of the monitoring and BMP construction.

March-May 2007
- Project finalization and presentation.
- Translate report to Spanish and deliver it to partners.
- Drink margaritas on the beach.

NOTE: For specific tasks that relate to BMP implementation, education, water quality, and reforestation, please see Appendix A.

Management Plan:

Group Structure, Management, and Responsibilities:
As a group, we have decided to maintain permanent positions with the possible exception of the project manager leadership role. Currently, the program manager role is being held by one individual group member for the duration of the spring 2006 quarter. At the end of the quarter, we will review the status of the leadership role and decide if we wish to make the position permanent or if we want to rotate the position among group members so that every person may gain experience in the leadership position. The group leader is responsible for informing group members of meetings and deadlines, preparing an agenda, and moderating the meeting. The data/information manager is responsible for maintaining and organizing files (including
electronic materials, references, proposals drafts, quantitative data, and budget projections) in the Chiapas drive and preparing the group website. The financial manager is responsible for all budget concerns, including fund allocation and purchases. The secretaries are responsible for recording meeting minutes and posting them to the group drive. As of spring 2006, the following positions are held by elected group members:

- **Project manager** - Deborah Glaser (may change)
- **Data/Information manager** - Matt Elke
- **Financial manager** - Dayna Yocum
- **Secretaries** – Karen Setty/Dan Sussman

**Meeting Structure:**
Weekly meetings are planned so that the primary advisor to the project, Arturo Keller, may attend them on a regular basis so that we may discuss issues we feel are pertinent to the project. As an external advisor, Jordan Clark and Bob Wilkinson will not be expected to attend our weekly meetings. They will be expected only to review our quarterly deliverables. If, as a group, we want to meet without our advisors, a separate meeting will be called to prepare for it, in order to conserve time during our meetings with advisors.

**Systems to Ensure Deadlines are Met:**
Each quarter when a deliverable is due, a set of deadlines will be set by the group, in consultation with the advisor, and enforced by the project manager. Prior to the official deadline date, we will have preliminary internal deadline date in order to ensure that revisions and editing may be complete before submitting the draft to our advisor. Once the draft is complete, we will submit it to Arturo, who will comment and/or revise as he sees fit. When the final copy is prepared, a hard copy will be submitted to our advisory board.

**Conflict Resolution Process:**
If a conflict arises within the group, the following steps will be followed to mitigate it.

1) The conflict will be identified by group members in a group meeting. The first person to identify the conflict should notify the group leader so that s/he can add it to the next meeting’s agenda (with group advisor) or can schedule a separate meeting with only group project members to address the conflict. The person can choose to discuss the nature of the conflict with the group leader at that point.

2) In the meeting, the conflict will be discussed openly, without accusations to avoid the conflict getting “personal.” Group members are encouraged to listen carefully to others’ concerns and feelings, and to promote an atmosphere for open communication. Lingering problems hurt the group’s work when not addressed.

3) The group members will take steps to mitigate the conflict through a number of techniques, which may include the following. Details about each technique may be found in the textbook “Behavior in Organizations” by James B. Lau and A.B. (Rami) Shani.
   a. Paraphrasing: this technique involves each person voicing his/her concerns one-by-one, where the next person is required to paraphrase what was said by preceding individuals before voicing his/her concerns.
b. Two-way feedback: this technique involves both or all people involved in the conflict to express their feelings about a subject, ensuring that both or all involved are able to feel heard.

c. Integrative negotiation or win-win negotiation: this technique involves expressing all desires that may come out of the negotiation on both sides and agreeing to make a decision that maximizes all outcomes.

d. NOTE: It should be recognized that many seemingly individual problems, such as the problem of a “slacker,” is likely caused by the group failing to motivate the individual. The group should take responsibility to share in the motivation of this individual, and should understand personal needs that must be satisfied.

4) If the conflict is resolved by the group, group members will determine if the group advisor, Arturo Keller, should be notified of the happenings.

