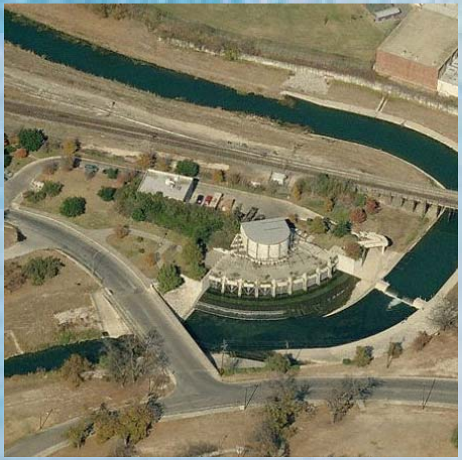
Upper San Antonio River Watershed Protection Plan

San Antonio River Authority
Bexar Regional Watershed Management Partnership
Texas Commission on Environmental Quality



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UPPER SAN ANTONIO RIVER WATERSHED PROTECTION PLAN

Prepared For:

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100 East Guenther Street
San Antonio, Texas 78204

and

Bexar Regional Watershed Management Partnership

Prepared in Cooperation With:

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LIST OF ABREVIATIONS

BASINS	Better Assessment Science Integrating Point and Nonpoint Sources
BMP	best management practice
BOD	biological oxygen demand
BRWM	Bexar Regional Watershed Management partners
BST	bacterial source tracking
cfs	cubic feet per second
C-7	Committee of Seven
COSA	City of San Antonio
DEM	digital elevation model
E. coli	*Escherichia coli*
EARZ	Edwards Aquifer Recharge Zone
EPA	United States Environmental Protection Agency
FC	fecal coliform
FWS	free water surface
GIS	geographic information system
gpm	gallons per minute
GSRD	gross solids removal devices

HEC-HMS	Hydraulic Engineering Center’s Hydrologic Modeling System
HSPF	Hydrologic Simulation Program – Fortran
I&I	infiltration and inflow
JMA	James Miertschin and Associates, Inc.
LU	land use
MGD	million gallons per day
MS4	municipal separate storm sewer system
NPS	nonpoint sources
NRCS	Natural Resources Conservation Service
org/100mL	bacteria count per 100 milliliters of water
OWS	Oil water separator
PRD	Parks and Recreation Department
QAPP	Quality Assurance Project Plan
SARA	San Antonio River Authority
SAROC	San Antonio River Oversight Committee
SAWS	San Antonio Water System
SCS	Soil Conservation Service
SSO	sanitary sewer overflows
TCEQ	Texas Commission on Environmental Quality
TMDL	total maximum daily load
TNRCC	Texas Natural Resource Conservation Commission
TSS	total suspended solids
TSSWCB	Texas State Soil and Water Conservation Board
TxDOT	Texas Department of Transportation
USAR	Upper San Antonio River
USGS	United States Geological Survey
UV	ultraviolet
UVT	ultraviolet transmission
VSB	Vegetated Submerged Bed
WERF	Water Environment Research Foundation
WIAC	Watershed Improvement Advisory Committee
WPP	Watershed Protection Plan
WQI	water quality inlets

I. WPP SUMMARY

1.0 INTRODUCTION

1.1 WATERSHED PROTECTION PLAN CONCEPT

A Watershed Protection Plan (WPP) is a study of pollutant sources and a plan of action consisting of control measures to control those sources. A WPP is voluntary in that it is not required by any applicable rules or regulations, in contrast to Total Maximum Daily Load (TMDL) studies which are mandated by the US Environmental Protection Agency (EPA). The WPP is meant to follow the TMDL and serve as a template for control measures that may be incorporated in the subsequent TMDL Implementation Plan. A benefit of the WPP is that it is a stakeholder-driven process. Stakeholders are local entities and individuals who provide input during development of the WPP. Therefore, the WPP is an opportunity for local control and direction to guide the Implementation Plan that will ultimately be approved by the Texas Commission on Environmental Quality (TCEQ).

This WPP presents a voluntary strategy for reducing bacteria levels in the Upper San Antonio River above Loop 410 South. A TMDL, currently in draft form, for the Upper San Antonio River, has set “allocations” for the allowable discharges of bacteria to the river. Adoption of the TMDL by the TCEQ represents an update to the state’s Water Quality Management Plan and will thus serve as the basis for permitting decisions in the watershed. In this way, the TMDL may lead to modifications to wastewater and storm water permits issued by the TCEQ, which may or may not be addressed in the WPP. The TMDL Implementation Plan may incorporate some or all of the action items of the WPP; but it will not be limited or postponed by the WPP. It is hoped that the implementation of the WPP will begin to reduce the amount of bacteria entering the river before the Implementation Plan is initiated.

1.2 PROJECT DEVELOPMENT

The WPP was prepared in response to a bacteria TMDL study for the Upper San Antonio River, Segment 1911, that is currently in draft phase at the TCEQ. In work completed to date in conjunction with the TMDL, it was confirmed that bacteria levels in the Upper San Antonio River regularly exceed state standards, and that significant load reductions are required in order for bacteria levels in the river to be reduced to levels considered acceptable for primary contact recreation.

The urban environment surrounding the Upper San Antonio River has many potential sources of bacteria. The ultimate source of these bacteria is fecal matter originating from warm blooded animals (wildlife, pets, livestock, and humans). Bacteria from these sources can reach the San Antonio River through numerous potential pathways, including:

1. Direct deposition into a waterbody (i.e. ducks)
2. Deposition onto the land surface which is available for subsequent washoff (i.e. dogs)

3. Leaking wastewater infrastructure (human)
4. Improperly treated municipal discharges (human)

The WPP addresses all potential sources in terms of their magnitude and in terms of available management measures - often referred to as best management practices (BMPs).

The characteristics and efficiencies of different BMPs vary considerably. Therefore, the costs, bacteria removal rates, and reliability of these systems have been evaluated, and recommendations have been made as to which BMPs will be most applicable for different types of sites and sources. With all of this information available, the effects of BMPs on the bacteria concentration in the Upper San Antonio River were simulated by using the same computer model that was used to develop the original TMDL. This report presents the results of this assessment by prioritizing and developing a proposed schedule for BMP deployment.

This report is conceptual with respect to the exact locations and sizes of structural stormwater BMPs. The report presents the level of treatment that will be required within the study area for various source types, and approximates the required cost assuming that the recommended types of BMPs are chosen for implementation. Additional planning and stakeholder input from local communities will be required before exact BMP locations can be selected and implemented. For non-stormwater point sources (San Antonio Zoo), conceptual design has been performed in order to determine the feasibility and costs associated with various treatment options.

Watershed management is an iterative process, and pollutant removal goals may not always be attained in the first or second round of BMP deployment (EPA, 2005). Therefore, monitoring will continue to be required to assess the health of the watershed and to determine the effectiveness of the various BMPs.

1.3 PROJECT BACKGROUND

1.3.1 Upper San Antonio River Basin

The study area for the WPP consists of the watershed of the Upper San Antonio River (TCEQ Segment #1911) upstream of Loop 410 South. The river basin encompasses all of San Antonio's downtown area and much of the central and eastern portions of the City. The total drainage area of the study is about 125 square miles (80,000 acres). The river's watershed and major tributaries are shown in Figure 1-1.

The San Antonio River essentially begins under another name – Olmos Creek, which has its headwaters just north of Loop 1604. Just south of Olmos Dam, the San Antonio Springs discharge at rates of 0 to 100 cfs, depending upon the level of the Edwards Aquifer. At this point, the creek becomes known as the San Antonio River. From here, the river flows through downtown San Antonio and the River Walk. South of downtown, the river is joined by San Pedro Creek and its tributaries. These tributaries have a drainage area of 45 square miles (29,000 acres), and represent a significant portion of the overall watershed. San Pedro Creek is fed by the San Pedro Springs which discharge at rates from 0 to 17 cfs, depending upon the level of the Edwards Aquifer.

Below the confluence with San Pedro Creek, the topography becomes relatively flat. Drainage in the southeast portion of the study area is defined primarily by a series of storm sewers and channels. Six-Mile Creek (also known as Piedras Creek) is the only major tributary, and it is highly channelized. Above the confluence with 6-Mile Creek, the 330 foot long New Espada Dam impounds Davis Lake. From Olmos Dam to Loop 410, the San Antonio River travels about 14.4 miles.

The San Antonio River has been modified to suit the needs of the urban environment. Several sections of the river have been straightened and lined with concrete or rock. Numerous small dams and gates control the flow of the river at various locations. Perhaps the most significant enhancement is the San Antonio River tunnel, which is a three mile long, 24-foot diameter conveyance structure that allows storm flows to bypass downtown. There is also a smaller tunnel that provides stormwater relief for San Pedro Creek. Many of these features are shown in Figure 1-2, which highlights the highly urbanized downtown portion of the river.

Springs and rainfall runoff are not the only major sources of flow in the San Antonio River. The San Antonio Water System (SAWS) has the ability to discharge reclaimed water (treated wastewater) into the river at various locations, as shown on Figure 1-2. These discharges are useful for keeping a minimum base flow moving through the river at all times. Therefore, these discharges are typically only active when natural stream flows are minimal (i.e. when San Antonio Springs are not discharging due to low aquifer level).

The river also receives regular flow from the San Antonio Zoo. This flow is pumped from the Edwards Aquifer at a relatively constant rate (averaging 3.8 cfs, 1700 gpm), and flows through a number of Zoo exhibits before discharging through an open channel to the San Antonio River. This flow will be discussed in further detail in Section 5.0.

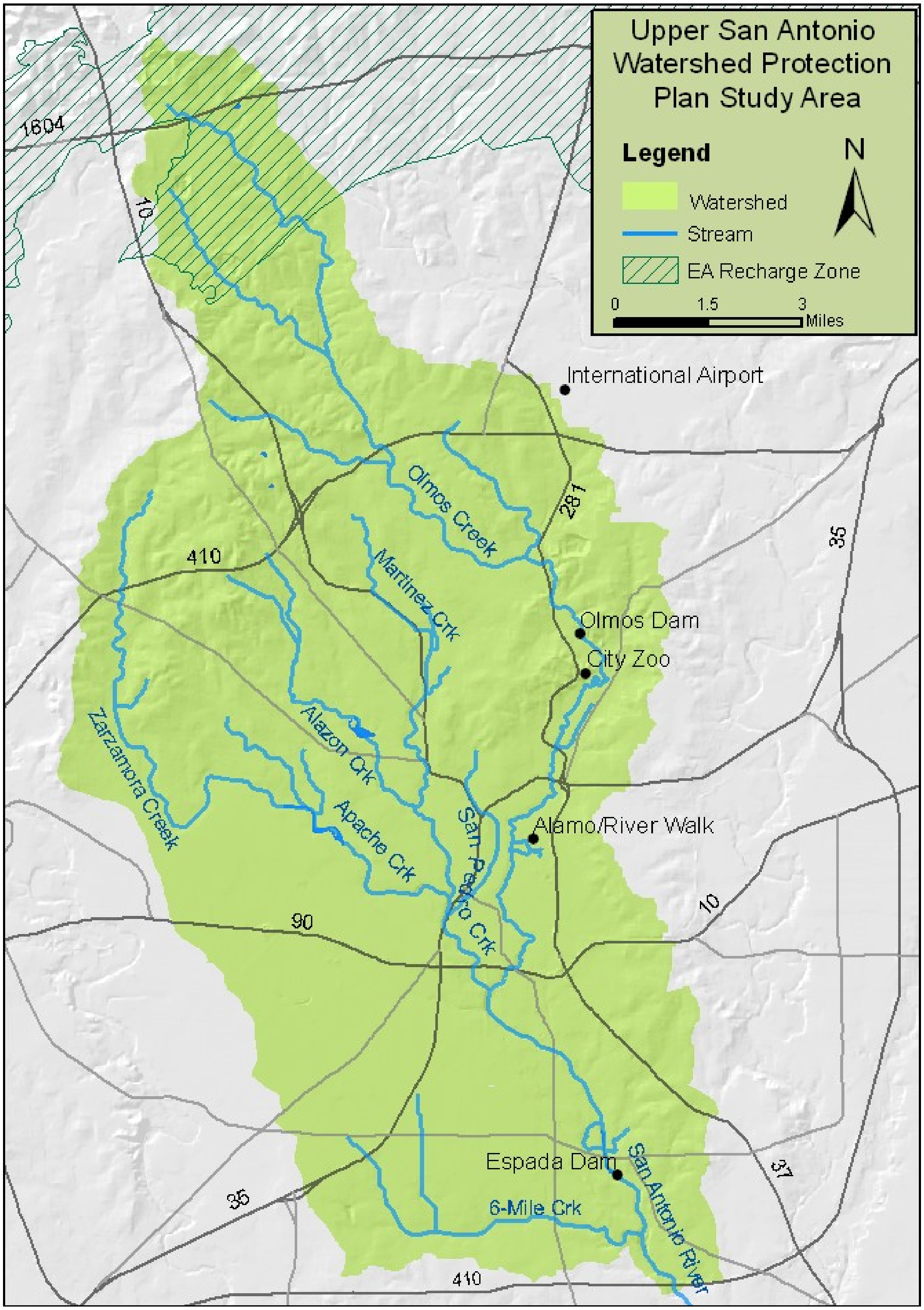


Figure 1-1: Upper San Antonio River Watershed and Tributaries

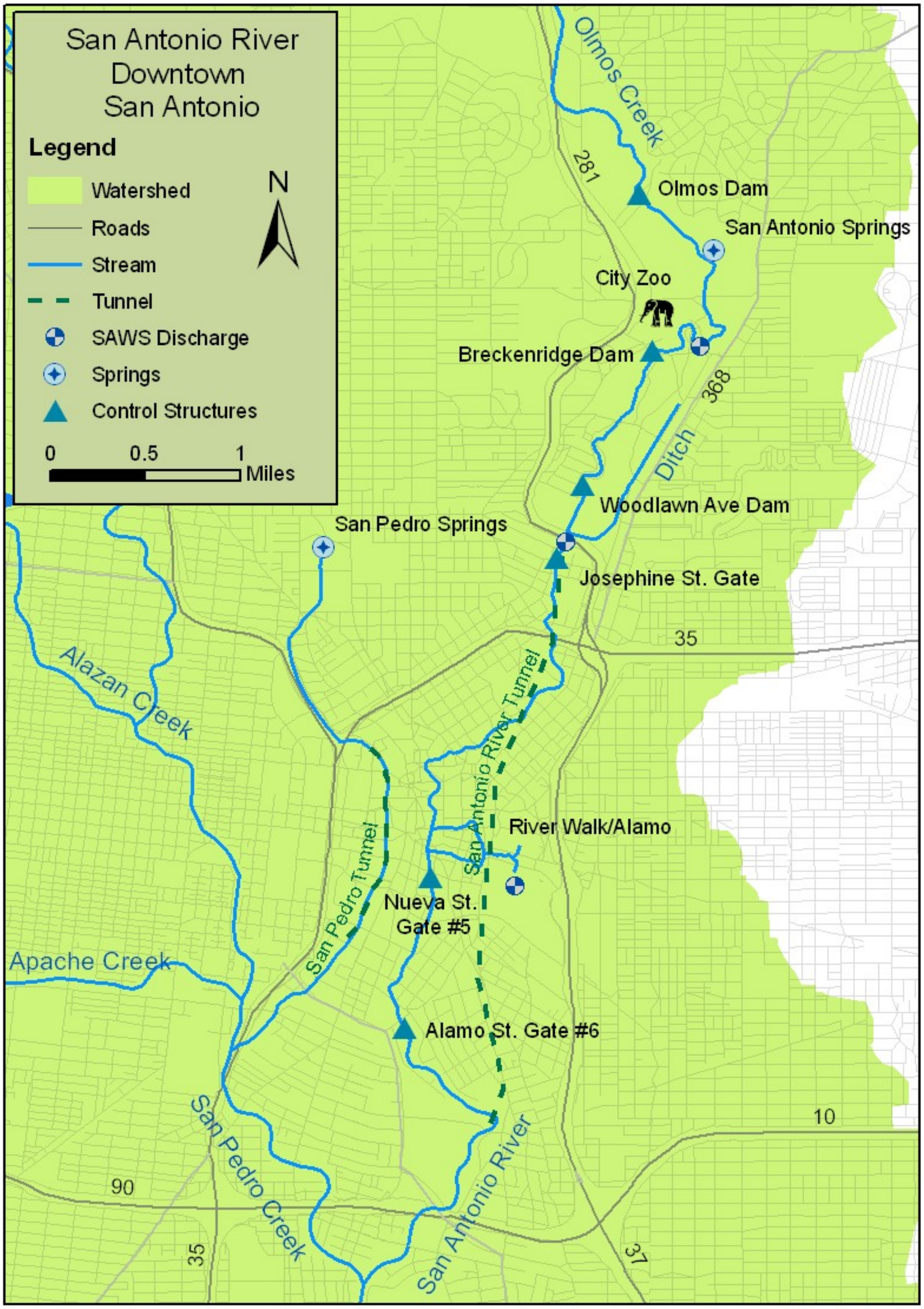


Figure 1-2: Upper San Antonio River in Downtown San Antonio

1.3.2 Water Quality Criteria for Bacteria

According to Texas water quality standards for contact recreation waters developed by the TCEQ, the geometric mean of samples should not exceed 126 org/100ml *E. coli*, or 200 org/100ml fecal coliform. In addition, grab samples should not exceed 394 org/100ml *E. coli* or 400 org/100ml fecal coliform. However, according to TCEQ guidance documents, if less than 25% of samples exceed the grab sample criterion, then the water body is not typically classified as impaired (unless the geometric mean criterion is exceeded).

It is standard convention to report bacteria levels in terms of a bacterial count per 100 milliliters. The bacterial count is often referred to in a number of different ways, including the number of organisms (org/100mL), or the number of colonies (col/100mL), or the number of colony forming units (CFU/100mL). In reality, these different nomenclatures all represent the same thing, which is the number of colony-forming bacteria identified during a laboratory test. This report will use "org/100mL" as the standard nomenclature.

1.3.3 Assessment of Bacteria Impairment

Section 303(d) of the Federal Clean Water Act and the U.S. Environmental Protection Agency (EPA) Regulation 40 CFR 130.7 require states to identify waterbodies that do not meet, or are not expected to meet applicable water quality standards. This compilation of subject waterbodies is known as the 303(d) List. Each state must assign priorities to waterbodies on the list in order to schedule development of TMDLs. The TMDL is an allocation of point and nonpoint source pollutant loadings that will enable the waterbody to meet water quality standards.

As a result, in 2000, the Upper San Antonio River (Segment 1911) was added to the state's 303(d) List due to nonsupport of contact recreation resulting from elevated levels of bacterial indicators for pathogens. Freshwater bacterial indicators for pathogens include fecal coliform and *Escherichia coli* (*E. coli*). *E. coli* has recently become the preferred indicator for estimating the level of pathogens, but fecal coliform can be used as an alternate indicator while additional data on *E. coli* are being collected. (Fecal coliform was selected as the key modeling parameter in work associated with the TMDL and WPP, but final TMDL allocations are assessed with respect to *E. coli*. Fecal coliform measurements were converted to *E. coli* using a ratio of 0.63 *E. coli* per fecal coliform.) These coliform bacteria are associated with the fecal matter of all warm-blooded animals.

1.4 REVIEW OF TMDL RESULTS

The TCEQ has nearly completed the TMDL development for the Upper San Antonio River. This work has included data collection, analysis, supplemental sampling, mathematical modeling of water quality, load allocations, and report preparation (JMA, 2006).

1.4.1 Source Identification

As part of this project, a number of bacterial sources were identified. These sources fall into two primary categories – point and nonpoint. Point sources are inputs of bacteria that can be attributed to a specific facility or a specific geographic location. Nonpoint sources include diffuse bacteria inputs that have the potential to occur over a large geographic area.

The TMDL identified several existing point and nonpoint sources for indicator bacteria. Point sources are typically regulated by a discharge permit, but this is not always the case. There are three permitted municipal effluent (SAWS reclaimed water) outfalls located in the WPP study area. However, these point sources utilize disinfection to ensure that bacteria concentrations consistently meet state criteria. Other permitted discharges, such as industrial outfalls, may also exist in the study area, but are not considered potential sources because of the low likelihood of containing pathogens. One significant non-permitted point source was identified as the San Antonio Zoo. As documented in Section 3.0, the Zoo has been identified as a significant contributor of indicator bacteria.

Stormwater runoff, which conveys bacteria from the land surface to the receiving stream, is a major source of bacterial loading in the San Antonio River. Traditionally, stormwater runoff has been considered a nonpoint source. However, as a result of new EPA guidelines, when stormwater is regulated by a municipal separate storm sewer system (MS4) permit, the stormwater is considered a point source. As a major municipality, San Antonio is required to have an MS4 permit, and thus all runoff-related bacteria loads in the study area are considered to be point sources. The reclassification of stormwater as a point source can result in some difficulty when explaining the ultimate source of the bacteria. For example, if a duck deposits fecal material directly into a stream it is considered a nonpoint source, but if the same duck deposits fecal material on the land surface (which is then available for rainfall washoff), it is considered a point source.

Nonpoint sources in the San Antonio River watershed include distributed sources not associated with rainfall runoff (direct nonpoint sources). Direct nonpoint sources are those sources that have the potential to enter the river system at all times, regardless of climatic conditions. Potential direct sources for indicator bacteria include sources such as wastewater infrastructure, direct animal defecation, and septic systems.

1.4.2 Linkage Between Sources and Receiving Waters

Establishing a link between in-stream water quality and the pollutant sources is a critical component of the TMDL process. This relationship allows for the evaluation of management options that will achieve the desired water quality goals. A variety of techniques are available for creating this link, ranging from qualitative assumptions based on scientific principles to sophisticated mathematical modeling. In the development of the TMDL for the Upper San Antonio River, the relationships were defined through a computer simulation model. Monitored flow and water quality data were used to calibrate the relationships used in this model. Water quality data and model development are discussed in further detail in Sections 3.0 and 4.0, respectively.

The bacterial loads associated with the model calibration can be readily examined in terms of load originating from the land use categories and point sources embodied in the analysis. The simulated loads for the WPP study area are compared graphically in Figure 1-3. The loads presented are the total annual average loads that enter the impaired stream under existing conditions. The loads do not account for decay that occurs as the bacteria travel downstream.

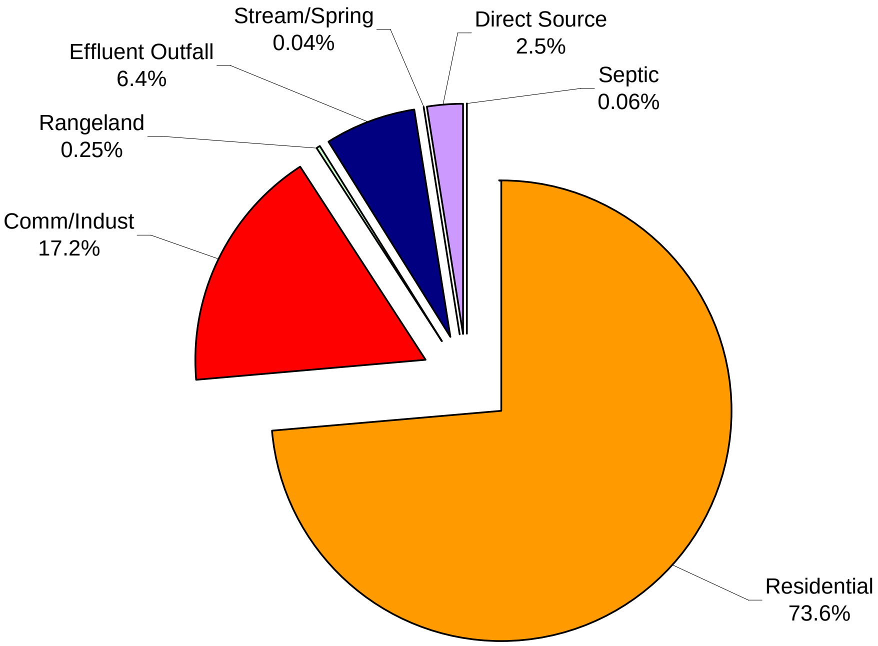


Figure 1-3: Bacteria Sources in the WPP Study Area

Loads from residential, commercial/industrial, and rangeland sources are the result of washoff during rainfall events. The remaining four source categories discharge continuously, independent of climatic conditions. Although the loads from these latter four categories appear relatively small, they have a disproportionately large effect on water quality in the river, because they are active when there is less flow available for dilution.

For the study reach, it is apparent that the largest presumed source of fecal coliform bacteria is washoff from residential areas. This is attributable to the fact that residential is the largest land use category in terms of acreage, and it is the recipient of bacterial deposition from pets and wildlife. The next largest contribution is estimated to be commercial/industrial, which also receives deposition from pets and wildlife, but at a presumably lower rate. The third largest source is shown to be effluent outfalls, and this source category is dominated by loads from the San Antonio Zoo.

1.4.3 Required Load Reductions

The TMDL modeling exercise led to the development of bacterial load allocations for the Upper San Antonio River. Allocations were determined based on the reductions in existing loads (Figure 1-3) required to bring the river into compliance with state criteria for bacteria. Table 1-1 summarizes the existing loads, required reductions, and loading allocations for bacteria sources within the WPP study area.

Table 1-1: Required Loading Reductions (10^9 org/year *E. coli*)

Source Type	Existing Load	Reduction	TMDL Allocation
Point Sources:			
Storm water (MS4 Permit)	5,549,146	30%	3,884,402
SAWS Reclaimed Effluent Outfalls	44	0%	44
San Antonio Zoo	391,860	99.9%	392
Point Source Subtotal	5,941,050		3,884,838
Nonpoint Sources			
Springs	2,453	0%	2,453
Septic Systems	3,381	0%	3,381
Other Direct Sources	151,080	50%	75,540
Nonpoint Source Subtotal	156,914		81,374
Total	6,097,965		3,966,212

It should be noted that the reductions shown in Table 1-1 are not the only combination of reductions that could be used to achieve compliance with state criteria. A similar scenario, but with 70% direct source reduction and 0% storm water reduction, was also shown to achieve compliance within the WPP study area (JMA, 2006). The combination of reductions included in Table 1-1 was determined based on best professional judgment, considering what reductions are most likely to be feasible and effective. Based on this fact, and the uncertainties inherent in the modeling process, it is possible that some other similar combination of loading reductions might also lead to compliance with water quality criteria. Ultimately, future in-stream bacteria monitoring will be the test of success for the WPP.

1.5 STAKEHOLDER INVOLVMENT

1.5.1 Stakeholder Groups, Roles, & Input

Stakeholders have played an important role in the development of the Upper San Antonio River Watershed Protection Plan (WPP) and include a range of people, from technical staff at water agencies to businesspeople to ordinary citizens. Collectively, their ideas, guidance and feedback are resulting in a workable plan that will benefit the San Antonio River and everyone concerned about its health. The stakeholder groups, their roles, and input are:

- *Stakeholder:* **Bexar Regional Watershed Management (BRWM) partners** – Group includes representatives from the San Antonio River Authority (SARA), City of San Antonio (COSA), Bexar County and suburban cities within Bexar County. The members came together in 2003 under an inter-local agreement to address flooding and water quality issues in a unified, regional approach.
  Role: This was the overall group responsible for organizing and executing the WPP.
  Input: Provided guidance and resources for the WPP, including watershed management and water quality expertise.

- *Stakeholder:* **BRWM Water Quality Focus Group** – This sub-group of BRWM is composed of water quality, storm water infrastructure and public works experts from the major water agencies in the study area, including input from the Edwards Aquifer Authority and San Antonio Water System.
  Role: Served as primary leaders, represented all the "major players" and had the most influence on the development of the WPP.
  Input: Provided direction during regular meetings; determined what projects could be done and what was already being done affecting water quality; conveyed suggestions to other stakeholder groups regarding WPP development.

- *Stakeholder:* **San Antonio River Oversight Committee (SAROC)** – A 22-person citizen committee that was appointed in 1998 to guide the planning and implementation of the San Antonio River Improvements Project (SARIP). The multi-million dollar SARIP is designed to restore and rejuvenate 13 miles of the River, including areas within the WPP.
  Role: Oversight of activities that occur in the SARIP area.
  Input: Most questions regarding the WPP came from this group. The SAROC provided no specific direction, but were agreeable to suggestions from the WPP partners.

- *Stakeholder:* **Watershed Improvement Advisory Committee (WIAC)** – This 15-member citizen participation group is one of three bodies that guide the BRWM program. Members are appointed so that each watershed in Bexar County is represented.
  Role: BRWM oversight; WPP guidance.
  Input: Like the SAROC, the WIAC was kept informed of the progress of the WPP during their regular meetings. They offered general questions and were agreeable to suggestions from the WPP partners.

- *Stakeholder:* **Committee of Seven (C-7)** – Another body that oversees the BRWM program, the C-7 includes two representatives from the San Antonio City Council, two from the Bexar County Commissioners Court, two from the SARA Board of Directors and one elected official representing suburban cities.
  Role: BRWM oversight; WPP guidance.
  Input: The C-7 was kept informed of the progress of the WPP, offered general questions and was agreeable to suggestions from the WPP partners.

- *Stakeholder:* **BRWM Management Committee** – Third guiding body of BRWM; members include the City of San Antonio's Director of Public Works, Bexar County's Executive Director of Infrastructure Services, SARA's General Manager and one representative from participating suburban cities.
  Role: BRWM oversight; WPP guidance.
  Input: The Management Committee was kept informed of the progress of the WPP during their regular meetings. They offered general questions and were agreeable to suggestions from the WPP partners.

- *Stakeholder:* **San Antonio Zoo –** Identified as a contributor to the bacterial load in the Upper San Antonio River by the WPP.
  Role: WPP guidance.

Input: Provided data, asked questions, and were agreeable to the direction of the WPP.

- *Stakeholder:* **Citizens from the project area** – This included citizens in the Bexar County area who either 1) Previously expressed interest in water quality issues and were on SARA's existing mailing list database or 2) Learned of the WPP through public outreach efforts (see below). The group was diverse, with people of various ages, backgrounds and professions.
  Role: WPP guidance.
  Input: At public meetings, citizens expressed likes and dislikes about the plan, asked general questions and indicated potential "problem areas" on maps (see Public Meetings below).

- *Stakeholder:* **Various organizations and governmental agencies** – This group included interested parties such as the Mitchell Lake Wetlands Society, Texas Parks & Wildlife Dept., Texas Dept. of Transportation, engineering firms and public interest groups.
  Role: WPP guidance.
  Input: Attended WPP public meetings and asked general questions.

A list of the stakeholder meetings (by date) can be found in Appendix G.

1.5.2 Public Outreach

In order to elicit general participation and input for the WPP among stakeholder groups, various outreach methods were employed. These included:

- Web sites – Extensive information regarding the WPP has been posted on two web sites: www.sara-tx.org (San Antonio River Authority) and www.bexarwatershed.org (Bexar Regional Watershed Management). This information includes:

    a. Explanation of the project and its scope of work
    b. WPP Communication & Public Information Plan
    c. WPP Quality Assurance Project Plan
    d. WPP Draft Report
    e. Public meeting notices
    f. Public meeting agendas
    g. Presentations from each of the three public meetings (PowerPoint)
    h. Press releases

- Newsletter article – SARA published a front-page article about the WPP in the spring 2006 issue of their quarterly newsletter, *River Reach*. The article was informative and positive and included a text box announcing an upcoming WPP public meeting. The newsletter was mailed to 6,580 stakeholders on SARA's mailing list database. Recipients include government agencies, water agencies, businesses and citizens with an interest in water issues.
- Public meeting notices – WPP public meeting notices were posted 30 days prior to each public meeting at SARA's headquarters and at San Antonio City Hall.

- Press releases – Two press releases regarding the WPP were distributed to media outlets in Bexar County. Substantial media coverage was generated that, while acknowledging bacterial problems in the River, was generally favorable to the WPP:

    a. Two radio interviews (KZEP 104.5 FM)
    b. Three TV stories (KSAT, WOAI, KENS-5)
    c. Three newspaper articles (*San Antonio Express-News, San Antonio Current*)

Public Meetings

Three WPP public meetings were held over an eight month period. The meetings were used to inform the public about the WPP, solicit input, and allow the public to identify issues they believed were contributing to bacterial pollution in the River. Meetings were held in SARA's boardroom on November 29, 2005, March 29, 2006 and July 24, 2006. Approximately 30 to 50 stakeholders attended each of the meetings. Most of the input from citizens involved what they didn't want in the WPP. As an example, most people felt that some type of disinfection was needed to deal with the bacteria coming from the San Antonio Zoo. While most were not sure what method would be best, the majority were sure that they did not want chlorine disinfection.

During the first public meeting citizens indicated water quality "problem areas" in the WPP study area using large maps provided by the organizers. Between the first and second public meeting the WPP organizers visited all of the locations and discussed the findings at the second meeting.

At the end of each meeting, questionnaires were distributed in order to gage stakeholder knowledge on bacterial pollution and the WPP. Five to 10 questions were listed on each questionnaire, such as:

- "What do you think is the most common pollutant in the River, and what do you think is the source of the pollutant?"
- "Do you feel that local governments should spend more resources on projects that improve water quality?"
- "Since learning about the Watershed Protection Plan, how confident are you that bacteria levels can be reduced in the Upper San Antonio River?"

Examples of conclusions gathered from returned questionnaires are as follows:

- The response to the first questionnaire identified several pollutants (bacteria, trash, and metals/mercury) the public thought were commonly found in the River.
- All respondents indicated that, after attending the public meeting, they understood what a Watershed Protection Plan was.
- A majority of citizens attending the public meetings believe having a WPP is a good idea.

One of the most significant effects of the public meetings was successfully conveying to the audience that there is no one simple solution to dealing with nonpoint sources of pollution.

Other Outreach

At least two consultation meetings regarding the WPP were held between SARA staff (representing BRWM) and San Antonio Zoo officials. The fact-finding meetings were designed to keep the Zoo officials up to date on WPP development and collect information about ongoing efforts by the Zoo to reduce bacteria leaving their property.

Issues

Most issues related to the WPP were connected with news reports. One issue arose when two San Antonio newspapers published articles that identified the San Antonio Zoo as the major source of bacterial pollution in the Upper San Antonio River. Citizens at the first public meeting indicated that they thought this meant the Zoo was the only bacterial source that needed to be addressed. Another news report was seen to link the turbidity in the San Antonio River Loop to the high bacteria levels coming from the Zoo. Both news reports generated some misunderstandings about the cause and effects of the bacterial problems in the WPP project area. These issues were dealt with through the stakeholder process.

Results

Overall, feedback from stakeholders on the WPP was positive and helpful in guiding development of the plan. Input from the public meeting questionnaires indicates that citizens were knowledgeable, engaged and interested in improving water quality in the Upper San Antonio River. Also evident was support for continuance of the WPP and implementation of some of the Best Management Practices it identifies. Stakeholder and public input identified concerns and expectations as well as identifying areas where background information and clarification were needed to dispel misconceptions and misinformation.

Future Stakeholder Activities

Based on this initial experience, organizers believe that the stakeholder consultation and involvement process can be refined and improved as the WPP enters the implementation phase. A possibility is the involvement of a sole, ongoing steering committee through which suggestions are filtered and guidance is provided. The SAROC (see Stakeholder Groups above), for example, could serve as this key guiding group because it includes members from the business community, local governments and public interests. It is believed that feedback could be gathered more efficiently from an existing group knowledgeable in water quality issues (such as the SAROC) during regularly scheduled meetings than from public meetings, which can be time-consuming to organize, require a large educational component, and are subject to low turnout.

2.0 WPP KEY ELEMENTS

According to guidance provided by the US EPA, a watershed protection plan should include nine specific elements considered "critical for achieving improvements in water quality" (EPA, 2005). These elements are summarized below:

a) Identification of causes and sources of impairment, and their estimated loads
b) An estimate of the load reductions expected from management measures
c) A description of the management measures, and the areas where they will be implemented
d) Costs associated with the management measures, and potential funding sources
e) Education component for each management measure
f) Schedule of implementation for management measure
g) Measurable milestones of management measure implementation, other than water quality indicators (element h)
h) Water quality indicators to quantify effectiveness of management measure
i) Water quality monitoring component to evaluate criteria from element h

Sections 2.1 through 2.3 discusses the management measures (aka BMPs) recommended by the WPP. Section 2.4 summarizes all of the recommended BMPs in a tabular format, emphasizing the nine key elements presented above. Finally, Section 2.5 presents the proposed timetable for BMP deployment.

2.1 MANAGEMENT MEASURES FOR POINT SOURCES

2.1.1 San Antonio Zoo Point Source

The San Antonio Zoo, located in Brackenridge Park, has been identified as a major point source contributor of bacteria in the Upper San Antonio River. The bacteria originate from resident and nonresident animals, principally waterfowl and other birds, that are located along the internal waterway that traverses the Zoo. The internal waterway is fed by a well, withdrawing water from the Edwards Aquifer at a rate of approximately 1700 gpm. There exists one primary and one secondary outfall from the internal waterway to the Upper San Antonio River. Flows from the secondary outfall are generally negligible, except under rainfall runoff conditions.

According to the water quality model, disinfection (99.9% bacteria removal) of the Zoo's discharge will bring most of the Upper San Antonio River into compliance with the state criteria, except under periods of prolonged wet weather. Under periods (months) of prolonged wet weather, bacteria concentrations are heavily influenced by loads from urban runoff, and Zoo controls alone are not sufficient.

The most cost effective BMP for reducing bacteria loads to the Upper San Antonio River would be to disinfect the dry weather flow leaving the San Antonio Zoo. The discharge from the Zoo is the primary cause of impairment from Brackenridge Park through downtown San Antonio. Removal of the bacteria load from the Zoo could be most efficiently achieved through the utilization of disinfection treatment facilities. This report recommends an ultraviolet (UV) disinfection process be installed at the Zoo's primary outfall, although other, more expensive disinfection options are also available. The estimated cost to construct the UV facility is about $700,000. This and other treatment options are discussed in more detail in Section 5.0.

Once the base flow from the Zoo has been controlled, there should be an immediate observable improvement in water quality in the upper reach of the river. With disinfection, concentrations at the Zoo outfall should be reduced to less than 50 org/100mL. Concentrations downstream of the outfall should also decrease substantially. According to the water quality model, concentrations as far downstream as Loop 410 should drop substantially (geometric means drop by about half). However, due to all of the variability associated with bacteria sampling, this can only be validated through long-term sampling.

Treatment of runoff-related flows from the Zoo is not recommended. If treatment is to be required, at a later stage of TMDL implementation, storm flows from the Zoo's primary waterway would need to be diverted to a large structural BMP or mechanical treatment facilities. However, due to the scarcity of undeveloped land near the Zoo grounds, this could be problematic.

2.1.2 Stormwater Runoff Point Sources

Stormwater regulated under an MS4 permit is considered to be a point source by the EPA. There are two basic types of BMPs for stormwater sources: structural and nonstructural. Section 6.0 of this report provides detailed information for both of these BMP types. In general, nonstructural BMPs are relatively inexpensive, but their effectiveness is difficult to quantify. The objective of most nonstructural BMPs is to prevent the accumulation of fecal material at the land's surface so that it is not available for washoff during runoff events. Structural BMPs, such as wet ponds and sand filters, are typically much more expensive to implement, but provide relatively reliable reductions in stormwater sources. The objective of structural BMPs is to remove pollutants that accumulate in runoff before that runoff reaches the receiving streams. An estimated 30% reduction in stormwater runoff loads is required to bring the river into compliance.

Retrofitting a major portion of the City's stormwater drainage system with structural BMPs could result in tens of millions of dollars in capital improvement costs. Therefore, this report recommends that stormwater BMPs be implemented using a phased approach. This phased approach is also known as adaptive implementation.

First, nonstructural BMPs should be implemented, and their effectiveness should be determined based on long term water quality monitoring. If success is indicated, implementation of additional items may cease. If success is not realized, additional controls are mandated, until compliance with water quality standards for bacteria is achieved.

Next, one or two representative watershed sites should be selected and scheduled for structural BMP pilot projects. This report recommends as candidates the San Pedro Creek, Alazan Creek, and/or Apache Creek watersheds. This limited first-phase implementation would incorporate site selection, design, construction, and post-construction monitoring of different types of structural BMPs. After this stage, a more thorough cost/benefit analysis could be developed.

Finally, in the second phase, additional structural stormwater BMPs can be implemented basin-wide, as required, to achieve compliance with water quality criteria. While it is expected that the City of San Antonio will be the primary initiator of stormwater BMPs, surrounding entities in the study area such as SARA, Bexar County, Alamo Heights, Balcones Heights, Castle Hills, Ft. Sam Houston, Leon Valley, Olmos Park, and Terrel Hills should also review their stormwater and drainage programs.

The effectiveness of stormwater BMPs will be determined by future water quality monitoring. Immediate results can be determined for structural BMPs by monitoring bacteria levels in the BMP outfall. However, for the river as a whole, most stormwater source control efforts will not produce immediate results. Incremental load reductions may not be immediately noticeable in the river sampling, since the inherent variability in bacteria sampling may be greater than the effect of individual BMPs. However, as progress continues, long-term monitoring should indicate a gradual decrease in bacteria concentrations.

Nonstructural Stormwater BMPs

An estimated 5% reduction in stormwater runoff loads may be achievable through the implementation of nonstructural BMPs. Much of this reduction may be achieved through the management of pet waste. The City of San Antonio already maintains a "Pooper Scooper" program to encourage the removal of pet waste from the land surface. The expansion of this program, and the enforcement of pet control ordinances, may significantly reduce nonpoint source loading. In addition, public education can be used to educate pet owners on the need for proper pet waste management, both at home and in public parks.

Other nonstructural stormwater BMPs will address wild birds, which are believed to be a large source of the stormwater runoff load. However, the complete exclusion of wild birds is unrealistic and undesirable. Instead, limited actions can be taken at key locations to reduce the number of birds present. The City of San Antonio can institute a bird feeding ban at the River Walk and at public parks in riparian areas. This action would be well served by a public awareness program explaining the purpose of the ban. Other bird deterrent practices, such as a falconer program and the removal of bird nesting locations, may also be considered to achieve the desired load reductions. These BMPs will also reduce direct nonpoint source loads, because birds often deposit fecal material directly into the stream.

Structural Stormwater BMPs

The City of San Antonio already maintains a number of structural stormwater BMPs. Elmendorf Lake, for example, eliminates bacteria through natural decay and settling. The City is currently planning to desilt this lake, increasing its treatment capacity. In addition the City maintains over 70 miles of vegetated swales and strips along the San Antonio River and its tributaries. Although the strips and swales do not have a high potential for bacteria removal, the City is taking actions to prevent the future dumping of debris (including fecal material) into these vegetated areas.

Additional structural stormwater BMPs will likely be required to achieve the load reductions required by the TMDL. These BMPs may range from large regional wet basins to small drain inserts for storm sewers. However, it is expected that large basin type BMPs will be most reliable and effective. As discussed above, it is recommended that these BMPs be implemented in a phased approach. The first phase of BMP deployment, including pilot projects for different BMP types, should begin in 2009, after nonstructural stormwater BMPs and other source controls have been implemented and evaluated. Deployment of structural BMPs basin-wide should begin in 2011, as required to achieve compliance with water quality criteria.

2.2 MANAGEMENT MEASURES FOR NONPOINT SOURCES

Because permitted stormwater runoff is now considered a point source by the EPA, the only types of nonpoint sources present in the study area are "direct" nonpoint sources. Direct nonpoint sources discharge without dependency on stormwater runoff, so they have the greatest impact under dry weather (baseflow) conditions. These sources have not been heavily monitored, and the magnitude and location of these sources are still largely unknown. The existing loads and proposed loading reductions for these sources are based on TMDL modeling results, the bacterial output of various animal species (as documented in literature), bacterial source tracking (BST) results, and best professional judgment. Based on information currently available, it is presumed that wildlife and humans are the two primary contributors to the total direct source loading.

Direct nonpoint source BMPs can be targeted to areas that exhibit high bacteria concentrations under base flow conditions, based on water quality monitoring data. For example, the verification sampling, performed as part of the WPP process, has indicated high levels of bacteria in San Pedro Creek at Alamo Street (see Figure 3-16). Therefore, it is likely that a significant bacteria source exists in the vicinity. During the implementation phase of the WPP, it is recommended that additional sampling be performed to better locate this and other potential direct nonpoint source contributions.

According to the TMDL modeling results, only 2.5% of the annual average load is attributable to direct sources (2.6% if septic systems are included in this category, see Figure 1-3). Nonetheless, because of their importance under baseflow conditions, a 50% reduction in direct nonpoint sources is required to bring the stream into compliance.

As with point source BMPs, the effectiveness of direct source BMPs will be determined by future water quality monitoring. For some potential sources, such as a septic system found discharging directly to the river, the effect of control measures could be very noticeable, particularly in the vicinity of the discharge. However, most direct source control efforts will not produce immediate results. Small direct source load reductions may not be immediately noticeable in the sampling, since the inherent variability in bacteria sampling may be greater than the effect of the source control. However, as progress continues, long-term monitoring should indicate a gradual decrease in bacteria concentrations, particularly under low flow conditions.

2.2.1 Direct Nonpoint Sources – Wildlife

Wildlife are presumed to be the greatest contributors to direct source loading. Avian wildlife and bats (which are technically not "avian") are expected to be the primary sources, because they frequently make streams and riparian areas their primary habitat. It is hoped that somewhere between a 30% and 70% reduction in direct source loading can be realized by controlling wildlife sources.

The uncertainty in the anticipated wildlife reduction (30%-70%) is primarily a result of the Houston Street bat colony. This bridge probably contains the largest population of source animals living directly above the river. However, the bat colony's population remains unknown, despite recent attempts by park officials to make an estimate. (For comparison, there are roughly 1.5 million bats at the Congress Avenue Bridge in Austin.) If there are just 50,000 bats at the Houston Street bridge, producing bacteria at a rate of 10^7 org/day, and they reside at the bridge nine months out of the year, then this would equal an annual load of $1.2x10^{14}$ org/yr. In this case, removal of the bat colony would achieve the entire 50% reduction in direct nonpoint sources. However, each of the numbers used in this calculation could easily be off by an order of magnitude (one tenth to ten times the correct value), and so, the actual load reduction will have to be determined during implementation. Regardless, the load from the bat colony is expected to be sizeable, and needs to be addressed. The City of San Antonio is expected to install bat deterrent/exclusion features on the bridge so that the bats do not return after their winter migration. Water quality monitoring should be performed immediately downstream of the bridge, before and after the bats leave, in order to determine the effectiveness of this control measure.

Wild birds, such as ducks, geese, egrets, and pigeons are also presumed to be a large source of direct nonpoint source loads. However, the complete exclusion of these animals is probably unrealistic and undesirable. Instead, limited actions can be taken at key locations to reduce the number of birds present. The City of San Antonio can institute a bird feeding ban at the River Walk and at public parks in riparian areas. This action would be well served by a public awareness program explaining the purpose of the ban. Other bird deterrent practices, such as a falconer program and the removal of bird nesting locations, may also be considered to achieve the desired load reductions. Because birds may deposit fecal material on the land's surface as well as in the river, these BMPs are also expected to reduce stormwater runoff loads, as described in Section 2.1.2.

The City of San Antonio has proposed to reduce bacteria concentrations by improving management practices downtown and along the River Walk. This effort will include several components including owner/tourist education, improved trash collection and maintenance operations, and improvements in flow circulation and general water quality. Although this effort is not expected to result in large bacteria load reductions for the overall river, it could significantly reduce bacteria concentrations in the River Walk area.

The City of San Antonio operates an animal control center near the San Antonio Zoo. This center is believed to be a potentially significant contributor of bacteria loads because of wash-down practices that can result in fecal material reaching the river. These wash-down practices are routine maintenance operations and not the result of rainfall. However, this facility is to be moved to a new location in a different watershed, resulting in a potential load reduction.

2.2.2 Direct Nonpoint Sources – Human Origin

It is hoped that a 15% (or greater) reduction in direct sources can be realized from targeting human waste sources. These sources potentially include wastewater infrastructure, septic systems, and the homeless population. Regarding wastewater infrastructure, SAWS, the primary wastewater service provider in the region, already has an aggressive program in place to reduce the potential for wastewater leakage. SAWS BMPs include sewer inspection, maintenance, emergency response, and rehabilitation. These BMPs are discussed in further detail in Section 6.0 and Appendix D. Surrounding wastewater entities in the study area (Alamo Heights, Balcones Heights, Castle Hills, Ft. Sam Houston, Leon Valley, Olmos Park, and Terrel Hills) should institute similar programs if they do not already exist, perhaps with SAWS guidance. It is anticipated that all of the wastewater entities will work jointly with SARA and other agencies, if future water quality monitoring identifies specific locations where wastewater infrastructure may be contributing to the bacteria load. The City of San Antonio is about to commence a project to identify and repair illicit connections (discharges) to the River Walk. Depending upon the number and types of connections identified, this could result in a significant bacteria load reduction.

Septic systems are becoming increasingly rare in the WPP study area, as most homes are now served by wastewater collection systems. Nonetheless, there are still isolated communities relying on relatively old septic facilities inside the city. In addition, septic systems are common among newer developments in the northernmost parts of the study area. Bexar County is generally responsible for the management of these systems, except in some of the smaller incorporated areas, and will continue inspections with an emphasis on locating potential discharges to surface waters. Bexar County should maintain records of failing systems and their repair, and make this information available during the WPP implementation. SAWS and COSA are also involved in reducing the potential for septic discharges. They are currently working together to provide service to the previously unsewered Espada community in San Antonio. This project and other BMPs for septic systems are discussed further in Section 6.0.

Another potential source of bacteria loads is the homeless/vagrant population. To help reduce this potential load, the City of San Antonio will provide restroom facilities and adequate maintenance in areas with concentrated homeless populations.

2.2.3 Direct Nonpoint Sources – Flow Augmentation

SAWS proposes to activate a third reclaimed water outfall, at the Henry B. Gonzales Convention Center on the River Loop. The additional flow will increase the assimilative capacity of the river, resulting in an effective direct nonpoint source load reduction. The effect of this discharge should be detectable through long-term monitoring, particularly under base flow conditions, and near the River Walk.

2.4 NINE ELEMENT SUMMARY TABLE

The following “Nine Key Elements Table” was developed by TCEQ staff to provide an effective template for documenting the nine critical elements of a WPP, as required by the US EPA. In the table, the order of items (b) and (c) have been reversed for a more effective presentation. Hopefully, this table will serve as a valuable tool in the development of the Implementation Plan. In addition, it will be the basis for requesting additional grants to assist in BMP deployment. For direct nonpoint sources, the sum of the estimated potential load reductions for control measures is greater than the required load reduction. This is a reflection of the uncertainty in the estimates, and will allow for adaptive management during implementation

Table 2-1 includes all of the BMPs discussed in Sections 2.1 and 2.2. The BMPs from these sections are expected to result in new load reductions, because they were not in existence (or were not fully established) at the time of TMDL development. At the end of Table 2-1 are also included a number of “existing programs”. These BMPs were already established at the time of the TMDL study, and are not expected to result in additional future load reductions. They are included in the table, however, because they continue to play an important role in controlling bacteria levels within the San Antonio River, and because they demonstrate the stakeholders’ proactive approach to protecting water quality in the river.

