Water Reuse and Conservation in the United States Virgin Islands

by

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ABSTRACT

An assessment of the current water conservation and reuse practices in the United States Virgin Islands was undertaken by administering surveys to Territory Permit Discharge Elimination System permit holders and performing interviews. Currently, many resorts and condominiums in the US Virgin Islands (USVI) reclaim wastewater in response to water scarcity for such things as irrigation and toilet flushing, but few practice water conservation. Unfortunately, the municipal wastewater treatment plants do not practice any form of reuse. Because of the need for reuse and conservation planning in the community, eight reuse alternatives were developed for the two large municipal wastewater treatment plants on St. Thomas and St. Croix. Those reuse alternatives include: (1) residential irrigation on St. Thomas, (2) habitat restoration utilizing wetlands on St. Thomas, (3) community-wide conservation and habitat restoration on St. Thomas, (4) airport irrigation on St. Croix, (5) commercial irrigation and industrial process/cooling water on St. Croix, (6) agricultural irrigation on St. Croix, (7) habitat restoration utilizing wetlands on St. Croix, and (8) community-wide conservation and habitat restoration on St. Croix. Out of these eight alternatives, habitat restoration on both St. Thomas and St. Croix, community-wide conservation and habitat restoration on both St. Thomas and St. Croix, and agricultural irrigation on St. Croix are the most economical based on the normalized cost per gallon of reclaimed and conserved water. However, agricultural irrigation on St. Croix and community-wide conservation and habitat restoration on both St. Thomas and St. Croix provide the most benefits to the community. Agricultural irrigation provides farmers a low-cost option to meet water demand and production requirements. Community-wide conservation and habitat restoration alternatives provide an educational environment and promote conservation practices thus reducing water consumption, water cost, and wastewater production. From the assessment it is apparent that promoting conservation and reclaiming wastewater effluent results in a reduction of effluent discharged to the ocean, conservation of fresh-water sources, reduction of energy and pollution due to lower production needed by USVI Water and Power Authority (WAPA), and avoidance or delay in USVI WAPA expansion to meet non-potable water needs. Before undertaking design of a reuse project incorporation of public information and participation, public health impact identification, and local and federal government participation is crucial to project success.

Thesis Supervisor: Dennis McLaughlin
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1.0 Introduction

According to the United States Environmental Protection Agency (USEPA), the average American citizen uses approximately 150 gallons of water per day (1996). Of that amount only one-half gallon is used as drinking water while the remaining amount is used for cooking, cleaning, flushing, irrigation, or non-consumptive uses. What can Americans do to provide potable water for purposes other than drinking? There is another way to meet the water demands without costly treatment: water recycling or reuse and conservation. Water recycling is "reusing treated wastewater for beneficial purposes such as agricultural and landscape irrigation, industrial processes, toilet flushing, and replenishing a ground water basin" (USEPA, 1998).

Dealing with water scarcity has been a challenge in the US Virgin Islands for many years. The combination of extreme events such as hurricanes and the lack of holistic infrastructure planning have conditioned the US Virgin Islands population to a state of constant drought. It is difficult to analyze the islands as a whole, because they are substantially different: St. Thomas is the center of tourism and commerce, St. Croix is the industrial center, and St. John is mainly a natural reserve with a low population. Water to support these islands is obtained in three ways (US Department of Interior, 2000):

- catchment of rainwater
- saltwater conversion or desalination
- extraction from wells

Prior to and since the development of the first USEPA Water Reuse Guidelines in 1980, communities across the continental United States have looked to wastewater reclamation, otherwise known as water reuse, as a potential source of non-potable water. With the development of advanced technologies water reuse and conservation have become attractive options for protecting water resources, eliminating the need to expand the potable water supply

and treatment facilities, and controlling pollution (Ammerman and McCullen, 2002). Water conservation and reuse are critical because population growth, higher living standards, and increased agricultural production cause increasing demands on the world's water resources (Bouwer, 2002). Water conservation and reuse planning may be appropriate for the US Virgin Islands.

The US Virgin Islands' current water supply and treatment systems have been taxed due to geology and climate and increases in population of both tourists and year-round inhabitants. Because of these pressures the US Virgin Islands has had to resort to rainwater catchment and desalination in order to meet water demand. One option for the citizens and businesses of the US Virgin Islands is to invest in water reuse, conservation, and treatment technologies with the ultimate goal being to make more water useable by the residents and businesses of the US Virgin Islands.

The following sections showcase and analyze various water reuse strategies utilized in other communities throughout the world, summarize current water reuse practices in the US Virgin Islands, and explore possible reuse programs for the larger municipal treatment plants on St. Thomas and St. Croix. This thesis will also touch on conservation practices and products for both residential and commercial customers, the political and regulatory aspects of reuse, and the implications of new programs on those regulatory bodies.

2.0 Water Reuse and Conservation Background

Total demand on the United States public water supply systems has nearly tripled in the past 50 years (USEPA, 1999). In order to meet current water demands in areas where adequate fresh water sources are scarce, water reuse and conservation are viable options that have been applied in an ever-increasing number of communities over the past 30 years.

2.1 Water Reuse History

Prior to developing initial guidelines in 1980, the US Environmental Protection Agency (USEPA) began generating interest and support in the area of water reuse and reclamation amongst wastewater operators (Ammerman and McCullen, 2002). The 1980 USEPA guidelines included information on proven technologies in the area of water reuse. In 1992, through funding from the USEPA and the US Agency for International Development's (USAID) Water and Sanitation for Health (WASH) program, these guidelines were updated to reflect technological advances in water reuse practices. In 2002, the USEPA decided to update the water reuse guidelines once again due to significant technological advancements over the past eleven years. These updates are planned to be completed and published by the USEPA in 2004.

Because of decreased availability of quality water supplies and increases in water demand from increases in population states were forced to focus on water resources planning. States such as Florida and California have developed and implemented their own water reuse programs and legislation in order to meet demand and have proven to be leaders in water reuse and reclamation. Several of the case studies featured in Chapter 3 occurred in these two states.

Reclamation of wastewater has been traditionally known to solve water quality issues and increase water supply (von Dohren, 1980). By utilizing reclaimed water a utility can reduce the cost of effluent disposal and surface water quality issues while maintaining the condition of fresh

water sources and utilizing large volumes of reclaimed water for non-potable uses. According to von Dohren this reduces the amount of pollutants entering water bodies and the potential of health hazards, and improves the aesthetics of the water body.

Various types of reuse projects can be applied in a community. Categories of reuse projects are: (1) urban reuse, such as for irrigation of commercial, residential, school areas, and golf courses; (2) industrial reuse, such as for cooling water and industrial process water; (3) agricultural reuse; (4) recreational reuse; (5) habitat restoration and enhancement; (6) groundwater recharge; and (7) augmentation of potable supplies (Ammerman et al., 1992). Sources of water for reuse projects are treated resort, condominium and municipal wastewater effluent. All of these reuse and source categories were evaluated and are described in the following sections.

2.1.1 Urban Reuse

Urban reuse requires a reclaimed or reused water distribution system to be installed parallel to potable water lines so that reused water can be distributed for use in homes or businesses. Retrofitting an urban area with the necessary infrastructure for reuse can be expensive and disrupting. Water demands can be estimated from a combination of local water company records and private records from each of the resorts, condominiums, and residential homes. Cisterns provide additional water therefore it is necessary to look at private records as well as public records to determine overall water demand. For the reclaimed system design the most important factors are the "reliability of service and protection of public health" (Ammerman et al., 1992). In order to address protection of public health and reliability of service the design must assure no cross-contamination with potable water lines and that the quality of the water is appropriate for the intended use. The community must also be informed of the proper uses of the reclaimed water.

When designing a system of this nature, the system must be flexible and robust to meet water demands and maintain water quality. Several strategies can be built-in to the system to mitigate service interruptions. These strategies include secondary treatment with disinfection and filtration, storage and piping networks sized to manage diurnal and seasonal fluctuations in demand, system pressure to satisfy residential and/or fire protection needs, and usage control such as varying the days or hours that golf courses, schools, and residences can irrigate to lower peak hourly demand of reclaimed water. Because of its practicality, the application of urban reuse will be investigated further for the US Virgin Islands in Chapters 5 and 6.

2.1.2 Industrial Reuse

According to a 1995 United States Geological Survey (USGS) report, water use by industrial customers accounted for an average of 5.5 % of the total water consumption in the United States. The water use by industrial users in the US Virgin Islands was approximately 20 million gallons per day (75.7 million liters per day) or 10% of the total water use on the islands. This is even higher on St. Croix as the others have very little to no industry. Because industrial demand is a relatively high fraction of total demand, the potential for reuse is promising. Within industrial processes, reclaimed water can be used for cooling water, boiler-feed water, process water, and irrigation of grounds (Ammerman et al., 1992). The water quality necessary for each process varies and must be considered on a case-by-case basis. The most common parameters that must be monitored are organics, ammonia, phosphorus, suspended solids, biological organisms, and metals such as calcium and magnesium. This reuse alternative will be evaluated for existing industrial facilities on St. Croix because of the potential for significant water savings.

2.1.3 Agricultural Reuse

Agricultural irrigation is another water reuse option that will be examined for the US Virgin Islands. Water demands for agricultural irrigation change based on the seasons, climate,

and crop type and can be estimated based on local knowledge of soil, climate, and agricultural conditions. According to Ammerman et al. (1992), the single most important factor in determining whether reclaimed water is suitable for agricultural irrigation is salinity because the tolerance of crops to salinity varies. Parameters such as chlorine, nutrients, and metals are also of concern and must be monitored. In addition to quality requirements, the reclaimed water must also be served by a reliable distribution system. Ground-water and reclaimed water quality prior to application must be monitored. Marketing strategies such as public outreach and education must be in place to gain the farmer's trust. Often times a pilot study is necessary to show that the reclaimed water will be of the same or better quality than water previously used for irrigation.

According to data from the University of Virgin Islands Conservation Data Center the amount of agricultural land on St. Thomas, St. John and St. Croix as of 2001 was 9.82 acres, 0.47 acres, and 623 acres, respectively. Due to the small amount of agriculture on St. Thomas and St. John, this reuse option does not seem to be feasible. However, this reuse option may be feasible on St. Croix depending on the proximity of agricultural land to the reclaimed water source.

2.1.4 Habitat Restoration and Enhancement

Three other reuse possibilities are habitat restoration, habitat enhancement, and recreational use. Reclaimed water can be applied to wetlands to restore or enhance the wetland system, provide additional treatment, or provide a wet weather disposal alternative for the reuse system (Ammerman et al., 1992). Reclaimed water can also be applied to landscape ponds, golf courses, recreational ponds for swimming or boating, ornamental fountains, and stream augmentation. Each of these uses requires the water to be treated to a certain level that is dependent on the intended use (i.e. recreational use will require a much higher level of treatment and disinfection). These types of reuse projects can easily be incorporated into a residential area

or golf course since most contain some type of water pond that could easily serve as a storage facility for reclaimed water.

2.1.5 Groundwater Recharge

When evaluating groundwater recharge as a water reuse alternative, one must consider the cost of energy and injection wells, increased risk of aquifer contamination, increased risk of flooding due to land requirements for surface spreading, and possible legal liabilities (Ammerman, et. al., 1992). Contaminants and pathogens in the reclaimed water must be taken into account when considering groundwater recharge as a possible use for reclaimed water since the boundary between potable and nonpotable aquifers is vague.

The primary aquifers on the islands of St. John and St. Thomas are volcaniclastic formations and coastal embayment formations which transmit water through fractures. In these formations the ground water is generally brackish to saline due to the proximity to the ocean (USGS, 1984 & 1995). However, ground-water recharge may be a useful option since ground-water injection can serve to prevent saltwater intrusion, provide further treatment of reclaimed water for future reuse, and provide storage for reclaimed water. The interaction between the volcaniclastic aquifer and coastal embayment aquifers may not allow for recharge to be used due to storage properties of the volcanic formation and the nonpotable uses of the coastal embayment aquifer.

The northwestern and eastern portions of St. Croix are dominated by similar volcaniclastic formation as that found on St. Thomas and St. John. The more productive Kingshill aquifer on St. Croix is a different type of formation. This aquifer occupies the central and southwestern portions of St. Croix. This formation consists of alluvial, slope wash, and debris flow deposits overlying limestone and marl. The Kingshill aquifer has properties that are conducive to groundwater recharge. This alternative may prove to be a viable option although a

recent policy decision by the Virgin Islands Department of Planning and Natural Resources (DPNR) to cease the granting of groundwater recharge permits may cease the use of this type of reuse alternative (Hutchinson, 2003). Because ground-water is considered a "water of the territory" and is extremely valuable and scarce, the DPNR decided to cease granting of groundwater injection permits.

2.1.6 Direct Potable Reuse

The final alternative that was examined is augmentation of potable water supplies (Ammerman et al, 1992). Indirect potable reuse is in practice in mainland areas today. Treated effluent from a wastewater facility is discharged to a river or lake while another community downstream takes in water from the river or lake as their potable water source. The public accepts this practice since wastewater effluent is seen as being further treated by nature. Direct potable reuse is currently not practiced in the United States although several communities are conducting extensive research. Since not much is known about the chemical impact of some compounds, specifically organic compounds, regulators and the public remain reluctant to accept direct potable reuse since it increases the degree of human contact with reclaimed water. In fact, a case study performed in Marin County, California in 2000 showed that there were many barriers to direct potable reuse (Sheikh et al., 2002). Two of the barriers identified were uncertainty of public reaction to the concept, and the lack of availability of an adequate detention facility requiring adequate mixing characteristics and volume for a residence time of at least one year (a widely accepted safety and psychological rule-of-thumb).

2.2 Water Conservation History

As of October 2000, no state is required by the federal government to have a water conservation program although some state and local governments require conservation programs for new developments. The USEPA has published guidelines regarding conservation practices

that can be undertaken by water distribution systems and water efficiency practices for residential, commercial, industrial, agricultural, municipal, and irrigation users (USEPA, 2000b). States such as Florida, California, Connecticut, New York, District of Columbia, Washington, Texas, Oregon, and Arizona have instituted a variety of water-efficiency requirements and education programs for all water users.

The USEPA suggests changing a few personal habits to effectively conserve water (USEPA, 2002c). Keeping a bottle of water in the refrigerator instead of running the water until it gets cold or washing dishes in a dishwasher rather than by hand are two of these habits. In the home, the most water is used in the bathroom. By turning off the faucet while brushing teeth and taking a three to five minute shower instead of a bath a person can conserve approximately 35 gallons of water per day. Flushing the toilet also uses a large percentage of water. Installing products from water conservation equipment vendors helps to conserve water. One such vendor, AM Conservation Group Inc., offers water conservation kits that include products such as a bath aerator, toilet tank water saver, showerhead, dye tablet, and instructions for less money than purchasing products separately. There are also new washing machines that reduce water consumption by one third.

Operators of residential and commercial irrigation systems can also conserve water by implementing the Xeriscaping concept (USEPA, 2000b). Developed in Colorado in the early 1980's as a result of prolonged drought Xeriscaping consists of seven steps to make irrigation systems more efficient: (1) plan and design to minimize cost and maintenance; (2) use turf only where needed and substitute drought-tolerant ground cover for other areas; (3) use drought-tolerant plants and plan sun-exposure accordingly; (4) use mulch for water retention, fertilization and weed control; (5) place plants according to water needs; (6) improve soil conditions to allow

for more efficient water absorption; and (7) properly maintain the landscape to reduce maintenance cost. The USEPA also recommended that operators of residential and commercial irrigation systems water lawns and plants early in the morning or at night to reduce loss from evaporation and ensure water is being used on lawns, not sidewalks or streets.

2.3 Funding Options

Funding for water reuse and conservation programs is available. Both Externally and internally generated options are available. An example of externally generated funding is the Clean Water State Revolving Fund (CWSRF) program. Under sections 212, 319, and 320 of the 1987 Clean Water Act (CWA) amendments gave authorization to fund point source, nonpoint source, and estuary projects, respectively (USEPA, 1999). Available in each of the fifty states and Puerto Rico the CWSRF program provides low or no-interest loans to municipalities for water quality improvement projects. The CWSRF program is managed by each state or territory, and the type of project that receives funding varies from state to state.

If water reuse and conservation plans are components of a publicly owned wastewater treatment works project they may be considered under the point source category (USEPA, 1999). Because of this water reuse and conservation plans may be eligible for funding from the CWSRF. Sections 212 and 603(c) of the CWA clarify the requirements. A very crucial first step to obtain CWSRF funding for eligible projects is to register the project in the state or territory's Intended Use Plan. Water reuse and conservation projects that have received funding include:

- Retrofitting and replacing plumbing fixtures in government buildings;
- Recycling gray water in municipal buildings;
- Reuse of wastewater for public purposes;
- Public education programs; and

- Use of water conservation ordinances and regulations.

If the water reuse and conservation project is innovative, states have often funded these projects to serve as demonstration of a particular technology or concept. This occurred at Toppan Electronics in San Diego, California. The next chapter will discuss this project as well as several other examples of water reuse. Examples of other external generated funds are municipal tax-exempt 20- or 30-year bonds and capital contributions from developers or industrial users.

Internally generated funding options include operating budget and cash reserves, property taxes and existing water and wastewater charges, special assessments or tax districts, connection fees, and reuse user charges. All of the previously mentioned funding options would be possible except using existing wastewater charges. The Virgin Islands DPW does not currently charge wastewater fees.

3.0 Case Studies of Water Reuse Projects

Water reuse has become a critical aspect of water management in many areas of the United States and around the globe due to ever increasing water demand. Because there are so many case studies of water reuse projects that could be discussed; examples are listed in Table 3-1. The following chapter discusses, in detail, four of these projects which illustrate different uses of reclaimed water that could be applied in the U.S. Virgin Islands: industrial, urban, groundwater recharge, and habitat restoration.

Table 3-1: Examples of Reuse Projects in the United States

PROJECT NAME AND LOCATION	REUSE TYPE	REFERENCE
Orlando Utilities Commission Stanton Energy Center, Orlando, FL	Industrial	Stalls and Weiss, 2002
Mountainview Power Company, Redlands, CA	Industrial	Headrick et al., 2002
Toppan Electronics, San Diego, CA	Industrial	Gagliardo et al., 2002
Indian River Lagoon, Vero Beach, FL	Urban	Olson et al., 2002
Project IRIS, Boca Raton, FL	Urban	Wellings, 2002
Project APRICOT, Altamonte Springs, CA	Urban	Helgeson, 2002
Volusian Water Alliance, Florida	Groundwater Recharge	Blais and Morrell, 2002
South Florida Water Management District	Groundwater Recharge	Elsner and Dernlan, 2002
Constructed Wetlands, Arcata, CA	Habitat Restoration and Recreation	USEPA, 2002c
Big Bear Valley, CA	Habitat Restoration and Recreation	Schindler, 2002
Golf Course and Farm Irrigation, Raleigh, NC	Urban and Agriculture	Rimer et al., 2002
Pajaro Valley, CA	Agriculture	Kubler et al., 2002
Landscape and Pasture Irrigation Reno and Sparks, NV	Urban and Agriculture	Dennis et al., 2002

3.1 Industrial Reuse

In San Diego, California, Toppan Electronics took part in the *Water for Industry* demonstration project sponsored by the City of San Diego to promote industrial use of reclaimed wastewater from the North City Water Reclamation Plant (Gagliardo et al., 2002). For Toppan Electronics a reliable water source is required since all production relies on water. Any loss of water supply will result in downtime and lost revenue. In order to mitigate possible reclaimed water system failure, a potable-water backup connection was installed using an air gap design to avoid cross connection of reclaimed and potable water.

Toppan Electronics had the need for two types of process water: reverse osmosis (R/O) and 18 Mohm quality water (see process flow diagram, Figure 3-1). Water purity can be measured by analyzing the resistance to electrical conduction in the water. This is done by using a conductivity meter. The conductivity meter produces a voltage differential across electrodes within the water. The current of electric flow between the two electrodes is then measured. The applied voltage and measured current are then used to determine the resistance of the water via the relationship V=IR. As the water quality increases (the number of dissolved ions decreases) the ability of the water to conduct electricity decreases. Water with a resistance of 18 Mohm has a high resistance that requires a low level of dissolved ions, thereby indicating that the water is of high quality.

