GROUP PROJECT BRIEF

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Framework for Developing a Sustainable Watershed Management Plan for San Cristóbal de Las Casas, Chiapas, Mexico

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ON THE WEB AT HTTP://WWW.BREN.UCSB.EDU SPRING 2006

Inside

Watershed Facts:

- **Area: 20,056 hectares**
- **Elevation: 2180-2800 meters**
- **Temperature — average monthly high and low: 11-25°C**
- **Average annual rainfall: 1,109 mm**
- **Rivers: Río Amarillo and Río Fogótico**
- **Population — urban area: 138, 000**
- **Population — outskirts: 32, 000**

Project Background

The colonial city of San Cristóbal de Las Casas, in the central highlands of Chiapas, Mexico, is the cultural and economic center for the indigenous Mayan population of southern Mexico. The region is also one of the poorest in Mexico, trailing the nation in most quality of life and economic indicators. On average, the region receives a high annual rainfall, but still experiences a supply deficit for human consumption due to a lack of management and infrastructure.

Figure 1. San Cristóbal is located in southern Mexico in the central highlands of the state of Chiapas.

Significance

Socio-political upheaval of the last two decades has brought many rural peasants into the city, more than doubling the population of the urban center. The city's population continues to grow at a rapid rate and is expected to double again by 2020. This explosion in population has placed the city's infrastructure under increased pressure and is insufficient to meet the basic needs of a large portion of the population. Further, there is anecdotal evidence that basin storage and recharge has diminished from historic levels and will continue to decline if proper management and planning strategies are not implemented to relieve the increased stress on the aquifer.

Sanitation services in San Cristóbal are even more limited. While sewerage infrastructure exists to convey waste out of the urban center of the city, none of the waste is treated before being discharged into the surface water system. The surface waters of the region have become increasingly polluted as the primary receptor of this untreated domestic sewage. Sewage input has increased in accordance with population growth, and as a result the water leaving San Cristóbal no longer meets the national surface water quality standards. As such, the municipality currently owes several million U.S. dollars to the National Water Commission and will continue to accrue fines as long as they remain out of compliance.

Approach

To address these concerns, the project took a watershed based approach to assess the problems that face the city. The project collected physical, social, economic, and political information about the area in order to begin developing an integrated watershed management plan. Furthermore, the project built a partnership between research and community based institutions in San Cristóbal and the University of California-Santa Barbara, laying the foundation for future cooperative research initiatives. This partnership has provided the region's stakeholders with a review of best management practices, a surface water quality monitoring plan, an analysis of wastewater treatment options, and a watershed model through which different management alternatives can be evaluated.

Project Partners

ECOSUR 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 one in San Cristóbal.

SYJAC is a nonprofit organization based in San Cristóbal, whose objective is to support community building and improve the quality of life in indigenous communities around the city. SYJAC regularly participates in sustainable works projects in indigenous communities, including potable water supply and sanitation improvements.

Watershed Description

The watershed occupies 20,056 hectares and is topographically concave. San Cristóbal is situated in the south central portion of the basin. The urbanized area occupies the lowest lying portions of the watershed and comprises about 18% of the area.

The two main rivers in the watershed are the Río Fogótico and the Río Amarillo. These rivers, as well as a number of other smaller tributaries and streams, converge in the lowest section of the watershed and flow south, out of the watershed through an outlet tunnel.

Historically, water flowed out of the watershed through a series of natural geologic features at the base of the southern mountains. Frequent flooding caused by slow drainage of the original outlet led to the eventual construction of a tunnel, 6 km in length, through the southern mountains of the watershed, allowing rapid drainage of the landscape.

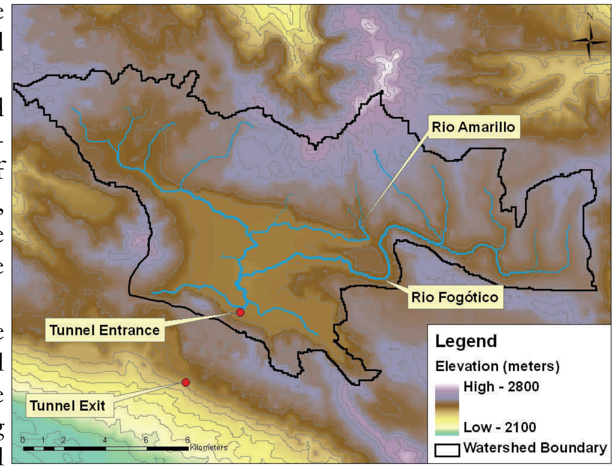

Figure 2. Watershed extent, main rivers, and outlet.

