DONALD BREN SCHOOL OF ENVIRONMENTAL SCIENCE & MANAGEMENT
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GROUP PROJECT BRIEF

# DESIGN AND IMPLEMENTATION OF SUSTAINABLE WATER RESOURCES PROGRAMS IN SAN CRISTÓBAL DE LAS CASAS, MEXICO

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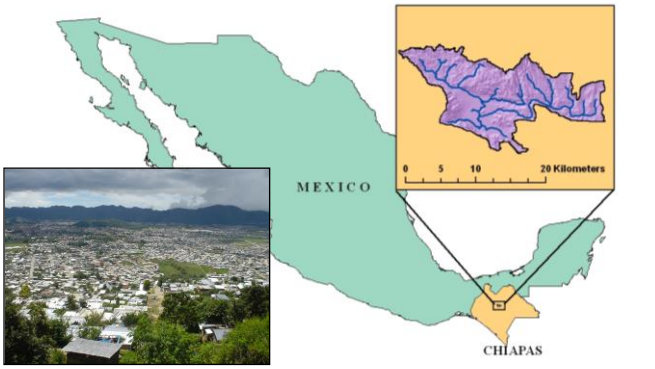


**Figure 1.** Photograph of San Cristóbal de las Casas and extent of the city's watershed

## BACKGROUND

San Cristóbal de las Casas is a historic city in Chiapas, the southernmost state of Mexico, which serves as the economic and cultural center for the surrounding region (Bencala et al. 2006).* Originally founded in 1528, the city rests on the floor of a high-elevation mountain basin (Figure 1). The state of Chiapas is both a hotspot for ecosystem biodiversity and home to a high concentration of indigenous populations (INEGI 2005). It is also one of the poorest states in Mexico, and maintains the highest childhood mortality rates (INSP 2000). The national average per-capita income in Chiapas has declined by an annual average of 6.5% over the last decade, the sharpest decline throughout Mexico (CONAPO 2006).

## PROBLEM STATEMENT

**"The availability of water is interconnected with the development of prosperous societies, both in Mexico and around the world"**
**– Karen Setty, Project Member**

Over the last decade, an increasing number of indigenous people from the rural highlands of Chiapas have concentrated along the periphery of San Cristóbal, partially due to social unrest in the surrounding region. This trend has exerted a strain on the city's limited utility infrastructure, leaving many of the peripheral communities without access to sufficient electricity, water supply, and sanitation. As an example, water for one community, Cinco de Marzo, is currently obtained through public spigots that turn on periodically, sometimes late at night (Figure 2). Residents can go days without a water supply from this source.

**Figure 2.** Buckets lined up under a community water spigot in the *colonia* Cinco de Marzo

Rivers in the watershed serve as conduits for untreated wastewater. An education disconnect further increases the spread of contaminating pathogens that cause gastrointestinal illnesses, which can lead to severe health problems and/or death in susceptible populations such as infants and the elderly (Figure 3). The lack of water supply, sanitation, and environmental protection has not yet been fully addressed by the federal and local governments, though many groups and individuals have concerns about the watershed. Significant improvement in the management of water resources is needed to improve public health, address environmental concerns, and re-align the area toward prosperity.

**Figure 3.** A woman washing clothes while children bathe in a highly polluted river in San Cristóbal

**Best Management Practice (BMP) - A technology or practice that is appropriate to the environmental, cultural and economic situation for the area in which it will be applied – Dayna Yocum, Project Member**

## GOALS

- **Implement pilot projects** that address water resources issues while utilizing practical and appropriate management techniques.

**Figure 4.** Implementing a domestic rainwater harvesting system in Cinco de Marzo

- Strengthen the long-term regional **water quality and quantity monitoring program** initiated in 2006, with a particular emphasis on increasing the accuracy of pathogen monitoring.


**Figure 5.** Water quality laboratory at the local university, El Colegio de la Frontera Sur (ECOSUR)

- Create an **educational program**, including both educational materials (worksheets and posters) and lesson plans, to educate community members on the effects of poor sanitation and contaminated drinking water, the benefits of watershed protection, and the function of recommended best management practices (BMPs).
- Update and calibrate the WARMF **watershed computer model** to better predict impacts on water quality that would occur with widespread BMP implementation, and to identify priority sub-watersheds for targeting specific BMP technologies.
- Write **design manuals** specific to Chiapas, but adaptable to other regions, for each of the recommended BMPs.
- Produce **case studies** for BMPs implemented or suggested for implementation in a particular location by this project, with a detailed outline of the objectives, functions, construction steps, and materials costs.