The complexity of the *Water for Industry* project increased because of a lack of space at the industrial facility for treatment equipment (Gagliardo et al., 2002). However, the brand of microfiltration pretreatment chosen and installed fit the space constraint and had no trouble meeting the production requirements. Another challenge faced by the project team was free chlorine levels in the reclaimed water. R/O membranes are extremely sensitive to free chlorine;

therefore, dechlorination is necessary to protect the R/O membranes from deterioration. Two compounds, sodium bisulfate and ammonium chloride, were evaluated separately to dechlorinate the reclaimed water upstream of the granular activated carbon (GAC) filter. Sodium bisulfate was found to cause fouling of the RO membranes due to biological growth in the GAC beds. The use of ammonium chloride converts free chlorine to chloramines. Maintaining the chloramine level in the water between 2 and 6 parts per million has inhibited biological growth and, unlike sodium bisulfate, resulted in consistent performance of the RO system.

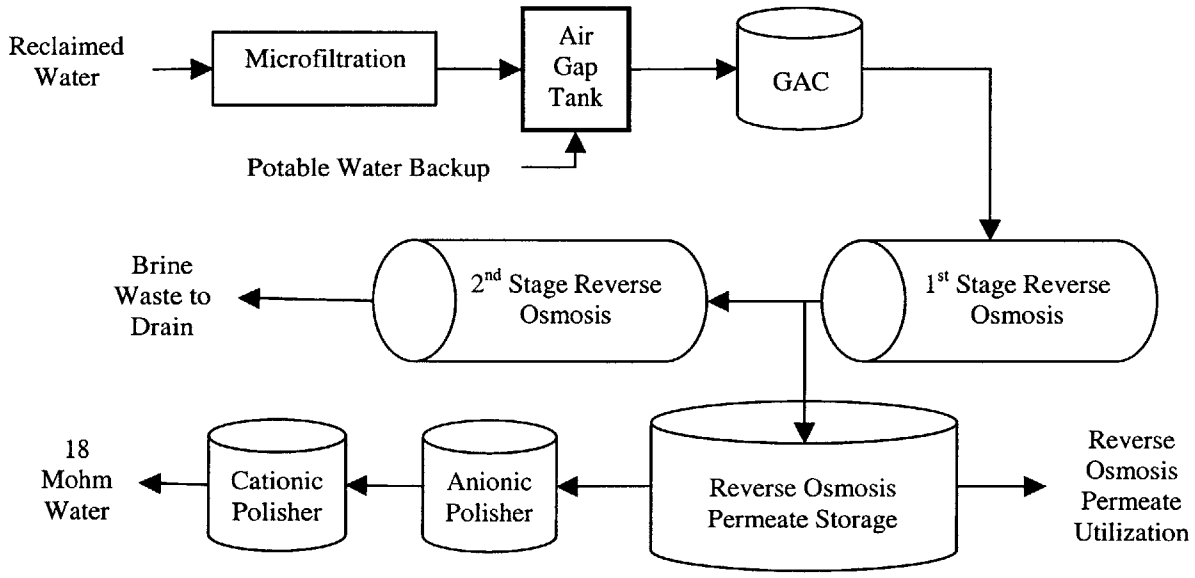

Figure 3-1: Process Flow Diagram of Reclaimed Water System, Toppan Electronics

One major objective of the *Water for Industry* project was to determine if reclaimed water can be a viable and cost effective source of industrial process water (Gagliardo et al., 2002). Operating costs for 18 Mohm quality and RO quality water using a potable water source were determined to be $4.98/Kilogallon and $4.50/Kilogallon, respectively, while utilizing reclaimed water resulted in $4.50/Kilogallon and $3.78/Kilogallon, respectively. The State of California funded the retrofit of the site and the purchase of the microfiltration unit, therefore, these costs were not included in the unit costs presented above.

Several technical and institutional difficulties arose during the course of this project. One difficulty that arose was the space constraint. To solve this problem the vendor of the microfiltration unit developed a compact design. Another difficulty was fouling of the R/O membranes. This was alleviated by using a different dechlorination chemical. By comparing the operating costs for a potable water source and reclaimed water source for the two types of process water mentioned above, it was determined that reclaimed water can be a viable and cost effective option even though technical and institutional difficulties arose. Depending on the capital investment required and the potential financial support received from state and federal agencies, industrial reuse may or may not be suitable for all companies.

Based on the project at Toppan Electronics, the use of reclaimed water as process water proves to be viable for industries. The St. Croix Renaissance Park, a proposed eco-industrial/recreational complex, is an excellent candidate for this type of reuse due to its proximity to a reclaimed water source (York, 2003). Reclaimed water applied to industries located in the St. Croix Renaissance Park could potentially lower operating cost and potentially improve public image through use of environmentally friendly processing.

3.2 Urban Reuse

The City of Altamonte Springs, Florida is home to one of the first large-scale public reuse systems in the United States, APRICOT (A Prototype Realistic Innovative Community Of Today) (Helgeson, 2002). The original intents of the reclamation facility were to decrease the demand for potable water for nonpotable uses and also decrease nitrogen and phosphorus loading into the Little Wekiva River from treated wastewater effluent.

Several items were crucial to the implementation of this reuse project: treatment plant upgrades, construction of a reclamation distribution system, and a public education program

(Helgeson, 2002). Proper operation of the treatment facility, strong and consistent ordinances, well-trained operations and field staff, as well as support from high level city officials affected the overall success and operation of the reuse system. Integration between installation of potable and reclaimed water supply lines when possible and the mandatory inclusion of a reclaimed water distribution system for all development constructed after 1992 were two examples of good planning and coordination. By creating an "Information Liaison" within the Public Works Department, the City of Altamonte was able to send a consistent message to interested residents and businesses regarding the project.

The water reclamation facility in Altamonte Springs treats an average of 6 to 6.5 million gallons per day (MGD) using primary clarification, secondary anoxic and aerated zone clarification, flocculation, denitrification, aeration, and disinfection. The treated water is then sent to one of two three-million gallon storage tanks. From the storage tanks an average of 94% of treated water is sent to the 500,000 gallon elevated storage tank prior to distribution through the reuse system. The remaining 6% of the water is dechlorinated and discharged to the Little Wekiva River.

Constructed over a 15-year period (from 1986 to 2001) for approximately $40 million, reclaimed water lines were installed parallel to potable water lines to provide irrigation water to residential and commercial customers. Recycled water is sent through the APRICOT distribution system via 83 miles of transmission mains to as many as 6000 residential customers and several hundred commercial customers (Helgeson, 2002). Most residents have access to the APRICOT system and pay a small monthly fee for the connection in order to cover the operation and maintenance fees associated with the reuse system.

Similar to potable water systems, the APRICOT recycled water system also had to deal with seasonal fluctuations (Helgeson, 2002). To handle the fluctuations in demand the City of Altamonte proposed the use of Cranes Roost, a stormwater storage facility within the city park. This facility stores reclaimed water as the plant produces it and supplies reclaimed water as customers need it. In cooperation with the Florida Department of Environmental Protection (FDEP), the City of Altamonte developed operating protocols to monitor the impacts of reclaimed water on Cranes Roost as well as allow the use of Cranes Roost for various community events. Using Cranes Roost allowed the city to attenuate the demand for reclaimed water and thus decrease the volume of reclaimed water discharged to the Little Wekiva River while maintaining the original stormwater control function of Cranes Roost. Although the APRICOT project has been successful, new challenges emerge as the reuse system expands its customer base and demand increases. These challenges include augmentation to meet fire demand, increased storage to handle larger reclaimed flow, and management of reclaimed water demand.

Similar to Altamonte Springs, many communities around the continental United States have successfully implemented urban reuse projects. Reuse in residential and commercial developments near reclaimed water sources in the U.S. Virgin Islands will prove to be a critical use of reclaimed water. Doing so will reduce the demand from the U.S. Virgin Islands Water and Power Authority (WAPA) and potentially reduce energy spent and operating cost for water production.

3.3 Groundwater Recharge

The South Florida Water Management District (SFWMD) covers an area and population of nearly 18,000 square miles and six million people, respectively (Elsner and Dernlan, 2002).

The Biscayne Aquifer is the primary source of water for residence and businesses in this area. In order to recharge the Biscayne Aquifer, prevent salt water intrusion, and provide agricultural and urban irrigation in south Florida, an average annual volume of 170 MGD of surface water was piped in and discharged into the aquifer prior to project implementation. This water is delivered via canals from the Everglades/Lake Okeechobee Regional Conveyance System, otherwise known as the Regional System. The SFWMD developed a pilot project to look at replacing deliveries of water with highly treated reclaimed water since reclaimed water does not experience seasonal fluctuations as do the Everglades and Lake Okeechobee.

Because of projected increases in demand from urban and agricultural customers, additional water supply deliveries will be needed to maintain the aquifer level and prevent saltwater intrusion (Elsner and Dernlan, 2002). Currently, wastewater flows totaling more than 600 MGD in the Lower East Coast Region (LEC), which includes Broward, Miami-Dade, and Palm Beach counties, are reused for irrigation (55 MGD), and discharged via ocean outfall or by deep well injection. With the projected increase in population these wastewater flows are projected to increase to more than 1 billion gallons per day (BGD).

The concept of indirect aquifer recharge would involve utilizing reclaimed water rather than water from the Regional System to recharge the Biscayne Aquifer (Elsner and Dernlan, 2002). By doing so, the dependency on the Regional System significantly diminishes, thus benefiting the entire community and supporting the objectives of the Comprehensive Everglades Restoration Plan (CERP). The quality of reclaimed water is much better than what is currently transported in the canals, the water level in the canal will be maintained, and transporting the reclaimed water via the canal system keeps the cost and disruption caused by construction of a reclaimed water distribution system to a minimum.

To develop the indirect aquifer recharge pilot study, SFWMD had to gain full support and participation of FDEP and USEPA staff (Elsner and Dernlan, 2002). These steps included establishing agency support, partnerships with utilities, a project team, developing an approach, utilizing team permitting concept, and implementing the pilot testing program. Because this type of reuse had never been pursued in Florida, amendments in 1999 to Part V of Chapter 62-610 of the Florida Administrative Code developed guidance and the regulatory framework to deal with indirect potable reuse and groundwater recharge.

Thus far the pilot study has engaged both FDEP and USEPA staff in a partnership (Elsner and Dernlan, 2002). Utilities in the LEC region with wastewater flows totaling more than 400 MGD have expressed interest in the study. Several meetings have been held to develop the project approach and educate agency staff on the concept of the pilot study. While developing the approach, questions regarding quality requirements have surfaced. Since sections of the canals are on the Florida 303(d) list of impaired water bodies, a Total Maximum Daily Load (TMDL) study will be completed for these segments.

Once the TMDL study is complete, the necessary quality of the reclaimed water can be determined. Along with the TMDL study, SFWMD suggested the use of three concurrent approaches to keep the project moving forward. The first such approach involved pollution credits or offsets to identify improvements within the watershed to reduce pollutant loading. The second proposed approach involved a review of the information used to determine that these canals were impaired such as in EPA's STORET database and additional data collected after the initial determination. The third approach proposed required reclassification or developing sub-classifications for the canals based on their current use instead of that used for streams.

This pilot study is ongoing, but the fate of indirect aquifer recharge seems to lie in the hands of regulators and the public. Other than gaining support from local utilities, SFWMD has done little to engage the public in the concept of indirect aquifer recharge. To engage the public SFWMD should utilize an information liaison such as the one used in the City of Altamonte, California.

Indirect recharge of the Biscayne Aquifer can be a viable source of water for the SFWMD. Because of the geology present in the U.S. Virgin Islands, this type of reuse would only be viable on the island of St. Croix. If the U.S. Virgin Islands Department of Planning and Natural Resources (DPNR) ceases to grant permits for groundwater injection, as was stated during an interview of a DPNR official (Hutchinson, 2003), this type of reuse may not be permitted under Virgin Islands Code.

3.4 Habitat Restoration

The Virgin Islands DPNR is currently reviewing a proposed project on St. Croix to demonstrate that wetlands can be used for additional wastewater treatment in the US Virgin Islands. Designs of several systems were used as models for this St. Croix wetlands project such as the design utilized in Arcata, California in the early 1980's.

Due to economic dependence on the local environment and increased restrictions on effluent discharge by the state of California, the city of Arcata and proponents of innovative treatment technologies piloted projects to demonstrate the effectiveness of wetland systems in treating wastewater (USEPA, 2002c). The primary objective of the projects was to treat wastewater to meet national and state water quality limitations. After performing several successful experiments and receiving support from both state and local agencies, the city began

to construct a wetland system that was incorporated into the Arcata Wastewater Treatment Facility.

The integrated Arcata wastewater treatment and wetland system consists of headworks, primary clarification, oxidation ponds, digester and cogeneration facilities, treatment marshes, enhancement marshes, and disinfection to treat an average annual flow of 2.3 MGD (USEPA, 2002c). Treated wastewater is then discharged to Arcata Bay. The headworks of the Arcata wastewater treatment plant is made up of several processes that remove inorganic material from the influent. The wastewater then proceeds to one of two clarifiers or settling tanks. The solids from this process are pumped to a two-stage digester/cogeneration process. By recirculating and burning the methane gas byproduct, the sludge is mixed and the heat from the methane gas aids in digestion of the sludge. The oxidation ponds receive clarified water and remove an estimated 50 percent of the remaining biochemical oxygen demand (BOD) and total suspended solids (TSS). Next, three two-acre marshes with native plants further reduce the levels of BOD and TSS before reclaimed water is sent to the chlorine gas disinfection unit. The effectiveness of BOD and TSS removal is dependent on the plant species chosen.

After the first pass through the disinfection process wastewater is sent to the first of three enhancement marshes. These marshes occupy 31 acres and are made up of a diverse number of aquatic plants to maintain water quality or further remove pollutants from the water. The water is then sent back to the chlorine gas disinfection unit before being discharged.

Wetlands can be a successful and economical way to treat wastewater and meet water quality criteria provided land is available (USEPA, 2002c). The wetlands in Arcata, now known as the Arcata Marsh and Wildlife Sanctuary, provide habitat for many species of birds and aquatic life, serve as educational and research tools for area Audubon Society members, students,

and visitors from around the world, and have improved the once rundown waterfront. Two of the main reasons this project was so successful are that land was available and land was available at a reasonable price.

Based on the success of the Arcata, California wetlands project and the fact that the DPNR is currently reviewing a St. Croix wetlands project proposal, wetlands seem to be a viable option for water reuse in the U.S. Virgin Islands. In addition to industrial and commercial reuse, the St. Croix Renaissance Park includes a recreational and educational component. Utilizing wetlands to satisfy this component may prove to be viable use of reclaimed water due to its proximity to the reclaimed water source.

3.5 Summary

The previous sections discussed four projects illustrating different uses of reclaimed water that could be applied in the U.S. Virgin Islands: industrial, urban, groundwater recharge, and habitat restoration. The *Water for Industry* project at Toppan Electronics shows that the use of reclaimed water can be viable for industries even though water quality requirements and space constraints can induce additional capital cost to treat reclaimed water. Using urban reuse, the City of Altamonte Springs achieved project APRICOT's original goals of decreasing potable water demand and reducing nitrogen and phosphorus loadings to the Little Wekiva River. The city is continuously dealing with water demand issues as the number of connections to the APRICOT system expands. Utilizing reclaimed water to recharge the Biscayne Aquifer may prove to be very important for the residents and businesses in the SFWMD. This type of reuse may also prove to be beneficial for the island of St. Croix yet it is unknown at this time if policy decisions by DPNR may prevent this type of reuse project from occurring. Because of land availability, potential improvement of the city waterfront, and regulatory and community

support, habitat restoration, and wetlands augmentation has been a successful wastewater treatment tool for the City of Arcata, California. This type of reuse along with industrial and commercial reuse may prove successful at the St. Croix Renaissance Park due to its proximity to a reclaimed water source on St. Croix.

4.0 USVI Case Studies

Many resorts and condominiums in the US Virgin Islands utilize water reuse to meet water demands despite lack of local regulatory oversight. The majority of resorts and condominiums that completed the survey and were interviewed were located on the southern, southeastern, and eastern shores of St. Thomas. This chapter will give an overview of water reuse and conservation regulatory requirements, survey layout, and survey and interview results.

4.1 Water Reuse and Conservation Regulatory Overview

As was stated in Chapter 2 of this thesis, there are no formal water reuse and conservation rules or regulations directed by the USEPA to each of the states or territories. In response to increased cases of water shortages and the positive outlook of wastewater reclamation, guidelines were developed by the USEPA to assist those interested in reclamation projects (Ammerman et al., 1992). In conjunction with the increased awareness of wastewater reclamation, water reuse legislation has been instituted in several states.

According to Virgin Islands Department of Natural Resources and Planning (DPNR) staff, currently there are no water reuse or conservation regulations (Simon, 2003). Permits will be required of those that utilize irrigation as a means of discharging treated wastewater effluent, but they are currently not required. However, as of January 2003 the final policy decision regarding when to institute these permits has not yet been made. These permits will require monitoring of flow and various water quality parameters such as BOD, TSS, fecal coliform, and TDS. These requirements are similar to wastewater discharge permits.

4.2 USVI Reuse and Conservation Assessment

Of particular concern when planning a reuse program is the quality of water required for each type of use. In order to identify a need for reuse programs, assess the current status of reuse

in the US Virgin Islands, and gather data on current drinking water and wastewater practices, a survey was developed and sent to managers of resorts, condominiums, and municipal wastewater plants. The mailing list was compiled based on an October 29, 2002 EPA Region 2 list of Territory Pollution Discharge Elimination System (TPDES) holders on St. John, St. Thomas, and St. Croix and consisted of 79 potential participants. This survey requested information regarding the type of business or municipality, processes used for drinking water treatment and wastewater treatment, flow during peak months, size of holding tanks and discharge, disinfectant utilization, reuse practices, and conservation practices. Based on the survey results and data gathered from the Virgin Islands Department of Public Works, United States Environmental Protection Agency, and the United States Geological Survey, persons interested in hearing about potential reuse opportunities were interviewed.

4.2.1 Survey Results

Of the 79 potential survey participants identified as TPDES permit holders, 68 surveys were mailed to businesses in the Virgin Islands since address information was not available for 11 businesses. Of the 68 surveys that were mailed, 54 surveys were presumed to have reached the intended business or municipality and 10 completed surveys were returned. Nine out of ten of the surveys completed showed reuse programs consisting of irrigation; only one facility discharged their treated wastewater via an ocean outfall. Six of these ten facilities use primary treatment with chlorine disinfection (60%), three (30%) utilize secondary treatment with chlorine disinfection, and one sends wastewater to the local municipal plant for treatment. The survey results may be biased as respondents may have a higher propensity to undertake water conservation and reuse projects.

Five of the ten surveys completed indicated conservation practices were in place other than water reuse. Notices indicating the importance of conserving water are posted at three

facilities, 1.6-gallon toilets were installed at two facilities, and 2.5-gallon per minute showerheads were installed in each of the 290 rooms of a local resort. All surveys can be found in Appendix A.

4.2.2 Interview Results

In order to assess the current water reuse and conservation practices in the U.S. Virgin Islands, interviews were conducted with facility managers. Of the ten facilities that completed and returned the survey discussed in the previous section, the managers of six agreed to be interviewed. The locations of the facilities can be seen in Figure 4-1. Since many of the resorts and condominiums on St. Thomas, St. John, and St. Croix are assumed to be similar to the ten survey respondents, it was determined that many businesses have implemented various levels of water reuse and conservation practices in order to decrease operating cost, decrease the amount of potable water needed, and to avoid filing a wastewater permit. The information gained from the six interviews is summarized in the following paragraphs.