Stakeholder Descriptions & Concerns

Within the watershed, we identified 12 groups that fall into four distinct areas: private citizens, government agencies, private industry, and organizations involved with research and/or community development.

Private Citizens

There are five groups of citizens that live with varying conditions of water supply and sanitation. Those that live in the city center have water that is consistently piped into their houses, have proper drainage systems, and most are able to afford bottled drinking water. The next two groups of citizens live just outside of the downtown region. One group has taps in their houses with water available five to six days a week, the other only has water available at neighborhood taps a couple of days every week. Generally, neither group can afford to buy additional bottled water and are often forced to use the nearby surface water to complete household tasks. In the outskirts of the watershed there are small communities that are not connected to the municipal water supply or conveyance system. These communities rely on nearby springs for their domestic water needs. Sanitation services for these groups varies from conventional toilets system to pit latrines. The final group of citizen stakeholders are those that live outside the watershed but receive the water that flows downstream of the city and out of the watershed and use it for agricultural purposes.

Government Agencies

The two government agencies that have been identified as stakeholders in the development of a watershed management plan are SAPAM and CNA. SAPAM, the municipal water utility, acts to supply the community with potable water and sanitation services. CNA, Mexico's federal water agency, is responsible for setting and enforcing water quality standards.

Private Industry

The private industries in San Cristóbal that are potentially interested in the management of the watershed are the tourism industry, water suppliers and bottlers, and a Coca-Cola/FEMSA bottling plant.

Research/Community Organizations

The final two stakeholders in this process are ECOSUR and SYJAC. Researchers at ECOSUR are involved both with water management and the generation of spatial information. The information coming from ECOSUR is being used to guide the actions of SAPAM and to help make recommendations as to how the resources should be managed in San Cristóbal. SYJAC is principally concerned with improving the lives of people throughout Chiapas and specifically in San Cristóbal. SYJAC works toward this aim through a variety of actions that includes improving human health, defending human rights, and stewardship of the environment.

Project Deliverables

The following four deliverables were designed and developed as part of a watershed management decision making framework. These tools are meant to be adaptable to the specific needs and management goals of the local water utility and other stakeholders.

1. Watershed Model

To gain insight into local watershed processes and explore the potential impacts of various management scenarios, a watershed model (WARMF) was implemented. The limited set of existing data did not allow for calibration, but the model still allowed us to integrate available data into a conceptual understanding of the hydrological processes within the watershed.

The model allowed us to estimate surface water flow and the movement of pollutants. We also modeled conditions under a variety of management scenarios including population growth, BMP implementation, and maintaining the status-quo.

A sensitivity analysis was conducted to determine which parameters most affect flow within the watershed. This information will assist our partners in their data collection efforts. We are delivering the model to our partners not as a finished product, but as a living tool to be updated and utilized as data is collected or new management strategies are suggested.

2. Wastewater Treatment Options

In the urban center of San Cristóbal, wastewater is collected in a combined sewage and stormwater conveyance system and discharged into the river system at various locations throughout and downstream of the city. As the municipality currently owes several million U.S. dollars in fines for being out of compliance with ambient surface water quality standards, one of their top priorities is wastewater treatment. To help the municipality assess the treatment options, we answered several important questions: 1) What are the population growth projections that need to be planned for; 2) How much wastewater is produced; 3) What is pollutant load produced; and 4) Where is the most suitable location for a treatment facility?

Treatment options considered for this analysis include a variety of lagoon systems, constructed wetlands, intermittent filtration systems, and conventional wastewater treatment plants. There are four scenarios under which each treatment option can be considered as depicted in Figure 3. The treatment facility can treat wastewater conveyed via a collection system, no longer discharging directly into the river, or it can treat the entire flow of the river, including the wastewater. Additionally, wastewater can be treated either before the tunnel entrance or at the exit of the tunnel, outside of the watershed boundary.