Table 2-1: Nine Key Elements of Proposed Management Measures

(a)	**(c)**	**(b)**	**(d)**	**(e)**	**(f)**	**(g)**	**(h)**	**(i)**	**(j)**
Causes and Sources of Bacterial Impairment	**Management Measures and Targeted Critical Areas**	**Estimated Potential Load Reduction (org/yr)**	**Technical and Financial Assistance Needed for Each Measure**	**Education Component for Each Measure (and Other Education)**	**Schedule of Implementation for Each Measure**	**Interim, Measurable Milestones for Each Measure**	**Indicators to Measure Progress**	**Monitoring Component**	**Responsible Entity**
STORM WATER RUNOFF POINT SOURCES, Existing Load = 5.55E+15 org/yr, Required Load Reduction = 1.67E+15 org/yr (30%)									
Avian land deposition (urban runoff)[1]	bird feeding ban at River Walk and City Parks in riparian areas	1.8E+14 (2%)	$100,000	signs and exhibits, public awareness programs	2007-2009	Fewer birds observed along riparian areas	reduction in runoff-related bacteria concentrations basin-wide	routine basin monitoring	COSA
	bird exclusion/deterrent practices and devices at River Walk and selected riparian areas		$100,000	education of COSA Parks staff by Texas Parks and Wildlife	2007-2009	Fewer birds roosting along riparian areas	reduction in runoff-related bacteria concentrations basin-wide	routine basin monitoring	COSA
Pet land deposition (urban runoff)	increase awareness and enforcement of pet control ordinance	2.6E+14 (3%)	already funded, additional funds could be used to expand public awareness campaign and enforcement	public awareness program at Community Link Centers: (Valley View, South Park, McCreless, and Las Palmas)	2007-2009	pet owner participation, number of citations and complaints	reduction in runoff-related bacteria concentrations basin-wide	routine basin monitoring	COSA
	expand Pooper Scooper programs		expand existing program to all City Parks: $100,000	signs and exhibits, community education, mitt dispensers and disposal	2007-2009	pet owner participation, number of citations and complaints; increase in number of mitts used per year	reduction in runoff-related bacteria concentrations basin-wide	routine basin monitoring	COSA

Table 2-1: Summary Table for Nine Key Elements of Proposed Control Measures (continued 2/8)

(a)	**(c)**	**(b)**	**(d)**	**(e)**	**(f)**	**(g)**	**(h)**	**(i)**	**(j)**
Causes and Sources of Bacterial Impairment	**Management Measures and Targeted Critical Areas**	**Estimated Potential Load Reduction (org/yr)**	**Technical and Financial Assistance Needed for Each Measure**	**Education Component for Each Measure (and Other Education)**	**Schedule of Implementation for Each Measure**	**Interim, Measurable Milestones for Each Measure**	**Indicators to Measure Progress**	**Monitoring Component**	**Responsible Entity**
continued: STORM WATER RUNOFF POINT SOURCES, Existing Load = 5.55E+15 org/yr, Required Load Reduction = 1.67E+15 org/yr (30%)									
General urban runoff sources	New structural stormwater BMPs (should cover ~50% of basin area based on BMPs with 50% overall effectiveness)	2.2E+15 (25%)	$74,000,000 (based on $2.00/cf BMP treatment volume, and $20,000/ac)	education for contractors and property managers on BMP construction and maintenance	As required, begin pilot projects 2009, basin-wide implementation begins 2011	complete pilot projects and make recommendations for basin-wide deployment by 2011	reduction in runoff-related bacteria concentrations basin-wide	monitor BMP inlets and outfalls during pilot project; routine basin monitoring for basin-wide deployment	COSA
	Provide illegal dumping signs for existing vegetated swales/filter strips (70.5 miles of earthen channel on Alazan, Apache, Martinez, Olmos, 6-Mile Creek, and USAR)		$10,000	signs	beginning 2007	regular site inspections to verify that refuse (including fecal material) is no longer being dumped in buffer areas	n/a	routine basin monitoring	COSA
	Elmendorf Lake Desilting Project: removal of 214,00 c.y. of silt and sediment from lake		staff currently trained and project funded	educate developers and contractors about BMPs for construction under TPDES permit	2007-08	cubic yards of sediment removed	reduction in bacteria levels released from lake	routine basin monitoring	COSA

Table 2-1: Summary Table for Nine Key Elements of Proposed Control Measures (continued 3/8)

(a)	(c)	(b)	(d)	(e)	(f)	(g)	(h)	(i)	(j)
Causes and Sources of Bacterial Impairment	**Management Measures and Targeted Critical Areas**	**Estimated Potential Load Reduction (org/yr)**	**Technical and Financial Assistance Needed for Each Measure**	**Education Component for Each Measure (and Other Education)**	**Schedule of Implementation for Each Measure**	**Interim, Measurable Milestones for Each Measure**	**Indicators to Measure Progress**	**Monitoring Component**	**Responsible Entity**
SAN ANTONIO ZOO POINT SOURCE, Existing Load = 3.92E+14 org/yr, Required Load Reduction = 3.91E+14 org/yr (99.9%)									
San Antonio Zoo internal waterway	disinfection of Zoo base flow	6.21E+14 (99.9%)	$1,000,000 (depending upon disinfection alternative selected, higher if stormwater also treated)	none/optional exhibits in Brackenridge Park	2007-2008	n/a	reduction in baseflow-related bacteria concentrations	monitor Zoo outfall to verify disinfection	COSA
San Antonio Zoo sewer	sump and interceptor maintenance plan and implementation	included above	n/a	develop maintenance plan for all interceptors and sumps	beginning 2007	regular inspections to document functionality of sumps and interceptors	n/a	n/a	Zoo

Table 2-1: Summary Table for Nine Key Elements of Proposed Control Measures (continued 4/8)

(a)	(c)	(b)	(d)	(e)	(f)	(g)	(h)	(i)	(j)
Causes and Sources of Bacterial Impairment	**Management Measures and Targeted Critical Areas**	**Estimated Potential Load Reduction (org/yr)**	**Technical and Financial Assistance Needed for Each Measure**	**Education Component for Each Measure (and Other Education)**	**Schedule of Implementation for Each Measure**	**Interim, Measurable Milestones for Each Measure**	**Indicators to Measure Progress**	**Monitoring Component**	**Responsible Entity**
DIRECT NONPOINT SOURCES, Existing Load = 1.51E+14 org/yr, Required Load Reduction[2] = 0.76E+14 org/yr (50%)									
Human origin (wastewater collection system)	institute ordinance/ subsidize private lateral rehab (an option offered for consideration, but not yet actively being considered by potential implementer)	2.9E+13 (12%)	investigate the level to which private sewer laterals may be contributing to bacteria loadings	homeowner education	research issue beginning 2007; scope development, funding, pilot testing, and evaluation to follow	number of defective connections, number repaired	reduction in baseflow-related bacteria concentrations	routine basin monitoring	COSA and other municipalities with SAWS assistance
	odor/corrosion control program (App. D, BMP 3): optimize existing ferrous sulfate injection program to preserve structural integrity of mains		in-house study and master plan development could be supplemented by financial aid and consulting assistance	none	pending completion of odor/corrosion control master plan	pending completion of odor/corrosion control master plan	reduction in baseflow-related bacteria concentrations	routine basin monitoring	SAWS
	wastewater main cleaning program (App. D, BMP4): improve flow capacity		unknown	eliminate illegal dumping of debris in manholes, i.e. vandalism	existing and ongoing	miles of mains cleaned annually	reduction in baseflow-related bacteria concentrations	routine basin monitoring	SAWS
	wastewater system capital improvement program (App. D, BMPs 5,6,7,10,11,12, 13): Comprehensive risk management approach to optimize infrstr. renewal decisions		unknown	none	existing and ongoing	miles of mains renewed annually	reduction in baseflow-related bacteria concentrations	routine basin monitoring	SAWS
	identify and repair illicit connections to River Walk		already funded, $1,300,000	education and training with TPDES permit	2007	number of illicit connections documented, repaired	reduction in baseflow-related bacteria concentrations	routine basin monitoring	COSA

Table 2-1: Summary Table for Nine Key Elements of Proposed Control Measures (continued 5/8)

(a)	(c)	(b)	(d)	(e)	(f)	(g)	(h)	(i)	(j)
Causes and Sources of Bacterial Impairment	**Management Measures and Targeted Critical Areas**	**Estimated Potential Load Reduction (org/yr)**	**Technical and Financial Assistance Needed for Each Measure**	**Education Component for Each Measure (and Other Education)**	**Schedule of Implementation for Each Measure**	**Interim, Measurable Milestones for Each Measure**	**Indicators to Measure Progress**	**Monitoring Component**	**Responsible Entity**
continued: DIRECT NONPOINT SOURCES, Existing Load = 1.51E+14 org/yr, Required Load Reduction^2 = 0.76E+14 org/yr (50%)									
Human origin (homeless/ vagrant population)	provide restroom facilities and maintenance in areas with significant vagrant populations	3.5E+12 (1.5%)	unknown	none	2007-2009	inspections to verify utilization of facilities provided	reduction in baseflow-related bacteria concentrations	routine basin monitoring	COSA
Human origin (septic systems)	Inspection and repair (if necessary) of near-stream septic systems	3.5E+12 (1.5%)	unknown	none	2007-2009	number of failures located, number repaired	reduction in baseflow-related bacteria concentrations	routine basin monitoring	Bexar County
	Connection of 117 homes in Espada Community.		currently funded	none	existing through 2007	number of homes connected to sewer	reduction in baseflow-related bacteria concentrations	routine basin monitoring	SAWS, COSA
Bat colony in Houston Street bridge	bat exclusion/ deterrent practices and devices	1.2E+14 (50%)	assistance from Texas Parks and Wildlife, $3,000	none	2007	annual inspections to verify exclusion of bats from city bridges	reduction in baseflow-related bacteria concentrations	monitoring at bridge, routine basin monitoring	COSA
Low flows	introduce new 0.65 MGD outfall at HB Gonzalez Convention Center	effective reduction: 1.7E+12 (0.7%)	already completed	none	beginning 2006	flow records	reduction in baseflow-related bacteria concentrations	basin monitoring inside and downstream of River Loop	SAWS
Avian direct deposition^1	bird feeding ban at River Walk and City Parks in riparian areas	1.75E+13 (7.3%)	$100,000	signs and exhibits, public awareness programs	2007-2009	Fewer birds observed along riparian areas	reduction in baseflow-related bacteria concentrations	routine basin monitoring	COSA
	bird exclusion/deterrent practices and devices at River Walk and selected riparian areas		$100,000	education of COSA Parks staff by Texas Parks and Wildlife	2007-2009	Fewer birds roosting along riparian areas	reduction in baseflow-related bacteria concentrations	routine basin monitoring	COSA

Table 2-1: Summary Table for Nine Key Elements of Proposed Control Measures (continued 6/8)

(a) Causes and Sources of Bacterial Impairment	(c) Management Measures and Targeted Critical Areas	(b) Estimated Potential Load Reduction (org/yr)	(d) Technical and Financial Assistance Needed for Each Measure	(e) Education Component for Each Measure (and Other Education)	(f) Schedule of Implementation for Each Measure	(g) Interim, Measurable Milestones for Each Measure	(h) Indicators to Measure Progress	(i) Monitoring Component	(j) Responsible Entity
continued: DIRECT NONPOINT SOURCES, Existing Load = 1.51E+14 org/yr, Required Load Reduction^2 = 0.76E+14 org/yr (50%)									
Animal pound washdown	relocate facility to another watershed	2.5E+12 (1.0%)	already funded	none	2007	n/a	reduction in baseflow-related bacteria concentrations	routine basin monitoring	COSA
River Walk/ downtown sources (from improper waste disposal and debris accumulation)	owner/tourist awareness and education campaign	1.2E+12 (0.5%)	part of City plan to improve overall water quality in River Walk, $320,000	provide training to stakeholders for proper cleanup and educate on water quality impacts	2007	stakeholder participation; visual improvements in appearance of water	reduction in baseflow-related bacteria concentrations	basin monitoring inside and downstream of River Loop	COSA
	investigate and implement measures to improve flow circulation/water quality		not currently funded; $12,000-$100,000 required	technical assistance required	2007	visual improvements in appearance of water and flow	reduction in baseflow-related bacteria concentrations	basin monitoring inside and downstream of River Loop	COSA
	specially designed boat (Lady Eco) for removing all floating debris on a daily basis. (~30,000 lb/yr)		$100,000 received from Parks Foundation	instruction provided by Aquasweep	beginning 2006	annual load of debris removed	reduction in baseflow-related bacteria concentrations	basin monitoring inside and downstream of River Loop	COSA
	investigate and implement measures to improve cleaning and maintenance operations, in order to prevent load from entering River Loop		Current costs: City-$46,000; SAWS grant-$15,000. More funding needed to purchase additional power washing equipment	education and training for maintenance personnel	2007	monitor and inspect River Loop clean-up practices	Reduction in baseflow-related bacteria concentrations	basin monitoring inside and downstream of River Loop	COSA

Table 2-1: Summary Table for Nine Key Elements of Proposed Control Measures (continued 7/8)

(a)	(c)	(b)	(d)	(e)	(f)	(g)	(h)	(i)	(j)
Causes and Sources of Bacterial Impairment	**Management Measures and Targeted Critical Areas**	**Estimated Potential Load Reduction (org/yr)**	**Technical and Financial Assistance Needed for Each Measure**	**Education Component for Each Measure (and Other Education)**	**Schedule of Implementation for Each Measure**	**Interim, Measurable Milestones for Each Measure**	**Indicators to Measure Progress**	**Monitoring Component**	**Responsible Entity**
EXISTING PROGRAMS, that reduce bacteria and should be continued, but are not recommended for expansion and are not expected to result in new load reductions									
Fecal deposition collecting in streets	citywide street sweeping, twice/yr on residential streets, 4/yr on major streets (11,025 tons/yr waste removal)	n/a	currently funded by storm water fee	existing community outreach programs, presentations.	existing and ongoing	miles/year of gutter cleaned and tons/year of waste removed	n/a	n/a	COSA
Fecal deposition collecting on sidewalks	downtown sidewalk cleaning (trash, waste, and litter). Scrubber cleans over 2.5 million sqft of sidewalk annually	n/a	currently funded and staff trained by storm water fee	existing community outreach program which educates the public on the importance of proper waste disposal	existing and ongoing	reduction in TSS, floatables, bacteria, etc. in city storm drains and River Loop; keep records on sqft cleaned	n/a	n/a	COSA
Pet land deposition (urban runoff)	Pooper Scooper program at city parks with mutt mitt dispensers (28,000 lb/yr based on 112,000 mitts x ~4 oz/mitt) note: this item includes existing program, recommendations for expansion included under stormwater source section	n/a	$5600/yr for mitts, ~$360/yr/dispenser	programs and signs	existing and ongoing at the following parks: Bluegrass Island, Clover Island, Guenther Mill, HEB, Johnson St bridge, Josephine St, King William, Mahncke, Mesquite, Nueva St, Scates, Sheridan, Wesley, and Woodlawn	mitts per year	n/a	n/a	COSA

Table 2-1: Summary Table for Nine Key Elements of Proposed Control Measures (continued 8/8)

(a) **Causes and Sources of Bacterial Impairment**	**(c)** **Management Measures and Targeted Critical Areas**	**(b)** **Estimated Potential Load Reduction (org/yr)**	**(d)** **Technical and Financial Assistance Needed for Each Measure**	**(e)** **Education Component for Each Measure (and Other Education)**	**(f)** **Schedule of Implementation for Each Measure**	**(g)** **Interim, Measurable Milestones for Each Measure**	**(h)** **Indicators to Measure Progress**	**(i)** **Monitoring Component**	**(j)** **Responsible Entity**
continued: EXISTING PROGRAMS, that reduce bacteria and should be continued, but are not recommended for expansion and are not expected to result in new load reductions									
Zoo animal husbandry wastewater	wet well installation to reroute zoo animal wastewater that has historically been released into USAR; and divert it to SAWS sanitary sewer system	n/a	already completed $33,000	Zoo maintenance personnel briefed on the sump and wet well operation.	installed 2004	bacteria from hippo, pheasant, parrot-raptor, and seal pens diverted from USAR	n/a	n/a	SAWS
Low flows	reclaimed wastewater outfalls (002 & 003) and flow recycling ("Bed and Banks" release) near Brackenridge Park	n/a	currently funded	none	existing and ongoing	flow records	n/a	n/a	SAWS
San Antonio River Tunnel	Maintenance: removal of debris after storm events (150 tons/yr)	n/a	currently funded	education is being provided on illegal dumping into drainage ways by community outreach	existing and ongoing	tons of debris removed	n/a	n/a	COSA

Notes: The reversal of elements (b) and (c) is intentional, based on TCEQ recommendation, to provide a more logical order of presentation.

1. Avian deposition contributes to both stormwater runoff point sources and direct nonpoint sources. Avian deposition to the land surface is a stormwater runoff point source; avian deposition to the waterway is a direct nonpoint sources.
2. The sum of the potential load reductions (column b) for direct nonpoint sources is greater than the required load reduction (50%). This is intentional, accounting for the uncertainty in the load estimates (particularly the bat colony). Adaptive management is recommended.

2.5 SUMMARY TIMETABLE FOR IMPLEMENTATION

Table 2-2 provides a further summary of all of the BMPs listed in Table 2-1. This table also presents a timeline for the implementation of these BMPs. As shown, most BMPs are scheduled to be implemented by 2009. Routine bacteria sampling in the San Antonio River and its tributaries will be essential to measuring progress toward compliance with water quality criteria for bacteria. Since many of the load reductions provided in Table 2-1 are only estimates, an adaptive approach should be taken to the implementation of BMPs. Full compliance with bacteria standards may not be achieved until after 2012, depending upon the success of the various BMPs, and depending upon the availability of project funding.

Table 2-2: Summary Timetable

Action ID	Description:	Year					
		2007	2008	2009	2010	2011	2012+
1	Fund and construct Zoo treatment facilities	🟦	🟦				
2	Bat exclusion at Houston Street bridge	🟧					
3	Relocate City animal control facility and/or modify washdown activities	🟦					
4	Bird feeding ban and bird deterrent practices at select locations	🟧	🟧	🟧			
5	Expand pet control and pooper scooper programs city-wide	🟦	🟦	🟦			
6	Implement downtown/River Walk BMPs for proper debris collection and disposal	🟧	🟧	🟧			
7	Provide restroom facilities and maintenance in areas with significant vagrant populations	🟦	🟦	🟦			
8	Provide inspections for septic systems, document and repair any system failures	🟧	🟧	🟧			
7	BMPs for wastewater collection system; document and repair any identified leaks/illicit discharges	🟦	🟦	🟦	🟦	🟦	🟦
8	Maintain existing stormwater BMPs and locate potential sites for future stormwater BMPs	🟧	🟧	🟧			
9	Implement new stormwater BMPs, Phase 1 - pilot projects			🟦	🟦	🟦	
10	Implement new stormwater BMPs, Phase 2 - basin-wide					🟧	🟧
11	Conduct routine surveys to determine overall river compliance	🟦	🟦	🟦	🟦	🟦	🟦

II. SUPPLEMENTAL SECTIONS

The supplemental sections (Sections 3.0-6.0) provide the data, analysis, and research that were essential to making informed decisions about BMP implementation. Information found in these sections, not included in the previous two sections, includes:

- A relatively detailed description of the available water quality data for bacteria.
- A description of the simulation model used to determine TMDL loading reductions and how that model was enhanced during the WPP development process.
- A description of the various control measures considered for the San Antonio Zoo, and the advantages and disadvantages of each.
- A description of the various nonpoint source controls and runoff controls considered for watershed-wide deployment, and the advantages and disadvantages of each.

During the implementation phase of the WPP, these sections should be referenced, particularly when determining the exact types of control measures to be implemented.

3.0 WATER QUALITY DATA REVIEW

This section of the report discusses the various types of bacteria data available for the Upper San Antonio River. Historical data have been routinely collected at several locations along the river. These data have been used to assess overall river compliance and to help determine locations of key concern. In addition, data have been collected at the Zoo outfall and at the outlets of the storm sewer collection system. These data help quantify specific loads to the river. As part of the TMDL project, bacterial source tracking (BST) data were collected to help determine the ultimate origin (animal species) of the bacteria loads. Finally, additional "verification sampling" at key locations was conducted as part of the WPP development process.

3.1 HISTORICAL SAMPLING

3.1.1 Routine River Sampling

Sampling for fecal coliform bacteria along the San Antonio River has been performed for several years. Much of this data has been summarized in the TMDL-related reports for the Upper San Antonio River (JMA, 2002, 2005). Figure 3-1 provides a summary of recent fecal coliform data collected from 2000 through 2005. The figure does not include storm sampling surveys, and does not include stations where less than 10 samples were collected over the subject period. Figure 3-2 provides *E. coli* data for the same set of stations. As shown, the number of samples (N) taken for *E. coli* exceeds the number of fecal coliform samples. This reflects the fact that *E. coli* is now the EPA's preferred indicator organism.

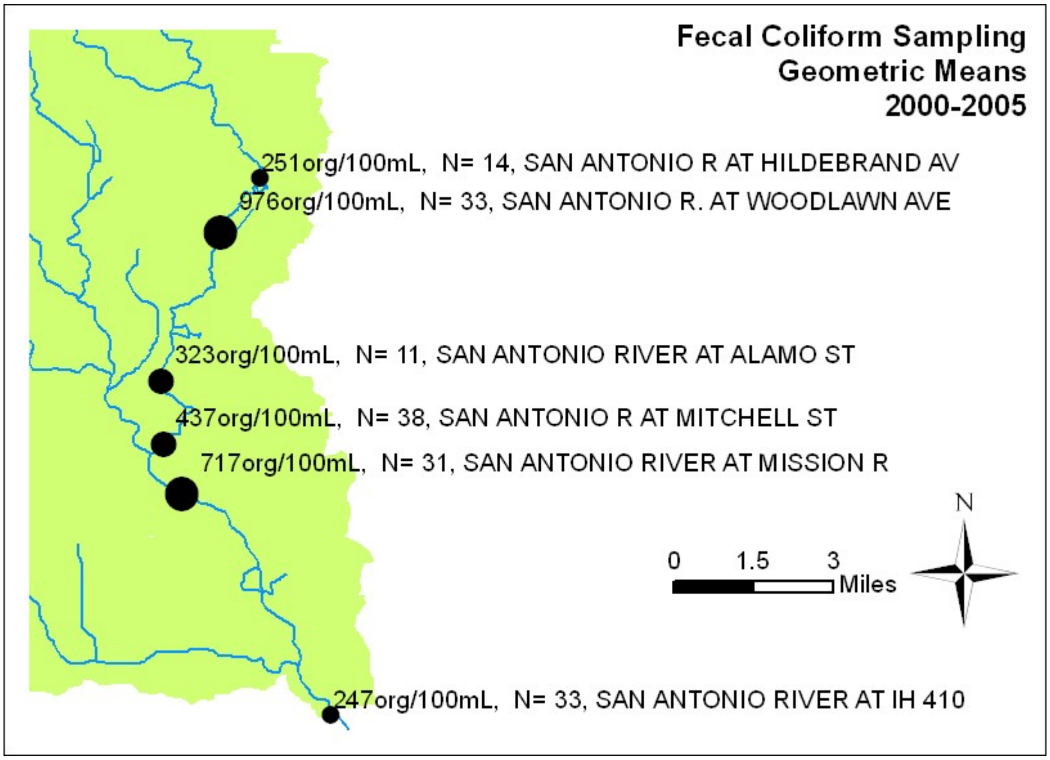


Figure 3-1: Fecal Coliform Sampling, 2000-2005

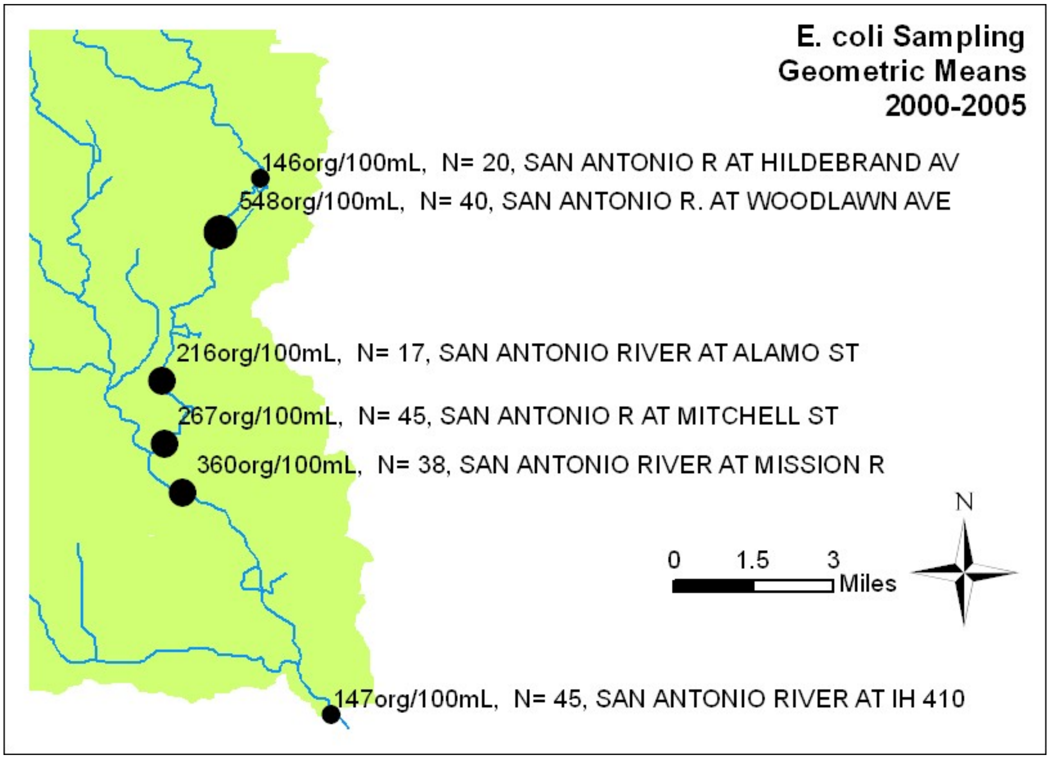


Figure 3-2: *E. coli* Sampling, 2000-2005

3.1.2 Urban Runoff Sampling

Stormwater Permit

The City of San Antonio (Department of Public Works), along with the Texas Department of Transportation, District 15 (TxDOT), and the San Antonio Water System (SAWS) are authorized as co-permittees for stormwater point discharges to surface waters of the State of Texas in the San Antonio area under Texas Pollutant Discharge Elimination System (TPDES) permit No. 04284 (TXS001901), issued Dec 22, 1995. The permit was issued to expire five years from the date of issuance following the requirements of 30 TAC § 305.71. Application for renewal of this permit has been made, however a final permit had not been received as of August 2006. Monitoring and reporting continue by the permittees under the December 1995 permit. A draft NPDES permit TXS001901, was developed for comment, dated July 31, 2003.

Permittee Responsibilities

Under the existing permit, the permittees are responsible for many facets of the Federal Storm Water Program. Associated responsibilities, especially those under the EPA National Pollutant Discharge Elimination System (NPDES) Permit are outlined below.

- Structural controls and storm water collection system operation;
- Areas of new development and significant redevelopment;
- Illicit discharges and improper disposal;
- Spill prevention and response;
- Industrial and high risk runoff;
- Construction site runoff;
- Public education; and
- Monitoring programs (including wet and dry weather screening programs and industrial and high risk runoff monitoring programs).

Discharge Locations

As authorized by Section 402(p) of the Clean Water Act (33 U.S.C. 1342), this permit is being proposed on a system-wide basis. This permit covers all areas, except for any agricultural lands, within the corporate boundary of the City of San Antonio MS4 served by, or otherwise contributing to discharges from municipal separate storm sewers owned or operated by the applicants listed above. As described in the application, the MS4 is located in Bexar County, Texas. Discharge is via the MS4 to various ditches and tributaries that eventually reach the Medina River Below Medina Diversion Lake, Lower Leon Creek, Upper Leon Creek, Upper Cibolo Creek, Salado Creek, Upper San Antonio River, Medio Creek, and Mid Cibolo Creek, in Segment Nos. 1903, 1906, 1907, 1908, 1910, 1911, 1912 and 1913 of the San Antonio River Basin. No significant degradation of high quality receiving waters is anticipated. (Note: Segment Nos. 1908 and 1913 were added to the new draft permit (2003) and are not in the final permit issued December 22, 1995.)

Receiving Stream Uses

The unclassified receiving waters have high, intermediate, limited, or no significant aquatic life use for the various ditches and tributaries. The designated uses for Segment Nos. 1903 and 1906 are high quality aquatic life use, contact recreation, and public water supply; 1907, 1908 and 1910 are high quality aquatic life use, contact recreation, public water supply, and aquifer protection; 1911 is high quality aquatic life use and contact recreation; 1912 is intermediate quality aquatic life use and contact recreation; and 1913 is limited quality aquatic life use and contact recreation.

Water Quality Monitoring

Through an inter-local agreement with the City and TxDOT, SAWS assumed the water quality monitoring responsibilities of the permit. The stormwater permit requires at least one quarterly grab sample from each of seven representative outfalls in the San Antonio Area.

The seven outfalls are summarized below:

- Outfall 001: San Pedro Rd @ Olmos Park;
- Outfall 002: So. Flores Rd @ Drainage Channel;
- Outfall 003: Alderete Park @ Zarzamora Creek;
- Outfall 004: Bandera Rd @ Zarzamora Creek;
- Outfall 005: Bitters Rd @ Salado Creek;
- Outfall 006: Business Park @ Rosillo Creek; and,
- Outfall 007: Ingram Rd @ Leon Creek

Locations for these outfalls are displayed in Figure 3-3.

The analytical data are submitted to TCEQ in quarterly Discharge Monitoring Reports (DMR) for daily average and daily maximum concentrations (per quarter). Parameters sampled and reported include the following:

> Water temperature, BOD 5-day, COD, pH, total suspended solids, oil & grease, total nitrogen, ammonia nitrogen, TKN, nitrite plus nitrate nitrogen, total phosphorus, dissolved phosphorus, cyanide, total hardness, total cadmium, total chromium, total copper, total lead, total nickel, total zinc, enterococci (Group D), diazinon, total dissolved solids, and fecal coliform.

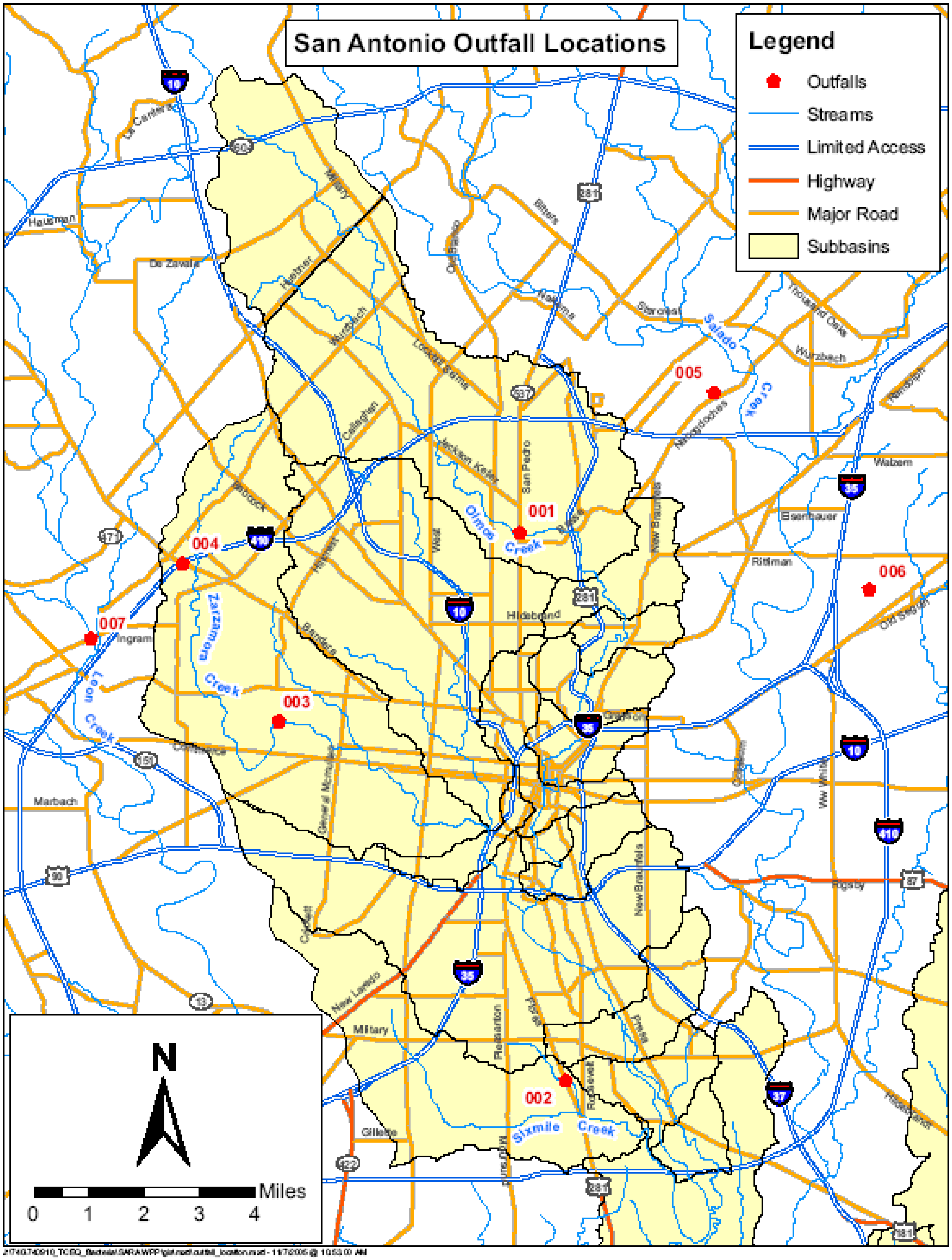


Figure 3-3: Stormwater Sampling Stations

Sample collection timing is dependent upon rainfall runoff events. "SAWS attempts to collect three grab samples a quarter, but with rainfall patterns, that is not always possible. In some cases during a single rain event SAWS only collects a limited number of the parameters due to limited volume because the rainfall stops. SAWS also attempts to collect three samples a quarter to ensure they have enough data points to be statistically accurate. Composite samples are collected in a flow weighted manner using an Isco sampler/bubbler. Grab samples are collected by field staff, preserved, and transported to the lab. Bacterial samples are set-up within the time frames outlined in standard methods. Sample locations were picked to represent the different land uses in San Antonio (residential, commercial, open space, industrial) and apply those land uses across the county." (SAWS, 2005)

San Antonio Stormwater Results

In any urban area, stormwater runoff is usually a major component of nonpoint source pollution. The City of San Antonio has been collecting runoff samples at various locations to quantify the concentrations of pollutants found in runoff from various land use types. A summary of this available data for fecal coliform is presented in Figure 3-4 below. This figure shows the annual average stormwater fecal coliform concentrations for seven monitoring locations throughout San Antonio. As demonstrated by this figure, concentrations typically vary between 10,000 and 100,000 org/100mL within each of the seven outfalls and from year to year.

Some data gaps exist due to no rainfall occurring in a given quarter or sample volumes not meeting the required volume for all parameters at each storm event. Variables such as rainfall amount and days since last rainfall (flushing of the watershed land surface) likely contribute to the variance in the results. A more complete summary of these data are provided in Appendix A.

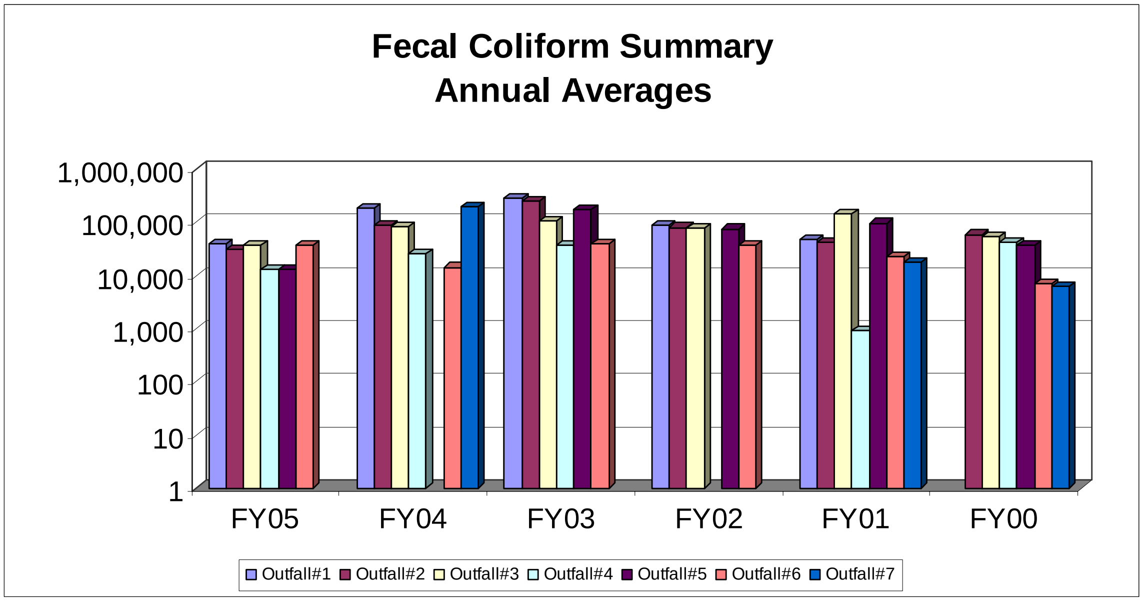


Figure 3-4: Stormwater Fecal Coliform Sampling, 2000-2005

The data from the tables and figures in Appendix A indicate routinely high fecal and enterococci results, with a great deal of variability from storm event to storm event, from season to season, from year to year, and between each of the seven outfall locations. Fecal coliform annual mean results range from a low of 900 org/100mL to a high of 287,722 org/100mL. Enterococci annual mean results range from 3,433 org/100mL to 602,500 org/100mL. TSS annual mean results range from 33.6 mg/L to 797.5 mg/L over the six years at the seven outfalls. BOD_5 annual mean results range from 4.0 mg/L to 103.0 mg/L.

3.1.3 Zoo Discharge Sampling

As attention has focused on bacteria in the basin, the San Antonio Zoo has undergone extensive monitoring. Most of the Zoo's flow originates from a well (Hippo well) which discharges into the Zoo's internal waterway. The internal waterway is essentially a series of ponds and channels that run through a series of Zoo exhibits before finally exiting the Zoo and flowing directly into the San Antonio River. The internal waterway receives wash-down water and animal wastewater from several adjacent and nearby animal pens. Stormwater runoff also flows to the internal waterway from most of the Zoo's pedestrian walkways, as well as from several animal pens and their contributing drainage areas. Almost all of the flow leaves the Zoo at the primary outfall located just south of the Zoo's entrance. This system is described in further detail in Section 5.0.

The San Antonio Water System (SAWS) conducted sampling of the Zoo's outfalls from the summer of 2003 to the spring of 2005. During this time, 55 samples were collected with a geometric mean value of about 15,000 org/100mL for fecal coliform. Additional Zoo outfall data were collected as part of the TMDL process. This sampling occurred in 2003, and included 10 samples with a 2,000 org/100mL geometric mean for *E. coli*.

3.1.4 Bacterial Source Tracking

In addition to traditional monitoring, bacterial source tracking (BST) was performed as a component of the TMDL to attempt to categorize the sources of the bacterial load (JMA, 2006). To accomplish this, *E. coli* bacteria were tested to determine the species of the host animal (human, chicken, dog, etc.) from which the bacteria originated. For this project, all laboratory experimentation was performed by the El Paso Agricultural Research and Extension Center (AREC), a part of the Texas A&M University System, under contract to TCEQ.

BST is a relatively new source classification methodology using advanced molecular and biological techniques. BST requires that a library of genetic fingerprints exists for the subject species. The libraries used in this study resulted from fecal source sampling conducted by JMA and the libraries of other concurrent BST projects in the state. This effort resulted in a combined library of about 2,000 source samples. These libraries were also used by the laboratory to test the effectiveness of different BST analysis methods. It was determined that a particular analysis method (ERIC-PCR/Riboprinting composite methodology with combined libraries) generally provided the best results, considering the rate of correct classification and the percentage of samples that could not be classified during the tests (Di Giovanni, 2006).

BST sampling for the Upper San Antonio River occurred in 2003 at the following four stations: Hildebrand Street, Mitchell Street, Loop 410, and Dietz Road. Table 3-1 shows the overall results of the San Antonio River source assessment. The first column in the table is the source category. The second column is the rate of random classification, which is based on the number of samples from each category that were included in the library. The third column gives the rate of correct classification, which is a measure of how effective the BST was at correctly identifying samples known to belong to a certain source category. Human sewage samples could be identified with the greatest rate of correct classification, while zoo animals were identified least successfully. The fourth column gives the estimated contribution from each source category for the Upper San Antonio River. Finally the fifth column specifies a 95% confidence bound for the estimated contributions (Di Giovanni, 2006).

Table 3-1: Overall BST Results for USAR

Source Category	Library Rates of Random Classification (%)	Library Rates of Correct Classification ERIC-PCR/ Riboprinting Composite (%)	Classification ERIC-PCR/ Riboprinting Composite for USAR (%)	95% Confidence Interval for ERIC-PCR/ Riboprinting Composite (%)
Human Waste	24	66	17	8-28
Pet	10	23	9	1-20
Cattle	14	47	12	3-23
Avian livestock	6	34	1	2-22
Non-avian livestock	10	29	10	
Wildlife avian	15	45	20	16-54
Wildlife non-avian	16	45	14	
Zoo	5	9	4	0-11
unidentified	n/a	13	13	n/a

A challenge noted by the principal investigator was accurately categorizing *E. coli* attributed to zoo animals, which had many similarities to *E. coli* found in wildlife and sewage. For this reason, the "[zoo] source class should be interpreted with caution" (Di Giovanni, 2006).

The BST results are helpful for identifying significant bacterial sources within the watershed. The results indicate that the largest source (34%) of bacteria potentially originates from wildlife. The second largest source (17%) is potentially human waste. However, based on the wide 95% confidence intervals in Table 3-1, these rankings are not certain.

Some results seem to contradict known characteristics of the basin. For example, cattle were shown to be a significant source of the bacterial (13% at Mitchell Street) where there is no known significant livestock population. (Union Stockyards in downtown San Antonio closed in 2001.) Another concern is that the Zoo was being identified as a source (6% at Hildebrand

Avenue), upstream of the actual Zoo location. For these reasons, the results of the BST need to be interpreted carefully, recognizing that a significant degree of error is possible.

Finally, it should be noted that the BST sampling results reflect baseflow conditions. Therefore, the BST source estimates may not be applicable to loads entering the stream under runoff conditions.

3.2 VERFICATION SAMPLING

Verification sampling was performed as part of the WPP study in order to better understand and quantify bacterial sources within the study area. Although there were several locations where sampling could be beneficial, it was necessary to limit sampling efforts to where they would be most cost-effective. The sampling plan for this project was developed by JMA and SARA. SARA incorporated the sampling activities into their existing Stream Monitoring Program, which is covered under the Quality Assurance Project Plan (QAPP) for TCEQ's Clean Rivers Program. (Zoo sites were not included in the QAPP, but were sampled and analyzed using protocol identical to the QAPP.) SARA staff performed all field activities and laboratory analysis. A summary of all sampling data is presented in Appendix B.

Selected sampling locations included the San Antonio Zoo, San Pedro Creek and its tributaries, and selected locations on the San Antonio River. Most of the sampling was performed on a weekly basis, as a "General Assessment" survey, described in Section 3.2.1. In addition, more intense sampling was performed at the Zoo under specific hydrologic conditions. Section 3.2.2 describes the results of Baseline Surveys that describe fluctuations in flows and concentrations from the Zoo during a typical dry day. Section 3.2.3 describes the results of a Runoff Survey that was performed to describe how flows and concentrations at the Zoo responded to a storm event.

3.2.1 General Assessment Survey

The general assessment survey was performed on an approximately weekly basis beginning 17 November 2005. This survey was performed to show the variability in bacteria levels over a period of months. In addition to water quality sampling, the corresponding flows were estimated using electronic flow meters.

San Antonio Zoo

Samples were collected at three locations in and around the Zoo. These locations are shown in Figure 3-5. The hippo pen site was sampled to determine concentrations in the Zoo's primary waterway within the Zoo grounds. The site is located at a walkway just below the hippo pen, relatively close to the well house, from which the Zoo's flow originates. The primary outfall is located near the Zoo's main entrance and parking area. Virtually all of the Zoo's flow is discharged to the San Antonio River via this outfall. The secondary (or rear) outfall is located at the east end of the Zoo. The discharge from the secondary outfall is usually very small except during rainfall events.

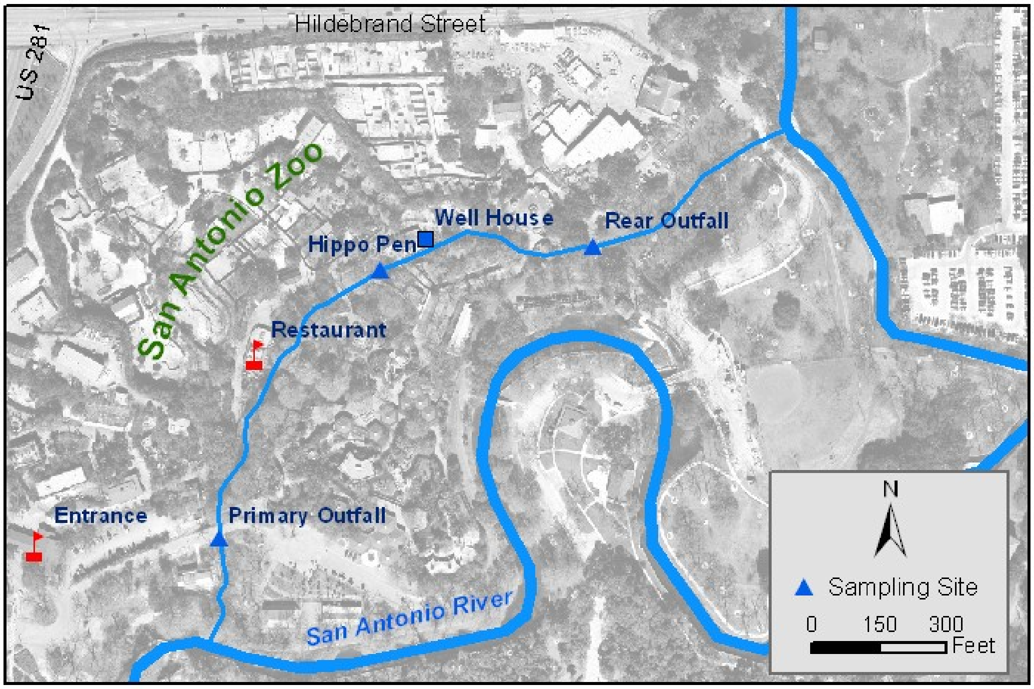


Figure 3-5: Zoo Verification Sampling Locations

The geometric mean of the fecal coliform and *E. coli* concentrations leaving the Zoo's primary outfall were 9,500 and 5,700 org/100mL, respectively. The average flow from the primary outfall was 3.9 cfs. At the secondary outfall, the flow was 0.14 cfs and the bacteria counts were usually less than 10 org/100mL. This indicated that the bacteria load from the secondary outfall is relatively insignificant. Figures 3-6 and 3-7 show the concentrations of individual samples at the three stations over time, for fecal coliform and E. coli, respectively. In the figures, the ">" symbol near some of the data points indicate that the lab was unable to measure an exact value, and the data point represents only the lower bound of the sample value. It can be observed that concentrations are highest during warmer months. This may be indicative of the seasonal presence of a large migratory bird population at the Zoo.

The bacteria data collected at the Zoo for this WPP exercise display generally similar characteristics as previous data (see Section 3.1.3). This provides confirmation of the magnitude of the bacteria contribution from the Zoo on a continuous basis. Photographs of the primary and secondary outfall are presented in Figure 3-8 and 3-9, respectively.

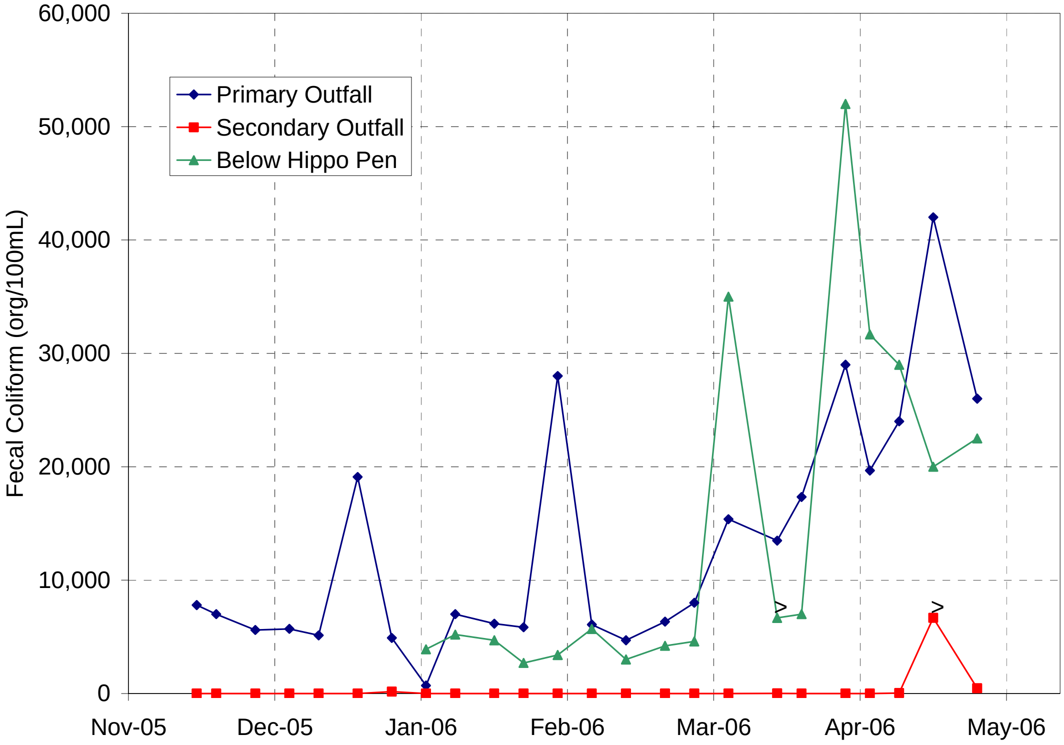


Figure 3-6: Zoo General Assessment Survey, Fecal Coliform Results

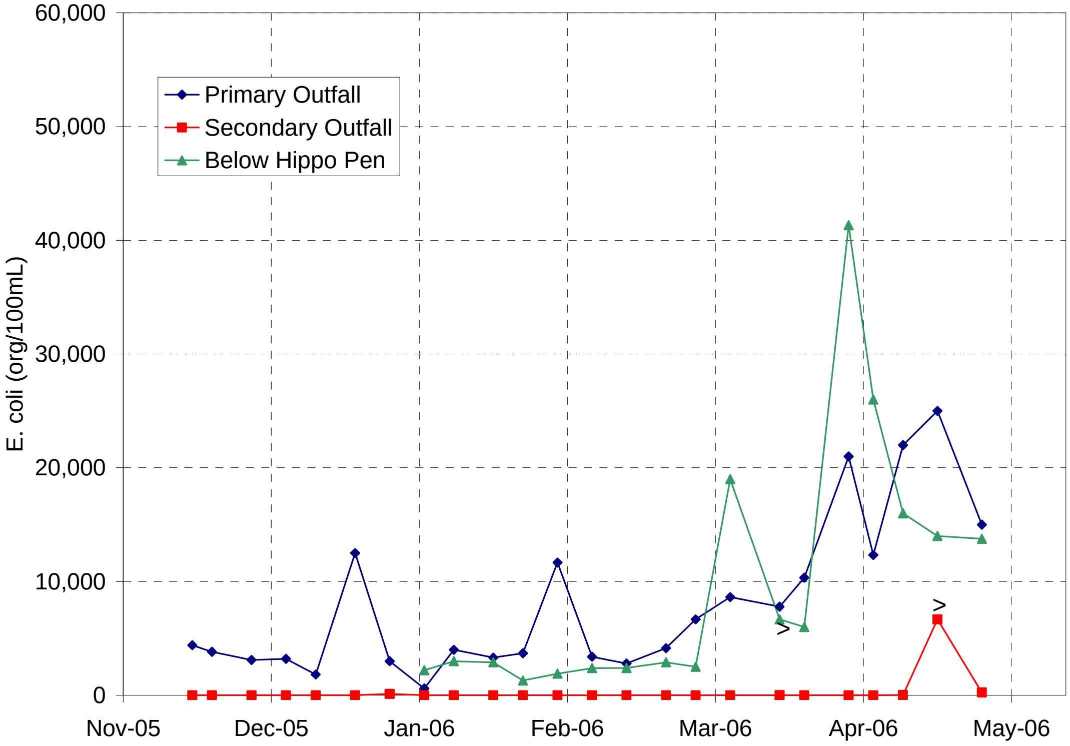


Figure 3-7: Zoo General Assessment Survey, *E. coli* Results

Figure 3-8: Primary Outfall Channel just outside of Zoo

Figure 3-9: Secondary Outfall Channel just outside of Zoo

San Antonio River – Main Stem

The general assessment survey also included routine bacteria data collection at three stations along the San Antonio River. These stations are located at Hildebrand Avenue, Alamo Street, and Mitchell Street, as shown in Figure 3-1. Figures 3-10 and 3-11 show the individual sample concentrations at the three stations over time. Bacteria concentrations along the San Antonio River do not exhibit the degree of seasonal variability observed at the Zoo monitoring locations.

It is observed that bacteria concentrations are relatively low at Hildebrand during winter months, but appear to increase significantly in warmer months. Bacteria concentrations increase at the Alamo station, largely due to the contribution from the Zoo. Concentrations at Mitchell are usually lower than those observed at Alamo, indicating die-off of bacteria as they travel downstream with the flow. The very high bacteria concentration measured on 21 March 2006 were attributable to rainfall on the previous day. (Large rainfall events produce runoff-related loads and the possibility of sanitary sewer overflow loads.)

The higher concentrations at Hildebrand may also be the result of the lower base flows due to dry conditions. Flows measured by SARA at each of the three river stations are shown in Figure 3-12. The majority of the base flow at Hildebrand originates from the nearby San Antonio Springs. Estimated spring flows (based on a relationship between spring flow and Edwards Aquifer level) are also shown in Figure 3-12.