Figure 4-1: Interview Locations, St. Thomas USVI

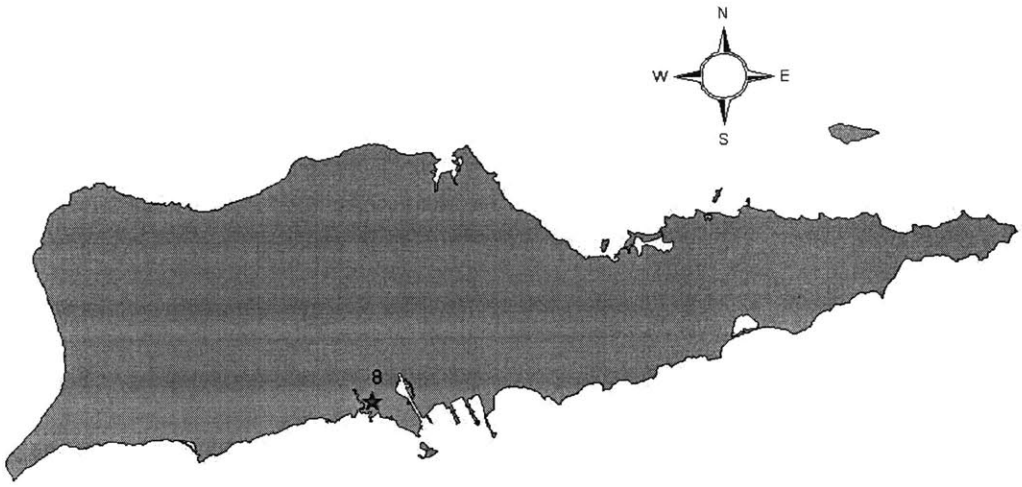

Figure 4-2: Interview Location, St. Croix USVI

Interview 1: Best Western Emerald Beach Resort

The Best Western Emerald Beach Resort is located in Lindbergh Bay approximately one-quarter mile from the Cypris E. King International Airport in St. Thomas (Number 1 on Figure 4-1). This 90-room resort averages between 60 and 80 percent occupancy throughout the year and uses between 14,000 and 17,000 gallons per day (gpd) of water. Since 1999, the primary source of drinking water has been desalination using reverse osmosis (R/O) technology. When demand exceeds output of the desalination plant, supplemental water is purchased from the Virgin Islands Water and Power Authority (WAPA). The R/O plant treats water extracted from a brackish well located on the resort's property, and is permitted under the Territory Permit Discharge Elimination System (TPDES) program. The brine discharge from the desalination process is sent to an on-site 100,000-gallon cistern to be utilized for irrigation and toilet flushing.

The Emerald Beach Resort's wastewater is sent for treatment to the municipal treatment plant located at the airport. At the time of this interview, all wastewater flows to the airport treatment plant were being sent without treatment to an ocean outfall until upgrades to the treatment plant are completed. Conservation practices at the hotel were few. In each room a

card is present on the wall that gives hotel guests the choice of having their towels and bedding washed and changed every day. Beyond this there are no other conservation practices in place. Unfortunately, when I stayed at the hotel, staff disregarded the card in my room and changed the bedding and towels in my room even though I had chosen the water conservation option. Thus, currently, no reuse and minimal conservation measures are utilized at this hotel.

Figure 4-3: Main Entrance to Best Western Emerald Beach Resort, St. Thomas

Interview 2: Anchorage Condominiums

Anchorage Condominiums overlook Cowpet Bay at the east end the island of St. Thomas (Number 2 on Figure 4-1). This condominium complex has 50 2-bedroom units and 25 3-bedroom units. On average, the complex is 35% occupied during off-peak season and 70% occupied during peak season (mid-November to mid-May). This causes water usage to increase from an average of 4,000 to 8,000 gpd and wastewater flows to increase from 4,000 to as much as 10,000 gpd. Currently, Virgin Islands WAPA drinking water service lines do not extend to the east end of the island. Therefore, desalination remains the only viable option for drinking water production since rainwater cisterns cannot meet the demand of the residents. Similar to the Emerald Beach Resort, this complex is permitted to utilize R/O technology, but unlike the Emerald Beach Resort this facility treats seawater withdrawn from an intake located in Cowpet

Bay and discharges waste brine into the ocean. Rainwater is collected and utilized to backwash the filter used after withdrawal from the bay.

Figure 4-4: Main Entrance to Anchorage Condominiums, St. Thomas

Built in 1978, the on-site wastewater facility utilizes a primary clarifier with extended aeration, chlorine tablets for disinfection, and a sand filter. The treated wastewater effluent is then sent to a 25,000-gallon cistern prior to being reused as irrigation supply. If irrigation cannot be carried out each night as planned the cistern has capacity for approximately two and a half days of average flow. According to the manager, the complex does not have a permit for an ocean discharge. Therefore, discharge through the irrigation system is their only option. Since no samples are analyzed of either the raw influent or treated effluent, there is no indication of the efficiency of total suspended solids (TSS), biochemical oxygen demand (BOD), and fecal coliform removal through the treatment process. In addition to reuse practices, water conservation equipment is also being utilized. Conservation equipment such as 1.6-gallon toilets were installed in each of the condominium units.

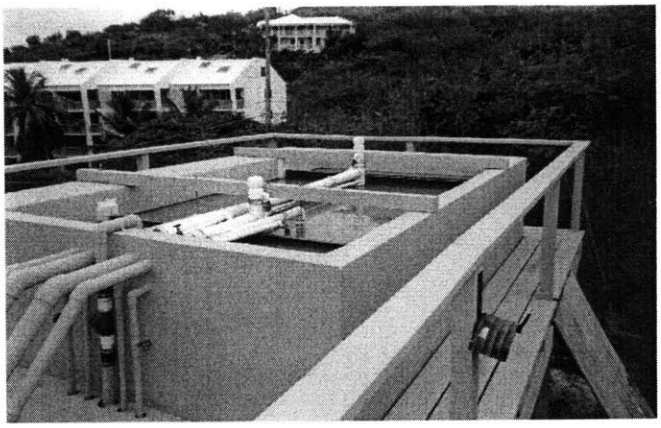

Figure 4-5: Primary Clarifier at Anchorage Condominiums, St. Thomas

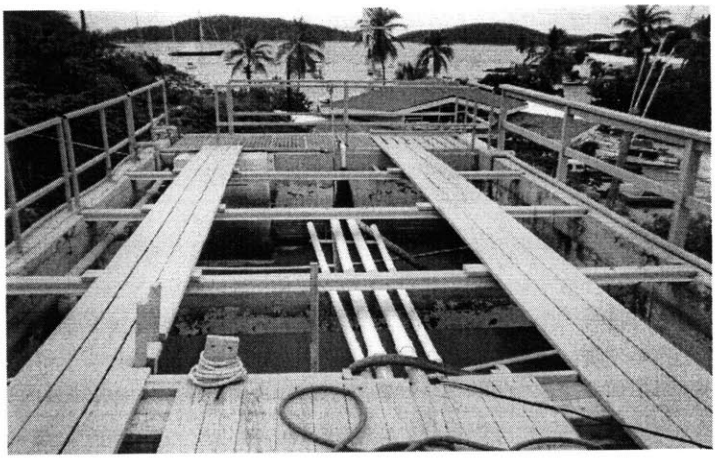

Figure 4-6: Primary Clarifier at Anchorage Condominiums, St. Thomas

Interview 3: Sapphire Village Condominiums

Located at the east end of St. Thomas overlooking St. John Bay (Number 3 on Figure 4-1), this condominium complex has 135 studio apartments and 90 one-bedroom apartments which are occupied by 70 permanent and approximately 145 temporary residents. Utilizing R/O technology due to lack of WAPA service in the area, the facility is permitted to treat and deliver an average of 8,000 gpd during peak season and 5,000 gpd during off-peak season. The water demand fluctuates throughout the year due to fluctuations in occupancy levels.

The setup of the wastewater treatment plant is rather unconventional. The facility is approximately 20 years old and currently utilizes secondary treatment processes without first going through primary treatment. After passing through secondary treatment, the wastewater is disinfected using an automated process with chlorine tablets. This treated effluent is then stored in a 27,000-gallon cistern and used for irrigation throughout the complex. Approximately 3,000 gallons of sludge from the activated sludge tank is taken by truck to be dewatered and landfilled each month. Because of the inefficient treatment scheme and clogging of sprinkler heads, the manager is working on improving the treatment process with the addition of minimal infrastructure.

Figure 4-7: View from docks of Sapphire Village Condominiums, St. Thomas

Interview 4: Compass Point Marina

Compass Point Marina, a complex consisting of a marina, commercial offices, restaurants, and apartments, is located near Benner Bay on the southeastern side of the island (Number 4 on Figure 4-1). For the same reason as Anchorage Condominiums and Sapphire Village Condominiums, Compass Point utilizes R/O technology to generate its drinking water. This facility is permitted for and produces approximately 2,500 gallons of drinking water per day by utilizing a seawater intake. The manager of Compass Point Marina would be very interested

in connecting to a water main along route 30 to the Red Hook area if and when the Virgin Islands WAPA installs this line.

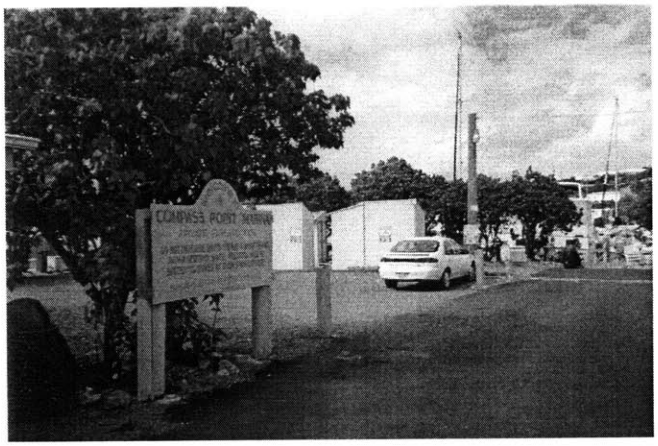

Figure 4-8: Main Entrance at Compass Point Marina, St. Thomas

Wastewater at Compass Point Marina is treated at an on-site treatment plant that utilizes primary treatment. Raw sewage enters the treatment system into a 2,500-gallon tank (Figure 4-9) and is then sent to one of two clarifying tanks which aerate the sewage (Figure 4-10). Treated water is then disinfected by chlorine tablets prior to being stored for use in irrigation and toilet flushing. Approximately 750 gpd is utilized for irrigation and 1000 gpd for toilet flushing since the marina does not have a permit to discharge treated effluent to the ocean. Unfortunately, no testing of effluent has been performed so no indication of treatment efficiency and effluent quality is known. Currently, this complex has not implemented water conservation practices.

Figure 4-9: Raw Wastewater Influent Tank – Compass Point Marina, St. Thomas

Figure 4-10: Primary Clarifier Tanks – Compass Point Marina, St. Thomas

Interview 5: Point Pleasant Resort

Point Pleasant Resort is located in Smith Bay on the eastern end of St. Thomas (Number 5 on Figure 4-1). There are 125 permanent residents that utilize approximately 10,000 gpd of drinking water and send approximately 10,000 gpd to an on-site wastewater treatment plant. Drinking water is obtained by extracting brackish water from an on-site well and treated using R/O technology.

The wastewater treatment plant (Figure 4-11) at Point Pleasant Resort was upgraded in 2001 with aeration and ultra-filtration membrane technology. As indicated by an increase in removal levels of TSS and BOD, this technology seems to be a good investment for the resort.

The only problem to report is that the system can become fouled if the grease trap is not working properly. Once wastewater travels through the filtration system, it passes through an automated chlorine disinfection unit and then is stored in one of two 25,000 gallon cisterns. All treated grey water is used for irrigation and toilet flushing. Currently, no water conservation practices, other than reuse of wastewater effluent, or equipment have been put into place at this complex.

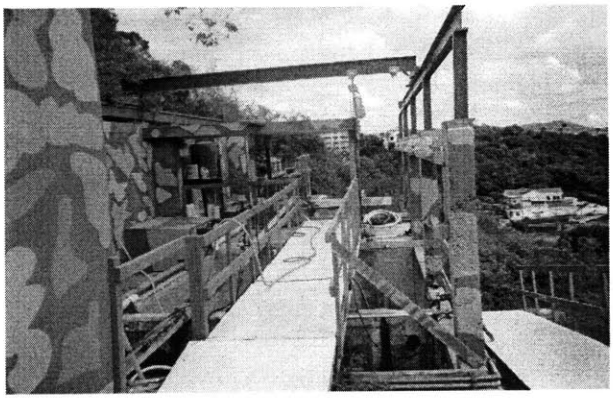

Figure 4-11: Wastewater Treatment Plant at Point Pleasant Resort, St. Thomas

Interview 6: Coral World

Located on the point of Coki Bay on the northeastern shore of St. Thomas (see number 6 on figure 4-1), Coral World is a well-known aquarium whose livelihood depends on the state of the environment and its preservation. It is one of the island's main tourist attractions because of the sea creatures housed there and because of its location, next to beautiful Coki Beach. Coral World entertains over 100,000 visitors each year and thus has a large drinking water demand (3,000 to 3,500 gpd) and a large amount of waste to treat and dispose of. In order to meet drinking water demand, water is not only generated using the permitted R/O desalination plant, but rainwater cisterns and tanker trucks also provide water for the complex since Coral World's location prohibits the use of Virgin Islands WAPA service. Unfortunately, the R/O facility is not obtaining the yield that is typical for the rest of the toured facilities on the island. Currently the

R/O plant produces 2 gallons per minute (gpm) of drinking water while it produces 12 gpm of waste brine. Other plants that I toured showed ratios of 2 to 1 of waste brine to fresh water production, not 6 to 1 as seen at the Coral World plant.

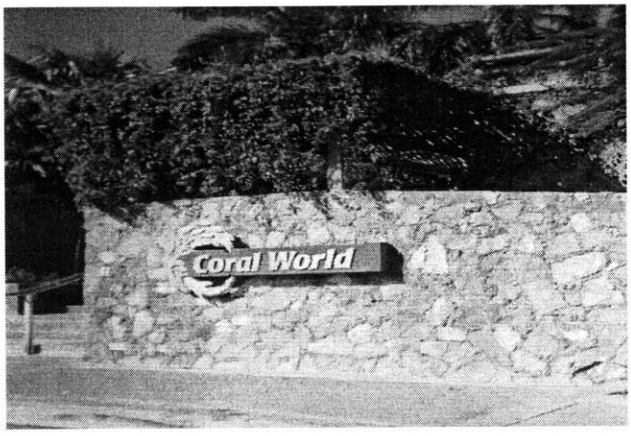

Figure 4-12: Main Entrance at Coral World Aquarium, St. Thomas

Along with drinking water, Coral World also must also treat its own wastewater. Traditional treatment processes consisting of extended aeration and chlorine disinfection are utilized by the on-site wastewater treatment plant (see Figure 4-13). The wastewater treatment plant has a capacity of 20,000 gpd. Treated effluent is then stored in a 4,200-gallon holding tank before being used for irrigation around the park (see Figure 4-14). Early in 2002 several of the ducks at the park showed signs of illness and eventually perished. In July, a sample of effluent was sent to the Ocean Systems Laboratory on St. Croix for analysis of TSS, BOD, and fecal coliforms. The analysis showed that the TSS level was 9.7 mg/L, the BOD level was 18.5 mg/L, and the fecal coliform count was 80,000 colony forming units (CFU)/100 mL. It is believed by the manager that the treated effluent/irrigation water with high fecal coliform counts was the most likely cause of the illness amongst the duck population at the park. Grey water is no longer

used to irrigate around the duck pond but is still used for irrigation at other locations around the park and the disinfection unit was adjusted to add more chlorine to the primary effluent.

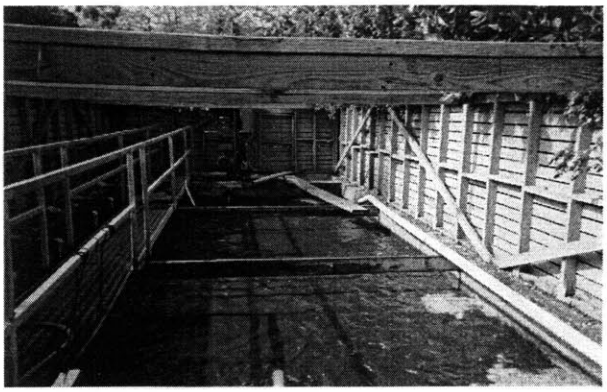

Figure 4-13: Primary aeration tank at Coral World, St. Thomas

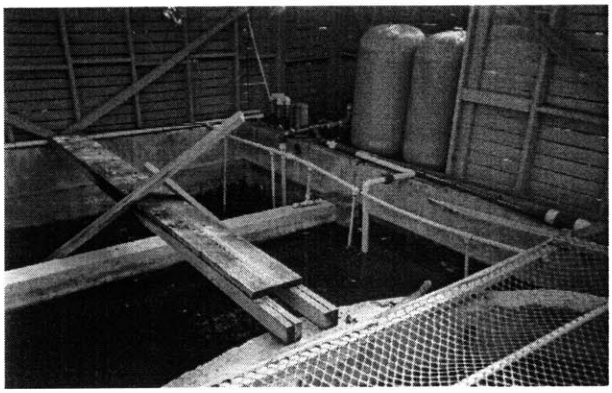

Figure 4-14: Treated Grey Water at Coral World, St. Thomas

Coral World is also the site of a relatively new on-site disposal system (OSDS) installed by the University of Virgin Islands as a demonstration project. By utilizing a three-stage process consisting of three concrete tanks in series, the roots of plants such as sunflowers carry out the treatment of the wastewater by absorbing the waste products. Wastewater is gravity-fed to each of the three tanks. This OSDS has the capacity to treat 600 gpd but currently treats around 400 gpd. Because of the smaller than expected flow in the third tank, plants are not growing as well

as expected. This is because the plants in the previous two tanks take up the majority of the nutrients in the wastewater.

Mangrove Lagoon WWTP and St. Croix WWTP

The Mangrove Lagoon and St. Croix wastewater treatment plants will be discussed at length in Chapter 5 (see number 7 in Figure 4-1 and number 8 in Figure 4-2), since neither of these plants currently have reuse programs. The overall management of both of these plants is overseen by the Department of Public Works, but private contractors were hired for everyday operations.

4.3 Summary

From the surveys and interviews it was determined that many resorts and condominiums in the US Virgin Islands utilize water reuse to meet wastewater constraints. It is important to note that survey results may be biased as respondents may be more likely to undertake water conservation and reuse projects. The level and type of wastewater treatment varies from place to place. However, the type of and reasons behind reuse were very similar: need for water that can not always be supplied by WAPA and desire to avoid discharge regulations. Each one of these facilities had different treatment and reuse problems to deal with: operations problems in the wastewater and water treatment plants, clogging of irrigation systems, and death of duck population. In addition, many of the interview participants produce their own drinking water due to lack of WAPA service in those areas. 1 of 6 facilities utilizes conservation measures consisting of notices in guestrooms. Only 1 of 5 that have their own wastewater plant performed laboratory testing and that was because several ducks died and fecal coliform levels were very high. Proposed reuse regulations in the US Virgin Islands will affect these facilities since reuse is undertaken to avoid testing of wastewater effluent. Further research is needed in order to determine the extent of commercial and residential water reuse on each of the islands in the US

Virgin Islands. The next chapter focuses on designing options for the two large municipal wastewater treatment plants on St. Thomas and St. Croix that currently do not reuse treated effluent.

5.0 Reuse, Conservation, and Disposal Alternatives

As seen in Chapter 4, water reuse at resorts and condominium complexes on St. Thomas is prevalent. Although no surveys were returned from businesses on St. Croix, the status of water reuse in these businesses on the island of St. Croix is expected to be similar to that of St. Thomas. In addition, conservation programs have not been implemented at a majority of residential communities, resorts, and condominium complexes in St. Thomas and a similar result is expected for St. Croix.

However, water reuse is not prevalent in the municipal wastewater plants. This chapter focuses on designing reuse, conservation and disposal options for two of these plants. In order to implement a reuse and conservation program a preliminary investigation, screening of potential markets, and detailed evaluation of the selected markets must be performed (Ammerman et. al., 1992). Developing a reliable cost estimate is also a crucial component of a successful reuse and conservation project. This allows the community and planners to compare options with a level of confidence. Critical issues that each alternative must address include the following:

- Identification and characterization of potential demand,
- Identification and characterization of existing sources,
- Treatment requirements for intended application,
- Storage requirements to deal with fluctuations in demand and supply,
- Equipment and facilities needed to distribute reclaimed water,
- Potential environmental impacts, and
- Local and federal agency approval.