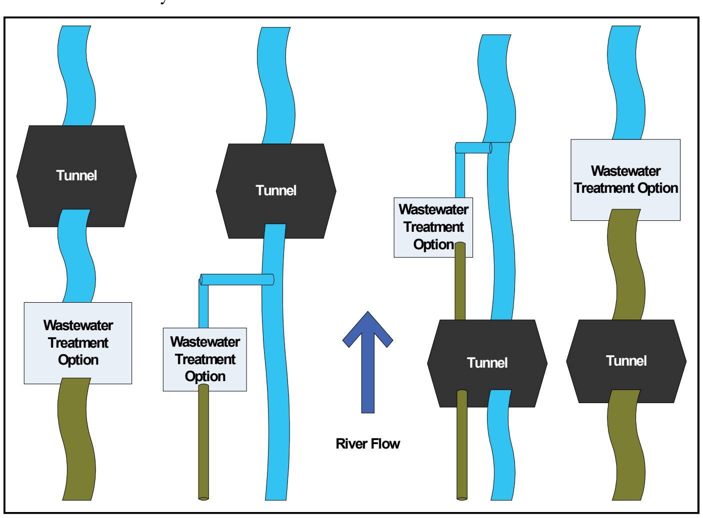

Figure 3. Possible wastewater treatment scenarios.

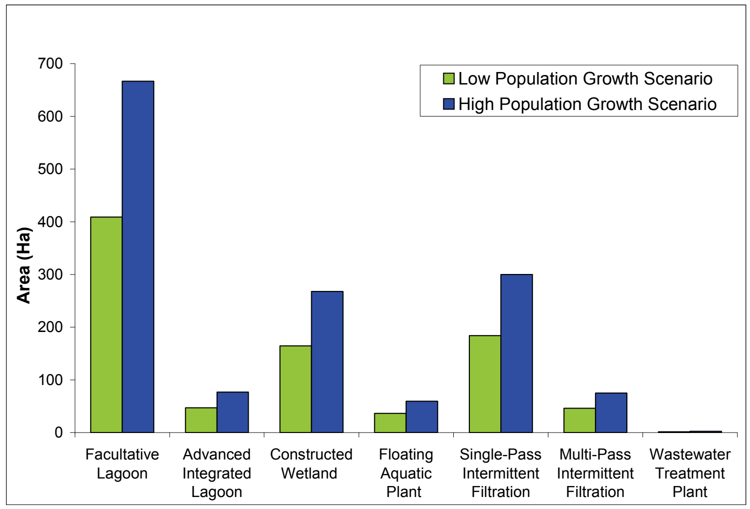

Figure 4. Area of land required to treat the future wastewater flow.

To determine the range of possible wastewater flows and pollutant loads requiring treatment, both high and low population growth scenarios were considered. The low growth scenario predicts a population of 230,000 people by the year 2030 and the high growth scenario predicts 375,000 people. Given these estimates, the average flow needing treatment in a combined wastewater and stormwater system is substantially lower as compared to the average flow to treat the whole river (river water, wastewater, and stormwater).

For each treatment option considered, the amount of land needed to accommodate the facility was estimated based on process design values for assimilating biochemical oxygen demand or hydraulic loading where appropriate. The amount of land needed for each option is shown in Figure 4 above.

Slope of the land also needs to be taken into account when selecting a treatment scenario, as many of the treatment options require a relatively low slope. The average slope of the land at the outlet of the tunnel is 17%, with a maximum grade of 40%. If the municipality wants to treat the wastewater here, this would require an additional 12 km of conveyance infrastructure, 6 km through the tunnel and 6 km to the nearest area of flat land.

3. Best Management Practices

Best management practices (BMPs) include a range of alternatives available to meet the goals of any watershed management plan. The management of a watershed that spans a diverse range of communities and landscapes requires the implementation of various strategies. These practices are designed to mitigate the effects of stormwater events, soil erosion, nitrogen and phosphorus loading, sedimentation, surface water contamination, as well as increase groundwater recharge and water availability for human consumption.