5) If the conflict cannot be solved, group members will discuss the conflict with the group advisor, Arturo Keller, who will attempt to mitigate the problem.

6) If the conflict still cannot be resolved, group members will discuss the conflict with Maria Alfaro, Student Affairs Assistant. Outside help may then be consulted, perhaps through ESM 208 Professor Rami Shani (shani@bren.ucsb.edu).

Data and Web Management:

- All case studies, papers, and documents will be organized by its relevance to education, BMPs, model, monitoring, etc. This information will be further organized with regards to the specific aspect of the topic it is covers.

- Hard copies of information will be stored in a binder(s) with tabs and dividers to provide for easy reference, while electronic information will be stored on our group’s shared drive on the Bren School network. A source list of all electronic information will be placed at the end of the binder so that it can be easily accessed.

- All other relevant books, pamphlets, flyers etc. will be kept in file boxes in the Periodical room or the student Commons, organized by type of information and type of resource.

- The group will have a website to act as the public face of the project. This website will be updated every two weeks as a way to chart our project’s progress.

- Texts, photos, and other data used on the web site will be listed in its own folder on the shared drive. This folder will act as a timeline for webpage construction.

Guidelines for Interaction with Clients:

The first language of our clients is Spanish, and many of them do not speak English. This necessitates that communication between group members and clients be conducted in Spanish. Our interaction with them will begin with an introductory email by Arturo Keller. When not traveling to Chiapas, the primary method of communication between the group and our clients will be through electronic mail. The groups’ travel to San Cristóbal will begin in late June when Dan Sussman travels with a member of the Chiapas I project to Chiapas to meet the clients. Later in the summer Matt Elke and Karen Setty will travel to Chiapas and work on implementation of BMPs. Further visits by group members will occur in December 2006, and again in March of 2007.

When not traveling to San Cristóbal, we will keep our clients informed of our progress through electronic mail. In addition, we will electronically send them any pertinent products that
we complete during the course of our work, such as GIS layers. At the end of our group project, we will send both a hard copy and electronic copies of our final report to our clients.

**Overall Expectations of Group Members and Faculty Advisors:**
Since the quality of our final product is related to the level of involvement from both the students and advisor, it is expected that team members and the advisor will maintain a high level of interest and enthusiasm in the project. It is expected that all project objectives will be achieved. On a weekly basis, team members should put in an average of 8-10 hours of work, and the advisor will attend all group meetings unless other arrangements are made. The grading criteria will be as follows:

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<td>Final Report</td>
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Student Evaluations (of each other) will be used in part to determine “Quality of Individual Work” and “Participation.” Different grades for different team members may be applied if there is a significant difference in the level of effort and involvement among team members.

**Deliverables:**
- Sustainable watershed management plan and status report in English
- Summary of watershed management plan and status report in Spanish
- Educational materials in both English and Spanish
- A “how-to” catalog describing results found and possible implementation techniques of researched best management practices for SYJAC and ECOSUR
- Updated watershed map with layers indicating:
  - location of implemented BMPs
  - potential location for future BMP implementations
  - monitoring locations for water quality and water quantity data collection
    - recommended by Chiapas I
    - implemented by ECOSUR
  - community locations and demographics
- Regional land area map depicting potential sites for reforestation projects
- Updated and calibrated WARMF model

**NOTE:** All datasets and models will be made available to all partners

**Outside Advisors:**
Currently, we have two external advisors:
- Professor Bob Wilkinson, the Director of the Water Policy Program and adjunct professor at the Bren School for Environmental Science and Management at UCSB.
- Professor Jordan Clark, Associate Professor of Geological Sciences & Environmental Studies at UCSB
Additionally, there is the possibility that David Bothman, Development Engineer in the Department of Engineering at UCSB, will also sign on to become an external advisor.