Because the two large municipal wastewater plants in the US Virgin Islands have not developed comprehensive reuse and conservation programs, preliminary plans and costs for eight potential reuse and conservation alternatives have been developed. To determine the overall value of each alternative, the costs were subtracted from the benefits. In lieu of having financial information for the benefits of each alternative, the value of benefits was assumed to be zero. To

normalize the cost and compare these alternatives, a value per gallon of reclaimed and conserved water was computed. In addition to developing a value per gallon of reclaimed and conserved water, the issues presented previously were addressed and a list of pros and cons for each alternative was developed.

5.1 Basis of Cost Estimates

In order to provide analysis of the various alternatives, the costs of standard activities for all projects were estimated. These costs are then used on a per-alternative basis. Utilizing a combination of the costs generated from the MEANS Cost Estimating Guide (2003), unit costs derived from a report by Sheikh et al. (2002), and unit costs derived from EPA design manuals (USEPA, 2000a), approximate cost for each reuse alternative can be determined. All total costs include a 25% factor to cover contingency, engineering, and startup.

5.1.1 Irrigation System

A unit cost for residential irrigation systems was determined using data given by Sheikh, Castle, Kasper and Roxon (2002). This unit cost includes materials, permit fees, installation, maintenance, and annual inspections. Sheik et al.'s estimates are given in December 2000 dollars and are scaled in this thesis to March 2003 dollars using Engineering News Record (ENR) construction cost indexes of 6283 and 6627, respectively. ENR construction cost indexes are an industry tool used to scale cost to present day values. As a result, a cost per typical residential irrigation system of $3375 in December 2000 was increased to $3560 in March 2003. This price in conjunction with the estimated number of residential connections was used to determine the cost for irrigation systems. Operation and maintenance cost were not included since individual residences are responsible for those costs.

5.1.2 Distribution Network

A distribution network is needed to transport the reclaimed water to its intended use. Based on an estimated demand the required pipe diameter was determined. The cost per foot of polyvinylchloride (PVC) pipe was determined using unit costs from Version 7 of a program titled CostWorks © developed by R.S. Means Company (2003) (Table 5-1). CostWorks © contains cost data for various cities throughout the United States. Unfortunately, cost information is not available for cities in the US Virgin Islands. Therefore, data presented in Table 5-1 represent unit cost for materials, labor, and equipment to install a distribution network in San Juan, Puerto Rico. Since San Juan is in close geographic proximity and faces similar construction obstacles, these costs were considered to be reflective of what would be expected in the US Virgin Islands. Annual operation and maintenance cost was estimated to be 10% of the construction cost.

Table 5-1: Pipe Diameter Unit Cost Data (R.S. Means, 2003)

Diameter (in)	Unit Cost ($/linear foot)
6	14.35
8	19.50
10	23.00
12	31.50
14	39.50
16	43.50
18	55.50
24	83.50

Excavation and backfilling of the ditches in which the distribution network lay are not included in the unit cost per linear foot. The labor and equipment unit cost is based on the number of cubic yards of soil excavated and backfilled. A unit cost of $37.20 per cubic yard was determined using CostWorks © by R.S. Means.

5.1.3 Constructed Wetland

Wetland systems provide many worthwhile functions including water quality enhancement, wildlife and waterfowl habitat, aquifer recharge, and natural water conservation. The September 2000 version of the EPA Manual for Constructed Wetlands Treatment of Municipal Wastewaters includes a case study of nine constructed wetland systems throughout the United States used to meet secondary effluent standards. The study examined the construction costs of four free water surface wetland (FWS) systems and five vegetated submerged bed (VSB) systems. For the purpose of this study, FWS systems will be examined since they have proven to be successful in the Caribbean climate and have been accepted by federal and US Virgin Islands territory regulators (Glogger, 2003).

FWS systems resemble natural wetland systems composed of both open-water and fully vegetated areas with fluctuating water levels (USEPA, 2002a). Utilizing a combination of fully vegetated and open zones further reduces BOD, TSS, and fecal coliform levels and removes various other trace pollutants such as metals remaining in the treated wastewater. The size and depth of FWS and other constructed wetland systems are site specific and depend on several variables including influent wastewater quality, effluent quality requirements, and soil characteristics.

A range of unit cost per hectare for construction was determined from the study (USEPA, 2000a). Based on average flow at the two municipal wastewater treatment plants on St. Thomas and St. Croix, the design and cost of the system would be similar to that used in Ouray, Colorado as presented in the EPA manual. The costs were given in August 1997 dollars and scaled to March 2003 utilizing ENR indexes of 5854 and 6627, respectively. A unit cost of $52,700 per acre in August 1997 was increased to $59,650 per acre in March 2003. The later will be utilized to estimate the cost of the FWS wetland system. This unit cost does not include the cost for

engineering design and site investigation. It was assumed that the US Virgin Islands Government already owns the land utilized for each wetland system. Annual operation and maintenance cost will also be included as a separate item using a factor of 7%.

5.1.4 Water Conservation Kits

There are currently many water and energy conservation vendors that supply products and information to promote conservation of water and energy resources. AM Conservation Group Inc., mentioned in Chapter 2.2, offers the E'Town Water Conservation Kit. The kit includes a 2.5-gallons per minute (gpm) showerhead, 1.5-gpm bath aerator, toilet tummy, dye tablet and instructions (AM Conservation Group, 2003). Kits of this nature are easy to use and available for $5.99 each.

5.1.5 Summary of Cost Estimating Basis

The basis for cost estimating has been established. These unit costs will be utilized to develop preliminary cost estimates for the alternatives presented in the following paragraphs. Table 5-2 summarizes the unit costs that will be used to evaluate each reuse alternative.

Table 5-2: Summary of Cost Estimating Basis

ITEM	COST ($)	UNIT
Residential Irrigation System	3560.00	$/irrigation unit
Distribution Network Piping – 6 inch	14.35	$/foot
Distribution Network Piping – 8 inch	19.50	$/foot
Distribution Network Piping – 10 inch	23.00	$/foot
Distribution Network Piping – 12 inch	31.50	$/foot
Distribution Network Piping – 14 inch	39.50	$/foot
Distribution Network Piping – 16 inch	43.50	$/foot
Distribution Network Piping – 18 inch	55.50	$/foot
Distribution Network Piping – 24 inch	83.50	$/foot
Distribution Network Labor and Equipment	37.20	$/cubic yard
E'Town Water Conservation Kit	5.99	$/kit

5.2 Reuse, Conservation, and Disposal on St. Thomas

Until recently the quality of effluent from the seven municipal plants on St. Thomas was extremely poor (Critchley, 2003). These plants utilized primary treatment with little or no disinfection. More often than not, treated effluent at this plant exceeded Territory Permit Discharge Elimination System (TPDES) permit limitations. As a result, the Virgin Islands Department of Public Works (DPW) entered into a consent decree with the USEPA in 1984 (Critchley and Simon, 2002). This consent decree legally bound DPW to making improvements to the wastewater treatment plant as well as the wastewater collection system. The DPW decided to consolidate the seven plants into one new and more effective plant.

In August of 2002, construction of the Mangrove Lagoon Wastewater Treatment Plant (MLWWTP) was completed, utilizing sequencing batch reactor (SBR) technology as well as ultraviolet disinfection (Figure 5-1). The MLWWTP, shown in Figure 5-2, is located next to the Bovoni Landfill and Mangrove Lagoon. Currently, the MLWWTP is operating in conjunction with a subset of the seven original wastewater treatment plants. The respective permit limits for daily maximum flow of each plant are shown in Table 5-3. Currently, only 130,000 gallons per day (gpd) is being treated by the MLWWTP plant, but the average flow is expected to reach 750,000 gpd by 2005 with a maximum flow of 1.25 million gallons per day (MGD) after all of the other treatment plants are taken off-line (DeRossett and Senn, 2003). A majority of treated effluent from the MLWWTP is discharged through a mile-long pipe into Stalley Bay with a small portion of the current flow used for irrigation on the grounds of the treatment plant.

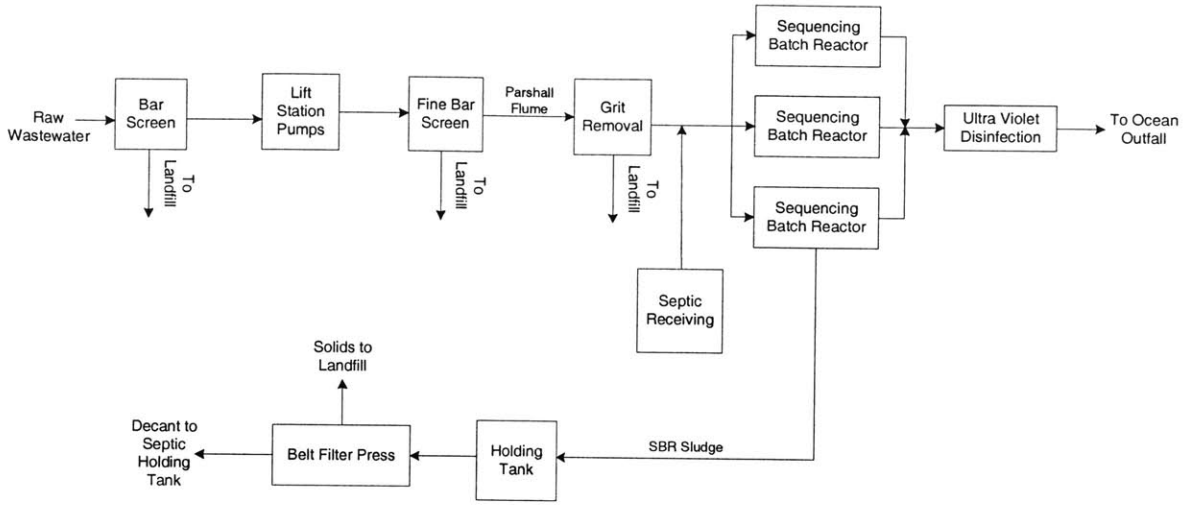

Figure 5-1: Process Flow Diagram for Mangrove Lagoon Wastewater Treatment Plant

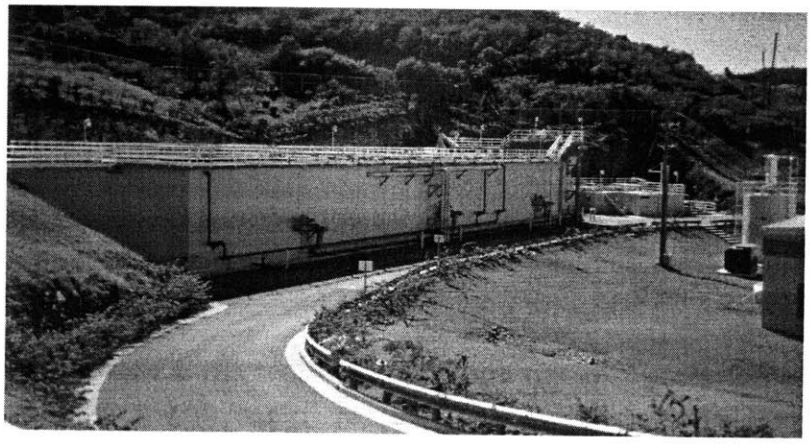

Figure 5-2: Mangrove Lagoon Wastewater Treatment Plant, St. Thomas, USVI

Biochemical oxygen demand (BOD), total suspended solids (TSS), and fecal coliform data were obtained for the months of October 2002 to December 2002 at the MLWWTP. Currently, removal rates for BOD and TSS averaged 95.2% and 89.6%, respectively. Fecal coliform samples were taken at the outfall and averaged 1600 colonies per 100 milliliters for the months of October through December 2002. The month of January 2003 found the fecal coliform level at zero. As additional wastewater flow is delivered to this treatment plant, BOD, TSS, and fecal coliform removal rates are expected to remain high.

Table 5-3: Permitted Flow Limits for St. Thomas Wastewater Treatment Facilities

Facility Name	Daily Maximum Flow (MGD)
Mangrove Lagoon	0.75/1.2
Bordeaux	0.176
Brassview	0.04
Airport	Under Renovation/Not in Service
Nadir	4 (Out of Service)
New Tutu	0.366
Old Tutu	0.190
Vessup	0.099

5.2.1 Identification of Promising Reuse/Disposal Alternatives

The issues presented at the beginning of this chapter will be addressed in the following paragraphs. These issues will be used to evaluate several reuse, conservation and disposal possibilities and are shown in Table 5-4. For the projects that are viable (as depicted by a yes in Table 5-4) based on demand, treatment requirements, and local and federal agency approval, the storage requirements, equipment and facility needs, potential environmental impacts, and construction cost will be discussed. See Appendix B for construction cost calculations determined using the values calculated in Section 1 of this chapter.

Table 5-4: Reuse, Conservation and Disposal Alternatives Matrix – St. Thomas, USVI

Planning and Design Questions	Reuse, Conservation, and Disposal Alternatives						
	Residential Irrigation	Habitat Restoration Utilizing Wetlands	Recharge of Aquifer	Direct Potable Reuse in Red Hook and Surrounding Area	Industrial Process / Cooling Water	Irrigation of Agricultural Land	Community-wide Conservation and Habitat Restoration
Has the Demand for Reclaimed Water been Identified?	Yes	Yes	Yes	No	No	No	Yes
Has the Demand for Reclaimed Water been Characterized?	No	No	No	No	No	No	No
Has the Reclaimed Water Source been Identified?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Has the Reclaimed Water Source been Characterized?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Are Treatment Requirements Met?	Yes	Yes	No	No	No	Yes	Yes
Do Local and Federal Agency Approve of the Project?	Maybe	Maybe	No	No	Maybe	Maybe	Maybe
Does this alternative utilize Reuse?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Does this alternative utilize an alternative Disposal technique?	No	Yes	No	No	No	No	Yes
Does this alternative utilize Conservation?	No	No	No	No	No	No	Yes

Potential demand, existing source, and treatment requirements were identified and characterized prior to the development of alternatives. As of 1992, most states required a minimum of secondary treatment for unrestricted urban reuse and environmental wetlands (Ammerman et al, 1992). Since the US Virgin Islands does not have reuse guidelines or regulations in place, I assumed that secondary treatment was sufficient for the urban reuse and environmental wetlands in the US Virgin Islands. Because the effluent from the MLWWTP

meets secondary treatment limits, the reuse alternatives presented in the following paragraphs are viable if based on this parameter alone.

Several other issues must be resolved for a reuse project to move forward. The positive impacts to the local environment by removing or reducing the ocean discharge are apparent. However, potential environmental impacts of reclaimed water to land use and groundwater must be examined prior to implementation and monitored throughout the life of the project. The ideas of local government or community groups must be considered since development objectives may or may not benefit from the use of reclaimed water. If a reuse project is to obtain federal funding, a formal Environmental Impact Statement must be completed. Since no large-scale reuse projects have been implemented in the US Virgin Islands, participation of local and federal agencies is critical in order to gain approval.

Reuse alternatives were developed for this thesis for the effluent from the Mangrove Lagoon treatment facility and are presented in the following paragraphs. Since there is very little industrial development (none in the proximity of the MLWWTP) and very little agricultural land on St. Thomas, industrial and agricultural alternatives were eliminated. Due to regulatory restrictions by the local and federal environmental agencies and potential lack of public acceptance, direct potable reuse in Charlotte Amalie and Red Hook and recharge of the aquifer on St. Thomas were discarded. Combinations of irrigation to nearby residential customers and wetland augmentation reuse with and without conservation prove to be viable reuse options for the MLWWTP.

A storage facility to handle fluctuations in demand and supply would be required for the three proposed reuse options and would be placed at the plant site since all suggested alternatives are located near the MLWWTP. The volume of storage required is dependent on the overall

demand and the type of reuse project(s) implemented and should be determined during a detailed evaluation of the potential markets and alternatives. An emergency disposal plan consisting of discharge through the current ocean outfall is also required in the instance that the treated water does not meet water quality requirements. Preliminary design options for residential irrigation and wetland augmentation were developed and are presented in the following paragraphs. Financial information is presented after the design paragraphs.

5.2.1.1 Residential Irrigation

Many residential units are located near the MLWWTP. Through the use of a 7.5-minute series topographic map updated by the United States Geological Survey (USGS) in 1982 it was estimated that reclaimed water for irrigation could be provided to approximately 260 housing units. Using the same USGS topographic map, it was determined that approximately 17,000 feet of piping would be necessary to distribute irrigation water from the MLWWTP along Route 30 to several residential areas (USGS, 1982). Additional piping would be necessary for each individual system which is included in the cost of the irrigation system presented in Chapter 5.1.1.

In a 1996 report dealing with the use of reclaimed water for golf course irrigation in Florida, the USGS reported that 297 MGD of reclaimed and freshwater were utilized to irrigate Florida's 1448 golf courses (USGS, 1996). The USGS also determined that the average golf course irrigates 65% of its land area and occupies 137 acres. The result is an average of 2303 gallons per day per acre used for irrigation. Using the irrigation rate presented previously and a rough estimate of the acres requiring irrigation in these residential areas from topographic maps, an estimated average of 200,000 gallons per day is required. For design purposes a peaking factor of three was used. In order to convert the average flow data to peak flow data, a peaking factor is employed that accounts for the time of day that most residents will use reclaimed water.

Using principles used for the design of a water distribution system, the pipe diameter can be determined from a nomogram based on Hazen-Williams' formula for pipe flow in a cast-iron pipe shown below (Steele & McGhee, 1979).

$$v = k(C)r^{0.63}s^{0.54}$$

Because the most common nomogram found in Steele and McGhee (1979) is for cast-iron pipe, a formula from the same book must be utilized to account for difference in pipe roughness.

$$d_c = d_{100}\left[\frac{100}{C}\right]^{0.38}$$

Assuming a velocity of 3 feet per second and a roughness coefficient of 150 a design flow of 595,000 gallons per day can be fed via one 8-inch PVC pipe. This flow and diameter pipe allow for increases in demand and expansion of the residential irrigation system.

5.2.1.2 Habitat Restoration Utilizing Wetlands

Based on the case study discussed in Chapter 3.4 and utilizing land owned by the Virgin Islands Government at the site of the Bovoni Landfill and MLWWTP, wetlands can be constructed to supply additional treatment, provide a habitat for various plant and animal species, and provide an educational tool for St. Thomas residents and visitors.

Using design principles and examples presented in Chapter 4 of the EPA Manual for Constructed Wetlands (USEPA, 2000a) and assuming the entire flow of 750,000 gallons per day flows through the wetland, 5 acres are needed (see Appendix B).

5.2.1.3 Community-wide Conservation and Habitat Restoration

A water conservation program implemented throughout the St. Thomas community involving the distribution of water conservation kits and information could potentially reduce the amount of wastewater needing treatment by the MLWWTP. Utilizing the conservation estimates cited in Chapter 2, a household could conserve approximately 35 gallons per day by taking a

shower instead of a bath, turning off the water when brushing teeth and installing aerated showerheads.

Based on the 2000 US Census, an estimated 24,030 households on St. Thomas could receive water conservation kits (US Census Bureau, 2002). The reduced wastewater flow from 13,748 households having connections to the municipal sewer system results in a flow of 269,000 gallons per day requiring treatment. Assuming that 100 percent of the flow is treated by the wetland, 1.75 acres (as apposed to 5 acres) are needed (Appendix B).

5.2.2 Financial Analysis of Promising Alternatives

5.2.2.1 Residential Irrigation

Using the description of project requirements and unit costs from Chapters 5.1.1 and 5.1.2, the total construction cost for residential irrigation near the MLWWTP was found to be $1,860,000 with an annual operation and maintenance cost of $186,000 (Table 5-5). The cost of pumping and storage were considered negligible compared to the total cost of the alternative and were not included in the following cost summary.