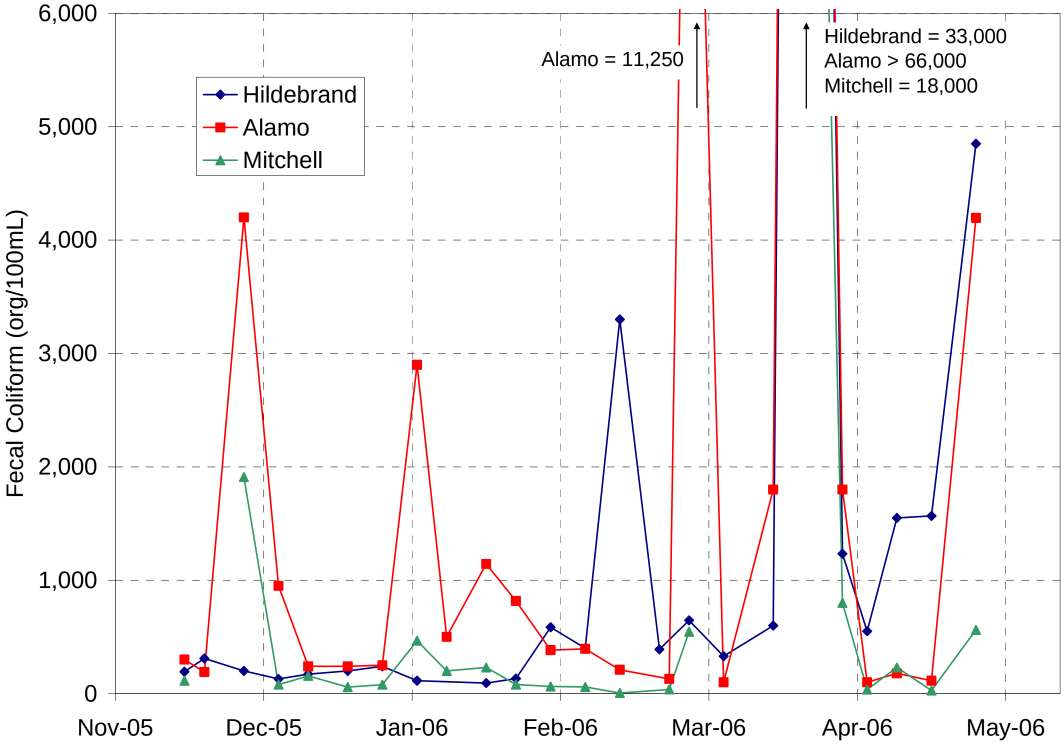


Figure 3-10: S.A. River General Assessment Survey, Fecal Coliform Results

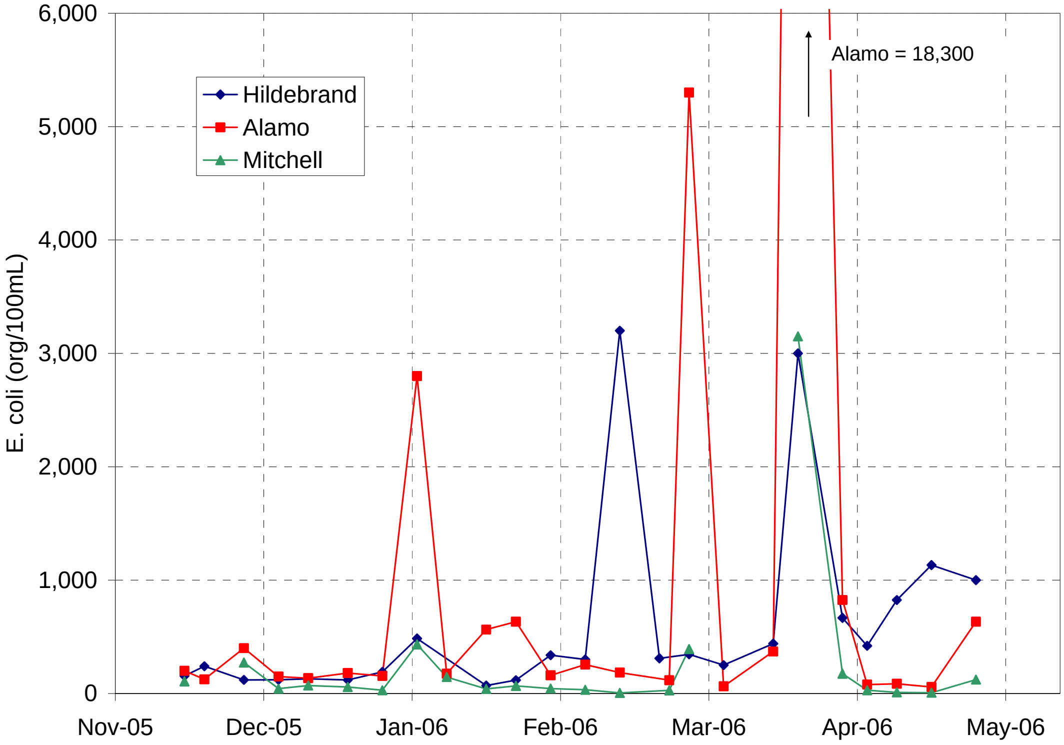


Figure 3-11: S.A. River General Assessment Survey, *E. coli* Results

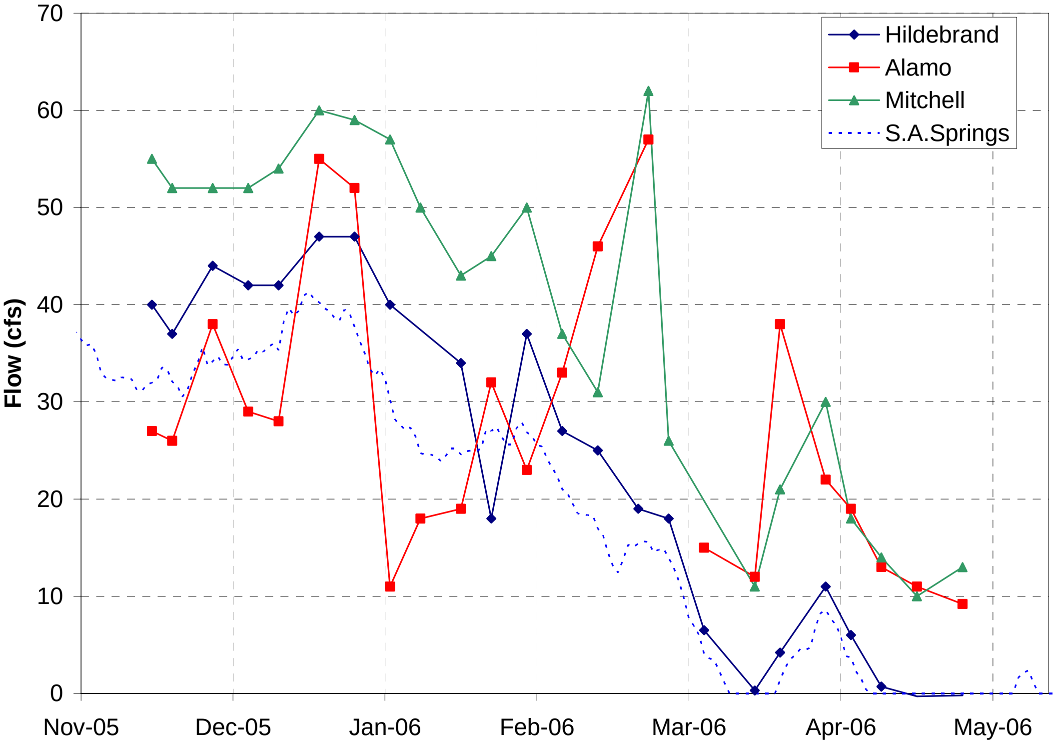


Figure 3-12: S.A. River General Assessment Survey, Flows

San Pedro Creek and Other Tributaries

San Pedro Creek and its primary tributaries (Apache Creek and Alazan Creek) were sampled in order to collect additional data on streams that might be contributing significant bacteria loads to the San Antonio River. Both Apache and Alazan Creek have impoundments that attract large bird populations. The sampling was also useful to determine if specific stream segments may not be meeting the Texas criteria for contact recreation. Figures 3-13 and 3-14 show the results for three of the stations that had relatively high bacteria levels.

Figure 3-15 shows flows at the three tributary stations. Also shown are the estimated flows from San Pedro Springs (based on the Edwards Aquifer Level). The flow in San Pedro Creek would be expected to be similar to the stream flow, but the operations of the San Pedro Tunnel could affect this relationship. There does not appear to be a clear relationship between flow and bacteria level at the tributary stations.

Figure 3-16 shows the location of each of the monitoring stations, including the San Antonio River stations and the primary Zoo outfall. The map also shows the geometric mean of the sampling data for both fecal coliform and *E. coli* bacteria. With the exception of San Pedro Creek at Alamo Street, most tributary stations either meet or are relatively close to meeting the state criteria of 126 org/100mL *E. coli* an 200 org/100ml fecal coliform (FC).

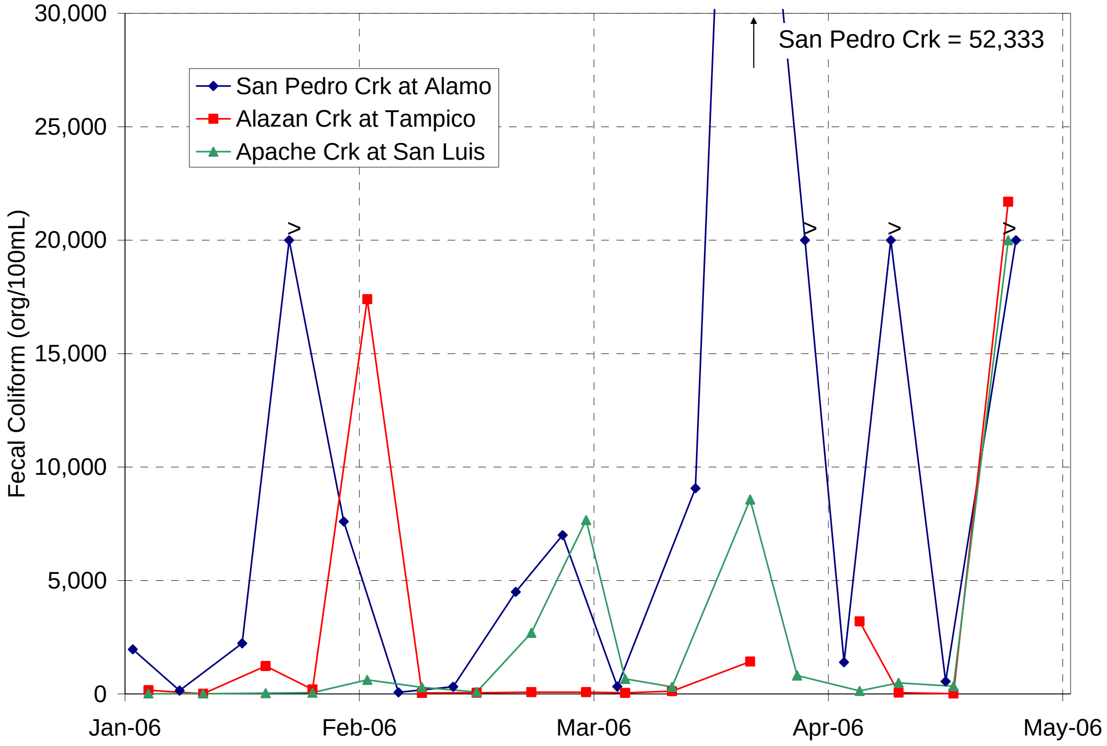


Figure 3-13: Tributaries General Assessment Survey, Fecal Coliform Results

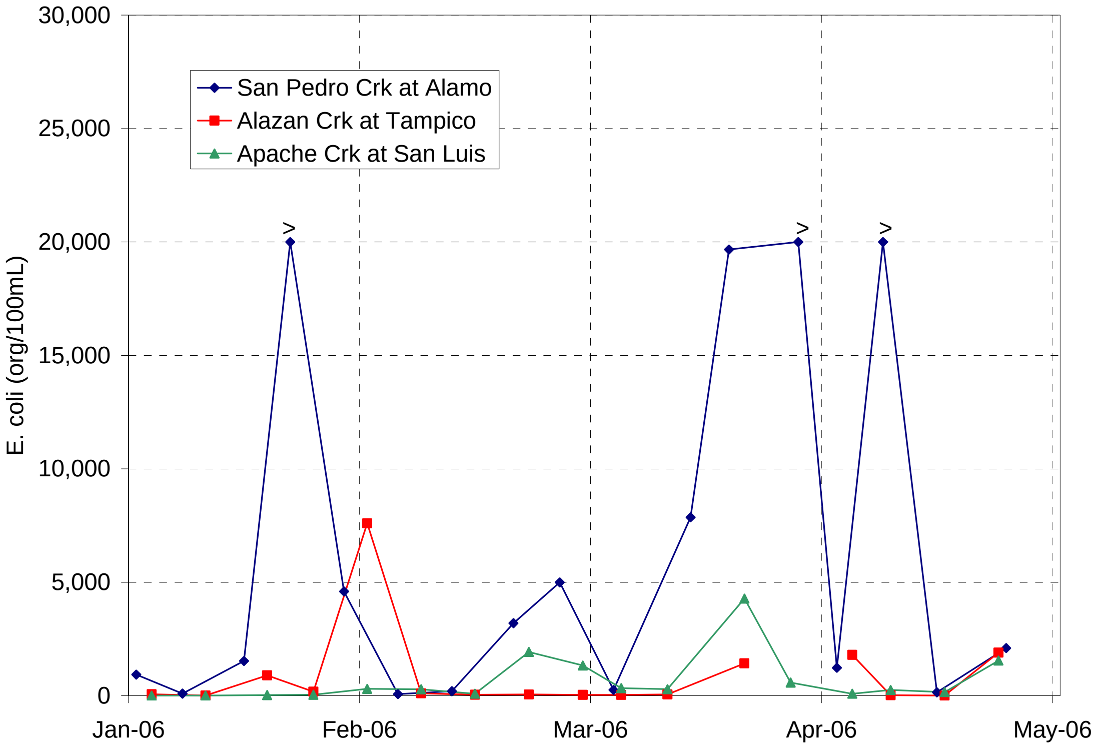


Figure 3-14: Tributaries General Assessment Survey, *E. coli* Results

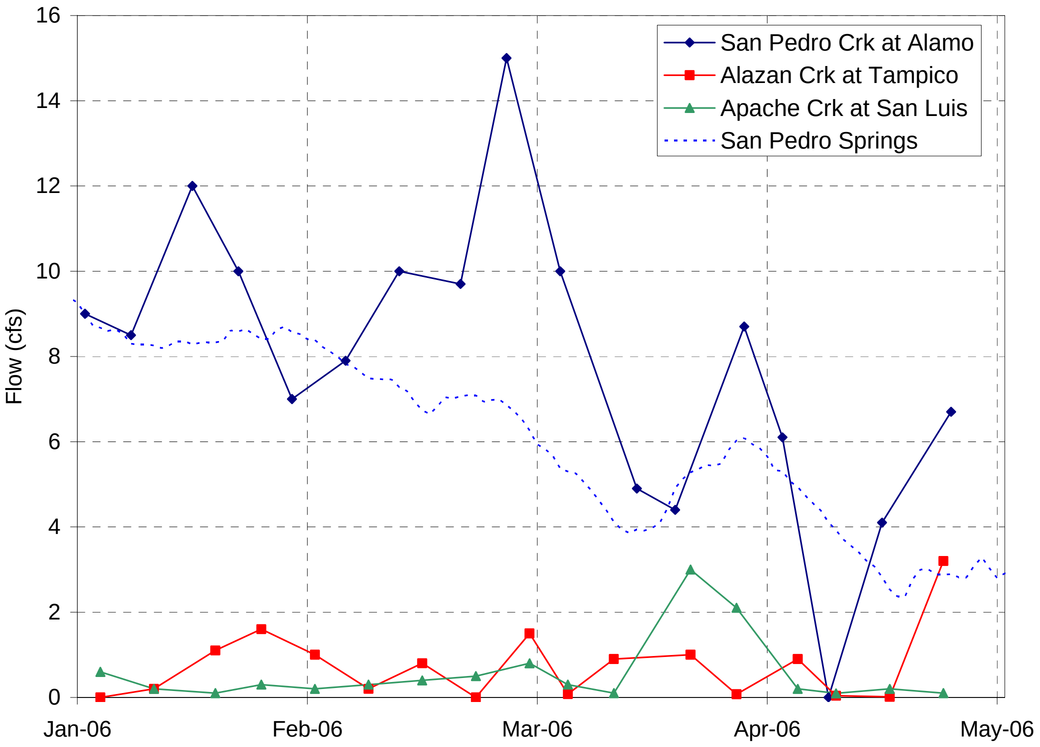


Figure 3-15: Tributaries General Assessment Survey, Flow Results

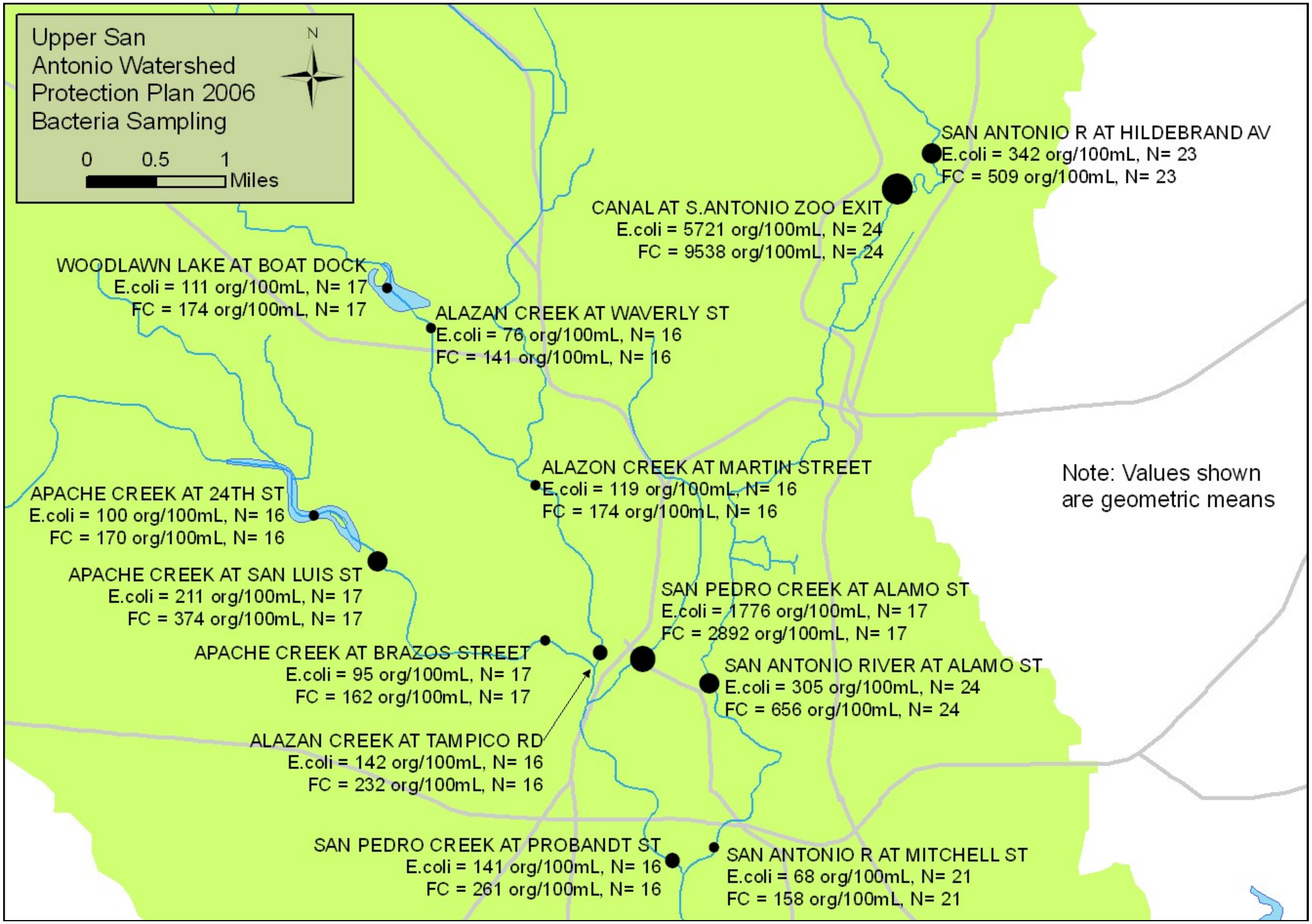


Figure 3-16: General Assessment Survey Results Map

3.2.2 Baseline Surveys

Two baseline surveys were performed at the San Antonio Zoo in order to help quantify the magnitude and variability in bacteria loads over the course of a day. The first baseline survey occurred 28 November 2005. Samples were taken at the primary and secondary outfalls at about 3 hour intervals from 6 AM to 6 PM. Figure 3-17 shows how the flow and bacteria counts varied over the course of this day at the primary outfall. For the baseline survey, only fecal coliform concentrations were measured (not *E. coli*). The average flow was 4.8 cfs, and the geometric mean of the fecal coliform samples was 8,200 org/100mL. At the secondary outfall, flows were between 0.1 and 0.2 cfs, and bacteria concentrations were consistently less than 30 org/100mL. These results suggest that the bacteria load exiting from the secondary outfall is insignificant compared to the load from the primary outfall under baseline conditions.

At the primary outfall, there was a moderate level of variation in concentration throughout the day. A spike in flow and concentration can be observed at the 9:00 hour. This may be the result of animal pen and walkway wash-down activities occurring during morning hours (see Figure 3-18).

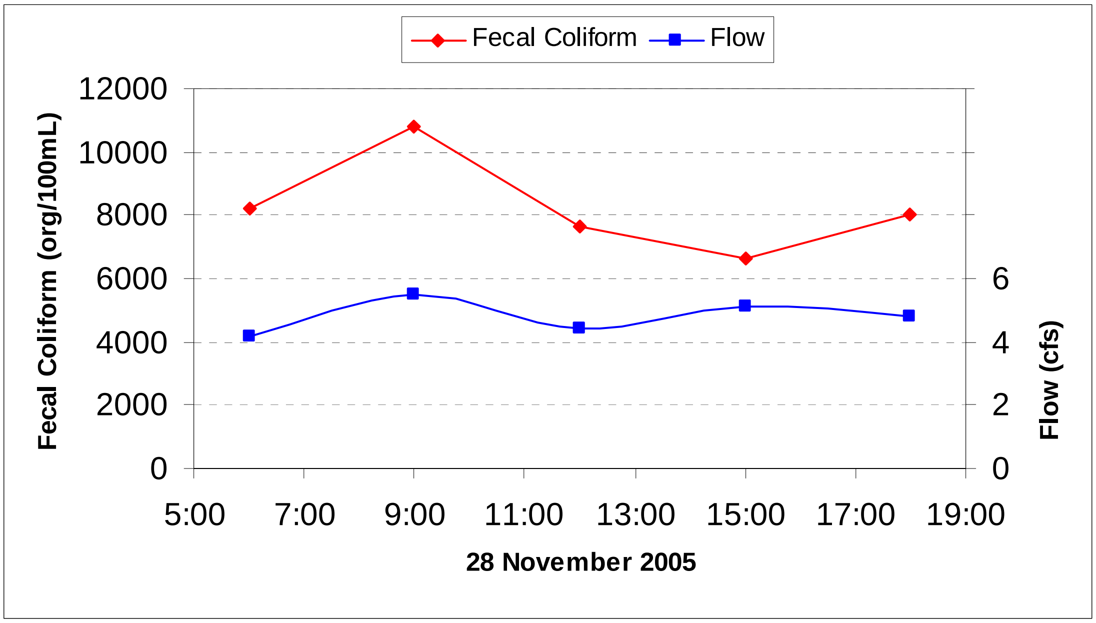


Figure 3-17: November Baseline Survey Results for Primary Outfall

Figure 3-18: Animal Pen Wash-down Activities at Zoo

A second baseline survey was conducted on 24 April 2006 from 7:51 AM to 7:15 PM. For this survey, sampling was performed at the outfalls, as well as several locations inside the Zoo. At each station, five samples were collected at roughly three hour intervals. Figure 3-19 shows the baseline survey results for the primary outfall. The results indicate higher bacteria concentrations than in the previous baseline survey. This is not surprising, considering the results of the general assessment survey discussed in Section 3.2, which indicate higher bacteria concentrations at the Zoo in warmer months. Also, the average flow leaving this outfall was lower than in the previous baseline survey, resulting in less dilution of the bacteria load. Once again, concentrations and flows at the secondary outfall (not shown) were relatively small, though one sample did reach 1,400 org/100 mL.

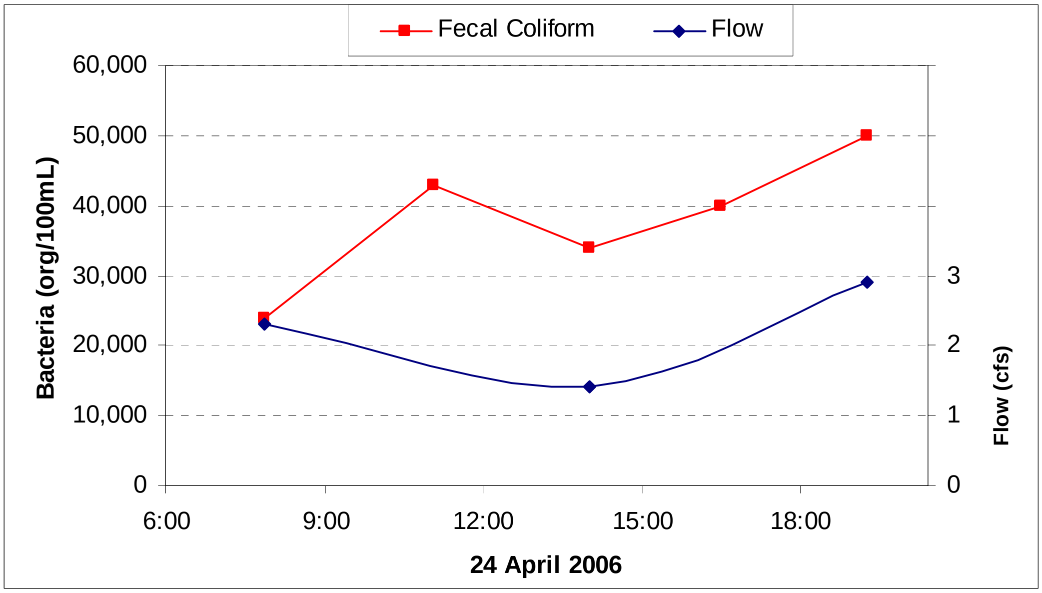
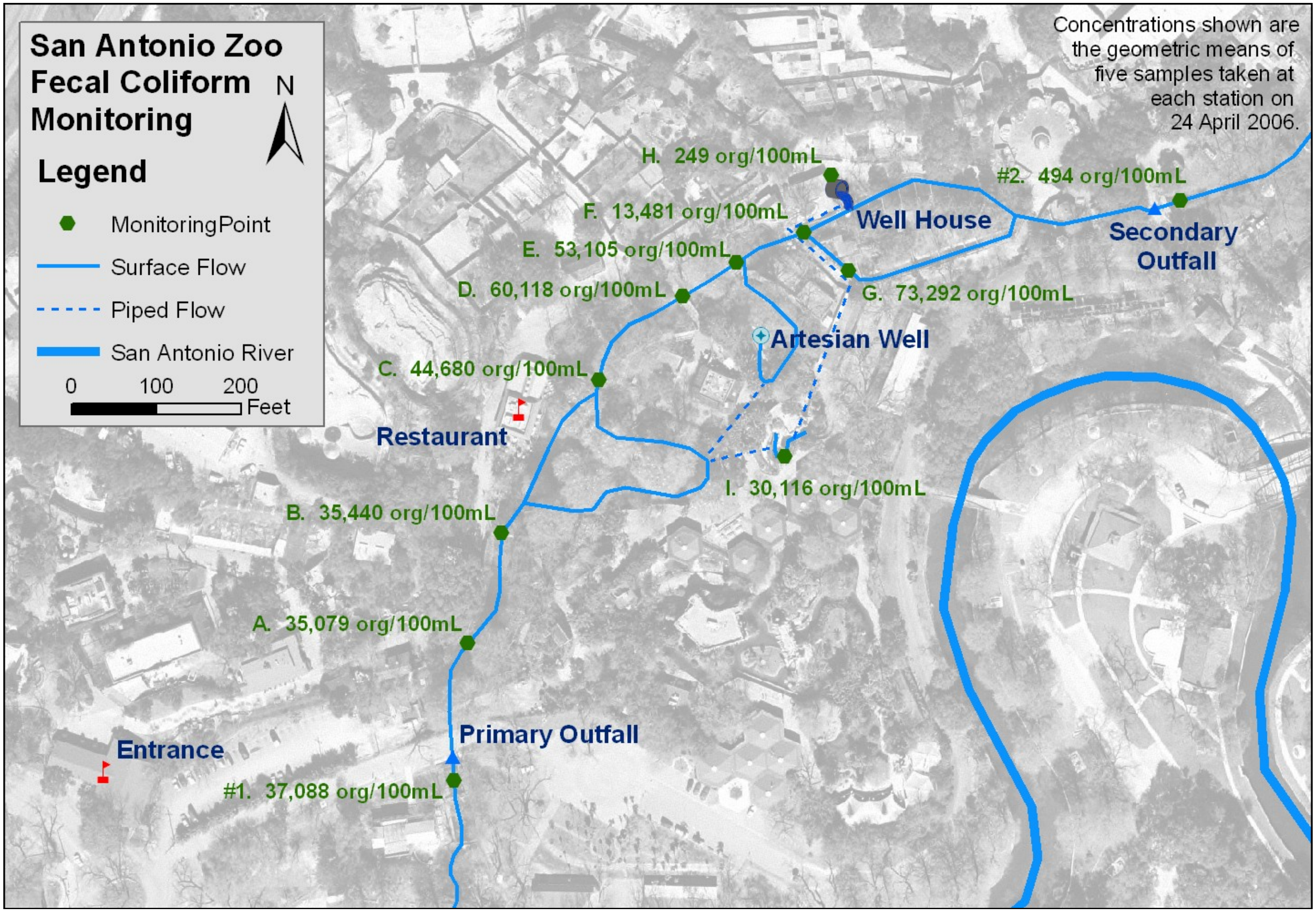


Figure 3-19: April Baseline Survey Results for Primary Outfall

For the April baseline survey, samples were also taken at several locations within the interior of the Zoo. The results of the sampling are summarized in Figure 3-21. Concentrations are shown as the geometric mean of the five samples taken at each location. Samples taken at site "H" were collected at the discharge pipe at the Zoo Well House, as shown in Figure 3-20. The bacteria concentrations at this location were the lowest observed inside the Zoo. Since this water comes directly from the Edwards Aquifer, it is suspected that fecal contamination from birds observed on the discharge pipe are responsible for the bacteria concentrations measured at this location. From the Well House, the flow of water splits into two directions, flowing around a loop of exhibits. Site G represents water that has flowed clockwise around the exhibits, and has a relatively high concentration. (Very little water leaves the loop through the secondary outfall.) Site F represents a confluence between the clockwise and counterclockwise flows. From Site F, water flows into the hippo pen, and Site E is located on the downstream end of the hippo pen. The bacteria level at Site E is quadruple that of Site F. Sites D, C, B, and A represent points farther downstream along the Zoo's internal waterway. Concentrations remain well above 40,000 org/100mL at Sites E, D, and C. Sites B and A have somewhat lower concentrations, at about 35,000 org/100mL each. Site I is a smaller water exhibit that receives water pumped directly from the Well House, and returns water to the primary waterway through a gravity pipe.

Figure 3-20: Discharge from Zoo Well House



Concentrations shown are the geometric means of five samples taken at each station on 24 April 2006.

Figure 3-21: April Baseline Survey Results for All Zoo Sampling Sites

A third runoff survey was conducted on 30 May 2006 from 7:41 AM to 7:52 PM. For this survey, sampling was performed at the outfalls, as well as several locations inside the Zoo. At each station, five samples were collected at roughly three hour intervals. Figure 3-22 shows the baseline survey results for the primary outfall. The magnitude of the bacteria concentrations and flows were relatively similar to the April baseline survey. The highest concentration was measured in the morning at about 11:00 AM. At the secondary outfall, (not shown) concentrations typically ranged from 200 to 400 org/100mL, and the flow was only 0.1 cfs.

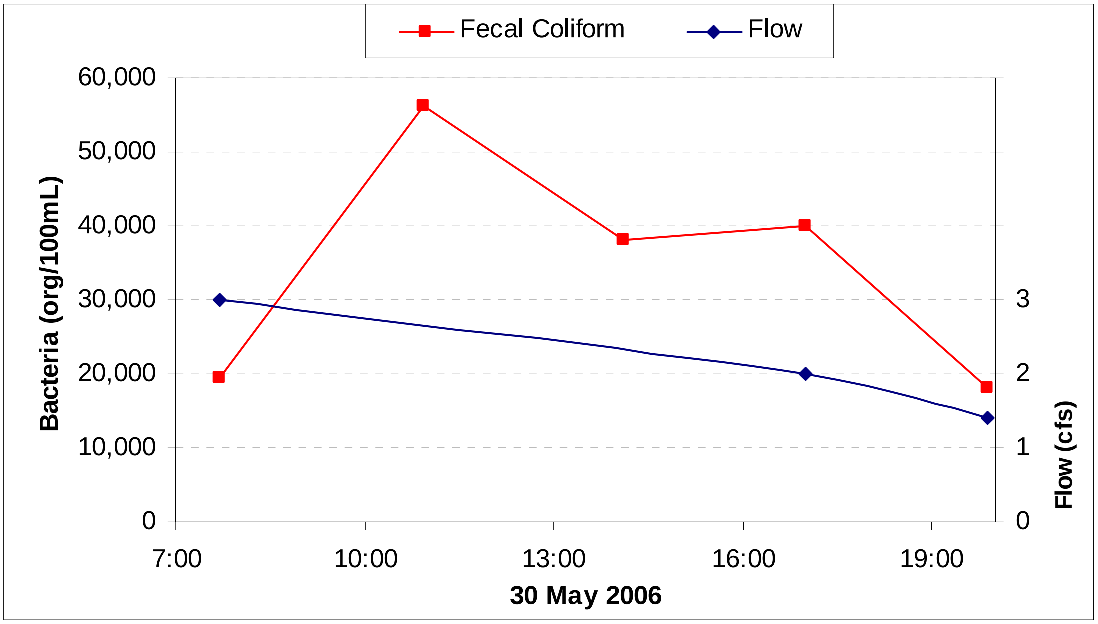
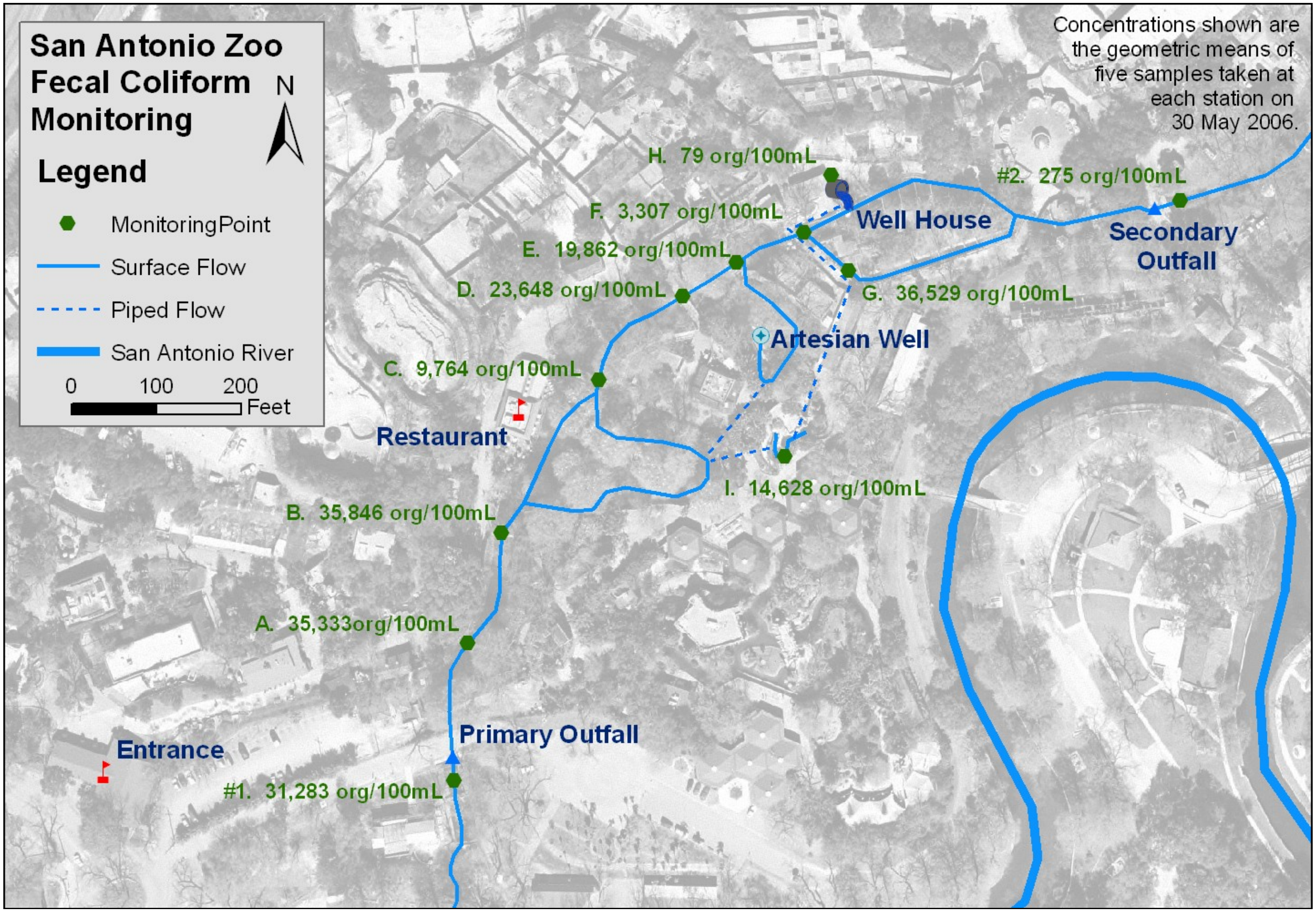


Figure 3-22: May Baseline Survey Results for Primary Outfall

Figure 3-23 shows the geometric mean concentrations for each of the sampling locations. For most stations, bacteria concentrations were typically lower than the concentrations observed in the April baseline survey. As with the previous survey, the greatest percent increase in bacteria concentration occurred between sites F and E. The downstream stations, near the primary outfall, had the highest bacteria concentrations (>30,000 org/100mL).



Concentrations shown are the geometric means of five samples taken at each station on 30 May 2006.

Figure 3-23: May Baseline Survey Results for All Zoo Sampling Sites

3.2.3 Runoff Survey

A runoff survey was performed to determine how storm events affect the Zoo's water quality and flow levels. This survey was performed during the night of 19 March and morning of 20 March 2006. During this period, 0.88 inches of rain fell at the weather station at San Antonio International Airport. This rainfall, along with the measured flow rates leaving the Zoo's two outfalls are shown in Figure 3-24. As shown in the figure, the rainfall event resulted in significant increases in flow at both the primary and secondary outfalls.

Figure 3-25 shows the fecal coliform concentrations at the two Zoo outfalls during the rainfall event. This figure shows bacteria counts frequently greater than 200,000 org/mL. The lab was unable to measure precise bacteria counts for the last two samples taken at the primary outfall, and it is not possible to know by how much these samples exceeded 200,000 org/100mL. The Zoo runoff bacteria concentrations are substantially higher than the typical baseline concentrations.

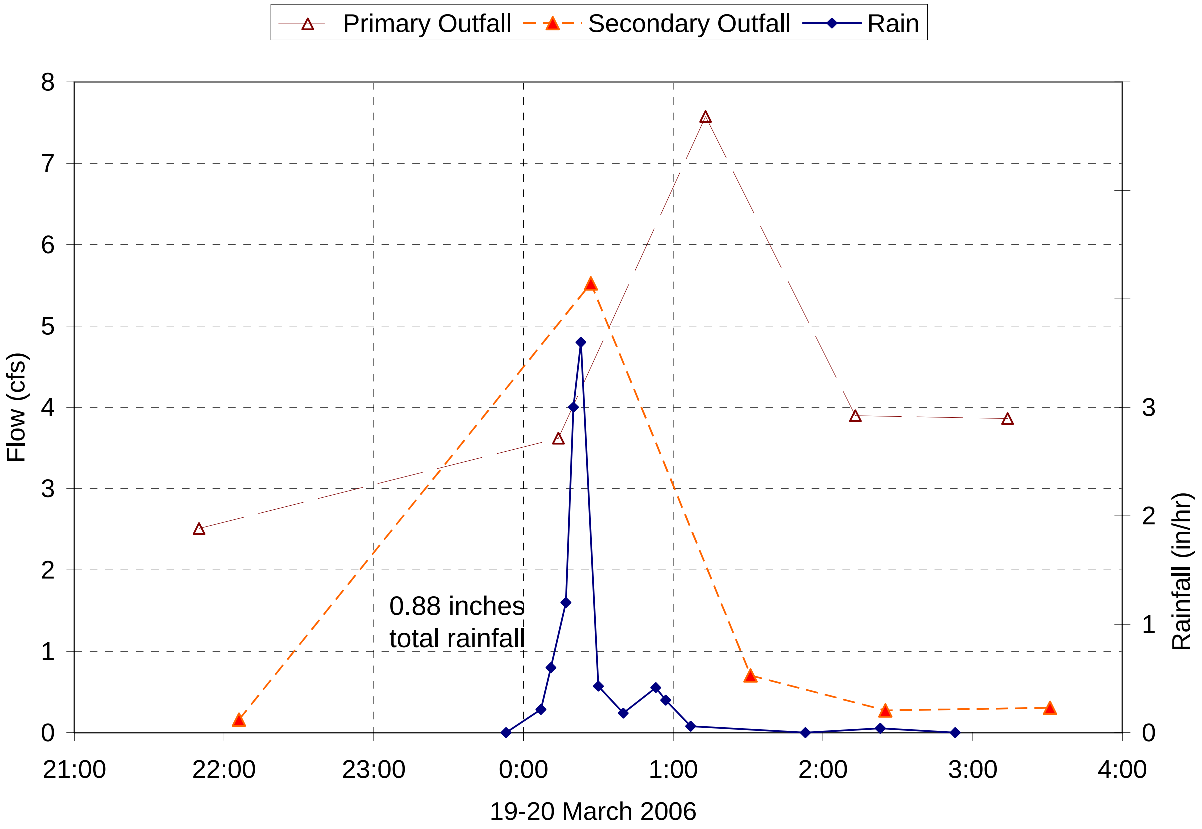


Figure 3-24: Rainfall and Zoo Outfall Flows from Runoff Survey

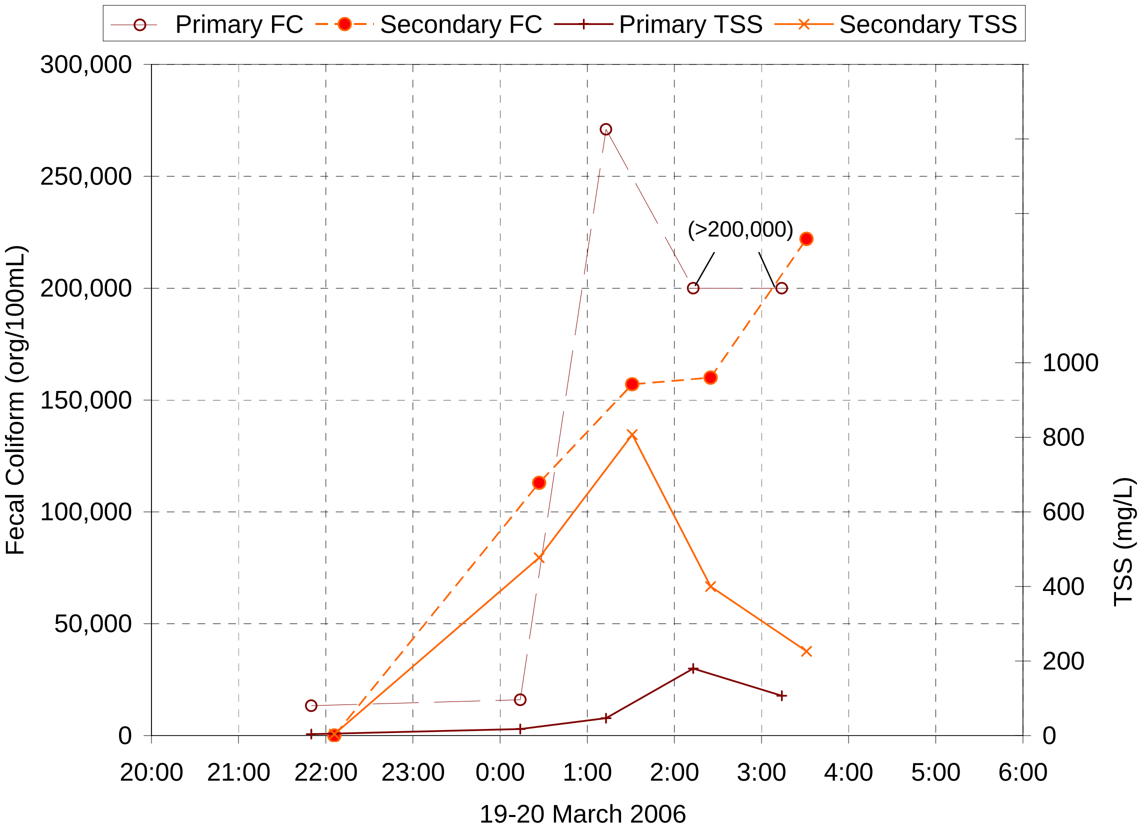


Figure 3-25: Zoo Fecal Coliform and TSS Concentrations from Runoff Survey

4.0 WATER QUALITY MODEL ENHANCEMENTS

The watershed water quality model HSPF (Hydrologic Simulation Program - Fortran) was applied to the Upper San Antonio River for development of a Total Maximum Daily Load (TMDL) for bacteria. HSPF is a widely used model that is supported by the US EPA, and it has been applied for simulation of a variety of constituents in waterbodies for more than 30 years. The model can account for both point source loadings and nonpoint source loadings in the watershed. HSPF includes simulation of the receiving stream and receives mass loadings from the watershed. A detailed description of the model setup is included in the Upper San Antonio River TMDL modeling report (JMA, 2006).

In the application of HSPF to the Upper San Antonio River, several subwatersheds were delineated, land use classifications were assigned, and stream channel characteristics were estimated. The model was calibrated for fecal coliform simulation based upon historical bacteria data available at several key monitoring locations. The calibrated model was used to determine bacterial loading allocations for point source and nonpoint source contributions to the Upper San Antonio River.

As a component of the WPP, the TMDL model was used to test the watershed management practices required to achieve bacteria loading reductions and bring the river into compliance with state criteria. Improved data and an enhanced understanding of the basin allowed the model to be modified as part of the WPP development process. The major enhancements made to the model are summarized as follows:

- San Antonio stormwater data were compiled and employed to adjust key bacterial wash off loading parameters
- Subbasin boundaries (delineations) were modified to reflect the networks of storm sewers and man-made channels that have altered natural drainage patterns
- The watershed that defined San Pedro Creek was split into two, so that concentrations in the creek could be more accurately simulated
- Newer and more accurate land use data were used to refine land use statistics for subbasins.
- Model hydraulics within the study area were revised, and the San Antonio River Tunnel was included.

The model enhancements were included in the final TMDL modeling work, as well as the WPP.

4.1 WATERSHED BOUNDARY ADJUSTMENTS

The original model utilized watershed boundaries developed using delineation from a digital elevation model (DEM). While this provided acceptable results for a regional water quality model, it did not allow for detailed analysis within the WPP study area. To improve this delineation, additional data were acquired from the City of San Antonio (COSA) showing the details of the City's storm drainage system. These data and the revised subbasin delineations are shown in Figure 4-1.

The COSA data include storm sewers, and earthen and concrete drainage channels. In the relatively flat, southern portions of the study area, these man-made drainage pathways proved more important for subbasin delineation than the indistinctive digital elevation data.

The storm sewer data were not found to be complete, however. Many areas, which appear to be served by storm sewer, as indicated by a GIS layer of sewer inlets, have no corresponding storm sewer line data. Aerial imagery and DEM data were used in conjunction with best professional judgment to augment the incomplete storm sewer data.

Watershed boundaries were also adjusted to align better with monitoring points, control structures, and stream confluences.   This allows for more detailed modeling results and improved model calibration within the WPP study area.

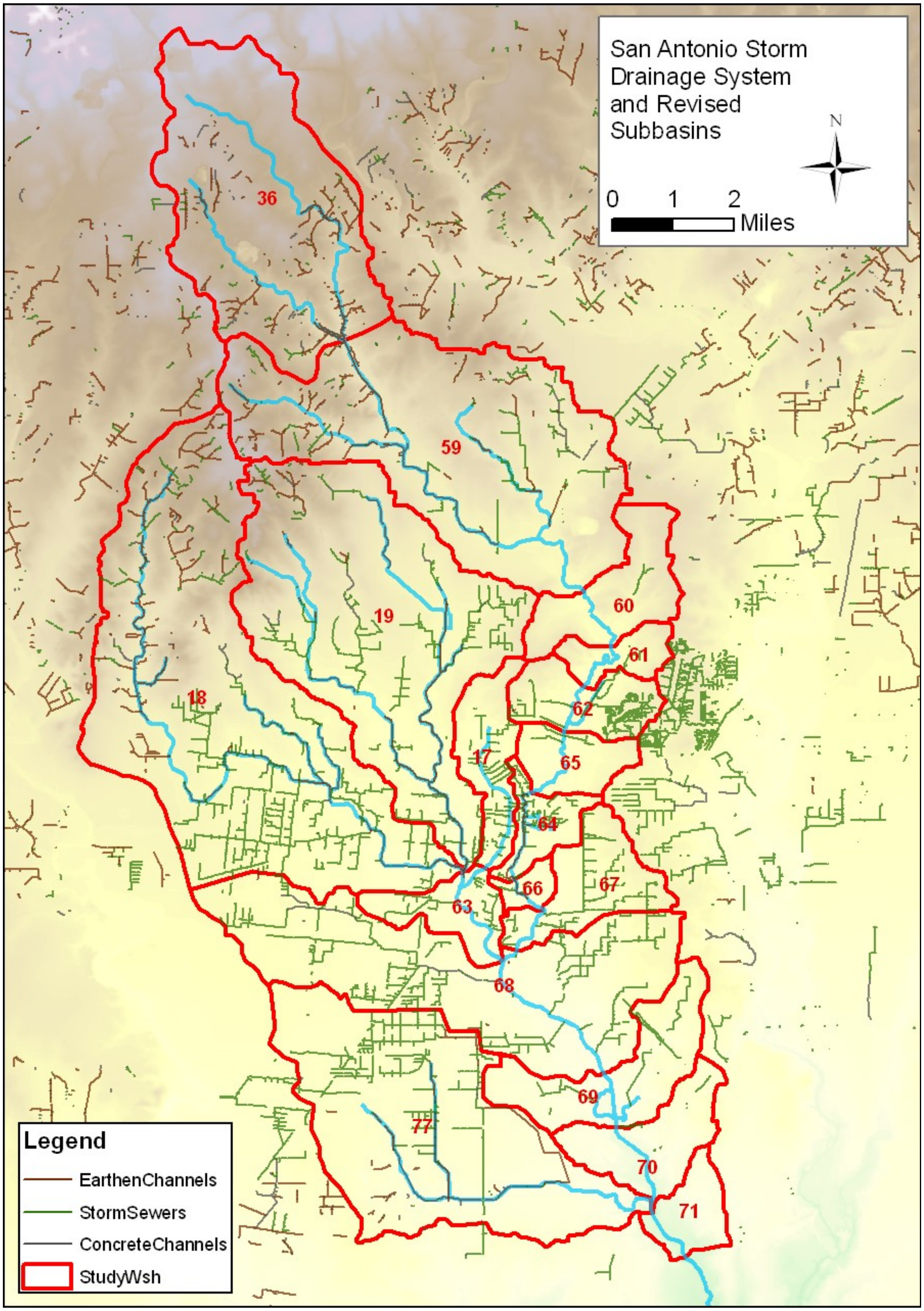


Figure 4-1: San Antonio Storm Drainage System and Revised Subbasins

4.2 REVISED LAND USE DATA

The San Antonio River Authority has recently completed a new "Composite" land use dataset, developed specifically for hydrologic modeling applications (PBS&J, 2006). Compared to previously available land use datasets, this dataset appears to be a significant improvement in terms of accuracy and applicability to water quality modeling. The Composite land use data are a synthesis of information from the following data sources:

1. City of San Antonio 2005 Zoning coverage
2. Bexar County 2004 Parcel coverage
3. USGS 1992 Land Cover Dataset
4. USGS National Hydrography Dataset

The WPP study area is highly urbanized. According to the Composite land use data, 49% of the watershed is classified as medium, high, or multi-family residential. About 14% of the watershed is industrial and commercial, and about 25% is transportation (roads, highways, and railways, including rights-of-way). The remaining 12% is composed mostly of parks and other relatively undeveloped areas. Figure 4-2 provides a map of these data.