We are currently looking into establishing contacts with local professionals who are involved with projects that focus on water management practices that are similar to those presented in our proposal.

**Budget Justification:**

A substantial portion of this project will take place in San Cristóbal. This project requires funding for airfare and living expenses while in Chiapas. Work done in Chiapas includes client development, data collection, and BMP construction. The timing and duration of these visits is detailed below. Data analysis to construct a reforestation prioritization map will primarily take place at UCSB and will therefore require no additional funds.

**Budget:**

**Current Funding:**
- $1,100 - MESM group project allocated funds
- $3,000 - Gift from ERM
- $15,000 - UC-MEXUS grant for site visits, BMP design, and additional training of ECOSUR researchers in watershed modeling and water monitoring.*
- $19,100 = Total

**Funding Needs:**

**Travel**

10 RT SB - Chiapas, Mexico, airfare $680 plus 10 days $14,300.00

**Water Quality Monitoring**

IDEXX equipment and supplies $3,215.00

**Education**

$300.00

**Rainwater Harvesting**

Cisterns range: $50-300 $175.00 **

Other items

**Latrine**

Construction (x1) 20,006 USD$334.86

**Bioswale**

Construction range: $200-300 $250.00 **

**Contour Based Erosion Control**

One Field $130.48 **
Retention Basin construction range: $874-3557 $2,215.50 **

Total: $20,585.98

*Expected
**Estimates still being calculated.
References:


Engineers for a Sustainable World USA and Consultoría, Proyectos e Investigación, S.C. “Construction of Dry Composting Latrines in Rural Southern Mexico.”


Appendix A: Technical Approach Specific to Each Project Component

Composting Latrines:
Technical Approach:
- One of the primary goals of our project will be to aid in the construction of a pilot composting latrine with the possibility of building several more latrines over a wider regional scope.
- Available Data: Water quality data for San Cristóbal identifying pollutants of concern

Subtasks:
- Visit a local composting latrine
- Design composting latrine prototype and determine specific costs of materials
- Review current household waste disposal systems and interview community members in the area in order to determine preferences regarding latrine type, size, and location
- Survey landscape to establish best location(s) to build latrine and number of latrines necessary for pilot project
- Construct latrines with local input
- Create “owner’s manual” for use of latrine in English and Spanish
- Educate community about importance of using latrine
- Continue with community interviews and water quality testing to gauge progress and effectiveness of BMP implementation

Costs:
- Estimated at $1,886 per latrine in southern Mexico (Engineers for a Sustainable World et al.).

Domestic Rain Water Catchment Systems:
Technical Approach:
- Rainwater catchments could potentially provide clean drinking water for communities that are not connected to the municipal water service provided by SAPAM.
- All rainwater catchment systems are comprised of three basic components:
  - A collection system (usually incorporated into the roof of a house);
  - A piping system as a means of transporting the collected water;
  - A storage container that holds the harvested water.
- Compact household filter systems may be used in conjunction with the rainwater collection system to provide high quality water for household use.
- If the BMP is expanded beyond the first pilot project, there are two types of rainwater catchment options to be considered.
  - The first entails designs for new housing construction and that has the rainwater catchment included in the initial building.
  - The other involves designs to retrofit current buildings with a rainwater catchment system.
- During the initial visit to Chiapas, we will assess feasibility of this BMP and determine the level of interest from SYJAC and other stakeholders.

Subtasks:
- Survey local rainwater catchment systems and ask owners about construction costs.
- Determine the feasibility of rainwater catchments in the designated communities.
• Assess local attitudes and the openness of communities to rainwater catchment systems.
• Construct a few prototype rainwater catchment systems.
• Design a “how-to” manual with designs for both new construction and retrofitting.
• Teach community members how to manage and perform maintenance on their rainwater catchment systems.
• Create a “shop manual” outlining the maintenance procedures for the rainwater catchment systems.
• Monitor the performance status and community views about these systems.