Table 5-5: Estimated Cost for Residential Irrigation, St. Thomas

Item	Cost ($)
Distribution Network	332,000
Individual Irrigation Systems	926,000
Labor and Equipment	230,000
Non-construction and Contingency (25%)	372,000
Total Construction Cost	1,860,000
Annual Operation and Maintenance	186,000

5.2.2.2 Habitat Restoration Utilizing Wetlands

Using the description of project requirements and unit costs from Chapter 5.1.3, the total construction cost for the habitat restoration project was calculated and was found to be $373,000

with an annual operating and maintenance cost of $21,000 (Table 5-6). Similar to the residential irrigation alternative presented in Chapter 5.2.1.1, the construction cost presented below were rounded to the nearest thousand dollars. The cost for pumps was not included in this analysis since the cost was determined to be negligible compared to the total cost of the alternative.

Table 5-6: Estimated Cost for Constructed Wetland, St. Thomas

Item	Cost ($)
Wetland Construction	298,000
Non-construction and Contingency (25%)	75,000
Total Construction Cost	373,000
Annual Operation and Maintenance	21,000

5.2.2.3 Community-wide Conservation and Habitat Restoration

Using the description of project requirements and unit costs from Chapters 5.1.3 and 5.1.4, the total construction cost for the community-wide conservation and habitat restoration project was calculated and was found to be $274,000 with an annual operating and maintenance cost of $9,000 (Table 5-7). The cost for pumps was not included in this analysis since the cost was determined to be negligible compared to the total cost of the alternative.

Table 5-7: Estimated Cost for Community-wide Conservation and Constructed Wetland, St. Thomas

Item	Cost ($)
E'Town Conservation Kits	144,000
Wetland Construction	104,000
Non-construction and Contingency (25%)	26,000
Total Construction Cost	274,000
Annual Operation and Maintenance	9,000

5.2.3 Pros and Cons of Each Alternative

In addition to a cost analysis the pros and cons of each St. Thomas alternative are presented in order to complete a thorough evaluation. For all proposed alternatives, reducing the amount of nutrient-rich effluent discharged to the ocean is an apparent benefit. One potential issue common to all is related to diminishing flow to the ocean outfall. Performance may be impaired and a minimum velocity to sweep out intruding salt water may be required. Specific pros and cons for each of the alternatives are presented below.

5.2.3.1 Residential Irrigation

Water needs of the residential area selected are not currently met by WAPA service. Water from rainwater cisterns and trucks is currently used to meet water needs. As an alternative water source, reclaimed water can be supplied as a low-cost irrigation alternative for residential customers near the MLWWTP. Besides positively affecting the ocean environment, little to moderate operation and maintenance of distribution system is needed.

This reuse alternative also has negative aspects. There is uncertainty in the extent of demand for irrigation water. This demand can be determined by surveying the community. Currently, the estimated irrigation demand exceeds reclaimed water supply, but supply will be increased to an average of 750,000 gpd by 2005 after all municipal waste is sent to this plant for treatment. Another negative aspect of this alternative deals with construction. A great degree of disturbance to local traffic will occur while installing the distribution system. However, if installation of the distribution is coordinated with WAPA's installation of potable water lines to the east end of the island, disturbance to the community would be minimized and labor and equipment cost would be decreased.

5.2.3.2 Habitat Restoration

Positive impacts of the habitat restoration alternative are many. Habitat restoration proves to be a low cost reuse alternative that provides a new or restored habitat for plant and animal species and educational tool for the local community and visitors. Construction of the wetland results in little to no impact on local traffic. Additional treatment of wastewater is provided by the wetland system prior to discharge. The government already owns the land needed to construct the wetlands.

A negative impact is that it was determined that a federal Superfund Site is located within close proximity of the Bovoni Landfill and MLWWTP, and therefore the implementation of this alternative may have regulatory challenges. Also, the topography of the area may not be conducive for a wetland system. Therefore, additional studies would be necessary.

5.2.3.3 Community-wide Conservation and Habitat Restoration

Positive impacts of the conservation and habitat restoration alternative are similar to that found in section 5.2.3.2. An additional benefit is that the use of conservation kits potentially reduces the potable water demand and wastewater needing treatment. This potentially reduces the amount of land needed for construction of wetlands compared to using habitat restoration alone.

The negative impacts of the community-wide conservation and habitat restoration alternative are similar to that described for the habitat restoration alternative presented in section 5.2.3.2. In addition, verifying community use of conservation kits is difficult. Therefore, the full benefits of conservation may or may not be realized by the community.

5.3 Reuse, Conservation, and Disposal on St. Croix

Similar to the situation on St. Thomas, the St. Croix Wastewater Treatment Plant (SCWWTP) discharges treated effluent via an ocean outfall. Designed in 1969 and put into operation starting in the early 1970's, primary treatment with chlorine disinfection has been utilized treating an average of 2.5 million gallons per day (MGD) (Figure 5-3). The current TPDES permit for this facility allows a maximum effluent discharge of 4 MGD. Figure 5-4 presents the current setup of the wastewater plant on St. Croix. In the past, the St. Croix WWTP has had problems meeting their TPDES permit limits and was covered under the consent decree with the USEPA in 1984 that was also placed on the St. Thomas wastewater treatment plants.

In January 2003, the St. Croix Department of Public Works published a Request for Proposals (RFP) for the design of secondary treatment facilities for the SCWWTP. Once this renovation is complete, the plant is expected to produce effluent meeting the US Virgin Islands secondary treatment requirements of 30 mg/L BOD and 30 mg/L TSS. As a result of this RFP and growing awareness of water scarcity issues within the community, a group called the Coalition for Comprehensive Development has been advocating reuse options such as wetlands. This group is comprised of representatives from the St. Croix Chamber of Commerce, St. Croix Board of Realtors, St. Croix Environmental Association, University of the Virgin Islands, and the Business Community (Glogger, 2003).

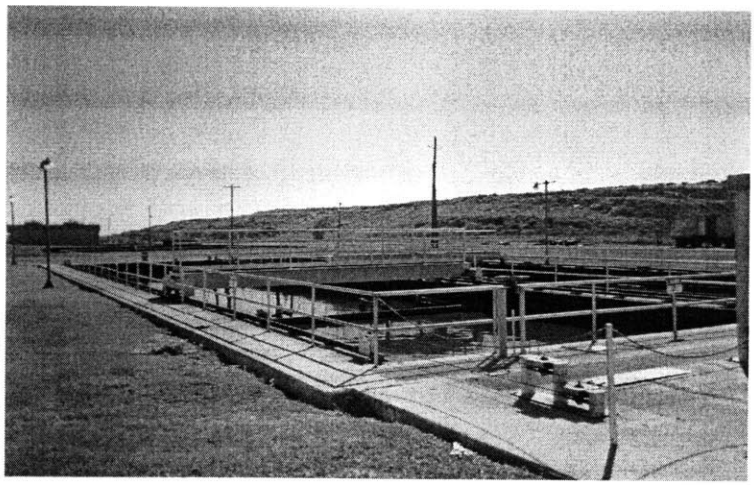

Figure 5-3: Primary Clarifiers at St. Croix Wastewater Treatment Facility, USVI

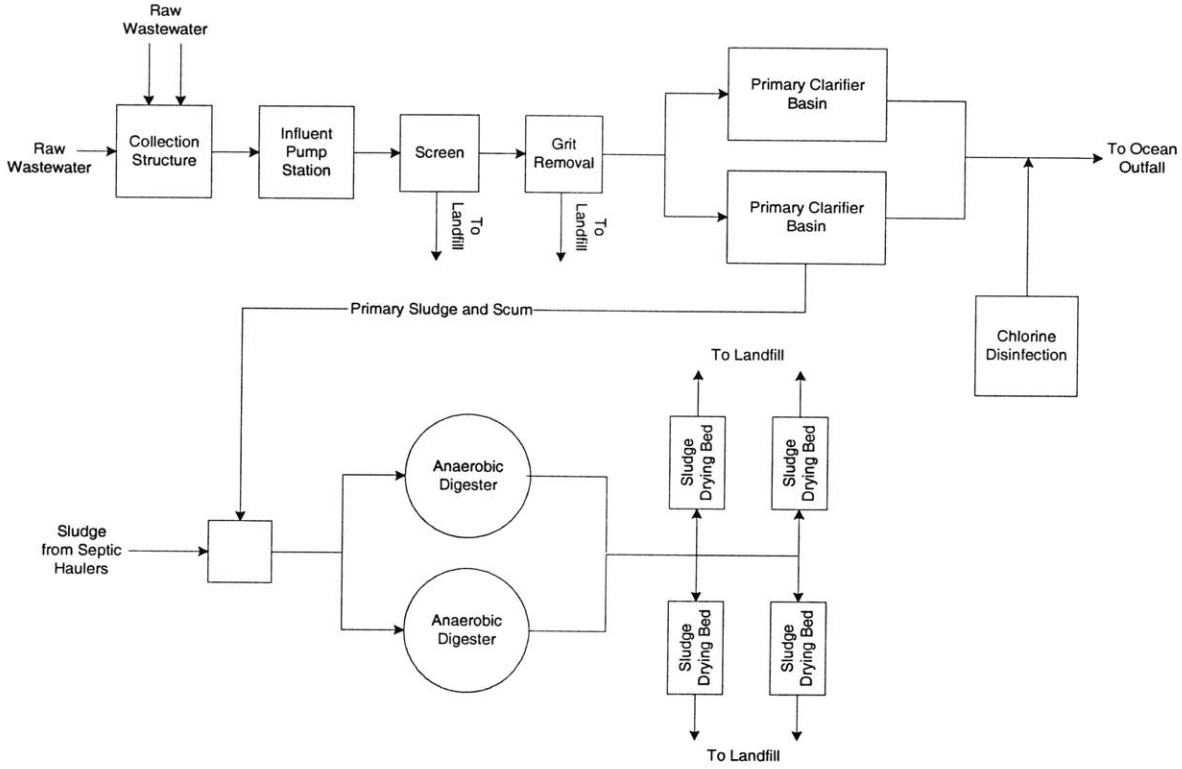

Figure 5-4: Process Flow for St. Croix Wastewater Treatment Plant as of January 2003

5.3.1 Identification of Promising Reuse/Disposal Alternatives

Similar to the St. Thomas alternatives, the issues presented at the beginning of this chapter will be addressed in the following paragraphs in order to satisfy the requirements of a

preliminary reuse investigation. The following matrix shows how several St. Croix satisfies these issues.

Table 5-8: Reuse, Conservation, and Disposal Alternatives Matrix - St. Croix, USVI

Planning and Design Questions	Reuse and Conservation Alternatives						
	Airport Irrigation	**Commercial Irrigation and Industrial Process / Cooling Water**	**Irrigation of USVI Government Agricultural Land**	**Habitat Restoration Utilizing Wetlands**	**Recharge of Kingshill Aquifer**	**Direct Potable Reuse in Christiansted and Frederiksted**	**Community-wide Conservation and Habitat Restoration**
Has the Demand for Reclaimed Water been Identified?	Yes	Yes	Maybe	Yes	Yes	No	Yes
Has the Demand for Reclaimed Water been Characterized?	No	No	No	No	No	No	No
Has the Reclaimed Water Source been Identified?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Has the Reclaimed Water Source been Characterized?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Are Treatment Requirements Met?	Yes	Not Available	Yes	Yes	No	No	Yes
Do Local and Federal Agency Approve of the Project?	Maybe	Maybe	Maybe	Maybe	No	No	Maybe
Does this alternative utilize Reuse?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Does this alternative utilize an alternative Disposal technique?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Does this alternative utilize Conservation?	No	No	No	No	No	No	Yes

From the matrix presented in Table 5-8, irrigation supply to the airport and nearby commercial areas, industrial process water, agricultural irrigation, wetland augmentation, and wetland augmentation with conservation appear to be options that meet the criteria. For these projects, the storage requirements, equipment and facility needs, and potential environmental impacts will be discussed.

A storage facility to handle fluctuations in demand and supply would be required for all options and would be placed at the plant site since all suggested alternatives are located near the St. Croix wastewater treatment plant. The volume of storage required is dependent on the overall demand and the type of reuse project(s) implemented and should be determined during a detailed evaluation of the potential markets and alternatives. An emergency disposal plan consisting of discharge through the current ocean outfall is also required in the instance that the treated water does not meet water quality requirements for the use of the reclaimed water. Due to regulatory restrictions by the local and federal environmental agencies and potential lack of public acceptance, direct potable reuse in Christiansted and Frederiksted and recharge of the Kingshill Aquifer were discarded.

Most states required a minimum of secondary treatment for unrestricted urban reuse and environmental wetlands and varying levels of treatment for agriculture and industrial. Since the US Virgin Islands does not have reuse guidelines or regulations in place, secondary treatment was assumed to be sufficient for the urban reuse and environmental wetlands in the US Virgin Islands. For crops that will be consumed, reclaimed water of secondary quality is sufficient for agricultural reuse. However, crops that will not be consumed by humans (such as hay) can be irrigated with primary effluent.

5.3.1.1 Airport Irrigation

Due to the proximity of the St. Croix wastewater facility to the airport, reclaimed water could be distributed via a new distribution network for irrigation needs with little to no disruption to the surrounding businesses. Through the use of USGS 7.5-minute topographic maps (Topozone, 2003), it was determined that approximately 4800 feet of piping would be necessary to distribute irrigation water from the SCWWTP along Route 64 to the Airport main

entrance. Additional piping would be necessary once on the grounds of the airport. This analysis assumed that the airport already has an irrigation system.

A rough estimate of the number of acres requiring irrigation at the airport was determined using information gathered from topographic maps and geographical information system (GIS) data. Using the irrigation rate determined in Chapter 5.2.1.1 (2303 gallons per acre), and the area requiring irrigation at the airport, 7.5 acres, an estimated 17,000 gpd is required. For design purposes a peaking factor of three was used. In order to convert the average flow data to peak flow data, a peaking factor is employed that accounts for the time of day that the airport will use reclaimed water. Using Hazen-Williams design principles, a peak flow rate of 51,000 gpd can be fed via 6-inch PVC pipe.

5.3.1.2 Commercial Irrigation and Industrial Process/Cooling Water

A former ALCOA facility is located adjacent to the St. Croix WWTP and island landfill. The St. Croix Renaissance Group, a local developer, is looking to renovate the facility into an eco-industrial park that would include facilities for commercial, industrial, and retail clients as well as recreational parks and wetlands (York, 2003). Because of the close proximity of this park to the SCWWTP, little piping would be needed to supply the facility with irrigation water, industrial process water, or water for recreational use. Utilizing the same irrigation rate as in the previous alternative (2303 gallons per day per acre), and a rough estimate of the acres requiring irrigation at the new industrial area from area topographic maps and information from Nina York's January 2003 article, the total flow needed to irrigate the eco-industrial park was estimated as 276,000 gallons per day. Utilizing a peaking factor of 3 and the Hazen-Williams equation, irrigation flow can be transported to the site via one 10-inch diameter PVC pipe. Approximately 2000 feet of new piping would be necessary to transfer water from the SCWWTP

to the eco-industrial park property boundary. Pumps at both the SCWWTP site and on the eco-industrial park property will be required for distribution.

Industrial tenants have not been identified as of January 2003. Therefore, water demand and required water quality are not known. Because of this, a cost estimate for this portion of the reuse alternative was not developed.

5.3.1.3 Agricultural Irrigation

After obtaining information from the USVI Department of Agriculture (DOA) it was determined that the majority of agricultural land is owned by the government (James, 2003). As was presented in Chapter 2, approximately 700 acres of agricultural land is productive. According to the DOA, a new marketing campaign is being implemented to increase the amount of productive land used for agriculture in the next two to three years. Based on projected increase in demand and the fact that water is supplied to these areas via a combination of wells, ponds, and trucked water from WAPA, an alternative source of irrigation water may be supported by local advocacy groups such as the St. Croix Farmers in Action for economical reasons.

Based on GIS information from the University of the Virgin Islands Caribbean Data Center (USVI CDC, 2001), it was estimated that approximately two-thirds of the 700 acres of productive agricultural land is both relatively close to the SCWWTP and grouped together. Using the irrigation rate from Chapter 5.2.1 of 2303 gallons per acre, the average demand was estimated to be 1,080,000 gpd. This irrigation rate was used since the types of crops grown and corresponding acreage for each crop were unknown. Utilizing a peaking factor of 2 to account for this volume being distributed over a 12 hour period, the distribution system was designed to transport 2,160,000 gpd. Using Hazen-Williams design principles, one 16-inch diameter PVC pipe is proposed. Based on topographic maps, approximately 27,000 feet of new piping would

be necessary for distribution to these agricultural areas. Several pumping stations would be required to maintain pressure throughout the system due to the greater transport distance needed compared to the commercial irrigation alternatives.

5.3.1.4 Habitat Restoration Utilizing Wetlands

Based on the case study discussed in Chapter 3.4 and utilizing a combination of land owned by the Virgin Islands Government at the site of the St. Croix WWTP, other government-owned land on the island and land within the eco-industrial park, wetlands could be constructed to supply additional treatment, provide a habitat for various plant and animal species, and provide an educational tool for St. Croix residents and visitors. Currently, this alternative is being proposed by one group of engineers in answer to the January 2003 RFP administered by the US Virgin Islands DPW.

As was stated in section 5.1.3, the design of an FWS wetland system will be utilized since a system of this nature requires lower capital investment and operation and maintenance cost than a VSB system (Glogger, 2003). Using design principles and examples presented Chapter 4 of the EPA Manual for Constructed Wetlands (USEPA, 2000a) and assuming the maximum design flow of 4 MGD flows through the wetland, 71 acres are needed (Appendix B). The FWS will utilize fully vegetated and open zones to further reduce BOD, TSS, and fecal coliform levels as well as remove various other trace pollutants remaining in the treated wastewater.

5.3.1.5 Community-wide Conservation and Habitat Restoration

A water conservation program implemented throughout the St. Croix community involving the distribution of water conservation kits and information could potentially reduce the amount of wastewater needing treatment by the SCWWTP. Using the water savings described in section 5.2.1.3 and the 2000 US Census information, an estimated 23,782 households on St.

Croix would receive water conservation kits (US Census Bureau, 2002). The reduced wastewater flow from 11,758 households having connections to the municipal sewer system results in a flow of 3,590,000 gallons per day requiring treatment. Assuming that 100 percent of the flow is treated by the wetland, 65.5 acres (a reduction of 8%) are needed (Appendix B). In order for this flow reduction to be realized, a thorough public education program to explain how to install the equipment and provide information on the importance of water conservation is also necessary.

5.3.2 Financial Analysis of Promising Alternatives

5.3.2.1 Airport Irrigation

Using the description of project requirements and unit costs from Chapter 5.1.1 and 5.1.2, the total cost for airport irrigation, $155,000, and annual operation and maintenance cost, $16,000, were determined and are presented in Table 5-9. The cost for pumping and storage was determined to be negligible compared to the total cost of the alternative and was therefore not included.

Table 5-9: Estimated Cost for Airport Irrigation, St. Croix

Item	Cost ($)
Distribution Network	66,000
Labor and Equipment	58,000
Non-construction and Contingency (25%)	31,000
Total Construction Cost	155,000
Annual Operation and Maintenance	16,000

5.3.2.2 Commercial Irrigation and Industrial Process/Cooling Water

Using the description of project requirements and unit costs from Chapter 5.1.1 and 5.1.2, the total cost for commercial irrigation was calculated and is found in Table 5-10. The total

construction cost was found to be $95,000 with annual operating and maintenance costs of $10,000.

Table 5-10: Estimated Cost for Irrigation of Eco-Industrial Park, St. Croix

Item	Cost ($)
Distribution Network	46,000
Labor and Equipment	30,000
Non-construction and Contingency (25%)	19,000
Total Construction Cost	95,000
Annual Operation and Maintenance	10,000

5.3.2.3 Agricultural Irrigation

Using the description of project requirements and unit costs from Chapter 5.1.1 and 5.1.2, the total cost for agricultural irrigation was determined and found to be $2,139,000 with annual operation and maintenance cost of $214,000 (Table 5-11).