For the purpose of water quality modeling, the land use data were divided into four primary land use categories: residential, commercial-industrial, forest, and rangeland. Table 4-1 shows how the original Composite land use data were divided into these four categories.

Table 4-1 also includes the percent impervious cover as estimated in the Composite land use dataset. These percent impervious cover estimates were used as the starting point for determining impervious cover values for the water quality model. However, using these numbers directly did not result in a reasonable hydrologic calibration. This is not unexpected, since the model uses "effective" impervious cover. Impervious areas that flow downgrade onto pervious areas, via sheet flow, are not considered fully effective. It is also possible that the impervious covers from the Composite land use dataset may have been overestimated.

To complete the hydraulic calibration, the impervious cover levels from the Composite land use dataset were reduced by 10% in the downtown subbasins and 40% in the suburban subbasins. These reductions were determined via the hydrologic calibration exercise, as values that would yield reasonable simulation results. In addition, the transportation and "mixed" land use categories were divided into the residential and commercial-industrial categories, and were assigned the percent impervious cover values corresponding to these categories.

With these adjustments, the total estimated effective impervious cover for the WPP study area is 36%. The land use statistics used in the revised water quality model are presented in Table 4-2.

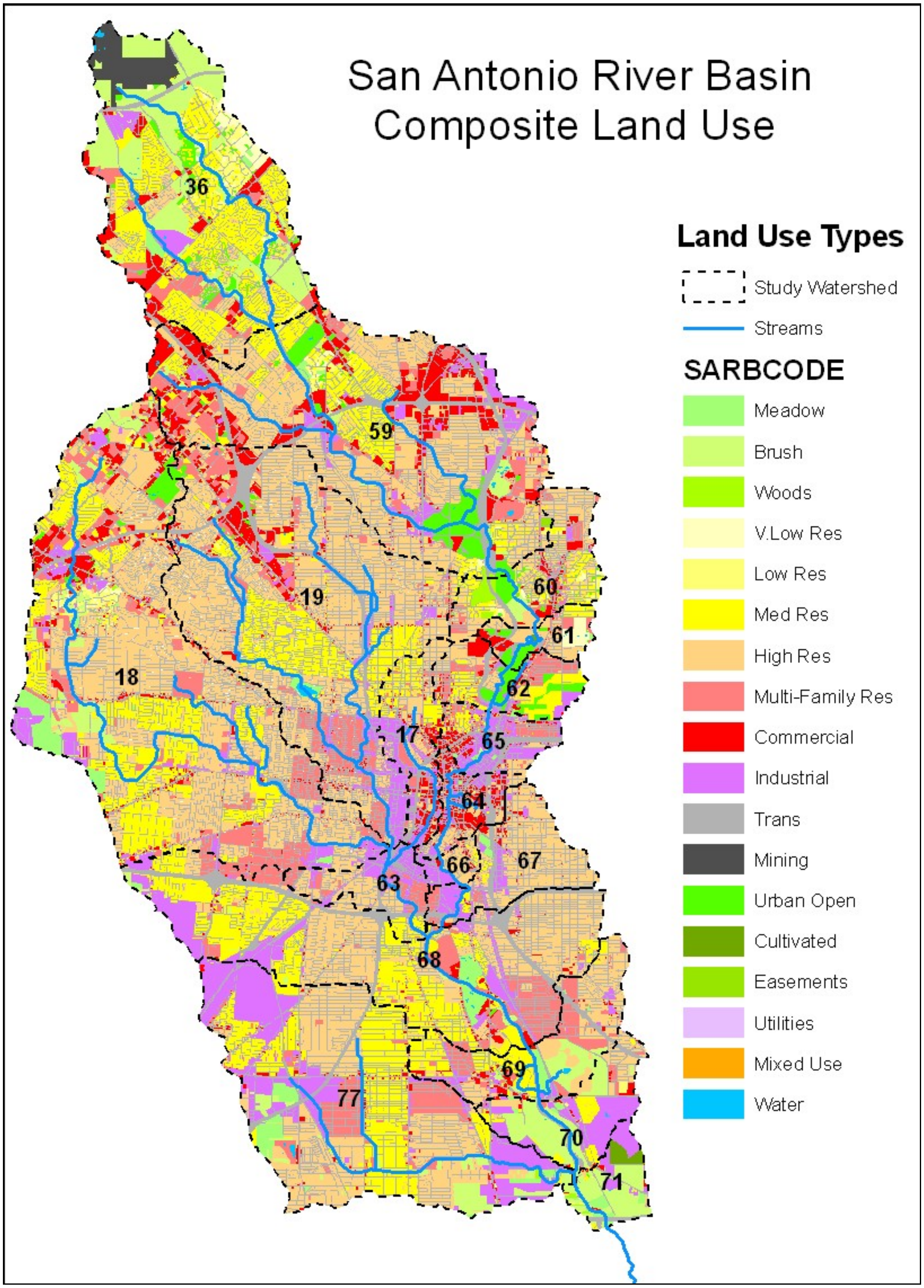


Figure 4-2: San Antonio Land Use Map

Table 4-1: Land Use Classification Summary

Composite LU Classification	Composite LU % Impervious	Water Quality Model Classification
Undeveloped		
Meadow	0	Rangeland
Brush	0	Rangeland
Woods	0	Rangeland
Residential		
Very Low Density	10	Residential
Low Density	25	Residential
Medium Density	38	Residential
High Density	65	Residential
Multi-Family	75	Residential
Commercial	90	Commercial-Industrial
Industrial	72	Commercial-Industrial
Transportation	90	Res/Comm-Ind*
Mining	0	Rangeland
Park	0	Rangeland
Crop	0	Cultivated
Easement	10	Rangeland
Utility	80	Commercial-Industrial
Mixed	40	Res/Comm-Ind*

*Assigned to Residential and Commercial-Industrial based on the ratio of residential to commercial-industrial land in each subbasin.

Table 4-2: Land Use by Subbasin for Water Quality Modeling (acres)

Subbasins	Residential Pervious	Residential Impervious	Commercial Pervious	Commercial Impervious	Range	Forest	Cultivated	Total	Percent Impervious
17	465	489	174	441	0	0	0	**1,568**	**59.3%**
18	7794	4232	927	882	1028	3	0	**14,866**	**34.4%**
19	6065	3542	753	728	118	0	0	**11,206**	**38.1%**
36 R*	1784	507	315	302	2462	0	0	**5,370**	**15.1%**
36	1724	702	164	191	557	3	0	**3,340**	**26.7%**
59	4815	2703	1403	1475	866	13	0	**11,276**	**37.1%**
60	1020	520	108	117	206	87	0	**2,058**	**30.9%**
61	305	236	17	68	128	0	9	**763**	**40.0%**
62	483	500	75	210	247	0	0	**1,515**	**46.9%**
63	368	501	132	244	0	0	0	**1,245**	**59.8%**
64	131	187	144	459	3	0	0	**924**	**69.9%**
65	185	246	213	461	21	0	0	**1,126**	**62.8%**
66	96	128	48	96	1	0	0	**368**	**60.8%**
67	629	874	133	282	28	0	0	**1,946**	**59.4%**
68	4551	2280	718	588	255	0	0	**8,392**	**34.2%**
69	1297	720	144	134	327	0	0	**2,623**	**32.6%**
70	400	195	381	301	587	0	0	**1,865**	**26.6%**
71	34	13	158	124	546	14	96	**985**	**14.0%**
77	3926	2024	1404	1098	661	12	0	**9,125**	**34.2%**
Total	**36071**	**20600**	**7410**	**8202**	**8042**	**132**	**105**	**80,561**	**80,561**
Percent	**44.8%**	**25.6%**	**9.2%**	**10.2%**	**10.0%**	**0.2%**	**0.1%**	**100.0%**	**35.8%**

*Edwards Aquifer Recharge Zone

4.3 SAN ANTONIO RIVER TUNNEL

The San Antonio River Tunnel, shown in Figure 4-3, has a major impact on the flow hydraulics through downtown San Antonio. Since it was constructed for flood control, stormwater runoff that enters the tunnel entrance is bypassed via the tunnel to the exit. Tunnel operations also influence base flow conditions in the original river channel. According to tunnel operators (City of San Antonio Public Works), the tunnel is operated to maintain 20-30 cfs in the above-ground stream channel that runs through the downtown area. All flow above this threshold is passed through the tunnel. However, no historical data are available to verify the consistency of this operating rule. Some of the flow measurements taken by SARA, as part the WPP study, indicate that the flows in the San Antonio River at Alamo Street are sometimes higher than 50 cfs under base flow conditions.

Flow can remain in the tunnel for several days under low base flow conditions, moving at a low velocity from upstream to downstream. However, when flows in the river become sufficiently low, recirculation pumps can pull water out of the tunnel’s upstream end and release it into the surface channel in order to maintain minimum flow levels in the River Walk and downtown San Antonio. This essentially causes flow in the tunnel to reverse.

In the water quality model, the San Antonio River Tunnel is modeled as a distinct reach. It receives water leaving Reach 62 (see Figure 4-1) and coveys that water to Reach 67. The tunnel accepts all flows greater than 30 cfs, so that no more than 30 cfs remains in the above-ground stream channel at any time under stable hydraulic conditions. Under runoff conditions, additional drainage may enter the natural river channel downstream of the tunnel entrance and be conveyed downstream.

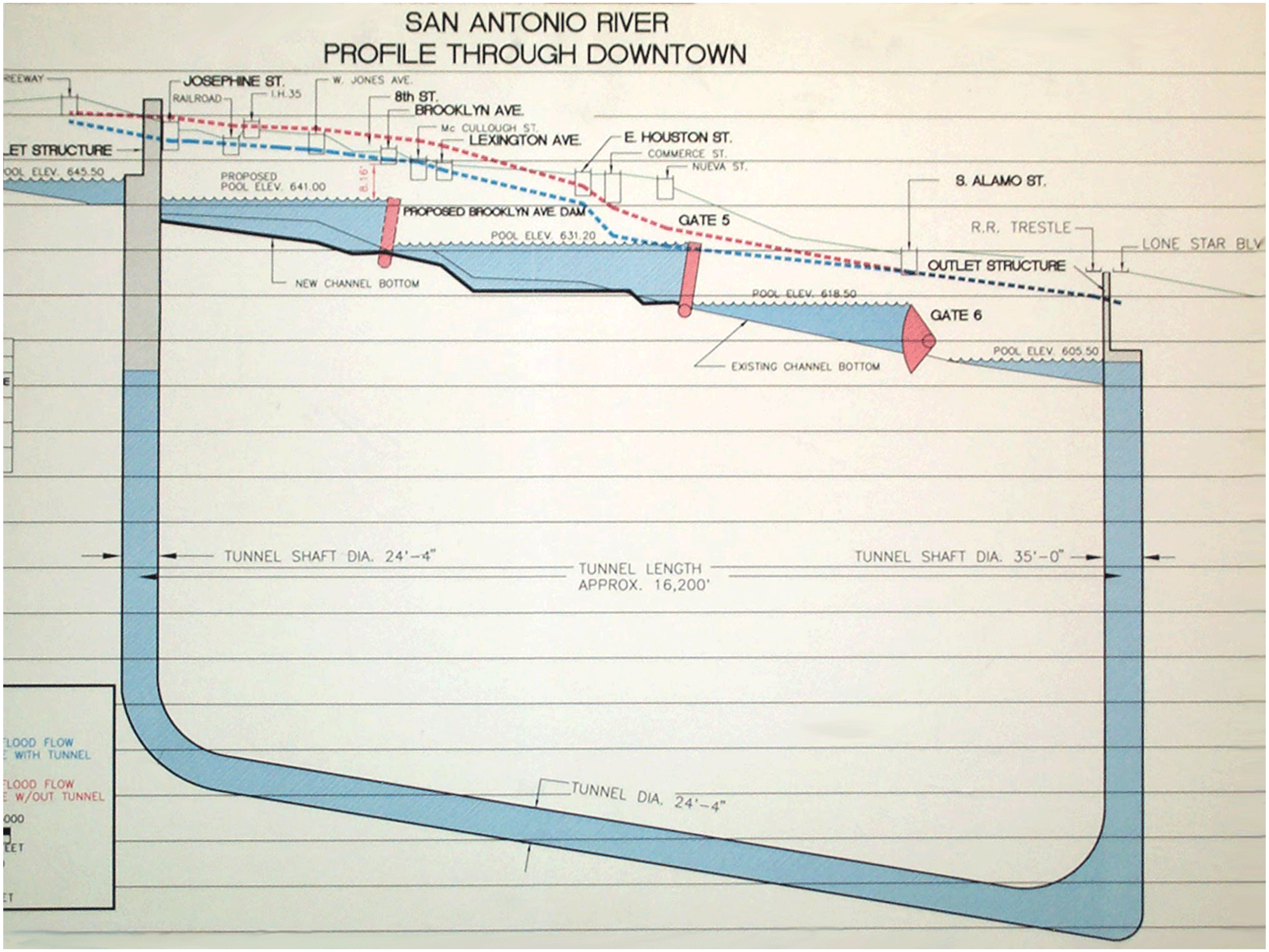


Figure 4-3: San Antonio River Tunnel (SARA, 2006)

5.0 MANAGEMENT MEASURES FOR POINT SOURCES

Because point source discharges occur at known locations, they are generally more easily identified, and treatment alternatives are usually more straightforward. As discussed in the previous sections, the San Antonio Zoo is the only known significant point source for indicator bacteria located in the WPP study area. However, the Zoo is not a typical point source, and it could arguably be classified as a nonpoint source as well. The Zoo is not a well-regulated municipal or industrial discharger or wastewater treatment facility. Instead, the Zoo is essentially a microcosm of a river basin, where an internal waterway accepts bacterial loads from dense animal populations. The headwater of the internal waterway is a well discharging from the Edwards Aquifer. The "nonpoint" sources are animal wastes that may be directly deposited into the waterway, or indirectly received when runoff reaches the waterway from animal pens during wash-down or storm events. The degree of loading can vary throughout the year as environmental conditions change and as wild birds, such as egrets, migrate in and out of the park. However, this entire bacteria load enters the river through two discrete outfalls, which is why the Zoo can also be classified as a point source.

Although this section focuses on the San Antonio Zoo, the technologies described here could be applicable to other, similar sources of bacteria pollution.

5.1 ZOO EXISTING CONDITIONS

The San Antonio Zoo is located within Brackenridge Park, near the intersection of the McAllister Freeway (US 281) and Hildebrand Avenue. The Zoo is a nonprofit 501(c)(3) organization, with a land lease from the City of San Antonio. According to Zoo literature, the Zoo's 56 acres accommodate over 3,500 animals as regular residents, and 850,000 human visitors each year. In addition, there exists a large population of birds that occupy the tree canopy surrounding the Zoo. Particularly noticeable is a large, undocumented, population of egrets that nests in and around the Zoo during summer months. The Zoo's internal waterway, supplied by pumpage from the Edwards Aquifer, and teeming with tilapia and other life, is one of the Zoo's many attractions. It is this internal waterway and its drainage area that have been identified as a major source of bacteria loading to the San Antonio River. The Zoo's waterway discharge typically contains bacteria levels 1 to 2 orders of magnitude higher than the state's criteria for contact recreation.

5.1.1 Dry Weather Conditions

The San Antonio Zoo is currently permitted to withdraw 2,750 ac-ft/year from the Edwards Aquifer. This withdrawal occurs via pumping at the Hippo Well House nonstop throughout the year so that the average flow rate is 1700 gpm (2.45 MGD). Due to fluctuations in the level of the Edwards Aquifer, the pump must be adjusted on a regular basis in order to maintain consistent flow rates. These adjustments, which are performed at least once per month, generally keep flow rates between 1400 and 2200 gpm at all times. The well is artesian, and if the pump is taken out of service, the well will continue to discharge from between zero and about 600 gpm depending upon aquifer level.

Another source of dry weather flow is a second, smaller artesian well. This well is located within an embayment on the internal waterway and is un-pumped and unmonitored. A third source of dry weather flow comes from animal pen wash down. According to the Zoo, many animal pens have been tied into the City's sanitary sewer system. However, a number of large mammal pens (lions, tigers, antelopes, etc.) still drain to the Zoo waterway. Also, all of the pens located adjacent to the Zoo's waterway drain directly to the waterway. These pens typically contain waterfowl, reptiles, and small mammals. The hippopotamus pen also drains to the Zoo waterway, but the hippopotami are going to be relocated in the near future. In the immediate vicinity of the Hippo well, a looped channel at the headwater of the internal waterway passes through numerous exhibits containing hundreds of waterfowl and other birds.

For conceptual design purposes, the average flow leaving the Zoo is estimated at 2080 gpm (3 MGD). This flow leaves the Zoo at two unmonitored locations. The primary outfall is located by the small-gauge train station near the Zoo entrance. The rear outfall is located at the east end of the Zoo grounds near the Hixon bird house. Under normal conditions the flow at the rear outfall is only a trickle. For design purposes, it is assumed that nearly 100% of the flow discharges from the primary outlet. A map of the Zoo grounds and internal waterway is shown in Figure 5-1.

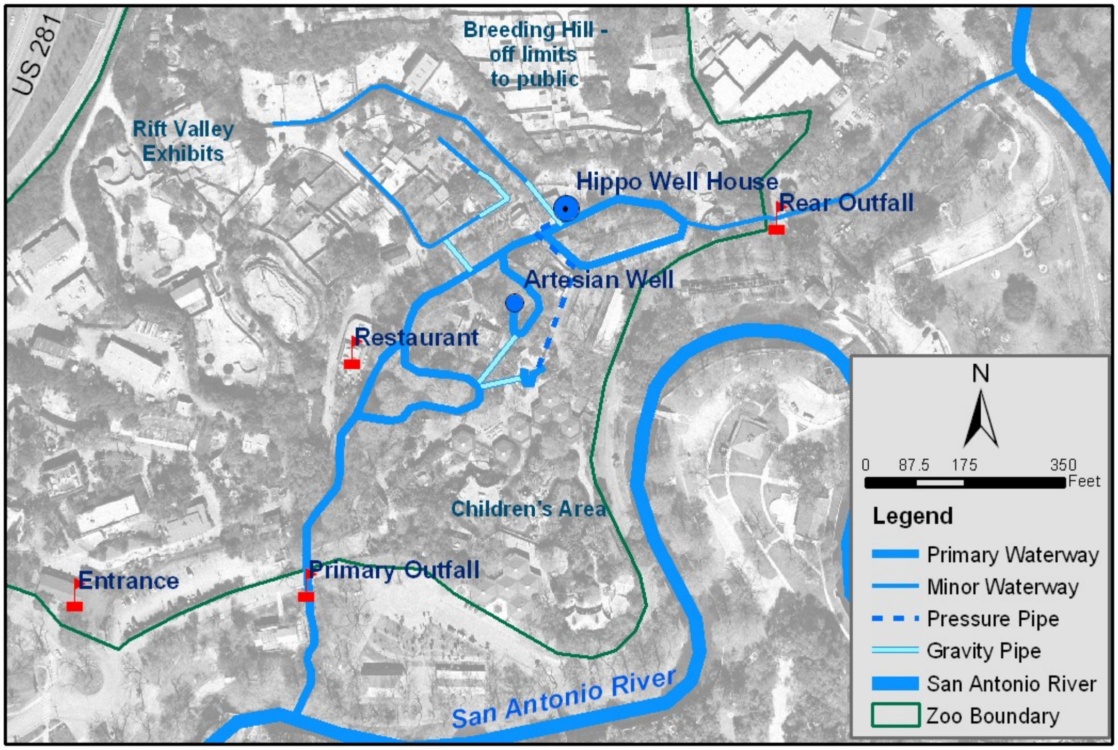


Figure 5-1: Zoo Grounds and Internal Waterways

5.1.2 Wet Weather Conditions

Based on topographic data and site investigations, an estimated 16 acres drain to the Zoo waterway during storm events. This area includes most of the pedestrian walkways, visitor parking area, all of the animal pens mentioned in the previous section, a small portion of the Zoo maintenance area, and the "Breeding Hill" area, as shown in Figure 5-2. For the purpose of analyzing stormwater treatment alternatives, the 2-year, 24-hour storm was considered. This is the storm referenced by TCEQ Rule §317.4 for sizing wastewater treatment facilities to treat inflow and infiltration. The peak flow and runoff volume for this event were estimated by using the Hydraulic Engineering Center's Hydrologic Modeling System (HEC-HMS). A detailed description of the procedures and assumptions used in this modeling analysis are provided in Appendix C. The resulting peak flow is 55.5 cfs and the runoff volume is 3.74 ac-ft (not including the base flow from the Zoo's well).

During larger storm events, it is possible that much of the Zoo grounds will be inundated by the rising waters of the San Antonio River. 100-year and 500-year flood plain boundaries were provided by SARA. These delineations are shown in Figure 5-2.

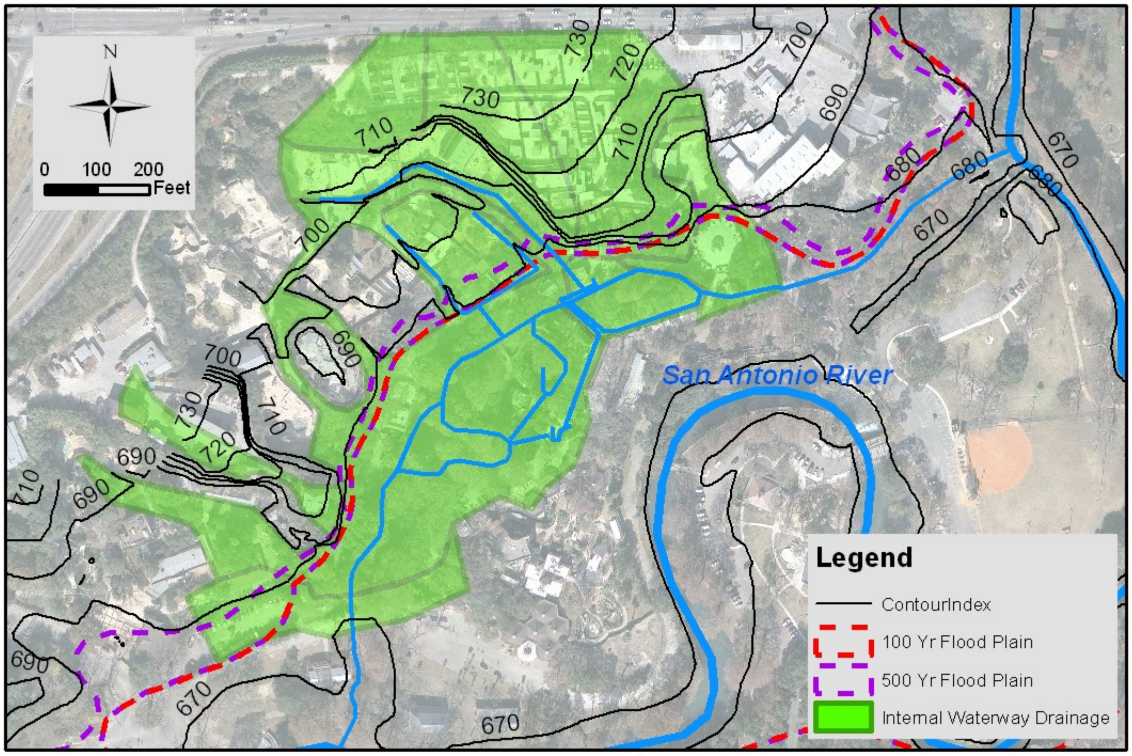


Figure 5-2: Internal Drainage to Waterway and Major Flood Plains

5.1.3 Water Quality

For dry weather conditions, the water quality in the Zoo waterway *appears* relatively good when compared to typical stormwater quality, due to low turbidity. Nonetheless, the flow contains high levels of fecal coliform and *E. coli*. According to monitoring performed by SAWS from 2003-2005, the average fecal coliform level in Zoo effluent was 22,000 org/100mL (15,000 org/100mL geometric mean). As part of this project, SARA performed additional monitoring in order to help verify the fecal coliform level, as discussed in detail in Section 3.0. According to this monitoring, concentrations of fecal coliform typically varied from 5,000-30,000 org/100mL, with the higher concentrations occurring in warmer months.

Total suspended solids (TSS), biochemical oxygen demand (BOD), and ultraviolet transmission (UVT) are three water quality parameters that are particularly important for the design of disinfection treatment systems. For dry weather conditions, TSS has been consistently measured at less than 10 mg/L, and UVT has been measured by a grab sample at 95%. BOD values have not been measured, but are estimated at less than 10 mg/L. These values suggest that the Zoo water is relatively clean and clear when compared to typical urban runoff or untreated wastewater. Water quality was measured by SARA during a storm event, as described in Section 3.4. During this wet weather event, TSS concentrations of up to 180 mg/L and 807 mg/L were measured at the primary and secondary outfalls, respectively. BOD and UVT would be expected to increase also, though this has not been measured.

5.2 ZOO TREATMENT ALTERNATIVES

The Zoo presents two unique treatment challenges. The first challenge is the Zoo's dry-weather base flow, which is characterized by a continuous 1700 gpm flow rate, low turbidity, and high bacteria counts. The second challenge is the Zoo's wet weather runoff. This flow does not occur continuously, but when it does occur, the peak flow rate is exceptionally high due to the highly impervious Zoo drainage area. Also, under stormwater conditions, the quality of the Zoo's discharge decreases significantly because of sediments and other pollutants that are washed off the land surface and/or resuspended from the channel bottom. The following sections describe treatment alternatives that were considered for one or both of these conditions. The treatment alternatives focus on disinfection of the Zoo's high bacterial content. Generally, it is assumed that the other characteristics of the Zoo waste stream are acceptable.

5.2.1 Chlorination

Chlorination is the most conventional method for the disinfection of water. Because of its potency, reliability, and low cost, it is a common choice for projects where a high level of disinfection is required, such as at water and wastewater treatment plants. However, chlorination has a number of disadvantages when compared to other alternatives. First, chlorine gas poses a significant safety risk. The gas must be carefully transported and stored because any leaks can be potentially fatal. For this reason, chlorine is sometimes applied in liquid form, as sodium hypochlorite (bleach). Although not as hazardous as chlorine gas, sodium hypochlorite is highly corrosive and more expensive. Another disadvantage of chlorine systems is that they require a contact chamber, with a minimum residence time of 20 minutes for disinfection of wastewater according to TCEQ design criteria. For a flow of 3 MGD, this equates to a 5,600 cubic foot chamber.

Another disadvantage of chlorine is that chlorinated water can be harmful to aquatic life. Therefore, with conventional disinfection applications in Texas, an additional chemical, such as sodium bisulfite, must be added after the disinfection step to dechlorinate the water prior to discharge to the receiving stream. Because of the multiple steps and multiple chemicals required for chlorine disinfection, it would be a relatively high maintenance treatment alternative. Due to the disadvantages of chlorination for this type of application, it is not a recommended alternative.

5.2.2 Chloramination

Chloramines are a relatively weak disinfectant formed by the addition of ammonia and chlorine gas. To be effective, they must be used in high concentration or in conjunction with another disinfectant. Chloramines are generally only used in potable water treatment applications where they are advantageous because they result in fewer disinfection by-products than regular chlorination and the residual disinfectant concentration is relatively persistent. Chloramination would provide no significant advantages for treating the Zoo effluent and is, therefore, not a recommended treatment alternative.

5.2.3 Ultraviolet (UV) Disinfection

After chlorination and chloramination, UV is probably the most commonly used method of disinfection today. There are several advantages to UV including: no chemicals are required, maintenance is relatively minimal, and capital costs are relatively low. There are no major disadvantages, although energy costs are considered to be higher than chlorination because of the electrical power required to operate the UV lamps. One factor that affects the feasibility and cost of UV treatment is the UV transmission (UVT) value of the water to be treated. This water quality parameter is basically a measure of water clarity, and waters that are very clear tend to have a high UVT. Waters that are murky will have a lower UVT value and will be more difficult to treat. One possible solution to low UVT values is pretreatment, in the form of sedimentation and/or filtration, but this would require additional unit processes, space, and capital expenditures. At the San Antonio Zoo, UVT values have been measured under dry weather conditions. The laboratory analysis, performed by Aquionics, Inc., resulted in a UVT value of 95%. This value is relatively high, compared to UVTs of 70% or less, which are not uncommon in wastewater treatment applications. This would suggest that UV disinfection is very well suited to treat Zoo effluent under dry weather conditions.

Under wet weather flow conditions, TSS concentrations at the Zoo have been observed to increase by two orders of magnitude (up to 807 mg/L). Since the maximum TSS concentration typically recommended for UV applications is 30 mg/L, UV would not be feasible to treat these flows directly. Instead the flows would have to be pretreated using some form of sedimentation and/or filtration.

There are two primary categories of UV disinfection equipment. The first category is low-pressure, open-channel UV disinfection. This category, which is probably the most common type of UV disinfection for wastewater facilities, uses large banks of lamps placed in an open concrete channel. As water flows through the channel, bacteria are eliminated as they come into close contact with the lamps. Figure 5-3 shows a typical low pressure UV disinfection channel. A cost estimate for a UV treatment facility designed to treat the dry weather design flow of 3 MGD is presented in Table 5-1.

Figure 5-3: Low Pressure UV Disinfection System

Table 5-1: Cost Estimate for 3 MGD Low-Pressure UV Treatment Facility

Item Number	Description	Unit Quantity	Unit Price	Component Price	Total Price
1	3 MGD Low Pressure UV				
	a. UV Disinfection Package - Lamps, controls, power	LS	LS	$157,500	
	b. 18'x2'x5' concrete channel	16 yd3	$400.00 /yd3	$6,400	
	c. Rain shelter (roof)	200 ft2	$35.00 /ft2	$7,000	
	d. Fence and gate	60 ft	$20.00 /ft	$1,200	
	e. Overhead lifting equipment	LS	LS	$10,000	
	f. Dewatering/diversion	LS	LS	$25,000	
	g. Excavation and erosion control	LS	LS	$40,000	
	h. Electric supply to site	LS	LS	$50,000	
	i. Floodproofing	LS	LS	$75,000	
	j. Control Building	LS	LS	$20,000	
	Total			$392,100	$392,100
	TOTAL COMPONENT COST				$392,100
	Mobilization, Bonding, and Insurance (5%)				$19,605
	Contingency (50%)				$196,050
	TOTAL CONSTRUCTION COST				$607,755
	Fees (Engineering, SurveyingGeotechnical Inspection, Testing) (25%)				$91,163
	TOTAL PROJECT COST				$698,918

The second category is medium-pressure, closed-pipe UV disinfection. The medium pressure lamps are much more powerful, yet less energy efficient than the low-pressure systems. The advantage to these more powerful lamps is that they can result in a system that requires less space and maintenance than a low-pressure system. The lamps are generally enclosed inside a small pressure vessel in order to minimize sizing requirements. This requires that the flow be pumped under pressure, through the UV disinfection vessel, which could be a disadvantage if pumps are not otherwise needed. Figure 5-4 shows a typical medium pressure UV disinfection facility. For medium pressure systems, it is also recommended that the treatment chamber be kept in a small building. Based on these criteria, a cost estimate for a 3 MGD medium-pressure UV treatment facility is presented in Table 5-2.

Figure 5-4: Medium Pressure UV Disinfection System

Table 5-2: Cost Estimate for 3 MGD Medium-Pressure UV Treatment Facility

Item Number	Description	Unit Quantity	Unit Price	Component Price	Total Price
1	3 MGD Medium Pressure UV				
	a. UV Disinfection Package - Lamps, controls, power	LS	LS	$105,000	
	b. Treatment Building	300 ft2	$100.00 /ft2	$30,000	
	c. Excavation and erosion control	LS	LS	$20,000	
	d. Electric supply to site	LS	LS	$50,000	
	Total			$205,000	$205,000
2	Pump Station				
	a. Non-clog submersible pumps	2 ea	$24,500.00 ea	$49,000	
	b. Electric and instrumentation	LS	LS	$50,000	
	c. 10" Ductile iron pipe	20 ft	$100.00 /ft	$2,000	
	d. Dewatering/diversion	LS	LS	$25,000	
	e. Channel/wetwell improvements	LS	LS	$50,000	
	f. Floodproofing	LS	LS	$75,000	
	g. Valves and appurtances	LS	LS	$10,000	
	Total			$261,000	$261,000
	TOTAL COMPONENT COST				$466,000
	Mobilization, Bonding, and Insurance (5%)				$23,300
	Contingency (50%)				$233,000
	TOTAL CONSTRUCTION COST				$722,300
	Fees (Engineering, Surveying, Geotechnical Inspection, Testing) (25%)				$180,575
	TOTAL PROJECT COST				$902,875

Low pressure lamps are generally considered to be more efficient because they are capable of focusing the majority of their output at 260 nanometers, which is believed to be the most lethal wavelength. Medium pressure lamps are generally considered less efficient because their output occurs over a wide range of wavelengths, not all of which are lethal to pathogens. Medium pressure lamps, however, result in pathogen inactivation that is less susceptible to photoreactivation. Photoreactivation occurs when UV (especially low pressure UV) treated bacteria repair themselves as a result of exposure to sunlight (Zimmer, 2002). Photoreactivation has generally been shown to be negligible for medium pressure UV systems, except when small UV doses are used (<5 mJ/cm^2). The effects of photoreactivation are small enough that they should not preclude the use of either low or medium pressure UV. However, because of the significant potential for exposure to sunlight at the Zoo outfalls, the UV doses should be sufficient, so that photoreactivation will not occur.

5.2.4 Ozonation

Ozone is a powerful but less commonly used disinfectant. Ozone is most commonly used in applications that require the production of “ultra-pure” water because it can help achieve high water clarity, complete odor removal, and effluents with high levels of dissolved oxygen. These characteristics are appealing from the standpoint of water recycling, but it is possible that a cheaper alternative such as UV may also provide satisfactory results. In fact, the primary disadvantage of ozonation is the capital cost, which is typically twice that of UV. An example ozone treatment facility is shown in Figure 5-5.

Figure 5-5: Ozone Side stream Contactor and Degasser

As a chemical, ozone gas is not considered to be as dangerous as chlorine. Also, ozone leaves no harmful residual that must be removed prior to discharge. Like chlorine, ozone requires a contact tank, but the required contacting time can be much less, typically around 5 minutes. During the initial contact period any ozone that escapes the water column into the air must be collected and treated by an ozone destroyer.

According to the manufacturers of ozone equipment, it is always necessary to perform pilot testing before ozone equipment can be accurately sized. In general, high TSS and BOD levels will result in higher ozone demand and correspondingly larger and more expensive ozonation equipment. Because of this, storm flows would require pretreatment in the form of sedimentation and/or filtration to reduce TSS and BOD levels in order to be treated economically with ozone. Assuming no pretreatment, a cost estimate for a 3 MGD ozone treatment facility is presented in Table 5-3.

Table 5-3: Cost Estimate for 3 MGD Ozone Treatment Facility

Item Number	Description	Unit Quantity	Unit Price	Component Price	Total Price
1	3 MGD Ozone Treatment System				
	a. Ozone generater, sidestream, diffuser, off-gas treatment	LS	LS	$427,500	
	b. Treatment Building	300 ft2	$100.00 /ft2	$30,000	
	c. Excavation and erosion control	LS	LS	$20,000	
	d. Dewatering/diversion	LS	LS	$25,000	
	e. Channel/wetwell improvements	LS	LS	$50,000	
	f. Floodproofing	LS	LS	$75,000	
	g. Electric supply to site	LS	LS	$50,000	
	Total			$677,500	$677,500
	TOTAL COMPONENT COST				$677,500
	Mobilization, Bonding, and Insurance (5%)		100	$0	$33,875
	Contingency (50%)				$338,750
	TOTAL CONSTRUCTION COST				$1,050,125
	Fees (Engineering, Surveying, Geotechnical Inspection, Testing) (25%)				$262,531
	TOTAL PROJECT COST				$1,312,656

5.2.5 Treatment Wetlands

Treatment wetlands are an alternative to traditional mechanical and chemical treatment systems. Advantages of wetlands include their aesthetic value and simplicity of operation. However, wetlands also have considerable disadvantages, that may make them infeasible; and in some cases, “the designer will have to convince the public that wetlands are not a viable option, in spite of their inherent [aesthetic] appeal” (EPA, 2000). The primary disadvantages of wetlands are their large areal requirements and their inability to consistently meet stringent discharge requirements. While some variability in effluent quality may be permissible and still allow for satisfactory TMDL reductions, the large spatial requirement of a wetland may make it unrealistic.

Treatment wetlands remove bacteria through promoting the natural decay of bacteria over time. Sunlight, biological activity, and sedimentation are three of the primary factors that encourage bacteria removal in wetland systems. Although wetland systems have been widely used in waste water treatment for over twenty years, wetlands are complex systems and their performance is difficult to quantify. Wetland design has yet to be well characterized by published design equations (EPA, 2000). There is also a real concern that wetlands will attract waterfowl, which can be a source of additional fecal contamination.

Bacteria can typically be found either suspended in the water column or attached to suspended sediment. Bacteria associated with total suspended solids (TSS) can usually be removed through settling. Once settled, the bacteria may eventually degrade. However, because the Zoo waterway has a very low TSS concentration when compared to typical wastewater or stormwater levels, it is unlikely that settling alone will achieve a significant bacteria reduction. Bacteria suspended in the water column can be removed through biological activity, solar irradiation, and natural die off over time. This process can be represented by a first order degradation equation, as shown below:

$$C(t) = C_0 * e^{-kt}$$

where… $C(t)$ = the concentration at a given time "t"
C_0 = the initial bacteria concentration
k = the first order decay coefficient (1/day)
t = time (days)

A first order decay coefficient "k" of 1.0 is a reasonable assumption based on information and measurements collected during the TMDL modeling project. Using the preceding equation and decay coefficient, the required hydraulic detention time of the wetland can be approximated. For a 97% removal (C/C_0 =0.97), the required residence time is 3.5 days. For our design flow rate of 3.0 MGD, and assuming an average wetland depth of 2 feet, this equates to a 16-acre wetland.

In addition to the theoretical wetland sizing, two case studies were examined to estimate the size of wetland required (Bays, 2003; Stewart Scott, 2003). These case studies suggest that satisfactory bacteria removals can be achieved in wetland systems when the hydraulic loading rate is somewhere in the range of 0.3 and 0.5 feet/day. For the San Antonio Zoo, this equates to a required wetland area of 15-30 acres to achieve removals from 94%-99%.

There are two primary types of constructed wetlands. Free water surface (FWS) wetlands are similar to a natural wetland because they are comprised of a large shallow pool of open water, and water flows through the stems of plants attached to the soil in the bottom of the pool. An example FWS wetland is shown in Figure 5-6. Vegetated submerged bed (VSB) wetlands are depressions filled with a sand, soil, and/or gravel media. Wetland plants are planted at the top of this media, but all water stays below the bed surface, contacting only the soils and roots of plants. In practice, VSBs are very similar to bioretention beds with under drains. A VSB can cost significantly more than an equivalently sized FWS because of the cost of added excavation and media material. In theory, either type of wetland could be used at the San Antonio Zoo, however, the high water table around the San Antonio River could limit the depth available for a VSB bed. Also, VSBs may require a longer contact time (larger volume), since they cannot take advantage of solar radiation, a significant factor in bacteria decay. An example VSB is shown in Figure 5-7.

According to the EPA (2000) "constructed wetlands are an appropriate technology for areas where inexpensive land is generally available and skilled labor is less available." Unfortunately, this is not generally the case in the vicinity of the Zoo. At the Zoo, land is neither inexpensive nor sufficiently available. To treat the 3 MGD dry weather flow, at least 15 acres of wetlands would be required. At the Zoo's primary outfall, only about 1.6 acres of land are available, and this would require the removal of existing parking areas and two pavilions. A treatment wetland would, therefore, have to be located away from the primary outfall, possibly somewhere else in Brackenridge Park. In this case the flow from the primary outfall would have to be pumped via a force main to the selected wetland site. Figure 5-8 provides an example of what this type of arrangement might look like, but should not be considered an endorsement of the particular locations shown.

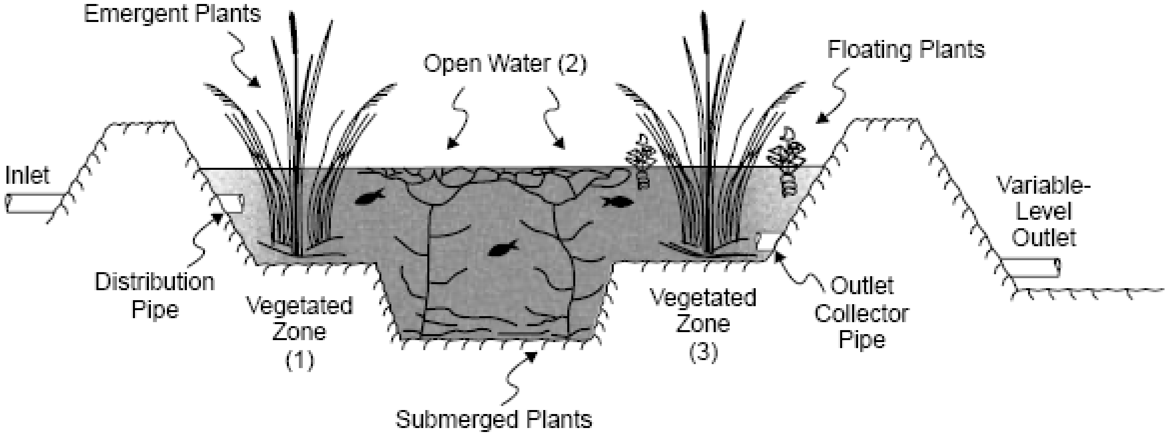


Figure 5-6: Free Water Surface (FWS) Wetland (EPA, 2000)

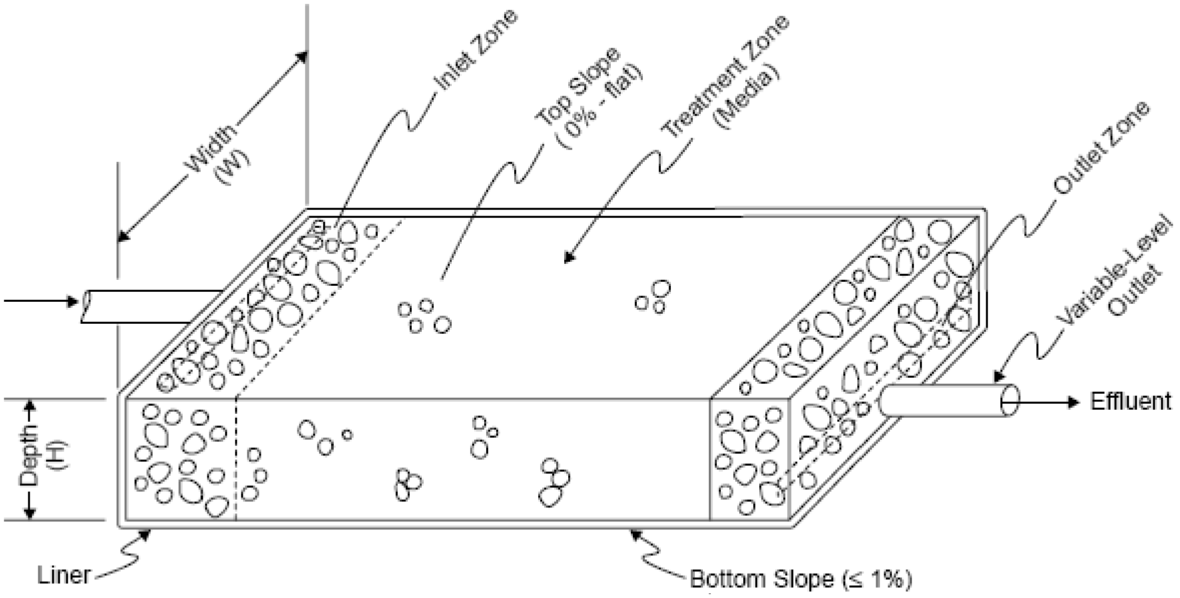


Figure 5-7: Vegetated Submerged Bed (VSB) Wetland (EPA, 2000)

Costs for the wetland alternative would include a pump station, force main, site clearing, excavation, and preparation. Potentially, the greatest cost in a wetland installation would be the installation of a clay or synthetic liner to prevent rapid groundwater recharge. However, since the soil types in the vicinity of Zoo are clays, as shown in Figure 5-8, these soils may be able to be compacted to form a satisfactory liner. A cost estimate for a 16 acre FWS wetland (without synthetic liner) with pump station and forcemain is shown in Table 5-4.

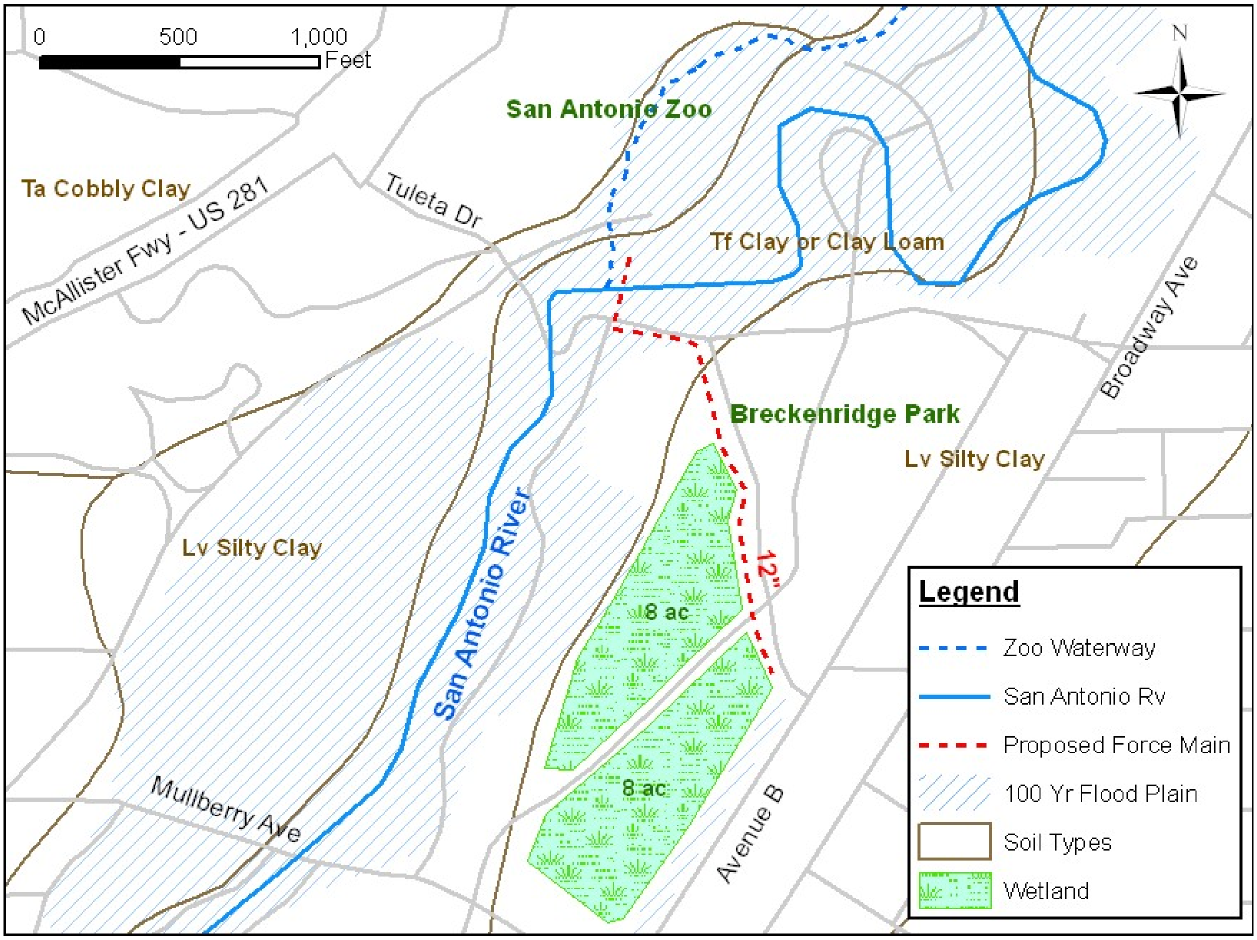


Figure 5-8: Example Wetland Site Alternative

Table 5-4: Cost Estimate for 16 Acre Free Water Surface Wetland

Item Number	Description	Unit Quantity	Unit Price	Component Price	Total Price
1	Wetland				
	a. Site Clearing	16 ac	$5,000.00 /ac	$80,000	
	b. Control Structures and Plumbing	LS	LS	$140,000	
	c. Earthwork (excavation, grading, compaction, etc.)	16 ac	$17,000.00 /ac	$272,000	
	d. Planting soil (6 inch layer)	16 ac	$3,500.00 /ac	$56,000	
	e. Wetland Plants	16 ac	$5,000.00 /ac	$80,000	
2	Pump Station				
	a. Non-clog submersible pumps	2 ea	$35,000.00 ea	$70,000	
	b. Electric and instrumentation	LS	LS	$75,000	
	c. 10" Ductile iron pipe	20 ft	$60.00 /ft	$1,200	
	d. Dewatering/diversion	LS	LS	$40,000	
	e. Floodproofing	LS	LS	$75,000	
	f. Channel/wetwell improvements	LS	LS	$50,000	
	g. Valves and appurtances	LS	LS	$10,000	
3	Force Main				
	a. Valves and appurtances	LS	LS	$20,000	
	b. Bore and casing	150 ft	$300.00 /ft	$45,000	
	c. 12-Inch force main	1800 ft	$100.00 /ft	$180,000	
	Total			$1,194,200	$1,194,200
	TOTAL COMPONENT COST				$1,194,200
	Mobilization, Bonding, and Insurance (5%)				$59,710
	Contingency (50%)				$597,100
	TOTAL CONSTRUCTION COST				$1,851,010
	Fees (Engineering, Surveying, Geotechnical Inspection, Testing) (25%)				$462,753
	TOTAL PROJECT COST				$2,313,763

5.2.6 Diversion to Sanitary Sewer

Diversion of the 3 MGD dry weather flow to the sanitary sewer system was also considered. As discussed previously, a number of animal pens have already been diverted away from the waterway and into the City's sanitary sewer system. The primary limitation to sanitary sewer diversion is the flow capacity of the sewers. The sewer main that flows through the Zoo is 18 inches in diameter at the primary outfall. The capacity of this sewer is well below what would be required to accept the Zoo's discharge. Attempting to upgrade this sewer would be cost prohibitive.

An alternative to the 18-inch sewer is a 54-inch sewer on the east side of the San Antonio River, directly opposite from the Zoo. This 54 inch pipe runs at a 0.24% slope, and would be expected to have a total capacity of over 60 MGD. However, according to SAWS, this sewer is already at capacity during rainfall events. SAWS has indicated that the Zoo's baseflow of 3MGD could exceed the collection system's capacity. This limitation would certainly be problematic, especially if collection and conveyance of stormwater from the Zoo is ultimately required.

There are also significant costs associated with this alternative. The largest cost would be the impact fee, required by SAWS, to help recover the capital costs associated with providing service to new developments. The 3 MGD discharge from the Zoo would result in an impact fee of $10,825,000. In addition, the flow could be subject to SAWS' Wastewater Fee and Surcharge, estimated at $145,843/month (SAWS, 2006). Connecting the Zoo's outfall to this sewer would also involve a force main (probably 12-inch pipe plus casing) bored underneath the San Antonio River, which could be cost prohibitive, but would need to be determined based on a site specific evaluation. Another disadvantage of this alternative is that it would remove 3 MGD of base flows from the San Antonio River (flows that could be beneficial if properly treated). Due to the financial and technical limitations of this alternative, it is not recommended.

5.2.7 BMPs Inside the Zoo

The primary source of fecal coliform bacteria from within the Zoo is the fecal deposition of the animals living there. In theory, if this fecal deposition can be prevented from reaching the Zoo's internal waterway then disinfection would not be required at the waterway's outfall. To this end, the Zoo has already undertaken best management practices (BMPs), by rerouting several outdoor animal pens to the sanitary sewer system. The Zoo, with technical and financial assistance from SAWS, also rerouted interior hippo pool water to a lift station for diversion to the sanitary sewer system. Construction is presently underway on a new hippo exhibit that will remove this potential source of bacteria from the internal waterway.

As discussed previously, the Zoo has already diverted the drainage from a number of animal pens away from the internal waterway and into the sanitary sewer system. The pens that have been diverted are typically large mammal pens located uphill of the waterway. However, there are a small number of large mammal pens that are believed to still drain to the internal waterway. These remaining pens could also be diverted to the sanitary sewer, or possibly to small wetlands or bioretention facilities capable of treating the relatively small pen wash-down volumes. It is relatively easy to divert these large mammal pens, because they are already connected to a conveyance system of channels and culverts. However, these "uphill" pens represent only a small fraction of the pens that are currently connected to the internal waterway

Most of the pens that now drain to the internal waterway are those pens located directly on the water's edge. These pens cannot be easily diverted because the land naturally slopes toward the waterway. To divert wash down water from these pens, they would have to be re-graded away from the waterway, and into a collection system or treatment BMP. Such an undertaking would require modifications to numerous animal exhibits, and may not be justifiable in light of other alternatives.