Costs:
• Can vary extensively depending upon the type of system that is built, and the materials used in construction.
• Storage vessels, a main component of rainwater harvest systems, can range in price from $30-$200 in developing countries.

Retention Basins:
Technical Approach:
• If our partners at ECOSUR are interested, we aim to implement at least one retention basin as a best management practice for the sub-watersheds located upstream of San Cristóbal.
• Available data: Model output from WARMF identifying key areas for BMP implementation, some water quality data, average rainfall and some streamflow data

Subtasks:
• Site visits: identify locations near Santa Barbara that use retention basins to treat storm-water runoff.
• Review the literature to determine the most applicable type of retention basin for San Cristóbal.
• Identify potential locations using watershed models/maps to evaluate slope, soil hydrologic type, and collection area/volume of runoff expected.
• Provide a document with a few design options including important design criteria, recommended methods for construction and maintenance, and expected benefits in English and Spanish.
• Estimate costs of construction.
• Include knowledge of retention basin ecological functions and water quality benefits in educational program.
• Evaluate the effect of implementing one retention basin, and conduct a scenario analysis in WARMF to observe the effect of implementing 5-10 additional basins.

Costs:
• Approximately $874-$3,557, depending on size of basin, cost of labor and materials used.

Contour Channels, Contour Trenches, Contour Buffers:
Technical Approach:
• These three BMPs are all variations on using earthworks and vegetation aligned along the contours of a hill slope to slow sheet flow of water, reduce erosion, and arrest movement of sediment, fertilizers, and pesticides before these pollutants reach waterways.
Available data: water quality data for San Cristóbal, pollutants of importance, topography, land use classification, and change in land use over time.

Subtasks:

- Site visits: identify locations near Santa Barbara that use contour BMPs to reduce soil erosion.
- Determine advantages of each contour technology.
- Use GIS to prioritize potential implementation of different watershed areas based on existing land use (crop type, grazing), slope, and soil type.
- Create one page information sheet with photos and method of construction.
- In Chiapas, determine best location to implement BMP based on local desire for implementation and physical constraints of landscape.
- Determine labor needs and material costs for implementation of pilot.
- Create manual for construction.
- Construct contour BMP
  - Choose site
  - Mark contours with an A Level or Hose Level
  - Construct features
    - Determine distance between trenches based on slope and width of farm equipment (tractor & plow)
    - Dig trenches (if channel or trench)
    - Plant stabilizing crops, leguminous shrubs and native grasses, on downhill of trench (berm).
    - Plant crops (trenches, channels)
- Educate citizens about maintenance of BMP.
- Monitor for effectiveness and for WARMF input.

Bioswales:
Technical Approach:

- One of the BMPs that will be suggested to SYJAC and ECOSUR is a bioswale. Easily incorporated in the landscape, a bioswale is a shallow depression created in the earth to accept and convey stormwater runoff.
- Used properly, it can reduce the volume of water to be treated as downstream wastewater. A bioswale uses natural ecosystems, including herbaceous vegetation and soil, to treat stormwater by filtering out contaminants being conveyed in the water.
- Available Data: Design information, water quality data

Subtasks:

- Site visits: visit bioswales in Santa Barbara that are active and currently under construction.
- Analyze soil designs to determine best-suited design for San Cristóbal.
- Create one page information sheet with photos and method of construction.
- Concur with ECOSUR to determine best location to implement bioswale based on local desire for implementation and physical constraints of landscape.
- Determine labor needs and material costs for implementation of pilot.
- Create manual for construction.
- Construct bioswale.
- Educate citizens about maintenance of bioswales.
- Monitor for effectiveness and for WARMF data.