Table 5-11: Estimated Cost for Irrigation of Agricultural Land, St. Croix

Item	Cost ($)
Distribution Network	1,175,000
Labor and Equipment	536,000
Non-construction and Contingency (25%)	428,000
Total Construction Cost	2,139,000
Annual Operation and Maintenance	214,000

5.3.2.4 Habitat Restoration Utilizing Wetlands

Using the description of project requirements and unit costs, the total cost for wetlands was found to be $5,294,000 with annual operation and maintenance cost of $296,000. These costs are summarized in Table 5-12.

Table 5-12: Estimated Cost for Constructed Wetland, St. Croix

Item	Cost ($)
Wetland Construction	4,235,000
Non-construction and Contingency (25%)	1,059,000
Total Construction Cost	5,294,000
Annual Operation and Maintenance	296,000

5.3.2.5 Community-wide Conservation and Habitat Restoration

Using the description of project requirements and unit costs, the total cost for a community-wide conservation program and constructed wetlands was found to be $5,027,000 with annual operation and maintenance cost of $274,000. These costs are summarized in Table 5-13.

Table 5-13: Estimated Cost for Community-wide Conservation Program and Constructed Wetland, St. Croix

Item	Cost ($)
Conservation Kits	143,000
Wetland Construction	3,907,000
Non-construction and Contingency (25%)	977,000
Total Construction Cost	5,027,000
Annual Operation and Maintenance	274,000

5.3.3 Pros and Cons of Each Alternative

Before projects could be implemented, the pros and cons of each need to be identified and used to determine whether or not the project should move forward. All alternatives presented for the SCWWTP positively impact the ocean environment by redirecting nutrient-rich wastewater effluent to uses as opposed to being discharged.

5.3.2.1 Airport Irrigation

Because of the airport's close proximity to the SCWWTP little infrastructure is needed to complete this alternative. This results in low construction cost. Other pros include little to moderate operation and maintenance of the distribution system and little disruption to traffic due to the project's proximity to the reclaimed water source. Lastly, irrigation water also indirectly recharges groundwater.

In order for this alternative to be implemented, additional treatment of the wastewater than is currently performed would be necessary to meet secondary standards. This requirement would be met if the treatment plant improvements proposed are implemented.

5.3.2.2 Commercial Irrigation and Industrial Process/Cooling Water

The irrigation and industrial reuse alternative proposed at the St. Croix Renaissance Park is within close proximity of the SCWWTP. Pros of this project thus include little to no disruption to traffic and low capital and construction cost. In addition, the eco-industrial park has not been constructed yet, therefore installation of reclaimed water lines can take place as potable water lines are being laid and with minimized disturbance and labor and equipment cost. In addition, since irrigation would be performed during the evening and nighttime hours, minimal human contact with reclaimed water would result and irrigation water also serve to recharge groundwater.

Similar to the airport irrigation alternative, additional treatment of the wastewater would be necessary to meet secondary standards. This requirement would be met if the treatment plant improvements proposed are implemented.

5.3.2.3 Agricultural Irrigation

As was explained earlier, there are many advocates for finding new and economical water sources for agricultural purposes on the island of St. Croix including both the DOA and St. Croix

Farmers in Action. Benefits of this reuse option are reclaimed water proves to be a relatively low cost irrigation option for local farmers. In addition, agricultural irrigation also recharges groundwater.

On potential drawback is the fact that depending on the total dissolved solids (TDS) level and irrigation rate, salts can buildup to levels unsuitable for agriculture. To avoid this, close monitoring of effluent and soil should be implemented. In addition, installing irrigation lines can cause a great disruption to traffic in the community. Lastly, pathogen contamination of the groundwater must be monitored since a great deal of groundwater is extracted as a water source. In fact, many households utilizing wells as their primary source of drinking water do not treat the water prior to use.

5.3.2.4 Habitat Restoration Utilizing Wetlands

Similar to the wetland alternative proposed for St. Thomas, the positive impacts of this alternative are many. Habitat restoration proves to be a low cost reuse alternative that provides a new or restored habitat for plant and animal species and an educational tool for the local community and visitors. Construction of the wetland results in little impact on local traffic. The additional treatment of wastewater provided by the wetland system can exceed secondary treatment standards. Because of this, this reuse alternative can be utilized in the place of conventional secondary treatment processes.

The large amount of land that is needed to construct the wetlands on St. Croix may not be available since the SCWWTP site of 14 acres does not satisfy the requirement. In order to determine if land is available, discussions with government officials owning adjacent land need to occur.

5.3.2.5 Community-wide Conservation and Habitat Restoration

Positive impacts of the conservation and habitat restoration alternative are similar to that found in Section 5.3.2.4. An additional benefit is that the use of conservation kits potentially reduces the potable water demand and wastewater needing treatment. This potentially reduces the amount of land needed for construction of wetlands compared to using habitat restoration alone.

The negative impacts of the community-wide conservation and habitat restoration alternative are similar to that described for the habitat restoration alternative presented in section 5.3.2.4. In addition, verifying community use of conservation kits is difficult. Therefore, the full benefits of conservation may or may not be realized by the community.

5.4 Summary and Recommended Reuse Alternatives

The previous chapter presented data and assumptions leading to a construction cost for each of the alternatives. The following paragraphs summarize those costs. Table 5-14 presents total construction cost, annual operation and maintenance cost, net present cost, and dollars per gallon of reclaimed water for each of the proposed reuse alternatives. Determining the net present cost of a project allows for a comparison of alternatives on a similar financial basis. The net present cost was calculated assuming a 3% discount rate over a 20-year useful life of the project. Using the following formula (Brealey and Myers, 2000), the total net present cost for a project equals the sum of the net present cost for each year.

$$NPC = \sum_{n} \frac{FC_n}{(1+i)^n}$$

Table 5-14 also presents the dollars per gallon of reclaimed water. By comparing these numbers, the community-wide conservation and habitat restoration alternative on St. Thomas, the agricultural irrigation on St. Croix, and community-wide conservation and habitat restoration on

St. Croix prove to be projects with the least amount of money invested per gallon of reclaimed water.

Table 5-14: Summary of Estimated Cost for Reuse Projects in the US Virgin Islands

Reuse Project	Total Construction Cost ($)	Annual Operating Cost ($)	Total Net Present Cost after 20 years ($)	$ per gallon of reused and conserved water
St. Thomas Residential Irrigation	1,860,000	186,000	4,573,000	23
St. Thomas Habitat Restoration	373,000	21,000	2,969,000	4
St. Thomas Conservation and Habitat Restoration	274,000	9,000	2,861,000	4
St. Croix Airport Irrigation	155,000	16,000	2,75,3,000	159
St. Croix Commercial Irrigation & Industrial Process Water	95,000	10,000	2,689,000	10
St. Croix Agriculture Irrigation	2,139,000	214,000	4,871,000	5
St. Croix Habitat Restoration	5,294,000	296,000	8,014,000	2
St. Croix Conservation and Habitat Restoration	5,027,000	274,000	7,733,000	2

6.0 Recommendations and Conclusions

This thesis investigated existing reuse and conservation practices in the US Virgin Islands and proposed reuse and conservation alternatives for two municipal wastewater treatment facilities in order to help meet the critical need for water supply in the US Virgin Islands. The results of a survey and interviews of businesses showed the following information: water reuse is currently being practiced at many of the resorts and condominium complexes on St. Thomas and conservation is practiced on the US Virgin Islands, but not as widely as is water reuse. Chapter 2 of this report presented conservation practices that are currently in place in the US Virgin Islands as well as conservation requirements implemented in various states. Low-cost and easily-executable conservation practices and equipment for residential and commercial users are also available. These conservation practices and equipment could be implemented with support from local government and community groups.

6.1 USVI Resorts and Condominiums

Although surveys were not returned from St. John and St. Croix, there is no reason to expect conditions to differ from businesses on St. Thomas. Unfortunately, many of the businesses and municipalities are not utilizing reclaimed water and conservation practices to their fullest potential. These businesses are also not testing the quality of the effluent on a regular basis due to cost, difficulty in obtaining consistent analytical results, and lack of a requirement to do so under current Virgin Islands DPNR permits. Analytical testing is not being undertaken even though most interviewees have noticed effects from high levels of pollutants such as clogging of irrigation systems and Coral World has observed death among the duck population.

When new irrigation permits are required for reuse, water quality sampling will be required and the TSS, BOD, fecal coliforms, and TDS values will be known. This would possibly force businesses to invest capital in their wastewater treatment processes in order to meet permit levels and maintain public and environmental health, or else may discourage the use of irrigation. TDS (or salinity) is a critical parameter to be monitored for all reuse projects due to the conditions in the US Virgin Islands and because plants have varying salinity tolerance levels (California Department of Land, Air & Water Resources, 1984).

6.2 USVI Municipal Wastewater Treatment Plants

The previous chapters of this thesis presented an assessment of water reuse and conservation practices in the US Virgin Islands and identified eight reuse alternatives that could be implemented by local municipalities. Those reuse alternatives include: (1) residential irrigation on St. Thomas, (2) habitat restoration utilizing wetlands on St. Thomas, (3) community-wide conservation and habitat restoration on St. Thomas (4) airport irrigation on St. Croix, (5) commercial irrigation and industrial process/cooling water on St. Croix, (6) agricultural irrigation on St. Croix, (7) habitat restoration utilizing wetlands on St. Croix, and (8) community-wide conservation and habitat restoration on St. Croix. Out of these eight alternatives: habitat restoration on both St. Thomas and St. Croix, community-wide conservation and habitat restoration on both St. Thomas and St. Croix, and agricultural irrigation on St. Croix, are the most economical based on the normalized cost per gallon of reclaimed and conserved water. However, agricultural irrigation on St. Croix and community-wide conservation and habitat restoration on St. Thomas and St. Croix provide the most benefit to the community. Agricultural irrigation provides farmers a low-cost option to meet water demand and production requirements. Community-wide conservation and habitat restoration alternatives provide an

educational environment and promote conservation practices thus reducing water consumption, water cost, and wastewater production.

From the assessment it is apparent that reclaiming wastewater effluent results in a reduction of nutrient-rich effluent discharged to the ocean, conservation of fresh-water sources, reduction of energy and pollution due to lower production needed by WAPA, and avoidance or delay in WAPA expansion to meet non-potable water needs. The next step before undertaking design of a reuse project is to incorporate several components prior to ensure success. Those components include: (1) public information and participation, (2) public health impact identification, and (3) local and federal government participation.

To identify water needs, determine demand for the proposed projects, and obtain local opinion regarding water reuse, a public information and participation program is necessary (Ammerman et al, 1992). The public includes local residents, interest groups, potential users of reclaimed water, freshwater suppliers, and water reuse experts. The level of public participation varies with the level of public impact. For instance, a public participation program for an urban irrigation project may be fairly extensive involving several information sessions, surveys of local residents and businesses as well as public hearings to determine local support and answer questions. On the other hand, a public participation program for an industrial reuse program may be minimal and involve technical and public health experts.

Before design of reuse systems can take place, additional research to gain a better understanding of the potential public health impacts of reuse alternatives should be undertaken. By testing ground-water, surface water, and reclaimed water quality and determining the extent to which people may be exposed to these water sources, the potential health impacts of reuse can

be determined. When implementing alternatives, safeguards to ensure treatment reliability and prevent cross-contamination with potable water lines must be installed.

Throughout the preliminary screening, design and implementation process it is crucial to include local and federal regulatory bodies. Regulatory concerns regarding protection of public health and water quality can be addressed at the beginning of the project rather than toward the implementation phase.

The US Virgin Islands faces the challenge of meeting the community's water needs at low cost. This can be done with careful planning and by incorporating water reuse and conservation programs into the overall water management plan for the islands.

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Appendix A: Water Reuse and Conservation Surveys

DEPARTMENT OF CIVIL & ENVIRONMENTAL ENGINEERING
MASTER OF ENGINEERING PROGRAM, 1-143
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CAMBRIDGE, MASSACHUSETTS 02139 USA

MIT/US Virgin Islands Survey
2002-2003
Please return by DECEMBER 21, 2002

1) Please check the type of business: ____ Resort ____ Condominium ____ Municipal __X__ Other (describe) Marina, Offices, Apartments, Restaurants

2) If you own/operate a Condominium please list the number of units: __2__ Studio __5__ 1Bedroom __1__ 2 Bedrooms ____ 3 Bedrooms ____ Other

Please list the number of permanent or temporary residences: __8__ Permanent __0__ Temporary (for visitors)

4) If you own/operate a Resort please list the number of rooms: ____

5) Please list average occupancy of resort during ____ Off-Peak ____ Peak

6) Peak season starts on ____ and ends on ____ (Fill in dates)

7) On average, how many gallons of water are used per day? Peak: 1500 Gallons/Day Non-peak: ____ Gallons/Day

8) At what time of day is water at peak use: ____ 6-8 am __X__ 8-10 am __X__ 10 am – 12 pm __X__ 12-4 pm ____ 4-7 pm ____ 7-11 pm ____ 11-5 am

9) Does the Resort/Condominium operate a desalination plant? __X__ Y ____ N (R/O PLANT)

From where does the facility obtain its drinking water? ____ Desalination ____ Ground water ____ Cistern ____ Public Water Supply __X__ Other (describe) R.O. (Reverse Osmosis)

Does the Resort/Condominium operate a wastewater treatment plant? __X__ Y ____ N

If yes, is this facility permitted? __X__ Y ____ N If yes, please give permit number ____

Please list wastewater treatment processes used (check as many as apply):
____ Aerated Lagoon ____ Oxidation Ditch ____ Trickling Filters ____ Contact Stabilization
____ Extended Aeration __X__ Activated Sludge ____ Sequencing Batch Reactor
____ Rotary Drum ____ Other (describe) ____

13) What level of treatment is provided: __X__ Primary ____ Secondary ____ Tertiary

If tertiary, please list: ____ % BOD Removal ____ % TSS Removal ____ % Nitrate Removal ____ % Phosphorus Removal

14) Is disinfection of effluent is provided? __X__ Y ____ N If Yes, please list technology:
__X__ Chlorine ____ Ozone ____ Ultraviolet Radiation ____ Other

15) How is effluent (treated wastewater) [illegible]
____ Discharge to ponds/stream If yes, please list size ____ gallons
____ Stored in holding tank(s) If yes, please list size ____ gallons
__X__ Other (describe) IRRIGATION ____ If yes, please list size 150 gallons pending

16) Is effluent currently being reused? __X__ Y ____ N If yes, please list nature: __X__ Irrigation __X__ Toilet flushing ____ Other (describe) ____

17) If effluent is reused, please list number of gallons per day for each activity: 150 Irrigation 1000 Toilet flushing ____ Other

18) Is salt water currently being used for toilet flushing? ____ Y __X__ N

19) Do you have any other reuse strategies not covered in this letter? If yes, please explain NO

20) Does your business participate in a water conservation program? If yes, please explain NO

21) If effluent is currently not being reused, would you be interested in hearing of opportunities to do so? ____ Y ____ N

22) Would you be willing to meet with an MIT student to talk about your treatment process and reuse and conservation practices? __X__ Y ____ N If yes, please supply contact name, phone number and address
DAVE WARREN 340-775-6144
↳ St. Thomas, VI – East end – 1 mile from Red Hook – call when get to islands

Thank you for taking the time to complete this survey. Should you have questions regarding this survey, please contact Heather Cheslek at hcheslek@mit.edu or 617-571-7072.

+ January 13th

DEPARTMENT OF CIVIL & ENVIRONMENTAL ENGINEERING
MASTER OF ENGINEERING PROGRAM, 1-143
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CAMBRIDGE, MASSACHUSETTS 02139 USA

MIT/US Virgin Islands Survey
2002-2003
Please return by December 20, 2002

1) Please check the type of business: _____ Resort ✓ [illegible]
(describe) *A Condominium complex with a [illegible]*

2) If you own/operate a Condominium please list the number of units: _____ Studio _____ 1Bedroom
_____ 2 Bedrooms _____ 3 Bedrooms _____ Other
Please list the number of permanent or temporary residences: *125* Permanent _____ Temporary (for visitors)

A 4) If you own/operate a Resort please list the number of rooms: *–*

5) Please list average occupancy of resort during *–* Off-Peak *–* Peak

6) Peak season starts on *–* and ends on *–* (Fill in dates)

7) On average, how many gallons of water are used per day? Peak: *10K* Gallons/Day Non-peak: *5K* Gallons/Day

8) At what time of day is water at peak use: *–* 6-8 am _____ 8-10 am _____ 10 am – 12 pm _____ 12-4 pm
✓ 4-7 pm _____ 7-11 pm _____ 12-3 am

9) Does the Resort/Condominium operate a desalination plant? ✓ Y _____ N

10) From where does the facility obtain its drinking water? ✓ Desalination _____ Ground water _____ Cistern
_____ Public Water Supply _____ Other (describe) _____

11) Does the Resort/Condominium operate a wastewater treatment plant? ✓ Y _____ N
If yes, is this facility permitted? _____ Y _____ N If yes, please give permit number _____

12) Please list wastewater treatment processes used (check as many as apply):
_____ Aerated Lagoons _____ Oxidation Ditch _____ Trickling Filters _____ Contact Stabilization
_____ Extended Aeration _____ Activated Sludge _____ Sequencing Batch Reactor
_____ Rotary Drum ✓ Other (describe) *Membrane Filtration*

13) What level of treatment is provided: ✓ Primary _____ Secondary _____ Tertiary
If tertiary, please list: *95* % BOD Removal *80* % TSS Removal
_____ % Nitrate Removal _____ % Phosphorus Removal

14) Is disinfection of effluent is provided? ✓ Y _____ N If Yes, please list technology:
✓ Chlorine _____ Ozone _____ Ultraviolet Radiation _____ Other

15) How is effluent (treated wastewater) handled?
_____ Discharge to ponds/stream If yes, please list size _____ gallons
✓ Stored in holding tank(s) If yes, please list size *50 K* gallons
_____ Other (describe) _____ If yes, please list size _____ gallons

16) Is effluent currently being reused? ✓ Y _____ N If yes, please list nature: ✓ Irrigation _____ Toilet flushing _____ Other (describe) _____

17) If effluent is reused, please list number of gallons per day for each activity: *5K* Irrigation
_____ Toilet flushing _____ Other

18) Is salt water currently being used for toilet flushing? _____ Y ✓ N

19) Do you have any other reuse strategies not covered in this letter? If yes, please explain _____

20) Does your business participate in a water conservation program? If yes, please explain *[illegible] our potable water by [illegible] of waste water treatment*

21) If effluent is currently not being reused, would you be interested in hearing of opportunities to do so? _____ Y _____ N

22) Would you be willing to meet with an MIT student to talk about your treatment process and reuse and conservation practices? ✓ Y _____ N If yes, please supply contact name, phone number and address
Keith Smith Tel # 340-775-7200 Ext 3003
Morning 10:30 am – Jan 20th

Thank you for taking the time to complete this survey. Should you have questions regarding this survey, please contact Heather Cheslek at hcheslek@mit.edu or 617-571-7072.