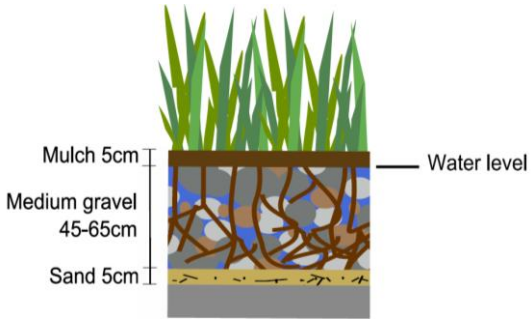


**Figure 6.** Diagram of the cross-section of a constructed wetland taken from the grey water treatment design manual

- **P**erform a **multi-criteria GIS analysis** to prioritize sites within the watershed that should be targeted by a reforestation campaign to promote sustainable protection of water resources, and also develop strategies for a successful reforestation program.

## APPROACH

**"This… project expressly aims to move from the planning stage to on-the-ground implementation."**
**- Deborah Glaser, Project Member**

**U**tilizing data gathered by a 2005-2006 Bren School group project, Bencala et al.'s *A Framework for Developing a Sustainable Watershed Management Plan for San Cristóbal de Las Casas, Chiapas, Mexico*, team members sought to apply thorough technical analyses to the specific water resources management issues facing San Cristóbal, in order to achieve workable and practical management solutions.

**F**urther analysis of the watershed was required, and in some cases, is required on an ongoing basis, to fully achieve the objectives of this project. A water quality and quantity monitoring program collects instantaneous water quality data from several surface water and water supply spring locations throughout the watershed. The information collected between May and December 2006 was used to calibrate a watershed model, WARMF, which holistically analyzes the sources, transport, and fate of various point and nonpoint source pollutants. In addition to this model,

a multi-criteria prioritization map was created using ArcGIS, in order to identify the most problematic locations that would have a large impact on watershed function if deforested.

In seeking appropriate Best Management Practices (BMPs) that would meet the needs of San Cristóbal residents while contributing to environmental improvement and watershed sustainability, this project first utilized a research-oriented approach (Figure 7), and then integrated the results with the needs of stakeholders through partner communication.

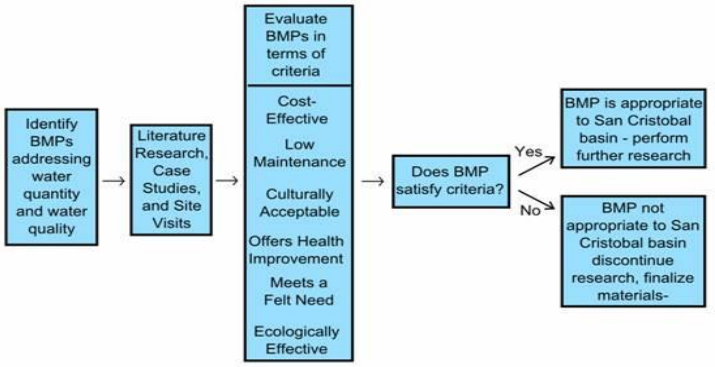


**Figure 7.** Initial decision-making process for BMP selection

## RESULTS & DISCUSSION

**"With the lack of water supply infrastructure in San Cristóbal, BMP projects must be both creative and flexible if they are to succeed."**
**- Matthew Elke, Project Member**

During this project, two BMP pilot projects were constructed in Cinco de Marzo: a domestic rainwater harvesting system and a community clothes-washing station integrating rainwater harvesting with grey water filtration through a constructed wetland (Figure 8).

**Figure 8.** Construction in progress and a conceptual drawing of the finished EcoLavadero

One additional project, a campus rainwater harvesting system for ECOSUR, was proposed and funding secured. Eight design manuals and three pilot project proposals were created to assist project partners in implementation of further BMP construction in San Cristóbal. These manuals were published on the project website in order to spread knowledge of these technologies to other regions facing similar problems.

An educational campaign was designed in conjunction with SYJAC (a San Cristóbal-based NGO) to target knowledge of watershed processes and sanitation, and to develop responsible individual practices. Based on preliminary survey findings, educational materials were developed for use in Cinco de Marzo's primary school classroom, as well as community groups in the greater San Cristóbal area. Deliverables included a number of lesson plans, classroom activities, posters, visual aids, and brochures (Figure 9).

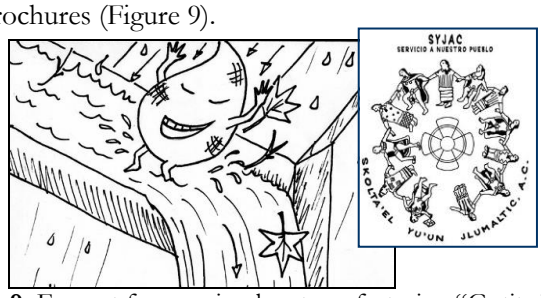


**Figure 9.** Excerpt from a visual cartoon featuring "Gotita," a character created by this project for use in education

A monthly water quality and quantity monitoring program of surface and spring water locations that includes nutrient and bacteria levels was first undertaken by the university El Colegio de la Frontera Sur (ECOSUR) in May 2006. This project worked to build the capacity of ECOSUR's laboratory by providing accurate flow and pathogen measuring equipment. The available data was analyzed for spatial and temporal trends. Within the watershed, all surface water locations and half of the water supply springs exceeded US and Mexican maximum quality standards for coliform levels. Levels also tended to be higher within the urban area (Figure 10).