**Reforestation Prioritization Analysis:**

**Technical Approach:**
- The goal of this task is to analyze the watershed’s deforested areas to prioritize potential sites for SYJAC to implement a reforestation program.
- The prioritization will be performed by developing a GIS layer in concert with WARMF. WARMF will be used to vet the recommended sites for load reduction effectiveness, and to help predict which sites currently contribute the heaviest loads.
- Available Data: Topography (slope and aspect), elevation, current land use, roads, waterways, soils
- Data to acquire: Ownership, accessibility, detailed soil properties, land use history (as an indication of nutrient degradation or soil damage), ideal growth conditions of species to be planted (does the desired species grow better as a secondary colonizer), stream influence on downstream water quality (stream order).

**Subtasks:**
- Create preliminary layer with current GIS data.
- Learn WARMF, determine heaviest load contribution source.
- Determine tree species to be planted, learn species specific growth considerations.
- Cross-check preliminary GIS map with LandSat imagery and aerial photos.
- Gather land ownership data from sources in Chiapas.
- Site visit and determine relative accessibility rating of sites (road condition).
- Ownership data will be collected as a binary (1 = owner cooperative, 0 = owner will not cooperate, perhaps 0.5 = TBD).
- Use WARMF data to classify relative need in different locations for GIS input.
- Create final GIS map to prioritize sites for reforestation implementation.

**Costs:**
- Primary monetary costs will be that of fuel for transportation during site identification/confirmation and purchase of remote sensing information.

**Water Quality and Quantity Monitoring Program:**

**Technical Approach:**

**Goals:**
- Track the water quality and quantity of the San Cristóbal watershed through water sampling and an analysis of pollutant load and runoff retention. Monitoring results will be compared with ambient water quality standards noted in Table 6.1.
- Collect GPS data points for the WARMF watershed model.
- Evaluate effectiveness of BMPs by taking water samples before and after BMP implementation.

**Available Data:**
- Measurements collected in 2005-2005 by ECOSUR using Hach Water Quality Test Strips for ammonia, nitrates, nitrites (all three of which give only general results), phosphorus, pH, alkalinity, hardness, free chlorine, and total chlorine;
• Measurements using Hach Pathogen Reagents for bacteria, qualitative observations of sediment load, odor, and color;
• GIS layers describing soil type, vegetation density, and topography for the region;
• 24 identified sampling sites including control sites, impact sites due to urban or agricultural contamination, impact sites due to tributary impact, recovery sites, and outlet sites.

**Data to acquire:**
• Weekly measurements (during periods of high flows) or monthly measurements (during periods of low flows) from each of 24 identified sites to be collected by ECOSUR of flow height, pH, pathogens (with IDEXX analytical system), nitrogen compounds, phosphate, dissolved oxygen, temperature, and conductivity. Additional data points will be added to evaluate the effects of implemented BMPs and changes in land use.

**Subtasks:**
• Contact ECOSUR and offer support to ensure continued water sampling.
• Ensure that ECOSUR has acquired IDEXX analytical system.
• Receive training in water sampling methods at UCSB.
• Train ECOSUR partners in water sampling methods, and accompany them on sampling trips when possible.
• Learn how to calibrate the WARMF model and enter new data as it becomes available.
• Answer questions from ECOSUR, modify monitoring plan as needed.

**Educational Campaign:**

**Technical Approach:**
• Available Data: Education material from the World Water Forum, contact person (Hilda) via SYJAC; survey results from Chiapas I regarding water use and sanitation/health issues.

**Subtasks:**
• Contact Hilda to establish partnership on educational campaign.
• Target age group, demographic sector to be taught.
• Target teaching points (i.e. sanitation and hygiene, fuel efficiency, reforestation, roles of water, etc).
• Assess availability of resources (materials, teachers, time).
• Find costs for necessary materials.
• Co-develop a booklet of teaching materials for water sanitation/health/environment issues.
• Train trainers to use the materials in the community center (will be done by Hilda).
• Monitor progress of educational campaign by interviewing students and trainers.

**Costs:**
• Cost of materials: printing, writing materials, paint, brushes, etc.