Smith Bay
Point Pleasant Resort

DEPARTMENT OF CIVIL & ENVIRONMENTAL ENGINEERING
MASTER OF ENGINEERING PROGRAM, 1-343
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CAMBRIDGE, MASSACHUSETTS 02139 USA

MIT/US Virgin Islands Survey
2002-2003
Please return by DECEMBER 21, 2002

1) Please check the type of business: _____ Resort ✓ Condominium _____ Hotel _____ Other _____ (describe)_____

2) If you own/operate a Condominium please list the number of units: _____ Studio _____ 1Bedroom
68 2 Bedrooms 29 3 Bedrooms 5 Other 4 BDRM
Please list the number of permanent or temporary residences: 40 Permanent 62 Temporary (for visitors)

4) If you own/operate a Resort please list the number of rooms: _____

5) Please list average occupancy of resort during _____ Off-Peak _____ Peak

6) Peak season starts on JAN 15 and ends on APRIL 15 (Fill in dates)

7) On average, how many gallons of water are used per day? Peak 8000 Gallons/Day Non-peak 6000 Gallons/Day

8) At what time of day is water at peak use: _____ 6-8 am ✓ 8-10 am _____ 10 am – 12 pm _____ 12-4 pm
_____ 4-7 pm _____ 7-11 pm _____ 12-5 am

9) Does the Resort/Condominium operate a desalination plant? ✓ Y _____ N

10) From where does the facility obtain its drinking water? ✓ Desalination _____ Ground water ✓ Cisterns
_____ Public Water Supply _____ Other (describe)_____

11) Does the Resort/Condominium operate a wastewater treatment plant? _____ ✓ Y _____ N
If yes, is this facility permitted? ✓ Y _____ N If yes, please give permit number _____

12) Please list wastewater treatment processes used (check as many as apply):
_____ Aerated Lagoon _____ Oxidation Ditch _____ Trickling Filters _____ Contact Stabilization
✓ Extended Aeration _____ Activated Sludge _____ Sequencing Batch Reactor
_____ Rotary Drum _____ Other (describe)_____

13) What level of treatment is provided: _____ Primary ✓ Secondary _____ Tertiary
If tertiary, please list: _____ % BOD Removal _____ % TSS Removal
_____ % Nitrate Removal _____ % Phosphorus Removal

14) Is disinfection of effluent is provided? ✓ Y _____ N If Yes, please list technology:
✓ Chlorine _____ Ozone _____ Ultraviolet Radiation _____ Other

15) How is effluent (treated wastewater) [illegible]
_____ Discharge to ponds/stream If yes, please list size _____ gallons
_____ Stored in holding tank(s) If yes, please list size _____ gallons
✓ Other (describe) PERCOLATION PITS If yes, please list size 30,000 gallons

16) Is effluent currently being reused? ✓ Y _____ N If yes, please list nature: ✓ Irrigation _____ Toilet flushing _____ Other (describe)_____

17) If effluent is reused, please list number of gallons per day for each activity 30,000 Irrigation
_____ Toilet flushing _____ Other

18) Is salt water currently being used for toilet flushing? _____ Y ✓ N

19) Do you have any other reuse strategies not covered in this letter? If yes, please explain _____

20) Does your business participate in a water conservation program? If yes, please explain _____

21) If effluent is currently not being reused, would you be interested in hearing of opportunities to do so? _____ Y _____ N

22) Would you be willing to meet with an MIT student to talk about your treatment process and reuse and conservation practices? _____ Y ✓ N If yes, please supply contact name, phone number and address _____

Thank you for taking the time to complete this survey. Should you have questions regarding this survey, please contact Heather Cheslek at hcheslek@mit.edu or 617-571-7072.

DEPARTMENT OF CIVIL & ENVIRONMENTAL ENGINEERING
MASTER OF ENGINEERING PROGRAM, 1-143
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CAMBRIDGE, MASSACHUSETTS 02139 USA

MIT/US Virgin Islands Survey
2002-2003
Please return by DECEMBER 21, 2002

1) Please check the type of business: _____ Resort _____ Condominium _____ Municipal ✓ Other

2) If you own/operate a Condominium please list the number of units: _____ Studio _____ 1Bedroom
_____ 2 Bedrooms _____ 3 Bedrooms _____ Other
Please list the number of permanent or temporary residences: _____ Permanent _____ Temporary (for visitors)

4) If you own/operate a Resort please list the number of rooms: _____

5) Please list average occupancy of resort during _____ Off-Peak _____ Peak

6) Peak season starts on 12/15 and ends on 4/15 (Fill in dates)

7) On average, how many gallons of water are used per day? Peak: 3500 Gallons/Day Non-peak: 3000 Gallons/Day

8) At what time of day is water at peak use: _____ 6-8 am _____ 8-10 am ✓ 10 am - 2 pm _____ 12-4 pm
_____ 4-7 pm _____ 7-11 pm _____ 12-5 am

9) Does the Resort/Condominium operate a desalination plant? ✓ Y _____ N

10) From where does the facility obtain its drinking water? _____ Desalination _____ Ground water ✓ Cistern
_____ Public Water Supply ✓ Other (describe) PURCHASE FROM WATER TRUCKERS

11) Does the Resort/Condominium operate a wastewater treatment plant? ✓ Y _____ N
If yes, is this facility permitted? _____ Y ✓ N If yes, please give permit number _____

12) Please list wastewater treatment processes used (check as many as apply):
_____ Aerated Lagoon _____ Oxidation Ditch _____ Trickling Filters _____ Contact Stabilization
✓ Extended Aeration _____ Activated Sludge _____ Sequencing Batch Reactor
_____ Rotary Drum _____ Other (describe)_____

13) What level of treatment is provided: _____ Primary ✓ Secondary _____ Tertiary (at least secondary- possibly tertiary)
If tertiary, please list: _____ % BOD Removal _____ % TSS Removal
_____ % Nitrate Removal _____ % Phosphorus Removal

14) Is disinfection of effluent is provided? ✓ Y _____ N If Yes, please list technology:
✓ Chlorine _____ Ozone _____ Ultraviolet Radiation _____ Other

15) How is effluent (treated wastewater) handled?
_____ Discharge to ponds/stream If yes, please list size _____ gallons
✓ Stored in holding tank(s) If yes, please list size 4200 gallons
_____ Other (describe)_____ If yes, please list size _____ gallons

16) Is effluent currently being reused? ✓ Y _____ N If yes, please list nature: ✓ Irrigation _____ Toilet flushing _____ Other (describe) _____

17) If effluent is reused, please list number of gallons per day for each activity: 1500 Irrigation
_____ Toilet flushing _____ Other

18) Is salt water currently being used for toilet flushing? _____ Y ✓ N

19) Do you have any other reuse strategies not covered in this letter? If yes, please explain WE HAVE AN ALTERNATIVE ON SITE SEWAGE DISPOSAL SYSTEM (CONSTRUCTED WETLANDS) PROJECT IN CONJUNCTION WITH UVI

20) Does your business participate in a water conservation program? If yes, please explain OTHER THAN THE REUSE OF WASTEWATER AND ENCOURAGING CAREFUL WATER USAGE - NO

21) If effluent is currently not being reused, would you be interested in hearing of opportunities to do so? ✓ Y _____ N
EVEN THOUGH WE REUSE EFFLUENT WE WOULD LIKE TO HEAR OF OTHER OPPORTUNITIES

22) Would you be willing to meet with an MIT student to talk about your treatment process and reuse and conservation practices? ✓ Y _____ N If yes, please supply contact name, phone number and address WE WOULD BE VERY PLEASED TO MEET WITH A STUDENT. PLEASE CONTACT TRUDIE PRIOR, GENERAL MANAGER, CORAL WORLD, 6450 ESTATE SMITH BAY

Thank you for taking the time to complete this survey. Should you have questions regarding this survey, please contact Heather Cheslek at hcheslek@mit.edu or 617-571-7072.

ST. THOMAS VI 00802-1800
T: (340) 775-1555 x245
F: (340) 775-9068
E: tprior@coralworldvi.com (preferred)

DEPARTMENT OF CIVIL & ENVIRONMENTAL ENGINEERING
MASTER OF ENGINEERING PROGRAM, 1-143
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CAMBRIDGE, MASSACHUSETTS 02139 USA

MIT/US Virgin Islands Survey
2002-2003
Please return by DECEMBER 21, 2002

1) Please check the type of business: _____ Resort ✓ Condominium _____ Municipal _____ Other (describe) 40 unit Comm. Condo.

2) If you own/operate a Condominium please list the number of units: _____ Studio _____ 1Bedroom
20 2 Bedrooms 10 3 Bedrooms 36 Other 2 Bd w Loft
Please list the number of permanent or temporary residences: 42 Permanent 20 Temporary (for visitors)

4) If you own/operate a Resort please list the number of rooms: _____

5) Please list average occupancy of resort during 43 % Off-Peak 92 % Peak

6) Peak season starts on Nov 3 and ends on Mid (Fill in dates)

7) On average, how many gallons of water are used per day? Peak: 4 [illegible]Gallons/Day Non-peak: [illegible]Gallons/Day

8) At what time of day is water at peak use: ✓ 6-8 am _____ 8-10 am _____ 10 am – 12 pm _____ 12-6 pm
_____ 4-7 pm _____ 7-11 pm _____ 12-5 am

9) Does the Resort/Condominium operate a desalination plant? ✓ Y _____ N

10) From where does the facility obtain its drinking water? ✓ Desalination _____ Ground water ✓ Cistern
_____ Public Water Supply _____ Other (describe)_____

11) Does the Resort/Condominium operate a wastewater treatment plant? ✓ Y _____ N
If yes, is this facility permitted? _____ Y ✓ N If yes, please give permit number _____

12) Please list wastewater treatment processes used (check as many as apply):
_____ Aerated Lagoon _____ Oxidation Ditch _____ Trickling Filters _____ Contact Stabilization
✓ Extended Aeration ✓ Activated Sludge _____ Sequencing Batch Reactor
_____ Rotary Drum _____ Other (describe)_____

13) What level of treatment is provided: _____ Primary ✓ Secondary _____ Tertiary
If tertiary, please list: _____ % BOD Removal _____ % TSS Removal
_____ % Nitrate Removal _____ % Phosphorus Removal

14) Is disinfection of effluent is provided? ✓ Y _____ N If Yes, please list technology:
✓ Chlorine _____ Ozone _____ Ultraviolet Radiation _____ Other

15) How is effluent (treated wastewater) handled?
_____ Discharge to ponds/stream If yes, please list size _____ gallons
_____ Stored in holding tank(s) If yes, please list size 25,000 gallons
_____ Other (describe)_____ If yes, please list size _____ gallons

16) Is effluent currently being reused? ✓ Y _____ N If yes, please list nature: ✓ Irrigation _____ Toilet flushing _____ Other (describe) _____

17) If effluent is reused, please list number of gallons per day for each activity: 5,000 Irrigation
1,000 Toilet flushing _____ Other

18) Is salt water currently being used for toilet flushing? _____ Y ✓ N

19) Do you have any other reuse strategies not covered in this letter? If yes, please explain Yes

20) Does your business participate in a water conservation program? If yes, please explain Yes - natural & Business / tourism.

21) If effluent is currently not being reused, would you be interested in hearing of opportunities to do so? _____ Y ✓ N

22) Would you be willing to meet with an MIT student to talk about your treatment process and reuse and conservation practices? _____ Y ✓ N If yes, please supply contact name, phone number and address _____

Thank you for taking the time to complete this survey. Should you have questions regarding this survey, please contact Heather Cheslek at hcheslek@mit.edu or 617-571-7072.

DEPARTMENT OF CIVIL & ENVIRONMENTAL ENGINEERING
MASTER OF ENGINEERING PROGRAM, 1-143
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CAMBRIDGE, MASSACHUSETTS 02139 USA

MIT/US Virgin Islands Survey
2002-2003
Please return by DECEMBER 21, 2002

1) Please check the type of business: X Resort ____ Condominium ____ Municipal ____ Other ____ (describe) 90 rooms [illegible]

2) If you own/operate a Condominium please list the number of units: ____ Studio ____ 1Bedroom ____ 2 Bedrooms ____ 3 Bedrooms ____ Other
Please list the number of permanent or temporary residences: ____ Permanent ____ Temporary (for visitors)

4) If you own/operate a Resort please list the number of rooms: 90

5) Please list average occupancy of resort during 60 Off-Peak 80 Peak

6) Peak season starts on 12/25 and ends on 05/31 (Fill in dates)

7) On average, how many gallons of water are used per day? Peak: 17,000 Gallons/Day Non-peak: 14,000 Gallons/Day

8) At what time of day is water at peak use: ____ 6-8 am X 8-10 am ____ 10 am – 12 pm ____ 12-4 pm ____ 4-7 pm ____ 7-11 pm ____ 12-5 am

9) Does the Resort/Condominium operate a desalination plant? (Y) N

10) From where does the facility obtain its drinking water? X Desalination ____ Ground water ____ Cistern ____ Public Water Supply ____ Other (describe) ____

11) Does the Resort/Condominium operate a wastewater treatment plant? ____ Y (N)
If yes, is this facility permitted? ____ Y ____ N If yes, please give permit number ____

12) Please list wastewater treatment processes used (check as many as apply):
____ Aerated Lagoon ____ Oxidation Ditch ____ Trickling Filters ____ Contact Stabilization
____ Extended Aeration ____ Activated Sludge ____ Sequencing Batch Reactor
____ Rotary Drum ____ Other (describe) ____

13) What level of treatment is provided: ____ Primary ____ Secondary ____ Tertiary
If tertiary, please list: ____ % BOD Removal ____ % TSS Removal ____ % Nitrate Removal ____ % Phosphorus Removal

14) Is disinfection of effluent is provided? (Y) (N) If Yes, please list technology:
X Chlorine ____ Ozone ____ Ultraviolet Radiation ____ Other

15) How is effluent (treated wastewater) handled?
____ Discharge to ponds/stream If yes, please list size ____ gallons
X Stored in holding tank(s) If yes, please list size 100,000 gallons
____ Other (describe) Toilet flush & irrigation If yes, please list size 100,000 gallons

16) Is effluent currently being reused? ____ Y (N) If yes, please list nature: ____ Irrigation ____ Toilet flushing ____ Other (describe) ____

17) If effluent is reused, please list number of gallons per day for each activity: 900 Irrigation 1300 Toilet flushing ____ Other

18) Is salt water currently being used for toilet flushing? (Y) N

19) Do you have any other reuse strategies not covered in this letter? If yes, please explain ____

20) Does your business participate in a water conservation program? If yes, please explain CARD/TENT in each guest rooms. Bathrooms + Rooms

21) If effluent is currently not being reused, would you be interested in hearing of opportunities to do so? ____ Y ____ N

22) Would you be willing to meet with an MIT student to talk about your treatment process and reuse and conservation practices? (Y) N If yes, please supply contact name, phone number and address 340-777-3800 [illegible]
[illegible]
Joel Kling -

Thank you for taking the time to complete this survey. Should you have questions regarding this survey, please contact Heather Chesluk at hchesluk@mit.edu or 617-571-7072.

DEPARTMENT OF CIVIL & ENVIRONMENTAL ENGINEERING
MASTER OF ENGINEERING PROGRAM, 1-143
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CAMBRIDGE, MASSACHUSETTS 02139 USA

MIT/US Virgin Islands Survey
2002-2003
Please return by DECEMBER 21, 2002

1) Please check the type of business: ___✓___ Resort _____ Condominium _____ Municipal _____ Other (describe) _____

2) If you own/operate a Condominium please list the number of units: _____ Studio _____ 1Bedroom _____ 2 Bedrooms _____ 3 Bedrooms _____ Other

Please list the number of permanent or temporary residences: _____ Permanent _____ Temporary (for visitors)

4) If you own/operate a Resort please list the number of rooms: 290

5) Please list average occupancy of resort during 80% Off-Peak 90% Peak

6) Peak season starts on NOV and ends on APRIL (Fill in dates)

7) On average, how many gallons of water are used per day? Peak: 180K Gallons/Day Non-peak: 22K Gallons/Day

8) At what time of day is water at peak use: ✓ 6-8 am _____ 8-10 am _____ 10 am – 12 pm _____ 12-4 pm ✓ 4-7 pm _____ 7-11 pm _____ 11-5 am

9) Does the Resort/Condominium operate a desalination plant? ✓ Y _____ N

10) From where does the facility obtain its drinking water? ✓ Desalination _____ Ground water _____ Cistern _____ Public Water Supply _____ Other (describe) _____

11) Does the Resort/Condominium operate a wastewater treatment plant? ✓ Y _____ N
If yes, is this facility permitted? ✓ Y _____ N If yes, please give permit number SIT-004-2000

12) Please list wastewater treatment processes used (check as many as apply):
_____ Aerated Lagoon _____ Oxidation Ditch _____ Trickling Filters _____ Contact Stabilization
✓ Extended Aeration _____ Activated Sludge _____ Sequencing Batch Reactor
_____ Rotary Drum _____ Other (describe) _____

13) What level of treatment is provided: ✓ Primary _____ Secondary _____ Tertiary
If tertiary, please list: _____ % BOD Removal _____ % TSS Removal
_____ % Nitrate Removal _____ % Phosphorus Removal

14) Is disinfection of effluent is provided? ✓ Y _____ N If Yes, please list technology:
✓ Chlorine _____ Ozone _____ Ultraviolet Radiation _____ Other

15) How is effluent (treated wastewater) handled?
_____ Discharge to ponds/streams If yes, please list size _____ gallons
✓ Stored in holding tank(s) If yes, please list size 100K gallons
_____ Other (describe) _____ If yes, please list size _____ gallons

16) Is effluent currently being reused? ✓ Y _____ N If yes, please list nature: ✓ Irrigation _____ Toilet flushing _____ Other (describe) _____

17) If effluent is reused, please list number of gallons per day for each activity: 45K Irrigation
_____ Toilet flushing _____ Other

18) Is salt water currently being used for toilet flushing? _____ Y ✓ N

19) Do you have any other reuse strategies not covered in this letter? If yes, please explain _____

20) Does your business participate in a water conservation program? If yes, please explain WE USE WATER CONSERVATION DEVICES SUCH AS 2.5GPM SHOWERHEADS, 1.6L TOILET TANKS AND 1.5GPM LAVATORY FAUCET AERATORS.

21) If effluent is currently not being reused, would you be interested in hearing of opportunities to do so? ✓ Y _____ N

22) Would you be willing to meet with an MIT student to talk about your treatment process and reuse and conservation practices? _____ Y ✓ N If yes, please supply contact name, phone number and address _____

Thank you for taking the time to complete this survey. Should you have questions regarding this survey, please contact Heather Cheslek at hcheslek@mit.edu or 617-571-7072.

DEPARTMENT OF CIVIL & ENVIRONMENTAL ENGINEERING
MASTER OF ENGINEERING PROGRAM, 1-143
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CAMBRIDGE, MASSACHUSETTS 02139 USA

MIT/US Virgin Islands Survey
2002-2003
Please return by DECEMBER 31, 2002

1) Please check the type of business: _____ Resort _____ Condominium X Municipal _____ Other (describe)

2) If you own/operate a Condominium please list the number of units: _____ Studio _____ 1Bedroom 50 2 Bedrooms 25 3 Bedrooms _____ Other
Please list the number of permanent or temporary residences: 30 Permanent 45 Temporary (for visitors)

4) If you own/operate a Resort please list the number of rooms: N/A

5) Please list average occupancy of resort during 85% Off-Peak 70% Peak

6) Peak season starts on 20 NOV and ends on 15 MAY (Fill in dates)

7) On average, how many gallons of water are used per day? Peak 8000 Gallons/Day Non-peak 4000 Gallons/Day

8) At what time of day is water at peak use: X 6-8 am _____ 8-10 am _____ 10 am – 12 pm _____ 12-4 pm
X 4-7 pm _____ 7-11 pm _____ 12-5 am

9) Does the Resort/Condominium operate a desalination plant? X Y _____ N

10) From where does the facility obtain its drinking water? X Desalination _____ Ground water _____ Cistern
_____ Public Water Supply _____ Other (describe) DESAL + ROOF CATCHMENT to CISTERN

11) Does the Resort/Condominium operate a wastewater treatment plant? X Y _____ N
If yes, is this facility permitted? X Y _____ N If yes, please give permit number _____

12) Please list wastewater treatment processes used (check as many as apply):
_____ Aerated Lagoon _____ Oxidation Ditch _____ Trickling Filters _____ Contact Stabilization
X Extended Aeration _____ Activated Sludge _____ Sequencing Batch Reactor
_____ Rotary Drum _____ Other (describe) _____

13) What level of treatment is provided: X Primary _____ Secondary _____ Tertiary
If tertiary, please list: _____ % BOD Removal _____ % TSS Removal
_____ % Nitrate Removal _____ % Phosphorus Removal

14) Is disinfection of effluent is provided? X Y _____ N If Yes, please list technology:
X Chlorine _____ Ozone _____ Ultraviolet Radiation _____ Other

15) How is effluent (treated wastewater) utilized?
_____ Discharge to ponds/stream If yes, please list size _____ gallons
X Stored in holding tank(s) If yes, please list size 20K gallons
_____ Other (describe) ALL USED BY IRRIGATION SYSTEM NIGHTLY If yes, please list size _____ gallons

16) Is effluent currently being reused? X Y _____ N If yes, please list nature: X Irrigation _____ Toilet flushing _____ Other (describe) _____

17) If effluent is reused, please list number of gallons per day for each activity: X 100% Irrigation
_____ Toilet flushing _____ Other

18) Is salt water currently being used for toilet flushing? _____ Y X N

19) Do you have any other reuse strategies not covered in this letter? If yes, please explain _____

20) Does your business participate in a water conservation program? If yes, please explain _____

21) If effluent is currently not being reused, would you be interested in hearing of opportunities to do so? N/A Y _____ N

22) Would you be willing to meet with an MIT student to talk about your treatment process and reuse and conservation practices? _____ Y _____ N If yes, please supply contact name, phone number and address JIM KELLOGG
6600 ESTATE NAZARETH #37, ST THOMAS, US VI 00802
PHONE 340-775-6938

Thank you for taking the time to complete this survey. Should you have questions regarding this survey, please contact Heather Chenlek at hchenlek@mit.edu or 617-571-7072.