There are many BMPs available to our partners in San Cristóbal. The criteria used to evaluate BMPs include their ability to address multiple concerns, potential load reductions, physical land requirements, and cost. The following BMPs were chosen as a representative package of low-cost options that address multiple concerns. These include rainwater capture and collection systems, composting latrines, retention basins, contour water retention trenches, buffer zones and bioswales, and educational campaigns. We recommend that these BMPs be implemented in the watershed as soon as possible in the form of pilot projects in order to begin measuring their effectiveness. In addition to this recommended set, we provide our partners with a suggested methodology for evaluating BMPs based on situation specific criteria. This will aid them in the final selection of management strategies.

4. Water Quality Monitoring Plan

Although the surface water is known to be contaminated with urban and agricultural loads, no data has been collected to characterize the water quality. In order to fill this gap, a surface water monitoring program was designed for the local watershed to provide a better understanding of the sources, amounts, movement, and fluxes of contaminants in the region. The monitoring plan outlines the following in detail:

- Water quality parameters to be tested
- Equipment needed to measure parameters
- Protocol and methods for data collection and analysis
- Site locations organized by suggested sampling priority
- Suggested sampling frequency
- Costs of resources needed to carry out the plan

Figure 5 details the suggested sampling locations by priority. High priority points are designed to give an understanding of the water quality just before it enters the urban area, medium priority points will give an understanding of the quality before it goes through rural and agricultural areas, and low priority points measure the quality of the water within the urban area itself. This design was used to allow for flexibility of implementation given the potential timing and cost constraints of ECOSUR who has committed to implementing the plan. As of April 2006 ECOSUR, with the help of SAPAM, installed flow meters and began implementing the monitoring protocol. The results of the study can be used to calibrate the WARMF model as well as allow for monitoring the impact of BMPs as they are implemented by quantifying the improvements in water quality over time.

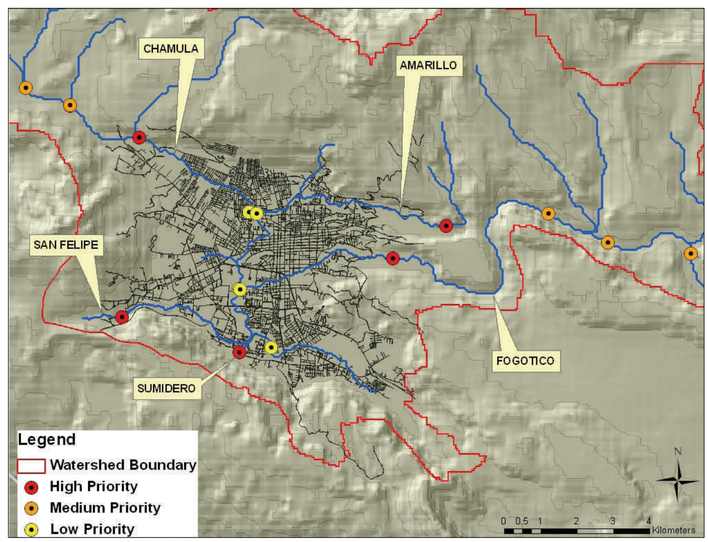

Figure 5. Prioritized sampling locations in the watershed.

Conclusions

The sustainable management of water resources in San Cristóbal requires more than just understanding the environmental factors governing the watershed. The social needs of the community, including consistent water supply and sanitation, need to be addressed. In order to create a management plan, a considerable amount of data must be collected first, including water quality information and the cost of project implementation. Essential to the proper management of the system is wastewater treatment. The current system of discharging wastewater directly into the area's surface waters results in a negative impact on both human heath and the environment - a relationship that is not fully understood by those who are most dependent on these waters to meet their domestic needs.

Recommendations

1. **Implement the specially designed water quality monitoring plan.**
2. **Conduct further analysis to determine the local costs of selected BMP strategies.**
3. **Establish pilot BMP projects to determine local effectiveness.**
4. **Use preliminary design considerations to further explore advanced treatment lagoons, intermittent filtration systems, or modular treatment plants to treat the city's wastewater**
5. **Implement a water resources educational campaign.**