Finally, if all wash down from pen surfaces could be diverted away from the waterway, there would still be the issue of direct animal deposition into the waterway. Numerous zoo birds and wild birds are known to spend much of their time in the water or in trees directly above the waterway. It is expected that any plan to remove or limit the movement of these birds over the waterway would not be desirable from the standpoint of the Zoo.

In summary, the deployment of BMPs throughout the interior of the Zoo will be limited. Some of the sources of fecal contamination cannot be removed without negatively impacting existing

Zoo exhibits. Selection of just a few of the more acceptable BMPs may have some positive effect on water quality within the internal waterway, but additional treatment at the outfall is still expected to be required.

It is recommended that the Zoo regularly inspect and perform maintenance of on-site sumps and interceptors, which collect animal husbandry waters from various zoo pens. This maintenance is required per City Ordinance every 90 days to address system overflows during rain events. Pursuant to San Antonio City Code, Chapter 34, Article V, Division 4, Section 34-518(1)(c); *A generator of greasetrap waste or grit trap waste shall have traps serviced as frequently as necessary to prevent bypass or overflow, and to insure proper operation of the trap. Such generators shall, at a minimum, have grease traps and grit traps serviced quarterly or as approved by the director in accordance with all other provisions of this division.* This will ensure that the Zoo's connections to the sanitary sewer are functional and will prevent unintentional discharges.

5.2.8 Treatment of Stormwater Flows

The cost estimates provided in the previous sections describe treatment alternatives designed for the dry weather, base flow condition. By themselves, these prescribed systems will not be capable of providing a significant level of treatment during storm events. Runoff events, as described previously (see Section 3.4) result in flows and pollutant concentrations several times higher than under dry weather conditions. Therefore, if stormwater flows from the Zoo are to be effectively treated, additional treatment mechanisms must be considered.

The first option considered was "in-line filtration". This system would filter out TSS and other pollutants prior to final disinfection. Such a system would improve water quality but would not reduce the peak flow. Because of the improved water quality, a UV or ozone disinfection system may be effective, though it would now have to be designed for the peak flow event.

A second option would be to bypass runoff flows into a detention facility. The detention facility could be a wet pond, wetland, or other structure designed to hold and treat the runoff volume from the design storm event. The facility would function similarly to urban runoff BMPs. A diversion structure and pump station would be required to divert the water from the outfall channel to the detention facility during storm events. The stormwater runoff would remain in the facility for a period of time adequate to achieve a satisfactory improvement in water quality primarily through sedimentation. After this period of detention, the water could be released directly into the San Antonio River, or it could be slowly returned to the Zoo's primary waterway. If the runoff volume is returned to the primary waterway, it could then additionally receive whatever treatment is in place to disinfect the dry weather base flow.

In addition to the two options described above, it may also be possible to reduce peak flows and improve runoff water quality by detaining runoff within the Zoo grounds. Detention facilities placed strategically in the Zoo grounds could reduce the size of the facilities required at the Zoo outfall. Though space is limited, there are a few potential storage areas inside the Zoo, including the moats of large animal pens, and along drainage pathways from uphill areas like Breeding Hill and the Zoo maintenance area. BMPs such as sand filter ponds and wet ponds would probably provide the best opportunity to detain runoff and also improve water quality. Any such practices would require close coordination with Zoo officials to ensure that Zoo facilities are not negatively impacted.

5.2.9 Water Recycling

Water recycling would not have a direct positive impact on water quality, but it could have a positive economic impact. Water purchases are a major expenditure for the Zoo and any reduction in water use could help offset the cost of installing and operating treatment systems. Furthermore, if water can be recirculated before receiving full treatment, then the size and cost of the treatment system can be significantly reduced. A potential problem with water recycling is that it might degrade water quality in the Zoo's internal waterway such that the animal health, water clarity, or odor becomes a concern. Additional water quality monitoring and analysis will have to be performed in order to determine the severity and possible remedies for these problems. Another disadvantage of this alternative is that it would remove base flows from the San Antonio River (flows that could be beneficial if properly treated). For the purposes of preliminary investigation, a recycle system of 2 MGD was considered. This system would return water from the primary outfall to the Hippo Well House. Estimated costs associated with this system are included in Table 5-5.

Table 5-5: Cost Estimate for 2 MGD Recycle System

Item Number	Description	Unit Quantity	Unit Price	Component Price	Total Price
1	Pump Station				
	a. Non-clog submersible pumps	2 ea	$26,250.00 ea	$52,500	
	b. Electric and instrumentation	LS	LS	$75,000	
	c. 10" Ductile iron pipe	20 ft	$60.00 /ft	$1,200	
	d. Dewatering/diversion	LS	LS	$25,000	
	e. Channel/wetwell improvements	LS	LS	$50,000	
	f. Floodproofing	LS	LS	$75,000	
	g. Valves and appurtances	LS	LS	$10,000	
2	Return Main				
	a. Valves and appurtances	LS	LS	$20,000	
	b. Bore and casing	100 ft	$350.00 /ft	$35,000	
	c. 12-Inch force main (placed in waterway bed)	1000 ft	$100.00 /ft	$100,000	
	Total			$443,700	$443,700
	TOTAL COMPONENT COST				$443,700
	Mobilization, Bonding, and Insurance (5%)				$22,185
	Contingency (50%)				$221,850
	TOTAL CONSTRUCTION COST				$687,735
	Fees (Engineering, Surveying, Geotechnical Inspection, Testing) (25%)				$171,934
	TOTAL PROJECT COST				$859,669

5.3 SUMMARY OF ZOO TREATMENT ALTERNATIVES

This section of the report considered several treatment options for disinfection of the flow leaving the San Antonio Zoo. As discussed previously, the cost estimates have been developed based on a dry weather flow of 3 MGD. Under runoff conditions, flows become much greater, and water quality deteriorates so that detention, settling, and possibly filtration will be required prior to disinfection, necessitating substantial additional costs. Furthermore, under heavy runoff conditions, significant flow also leaves the Zoo via the secondary outfall. If runoff flows are to be treated, then all flow must be routed to the primary outfall or additional treatment units would be required at the secondary outfall. Therefore, treatment of storm flows is not recommended at this time.

Table 5-6 ranks and the three recommended Zoo treatment alternatives. Low pressure UV is the highest ranked choice because it is a fairly common and accepted method of disinfection, with relatively low costs and low maintenance. Medium pressure UV would require pumps and additional costs, but is otherwise similar to low pressure UV, and may be simpler to maintain. The ozone alternative has merits similar to UV, but it is a less common method of municipal disinfection and has a substantially higher price. If water recycling at the Zoo was to be considered, then ozone may be more advantageous since it would result in the highest water quality for the recycled stream (high dissolved oxygen and low biological oxygen demand). Some pilot testing would probably need to be performed prior to final design of an ozone system.

Table 5-6: Treatment Alternatives Summary

Rank	Treatment Alternative	Cost Estimate	Reliability
1	Low-Pressure UV Disinfection	$700,000	High
2	Medium-Pressure UV Disinfection	$900,000	High
3	Ozone Disinfection	$1,300,000	High

6.0 MANAGEMENT MEASURES FOR NONPOINT & RUNOFF SOURCES

6.1 INTRODUCTION

The following sections describe the potential nonpoint sources of bacteria loadings in the Upper San Antonio River watershed and summarize the possible management measures for addressing them. In this section, runoff sources are generally referred to as nonpoint sources. This is the appropriate classification based on the conventional understanding of pollutant sources. However, as discussed in Section 1.3.1, permitted runoff sources are considered point sources for the purposes of TMDL calculation.

Nonpoint source management measures are divided into two primary categories: structural and non-structural BMPs. Structural BMPs, as the name suggests, are typically structures of some sort that are designed to function with or without human intervention once a storm event occurs. Wet ponds, dry ponds, constructed wetlands, and filters are examples of structural BMPs. Non-structural BMPs are generally programmatic, good-housekeeping practices or measures that are designed to prevent or reduce pollutant deposition on a watershed (e.g., public education, regulation, volunteer programs). A range of management measures is described in this chapter and their effectiveness in addressing bacteria contributions is summarized. Where available, performance data are also provided to give an indication of how effective the BMPs might be at reducing bacteria levels in the watershed. Based on their effectiveness, selected management measures are recommended for implementation or further evaluation in the Upper San Antonio River watershed.

6.2 ASSESSMENT OF POTENTIAL SOURCES

A variety of nonpoint sources contribute bacteria to streams in the WPP study area. These can be categorized broadly as arising from either urban runoff, direct animal deposition, failing septic systems, or leaking wastewater infrastructure. Key contributions from these sources are described below.

6.2.1 Urban Runoff

General urban runoff, with its myriad of potential contributions from human, pet, and wildlife sources, would be expected to be the largest source of bacteria in the Upper San Antonio River watershed. This expectation would reflect the fact that the watershed is highly urbanized with a complex of residential and commercial land use types. Most of the intensely developed San Antonio core area is within the WPP study area.

Runoff occurs in response to precipitation that falls on the land surface. This runoff of incident rainfall then washes pollutants from the land surfaces and conveys them to receiving streams. In a highly urbanized area, the pressure of a large amount of impervious cover results in increased runoff quantities and velocities and enhanced ability to scour pollutants from the land surface.

The TMDL modeling confirms that urban runoff is the major source of bacterial loadings in the area. These runoff bacteria loads are not continuous, instead they occur only when precipitation events produce runoff. Therefore on most days of the year, there is no bacteria loading due to urban runoff.

6.2.2 Direct Animal Deposition

Pets and wildlife can deposit fecal contamination directly into the tributaries and main stem of the Upper San Antonio River. This is a nonpoint source, since the location is variable and not confined to an outfall. This phenomenon was incorporated in the TMDL model as the category of “direct nonpoint source” contributions. There exist no actual data or measurements that can be used to quantify the direct source contribution. It would be expected to be highly variable in any specific location, depending upon animal visitation. However, certain locales could represent relatively continuous sources, such as avian nesting areas in the riparian tree canopy.

6.2.3 Septic Systems

Private residential sewage treatment systems (septic systems) typically consist of one or more septic tanks and a drainage or distribution field. Household waste flows into the septic tank, where solids settle out. The liquid portion of the waste flows to the distribution system which may consist of perforated pipes buried in a soil or gravel bed. Effluent in the bed may move vertically to groundwater, laterally to surface water, or upward to the ground surface. As it moves, the majority of the liquid portion is consumed by evapotranspiration of vegetation planted on top of the distribution field or adjacent to it. Properly designed, installed, and maintained septic systems would be expected to contribute virtually no fecal coliform to surface waters. The principal removal mechanism for the fecal coliform would be die-off as the liquid moves through the soil. Various studies have attempted to quantify the transport and delivery of bacteria in effluent from septic systems. For example, it has been reported that less than 0.01% of fecal coliform originating in the household waste moves farther than 6.5 feet downgradient from the drainfield (Weiskel, 1996).

A septic system failure can occur via two mechanisms. First, drainfield failures, broken pipes, or overloading could result in uncontrolled, direct discharges to the streams. Such failures would not be expected to be common in the study watershed, but they could occur in reaches with older homes located near a watercourse. As a second mechanism, and overloaded drainfield could experience surfacing of effluent, and the pollutants would then be available for surface accumulation and subsequent wash off under runoff conditions.

6.2.4 Wastewater Collection Systems

The San Antonio Water System (SAWS), along with seven other local wastewater utility entities (Alamo Heights, Balcones Heights, Castle Hills, Ft. Sam Houston, Leon Valley, Olmos Park, and Terrel Hills), has miles of buried pipes that form the sanitary sewer collection system. The sanitary collection system represents a potential source of bacterial contribution in the WPP study area. Leakage from the collection system could occur via cracks or other pipe failures, or via overflow from manholes or lift stations. In order for a collection system leak to release bacteria to the receiving stream, the pipe would have to be located in reasonable proximity to the receiving stream.

While the City of San Antonio's NPDES Storm Water Annual Reports (City of San Antonio, 2002 through 2004) provides minimum estimates of sanitary sewer overflows, there is no set of data or measurements that precisely quantifies leakage from the City's sanitary collection system. SAWS operates and maintains the most extensive collection system in the study area, and they have in place an aggressive maintenance program to minimize problems. More detailed information on the SAWS procedures are provided in Appendix D.

6.2.5 Homeless/Transient Population

Another potential source of human waste in the study area could be untreated waste from transients or the homeless population. These individuals do not always have access to centralized plumbing and restroom facilities. They may deposit waste directly into or in close proximity to the study area's waterways. This is a plausible source, since bridges along the waterway may provide temporary or semi-permanent shelter. There exist no actual measurements of this potential source of bacteria.

6.3 ASSESSMENT OF BMPS FOR WW COLLECTION INFRASTRUCTURE

In the City of San Antonio, SAWS' BMPs (Appendix D) address proper operation and maintenance of the wastewater collection system. These non-structural BMPs are activities such as emergency response, sewer system line cleaning and maintenance, reducing infiltration and inflow through sewer rehabilitation and repair of broken or leaking lines, or the replacement and upgrade of aging or undersized sewers and lift stations.

Part of SAWS' Capital Improvement Program (CIP) is designed to systematically prioritize, rehabilitate, and replace the wastewater collection system in the City of San Antonio. Additionally, consideration can be given to the rehabilitation/replacement of private sewer laterals, which are not currently included in the SAWS CIP program, though the extent to which this element might be contributing to current bacteria levels is unknown. The current City of San Antonio Code assigns maintenance responsibility for all laterals in the public right-of-way to SAWS; property owners are responsible for lateral maintenance within their private property boundaries.

6.3.1 Rehabilitation, Replacement, and Maintenance of City Sewers

SAWS has an aggressive collection system maintenance program in place, and it is described in detail in Appendix D. There are also other municipal entities in the study area that operate and maintain collection systems, listed in Section 6.2.4.

The following activities are recommended for a comprehensive sewer maintenance program (CASQA, 2004):

- Clean sewer lines on a regular basis to remove grease, grit, and other debris that may lead to sewer backups.

- Establish routine maintenance program. Cleaning should be conducted at an established minimum frequency and more frequently for problem areas such as restaurants that are identified

- Cleaning activities may require removal of tree roots and other identified obstructions.

- During routine maintenance and inspection note the condition of sanitary sewer structures and identify areas that need repair or maintenance. Items to note may include the following:

    - Cracked/deteriorating pipes
    - Leaking joints/seals at manhole
    - Frequent line plugs
    - Line generally flows at or near capacity
    - Suspected infiltration or exfiltration.

- Prioritize repairs based on the nature and severity of the problem. Immediate clearing of blockage or repair is required where an overflow is currently occurring or for urgent problems that may cause an imminent overflow (e.g. pump station failures, sewer line ruptures, sewer line blockages). These repairs may be temporary until scheduled or capital improvements can be completed.

- Review previous sewer maintenance records to help identify “hot spots” or areas with frequent maintenance problems and locations of potential system failure.

6.3.2 Rehabilitation, Replacement, and Maintenance of Private Sewer Laterals

It is widely accepted in the wastewater industry that private sewer laterals contribute significantly to infiltration and inflow (I&I) entering a wastewater system. Consequently, it can be inferred that I&I from these laterals contribute to sanitary sewer overflows (SSOs) during wet weather events and also that they may be the source of exfiltration.

The City of San Antonio has adopted a BMP for newly constructed sewer laterals on private property that is based on the International Plumbing Code but this does not apply to existing sewer laterals. The current City Code of Ordinances (City of San Antonio, 2006) does make property owners responsible for the maintenance and repair of the sewer laterals within their private property, with the threat of a fine or termination of water service for non-compliance. SAWS, in conjunction with the City of San Antonio, initiated a sewer lateral program (“Laterals to People”) in 1999 to assist qualified low-income residential customers who require repair of their private sewer laterals. However, this program deals with a limited number of customers on a “case by case” basis.

In 1999, when the City of Austin received an administrative order from the EPA requiring them to eliminate their SSOs by December 2007, one of the issues that they decided to address was leaking private sewer laterals. This decision was made following their estimate that private sewer laterals represented approximately 50 percent of their collection system. They also estimated that approximately 10,000 private laterals were in need of repair. Further details of their program are provided here as an example of an approach that could be followed by the City of San Antonio to address private sewer laterals.

The major part of the City of Austin's approach involved the development of a new ordinance that addresses private sewer laterals. Austin did have an existing ordinance that requires property owners to repair defects in their sewer laterals within 60 days of written notice, but this was contingent on the leaking lateral contributing "excess flow" to the overall system, which they found very hard to prove in many cases. To ensure community participation, Austin formed a Private Laterals Task Force as a subset of their Citizens Advisory Group and it was this task force that ultimately recommended a new ordinance that gave incentive for homeowner compliance but that also provided for stronger enforcement if necessary.

The ordinance requires owners to maintain their private laterals but, in the event that repair is required, the City of Austin will provide an interest free loan for the work as an incentive. There would also be criminal and civil penalties if the property owner fails to perform the repair. Eligible homeowners have to be customers and have to be living in a single family dwelling or owner-occupied duplex. The program does not apply to commercial or multi-family properties and eligible costs do not include replacing or repairing internal plumbing, landscaping, or paving. The final installation or repair must also be inspected and approved by the City of Austin. Loans can be between $1,000 and $3,000, and the City estimates that the whole program will cost approximately $20-30 million.

6.4 ASSESSMENT OF BMPS FOR SEPTIC SYSTEMS

Septic systems can act as sources of nutrients and pathogens for reasons related to inadequate design, inappropriate installation, neglectful operation, or exhausted lifetime. In terms of system operation, as many system failures can be attributed to hydraulic overloading. Also, the regular inspection and maintenance required to keep the systems operating effectively is often not performed. Finally, all septic systems require maintenance and, if this is not performed, the design life of the system components will be shortened and the likelihood of sewage discharges increases. For this reason, all aspects of permitting, planning, construction, operation, and maintenance should be conducted in accordance with Title 30 Texas Administrative Code, Chapter 285.

Where development using septic systems has already occurred, state and local governments have a relatively limited ability to reduce pollutant loadings from them. However, a number of non-structural BMPs can be implemented. An onsite wastewater management program can reduce water quality degradation and save local governments and homeowners time and money. A variety of agencies can take on management of existing septic systems; wastewater management utilities or districts are the leading decentralized agencies. A range of measures that can be taken or initiated by such entities is described below.

6.4.1 Public Education

Many of the problems involved with improper use of septic systems can be attributed to a lack of user knowledge concerning the operation and maintenance of the system. Making educational materials available to homeowners and providing training courses for septic system installers and inspectors can reduce the incidence of pollution from these systems. Education is most effective when used as part of a BMP system which involves other source reduction practices such as the use of low-volume plumbing fixtures, as well as mitigative BMPs such as upgrading and maintenance.

6.4.2 Inspection and Maintenance

Regular system inspections are essential for monitoring system performance and, while homeowners can be provided with educational materials and can monitor their own systems, inspection programs should also be developed by local governments. A lower cost, though less reliable, alternative is for local governments to distribute reminders to septic system owners to let them know when inspection and/or maintenance is due for their systems (e.g., a reminder on a tax statement). Utilities or other agencies can sometimes be utilized at reduced expense to implement a program like this. At a minimum, requirements should be established for inspection during change of property ownership.

Septic tanks need to be pumped to remove accumulated biosolids approximately every 3 to 5 years, though this required frequency may vary based on the size of the tank, the number of users in the home, and whether or not a garbage disposal is being used. Failure to remove biosolids periodically will likely result in reduced tank settling capacity and eventual overloading of the soil absorption system, which is more expensive to remedy.

Septic tank maintenance can be required by using contracts, operating permits, and local ordinances and/or utility management. Local governments can issue renewable operating permits that require users either to have a contract with an authorized inspection/maintenance professional or to demonstrate that inspection and maintenance procedures have been performed on a periodic basis. Permit fees can be assessed to cover the program costs. Inspection and maintenance are more effective when used as parts of a BMP system which involves source reduction through elimination use of low-volume plumbing fixtures.

For the City of San Antonio, inspection and certification of septic systems are performed by the San Antonio Metropolitan Health District. Outside the City limits, Bexar County and other municipalities have respective enforcement jurisdictions.

6.4.3 Upgrade or Replacement of Failing Systems

Replacement of aging or inadequate systems and the repair of failing ones is an important component of an onsite wastewater management program. Typical repairs include fitting the septic system with new inflows and outlets, creating a new drainfield, or the use of other alternative technologies. Complete replacement of the system may be required in the event that the original one is inadequate, incorrectly constructed or installed, or if the system deficiencies cannot be addressed by other corrective measures. If the systems are sufficiently close to an existing sewer system, connection to that system may also be an alternative.

Local governments and other programs can facilitate these remedial measures through the provision of technical assistance to septic system owners, a recommended list of licensed installers, a complaint response system, and financial assistance to low income households for performing the necessary repairs.

Several alternative technologies are available for the upgrade or replacement of failing septic systems. These include leaching chambers, drip distribution, low pressure dosing, and surface irrigation. Upgrade or replacement is more effective when used as part of a BMP system which involves source reduction through elimination of garbage disposals and use of low-volume plumbing fixtures.

6.4.4 Chemical Additive Restrictions

Organic solvents are advertised for cleaning septic systems and also sometimes as substitutes for sludge pumping. However, there is limited evidence that these cleaning agents effectively achieve the intended functions, though they can inhibit microbial activity in the system and consequently result in increased discharge of pollutants. Additionally, the solvent chemicals themselves can potentially contaminate receiving waters and some common cleaner constituents are listed with USEPA as priority pollutants. Therefore, restrictions on the use of these additives can prevent the worsening of poor system function. Additive restrictions are most effective when used as part of a BMP system that involves other source reduction practices such as use of low-volume plumbing fixtures, as well as mitigative BMPs such as upgrading and maintenance.

6.4.5 Connect Customer to Sewer System

In some cases, it may be more cost-effective and practical to address an area served by failing septic systems by connecting that area to a nearby sewer system, if there is one in the vicinity. This is what is being done for the Espada Unsewered Area Project, which is a project to connect 117 homes in the Espada community north of loop 410 between the San Antonio River and Roosevelt Avenue and south of Ashley Road.

The project will result in the installation of approximately 23,000 feet (4.35 miles) of small diameter sewer mains and two lift stations in the Espada community and is projected to cost $3.2 million. As well as addressing what has been classified by the Metropolitan Health District as a serious health risk, the project will also remove a potential source of bacteria in the watershed. The project is scheduled for completion by fall of 2007.

SAWS has estimated that another 14 neighborhoods in its service area lack sewer connections. However, most of these are newer neighborhoods with functioning septic systems that do not pose the same level of risk to public health or water quality (Needham, 2005).

6.5 ASSESSMENT OF BMPS FOR DIRECT ANIMAL DEPOSITION

BMPs to reduce bacteria contributions from direct animal deposition are primarily non-structural. These BMPs are separated into three basic types, based on the source of direct animal deposition: wildlife, domestic pets, and zoo animals. The methods for dealing with bacteria contributions from zoo animals are addressed in a separate chapter. This section focuses on the possible BMPs that may be used to reduce contributions from wildlife and domestic pets. These are all non-structural BMPs and, as is typical of programmatic control methods, there is no real data available to indicate how effective they might be.

6.5.1 Wildlife

While there are potential methods available, attempting to control the contribution of bacteria from wildlife is an extremely challenging proposition. Most of the techniques for managing birds have been developed by airports and are, therefore, not necessarily suitable for control of wildlife in an urban environment. Also, as wildlife management surrounding airports is performed to increase aircraft safety, some of the techniques involve measures (i.e., culling) that might be inappropriate for a goal of pollution control.

Vegetation in the watershed can be managed to minimize the attractiveness of the habitat to wildlife. Available techniques include turf maintenance and planting of agricultural species that do not provide food for migrating birds and other species. Modifying the habitat around waterbodies can also help to minimize the attractiveness of the areas to waterfowl. However, these methods can have adverse aesthetic impacts that may not be desirable. It is also uncertain how effective these habitat modification methods might be when buildings are available as alternative locations in which birds may roost. The City of San Antonio, in cooperation with the Texas Department of Transportation, is currently investigating a program of habitat modification to address a possible source of bacteria along the San Antonio River: bats. If implemented, this program will involve filling in void spaces beneath the bridges along the river to eliminate potential roosting sites for bats.

Another simple form of habitat modification is to pass an ordinance prohibiting the feeding of birds in park areas close to waterbodies. While such a measure would not keep all birds away, it might reduce the number present and give them a reason to go elsewhere. If an ordinance cannot be passed, a program of public education could be attempted to encourage the public not to feed wildlife in the vicinity of waterbodies.

Wildlife harassment techniques, such as noise cannons, screamers, and banger shells, are commonly used to move wildlife away from runways and flight paths and deter them from taking up permanent residence in the area. However, these noise-making devices are clearly not suitable for urbanized areas where they would cause as much disturbance to the local population as to the wildlife. Another technique that has been used at both airports and landfills for controlling nuisance avian fauna is the use of one or more Falconers. These individuals could routinely fly a bird of prey in the vicinity of known nesting areas during peak nesting periods in order to deter birds from besting and roosting in those locations.

Live trapping of wildlife or nest removal can also be performed, though this is likely impractical in the City's case. Finally, the culling of birds and species that attract predators (e.g., rodents) is a wildlife control technique that can be used, but this is typically only done when other techniques have not been effective. Additionally, while pest control is a good alternative for discouraging predatory birds, the number of raptors present is unlikely to be significant when compared to more numerous avian wildlife.

One innovative program has been successfully implemented in numerous locations by a group called GeesePeace. This organization promotes humane methods to control urban populations of Canada geese, including locating nesting sites and addling/oiling eggs (a technique on a par with spaying and neutering dogs and cats), then using site aversion strategies to discourage the geese from nesting close to residential areas. Although Canada geese are not present in the study area, this technique may be effective with other similar species.

6.5.2 Domestic Pets

Pet waste deposited on the yard, sidewalk, or gutter, can easily end up in the storm drain, and eventually enter into local waterways. Many people do not realize the harm that the careless disposal of pet wastes may have on water quality. However, despite their apparent inconsequence, pet wastes can be major source of nutrients and bacteria in urban streams.

Local Ordinances

Local ordinances can be used to require that pet owners pick up after their pets and then dispose of the pet waste correctly. The City already has such an ordinance in place. Section 5-24 of the San Antonio City code (City of San Antonio, 2006) requires that "*an animal owner or keeper shall not walk his/her animals without a leash restraint, and shall not guide or take animals onto the yards or driveways of property not owned, leased or occupied by the animal owner for the purpose of allowing the animal to defecate, but shall keep his/her animal in the public right-of-way, and shall carry a container and scooper for the sanitary removal of his/her animal's fecal matter from the public sidewalk and public right-of-way adjacent to any property with a structure or other improvements thereon*."

With regard to disposal of the waste, the ordinance states that "*animal owners shall collect and dispose of animal waste by flushing it down a commode, by burial at least six (6) inches below the surface of the ground, or by placing it in a disposable container, sealing the container, and disposing of it as household garbage*." Violation of this ordinance is considered to be a health and safety related misdemeanor crime, and is punishable by a fine of up to $2,000. Clearly, to be fully effective such ordinances must be enforced.

While most localities have some form of pet waste ordinance, many put little effort into enforcement (EPA, 2004). Enforcement and public outreach (see below) are vital elements that complement the rules outlined in the ordinance.

This element can also be used in conjunction with "pooper scooper" programs that involve public outreach, signage, and the placement of stations for pet waste pick-up and disposal.

Pooper Scooper Program

"Pooper scooper" programs use a combination of public outreach and provision of pet waste pick-up materials to encourage owners to pick up after their pets. This kind of pet waste reduction program can result in less bacteria from domestic pets finding its way into the City's waterways and storm drains. Multiple vendors supply pet waste pick-up products. Currently, the City Parks and Recreation Department (PRD) uses Mutt Mitts®.

Mutt Mitts (http://www.pickupmitts.com/muttmitt/) are double-ply, degradable, mitten-like plastic bags that can be used to pick up pet waste. As well as the mitts, the manufacturer also sells dispensers that can be pole- or wall-mounted in public places, along with signs encouraging pet owners to use them to pick up after their pets. Mutt Mitt dispensers were first installed by the PRD in McAllister Park in 2002 using funds from a TCEQ grant. To date, the PRD has installed dispensers in 23 public parks and more are likely to be added, though there is no fixed schedule for the expansion of this program.

The capital cost for each Mutt Mitt dispenser is approximately $60, with optional accompanying waste cans costing $160 each, and signs costing $30 each. While signs in parks can have a higher cost than other printed outreach materials, they can last for many years and can also be more effective as they act as on-site reminders to dog owners to clean up after their pets.

Figure 6-1: Pooper Scooper Dispenser and Sign

There is additional labor cost for installation of these items, which is performed by PRD staff. PRD maintenance personnel replenish dispensers as part of their regular duties while they are emptying trash cans around the City parks. Refill cases of Mutt Mitts, each containing 800 bags, cost approximately $56 per case. The City expects to use over 150 cases during fiscal year 2006, at a total cost of over $8,400.

Dog Parks

Dog parks provide enclosed areas where owners can let their pets run off-leash and typically include signage reminding the owners to remove waste. In addition to providing a public amenity, these dog parks also help to transfer the conscientious behavior of responsible pet owners who pick up after their pets to less conscientious owners, which helps to establish a social norm (EPA, 2004). These parks can be designed to further mitigate stormwater impacts. For example, using vegetated buffers, pooper scooper stations, and siting away from drainage-ways, streams, and steep slopes will help to minimize impacts.

There is currently one dog park in San Antonio. It was opened in June 2004 and is located in Pearsall Park (http://www.sanantonio.gov/sapar/dogpark.asp). The park is one and half acres in size and is the only park in the City where dogs are allowed to be off-leash. A second dog park is currently being constructed in McAllister Park. This dog park is two acres in size, has cost approximately $80,000, and is scheduled to open in the fall of 2006.

Figure 6-2: Pearsall Dog Park, San Antonio

Public Education

In conjunction with the above programs, public education and outreach can be used to increase public awareness of the issue. While passing local ordinances and setting up pooper scooper programs provide the opportunity for people to be “good citizens,” public education campaigns help to inform pet owners about the importance of cleaning up after their pets. Many communities implement pet waste management programs by posting signs in parks or other pet-frequented areas, by mass mailings, and by broadcasting public service announcements. Some develop brochures that instruct pet owners about the proper disposal of pet waste or that describe the problems associated with pet waste and how to properly dispose of it.

Sign posting is one of the most common outreach strategies. Signs can designate areas where dog walking is prohibited, where waste must be recovered, or where dogs can roam freely. Many communities post neighborhood signs that ask pet owners to “Curb Your Dog.” The rationale behind this request is that dogs walked along the curb are more likely to defecate on the road, where the waste can be captured by street sweeping. However, waste deposited in the road is also more likely to be washed down storm drains so this tactic has limited usefulness.

6.6 ASSESSMENT OF STRUCTURAL BMPS FOR URBAN RUNOFF

Structural stormwater BMPs exhibit varying efficiencies for volume reduction and the removal of suspended solids, nutrients, and metals. These BMPs have not typically been designed to control pathogens as a primary goal and for this reason their performance in this regard is not well documented. However, while data on this topic is not widely available, some studies have been performed to assess BMP performance with regard to bacteria removal.

The first part of this section addresses the general treatment factors and processes that affect bacteria removal in structural stormwater BMPs. The following parts describe a range of commonly used BMPs and provide information on their reported bacteria removal efficiencies. Some suggestions on how to modify BMP design for improved bacteria treatment are presented at the end of this section.

6.6.1 Bacteria Treatment Factors and Processes

There are six primary factors/processes that can be used to remove and/or increase the die-off of bacteria: sunlight (ultraviolet [UV] light), sedimentation, sand filtration, soil filtration, chemical disinfection, and growth inhibition. One or more of these processes are used in one way or another by any stormwater BMP that effectively treats bacteria. These processes are expanded on further below to explain the differences between stormwater BMPs with regard to bacteria treatment. The information below is sourced from an article by the Center for Watershed Protection (CWP, 2000).

With respect to bacteria “die-off,” most research measures the removal of bacteria from the water column. In sedimentation and filtration systems, bacteria and viruses leave the water column and concentrate in the removed sediments. Since this environment is often warm, dark, moist, and rich in organic material, many bacteria can survive and even multiply under these conditions. For this reason, if settled sediments are resuspended by subsequent turbulent stormwater flows, some bacteria can reappear in the water column. Some studies have shown that as actual bacteria “die-off” occurs, it results in the disappearance of approximately 90 percent of bacteria present within two to five days.

UV Light

Bacteria are killed when they’re exposed to UV light and, consequently, exposure to sunlight is one way to cause die-off. However, maximum effect requires clear water so the turbidity found in urban runoff can interfere with the success of this method. UV light has been used extensively in wastewater and drinking water treatment, and there has been some end-of-pipe usage for combined sewers and stormwater. However, in these initial cases considerable stormwater treatment is needed to remove solids before the UV treatment is effective.

Sedimentation

Individual bacteria cells are very small particles but they can adsorb to sediment particles or attach to other bacterial cells. One study has reported that approximately 15 to 30 percent of fecal coliform cells present in stormwater are adsorbed to larger suspended particles, most of which were larger than 30 µm in diameter. Fecal coliform that do adsorb to these larger particles can rapidly settle out of the water column, though bacteria that are not attached or adsorbed to particles are much harder to settle. It has been estimated that, under ideal conditions, about 90 percent of bacteria would settle out from a typical stormwater pond in about two days.

Sand Filtration

Sand filtration is commonly used as a drinking water treatment method, though typically following chemical pretreatment and sedimentation steps. Under these conditions, bacteria removal rates of greater than 95 percent can be achieved in a properly operated treatment plant, but these drop to about 60 percent without prior chemical pretreatment.

Sand filtration has been adapted to treat stormwater runoff, but stormwater sand filters differ from those used to treat drinking water. The primary differences are that drinking water sand filters employ several layers of filter media, they are designed to permit daily "back flushing" to restore permeability and minimize microbial breakthrough in the filter media, and they typically follow a chemical pretreatment step that removes larger solids prior to filtration. Most stormwater sand filters lack these characteristics, principally the ability to back flush, and this means that individual bacterial cells, which are only a few microns in size, may not be fully strained out by passing through sand grains that are much larger in size (45 to 55 microns).

Soil Filtration

Bacteria can also be treated effectively by filtering water through the soil profile, similar to a septic tank system. Soil filtration is comparable to sand filtration, but can achieve higher bacteria removal rates as the organic matter and clay content in most soils increases the potential for bacteria adsorption. When properly located, installed and maintained, septic systems can achieve virtually complete bacteria removal over a distance of 50 to 300 feet (though not necessarily complete removal of much smaller enteric viruses). Several stormwater BMPs employ some degree of soil filtration to aid in pollutant removal. Examples include infiltration practices and bioretention facilities that divert runoff through the soil. To a lesser degree, grass swales allow for some soil filtration if runoff infiltrates into the channel during smaller storms.

Chemical Disinfection

Bacteria can be rapidly killed using chemical disinfection. The most common approach is to use chlorine or chlorine-related compounds to achieve this, though these compounds need to be added in precise quantities to achieve the desired results without undesirable side-effects (too little of the chemical won't kill the bacteria but too much may produce harmful chlorine residuals). While precise dosing is possible at drinking water or wastewater treatment plants, it is much harder to manage when flow and turbidity are extremely inconsistent, as is typically the case with stormwater flows. For this reason, chemical disinfection of stormwater has typically been largely restricted to combined sewer overflow treatment facilities.

Growth Inhibition

A series of things can inhibit the growth of bacteria in surface waters and sediments and, while these factors do not technically kill the organisms, they can slow their growth, reduce survival and increase predation. Major factors that can inhibit the growth of bacteria include colder water temperatures, low nutrient levels, low carbon supplies, low pH levels, and moisture loss. While it is difficult for a watershed manager to directly control these factors, they can sometimes be manipulated in the design of stormwater BMPs to augment bacteria removal.

6.6.2 Types of Structural Stormwater BMPs

As mentioned earlier, there are many structural BMPs available for stormwater treatment and, while most of these are not designed specifically for bacteria removal, their treatment processes can achieve this function. Table 6-1 summarizes the major structural stormwater BMPs available.

As of 2000, only 24 BMP performance monitoring studies had measured the input and output of fecal coliform bacteria from stormwater BMPs during storm events (CGER, 2000) and, currently, there is still very little additional data available on bacteria removal by stormwater BMPs. The most recent available study that has compared the relative performance of BMPs is a Water Environment Research Foundation (WERF)-sponsored evaluation conducted by Lampe et al. (2005), which used the International BMP Database (www.BMPDatabase.org) as its primary source of data. This database is a repository of data from numerous national BMP performance studies and has been historically supported by EPA and by the American Society of Civil Engineers. There is substantial information in the database concerning retention ponds (wet ponds), less so for extended detention basins (dry ponds) and vegetated swales, and essentially no data for bioretention systems, infiltration devices, and porous pavement (Lampe et al., 2005).

Table 6-1: Structural Stormwater BMP Types

Non-Proprietary	Vendor-Supplied Systems
Infiltration Trench Infiltration Basin Wet Pond Constructed Wetland Extended Detention Basin Vegetated Swale/Filter Strip Bioretention System Sand Filter Water Quality Inlet Screens, Nets, and Trash Racks Multiple Systems	Manufactured Wetland Media Filter Wet Vault Vortex Separator Drain Inserts Antimicrobial Filters

Data regarding bacteria reduction in these BMPs is more limited. Much of the data employed in studies of BMP performance with regard to coliform removal is derived using grab samples collected during the storm events (Strecker et al., 2004). The difficulty of collecting such samples throughout a storm event, coupled with the strict analytical holding time requirements for biological samples, are likely the primary reasons why there is so little stormwater BMP performance data available concerning bacteria. The City of San Diego has developed a "Treatment Best Management Practices Technologies Matrix" as a part of their Source Water Protection Guidelines for New Development (City of San Diego, 2004). This matrix summarizes information on various types of stormwater BMPs including an extensive review of percent removals for various pollutants, including bacteria. This matrix, along with EPA BMP Stormwater Technology Fact Sheets (EPA, 1999) and the California BMP Handbooks (CASQA, 2004) were major sources used for BMP performance data, though other data was researched to supplement these.

The following sections summarize the details of each type of BMP and also provide what is known or considered regarding the performance of the BMP with regard to bacteria removal.

6.6.3 Infiltration Trench

An infiltration trench is a long, narrow, rock-filled trench with no outlet that receives stormwater runoff. Runoff is stored in the void space between the stones and infiltrates through the bottom and into the soil matrix. Infiltration trenches perform well for removal of fine sediment and associated pollutants and bacteria removal is accomplished primarily by the process of soil filtration. These BMPs capture and treat small amounts of runoff but do not control peak wet weather flows. Infiltration trenches may be used in conjunction with other BMPs, such as detention ponds, to provide both water quality and peak flow control. Pretreatment using buffer strips, swales, or detention basins is important for limiting amounts of coarse sediment entering the trench which can clog and render the trench ineffective.

Figure 6-3: Typical Infiltration Trench (CASQA, 2004)

Infiltration trenches are most widely used in warmer, less arid regions of the US (EPA, 1999c). Based on a comparison with the performance of septic systems, with which infiltration systems share similar processes, bacteria removal should be excellent (Lampe et al., 2005). EPA compared the performance of infiltration trenches to rapid infiltration systems that are used in wastewater treatment and, based on this, they are typically expected to achieve a coliform bacteria removal efficiency of 90 percent (EPA, 1999c).

The use of infiltration trenches may be limited by a number of factors, including native soils, climate, and the location of the groundwater table. Site characteristics such as excessive drainage area slopes, fined-grained soil types, and proximate location of the water table and bedrock may preclude the use of infiltration trenches. Groundwater separation should be at least 3m from the basin invert to the water table height. Generally, infiltration trenches are not suitable for areas with relatively impermeable soils containing clay and silt (should not exceed 30 percent clay or combined 40 percent clay and silt) or in areas with fill. As with any infiltration BMP, the potential for groundwater contamination must be considered, especially if the local groundwater is used for drinking water or agriculture. The infiltration trench is not suitable for sites that use or store chemical or hazardous materials unless those materials are prevented from entering the trench.

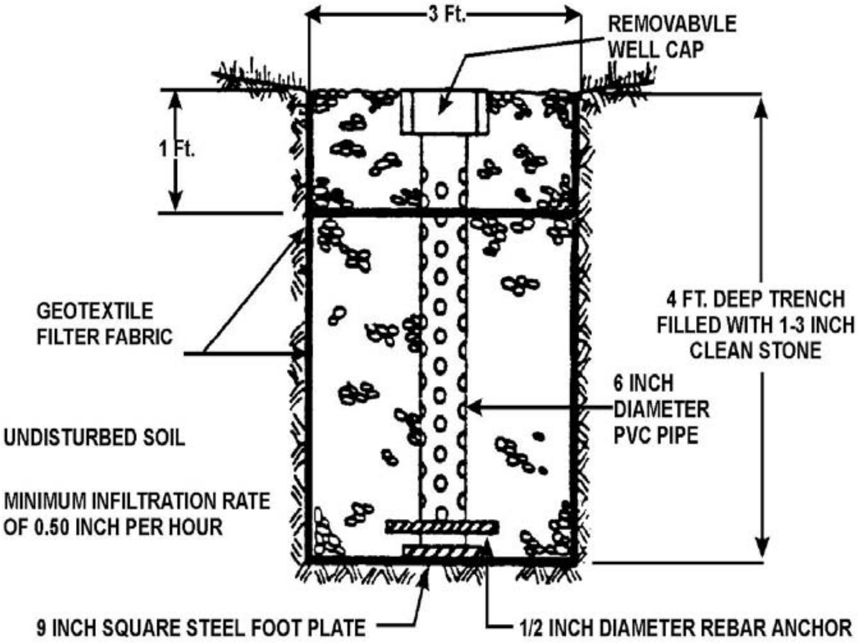


Figure 6-4: Infiltration Trench Diagram (EPA, 1999c)

The principal maintenance objective for infiltration trenches is to prevent clogging, which if allowed may lead to the failure of the trench. The trench needs to be inspected after any large storm and any accumulated debris or material needs to be removed. A more thorough inspection of the trench should be conducted at least annually. This inspection should involve monitoring of the observation well to ensure that the trench is draining as designed. If inspection finds that the trench is partially or completely clogged, then the BMP would need to be restored to its design condition. If vegetated buffer strips are used with the infiltration trench for pretreatment, these also need to be inspected after every major storm event.

6.6.4 Infiltration Basin

An infiltration basin is a shallow impoundment that is designed to infiltrate stormwater. Infiltration basins use the natural filtering ability of the soil to remove pollutants in stormwater runoff. Infiltration facilities store runoff until it gradually exfiltrates through the soil and eventually into the water table. This practice has high pollutant removal efficiency and can also help recharge groundwater, thus helping to maintain low flows in stream systems. Infiltration basins can be challenging to apply on many sites, however, because of soils requirements. In addition, some studies have shown relatively high failure rates compared with other management practices, though it is possible that basins in these studies may have been poorly sited with regard to soil type.

Figure 6-5: Typical Infiltration Basin (CASQA, 2004)

The effectiveness of infiltration basins is a function of the fraction of stormwater infiltrated; i.e., the amount of stormwater that bypasses the system due to overflow during large events determines effectiveness (FHWA, 2004). Limited data are available though, as with infiltration trenches, bacteria removal should be similar to that of septic systems. Removal rates have been estimated between 75 percent and 90 percent for infiltration basins designed to capture between half an inch and two inches of runoff, respectively (FHWA, 2004). Bacteria removal is accomplished primarily by the process of soil filtration.

Infiltration basins should only be installed where there is sufficient surface area and soil infiltration capacity. For this reason, infiltration trenches are generally more applicable than infiltration basins in very urbanized settings. However, infiltration basins can be employed where large redevelopments are planned or along roadways where there is sufficient right-of-way area available.

As with infiltration trenches, native soils, climate, and the location of the groundwater table are siting criteria for infiltration basins. Excessive drainage area slopes, fined-grained soil types, and proximate location of the water table and bedrock may prevent the use of infiltration basins. Groundwater separation should be at least 3m from the basin invert to the water table height. Generally, infiltration basins are not suitable for areas with relatively impermeable soils containing clay and silt (should not exceed 30 percent clay or combined 40 percent clay and silt) or in areas with fill.

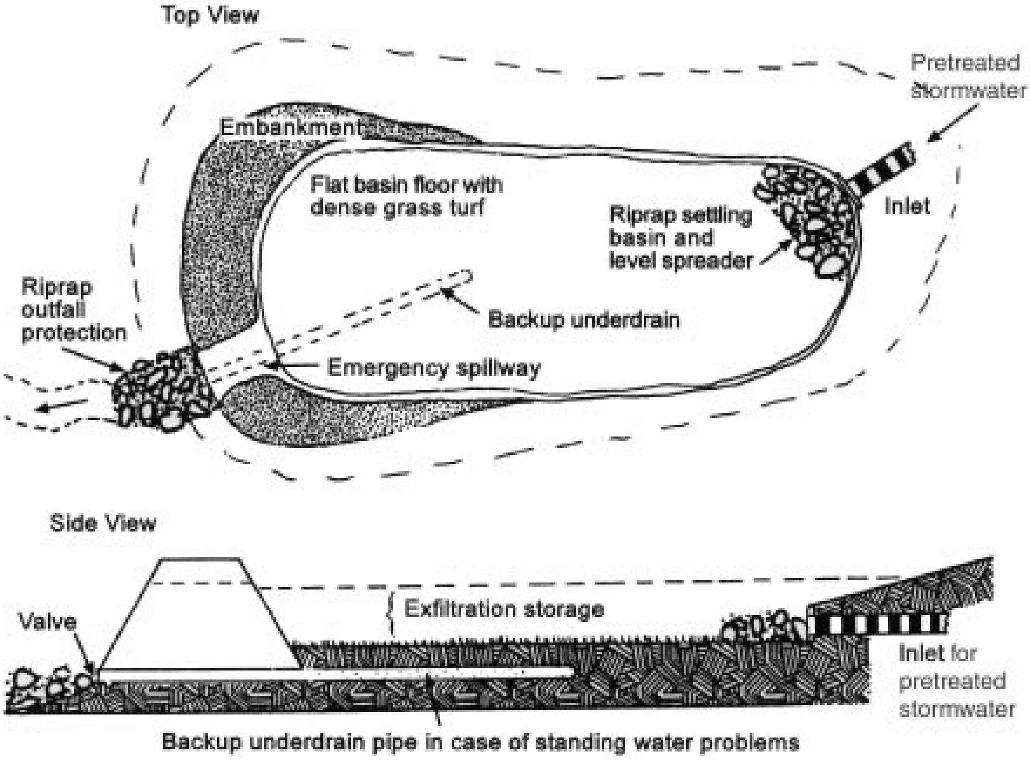


Figure 6-6: Infiltration Basin Diagram (Schueler, 1987)

Regular maintenance is critical for infiltration basins and includes inspections to confirm proper drainage, vegetation management, and erosion. Infiltration basins have a high failure rate if they are improperly maintained. Accumulated sediment needs to be removed when the accumulation exceeds 10 percent of the basin volume and any erosion needs to be revegetated immediately after it occurs. At a minimum, trash and debris should also be removed from the basin before and after the wet season.

6.6.5 Wet Pond

Wet ponds (a.k.a. stormwater ponds, retention ponds, wet extended detention ponds) are constructed basins that have a permanent pool of water throughout the year (or at least throughout the wet season) and differ from constructed wetlands primarily in having a greater average depth. Ponds treat incoming stormwater runoff by settling and biological uptake. The primary removal mechanism is settling as stormwater runoff resides in this pool, but pollutant uptake, particularly of nutrients, also occurs to some degree through biological activity in the pond. Wet ponds are among the most widely used stormwater practices. While there are several different versions of the wet pond design, the most common modification is the extended detention wet pond, where storage is provided above the permanent pool in order to detain stormwater runoff and promote settling.

Figure 6-7: Typical Wet Pond (CASQA, 2004)

The data on bacteria reduction in the International BMP Database for ponds are limited; however the median discharge concentrations of fecal coliform at the sites for which data is available in the International BMP Database were below the US standard for contact recreation (200 cfu/100mL). While there appeared to be high variability in sample concentrations between the sites, the data suggested that discharge concentrations are usually low (Lampe et al., 2005). The City of San Diego (2004) reported percent removals of 64 percent and 99 percent for wet ponds. The bacteria removal mechanisms used in wet ponds include sedimentation and, to varying degrees, exposure to sunlight.

Wet ponds are a widely applicable BMP and may be used for a large range of drainage areas, land use types, and storm frequencies and sizes. Although their applicability is restricted in densely urbanized areas and in arid climates, they have few other limitations. Wet ponds may be designed as on-line or off-line, though off-line is preferred, and can also be sited at locations along established drainage ways with consistent base flow. It is also possible to retrofit existing flood control basins to act as wet ponds, if existing structures are available. While ponds do not require a large area relative to their drainage area (2-3 percent of the contributing drainage area), the facilities themselves typically require a large continuous area. Wet ponds are often sited to function as an aesthetic amenity in addition to their stormwater management features.

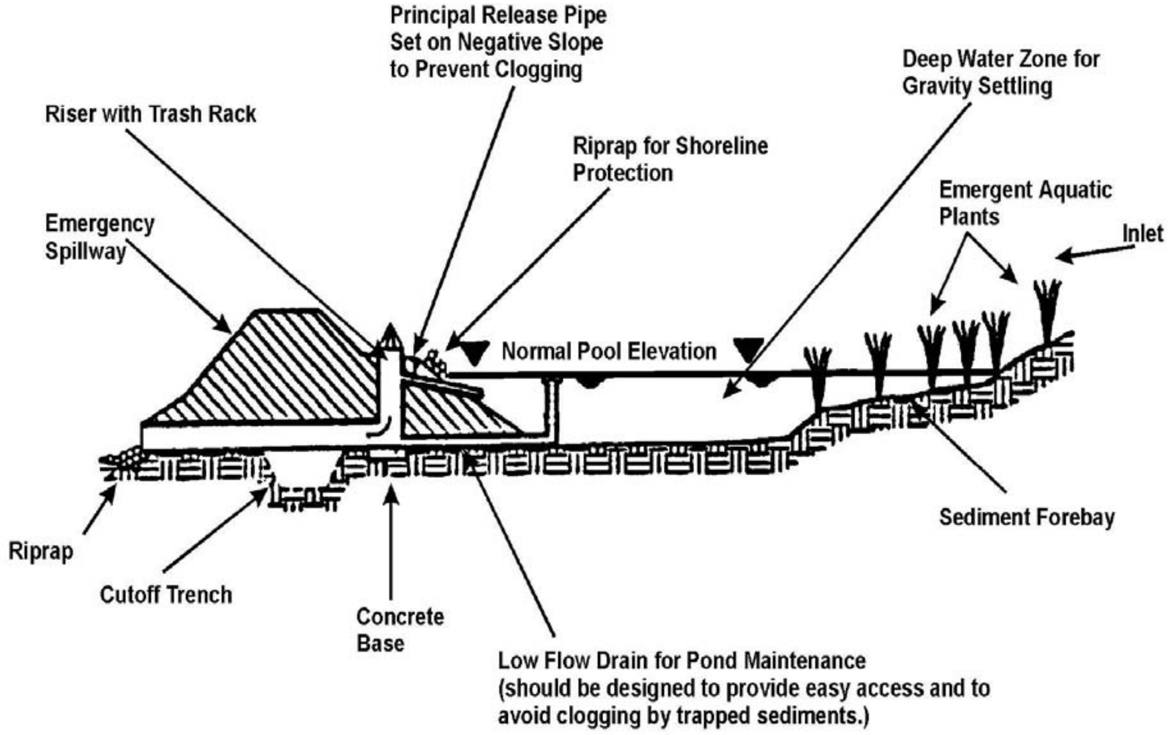


Figure 6-8: Wet Pond Diagram (EPA, 1999g)

Routine maintenance of a wet pond includes mowing of the embankment and buffer areas, and inspection for erosion and nuisance problems (e.g., burrowing animals, weeds, odors). Generally, the pond should be inspected after every storm event. Trash and debris should be removed routinely to maintain the aesthetic appearance of the pond and to prevent clogging of the outlet structure. The embankment and emergency spillway should also be regularly inspected for structural integrity, particularly following major storm events. Typically, maintenance includes repairs to the spillway, embankment, and the inlet and outlet structures, removal of sediment, and control of algal growth, insects, and odors.

6.6.6 Constructed Wetland

Constructed wetlands are constructed basins that have a permanent pool of water throughout the year (or at least throughout the wet season) and differ from wet ponds primarily in being shallower and having greater vegetation coverage. There is a distinction between using a constructed wetland for stormwater management and diverting stormwater into a natural wetland. The latter practice is not recommended and in all circumstances, natural wetlands should be protected from the adverse effects of development, including impacts from increased stormwater runoff. This is especially important because natural wetlands provide stormwater and flood control benefits on a regional scale.

Figure 6-9: Typical Stormwater Wetland (CASQA, 2004)

Wetlands are among the most effective stormwater practices in terms of pollutant removal and they also offer good aesthetic value. As stormwater runoff flows through the wetland, pollutant removal is achieved through settling and biological uptake within the wetland. Flow through the root systems forces the vegetation to remove nutrients and dissolved pollutants from the stormwater.