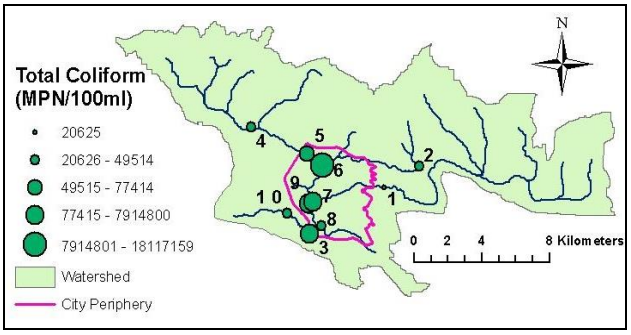


**Figure 10.** Watershed map showing averaged values (n=7) of Total Coliform Most Probable Number (MPN) for the monitoring program from May to December 2006

As a decision-making tool for environmental managers, this project calibrated and increased utility of a watershed simulation model called WARMF that was partially built by the previous group project. The model will be transferred to partners in Chiapas for use in predicting the watershed's response to implementation of proposed projects in the future.

To cope with the deforestation effects caused by San Cristóbal's rapid expansion, local activist Alejandro Ruíz Guzmán requested a land prioritization model and program strategies to support a reforestation campaign, which is backed by a local coalition including the municipal water supply agency, SAPAM. With maintenance and enhancement of watershed health in mind, the model focused on areas of high erosion potential, incorporating four equally weighted input layers: distance to streams, slope, soil erodibility, and precipitation (Figure 11).

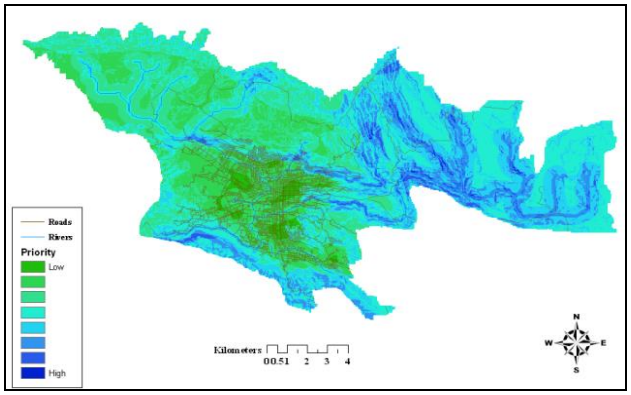


**Figure 11.** The results of a multi-criteria analysis for reforestation target areas show more critical land (dark blue) in the northeastern section of the watershed.

## RECOMMENDATIONS

- BMP technologies that address watershed-wide concerns including both human and environmental health should be implemented:
  - Rainwater Harvesting;
  - Wastewater Treatment Constructed Wetlands;
  - Composting Latrines;
  - Retention Basins and Bioswales; and
  - Contour Trenches.
- BMP pilot projects should serve as prototypes for other nearby communities, incorporating lessons learned and user satisfaction into both formal and informal social networking.
- Educational materials created by this project should be reproduced and taught within the framework of pre-formed community groups with individuals of a similar age bracket.
- A survey assessing knowledge of the link between water quality and human health should be administered both prior to the educational sessions and within six months to one year later.
- The water quality and quantity monitoring program administered by ECOSUR should expand to include all recommended monitoring locations and laboratory tests, especially field measurement of flow volume.
- Capacity building should be made a priority to increase the funding and manpower resources available to ECOSUR's water testing laboratory.
- Temporal flexibility should be incorporated into the water monitoring dates, so that data captures the fluctuation of conditions throughout the year.
- The watershed model (WARMF) should be utilized to make management decisions, especially to determine validity and cost-effectiveness of proposed water resources projects.
- Reforestation campaign tree planting efforts should focus on areas identified as "high priority" in this project's multi-criteria model, if all other social and economic factors are held constant.

## CONCLUSION

**"The true efficacy of these projects will not be known for some time, and depends upon whether these actions effect measurable changes in human health indicators and sustainability of water resources in the basin."**

**- Dan Sussman, Project Member**

Recognizing a problem with the water resources dynamics in this watershed, the project set out to provide solutions that would improve both human health and the environment. Methods employed by this project encompassed both practical applications, such as creating BMP design manuals and improving the water monitoring program, and theoretical research aimed at informing management of the watershed, such as modeling drivers and outcomes in ArcGIS and WARMF.

## ACKNOWLEDGEMENTS

We greatly appreciate the invaluable assistance of project advisor Dr. Arturo Keller, project partners, external advisors, and contributing fellow students.

* Please see the project report for a complete listing of references.