DEPARTMENT OF CIVIL & ENVIRONMENTAL ENGINEERING
MASTER OF ENGINEERING PROGRAM, 1-143
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CAMBRIDGE, MASSACHUSETTS 02139 USA

MIT/US Virgin Islands Survey
2002-2003
Please return by DECEMBER 21, 2002

1) Please check the type of business: _____ Resort _____ Condominium _____ Municipal \ Other

N/A 2) If you own/operate a Condominium please list the number of units: _____ Studio _____ 1Bedroom
_____ 2 Bedrooms _____ 3 Bedrooms _____ Other
Please list the number of permanent or temporary residences: _____ Permanent _____ Temporary (for visitors)

N/A 4) If you own/operate a Resort please list the number of rooms: _____

N/A 5) Please list average occupancy of resort during _____ Off-Peak _____ Peak

6) Peak season starts on Nov and ends on May (Fill in dates)

N/A 7) On average, how many gallons of water are used per day? Peak:_____ Gallons/Day Non-peak:_____ Gallons/Day

N/A 8) At what time of day is water at peak use: _____ 6-8 am _____ 8-10 am _____ 10 am - 12 pm _____ 12-4 pm
_____ 4-7 pm _____ 7-11 pm _____ 12-5 am

N/A 9) Does the Resort/Condominium operate a desalination plant? _____ Y _____ N

10) From where does the facility obtain its drinking water? _____ Desalination _____ Ground water \ Cistern
\ Public Water Supply _____ Other (describe)_____

N/A 11) Does the Resort/Condominium operate a wastewater treatment plant? _____ Y _____ N
If yes, is this facility permitted? _____ Y _____ N If yes, please give permit number _____

12) Please list wastewater treatment processes used (check as many as apply):
_____ Aerated Lagoon _____ Oxidation Ditch _____ Trickling Filters _____ Contact Stabilization
_____ Extended Aeration \ Activated Sludge _____ Sequencing Batch Reactor
_____ Rotary Drum _____ Other (describe)_____

13) What level of treatment is provided: _____ Primary \ Secondary _____ Tertiary
If tertiary, please list: _____ % BOD Removal _____ % TSS Removal
_____ % Nitrate Removal _____ % Phosphorus Removal

14) Is disinfection of effluent is provided? \ Y _____ N If Yes, please list technology:
\ Chlorine _____ Ozone _____ Ultraviolet Radiation _____ Other

15) How is effluent (treated wastewater) [illegible]
_____ Discharge to ponds/stream If yes, please list size _____ gallons
_____ Stored in holding tank(s) If yes, please list size _____ gallons
\ Other (describe) Ocean outfall If yes, please list size _____ gallons

16) Is effluent currently being reused? _____ Y \ N If yes, please list nature: _____ Irrigation _____ Toilet flushing _____ Other (describe) _____

N/A 17) If effluent is reused, please list number of gallons per day for each activity: _____ Irrigation
_____ Toilet flushing _____ Other

18) Is salt water currently being used for toilet flushing? _____ Y \ N

19) Do you have any other reuse strategies not covered in this letter? If yes, please explain NO

20) Does your business participate in a water conservation program? If yes, please explain N/A

21) If effluent is currently not being reused, would you be interested in hearing of opportunities to do so? _____ Y \ N

22) Would you be willing to meet with an MIT student to talk about your treatment process and reuse and conservation practices? _____ Y \ N If yes, please supply contact name, phone number and address _____

Thank you for taking the time to complete this survey. Should you have questions regarding this survey, please contact Heather Cheslek at hcheslek@mit.edu or 617-571-7072.

DEPARTMENT OF CIVIL & ENVIRONMENTAL ENGINEERING
MASTER OF ENGINEERING PROGRAM, 1-143
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CAMBRIDGE, MASSACHUSETTS 02139 USA

MIT/US Virgin Islands Survey
2002-2003
Please return by DECEMBER 21, 2002

1) Please check the type of business: ______ Resort __X__ Condominium ______ Municipal ______ Other (describe)______________________________

2) If you own/operate a Condominium please list the number of units: 135 Studio 90 1Bedroom ______ 2 Bedrooms ______ 3 Bedrooms ______ Other
Please list the number of permanent or temporary residences: 70 Permanent 145 Temporary (for visitors) Estimated

4) If you own/operate a Resort please list the number of rooms: ______

5) Please list average occupancy of resort during ______ Off-Peak ______ Peak

6) Peak season starts on ______ and ends on ______ (Fill in dates)

7) On average, how many gallons of water are used per day? Peak: 8,000 Gallons/Day Non-peak: 5,000 Gallons/Day

8) At what time of day is water at peak use: __X__ 6-8 am ______ 8-10 am ______ 10 am – 12 pm ______ 12-4 pm ______ 4-7 pm ______ 7-11 pm ______ 12-5 am

9) Does the Resort/Condominium operate a desalination plant? __X__ Y ______ N

10) From where does the facility obtain its drinking water? __X__ Desalination ______ Ground water ______ Cistern ______ Public Water Supply ______ Other (describe)______________________________

11) Does the Resort/Condominium operate a wastewater treatment plant? __X__ Y ______ N
If yes, is this facility permitted? ______ Y __X__ N If yes, please give permit number ______________

12) Please list wastewater treatment processes used (check as many as apply):
______ Aerated Lagoon ______ Oxidation Ditch ______ Trickling Filters ______ Contact Stabilization
__X__ Extended Aeration __X__ Activated Sludge ______ Sequencing Batch Reactor
______ Rotary Drum ______ Other (describe)______________________________

13) What level of treatment is provided: __X__ Primary __X__ Secondary ______ Tertiary
If tertiary, please list: ______ % BOD Removal ______ % TSS Removal
______ % Nitrate Removal ______ % Phosphorus Removal

14) Is disinfection of effluent is provided? __X__ Y ______ N If Yes, please list technology: tablets - automatic 2-4 ppm free chlorine
__X__ Chlorine ______ Ozone ______ Ultraviolet Radiation ______ Other

15) How is effluent (treated wastewater) handled?
______ Discharge to ponds/stream. If yes, please list size ______ gallons
__X__ Stored in holding tank(s) If yes, please list size 27,000 gallons
______ Other (describe)______________________________ If yes, please list size ______ gallons

16) Is effluent currently being reused? __X__ Y ______ N If yes, please list nature: __X__ Irrigation ______ Toilet flushing ______ Other (describe) ______________________________

17) If effluent is reused, please list number of gallons per day for each activity: 8,000 Irrigation
______ Toilet flushing ______ Other

18) Is salt water currently being used for toilet flushing? ______ Y __X__ N

19) Do you have any other reuse strategies not covered in this letter? If yes, please explain NO ______________________________

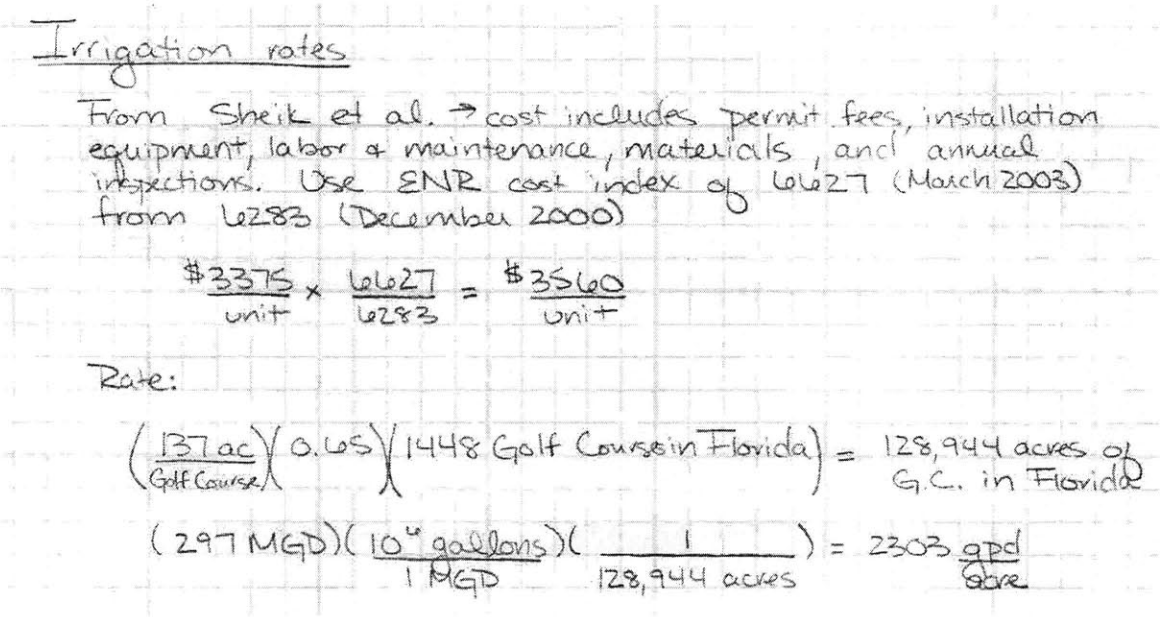
20) Does your business participate in a water conservation program? If yes, please explain NO ______________________________

21) If effluent is currently not being reused, would you be interested in hearing of opportunities to do so? __X__ Y ______ N

22) Would you be willing to meet with an MIT student to talk about your treatment process and reuse and conservation practices? __X__ Y ______ N If yes, please supply contact name, phone number and address Randy Bausteel
6700 Sapphire Vlg. St. Thomas VI 00802 340-775-6123
38 left by pool 8:30-4:30

Thank you for taking the time to complete this survey. Should you have questions regarding this survey, please contact Heather Cheslek at hcheslek@mit.edu or 617-571-7072. 1/10/03 Friday:

Appendix B: Alternatives Demand and Cost Calculations



St. Thomas Conservation & Wetlands

Q_{ave}:

$269{,}000\ gpd \times \frac{1\ d}{(24 \cdot 60)} \times \frac{3.451\ m^3/d}{gpm} = 1018.3\ \frac{m^3}{d}$

Q_{max}: $\frac{1.25}{0.75} = 1.67 \Rightarrow 1018.3 \times 1.67 = 1700.6\ \frac{m^3}{d}$

↑ current Q_{ave} & Q_{max}

BOD:

Q_{ave}: $A_w = (1018.3\ \frac{m^3}{d})(1000\ \frac{L}{m^3})(10\ \frac{mg}{L}) / (40\ \frac{kg}{ha \cdot d})(10^6\ \frac{mg}{kg})$

$A_w = 2401 = 0.24\ ha = 0.6\ ac$

Q_{max}: $A_w = (1700.3\ \frac{m^3}{d})(1000\ \frac{L}{m^3})(10\ \frac{mg}{L}) / (40\ \frac{kg}{ha \cdot d})(10^6\ \frac{mg}{kg})$

$A_w = 4009 = 0.43\ ha = 1.05\ ac$

TSS:

Q_{ave}: $A_w = (1018.3\ \frac{m^3}{d})(1000\ \frac{L}{m^3})(10\ \frac{mg}{L}) / (30\ \frac{kg}{ha \cdot d})(10^6\ \frac{mg}{kg})$

$A_w = 3202 = 0.34 = 0.83\ ac$

Q_{max}: $A_w = (1700.3\ \frac{m^3}{d})(1000\ \frac{L}{m^3})(10\ \frac{mg}{L}) / (30\ \frac{kg}{ha \cdot d})(10^6\ \frac{mg}{kg})$

$A_w = 5347 = 0.57 =$ **1.4 ac** ← Limiting Condition

Accounting for buffers & setbacks → $(1.25)(1.4\ ac) =$ **1.75 ac**

Cost is $59,650/acre ⇒ **$104,400**

Non-Construction + Contingency ⇒ **$26,100**

Cost for Conservation Kits ⇒ **$144,000**

St. Thomas Wetlands

Q_{ave}: $750{,}000\ gpd \times \frac{1\ day}{(24 \cdot 60)\ min} \times \frac{5.451\ m^3/d}{gpm} = 2839\ \frac{m^3}{d}$

Q_{max}: $1{,}256{,}000\ gpd \times \frac{1\ day}{(24 \cdot 60)\ min} \times \frac{5.451\ m^3/d}{gpm} = 4732\ \frac{m^3}{d}$

BOD:

Q_{ave}: $A_w = (2839\ \frac{m^3}{d})(1000\ \frac{L}{m^3})(10\ \frac{mg}{L})\ /\ (40\ \frac{kg}{ha \cdot d})(10^6\ \frac{mg}{kg})$

$A_w = 66960 = 0.72\ ha = 1.8\ ac$

Q_{max}: $A_w = (4732\ \frac{m^3}{d})(1000\ \frac{L}{m^3})(10\ \frac{mg}{L})\ /\ (40\ \frac{kg}{ha \cdot d})(10^6\ \frac{mg}{kg})$

$A_w = 11{,}160 = 1.2\ ha = 3\ ac$

TSS:

Q_{ave}: $A_w = (2839\ \frac{m^3}{d})(1000\ \frac{L}{m^3})(10\ \frac{mg}{L})\ /\ (30\ \frac{kg}{ha \cdot d})(10^6\ \frac{mg}{kg})$

$A_w = 0.96\ ha = 2.4\ ac$

Q_{max}: $A_w = (4732\ \frac{m^3}{d})(1000\ \frac{L}{m^3})(10\ \frac{mg}{L})\ /\ (30\ \frac{kg}{ha \cdot d})(10^6\ \frac{mg}{kg})$

$A_w = 1.6\ ha = 4\ ac$ ← Limiting Condition

Accounting for Buffers & Setbacks → $(1.25)(4\ ac) =$ **5 ac**

Cost is $59,650/acre ⇒ **$298,000**

Non-construction & Contingency ⇒ **$75,000**

St. Croix Commercial Irrigation

From maps from York, 2003, assume 1/10 of 1200 acres needs irrigation.
→ recreational areas plus around commercial & industrial buildings

→ 120 acres ⇒ 276,360 gpd for irrigation

Peaking factor of 3 → design must be for 829,080 gpd to account for when irrigation occurs.

1.28 ft^3/s → corresponds to 10-inch diameter pipe from nomogram (assuming $V = 3$ ft/s)

Piping Needs: 2000 ft to get to plant site

$\frac{\$23.00}{ft} \times 2000\ ft = \$46{,}000$ for pipe

St. Croix Airport Irrigation

From topographic maps, assumed 1/8 of airport land required irrigation.
→ 7.5 acres ⇒ 17,273 gpd for irrigation

From nomogram, need 6-inch pipe

Piping Needs: 4600 ft x \$14.35 ≅ \$66,000

St. Thomas Irrigation

From USGS Quad maps, found 260 housing units requiring irrigation and 17,000 ft of pipe.

→ 86.1 acres ⇒ 198,550 gpd for irrigation

From nomogram, need 6-inch pipe to convey water.

$$d_c = d_{100}\left(\frac{100}{C}\right)^{0.38} \Rightarrow d_c = (6)\left(\frac{100}{150}\right)^{0.38} \Rightarrow d_c = 5.14\ in$$

Piping Needs: $17{,}000\ ft \times \frac{\$14.35}{ft} \cong \$244{,}000$

St. Croix Conservation & Wetlands

Q_{max}: $3{,}590{,}000\ gpd \times \frac{1\ d}{(24 \cdot 60)} \times \frac{5.451\ m^3/d}{gpm} = 13{,}589.6\ \frac{m^3}{d}$

Q_{ave}: $2{,}340{,}000\ gpd \times \frac{1\ d}{(24 \cdot 60)} \times \frac{5.451\ m^3/d}{gpm} = 8857.9\ \frac{m^3}{d}$

BOD:

Q_{ave}: $A_W = (8857.9\ \frac{m^3}{d})(1000\ \frac{L}{m^3})(63\ \frac{mg}{L}) / (40\ \frac{kg}{ha \cdot d})(10^6\ \frac{mg}{kg})$

$A_W = 131{,}615 = 14.1\ ha = 34.1\ ac$

Q_{max}: $A_W = (13{,}589.6\ \frac{m^3}{d})(1000\ \frac{L}{m^3})(63\ \frac{mg}{L}) / (40\ \frac{kg}{ha \cdot d})(10^6\ \frac{mg}{kg})$

$A_W = 201{,}921 = 21.6\ ha = 52.4\ ac$

↑ Limiting Condition

TSS:

Q_{ave}: $A_W = (8857.9\ \frac{m^3}{d})(1000\ \frac{L}{m^3})(32\ \frac{mg}{L}) / (30\ \frac{kg}{ha \cdot d})(10^6\ \frac{mg}{kg})$

$A_W = 89{,}136 = 9.56\ ha = 23.1\ ac$

Q_{max}: $A_W = (13{,}589.6\ \frac{m^3}{d})(1000\ \frac{L}{m^3})(32\ \frac{mg}{L}) / (30\ \frac{kg}{ha \cdot d})(10^6\ \frac{mg}{kg})$

$A_W = 136{,}750.7 = 14.7\ ha = 35.5\ ac$

Accounting for buffers & setbacks → $(1.25)(52.4ac) = \boxed{65.5ac}$

Cost is $59,650/acre ⇒ $\boxed{\$3{,}907{,}000}$

Non-Construction & Contingency ⇒ $\boxed{\$977{,}000}$

Operation & Maintenance ⇒ $\boxed{\$274{,}000}$

Cost for Conservation Kits ⇒ $\boxed{\$143{,}000}$

St. Croix Wetlands

Q_{ave}: $2{,}750{,}000\ gpd \times \frac{1\ day}{(24.66)\ min} \times \frac{5.451\ m^3/d}{gpm} = 10{,}410\ m^3/d$

Q_{max}: $4{,}000{,}000\ gpd \times \frac{1\ day}{(24.66)\ min} \times \frac{5.451\ m^3/d}{gpm} = 15{,}142\ m^3/d$

BOD:

Q_{ave}: $A_W = (10{,}410\ \frac{m^3}{d})(1000\ \frac{L}{m^3})(63\ \frac{mg}{L})/(40\ \frac{kg}{ha \cdot d})(10^6\ \frac{mg}{kg})$

$A_W = 154{,}677 = 16.6\ ha = 40\ ac$

Q_{max}: $A_W = (15{,}142\ \frac{m^3}{d})(1000\ \frac{L}{m^3})(63\ \frac{mg}{L})/(40\ \frac{kg}{ha \cdot d})(10^6\ \frac{mg}{kg})$

$A_W = 224{,}987 = 24.2\ ha = 58.6\ ac$ ← Limiting Condition

TSS:

Q_{ave}: $A_W = (10{,}410\ \frac{m^3}{d})(1000\ \frac{L}{m^3})(32\ \frac{mg}{L})/(30\ \frac{kg}{ha \cdot d})(10^6\ \frac{mg}{kg})$

$A_W = 11.3\ ha = 27\ ac$

Q_{max}: $A_W = (15{,}142\ \frac{m^3}{d})(1000\ \frac{L}{m^3})(32\ \frac{mg}{L})/(30\ \frac{kg}{ha \cdot d})(10^6\ \frac{mg}{kg})$

$A_W = 16.4\ ha = 40\ ac$

Accounting for Buffers & Setbacks → $(1.25)(58.6\ ac) = \boxed{71\ ac}$

Cost is \$59,650/acre ⇒ **\$4,235,000**

Non-construction & Contingency ⇒ **\$1,059,000**