In general, wetlands remove pollutants as effectively as conventional pond systems, with bacteria removal rates being estimated at 76 percent (EPA, 1999f). In general, removal of fecal indicators from wastewater by constructed wetlands is well documented and percent removal for fecal streptococci and coliforms typically exceeded 80 percent and 90 percent, respectively (Struck,et al., 2005). The major bacteria removal mechanism used in wetlands is sedimentation.
There are four basic types of stormwater wetlands: shallow marsh, extended detention wetland, pond/wetland system, and pocket wetland. These wetlands store runoff in a shallow, vegetated basin. The shallow marsh design requires the most land area, as well as sufficient base flow to maintain the water depth. An extended detention wetland is a modified shallow marsh design that has been adapted to store additional water above the normal pool elevation. As well as providing treatment, the extended detention wetland can attenuate flows and act as a flood control measure. The pond/wetland system has two separate cells – a wet pond and a shallow

wetland. The wet pond removes sediments and reduces runoff velocities before the flows enter the wetland. This type of wetland typically requires less land area than the other types. Pocket wetlands are an alternative for smaller development situations and are generally excavated down to the groundwater table to maintain adequate water levels. They are supported exclusively by stormwater runoff and typically will have difficulty maintaining marsh vegetation due to extended periods of drought.

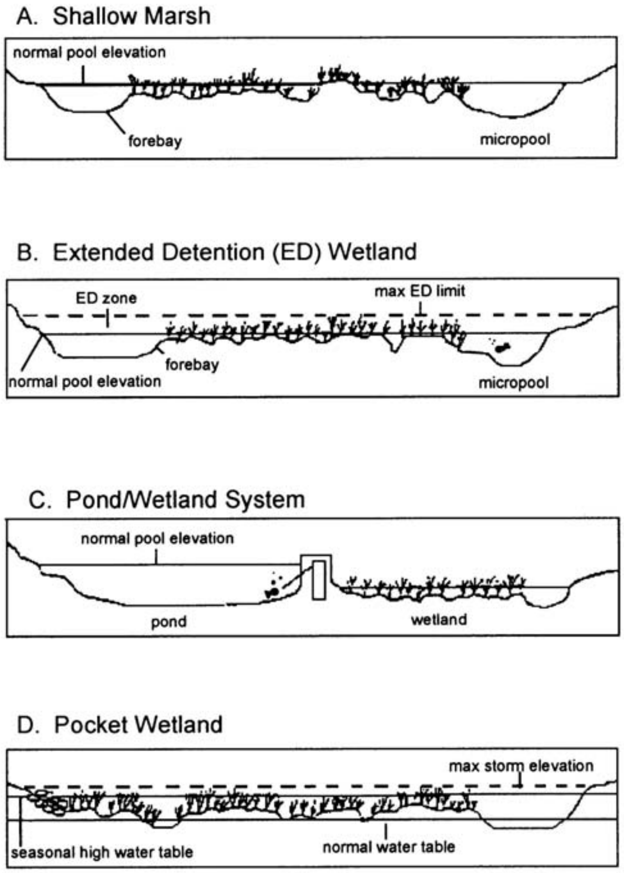


Figure 6-10: Types of Stormwater Wetlands (EPA, 1999f)

Similar to wet ponds, stormwater wetlands are widely applicable and may be used for a large range of drainage areas, land use types, and storm frequencies and sizes. Their applicability is somewhat restricted in densely urbanized areas and in arid climates but they have few other limitations. Wetlands may be designed as on-line or off-line, though off-line is preferred, and they can also be sited at locations along established drainage ways with consistent base flow. Wetlands typically require a larger area than wet ponds (4-6 percent of the contributing drainage area) because their average depth is less.

Maintenance activities for stormwater wetlands include inspections for burrows, outlet structure integrity, and sediment and litter accumulation; removal of trash and debris; mowing and maintenance of vegetation; and sediment removal from the forebay. Maintenance is particularly important over the initial period while the wetland is becoming established. Regular maintenance activities may also involve the harvesting of wetland plants. Wetlands should be inspected after major storms and checked for bank stability, erosion, flow channelization, and sediment accumulation.

6.6.7 Extended Detention Basin

Extended detention basins (a.k.a. dry ponds, dry extended detention ponds, detention ponds, extended detention ponds) are basins whose outlets have been designed to detain the stormwater runoff from a water quality design storm for some minimum time (e.g., 48 hours) to allow particles and associated pollutants to settle. Unlike wet ponds, these facilities do not have a large permanent pool. The primary purpose of most extended detention basins is to provide flood control using their flood detention storage.

Figure 6-11: Typical Extended Detention Basin (CASQA, 2004)

The International BMP Database data on bacteria reduction for extended detention basins are very limited but they suggest that bacteria concentrations in the treated runoff are similar or slightly higher in the discharge than in the untreated runoff (Lampe et al., 2005). This conclusion is likely the result of limited data. From a technical standpoint, some bacteria removal would be expected through the settling and natural die-off that occurs while the stormwater is detained in the basin. The major bacteria removal mechanism used in extended detention basins is sedimentation, though there is also some soil filtration and there may also be some contribution from exposure to sunlight.

Extended detention basins are widely applicable BMPs and can be used in areas with almost all soils and geology, though liners may be required in areas with rapidly percolating soils. In general, they should be used for sites with a minimum drainage area of 5 acres. At smaller sites, the required outlet orifice size may be too small and, consequently, may be more prone to clogging. The base of the dry pond should not intersect the water table as standing water may lead to problems with insects.

Routine maintenance for extended detention basins primarily involves vegetation management and trash and debris removal. Vegetation needs to be trimmed and mowing should be performed at least annually to avoid the development of woody vegetation. Accumulated sediment should be removed and the pond should be regraded every 10 years or if the accumulation exceeds 10 percent of the basin volume. At a minimum, trash and debris should also be removed from the basin and around the outlet structure before and after the wet season.

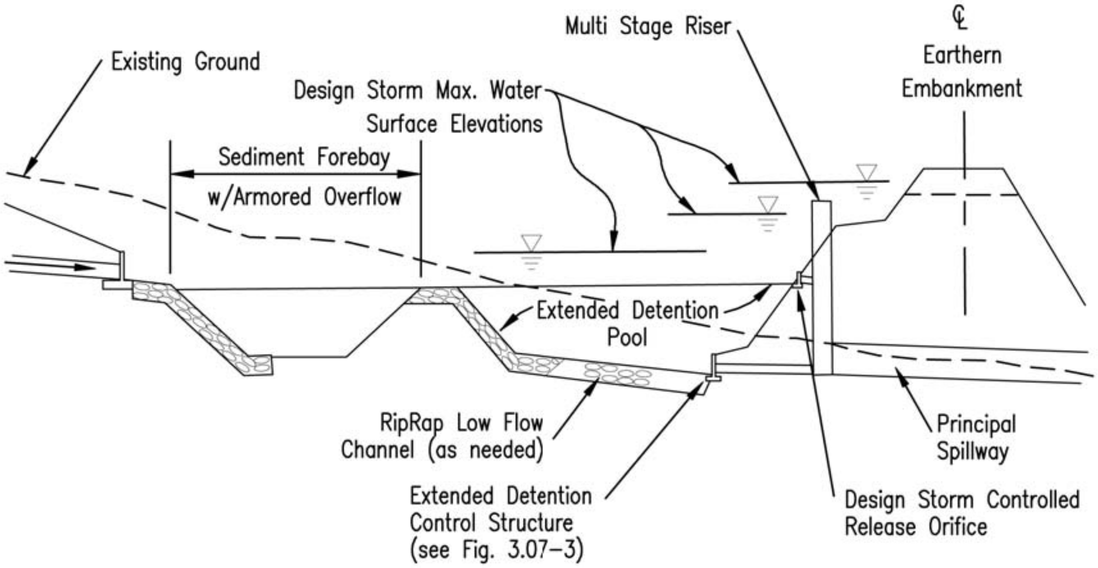


Figure 6-12: Extended Detention Basin Diagram (VA DCR, 1999)

6.6.8 Vegetated Swales/Filter Strips

Vegetated swales are broad, shallow channels with vegetation covering the side slopes and bottom that collect and convey runoff slowly to downstream discharge points. Swales can be natural or manmade and are designed to treat runoff by filtration through the vegetation in the channel, filtration through a subsoil matrix, and/or infiltration into the underlying soils. They trap particulate pollutants, promote infiltration, and reduce the flow velocity of stormwater runoff. Vegetated swales can serve as part of a stormwater drainage system and can replace curbs, gutters and storm sewer systems.

Vegetated filter strips (vegetated buffer strips, filter strips, and grassed filters) are vegetated surfaces that are designed to treat sheet flow from adjacent surfaces. Filter strips function by slowing runoff velocities and allowing sediment and other pollutants to settle and by providing some infiltration into underlying soils. Filter strips were originally used as an agricultural treatment practice and have more recently evolved into an urban practice. With proper design and maintenance, they can provide relatively effective pollutant removal and, in addition, they are typically viewed by the public as landscaped amenities rather than stormwater infrastructure. Consequently, there is little resistance to their use.

There is very little data available describing the performance of swales and buffer strips for bacteria removal. Data from the International BMP Database suggest that concentrations of bacteria tend to increase in swales (Lampe et al., 2005); an observation that has also been noted in other studies (CASQA, 2004). It is not clear why bacteria counts increase in swales. One possible explanation is that bacteria multiply in the warm, damp soil conditions. The major bacteria removal mechanisms expected to be present in swales and buffer strips are sedimentation and soil filtration, though current performance data would suggest that these mechanisms are not effective in these BMPs.

Figure 6-13: Typical Swale (CASQA, 2004)

Swales and filter strips should be sited on gently sloping areas where shallow flow conditions are achievable. Steep slopes increase flow velocity, which decrease detention time and may adversely affect efficiency. Maintenance for swales and filter strips primarily involves inspection for erosion, vegetation damage, and sediment and debris accumulation. Grass height does not appear to have a major impact on performance so mowing is typically only required once or twice per year for aesthetic reasons. Trash and debris should be regularly removed from the BMPs and accumulated sediment should be removed if it begins to build up above 3 inches in any spot or if it covers the vegetation. Standing water may also develop as a result of sediment accumulation or invasive vegetation build-up and this should be controlled to prevent the breeding of insects.

6.6.9 Bioretention System

The bioretention BMP functions as a soil and plant-based filtration device that removes pollutants through a variety of physical, biological, and chemical treatment processes. These facilities normally consist of a grass buffer strip, sand bed, ponding area, organic layer or mulch layer, planting soil, and plants. The runoff's velocity is reduced by passing over or through buffer strip and subsequently distributed evenly along a ponding area. Exfiltration of the stored water in the bioretention area planting soil into the underlying soils occurs over a period of days. Bioretention systems are typically used to treat the runoff from impervious areas located in commercial, residential, and industrial areas and they are well suited to installation in parking lot islands, intermediate areas in office parks and apartment complexes, and median strips. These areas can be designed to have runoff flow directly into the bioretention area or to convey the flow via a curb and gutter system.

Bacteria removal performance data for bioretention systems is essentially non-existent; however, similar processes operate in septic systems where removal is generally excellent (Lampe et al., 2005). The performance of bioretention systems is considered to be similar to that of infiltration systems, so a 90 percent coliform bacteria removal efficiency would be expected (EPA, 1999a). A study that modeled the processes found in a bioretention system determined that removal of fecal coliform would be in the range of 55 to 99 percent, with an average removal of 88 percent (Rusciano & Obropta, 2005), which appears to support these expectations. The major bacteria removal mechanisms used by biofiltration systems are sedimentation and soil filtration, though there may also be some treatment from exposure to sunlight.

Figure 6-14: Typical Bioretention Basin (CASQA, 2004)

The bioretention system should be configured according to site constraints (e.g., soil types, existing vegetation, utility locations, drainage). Soils with high clay content (greater than 25 percent) or that are unstable may make installation of bioretention facilities infeasible. Also, sites with slopes greater than 20 percent are not suitable. The preferred soil types for these systems are sandy loam, loamy sand, or loams. These soil types provide the necessary infiltration rates and also are good planting soils for the bioretention area vegetation. Vegetation should be selected based on maintenance requirements and aesthetics, and care should be taken to prevent nearby invasive species from entering the system. A typical bioretention system is suitable for serving a drainage area of between 0.25 and 1 acres. Larger drainage areas would require multiple systems.

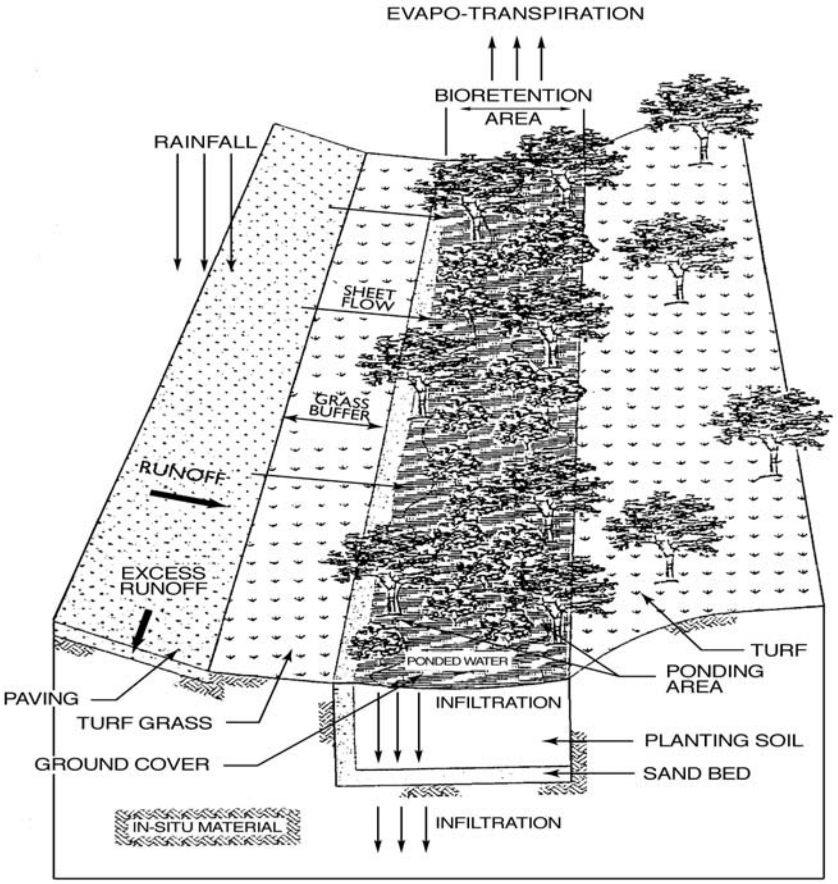


Figure 6-15: Bioretention Diagram (EPA, 199a)

Recommended maintenance for bioretention systems includes routine inspection and repair and/or replacement of system components, which typically involves similar maintenance measures that are required for normal landscaped areas. Trees and shrubs in the system should be inspected twice per year and any dead or diseased vegetation should be removed. Pruning and weeding may also be required to maintain the appearance of the area, as might replacement of mulch. Any areas of standing water should be addressed to discourage the attraction of insect vectors. Other than maintenance of vegetation, removal of debris and accumulated sediment should be the major maintenance required.

6.6.10 Sand Filter

Stormwater sand filters are usually two-chambered including a pretreatment settling basin and a filter bed filled with sand. As stormwater flows into the first chamber, large particles settle out, and then finer particles and other pollutants are removed as stormwater flows through the sand in the second chamber. There are a number of design variations including the Austin sand filter, Delaware sand filter, and Washington, D.C. sand filter).

Figure 6-16: Austin Sand Filter (CASQA, 2004)

Sand filters are generally considered able to achieve high removal efficiencies for fecal coliform bacteria and typical removal efficiency has been reported to be between 60 and 75 percent (City of San Diego, 2004). The EPA Storm Water Technology Fact Sheet (1999e) confirms this, reporting a typical bacteria removal of 76 percent for sand filters. However, some studies have found that efficiency could be as low as 22 percent under some conditions (City of San Diego, 2004). The major bacteria removal mechanisms used by sand filters are sedimentation and sand filtration.

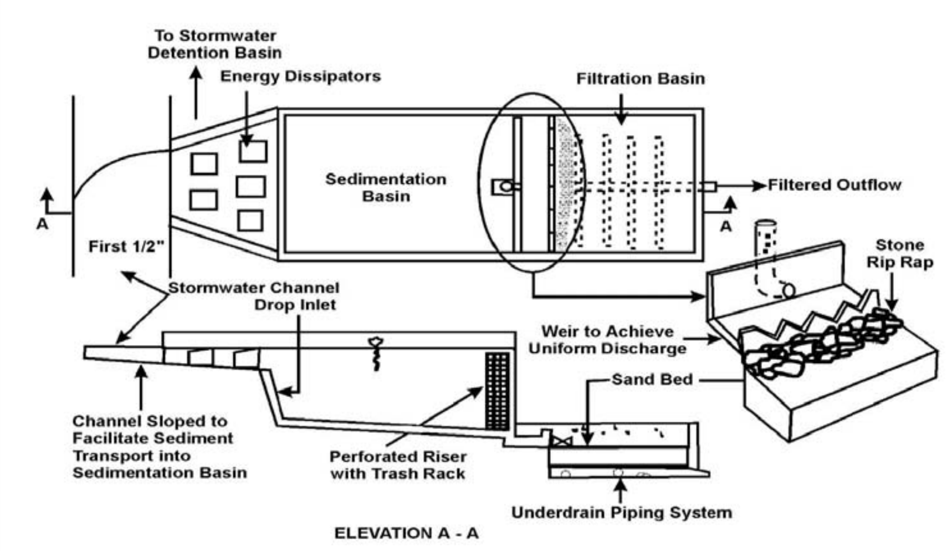


Figure 6-17: Diagram of Austin Sand Filter (EPA, 1999e)

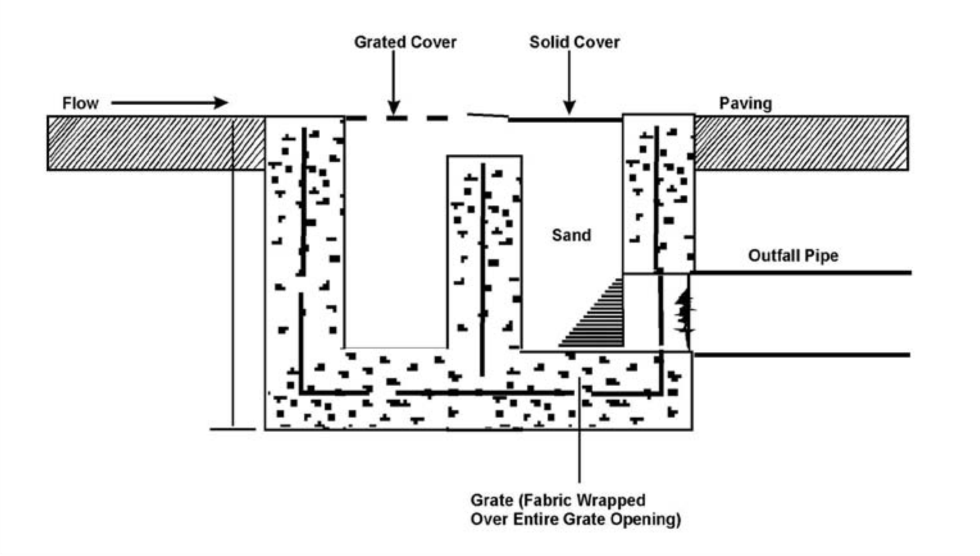


Figure 6-18: Diagram of Delaware Sand Filter (EPA, 1999e)

Sand filters are typically preferred to infiltration BMPs in areas where groundwater contamination might be of concern or where the water table is high. In relation to other BMPs sand filters take up little space and they can be used on highly developed sites with steep slopes. They can also be used in arid areas where wet ponds or wetlands would be unlikely to maintain the necessary permanent pool.

The Delaware or Washington, D.C. type sand filters are both installed underground and, consequently, are typically used in highly impervious areas where available land is limited (e.g., parking lots, loading docks, service stations, garages, and storage areas). Austin sand filters are more commonly used for larger drainage areas. They are installed at grade and can treat runoff from any urban land use. Most sand filters require a considerable amount of head to achieve the necessary flow through the system so they are not well suited to very flat terrain.

Sand filters are best used on relatively small sites (less than 25 acres for surface sand filters and less then 2 acres for underground filters) and, while they have been used on larger sites, these systems have been prone to clogging. In fact, pretreatment is critical for sand filters and is typically achieved by a chamber that precedes the filter bed. This chamber settles out the larger particles and, therefore, reduces the load on the bed.

All filter designs need to provide access to the filter to allow for inspection and maintenance. Sand filters should be inspected after every storm event to ensure that they are working as designed. Sand filters typically begin to experience clogging problems within 3 to 5 years. Accumulated trash and debris should be removed from the filter at least twice a year to maintain its operation. Corrective maintenance of the filtration chamber involves removal of the clogged upper layers of sand and gravel. Sand filter systems may also require the occasional removal of vegetative growth.

6.6.11 Water Quality Inlet

Water Quality Inlets (WQIs), also commonly called trapping catch basins, oil/grit separators, or oil/water separators, consist of one or more chambers that promote sedimentation of coarse materials and separation of free oil (as opposed to emulsified or dissolved oil) from stormwater. Some WQIs also contain screens to help retain larger or floating debris, and many of the newer designs also include a coalescing unit that helps promote oil/water separation. A typical WQI consists of a sedimentation chamber, an oil separation chamber, and a discharge chamber.

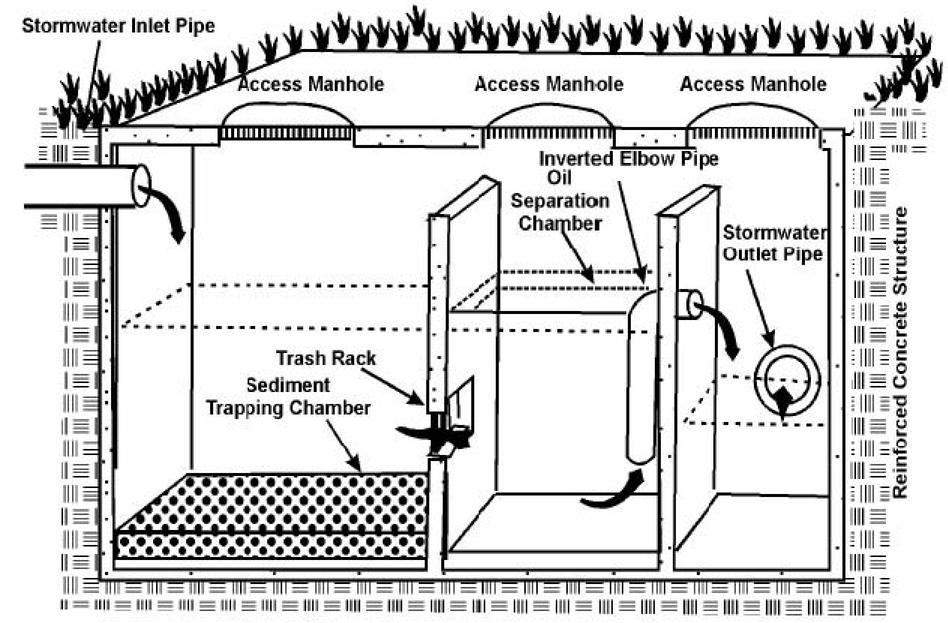


Figure 6-19: Typical Water Quality Inlet (CASQA, 2004)

These devices are appropriate for capturing hydrocarbon spills, but provide very marginal sediment removal and are not very effective for treatment of stormwater runoff. Oil/water separators (OWSs) typically capture only the first portion of runoff for treatment and are generally used for pretreatment before discharging to other BMPs. There is no available data concerning the bacterial removal efficiency of OWSs but, based on the pollutant removal mechanisms they use, there is little reason to expect that they would be highly effective in this role. For this reason, additional details on the WQI are not provided in this section.

6.6.12 Screens, Nets, and Trash Racks

A range of BMPs, collectively known as gross solids removal devices (GSRDs) can be installed at stormwater drain outlet structures to capture floatables and other gross debris that are carried by runoff. There is no data available concerning bacteria removal efficiency for these various devices though, while these BMPs can be very effective at capturing and controlling gross solids and floatables, it is highly unlikely based on their treatment mechanisms that they would be effective for bacteria removal. For this reason, additional details on GSRDs are not provided here.

The City of San Antonio has recently installed a number of actuating gates at its downtown drain inlets. These gates remain closed during dry weather, preventing floatables and gross solids from entering the storm drain system, but are set to open during wet weather to allow runoff into the storm drains. These gates augment the street sweeping program operated by the City by helping to keep floatables and gross solids where they can be removed by the street sweepers. However, it is unclear whether these devices have a direct effect on keeping bacteria out of the stormwater drains.

6.6.13 Multiple Systems

A multiple BMP system employs several stormwater BMPs in series to enhance the treatment of the runoff. They are also known as a stormwater treatment trains and consist of a sequence of BMPs, and possibly natural features, each of which are designated to treat a different aspect of runoff, maximizing pollutant removal and stormwater infiltration. For example, a multiple system could include a combination of vegetated filter strips with swales, infiltration basins, and pond systems.

By combining these structural treatment mechanisms in series rather than using a single method of treatment, the levels and reliability of pollutant runoff can be improved. Employing BMPs in series makes it possible to use a BMP that might be the most effective for some pollutants but that might not achieve the desired level of treatment for some others because another level of treatment will take place further downstream. The effective life of a BMP can also be increased by combining it with a device for pretreatment, such as a buffer strip or swale, to remove suspended particulates prior to treatment in a downstream unit. Many BMPs are commonly designed with some form of pretreatment for gross solids and debris. Sequencing of BMPs can also reduce the potential for re-suspension of deposited sediments by reducing flow energy levels or by providing longer paths for flow runoff.

Bacteria removal performance for a multiple system would be dependent upon the components of that system, though it is important to note that placing BMPs in series will not necessarily result in cumulative performance (CASQA, 2004). This is because the first BMP may achieve part of the gain typically achieved by the subsequent BMPs. Alternatively, efficient combination of BMPs can optimize the overall system performance as the effluent from the first treatment system should be of more consistent quality, which allows subsequent BMPs to be designed for optimum performance (CASQA, 2004).

Siting and maintenance for these multiple systems would depend upon the BMPs used in the treatment train. The possibility of combined and therefore more complex maintenance requirements, along with the larger land area required for the various treatment systems, are the major disadvantages of using a multiple system.

6.6.14 Manufactured Wetland

A manufactured wetland is a proprietary stormwater BMP that is quite similar in function to public domain constructed wetlands. Currently, one company manufactures this type of system, which consists of a uniform module approximately 9½ feet in diameter and 4 feet high that contains a series of sedimentation chambers and vegetated treatment units. Unlike most constructed wetland systems, this BMP conveys the stormwater directly into the subsurface of the wetland and through the root zone of the vegetation. Pollutants are removed through filtration, adsorption, and biochemical reactions (EPA, 1999d). The design volume for the site determines how many of the standardized modules are required for stormwater treatment.

With regard to system performance, while there are few data available, the manufacturer reports a bacteria removal efficiency of 97 percent based on a 1998 pilot study (EPA, 1999d). However, no independent assessments of performance have been conducted. The major bacteria removal mechanism used by manufactured wetlands is sedimentation.

These treatment systems are likely not suitable for drainage areas greater than an acre because of the number of units that would be required for larger sites, though this is not stated by the manufacturer. However, for small areas this type of modular system may be a good option. Maintenance for this system is relatively low and involves seasonal harvesting of vegetation and regular removal of floatables and debris from the pretreatment unit.

6.6.15 Media filter

Proprietary stormwater media filters are typically dual-chambered and consist of a pretreatment settling basin and a filter bed filled with sand or other absorptive filtering media. As stormwater flows into the first chamber, the large particles settle out, and then smaller particles and other pollutants are removed as the water flows through the media in the next chamber.

There are three major manufacturers of proprietary stormwater filter systems. Two are similar in that they use cartridges of a standard size. The cartridges are placed in vaults – the number of cartridges required is a function of the design flow rate. The water enters the vault, flows horizontally into the cartridge to a centerwell, and then downward to an underdrain system. The third proprietary product is a flatbed filter, similar in appearance to a sand filter.

None of the manufacturers of these systems have presented data on bacteria removal, though the City of San Diego (2004) reported a general 47 percent bacteria removal for media filters. Most of these systems function at higher flow rates and have larger media than are used in standard sand filters and, consequently, may not achieve the same level of treatment performance (CASQA, 2004). The major bacteria removal mechanisms employed by media filters would be sand filtration or filtration via the selected media being used.

There are no unique siting criteria for this type of system. Maintenance requirements are dependent on the proprietary product being used, though they are expected to be similar to sand filters.

6.6.16 Wet Vault

A wet vault is an underground structure designed to provide both temporary and permanent storage for runoff from a storm event. Wet vaults have a permanent pool of water that dissipates energy and improves the settling of particulate pollutants. The vault may also have a constricted outlet that causes a temporary rise in the water level during each storm (i.e., extended detention). This volume typically drains within 12 hours to 2 days after the end of the storm. Wet vaults are typically in-line, end-of-pipe BMPs.. There are three primary types of wet vault that are marketed by various vendors.

Wet vaults are primarily designed to remove coarse sediments from runoff and, consequently, are not expected to provide efficient bacteria removal (CASQA, 2004). No data are available concerning bacteria removal efficiency for wet vaults. If bacteria removal occurred, the major mechanism employed by wet vaults would likely be sedimentation.

Maintenance for wet vaults involves the removal of accumulated sediments and debris. This is typically accomplished at least annually using a vacuum truck.

6.6.17 Vortex Separator

Vortex separators (aka swirl concentrators) are flow-through, gravity separator structures that are similar to wet vaults. The major difference is that the vortex separator is round and uses the circular flow of the water to enhance the settling of suspended sediments and attached pollutants. These BMPS can be installed as either on-line or off-line treatment units. Vortex separators were first designed for treating combined sewer overflows but the technology has now been adapted for stormwater treatment by several manufacturers.

Though vortex separators do remove solids, they are principally designed to remove floatables and gritty materials. Consequently, they may have difficulty removing the finer solids typically found in runoff. Pollutants that adhere to fine particulates or are dissolved will not be significantly removed by the unit (EPA, 1999b). Bacteria removal data is extremely limited for these systems, though one study indicated that one system might achieve between 50 and 88 percent removal of fecal coliform (Neary, 2004). Some examples were found of case studies where a vortex separator was used as a primary treatment step before a wetland or a UV treatment unit. None of the four major vortex separator vendors make any claims regarding bacteria removal. The major bacteria removal mechanism employed by vortex separators would be sedimentation.

There are no unique siting criteria required for vortex separators. The size of drainage area that could be served is only limited by the capacity of the largest available unit. As with wet vaults, maintenance usually involves the removal of accumulated sediments and debris, which is typically accomplished annually using a vacuum truck.

6.6.18 Drain Inserts

Drain inserts are manufactured filters or fabric that can be placed in a drop inlet to remove sediment and debris. There are a multitude of inserts available, though they usually are one of three broad types: boxes, socks or trays. Box inserts are plastic or wire mesh structures into which a “bag” is placed. The bag is usually made of polypropylene and takes the form of the box. Sock inserts consist of a fabric, also typically made of polypropylene, that can be attached to a frame or the grate of the inlet. Socks are designed for vertical (drop) inlets. Tray inserts consist of one or more trays or mesh grates that may hold different types of media. Filtration media vary by manufacturer and include polypropylene, porous polymer, treated cellulose, and activated carbon.

Based on the treatment processes used, this type of BMP would not be expected to achieve significant treatment with regard to bacteria. Siting and installation for these inserts is generally straightforward as they are simply fitted into existing drain structures. Maintenance requirements involve inspection of the inserts to ensure that they remain correctly installed and that they have not become blocked by floatables or other debris.

6.6.19 Anti-Microbial Filters

Recently, some manufacturers of proprietary BMPs have begun to target bacteria removal through the use of antimicrobial filters. The appeal of these filters is that they have a small footprint when compared to conventional BMPs, and they lack the complex operational requirements of treatment plant-type disinfection methods. The filters are created by the permanent bonding of an antimicrobial chemical agent to the surface of a polymer media. The antimicrobial agent disrupts the cell membrane of bacteria that it contacts causing the bacteria to be destroyed. The polymer media is typically inserted into the tops of catch basins, packed into pipes, or otherwise arranged so that the flow of stormwater is completely contacted with the media.

The use of these antimicrobial devices is still in its infancy, and there is no consensus regarding optimum media design, required contact time, and expected removal rates. A few case studies have been performed using catch basin inserts and packed pipes. Most of these studies resulted in 70-100% bacteria removal, but using unrealistically low flow rates. Only one study has been performed using large storm-driven flows. This study, performed in New Hampshire, used a 9 foot deep stormwater vault fitted with antimicrobial filters. Fifteen storms were sampled with runoff volumes ranging from 0.1 to 2.7 million gallons. During these events, flow rates often exceeded 5,000 gpm. Removal rates ranged from negligible to 85 percent with an average rate of about 50 percent (Nolan, 2004).

6.6.20 Improved Bacteria Removal by Design

There is limited guidance available on recommended methods to design or select stormwater practices for greater bacteria removal. However, several design enhancements are provided in the following paragraphs that might enhance the performance of current stormwater BMPs (Center for Watershed Protection, 2000).

Steps could be taken to create high light conditions in the water column of stormwater ponds or wetlands to promote greater exposure of bacteria to sunlight and, therefore, improved removal. For example, storage could be provided in a series of separate and shallow cells. The last cells should have lower turbidity and would consequently permit greater UV light penetration. However, one drawback to this approach is that this may also increase algal growth in the pond or wetland.

Additional retention or detention time (e.g., two to five days) could be provided in stormwater ponds to promote greater settling. Alternatively, engineers could size ponds based on a smaller minimum design particle (e.g., 15 microns). Either of these measures should increase bacteria removal through sedimentation.

Inlet and outlet structures of stormwater ponds could be designed to prevent bacteria-laden bottom sediments from being resuspended and exported. Reducing turbulence in ponds is essential for extended detention basins that do not have a “pool barrier” to trap and retain bottom sediments.

Turf and open water areas surrounding stormwater ponds should be reduced to discourage the creation of resident geese and waterfowl populations that might become an internal bacterial source.

Shallow benches and wetland areas could be added to stormwater ponds to enhance the plankton community and therefore increase bacterial predation.

Infiltration practices can play a role in reducing bacteria yields to surface waters where soil conditions permit. Optimal soil infiltration rates range from 0.5 to 2.0 inches. Even when infiltration is not feasible at a site, designers should attempt to achieve as much soil filtration as possible by using filter strips, rooftop disconnection, and open channels. While this should have the added benefit of improving groundwater recharge, it may decrease surface water availability.

If filtering practices are used, finer-grained media should be used in the filter bed (e.g., 15 microns), or at least a finer-grained layer at mid-depth in the filter profile. The typical “concrete-grade” sand used in most sand filters may be too coarse-grained to prevent bacteria breakouts. However, the disadvantage of using finer-grained media would be that it might lead to more chronic clogging of the filter bed. The bacteria removal efficiency of sand filters is also likely to be improved by extending the process for pretreatment and/or filtration for 40 hours or more. This is most easily achieved by extending the detention time in the sedimentation chamber used for pretreatment.

Trapped sediments should be removed from filter pretreatment chambers on a more frequent basis during the growing season. In addition, “dry” pretreatment chambers may be more desirable since bacteria-laden sediment would be subject to both sunlight and desiccation. In general, where practical, sand filters should be oriented to provide maximum solar exposure.

6.7 ASSESSMENT OF NON-STRUCTURAL BMPS FOR URBAN RUNOFF

Non-structural BMPs include institutional and educational practices whose goal is the modification of behaviors and/or work practices with the aim of reducing the amount of pollutants entering storm drains and receiving waters. These are largely common sense measures such as limiting public and animal access to sensitive watershed or riparian areas, public education on the role of storm drains, erosion control, vegetative buffers, street sweeping, animal waste management, and pet waste (“poop-scoop”) programs. Quantitative data are very limited concerning the effectiveness of these programs, though some of these non-structural measures have been shown to reduce receiving water bacteria levels in rural and agricultural settings (Perdek et al., 2003).

The non-structural BMPs that address leaking sewers, failing septic systems, and direct animal deposition have already been addressed earlier in this chapter. This section describes the remaining non-structural BMPs currently being implemented within the City of San Antonio that might reduce bacteria loadings in the watershed. These remaining programs are summarized in Table 6-2. Other than the existing City programs described in this section, and the BMPs discussed in Sections 6.3.1 through 6.3.3, there were no additional non-structural BMPs identified that are available to reduces bacteria loadings in the watershed.

Table 6-2: Non-Structural Stormwater BMPs for Urban Runoff

Program	Responsible Agency
Street Sweeping	COSA Public Works Department, Alamo Heights, Castle Hills, etc.
Stormwater System Maintenance	COSA Public Works Department, Alamo Heights, Castle Hills, etc.
River Maintenance	COSA Public Works Department

6.7.1 Street Sweeping

The Public Works Department is primarily responsible for implementing the City’s street sweeping program to clean the City streets and remove the potentially floatable debris that accumulates in the curb lines. Removal of this material prevents floatable material from entering the drainage systems which could potentially cause blockages in the channels that could lead to flooding of area residences. Regenerative air sweepers are used versus broom sweepers to remove pollutants from the road surfaces.

Street sweeping occurs at varying frequencies across the City, depending upon the location and nature of the street. Streets in the Central Business District are cleaned most frequently (approximately 363 times per year), with arterial roads being cleaned at least four times per year, and residential streets being cleaned at least twice per year. Street cleaning also occurs following special events held by the City, such as Fiesta, New Year's Eve celebrations, Alamo Bowl, and other City-sponsored events.

A 1993 study identified streets and parking lots as significant potential sources or carriers for bacteria and other pollutants (EPA, 2004). Bacteria have an affinity for attaching themselves to fine sediments and can form biofilms on gutters, both of which can be swept away by street sweepers, particularly if the street sweepers used are efficient at removing fine particles, as are the Regenerative air sweepers used by the City. However, research to quantify the effects of this activity on resulting bacteria loads is currently lacking (EPA, 2004).

The Street Cleaning Section also works cooperatively with the City's Park and Recreation and Public Works Departments to keep the Mission Trails Hike & Bike Trails swept and free of litter, trash or debris. This maintenance includes the upkeep of the street surface of the Mission Parkway. The section is also involved with the Neighborhood Action Department Management Program, which performs additional sweeps of residential areas to help with trash removal.

6.7.2 Stormwater System Maintenance

The Public Works Department is also responsible for insuring that the City's stormwater facilities are operating correctly. They use remote cameras to visually inspect underground drainage systems and they also carry out minor concrete channel maintenance, storm drain inlet repairs, box culvert and concrete pipe replacement, as well as performing the maintenance of storm water lift stations and hazardous material traps.

The Public Works Department inspects the underground storm sewer system (estimated to be approximately 500 miles of pipe) to identify any illicit connections and to document damage including collapsed pipes requiring replacement. About 20 percent of the existing system is inspected each year, and this program also provides inspections on newly constructed infrastructure to ensure compliance with plans and specifications. The subsequent repair or replacement of concrete infrastructure such as concrete drainage channel aprons and wing walls, box culverts, and concrete drainage channels is required to keep the municipal separate storm sewer system operating as designed and at maximum capacity. Subsurface collapsed storm sewer pipes are identified and replaced on an as-needed basis - approximately 1,300 linear feet of pipes are replaced annually. Drainage inlet and hazardous material trap cleaning is conducted to keep them free and clear of debris and floatable material. Several of the City's street sweepers have been equipped with vacuum hoses so they can help support this activity.

It is not clear the extent to which this program might help to reduce bacteria in the watershed though, at minimum, the identification of illicit stormwater sewer connections and perhaps catch basin cleaning should both contribute to this goal.

This BMP is further described in Appendix E.

6.7.3 River Maintenance

The Public Works Department is responsible for the maintenance of designed channels, natural waterways, and lakes in the City. All improved drainage channels are inspected on a regular basis and re-grading, de-silting, and debris removal projects are scheduled and conducted on a priority basis. Channel de-silting helps with reducing the TSS contributed to local waterways, as well as aiding with the conveyance of stormwater by maintaining the design characteristics and conveyance capacity of the channels. De-silting of the lakes similarly maintains the stormwater capacity of area lakes and ponds that receive surface run-off. Seven area lakes and ponds receive de-silting operations: Woodlawn Lake, Davis Lake, Elmendorf Lake, Southside Lions Park, Miller's Pond, San Antonio River, and Friesenhahn Pond.

The Public Works Department also conducts regular re-grading, restoration, and reshaping of earthen channels for de-silting and erosion repair maintenance, which also maintains their design characteristics and conveyance capacity. These activities can also involve removal or re-establishment of vegetation, as necessary. Natural creek maintenance is also a part of this program and involves removal of debris and floatables from the City's creeks. This effort is supplemented by a community program (the Storm Water Community Service/Restitution program) that involves public participation in creek clean-up. This section is also responsible for the removal of un-permitted fill in the floodplain for compliance with the City's Development Code and to maintain the integrity of the Flood Insurance Program.

Again, it is not clear the extent to which this program might help to reduce bacteria in the watershed though the lake desilting helps to maintain their capacity, which should enhance any sedimentation functions that they perform.

This BMP is further described in Appendix E.

6.8 MISCELLANEOUS SAN ANTONIO RIVER BMPS

There are a series of impoundments along the San Antonio River throughout the downtown area that experience low flows during the summer months. Some of the elevated bacterial counts in the river may be exacerbated by these seasonal low flows and the resulting absence of dilution. SAWS is already using re-use water to augment the base flows in the San Antonio River and is also investigating the possibility of diverting air conditioner condensate into the river to further enhance flows.

Another program worthy of mention is the San Antonio River Improvements Project, which is a $140 million city, county and federal investment in a four-mile segment of the river from Hildebrand to Lexington called the Museum Reach, and a nine-mile segment from South Alamo Street to Mission Espada called the Historic Mission Reach. The aim of the River Improvements Project is to provide stable, maintainable flood control while environmentally restoring sections of the river to their natural meanders, in addition to adding amenities and recreational opportunities along 13 miles of the river.

The River Improvements Project is currently in the final design phase, with the first stages of construction scheduled to commence in late 2006. Further final design and construction on the River Improvements Project will occur in phases over the 10-year project schedule, and will occur on both the Museum Reach and the Historic Mission Reach simultaneously.

It is currently anticipated that the City of San Antonio will contribute approximately $37 million over the 10 years of the project and that Bexar County will contribute approximately $53 million. Local funding is derived from the City's capital improvements fund and the County's flood tax. Additionally, project leaders are seeking partnerships with the private sector to fund enhancements to amenities along the river. Total federal contribution over the life of the project could exceed $30 million.

The objective of the River Improvements Project is to provide stable, maintainable flood control while reclaiming the river's natural meanders and appearance along the Historic Mission Reach. This will be accomplished through the use of fluvial geomorphology. Project designers plan to re-create the contoured path of the river wherever possible, restore the gradually descending slopes of the riverbanks, and remove the concrete rubble lining the river channel. At several points along the Historic Mission Reach, stacked pieces of limestone will be used to create small dams, or weirs, in order to prevent erosion of the river bottom.

In the Museum Reach of the project, the river flows through a narrow channel with sloping banks covered by thick vegetation. The channel averages 80 feet in width and is bordered largely by private properties that contain commercial and light industrial businesses which do not currently utilize the riverbank space. From Highway 281 North to Hildebrand, the Museum Reach has a more natural setting as it flows through Brackenridge Park.

In these areas north of downtown, the River Improvements Project will create designated wildlife habitat areas, and the river bottom will be lined with natural cobblestones to create a healthier environment for fish and other aquatic organisms. The project will help restore native fish communities including Guadalupe bass, blue gill, channel catfish, sunfish and shad.

The River Improvements Project will also reintroduce native trees, grasses and plant life along the river's edge including pecan, redbud and wild olive trees, buttonbush shrubs, Texas bluebonnets and scarlet sage among others. The preservation and planting of native plants including seed and fruit producing species, such as oak, pecan and walnut, will encourage wildlife to forage within these areas along the river. The planting of native understory species will also provide stratification along the river, which is essential to attracting species that would not use the area if only overstory canopy plant species were present.

The extent to which the River Improvements Project might help to reduce bacteria in the watershed is not quantifiable. However, the addition of wetlands areas to certain stormwater outfalls may help to treat runoff entering the river to some degree. Additionally, some sedimentation might be effected by the small dams and weirs constructed along the river as part of the project.

6.9 RECOMMENDED FUTURE MANAGEMENT METHODS

This section provides several recommendations concerning BMPs to be implemented in the Upper San Antonio River Watershed to promote the reduction of bacteria loadings.

Based on the discussions and data presented in the previous sections, this part of the chapter describes the potential BMPs that could be implemented to promote the reduction of bacteria loadings in the Upper San Antonio River Watershed. For each of the four basic categories of bacteria source (leaking sewer infrastructure, failed septic systems, direct animal deposition, and urban runoff), potential BMPs are listed. In most cases, where new activities are recommended some provisional cost data is provided.

6.9.1 Wastewater Collection Infrastructure

The primary recommendation for the City of San Antonio to address bacteria loadings that might arise from leaking sewer mains is to maintain the existing sewer inspection and rehabilitation program being implemented by SAWS. This program is currently addressing the maintenance of City sewers in an aggressive manner. It is also recommended that other cities and entities in the study area, listed in Section 6.2.4, also address their respective areas of jurisdiction.

In addition to the above SAWS program, the City may want to consider investigating a program that addresses potential bacteria contributions from private sewer laterals. While the current City Code of Ordinances (City of San Antonio, 2006) makes property owners responsible for the upkeep of their sewer laterals, a funding assistance program such as the one being implemented by the City of Austin might help to provide residential property owners with additional incentive to comply. As a first step in this process, it would be advisable to investigate the level to which private sewer laterals might be contributing to bacteria loadings in the watershed.

6.9.2 Septic Systems

A potential problem area of failed septic systems in the Upper San Antonio River Watershed is currently being addressed by the Espada Unsewered Area Project. Once complete, this $3.2 million project will have connected 117 residences to the City sewers that were previously served by failing septic systems or outhouses. The project is scheduled for completion by fall of 2007. There are no other known neighborhoods in the Upper San Antonio River Watershed that have issues with failing septic systems, though individual system failures may take place.

6.9.3 Direct Animal Deposition

While wildlife, particularly birds, are a major contributor to the bacteria loadings in the Upper San Antonio River Watershed, there are few viable BMP alternatives available to address this source. While attempts could be made to modify wildlife habitats in the watershed, such measures could have adverse aesthetic impacts that local residences may find disagreeable and there is also no certainty that these measures would achieve the desired results. Wildlife harassment techniques are similarly undesirable and unproven in heavily urbanized areas.

One alternative to be investigated that might contribute to a bacteria loading reduction from wildlife would be to codify and then enforce an ordinance prohibiting the feeding of birds in parks close to rivers and streams or with lakes, such as Woodlawn Lake Park. Some public outreach might also be required to explain the reasons for the ordinance. As with the measures described above, there is no guarantee that the creation of the ordinance would reduce the bacteria loadings from birds; however, it is a relatively simple step to take and is unlikely to have adverse impacts in this regard.

Figure 6-20: Bird Feeding at Woodlawn Lake, San Antonio

With regard to bacteria loadings from domestic pets, the main recommendation for the City is to ensure that the pet waste ordinance is enforced, and to maintain the existing pooper scooper and dog parks initiatives. To this end, a review of ordinance enforcement could be undertaken to review the level to which Section 5-24 of the City Code is being implemented.

With regard to the pooper scooper program, the City should continue to expand the number of public parks that have pooper scooper stations and, where necessary, place additional stations in parks that currently have them. At the present time, 25 of the approximately 120 public parks in the City have pooper scooper stations in place. The capital cost for each pooper scooper station (including bag dispenser, waste can, and sign) is approximately $250, not including the cost for installation, and multiple stations would likely be required at each park. Refills for the present number of installed pooper scooper stations currently cost the City approximately $8,400 annually. The addition of new stations should be focused in parks near to creeks and lakes, where the risk of bacteria to loadings to the waterways is highest.

The City should also continue to expand its dog park program. There is currently one dog park in the City located in Pearsall Park, but a second is under construction in McAllister Park. Other future dog parks should be located in parks away from creeks and lakes to help attract dog owners to locations removed from local waterbodies. The construction of dog parks is obviously more costly than installing pooper scooper stations. Once complete, the area in McAllister Park will cost approximately $80,000.

6.9.4 Structural Urban Runoff BMPs

A summary of the structural BMPs for treating urban runoff that were reviewed is provided in Table 6-3. For each BMP, the reported bacteria removal efficiencies that were cited earlier in this chapter have been listed. Because of the limited data available concerning bacteria removal by BMPs, a BMP that could achieve an approximate bacteria removal of 60 percent or greater was considered to be acceptable for possible further implementation. Based on this criterion, the structural BMPs most suitable for possible further consideration are:

- Infiltration trenches
- Infiltration basins
- Wet ponds
- Constructed wetlands
- Bioretention systems
- Sand filters
- Manufactured wetland (proprietary system)
- Vortex separator (proprietary system)
- Antimicrobial filters (proprietary system)

Table 6-3: Summary Structural Stormwater BMPs

Non-Proprietary	**Bacteria Removal**	**Vendor-Supplied Systems**	**Bacteria Removal**
Infiltration Trench	~ 90%	Manufactured Wetland	97% [4]
Infiltration Basin	75% - 90%	Media Filter	47%
Wet Pond	64%, 99%	Wet Vault	No data [2]
Constructed Wetland	77%, 80% -90%	Vortex Separator	50% - 88%
Extended Detention Basin	Limited data [1]	Drain Inserts	No data [2]
Vegetated Swale/Filter Strip	-33%	Antimicrobial Filters	50%
Bioretention System	~ 90%, 88%		
Sand Filter	60%-75%, 76%, 22%		
Water Quality Inlet	No data [2]		
Screens, Nets, and Trash Racks	No data [2]		
Multiple Systems	Varies [3]		

Notes:

1. Data suggest that there is little bacteria removal in extended detention basins.
2. Unlikely to achieve good bacteria removal based on treatment mechanisms used.
3. Dependent upon combination of BMPs used.
4. Data from system manufacturer based on one pilot study.

Infiltration Trench

Advantages:

- Provides 100% reduction in the load discharged to surface waters.
- If the water quality volume is adequately sized, infiltration trenches can be useful for providing control of channel forming (erosion) and high frequency (generally less than the 2-year) flood events.
- As an underground BMP, trenches are unobtrusive and have little impact of site aesthetics.

Limitations:

- Have a high failure rate if soil and subsurface conditions are not suitable.
- May not be appropriate for industrial sites or locations where spills may occur.
- The maximum contributing area to an individual infiltration practice should generally be less than 5 acres.
- Infiltration trenches typically require a minimum soil infiltration rate of 0.5 inches/hour, and are not appropriate at sites with Hydrologic Soil Types C and D.
- If infiltration rates exceed 2.4 inches/hour, then the runoff should be fully treated prior to infiltration to protect groundwater quality.
- Not suitable on fill sites or steep slopes.
- Risk of groundwater contamination in very coarse soils.
- Upstream drainage area must be completely stabilized before construction.
- Difficult to restore functioning of infiltration trenches once clogged.

Table 6-4: Cost Estimates for Infiltration Trench BMP

System Size	Capital Cost	Surface Area (ft. sq.)	Volume (cu. ft.)	Cost $/cu.ft.
0.08 Acre System, approximately 4 ft deep	$55,194	3,400	4,760	$11.60
0.31 Acre System, approximately 4 ft deep	$148,361	13,400	18,760	$7.91
0.61 Acre System, approximately 4 ft deep	$243,036	26,700	37,380	$6.50

In general, maintenance costs for infiltration trenches typically range from between 5% and 20% of the construction cost of the BMP, depending upon BMP complexity. More realistic values are probably closer to the 20-percent range, to ensure long-term functionality of the practice (CASQA, 2003).

Infiltration Basin

Advantages:

- Provides 100% reduction in the load discharged to surface waters.
- If the water quality volume is adequately sized, infiltration basins can be useful for providing control of channel forming (erosion) and high frequency (generally less than the 2-year) flood events.

Limitations:

- May not be appropriate for industrial sites or locations where spills may occur.
- Infiltration basins require a minimum soil infiltration rate of 0.5 inches/hour, not appropriate at sites with Hydrologic Soil Types C and D.
- If infiltration rates exceed 2.4 inches/hour, then the runoff should be fully treated prior to infiltration to protect groundwater quality.
- Not suitable on fill sites or steep slopes.
- Risk of groundwater contamination in very coarse soils.
- Upstream drainage area must be completely stabilized before construction.
- Difficult to restore functioning of infiltration basins once clogged.

Table 6-5: Cost Estimates for Infiltration Basin BMP

System Size	**Capital Cost**	**Surface Area (ft. sq.)**	**Volume (cu. ft.)**	**Cost $/cu.ft.**
1¾ Surface Acre Basin approx. 2 ft deep	$286,173	76,230	152,460	$1.88
3½ Surface Acre Basin approx. 2 ft deep	$561,234	152,460	304,920	$1.84
35 Surface Acre Basin, approx. 2 ft deep	$4,782,864	1,524,600	3,049,200	$1.57

Maintenance costs for infiltration basins are estimated at 5 to 10% of construction costs (CASQA, 2003).

Wet Pond

Advantages:

- If properly designed, constructed and maintained, wet basins can provide substantial aesthetic/recreational value and wildlife and wetlands habitat (however, also see disadvantages below).
- Ponds are often viewed as a public amenity when integrated into a park setting.
- Due to the presence of the permanent wet pool, properly designed and maintained wet basins can provide significant water quality improvement across a relatively broad spectrum of constituents including dissolved nutrients.
- Widespread application with sufficient capture volume can provide significant control of channel erosion and enlargement caused by changes to flow frequency relationships resulting from the increase of impervious cover in a watershed.
- Wet ponds could be constructed by retrofitting existing ponds used for flood control.

Limitations:

- Some concern about safety when constructed where there is public access.
- Mosquito and midge breeding is likely to occur in ponds.
- Cannot be placed on steep, unstable slopes.
- Need for base flow or supplemental water if water level is to be maintained.
- Require a relatively large footprint.
- In cases where heavy wildlife use has been observed around constructed wetlands, increases in coliform have been seen in effluent from the BMPs (Strecker et al., 2004). As wet ponds also can provide habitat for waterfowl, they may experience similar results.

Table 6-6: Cost Estimates for Wet Pond BMP

System Size	Capital Cost	Surface Area (ft. sq.)	Volume (cu. ft.)	Cost $/cu.ft.
½ Surface Acre Pond, approximately 7 ft deep (5' of water plus freeboard)	$166,963	21,780	87,120	$1.92
1 Surface Acre Pond, approximately 7 ft deep (5' of water plus freeboard)	$292,643	43,560	174,240	$1.68
10 Surface Acre Pond, approximately 7 ft deep (5' of water plus freeboard)	$1,721,196	435,600	1,742,400	$0.99

For wet ponds, the annual cost of routine maintenance has typically been estimated at about 3% to 5% of the construction cost (CASQA, 2003).

Constructed Wetland

Advantages:

- If properly designed, constructed and maintained, wet basins can provide substantial aesthetic/recreational value and wildlife and wetlands habitat (however, also see disadvantages below).
- Due to the presence of the permanent wet pool, properly designed and maintained wet basins can provide significant water quality improvement across a relatively broad spectrum of constituents including dissolved nutrients.
- Widespread application with sufficient capture volume can provide significant control of channel erosion and enlargement caused by changes to flow frequency relationships resulting from the increase of impervious cover in a watershed.

Limitations:

- There may be some aesthetic concerns about a facility that looks swampy.
- Some concern about safety when constructed where there is public access.
- Mosquito and midge breeding is likely to occur in wetlands.
- Cannot be placed on steep unstable slopes.
- Need for base flow or supplemental water if water level is to be maintained.
- Require a relatively large footprint.
- If structural complexity is not taken into account during BMP design, geese and mallards may become undesirable year-round residents and, in cases where heavy wildlife use has been observed, increases in coliform have been seen in effluent from the BMPs (Strecker et al., 2004).

Table 6-7: Cost Estimates for Constructed Wetland BMP

System Size	**Capital Cost**	**Surface Area (ft. sq.)**	**Volume (cu. ft.)**	**Cost $/cu.ft.**
½ Surface Acre Wetland, approximately 7 ft deep (1' of water plus storm freeboard)	$184,563	21,780	87,120	$2.12
1 Surface Acre Wetland, approximately 7 ft deep (1' of water plus storm freeboard)	$323,093	43,560	174,240	$1.85
10 Surface Acre Wetland, approximately 7 ft deep (1' of water plus storm freeboard)	$1,960,446	435,600	1,742,400	$1.13

For constructed wetlands, O&M costs have been estimated to be similar to those for wet ponds: about 3% to 5% of the construction cost (CASQA, 2003). However, if the wetland vegetation required involved maintenance, these costs would be expected to be higher.

Bioretention

Advantages:

- Bioretention provides stormwater treatment that enhances the quality of downstream water bodies by temporarily storing runoff in the BMP and releasing it over a period of four days to the receiving water.
- The vegetation provides shade and wind breaks, absorbs noise, and improves an area's landscape.

Limitations:

- The bioretention BMP is not recommended for areas with slopes greater than 20% or where mature tree removal would be required since clogging may result, particularly if the BMP receives runoff with high sediment loads.
- Bioretention is not a suitable BMP at locations where the water table is within 6 feet of the ground surface and where the surrounding soil stratum is unstable.
- By design, bioretention BMPs have the potential to create very attractive habitats for mosquitoes and other vectors because of highly organic, often heavily vegetated areas mixed with shallow water.
- If structural complexity is not taken into account during BMP design, geese and mallards may become undesirable year-round residents and, in cases where heavy wildlife use has been observed, increases in coliform have been seen in effluent from the BMPs (Strecker et al., 2004).

Table 6-8: Cost Estimates for Bioretention BMP

System Size	**Capital Cost**	**Surface Area (ft. sq.)**	**Volume (cu. ft.)**	**Cost $/cu.ft.**
¼ Surface Acre System, approximately 2 ft deep	$50,321	10,900	21,800	$2.31
0.9 Surface Acre System, approximately 2 ft deep	$166,919	39,200	78,400	$2.13
1.8 Surface Acre System, approximately 2 ft deep	$293,551	78,400	156,800	$1.87

The O&M costs for a bioretention facility will correspond to the costs for maintaining the typical landscaping required for a site. In addition to the normal landscaping fees, O&M costs will include soil testing and may also include costs for a sand bed and planting soil (CASQA, 2003).

Sand Filters

Advantages:

- Relatively high pollutant removal, especially for sediment and associated pollutants.
- Relatively small footprint.
- Widespread application with sufficient capture volume can provide significant control of channel erosion and enlargement caused by changes to flow frequency relationships resulting from the increase of impervious cover in a watershed.

Limitations:

- May require more maintenance that some other BMPs depending upon the sizing of the filter bed.
- Generally require more hydraulic head to operate properly (minimum 4 feet).
- High solids loads will cause the filter to clog.
- Work best for relatively small, impervious watersheds.
- Filters in residential areas can present aesthetic and safety problems if constructed with vertical concrete walls.
- Certain designs (e.g., Delaware sand filter) maintain permanent sources of standing water where mosquito and midge breeding is likely to occur.

Table 6-9: Cost Estimates for Austin Sand Filter BMP

System Size	Capital Cost	Surface Area (ft. sq.)	Volume (cu. ft.)	Cost $/cu.ft.
~20,000 cu ft System, approximately 5 ft deep	$119,555	4,000	20,000	$5.98
~80,000 cu ft System, approximately 5 ft deep	$336,426	16,000	80,000	$4.21
~160,000 cu ft System, approximately 5 ft deep	$632,755	32,000	160,000	$3.95

Table 6-10: Cost Estimates for Washington, D.C./Delaware Sand Filter BMP

System Size	Capital Cost	Surface Area (ft. sq.)	Volume (cu. ft.)	Cost $/cu.ft.
~20,000 cu ft System, approximately 6 ft deep	$180,824	3,333	20,000	$9.04
~80,000 cu ft System, approximately 6 ft deep	$491,077	13,333	80,000	$6.14
~160,000 cu ft System, approximately 6 ft deep	$776,796	26,667	160,000	$4.85

Annual O&M costs for maintaining sand filter systems average about 5% of the initial construction cost of the BMP (CASQA, 2003).

Manufactured Wetlands

Advantages:

- Constructed wetlands remove dissolved pollutants unlike many of the other treatment technologies, whether manufactured or in the public domain.
- Gravel substrate and subsurface flow of the stormwater through the root systems forces the vegetation to remove nutrients and dissolved pollutants from the stormwater.
- Unlike standard constructed wetlands, there is no standing water in the manufactured wetland between storms (after emptying with each storm). This minimizes but does not entirely eliminate the opportunity for mosquito breeding.
- Can be incorporated into the landscaping of the development.
- The gravel substrate likely provides a good environment for bacteria, facilitating the removal of nitrogen and the degradation of oil and greases, and other organic compounds.
- The gravel substrate can be augmented with media that is specifically effective at removing dissolved pollutants, increasing further the performance of the system.
- Vegetation is more easily harvested in comparison to a wet pond or standard constructed wetland.
- Provides modest habitat for insects and other small invertebrates which in turn provide food for birds and other small animals.

Limitations:

- Not likely suitable for drainage areas greater than an acre due to the number of units that is required for larger sites.
- May attract invasive wetland species.
- May require irrigation during the dry season.
- With an emptying time as much as 5 days, a breeding ground for mosquitoes may occur during and immediately following each storm
- Where many units are required, the pattern of circular plastic covers of the center wells may not be appealing.
- Pilot testing would certainly need to be conducted prior to the consideration of proprietary BMPs for widespread use in the Upper San Antonio River watershed. In particular, the hydraulic characteristics and pollutant removal rates of individual designs will have to be determined by field verification.

Vortex Separator

Advantages:

- May provide the desired performance in less space and therefore less cost.
- Mosquito control may be less of an issue than with traditional wet basins.

Limitations:

- As some of the systems have standing water that remains between storms, there is concern about mosquito breeding.

- It is likely that vortex separators are not as effective as wet vaults at removing fine sediments, on the order 50 to 100 microns in diameter and less.
- The area served is limited by the capacity of the largest models.
- As the products come in standard sizes, the facilities will be oversized in many cases relative to the design treatment storm, increasing the cost.
- The non-steady flows of stormwater decreases the efficiency of vortex separators from what may be estimated or determined from testing under constant flow.
- Do not remove dissolved pollutants.
- A loss of dissolved pollutants may occur as accumulated organic matter (e.g., leaves) decomposes in the units.
- Pilot testing would certainly need to be conducted prior to the consideration of proprietary BMPs for widespread use in the Upper San Antonio River watershed. In particular, the hydraulic characteristics and pollutant removal rates of individual designs will have to be determined by field verification.

Antimicrobial Filters

Advantages:

- Have a small footprint and are simple to operate compared to conventional BMPs.
- Could be used in combination with other BMPs to enhance bacteria removal.

Limitations:

- Use of these devices is in its infancy and there is no consensus regarding optimum media design, required contact time, and expected removal rates.
- Pilot testing would certainly need to be conducted prior to the consideration of proprietary BMPs for widespread use in the Upper San Antonio River watershed. In particular, the hydraulic characteristics and pollutant removal rates of individual designs will have to be determined by field verification.

6.8.5 Non-Structural Urban Runoff BMPs

The primary recommendation for the City with regard to non-structural BMPs for urban runoff is to maintain its current programs. While the benefits of the street sweeping, stormwater system maintenance, and river maintenance programs cannot be easily quantified with regard to bacteria loadings, these programs are certainly of general benefit to the stormwater program and will have an overall positive affect on the water quality in the Upper San Antonio River Watershed.

6.9 SUMMARY

A summary of the future management measures recommended in the previous section is provided in Table 6-11. Also listed in this table is the current status of the BMP, the recommendation for potential future investigation or implementation, and the City entity that would likely be responsible for addressing further implementation.

Table 6-11: Summary of Potential BMPs for Bacteria Reduction

Source	Class	BMP Type	Current Status	Recommendation	Comments	Responsible Entity
Wastewater Collection	ST	None	n/a	n/a	n/a	n/a
	NS	Municipal sewer inspection, rehab, & maintenance	Program ongoing	Maintain program	Use current prioritization system	SAWS, All other WW Utilities
		Private sewer lateral inspection, rehabilitation, & maintenance	Not currently implemented	Develop ordinance, subsidize private lateral rehabilitation	City of Austin has developed a program for this	All cities, Ft. Sam Houston
Septic Systems	ST	Connect to sewer system	Espada project underway	Continue & complete project	Scheduled 10/07 completion	SAWS, COSA, Metro Health Dist.
	NS	Public education/awareness	Not currently implemented	Not required	n/a	All stakeholders
		Inspection and maintenance	Inspection program ongoing	Maintain Program	n/a	Bexar County
		Upgrade or replacement	Not currently implemented	Not required	n/a	Bexar County
		Chemical additive restrictions	Not currently implemented	Not required	n/a	Bexar County
Animal Deposition	ST	None	n/a	n/a	n/a	n/a
	NS	Habitat modification/bird scaring	Not currently implemented	Probably not viable	n/a	n/a
		Bird feeding ban	Not currently implemented	Consider implementation in City Parks	Focus on known problem areas & in parks near creeks/lakes	COSA PRD
		Pet waste ordinance	Ordinance currently in place	Maintain & enforce	n/a	COSA
		Dog parks	1 existing (Pearsall) & 1 under construction (McAllister)	Continue program	Site in parks away from creeks/lakes	COSA PRD
		“Pooper scooper” program	Mutt Mitt dispensers in 23 parks	Continue and expand program	Focus on parks near creeks/lakes	COSA PRD

Table 6-11: Summary of Potential BMPs for Bacteria Reduction (Continued)

Source	Class	BMP Type	Current Status	Recommendation	Comments	Responsible Entity
Urban Runoff	ST	Infiltration trench	Not currently implemented	Recommend for new development		COSA/SARA
		Infiltration basin	Not currently implemented	Construct or retrofit in watershed		COSA/SARA
		Wet pond	Not currently implemented	Construct or retrofit in watershed		COSA/SARA
		Constructed wetland	Not currently implemented	Construct or retrofit in watershed		COSA/SARA
		Bioretention systems	Not currently implemented	Recommend for new development		COSA/SARA
		Sand filters	Not currently implemented	Construct or retrofit in watershed		COSA/SARA
		Manufactured wetland	Not currently implemented	Investigate further, possibly pilot test	Proprietary treatment system	SARA/COSA PWD
		Vortex separators	Not currently implemented	Investigate further, possibly pilot test	Proprietary treatment systems	SARA/COSA PWD
		Antimicrobial filters	Not currently implemented	Investigate further, possibly pilot test	Proprietary treatment system	SARA/COSA PWD
	NS	Street sweeping/trash removal	Program ongoing	Continue program		COSA PWD/PRD
		SW system maintenance	Program ongoing	Continue program		COSA PWD

ST – Structural BMP.

NS – Non-structural BMP.

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APPENDIX A: Urban Runoff Sampling

Typical Stormwater Outfall Sampling Location

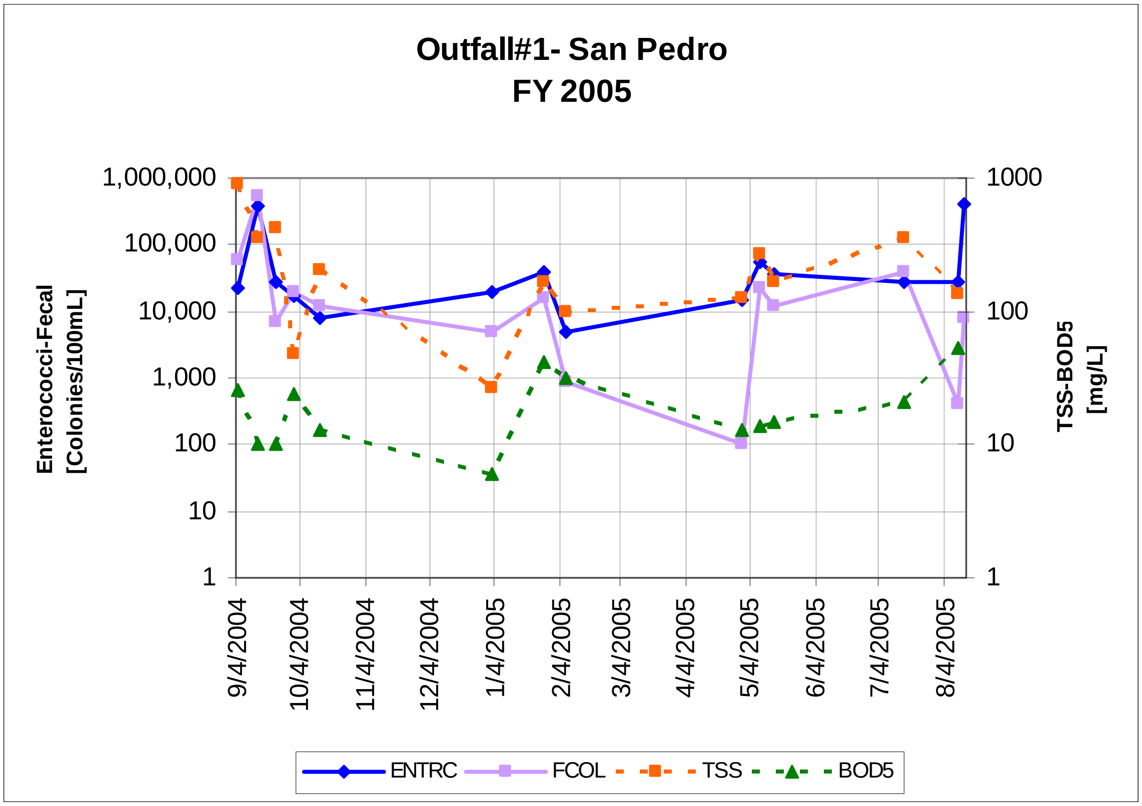
South Flores St @ Six Mile Creek

Storm Water Discharge Point

Outfall 002

Looking at the Discharge Location from Across the Creek

Samples are collected from water inside the outfall pipe and not from water in the creek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10,000
1,000
100
10
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1000
100
10
1
9/4/2004
10/4/2004
11/4/2004
12/4/2004
1/4/2005
2/4/2005
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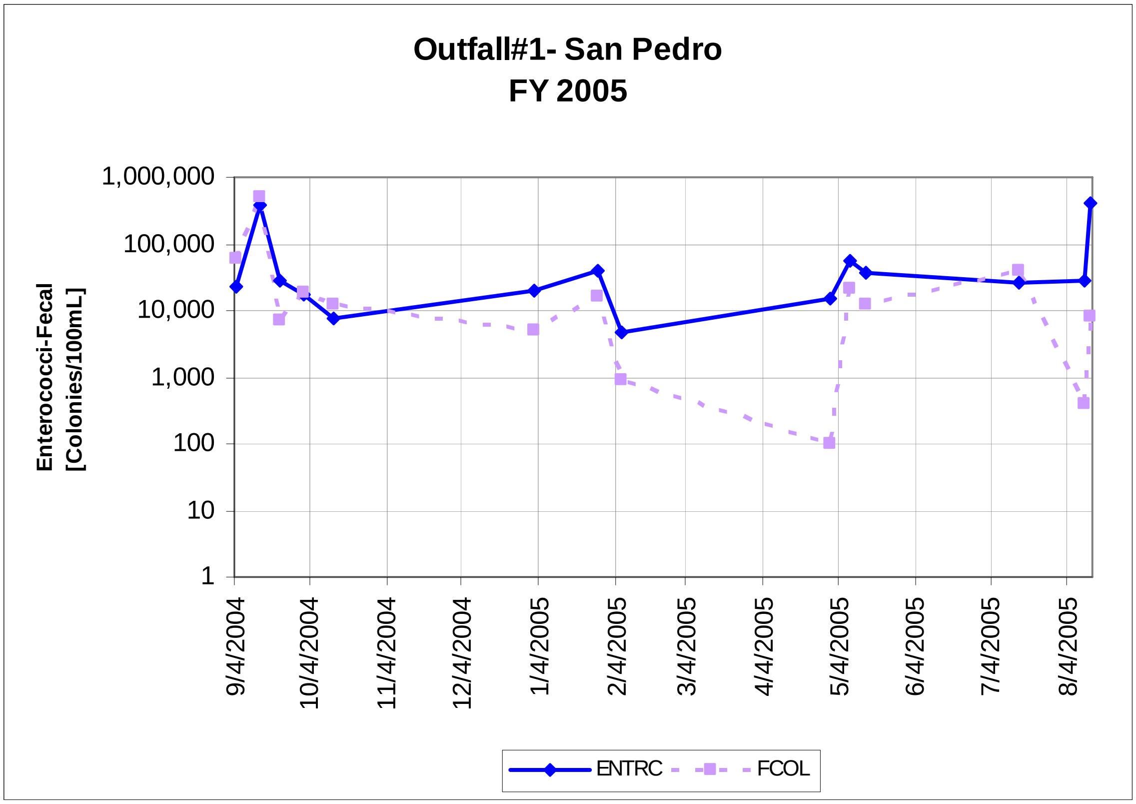
ENTRC
FCOL
TSS
BOD5


Outfall#1- San Pedro
FY 2005
Enterococci-Fecal [Colonies/100mL]
1,000,000
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10,000
1,000
100
10
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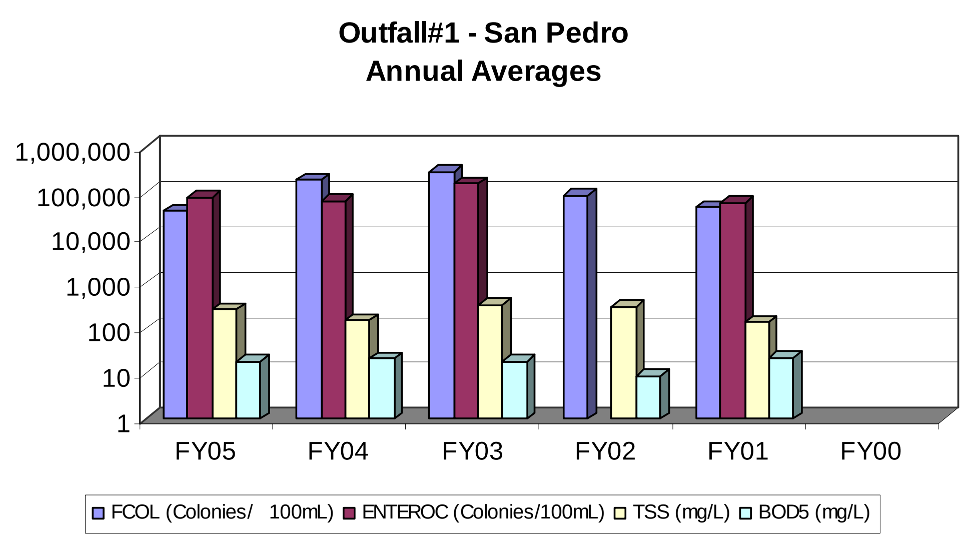
11/4/2004
12/4/2004
1/4/2005
2/4/2005
3/4/2005
4/4/2005
5/4/2005
6/4/2005
7/4/2005
8/4/2005
ENTRC
FCOL

Outfall#1 - San Pedro

DATE		FCOL (Colonies/ 100mL)	ENTEROC (Colonies/ 100mL)	TSS (mg/L)	BOD5 (mg/L)
1-Sep-04	30-Nov-04	123,600.00	93,160.00	563.67	15.33
1-Dec-04	31-Mar-05	7,300.00	21,600.00	92.22	14.33
1-Apr-05	30-Jun-05	11,366.67	35,666.67	131.33	28.67
1-Jul-05	31-Aug-05	16,133.33	158,333.33	260.67	16.67
FY 2005 Mean		**39,600.00**	**77,190.00**	**261.97**	**18.75**
1-Sep-03	30-Nov-03	460,000.00	84,000.00	100.00	< 20.00
1-Dec-03	31-Mar-04	106,940.00	72,800.00	166.10	20.80
1-Apr-04	30-Jun-04	50,667.00	80,330.00	82.50	11.00
1-Jul-04	31-Aug-04	124,450.00	16,500.00	241.70	33.33
FY 2004 Mean		**185,514.25**	**63,407.50**	**147.58**	**21.28**
1-Sep-02	30-Nov-02	76,500.00	59,500.00	321.00	16.00
1-Dec-02	31-Mar-03	No Discharge	No Discharge	No Discharge	No Discharge
1-Apr-03	30-Jun-03	620,000.00	350,000.00	454.00	9.80
1-Jul-03	31-Aug-03	166,667.00	51,667.00	197.00	< 30.00
FY 2003 Mean		**287,722.33**	**153,722.33**	**324.00**	**18.60**
1-Sep-01	30-Nov-01	81000	Not Analyzed	136.00	4.60
1-Dec-01	31-Mar-02	Missing Data	Not Analyzed	418.00	14.00
1-Apr-02	30-Jun-02	90,000.00	Not Analyzed	340.00	8.00
1-Jul-02	31-Aug-02	No Discharge	No Discharge	No Discharge	No Discharge
FY 2002 Mean		**85,500.00**		**298.00**	**8.87**
1-Sep-00	30-Nov-00	No Discharge	No Discharge	No Discharge	No Discharge
1-Dec-00	31-Mar-01	No Discharge	No Discharge	No Discharge	No Discharge
1-Apr-01	30-Jun-01	47,500.00	58,000.00	139.00	23.00
1-Jul-01	31-Aug-01	No Discharge	No Discharge	No Discharge	No Discharge
FY 2001 Mean		**47,500.00**	**58,000.00**	**139.00**	**23.00**
1-Sep-99	30-Nov-99	No Discharge	No Discharge	No Discharge	No Discharge
1-Dec-99	31-Mar-00	No Discharge	No Discharge	No Discharge	No Discharge
1-Apr-00	30-Jun-00	No Discharge	No Discharge	No Discharge	No Discharge
1-Jul-00	31-Aug-00	No Discharge	No Discharge	No Discharge	No Discharge

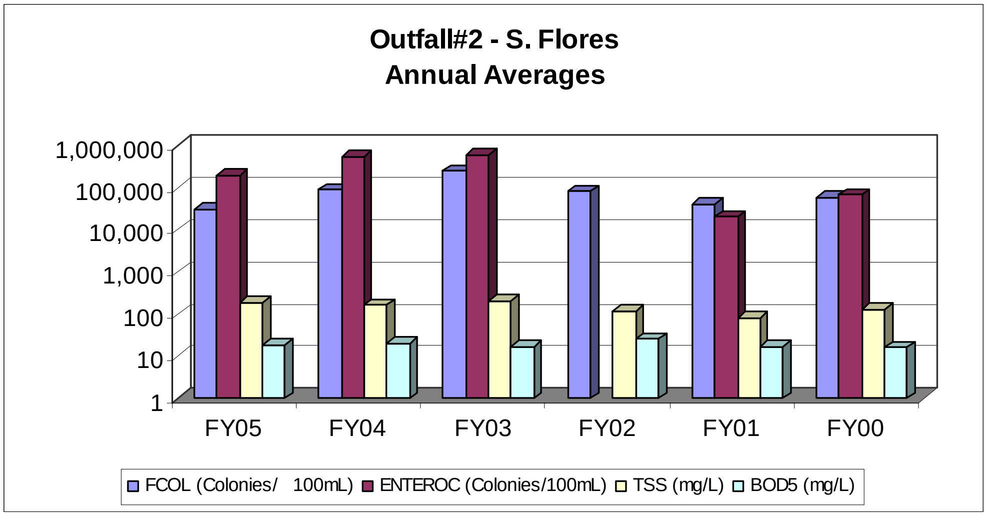
K indicates not an ideal range of fecal colonies to count.
E indicates estimated value, QA/QC problem.
** No data present in DMRs for this parameter for this period.*



Outfall#2 - S. Flores

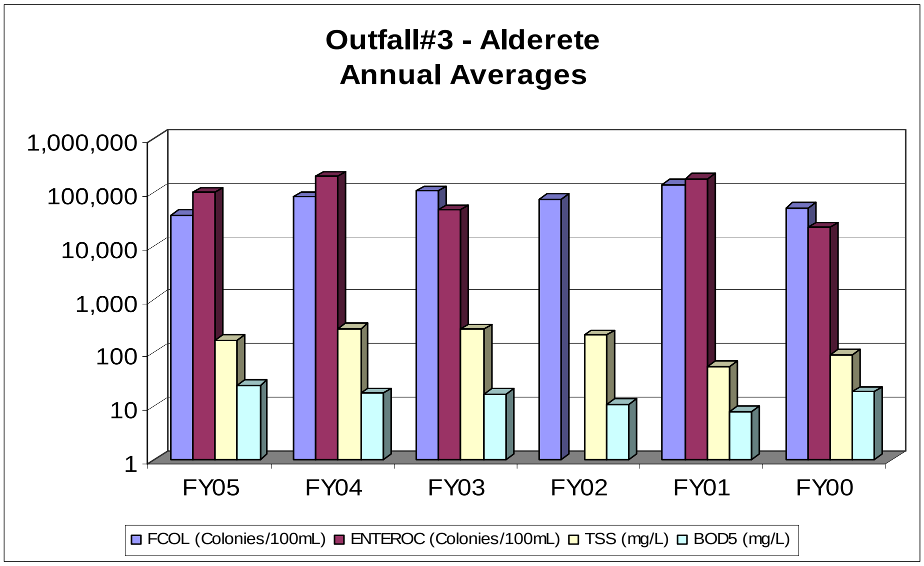
DATE		FCOL (Colonies/ 100mL)	ENTEROC (Colonies/ 100mL)	TSS (mg/L)	BOD5 (mg/L)
1-Sep-04	30-Nov-04	44,000.00	429,000.00	171.33	11.33
1-Dec-04	31-Mar-05	12,366.67	59,333.33	145.00	14.50
1-Apr-05	30-Jun-05	34,333.33	128,000.00	312.67	22.00
1-Jul-05	31-Aug-05	31,500.00	178,500.00	115.00	26.00
FY 2005 Mean		**30,550.00**	**198,708.33**	**186.00**	**18.46**
1-Sep-03	30-Nov-03	No Discharge	No Discharge	No Discharge	No Discharge
1-Dec-03	31-Mar-04	91,800.00	387,500.00	131.30	19.33
1-Apr-04	30-Jun-04	123,333.00	483,333.00	155.00	13.50
1-Jul-04	31-Aug-04	52,750.00	736,667.00	205.80	28.00
FY 2004 Mean		**89,294.33**	**535,833.33**	**164.03**	**20.28**
1-Sep-02	30-Nov-02	155,000.00	600,000.00	180.00	12.00
1-Dec-02	31-Mar-03	No Discharge	No Discharge	No Discharge	No Discharge
1-Apr-03	30-Jun-03	No Discharge	No Discharge	No Discharge	No Discharge
1-Jul-03	31-Aug-03	340,000.00	605,000.00	238.00	22.70
FY 2003 Mean		**247,500.00**	**602,500.00**	**209.00**	**17.35**
1-Sep-01	30-Nov-01	63,000.00	NA*	NA*	NA*
1-Dec-01	31-Mar-02	No Discharge	No Discharge	No Discharge	No Discharge
1-Apr-02	30-Jun-02	96,000.00	Not Analyzed	118.00	< 26.00
1-Jul-02	31-Aug-02	No Discharge	No Discharge	No Discharge	No Discharge
FY 2002 Mean		**79,500.00**		**118.00**	**26.00**
1-Sep-00	30-Nov-00	41,000.00	20,000.00	40.00	NA*
1-Dec-00	31-Mar-01	No Discharge	No Discharge	No Discharge	No Discharge
1-Apr-01	30-Jun-01	K NA*	K NA*	127.00	17.00
1-Jul-01	31-Aug-01	No Discharge	No Discharge	No Discharge	No Discharge
FY 2001 Mean		**41,000.00**	**20,000.00**	**83.50**	**17.00**
1-Sep-99	30-Nov-99	Not sampled	Not sampled	Not sampled	Not sampled
1-Dec-99	31-Mar-00	6,750.00	37,000.00	64.00	21.50
1-Apr-00	30-Jun-00	110,000.00	99,000.00	197.00	E 11.00
1-Jul-00	31-Aug-00	No Discharge	No Discharge	No Discharge	No Discharge
FY 2000 Mean		**58,375.00**	**68,000.00**	**130.50**	**16.25**

K indicates not an ideal range of fecal colonies to count.
E indicates estimated value, QA/QC problem.
** No data present in DMRs for this parameter for this period.*



Outfall#3 - Alderete					
DATE		FCOL (Colonies/ 100mL)	ENTEROC (Colonies/ 100mL)	TSS (mg/L)	BOD5 (mg/L)
1-Sep-04	30-Nov-04	29,500.00	169,750.00	365.00	21.75
1-Dec-04	31-Mar-05	23,933.33	156,333.33	82.00	23.50
1-Apr-05	30-Jun-05	12,333.33	42,333.33	193.50	28.00
1-Jul-05	31-Aug-05	85,000.00	31,500.00	49.67	24.67
FY 2005 Mean		**37,691.67**	**99,979.17**	**172.54**	**24.48**
1-Sep-03	30-Nov-03	No Discharge	No Discharge	No Discharge	No Discharge
1-Dec-03	31-Mar-04	46,960.00	150,000.00	170.50	14.75
1-Apr-04	30-Jun-04	82,000.00	427,667.00	373.80	11.75
1-Jul-04	31-Aug-04	121,250.00	17,670.00	294.90	26.00
FY 2004 Mean		**83,403.33**	**198,445.67**	**279.73**	**17.50**
1-Sep-02	30-Nov-02	128,750.00	66,500.00	90.00	15.00
1-Dec-02	31-Mar-03	No Discharge	No Discharge	No Discharge	No Discharge
1-Apr-03	30-Jun-03	No Discharge	No Discharge	No Discharge	No Discharge
1-Jul-03	31-Aug-03	86,667.00	28,800.00	467.00	18.70
FY 2003 Mean		**107,708.50**	**47,650.00**	**278.50**	**16.85**
1-Sep-01	30-Nov-01	No Discharge	No Discharge	No Discharge	No Discharge
1-Dec-01	31-Mar-02	No Discharge	No Discharge	No Discharge	No Discharge
1-Apr-02	30-Jun-02	77,000.00	Not Analyzed	216.00	11.00
1-Jul-02	31-Aug-02	No Discharge	No Discharge	No Discharge	No Discharge
FY 2002 Mean		**77,000.00**		**216.00**	**11.00**
1-Sep-00	30-Nov-00	No Discharge	No Discharge	No Discharge	No Discharge
1-Dec-00	31-Mar-01	No Discharge	No Discharge	No Discharge	No Discharge
1-Apr-01	30-Jun-01	140,000.00	180,000.00	57.00	7.90
1-Jul-01	31-Aug-01	No Discharge	No Discharge	No Discharge	No Discharge
FY 2001 Mean		**140,000.00**	**180,000.00**	**57.00**	**7.90**
1-Sep-99	30-Nov-99	80,000.00	31,000.00	92.00	15.00
1-Dec-99	31-Mar-00	25,000.00	14,000.00	92.00	22.00
1-Apr-00	30-Jun-00	No Discharge	No Discharge	No Discharge	No Discharge
1-Jul-00	31-Aug-00	No Discharge	No Discharge	No Discharge	No Discharge
FY 2000 Mean		**52,500.00**	**22,500.00**	**92.00**	**18.50**

K indicates not an ideal range of fecal colonies to count.
E indicates estimated value, QA/QC problem.
** No data present in DMRs for this parameter for this period.*

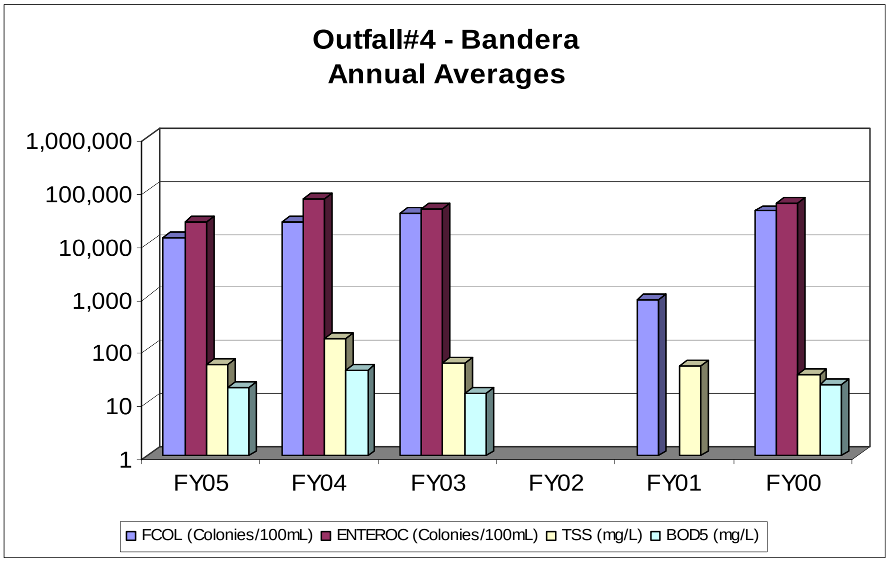


Outfall#4 - Bandera					
DATE		**FCOL (Colonies/ 100mL)**	**ENTEROC (Colonies/ 100mL)**	**TSS (mg/L)**	**BOD5 (mg/L)**
1-Sep-04	30-Nov-04	4,200.00	26,150.00	88.75	15.00
1-Dec-04	31-Mar-05	5,525.00	27,175.00	68.00	42.00
1-Apr-05	30-Jun-05	30,000.00	25,000.00	4.00	2.00
1-Jul-05	31-Aug-05	No Discharge	No Discharge	No Discharge	No Discharge
FY 2005 Mean		**13,241.67**	**26,108.33**	**53.58**	**19.67**
1-Sep-03	30-Nov-03	No Discharge	No Discharge	No Discharge	No Discharge
1-Dec-03	31-Mar-04	19,630.00	143,000.00	78.00	53.33
1-Apr-04	30-Jun-04	44,670.00	34,330.00	118.80	12.50
1-Jul-04	31-Aug-04	12,000.00	34,500.00	286.00	60.00
FY 2004 Mean		**25,433.33**	**70,610.00**	**160.93**	**41.94**
1-Sep-02	30-Nov-02	13,000.00	58,500.00	35.00	19.25
1-Dec-02	31-Mar-03	No Discharge	No Discharge	No Discharge	No Discha
1-Apr-03	30-Jun-03	30,000.00	26,000.00	95.00	7.80
1-Jul-03	31-Aug-03	70,000.00	51,666.00	37.00	19.00
FY 2003 Mean		**37,666.67**	**45,388.67**	**55.67**	**15.35**
1-Sep-01	30-Nov-01	No Discharge	No Discharge	No Discharge	No Discharge
1-Dec-01	31-Mar-02	No Discharge	No Discharge	No Discharge	No Discharge
1-Apr-02	30-Jun-02	No Discharge	No Discharge	No Discharge	No Discharge
1-Jul-02	31-Aug-02	No Discharge	No Discharge	No Discharge	No Discharge
FY 2002 Mean					
1-Sep-00	30-Nov-00	900.00 K	NA*	50.00 E	NA*
1-Dec-00	31-Mar-01	No Discharge	No Discharge	No Discharge	No Discharge
1-Apr-01	30-Jun-01	No Discharge	No Discharge	No Discharge	No Discharge
1-Jul-01	31-Aug-01	No Discharge	No Discharge	No Discharge	No Discharge
FY 2001 Mean		**900.00**		**50.00**	
1-Sep-99	30-Nov-99	75,000.00	31,000.00	7.00	12.00
1-Dec-99	31-Mar-00	24,000.00	71,000.00	47.00	27.00
1-Apr-00	30-Jun-00	24,000.00	71,000.00	47.00	27.00
1-Jul-00	31-Aug-00	No Discharge	No Discharge	No Discharge	No Discharge
FY 2000 Mean		**41,000.00**	**57,666.67**	**33.67**	**22.00**

K indicates not an ideal range of fecal colonies to count.

E indicates estimated value, QA/QC problem.

** No data present in DMRs for this parameter for this period.*



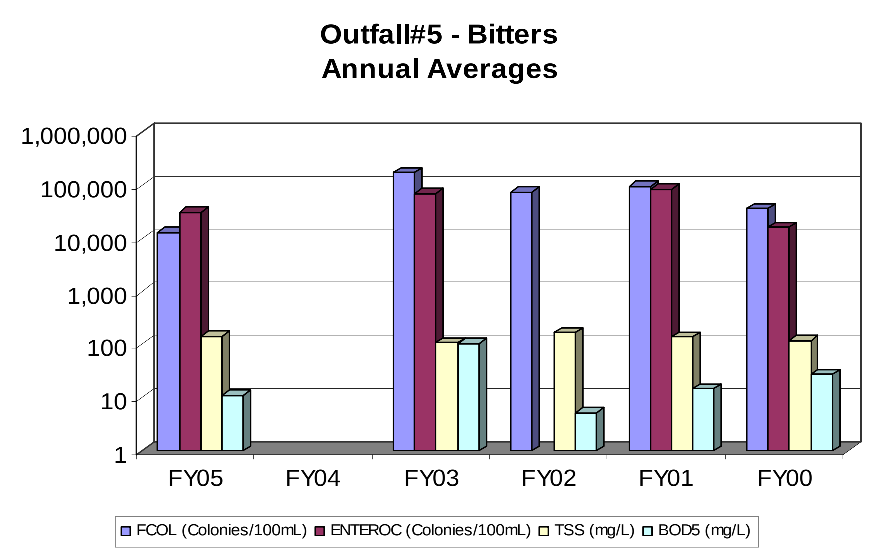
Outfall#5 - Bitters

DATE		FCOL (Colonies/ 100mL)	ENTEROC (Colonies/ 100mL)	TSS (mg/L)	BOD5 (mg/L)
1-Sep-04	30-Nov-04	17,666.67	44,000.00	132.00	5.67
1-Dec-04	31-Mar-05	4,700.00	20,733.33	246.00	8.00
1-Apr-05	30-Jun-05	9,750.00	40,000.00	91.50	22.50
1-Jul-05	31-Aug-05	20,000.00	21,000.00	115.5	7.50
FY 2005 Mean		**13,029.17**	**31,433.33**	**146.25**	**10.92**
1-Sep-03	30-Nov-03	Missing DMR	Missing DMR	Missing DMR	Missing DMR
1-Dec-03	31-Mar-04	Missing DMR	Missing DMR	Missing DMR	Missing DMR
1-Apr-04	30-Jun-04	Missing DMR	Missing DMR	Missing DMR	Missing DMR
1-Jul-04	31-Aug-04	Missing DMR	Missing DMR	Missing DMR	Missing DMR
FY 2004 Mean					
1-Sep-02	30-Nov-02	101,000.00	78,300.00	148.00	6.00
1-Dec-02	31-Mar-03	No Discharge	No Discharge	No Discharge	No Discharge
1-Apr-03	30-Jun-03	No Discharge	No Discharge	No Discharge	No Discharge
1-Jul-03	31-Aug-03	250,000.00	60,000.00	70.00	< 200.00
FY 2003 Mean		**175,500.00**	**69,150.00**	**109.00**	**103.00**
1-Sep-01	30-Nov-01	74,500.00	Not Analyzed	168.00	5.20
1-Dec-01	31-Mar-02	No Discharge	No Discharge	No Discharge	No Discharge
1-Apr-02	30-Jun-02	No Discharge	No Discharge	No Discharge	No Discharge
1-Jul-02	31-Aug-02	No Discharge	No Discharge	No Discharge	No Discharge
FY 2002 Mean		**74,500.00**		**168.00**	**5.20**
1-Sep-00	30-Nov-00	175,000.00	43,000.00	153.00	11.00
1-Dec-00	31-Mar-01	No Discharge	No Discharge	No Discharge	No Discharge
1-Apr-01	30-Jun-01	17,133.00	123,733.00	126.70	18.30
1-Jul-01	31-Aug-01	No Discharge	No Discharge	No Discharge	No Discharge
FY 2001 Mean		**96,066.50**	**83,366.50**	**139.85**	**14.65**
1-Sep-99	30-Nov-99	52,000.00	5,200.00	45.00	< 46.00
1-Dec-99	31-Mar-00	35,000.00	31,000.00	181.00	NA*
1-Apr-00	30-Jun-00	23,000.00	12,000.00	138.00	E 8.70
1-Jul-00	31-Aug-00	No Discharge	No Discharge	No Discharge	No Discharge
FY 2000 Mean		**36,666.67**	**16,066.67**	**121.33**	**27.35**

K indicates not an ideal range of fecal colonies to count.

E indicates estimated value, QA/QC problem.

** No data present in DMRs for this parameter for this period.*



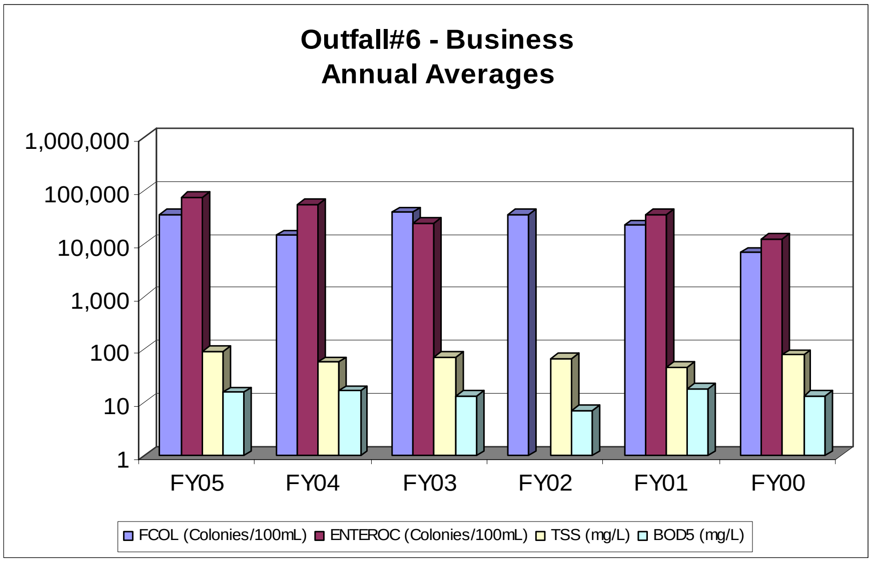
Outfall#6 - Business

DATE			FCOL (Colonies/ 100mL)	ENTEROC (Colonies/ 100mL)	TSS (mg/L)		BOD5 (mg/L)
1-Sep-04	30-Nov-04		117,333.33	234,500.00	134.00		14.33
1-Dec-04	31-Mar-05		10,366.67	37,266.67	59.00		12.67
1-Apr-05	30-Jun-05		6,000.00	13,000.00	108.67		20.00
1-Jul-05	31-Aug-05		10,000.00	13,000.00	73.00		16.00
FY 2005 Mean			**35,925.00**	**74,441.67**	**93.67**		**15.75**
1-Sep-03	30-Nov-03		No Discharge	No Discharge	No Discharge		No Discharge
1-Dec-03	31-Mar-04		4,940.00	22,000.00	67.40		21.20
1-Apr-04	30-Jun-04		19,330.00	86,330.00	50.00		18.33
1-Jul-04	31-Aug-04		18,330.00	53,000.00	58.00		10.50
FY 2004 Mean			**14,200.00**	**53,776.67**	**58.47**		**16.68**
1-Sep-02	30-Nov-02		14,000.00	14,500.00	37.30		7.80
1-Dec-02	31-Mar-03		No Discharge	No Discharge	No Discharge		No Discharge
1-Apr-03	30-Jun-03		69,000.00	41,000.00	146.00		8.20
1-Jul-03	31-Aug-03		33,000.00	18,200.00	36.70		24.00
FY 2003 Mean			**38,666.67**	**24,566.67**	**73.33**		**13.33**
1-Sep-01	30-Nov-01		42,000.00	Not Analyzed	35.00	<	4.00
1-Dec-01	31-Mar-02		30,000.00	Not Analyzed	100.00		10.00
1-Apr-02	30-Jun-02		No Discharge	No Discharge	No Discharge		No Discharge
1-Jul-02	31-Aug-02		No Discharge	No Discharge	No Discharge		No Discharge
FY 2002 Mean			**36,000.00**		**67.50**		**7.00**
1-Sep-00	30-Nov-00		24,000.00	8,700.00	27.00		25.00
1-Dec-00	31-Mar-01		No Discharge	No Discharge	No Discharge		No Discharge
1-Apr-01	30-Jun-01		20,000.00	61,000.00	65.00	<	11.00
1-Jul-01	31-Aug-01		No Discharge	No Discharge	No Discharge		No Discharge
FY 2001 Mean			**22,000.00**	**34,850.00**	**46.00**		**18.00**
1-Sep-99	30-Nov-99		10,000.00	25,000.00	27.00	<	17.00
1-Dec-99	31-Mar-00	K	420.00	2,900.00	86.00		16.00
1-Apr-00	30-Jun-00		10,000.00	9,500.00	124.00		7.70
1-Jul-00	31-Aug-00		No Discharge	No Discharge	No Discharge		No Discharge
FY 2000 Mean			**6,806.67**	**12,466.67**	**79.00**		**13.57**

K indicates not an ideal range of fecal colonies to count.

E indicates estimated value, QA/QC problem.

** No data present in DMRs for this parameter for this period.*

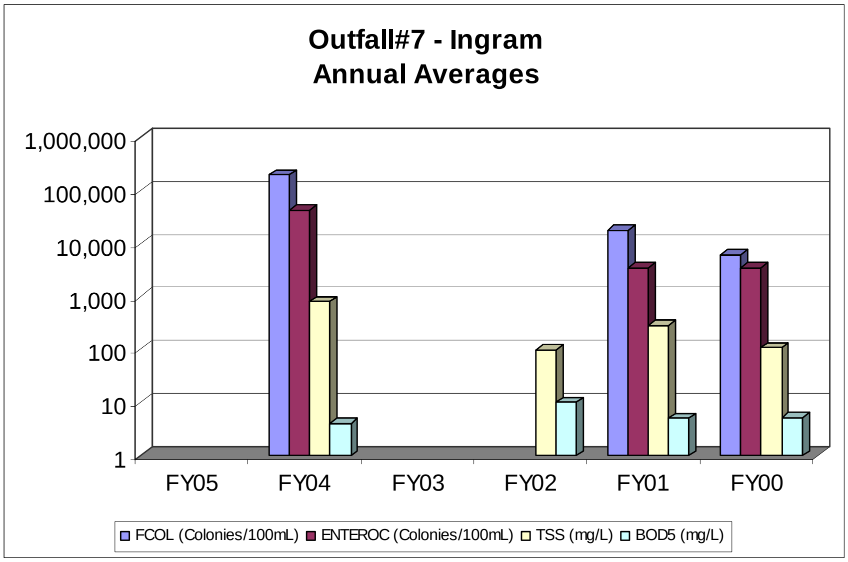


Outfall#7 - Ingram					
DATE		FCOL (Colonies/ 100mL)	ENTEROC (Colonies/ 100mL)	TSS (mg/L)	BOD5 (mg/L)
1-Sep-04	30-Nov-04	Missing DMR	Missing DMR	Missing DMR	Missing DMR
1-Dec-04	31-Mar-05	Missing DMR	Missing DMR	Missing DMR	Missing DMR
1-Apr-05	30-Jun-05	Missing DMR	Missing DMR	Missing DMR	Missing DMR
1-Jul-05	31-Aug-05	Missing DMR	Missing DMR	Missing DMR	Missing DMR
FY 2005 Mean					
1-Sep-03	30-Nov-03	5,418.00	6,609.00	655.00	2.00
1-Dec-03	31-Mar-04	No Discharge	No Discharge	No Discharge	No Discharge
1-Apr-04	30-Jun-04	390,000.00	80,000.00	940.00	6.00
1-Jul-04	31-Aug-04	No Discharge	No Discharge	No Discharge	No Discharge
FY 2004 Mean		**197,709.00**	**43,304.50**	**797.50**	**4.00**
1-Sep-02	30-Nov-02	No Discharge	No Discharge	No Discharge	No Discharge
1-Dec-02	31-Mar-03	No Discharge	No Discharge	No Discharge	No Discharge
1-Apr-03	30-Jun-03	No Discharge	No Discharge	No Discharge	No Discharge
1-Jul-03	31-Aug-03	No Discharge	No Discharge	No Discharge	No Discharge
FY 2003 Mean					
1-Sep-01	30-Nov-01	No Discharge	No Discharge	No Discharge	No Discharge
1-Dec-01	31-Mar-02	No Discharge	No Discharge	No Discharge	No Discharge
1-Apr-02	30-Jun-02	Not Analyzed	Not Analyzed	100.00	10.00
1-Jul-02	31-Aug-02	No Discharge	No Discharge	No Discharge	No Discharge
FY 2002 Mean				**100.00**	**10.00**
1-Sep-00	30-Nov-00	17,900.00	3,500.00	292.00	5.10
1-Dec-00	31-Mar-01	No Discharge	No Discharge	No Discharge	No Discharge
1-Apr-01	30-Jun-01	No Discharge	No Discharge	No Discharge	No Discharge
1-Jul-01	31-Aug-01	No Discharge	No Discharge	No Discharge	No Discharge
FY 2001 Mean		**17,900.00**	**3,500.00**	**292.00**	**5.10**
1-Sep-99	30-Nov-99	8,000.00	1,900.00	43.00	< 6.70
1-Dec-99	31-Mar-00	3,100.00	3,000.00	87.00	NA*
1-Apr-00	30-Jun-00	K 7,000.00	5,400.00	193.00	E 3.80
1-Jul-00	31-Aug-00	No Discharge	No Discharge	No Discharge	No Discharge
FY 2000 Mean		**6,033.33**	**3,433.33**	**107.67**	**5.25**

K indicates not an ideal range of fecal colonies to count.

E indicates estimated value, QA/QC problem.

** No data present in DMRs for this parameter for this period.*



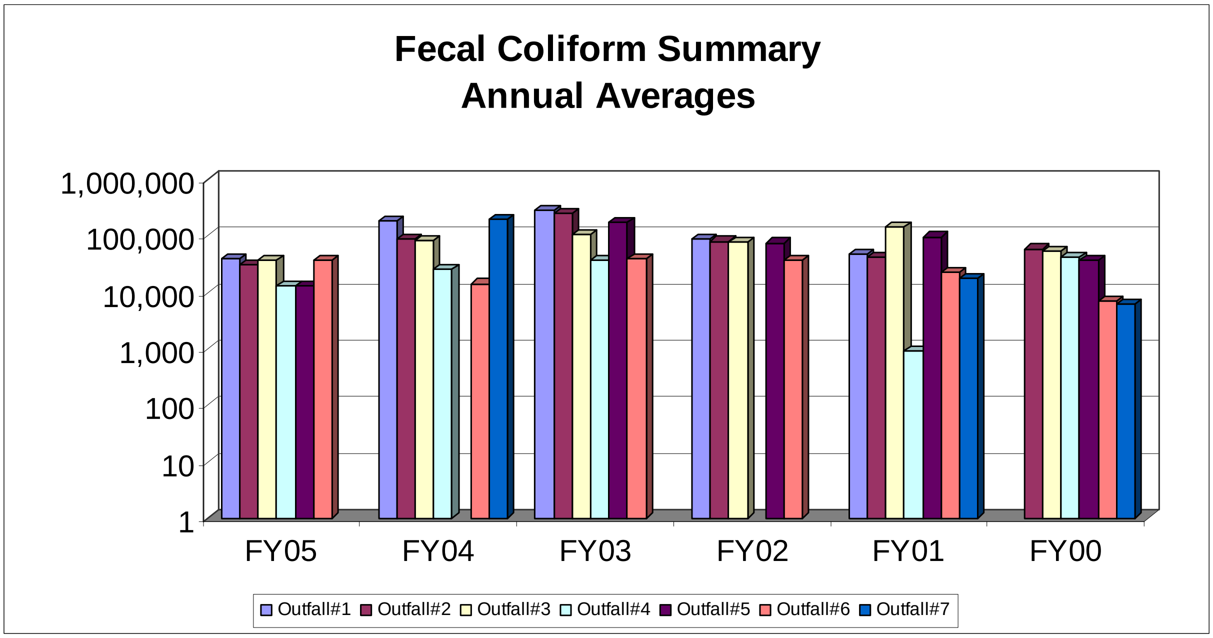
Outfall Summary

		Outfall#1	Outfall#2	Outfall#3	Outfall#4	Outfall#5	Outfall#6	Outfall#7
DATE		FCOL (Colonies /100mL)	FCOL (Colonies /100mL)	FCOL (Colonies /100mL)	FCOL (Colonies /100mL)	FCOL (Colonies /100mL)	FCOL (Colonies /100mL)	FCOL (Colonies /100mL)
1-Sep-04	30-Nov-04	123,600.00	44,000.00	29,500.00	4,200.00	17,666.67	117,333.33	Missing DMR
1-Dec-04	31-Mar-05	7,300.00	12,366.67	23,933.33	5,525.00	4,700.00	10,366.67	Missing DMR
1-Apr-05	30-Jun-05	11,366.67	34,333.33	12,333.33	30,000.00	9,750.00	6,000.00	Missing DMR
1-Jul-05	31-Aug-05	16,133.33	31,500.00	85,000.00	No Discharge	20,000.00	10,000.00	Missing DMR
FY 2005 Mean		**39,600.00**	**30,550.00**	**37,691.67**	**13,241.67**	**13,029.17**	**35,925.00**	
1-Sep-03	30-Nov-03	460,000.00	No Discharge	No Discharge	No Discharge	Missing DMR	No Discharge	5,418.00
1-Dec-03	31-Mar-04	106,940.00	91,800.00	46,960.00	19,630.00	Missing DMR	4,940.00	No Discharge
1-Apr-04	30-Jun-04	50,667.00	123,333.00	82,000.00	44,670.00	Missing DMR	19,330.00	390,000.00
1-Jul-04	31-Aug-04	124,450.00	52,750.00	121,250.00	12,000.00	Missing DMR	18,330.00	No Discharge
FY 2004 Mean		**185,514.25**	**89,294.33**	**83,403.33**	**25,433.33**		**14,200.00**	**197,709.00**
1-Sep-02	30-Nov-02	76,500.00	155,000.00	128,750.00	13,000.00	101,000.00	14,000.00	No Discharge
1-Dec-02	31-Mar-03	No Discharge	No Discharge	No Discharge	No Discharge	No Discharge	No Discharge	No Discharge
1-Apr-03	30-Jun-03	620,000.00	No Discharge	No Discharge	30,000.00	No Discharge	69,000.00	No Discharge
1-Jul-03	31-Aug-03	166,667.00	340,000.00	86,667.00	70,000.00	250,000.00	33,000.00	No Discharge
FY 2003 Mean		**287,722.33**	**247,500.00**	**107,708.50**	**37,666.67**	**175,500.00**	**38,666.67**	
1-Sep-01	30-Nov-01	81000	63,000.00	No Discharge	No Discharge	74,500.00	42,000.00	No Discharge
1-Dec-01	31-Mar-02	Missing Data	No Discharge	No Discharge	No Discharge	No Discharge	30,000.00	No Discharge
1-Apr-02	30-Jun-02	90,000.00	96,000.00	77,000.00	No Discharge	No Discharge	No Discharge	Not Analyzed
1-Jul-02	31-Aug-02	No Discharge	No Discharge	No Discharge	No Discharge	No Discharge	No Discharge	No Discharge
FY 2002 Mean		**85,500.00**	**79,500.00**	**77,000.00**		**74,500.00**	**36,000.00**	
1-Sep-00	30-Nov-00	No Discharge	41,000.00	No Discharge	900.00	175,000.00	24,000.00	17,900.00
1-Dec-00	31-Mar-01	No Discharge	No Discharge	No Discharge	No Discharge	No Discharge	No Discharge	No Discharge
1-Apr-01	30-Jun-01	47,500.00	K NA*	140,000.00	No Discharge	17,133.00	20,000.00	No Discharge
1-Jul-01	31-Aug-01	No Discharge	No Discharge	No Discharge	No Discharge	No Discharge	No Discharge	No Discharge
FY 2001 Mean		**47,500.00**	**41,000.00**	**140,000.00**	**900.00**	**96,066.50**	**22,000.00**	**17,900.00**
1-Sep-99	30-Nov-99	No Discharge	Not sampled	80,000.00	75,000.00	52,000.00	10,000.00	8,000.00
1-Dec-99	31-Mar-00	No Discharge	6,750.00	25,000.00	24,000.00	35,000.00	K 420.00	3,100.00
1-Apr-00	30-Jun-00	No Discharge	110,000.00	No Discharge	24,000.00	23,000.00	10,000.00	K 7,000.00
1-Jul-00	31-Aug-00	No Discharge	No Discharge	No Discharge	No Discharge	No Discharge	No Discharge	No Discharge
FY 2000 Mean			**58,375.00**	**52,500.00**	**41,000.00**	**36,666.67**	**6,806.67**	**6,033.33**

K indicates not an ideal range of fecal colonies to count.

E indicates estimated value, QA/QC problem.

** No data present in DMRs for this parameter for this period.*



APPENDIX B: Verification Sampling Results

General Assessment Survey

November 2005 – April 2006

Bacteria counts in org/100mL
All other concentrations mg/L

Zoo Primary Outfall, Station ID # 15722

Date	DO	Temp ºC	pH	Cond.	TDS (calc)	Last Rain (days)	Discharge (cfs)	TSS	E. coli	Fecal Coliform
11/17/2005	7.3	21.9	7.6	502	326	>7	3.2	<4.0	4400	7800
11/21/2005	7.3	22.7	7.6	506	329	>7	4	<4.0	3818	7000
11/29/2005	7.2	22.1	7.7	506	329	3	5.1	<4.0	3100	5600
12/6/2005	7.2	21.8	7.6	496	322	>7	3.8	<4.0	3200	5700
12/12/2005	7.3	22.3	7.6	503	327	>7	5	<4.0	1825	5125
12/20/2005	6.9	22.1	7.5	505	328	>7	4.7	7.7	12,500	19,100
12/27/2005	6.6	22.8	7.5	505	328	>7	5.5	<4.0	3000	4900
1/3/2006	6.9	22.5	7.5	505	328	>7	3.3	<1.0	600	700
1/9/2006	6.7	23.2	7.5	505	328	>7		<4.0	4000	7000
1/17/2006	7	21.8	7.6	505	328	>7	4.1	<4.0	3308	6154
1/23/2006	7.3	22.1	7.6	502	326	1	3.5	5	3692	5846
1/30/2006	7.3	22.6	7.6	507	330	2	5.1	<4.0	11,667	28,000
2/6/2006	7.6	22.2	7.6	505	328	>7	2.9	<4.0	3,385	6,077
2/13/2006	7.6	21.7	7.7	503	327	3	4.4	<4.0	2800	4700
2/21/2006	7.1	21.7	7.6	497	323	<1	4.6	<4.0	4138	6340
2/27/2006	7.7	23.1	7.5	500	325	2	3.7	6.4	6667	8000
3/6/2006	6.5	23.5	7.5	382	248	>7	3.2	<4.0	8625	15,375
3/16/2006	6.1	23.2	7.1	482	313	>7	2.5	<4.0	7784	13,483
3/21/2006	6.7	22.4	7.6	494	321	1	3.7	8.8	10,333	17,333
3/30/2006	6.9	23.72	7.4	500	325	3	5	6.9	21,000	29,000
4/4/2006	6	23.6	7.5	496	322	>7	4.4	6.2	12,333	19,667
4/10/2006	6.5	22.8	7.5	498	324	>7	2.4	<4.0	22,000	24,000
4/17/2006	6.3	24.4	7.4	500	325	>7	3.2	5.5	25,000	42,000
4/26/2006	6.2	22.5	7.6	496	322	5	2.6	7.2	15,000	26,000

Zoo Site 'E' (Hippo Pen), Station ID # 127021

Date	DO	Temp ºC	pH	Cond.	TDS (calc)	Last Rain	TSS	E. coli	Fecal Coliform
1/3/2006	7.3	23.8	7.4	498	324	>7	<4.0	2200	3900
1/9/2006	7.5	24	7.5	501	326	>7	<4.0	3000	5200
1/17/2006	7.3	23.4	7.5	500	325	>7	<4.0	2900	4700
1/23/2006	7.6	23.7	7.5	499	324	1	<4.0	1300	2700
1/30/2006	7.7	23.8	7.5	500	325	2	<4.0	1900	3400
2/6/2006	7.8	23.7	7.5	501	326	>7	39	2385	5692
2/13/2006	7.7	23.5	7.5	499	324	3	<4.0	2400	3000
2/21/2006	7.4	23.6	7.5	487	316	<1	<4.0	2900	4200
2/27/2006	8	24.2	7.5	495	322	2	<4.0	2500	4600
3/6/2006	7.5	24.1	7.4	500	325	>7	<4.0	19,000	35,000
3/16/2006	6.97	24.04	7.02	482	313	>7	<4.0	>6667	>6667
3/21/2006	7.8	24.1	7.5	495	322	1	<4.0	6000	7000
3/30/2006	7.8	24.4	7.4	500	325	3	<4.0	41,333	52,000
4/4/2009	7.3	24.2	7.5	495	322	>7	<4.0	26,000	31,667
4/10/2006	7.3	24.2	7.4	499	324	>7	4.7	16,000	29,000
4/17/2006	7.7	24.8	7.4	499	324	>7	<4.0	14,000	20,000
4/26/2006	7.1	23.8	7.5	496	322	5	<4.0	13,750	22,500

Zoo Secondary Outfall, Station ID #18803

Date	DO	Temp ºC	pH	Cond.	TDS (calc)	Last Rain (days)	Discharge (cfs)	TSS	E. coli	Fecal Coliform
11/17/2005	5.6	21.4	7.5	510	332	>7	0.5	10.9	<7	<7
11/21/2005	5.4	22.2	7.5	529	344	>7	0.1	<4.0	<9	<9
11/29/2005	5.8	21.4	7.6	526	342	3	0.15	17	<9	<9
12/6/2005	5.4	20.5	7.6	513	333	>7	0.1	<4.0	<7	<7
12/12/2005	5.8	21.1	7.4	520	338	>7	0.1	4	<7	<7
12/20/2005	5.8	22.6	7.5	511	332	>7	0.2	<4.0	2	2
12/27/2005	5.1	22.7	7.4	508	330	>7	0.7	<4.0	117	167
1/3/2006	4.7	21.5	7.4	514	334	>7	-0.01	<4.0	<2	<2
1/9/2006	4.4	22.5	7.3	520	338	>7	0.16	<4.0	<2	<2
1/17/2006	5.2	20.7	7.4	518	337	>7	0.041	6.2	<2	<2
1/23/2006	5.2	20.8	7.4	523	340	1	0.013	<4.0	<2	<2
1/30/2006	5.3	21.5	7.4	522	339	2	0.084	<4.0	<2	<2
2/6/2006	5.6	21	7.4	522	339	>7	0.1	6.7	<2	<2
2/13/2006	4.9	19.2	7.3	525	341	3	0.1	<4.0	<2	<2
2/21/2006	4.7	20.2	7.3	550	358	<1	0.0735	141	<2	<2
2/27/2006	5	21.7	7.3	515	335	2	0.065	7.1	<2	<2
3/6/2006	4.3	22.7	7.2	546	355	>7	0.0357	13.3	<2	<2
3/16/2006	3.6	22.3	6.8	533	346	>7	0.0771	<4.0	7	9
3/21/2006	5.6	21.6	7.4	523	340	1	0.021	22	<9	<9
3/30/2006	4.6	23.2	7.3	526	342	3	0.2	<4.0	<2	<2
4/4/2006	4.3	23.2	7.4	522	339	>7	0.1	6.6	<2	<2
4/10/2006	4.4	22.8	7.3	524	341	>7	0.2	9.7	21	33
4/17/2006	2.5	24.1	7.2	561	365	>7	0.2	5.3	>6667	>6667
4/26/2006	4.4	22.9	7.2	519	337	5	0.064	15.2	246	469

San Antonio River @ Hildebrand, Station ID # 12912

Date	DO	Temp ºC	pH	Cond.	TDS (calc)	Last Rain (days)	Discharge (cfs)	T-PO4	NH3N	TKN	NO2N	NO3N	TSS	TOC	CL	SO4	E. coli	Fecal Coliform
11/17/2005	7.3	23	7.5	497	323	>7	40	<0.06	<0.02	<0.2	<0.02	1.74	<4.0	<2.0	17.6	16.3	154	193
11/21/2005	7.6	23.6	7.6	502	326	>7	37						<4.0				240	310
11/29/2005	7.2	23.1	7.6	501	326	3	44						<4.0				120	200
12/6/2005	7.4	23.2	7.6	492	320	>7	42	<0.06	<0.02	<0.2	<0.02	1.7	<4.0	<2.0	17.4	16	121	129
12/12/2005	7.7	23.4	7.5	498	324	>7	42						<4.0				129	171
12/20/2005	7.1	23.2	7.6	498	324	>7	47						<4.0				120	200
12/27/2005	7.2	23.5	7.5	499	324	>7	47						<4.0				190	240
1/3/2006	7.2	23	7.5	500	325	>7	40	<0.06	<0.02	0.214	<0.02	1.89	<4.0	<2.0	18.9	17.2	485	114
1/17/2006	7.1	22.7	7.6	501	326	>7	34						<4.0				71	93
1/23/2006	7.1	22.4	7.5	518	337	1	18						9				117	133
1/30/2006	7.4	23	7.5	502	326	2	37						<4.0				338	585
2/6/2006	8.4	23	7.6	500	325	>7	27	<0.06	<0.02	<0.2	<0.02	1.7	<4.0	<2.0	17.6	15.7	300	400
2/13/2006	7.5	22.5	7.5	498	324	3	25						<4.0				3200	3300
2/21/2006	7.8	23.1	7.5	491	319	<1	19						<4.0				310	390
2/27/2006	7.6	23.1	7.4	491	319	2	18						<4.0				346	646
3/6/2006	7.7	24.1	7.5	395	257	>7	6.5	<0.06	<0.02	<0.2	<0.02	1.71	<4.0	<2.0	18.5	16.2	250	330
3/16/2006	3.8	22.3	7	496	322	>7	0.3						5.6				440	600
3/21/2006	6	22.3	7.5	481	313	1	4.2						6.3				3000	33,333
3/30/2006	6.8	23.6	7.4	494	321	3	11						<4.0				667	1233
4/4/2006	6.1	23.6	7.4	498	324	>7	6	<0.06	<0.02	<0.2	<0.02	1.68	<4.0	<2.0	18.5	16.9	420	550
4/10/2006	5.9	22.4	7.5	503	327	>7	0.7						<4.0				825	1550
4/17/2006	2.7	25.5	7.4	1110	722	>7	-0.3						6.2				1133	1567
4/26/2006	2.6	21.6	7.6	931	605	5	-0.2						4				1000	4850

San Antonio River at Alamo, Station ID # 12904

Date	DO	Temp ºC	pH	Cond.	TDS (calc)	Last Rain (days)	Discharge (cfs)	T-PO4	NH3N	TKN	NO2N	NO3N	TSS	TOC	CL	SO4	E. coli	Fecal Coliform
11/17/2005	9.6	18	8.2	535	348	>7	27	0.116	<0.02	0.239	<0.02	2.11	<4.0	<2	24.4	23.3	200	300
11/21/2005	9.7	18.7	8.2	537	349	>7	26						9.8				125	190
11/29/2005	9	18.3	8.2	517	336	3	38						4.6				400	4200
12/6/2005	9.4	17	8.2	501	326	>7	29	<0.06	<0.02	0.342	<0.02	1.64	6	<2.0	20.8	19.1	150	950
12/12/2005	10.2	16.1	7.9	512	333	>7	28						<4.0				135	240
12/20/2005	9.3	18.2	8.2	512	333	>7	55						<4.0				180	240
12/27/2005	9	18.5	8	513	333	>7	52						<4.0				155	250
1/3/2006	6.1	21.7	7.7	612	398	>7	11	0.484	1.25	2.51	0.041	1.8	308	4.19	33.6	39.4	2800	2900
1/9/2006	7.6	21.5	8.1	636	413	>7	18						53				175	500
1/17/2006	9.2	17.2	8.1	521	339	>7	19						6.1				564	1144
1/23/2006	9.6	16.4	8	511	332	1	32						7.4				634	817
1/30/2006	9.4	18.8	8.1	518	337	2	23						<4.0				160	384
2/6/2006	9.3	18.2	8.1	516	335	>7	33	<0.06	<0.02	0.204	<0.02	1.58	<4.0	<2.0	20.2	19.3	255	395
2/13/2006	10.1	15.1	8.1	511	332	3	46						4.2				185	210
2/23/2006	10	18.8	8.2	523	340	3	57						9.2				117	130
2/27/2006	9	17	7.8	398	259	2							33				5300	11,250
3/6/2006	9.8	22.7	8	541	352	>7	15	<0.06	1.048	<0.2	<0.02	1.43	<4.0	<2.0	24.5	23.8	64	100
3/16/2006	10.6	21.1	7.9	801	521	>7	12						<4.0				370	1800
3/21/2006	8	19.3	7.7	392	255	1	38						31.2				18,334	>66,667
3/30/2006	8.4	20.4	7.7	546	355	3	22						16.9				825	1800
4/4/2006	8.5	24.6	8	713	463	>7	19	0.721	0.132	0.57	0.062	3.47	<4.0	2.24	65.2	34.4	79	100
4/10/2006	8.3	22.3	8.1	793	515	>7	13						<4.0				86	178
4/17/2006	9	24.7	8.2	913	593	>7	11						5.5				57	114
4/26/2006	7	23.1	7.7	496	322	5	9.2						9.5				634	4196

San Antonio River at Mitchell, Station ID # 14256

Date	DO	Temp ºC	pH	Cond.	TDS (calc)	Last Rain (days)	Discharge (cfs)	T-PO4	NH3N	TKN	NO2N	NO3N	TSS	TOC	CL	SO4	E. coli	Fecal Coliform
11/17/2005	11.3	20.2	8.5	529	344	>7	55	0.11	<0.02	0.206	<0.02	2.1	<4.0	<2.0	24.7	20.9	107	114
11/21/2005	11.5	20	8.4	532	346	>7	52						<4.0				lost	lost
11/29/2005	9.5	19.1	8.2	522	339	3	52						<4.0				273	1909
12/6/2005	10.1	19	8.3	502	326	>7	52	<0.06	<0.02	<0.2	<0.02	1.64	<4.0	<2.0	20.4	19.1	43	79
12/12/2005	9.9	18.4	8.1	509	331	>7	54						<4.0				71	157
12/20/2005	10.4	18.8	8.3	512	333	>7	60						<4.0				57	57
12/27/2005	9.1	19.3	8.1	514	334	>7	59						<4.0				29	79
1/3/2006	9.6	22.2	8.1	519	337	>7	57	<0.06	0.046	<0.2	<0.02	1.83	8.7	<2.0	21.5	20.4	433	467
1/9/2006	10.2	21	8.2	542	352	>7	50						<4.0				145	200
1/17/2006	10.4	18.5	8.3	524	341	>7	43						<4.0				40	230
1/23/2006	10.8	19.3	8.3	508	330	1	45						5.5				67	80
1/30/2006	10.7	20.7	8.2	515	335	2	50						4				44	63
2/6/2006	11.7	18.7	8.4	508	330	>7	37	<0.06	<0.02	<0.2	<0.02	1.54	<4.0	<2.0	20.9	19.8	33	58
2/13/2006	12.9	16.6	8.3	501	326	3	31						<4.0				5	5
2/23/2006	12.2	18.6	8.3	519	337	3	62						5				28	37
2/27/2006	10.6	19.3	7.9	416	270	2	26						8.5				392	546
3/16/2006	12.5	21.6	8.1	784	510	>7	11						<4.0					
3/21/2006	9.3	20.4	7.7	381	248	1	21						12.8				3150	18,000
3/30/2006	9.3	21.7	7.8	558	363	3	30						<4.0				175	800
4/4/2006	10.3	25.3	8.2	704	458	>7	18	0.659	0.077	0.509	0.051	3.43	4.1	2.32	63.5	35.1	29	36
4/10/2006	11.2	22.5	8.2	774	503	>7	14						<4.0				10	230
4/17/2006	12.9	27.2	8.4	852	554	>7	10						<4.0				7	28
4/26/2006	9	22.4	7.8	506	329	5	13						11				123	562

San Pedro Ck @ S. Alamo, Station ID # 12708

Date	DO	Temp ºC	pH	Cond.	TDS (calc)	Last Rain (days)	Discharge (cfs)	T-PO4	NH3N	TKN	NO2N	NO3N	TSS	TOC	CL	SO4	E. coli	Fecal Coliform
1/3/2006	10.1	19.7	8	597	388	>7	9	<0.06	0.046	0.254	<0.02	1.9	<4.0	<2.0	42.9	25.3	933	1967
1/9/2006	10.2	22.3	8.1	535	348	>7	8.5						<4.0				95	152
1/17/2006	9.1	20.4	8.1	550	358	>7	12						<4.0				1533	2233
1/23/2006	5.5	16.9	7.6	550	0.21	1	10						22.8				>20,000	>20,000
1/30/2006	9.3	19.4	8	663	431	2	7						<4.0				4600	7600
2/6/2006	10.9	21.6	8.1	539	350	>7	7.9	<0.06	0.03	0.201	<0.02	1.82	<4.0	<2.0	23.2	22.7	70	70
2/13/2006	11.3	20.6	8.1	602	391	3	10						<4.0				200	320
2/21/2006	8.1	15.8	7.9	636	413	<1	9.7						<4.0				3200	4500
2/27/2006	8.9	21.4	7.9	500	325	2	15						7.4				5000	7000
3/6/2006	12.1	22.8	8	550	358	>7	10	<0.06	0.024	<0.2	<0.02	1.82	<4.0	<2.0	26.9	25.6	256	326
3/16/2006	10.7	22.5	7.7	547	356	>7	4.9						5.4				7867	9067
3/21/2006	6.6	22.5	7.7	264	172	1	4.4						15.3				19,667	52,333
3/30/2006	7.8	21.8	7.8	579	376	3	8.7						<4.0				>20,000	>20,000
4/4/2006	9.7	23.5	8	555	361	>7	6.1	0.063	0.072	0.232	0.031	1.91	<4.0	<2.0	27	28.7	1233	1400
4/10/2006	7	22.1	7.9	761	495	>7	0						<4.0				>20,000	>20,000
4/17/2006	11.8	26.6	8	573	372	>7	4.1						<4.0				151	558
4/26/2006	4	22.8	7.6	558	363	5	6.7						<4.0				2100	20,000

San Pedro Ck @ Probandt, Station ID # 18736

Date	DO	Temp ºC	pH	Cond.	TDS (calc)	Last Rain (days)	Discharge (cfs)	T-PO4	NH3N	TKN	NO2N	NO3N	TSS	TOC	CL	SO4	E. coli	Fecal Coliform
1/3/2006	17.2	21.7	8.4	504	328	>7	11	<0.06	<0.02	<0.2	<0.02	2.13	<4.0	<2.0	32.5	32.7	23	28
1/9/2006	16	22.3	8.3	522	339	>7	10						<4.0				667	667
1/17/2006	16.7	17.5	8.5	584	380	>7	8.2						<4.0				90	420
1/23/2006	14.8	19.4	8.5	538	350	1	11						<4.0				250	300
1/30/2006	14.4	20.8	8.4	533	346	2	17						8.1				56	60
2/6/2006	13.4	19.6	8.2	528	343	>7	10	<0.06	<0.02	<0.2	<0.02	1.92	8.2	<2.0	29.7	29.2	5	21
2/13/2006	16.6	19.6	8.5	536	348	3	6.6						<4.0				<2	5
2/21/2006	15.1	17	8.5	577	375	<1	9.6						<4.0				150	171
2/27/2006	12.2	22.1	8.3	497	323	2	18						10.2				1375	1975
3/6/2006	19	25	8.5	547	356	>7	7.9	<0.06	<0.02	<0.2	<0.02	1.85	<4.0	<2.0	37.4	34.4	23	23
3/16/2006	17.6	23.6	8.2	533	346	>7	6.8						<4.0					
3/21/2006	10.3	22	8.1	407	264	1	9.3						9				5667	63,000
3/30/2006	13.1	23.8	8.2	510	332	3	14						<4.0				1233	1867
4/4/2006	18.2	27	8.5	531	345	>7	7.5	<0.06	<0.02	<0.2	<0.02	1.71	<4.0	<2.0	37.3	37.2	86	86
4/10/2006	17.5	25.8	8.4	536	348	>7	9.8						6.7				933	1167
4/17/2006	16.7	31.9	8.3	544	354	>7	4.1						<4.0				164	280
4/26/2006	13.4	22.2	8.3	537	349	5	12						<4.0				600	1233

Apache Ck @ San Luis, Station ID # 15707

Date	DO	Temp ºC	pH	Cond.	TDS (calc)	Last Rain (days)	Discharge (cfs)	T-PO4	NH3N	TKN	NO2N	NO3N	TSS	TOC	CL	SO4	E. coli	Fecal Coliform
1/5/2006	4.5	12.6	7.5	570	370	>7	0.6	<0.06	0.054	0.525	<0.02	0.441	<4.0	4.94	39.2	44.2	8	12
1/12/2006	2.8	15.7	7.5	615	400	>7	0.2						<4.0				10	10
1/20/2006	4.5	13.5	7.2	666	433	5	0.1						10				32	35
1/26/2006	5.5	13.5	7.6	624	406	4	0.3						<4.0				46	57
2/2/2006	2.3	13.6	7.5	732	476	5	0.2						<4.0				305	622
2/9/2006	8.3	11.8	7.8	734	477	>7	0.3	<0.06	0.029	0.353	0.042	0.639	<4.0	2.94	61.5	90.5	285	295
2/16/2006	4.28	19.9	7.19	829	329	6	0.4						<4.0				90	90
2/23/2006	9.1	13.4	7.9	585	341	3	0.5						6.6				1934	2700
3/2/2006	8.9	17.7	7.6	568	369	5	0.8						58				1334	7666
3/7/2006	5.4	19.6	7.3	698	454	>7	0.3	0.115	0.037	0.916	<0.02	0.305	<4.0	6.82	55.9	110	338	663
3/13/2006	1.6	20.5	7.1	822	534	>7	0.1						<4.0				290	314
3/23/2006	10.1	13.5	7.9	380	247	3	3						24.4				4286	8571
3/29/2006	9.4	17.4	8	425	276	1	2.1						6.7				582	814
4/6/2006	4.5	20.8	7.7	911	592	>7	0.2	<0.06	<0.02	0.493	<0.02	<0.02	<4.0	5.79	104	156	90	136
4/11/2006	3.5	18.8	7.3	853	554	>7	0.096						4.1				255	495
4/18/2006	12	28	8	974	633	>7	0.2						9.6				160	340
4/25/2006	4.3	23.3	7.8	775	504	4	0.1						<4.0				1550	>20,000

Apache Ck @ 24th St, Station ID # 12712

Date	DO	Temp ºC	pH	Cond.	TDS (calc)	Last Rain (days)	T-PO4	NH3N	TKN	NO2N	NO3N	TSS	TOC	CL	SO4	E. coli	Fecal Coliform
1/5/2006	12.4	15	8.1	447	290	>7	0.091	<0.02	1.04	<0.02	<0.02	12.2	7.89	29.2	25.5	53	72
1/12/2006	11.4	15.6	8.2	471	306	>7						7.5				80	103
1/20/2006	7.8	14.7	7.8	484	315	5						6.8				19	21
1/26/2006	7.7	13.8	7.8	497	323	4						8.8				231	546
2/2/2006	8.2	15.7	7.8	508	330	5						6.6				63	120
2/9/2006	10.8	15.5	8.1	518	337	>7	0.098	0.307	1.32	<0.02	0.052	23	8.69	37.5	33.8	23	23
2/16/2006	13.2	17.3	8	500	325	6						4.8				35	49
2/23/2006	14.8	13.1	8.4	495	322	3						19.5				154	185
3/2/2006	15.8	19.6	8	390	254	5						17				75	100
3/7/2006	13.6	21.7	8	391	254	>7	0.193	<0.02	1.85	<0.02	<0.02	24	9.14	36.5	32.7	71	93
3/13/2006	9.9	21.8	7.9	426	277	>7						12.6				86	86
3/23/2006	5.3	16.6	7.8	367	238	3						15				5000	7143
3/29/2006	6.8	18.4	7.8	402	261	1						10.3				<233	<233
4/6/2006	6.8	24.3	8.1	429	279	>7	0.109	<0.02	1.17	<0.02	<0.02	13	7.93	39.1	23.7	50	71
4/11/2006	7.4	23.3	7.8	431	280	>7						11				79	100
4/18/2006	9.6	29.2	8.1	449	292	>7						8.8				90	290
4/25/2006	6.7	25.5	8.1	421	274	4						11.7				800	>20,000

Woodlawn Lake @ Boat Dock, Station ID # 12718

Date	DO	Temp ºC	pH	Cond.	TDS (calc)	Last Rain (days)	T-PO4	NH3N	TKN	NO2N	NO3N	TSS	TOC	CL	SO4	E. coli	Fecal Coliform
1/5/2006	7.8	15	8	407	264	>7	0.204	0.039	2.02	<0.02	<0.02	72	11.7	20.3	34.4	67	167
1/12/2006	6.5	14.9	7.8	426	277	>7						49				36	114
1/20/2006	6	14.9	7.5	449	292	5						42.7				107	164
1/26/2006	5.5	13.7	7.5	466	303	4						47				86	129
2/2/2006	5.4	16	7.6	475	309	5						40				190	210
2/9/2006	13.9	15.3	8.3	473	307	>7	0.147	1.13	2.65	0.047	0.101	40	10.1	27.6	46	47	47
2/16/2006	12.2	17.1	8.1	449	292	6						27.5				50	50
2/23/2006	11.2	12.2	8.2	476	309	3						33.6				136	186
3/2/2006	11.2	19.5	8	416	270	5						13.8				114	200
3/7/2006	5.3	21.6	7.2	436	283	>7	0.103	0.432	1.44	0.03	0.146	15.2	10.3	25.8	42	64	79
3/13/2006	6.3	22.2	7.3	458	298	>7						37.5				25	75
3/23/2006	6.2	14.6	7.6	362	235	3						50				2143	2857
3/29/2006	5.1	18.5	7.6	338	220	1						33				6000	7333
4/6/2006	6.5	23.7	7.8	395	257	>7	0.109	0.262	1.33	<0.02	<0.02	28.7	9.01	38.9	23.6	140	140
4/11/2006	7.9	22.7	7.9	396	257	>7						35				14	29
4/18/2006	10.3	30.5	8.1	410	266	>7						22.1				50	71
4/25/2006	5.1	25.2	7.8	332	216	4						21				180	480

Alazon Ck @ Waverly, Station ID # 12716

Date	DO	Temp ºC	pH	Cond.	TDS (calc)	Last Rain (days)	Discharge (cfs)	T-PO4	NH3N	TKN	NO2N	NO3N	TSS	TOC	CL	SO4	E. coli	Fecal Coliform
1/5/2006	7.8	12	7.9	560	364	>7	>0.01	0.202	0.074	1.34	0.076	0.786	54	8.26	34.2	68.2	767	3733
1/12/2006	5.5	14.9	7.9	508	330	>7	0.068						5.5				29	29
1/20/2006	9.1	14.8	7.8	450	292	5	2.1						180				57	71
1/26/2006	9.3	13.7	7.8	465	302	4	1.6						40.5				25	50
2/2/2006	9	15.6	7.9	473	307	5	0.9						48				170	200
2/9/2006	11.5	12.9	7.9	470	306	>7	0.046	<0.06	0.042	0.792	<0.02	0.339	13	9.49	30.2	51	<7	<7
2/16/2006	9.5	17.1	8	452	294	6	0.9						17				49	56
2/23/2006	9.5	13.9	7.8	483	319	3	<0.01						16.7				<7	<7
3/2/2006	11.5	19.3	8	407	265	5	0.6						24.9				114	164
3/7/2006	4.3	21.1	7.2	1480	962	>7	0.0296	0.082	0.475	1.4	0.117	0.384	46.7	8.43	106	530	71	121
3/13/2006	8	21.5	7.4	472	307	>7	0.1						85.6				79	207
3/23/2006	10.2	14.5	8.1	392	255	3	4.2						24				714	2143
3/29/2006	9.6	18	8	391	254	1	3.3						32				<233	<233
4/6/2006	8	23.6	7.7	395	257	>7	0.7	0.13	0.257	1.47	0.03	0.11	22	8.79	20.3	32.3	280	470
4/11/2006	9.4	22.4	7.9	397	258	>7	0.5						30.3				160	260
4/18/2006	5.2	23.8	7.8	685	445	>7	-0.004						42.1				633	967
4/25/2006	6.9	24.9	7.9	336	218	4	2.2						45.7				348	5302

Alazon Ck @ Martin, Station ID # 18737

Date	DO	Temp °C	pH	Cond.	TDS (calc)	Last Rain (days)	Discharge (cfs)	T-PO4	NH3N	TKN	NO2N	NO3N	TSS	TOC	CL	SO4	E. coli	Fecal Coliform
1/5/2006	14.5	16.2	8.2	503	327	>7	>0.01	0.07	<0.02	0.796	<0.02	0.054	18.2	5.05	30.1	54.5	14	21
1/12/2006	12.3	16.9	8.1	577	375	>7	0.2						4.1				5	7
1/20/2006	12	17.5	7.9	510	332	5	1.5						14				1333	1900
1/26/2006	11.3	14	8	486	316	4	1.4						7.8				57	64
2/2/2006	9.2	15	7.9	505	328	5	0.8						6.4				1833	1833
2/9/2006	14	16.1	8.3	485	315	>7	0.2	<0.06	0.024	0.729	<0.02	0.03	7.2	10.1	44.3	62.5	7	7
2/16/2006	12.1	22.1	7.67	746	485	6	0.6						4.5				>6667	>6667
2/23/2006	13.2	15	8	528	343	3	0.05						10.3				<7	<7
3/2/2006	14.5	22.6	8	452	294	5	0.8						5				29	43
3/7/2006	9.2	22.9	7.5	506	329	>7	0.4	0.073	0.056	1.03	<0.02	0.114	21	8.76	42.3	50.7	28	44
3/13/2006	8.9	20.4	7.5	497	323	>7	0.6						8				53	74
3/23/2006	11.2	13.2	8	551	358	3	2.5						7.6				<714	<714
3/29/2006	9	18.6	8	405	263	1	4						23.5				465	465
4/6/2006	9.1	23.9	8	446	290	>7	0.6	0.133	<0.02	0.97	<0.02	0.066	47.5	8.26	25.2	43.6	700	733
4/11/2006	9.6	22.5	7.7	489	318	>7	0.3						32.3				700	1100
4/18/2006	10.7	32.2	7.8	447	290	>7	0.2						41				335	430
4/25/2006	7.5	24.9	7.9	398	259	4	2.8						30.8				1000	>20,000

Alazon Ck @ Brazos, Station ID # 18735

Date	DO	Temp ºC	pH	Cond.	TDS (calc)	Last Rain (days)	Discharge (cfs)	T-PO4	NH3N	TKN	NO2N	NO3N	TSS	TOC	CL	SO4	E. coli	Fecal Coliform
1/5/2006	18.9	17.5	8.4	717	466	>7	<0.01	0.085	0.035	0.851	0.07	2.34	13.8	4.05	65.4	72.5	70	77
1/12/2006	14	20.2	8.1	716	465	>7	0.5						8				138	169
1/20/2006	18.5	19.6	8.2	723	470	5	0.7						16.3				19	23
1/26/2006	19.4	15.8	8.4	694	451	4	0.9						<4.0				33	40
2/2/2006	15.1	16.6	8	864	562	5	0.6						<4.0				70	107
2/9/2006	20.5	22.6	8.4	754	490	>7	0.4	0.219	0.039	1.72	0.094	3.6	8.8	3.98	79.2	79.3	21	21
2/16/2006	17.6	26.6	8.2	723	470	6	0.7						148				21	21
2/23/2006	17.4	17.5	8.4	704	458	3	0.9						5.6				87	100
3/2/2006	15.2	26.1	8	636	413	5	1.2						6.7				87	160
3/7/2006	16.6	25.5	8.4	653	424	>7	0.7	<0.06	<0.02	0.791	0.044	2.32	<4.0	4.6	68.7	80.6	26	49
3/13/2006	22	20.7	8.3	764	497	>7	0.4						56				21	40
3/23/2006	11.5	15.9	7.9	550	358	3	3.6						28.2				2500	4286
3/29/2006	16.1	22	8.5	501	326	1	2.1						11				465	465
4/6/2006	18.3	26.3	8.5	853	554	>7	0.4	<0.06	0.025	0.789	0.136	3.32	7.8	3.63	91.9	108	210	400
4/11/2006	15.3	25.5	8.1	801	521	>7	0.6						4.7				30	280
4/18/2006	15.5	36.6	8.1	751	488	>7	1.2						22.7				567	700
4/25/2006	13	25.9	8.2	749	487	4	0.5						<4.0				1400	13,500

Alazon Ck @ Tampico, Station ID # 18715

Date	DO	Temp ºC	pH	Cond.	TDS (calc)	Last Rain (days)	Discharge (cfs)	T-PO4	NH3N	TKN	NO2N	NO3N	TSS	TOC	CL	SO4	E. coli	Fecal Coliform
1/5/2006	12.9	16.5	8.2	765	497	>7	<0.01	<0.06	<0.02	0.689	<0.02	0.244	5	6.01	76.6	97.9	67	167
1/12/2006	12.3	15.9	8.1	928	603	>7	0.2						29.5				14	14
1/20/2006	13.1	18.6	8.3	655	426	5	1.1						11.2	900	1233		900	1233
1/26/2006	11.5	14.3	8.2	525	341	4	1.6						7.8				180	200
2/2/2006	9.5	15.5	8	540	351	5	1						<4.0				7,600	17,400
2/9/2006	12.4	16.2	8.1	807	524	>7	0.2	<0.06	0.115	0.665	0.036	0.869	8.7	6.86	89.6	90.1	107	43
2/16/2006	9.51	20.38	7.63	643	418	6	0.8						<4.0				44	53
2/23/2006	13.5	14.8	8.2	846	550	3	<0.01						9.8				57	79
3/2/2006	9.6	20.6	7.6	522	339	5	1.5						4.4				40	80
3/7/2006	5.4	22.9	7.4	690	448	>7	0.0788	0.07	0.132	0.988	0.022	0.181	155	6.52	67.7	73.9	37	51
3/13/2006	10.4	20.8	7.8	613	398	>7	0.9						<4.0				63	123
3/23/2006	10.5	13.9	8	516	335	3	1						10.8				1429	1429
3/29/2006	10.4	21	8	432	281	1	0.074						106				<233	<233
4/6/2006	12.1	24.3	8.3	624	406	>7	0.9	<0.06	<0.02	0.667	<0.02	0.062	18.8	7.14	47.3	80.3	1800	3200
4/11/2006	9.1	23.2	7.8	741	482	>7	0.039						16.9				29	57
4/18/2006	9.2	30.9	7.9	864	562	>7	0.013						18.5				7	14
4/25/2006	9.3	25.6	8.1	415	270	4	3.2						15.2				1900	21,700

Baseline Surveys

28 November 2005; 24 April 2006; 30 May 2006

Bacteria counts in org/100mL
All other concentrations mg/L

Date	Time	DO	Temp ºC	pH	Cond.	TDS (calc)	Last Rain (days)	Q (cfs)	T-PO$_4$	NH$_3$N	TKN	NO$_2$N	NO$_3$N	TSS	CBOD	COD	Fecal Coliform
Primary Zoo Outfall Station ID # 15722																	
11/28/2005	0600hrs	6.9	22.5	7.5	505	328	2	4.2						<4.0			8182
11/28/2005	0900hrs	6.6	22.4	7.5	505	328	2	5.5						<4.0			10818
11/28/2005	1200hrs	7.1	22.5	7.6	505	328	2	4.4						<4.0			7636
11/28/2005	1500hrs	6.8	22.8	7.5	506	329	2	5.1						<4.0			6636
11/28/2005	1800hrs	6.9	22.6	7.6	507	330	2	4.8						5.4			8046
4/24/2006	0751hrs	5.8	23.9	7.5	498	324	3	2.3						16.2			24,000
4/24/2006	1104hrs	5.5	24	7.5	498	324	3		0.103	0.182	0.483	0.033	1.62	6.4	<2	<10.0	43,000
4/24/2006	1400hrs	5.6	24.3	7.5	497	323	3	1.4						9.8			34,000
4/24/2006	1630hrs	5.5	24.6	7.4	498	324	3							15.6			40,000
4/24/2006	1915hrs	5.5	24.7	7.4	497	323	3	2.9						4.6			50,000
5/30/2006	0741hrs	6	23.8	7.1	487	316	>7	3						4.1			19,500
5/30/2006	1056hrs	6.2	24	7.2	487	316	>7							6.3			56,154
5/30/2006	1407hrs	6	24.8	7.2	488	317	>7							15.7			38,000
5/30/2006	1700hrs	5.6	25.8	7.2	488	317	>7	2						7.4			40,000
5/30/2006	1952hrs	5.5	25.6	7.2	488	317	>7	1.4						8			18,000
Secondary Zoo Outfall Station ID #18803																	
11/28/2005	0630hrs	4.9	21.9	7.4	526	342	2	0.1						14.9			<9
11/28/2005	0935hrs	4.9	21.6	7.4	525	341	2	0.2						<4.0			<9
11/28/2005	1235hrs	5.2	21.8	7.5	524	341	2	0.1						<4.0			<9
11/28/2005	1528hrs	5.3	22	7.4	523	340	2	0.2						<4.0			27
11/28/2005	1822hrs	5.5	21.9	7.5	524	341	2	0.1						<4.0			<9
4/24/2006	0822hrs	4.3	23.8	7.2	524	341	3	0.2						18.9			786
4/24/2006	1120hrs	4	24	7.3	521	339	3		<0.6	0.114		<0.02	1.55	17.2	<2	<10.0	286
4/24/2006	1425hrs	3.4	24.2	7.2	524	341	3	0.2						5.9			143
4/24/2006	1640hrs	4.2	24.4	7.2	524	341	3							13			643
4/24/2006	1943hrs	4.1	24.5	7.2	521	339	3	0.3						17.1			1429
5/30/2006	0605hrs	6.9	24	7	487	316	>7							<4.0			71
5/30/2006	0815hrs	3.3	23.7	6.9	523	340	>7							8.3			270
5/30/2006	1108hrs	3.4	23.9	6.9	525	341	>7							15.6			410
5/30/2006	1442hrs	3.3	24.5	6.9	529	344	>7							16.8			400
5/30/2006	1729hrs	3.4	25.1	7	534	347	>7	0.1						14.6			767
5/30/2006	2023hrs	2.9	25.1	7	533	346	>7	0.1						6.6			179

Date	Time	DO	Temp ºC	pH	Cond.	TDS (calc)	Last Rain (days)	Q (cfs)	T-PO$_4$	NH$_3$N	TKN	NO$_2$N	NO$_3$N	TSS	CBOD	COD	Fecal Coliform
Zoo Site "A" Station ID # 18804																	
4/24/2006	0728hrs	4.3	23.9	7.4	497	323	3							10.3			39,000
4/24/2006	1025hrs	4.3	24	7.4	498	324	3		0.094	0.182	0.344	0.03	1.6	7.3	<2	<10.0	28,000
4/24/2006	1335hrs	4.5	24.3	7.4	498	324	3							12.4			38,000
4/24/2006	1610hrs	4.4	24.6	7.4	497	323	3							7.6			40,000
4/24/2006	1855hrs	4.5	24.8	7.4	497	323	3							5.9			32,000
5/30/2006	0712hrs	5.1	23.8	7.1	487	316	>7							7.4			22,000
5/30/2006	1037hrs	5.3	24.1	7.1	487	316	>7							10.9			86,667
5/30/2006	1335hrs	5.2	24.8	7.1	487	316	>7							7.4			38,000
5/30/2006	1633hrs	4.8	25.8	7.1	488	317	>7							8.2			38,000
5/30/2006	1922hrs	5.2	25.4	7.2	487	316	>7							7.5			20,000
Zoo Site "B" Station ID # 18805																	
4/24/2006	0712hrs	5.2	23.9	7.5	497	323	3							<4.0			32,000
4/24/2006	1010hrs	5.1	24.1	7.5	497	323	3		0.079	0.112	0.38	0.021	1.64	<4.0	<2.0	<10.0	50,000
4/24/2006	1323hrs	5.6	24.4	7.5	498	324	3							8.5			42,000
4/24/2006	1600hrs	5.6	24.6	7.4	498	324	3							9.8			26,000
4/24/2006	1848hrs	5.4	24.7	7.4	496	322	3							8.7			32,000
5/30/2006	0705hrs	5.7	23.8	7.1	486	316	>7							<4.0			21,500
5/30/2006	1028hrs	5	24	7.2	487	316	>7							7.8			220,000
5/30/2006	1325hrs	5.5	25	7.2	486	316	>7							13.5			34,000
5/30/2006	1624hrs	6.1	25.7	7.2	488	317	>7							9.2			24,000
5/30/2005	1911hrs	6.1	25.2	7.2	487	316	>7							9.5			15,333

Date	Time	DO	Temp °C	pH	Cond.	TDS (calc)	Last Rain (days)	Q (cfs)	T-PO_4	NH_3N	TKN	NO_2N	NO_3N	TSS	CBOD	COD	Fecal Coliform
Zoo Site "C" Station ID # 18806																	
4/24/2006	0709hrs	6.2	24.1	7.5	496	322	3							<4.0			35,000
4/24/2006	1000hrs	6.4	24.2	7.5	496	322	3		<0.06	0.041	<0.2	<0.02	1.68	<4.0	<2	<10.0	81,500
4/24/2006	1316hrs	6.5	24.4	7.5	496	322	3							<4.0			25,375
4/24/2006	1555hrs	6.5	24.6	7.4	496	322	3							<4.0			60,000
4/24/2006	1837hrs	6.3	24.5	7.4	497	323	3							7			41,000
5/30/2006	0655hrs	6.5	24	7.1	486	316	>7							4.4			<233
5/30/2006	1018hrs	6.2	24.2	7.1	487	316	>7							8.3			66,154
5/30/2006	1320hrs	7.1	25	7.2	487	316	>7							<4.0			13,167
5/30/2006	1613hrs	7	25.4	7.2	486	316	>7							4			32,000
5/30/2006	1901hrs	6.7	24.7	7.2	487	316	>7							4.7			13,667
Zoo Site "D" Station ID # 18807																	
4/24/2006	0658hrs	6.7	24	7.5	496	322	3							<4.0			31,000
4/24/2006	0957hrs	6.7	24.2	7.5	496	322	3		<0.06	0.033	0.241	<0.02	1.7	4.9	<2	10.2	101,000
4/24/2006	1308hrs	6.8	24.4	7.5	497	323	3							6.7			33,000
4/24/2006	1549hrs	6.8	24.5	7.4	497	323	3							4.2			>200,000
4/24/2006	1828hrs	6.7	24.4	7.4	498	324	3							20.2			38,000
5/30/2006	0648hrs	6.7	24	7.1	487	316	>7							4.9			17,000
5/30/2006	1010hrs	6.6	24.2	7.2	488	317	>7							<4.0			58,000
5/30/2006	1310hrs	7.1	25	7.2	486	316	>7							5.9			18,750
5/30/2006	1555hrs	7.2	25.2	7.2	486	316	>7							6.6			24,000
5/30/2006	1844hrs	7	24.7	7.2	487	316	>7							5.1			16,667

Date	Time	DO	Temp °C	pH	Cond.	TDS (calc)	Last Rain (days)	Q (cfs)	T-PO$_4$	NH$_3$N	TKN	NO$_2$N	NO$_3$N	TSS	CBOD	COD	Fecal Coliform
Zoo Site "E" Station ID # 15721																	
4/24/2006	0638hrs	6.7	24.1	7.4	496	322	3							<4.0			20,000
4/24/2006	0942hrs	6.8	24.2	7.4	496	322	3		<0.06	0.02	0.206	<0.02	1.73	<4.0	<2	<10.0	74,000
4/24/2006	1245hrs	6.9	24.3	7.4	496	322	3							<4.0			22,000
4/24/2006	1536hrs	7.1	24.4	7.4	496	322	3							<4.0			119,000
4/24/2006	1813hrs	6.3	24.4	7.2	500	325	3							56.7			109,009
5/30/2006	0633hrs	6.9	24.1	7	487	316	>7							<4.0			19,250
5/30/2006	0947hrs	6.4	24.2	7.1	488	317	>7							9.7			58,605
5/30/2006	1257hrs	7.3	24.8	7.1	487	316	>7							<4.0			12,667
5/30/2006	1544hrs	7.3	24.9	7.1	487	316	>7							<4.0			31,000
5/30/2006	1838hrs	7.2	24.6	7.1	487	316	>7							<4.0			6,977
Zoo Site "F" Station ID # 18808																	
4/24/2006	0620hrs	7.2	24.1	7.5	496	322	3							<4.0			48,000
4/24/2006	0922hrs	7.4	24.2	7.4	496	322	3		<0.06	<0.02	<0.2	<0.02	1.77	<4.0	4	<10.0	5,462
4/24/2006	1228hrs	7.6	24.2	7.4	497	323	3							<4.0			6615
4/24/2006	1525hrs	7.6	24.4	7.4	495	322	3							<4.0			13,000
4/24/2006	1805hrs	7.4	24.3	7.4	496	322	3							<4.0			19,750
5/30/2006	0618hrs	7.9	24.2	7.1	486	316	>7							<4.0			114
5/30/2006	0930hrs	6.1	24.1	7.1	488	317	>7							6.6			18,000
5/30/2006	1245hrs	7.9	24.6	7.1	487	316	>7							<4.0			14,333
5/30/2006	1528hrs	7.4	24.9	7.1	486	316	>7							<4.0			5,600
5/30/2006	1820hrs	7.4	24.6	7.2	487	316	>7							<4.0			2,400

Date	Time	DO	Temp °C	pH	Cond.	TDS (calc)	Last Rain (days)	Q (cfs)	T-PO_4	NH_3N	TKN	NO_2N	NO_3N	TSS	CBOD	COD	Fecal Coliform
Zoo Site "G" Station ID # 18809																	
4/24/2006	0628hrs	5.9	24	7.4	496	322	3							<4.0			100,000
4/24/2006	0935hrs	6.1	24.1	7.4	497	323	3		0.085	0.047	0.327	<0.02	1.69	5.8	3	<10.0	152,000
4/24/2006	1238hrs	6.5	24.3	7.4	497	323	3							<4.0			46,000
4/24/2006	1532hrs	6.6	24.6	7.3	497	323	3							4.9			55,500
4/24/2006	1810hrs	6	24.5	7.3	496	322	3							<4.0			54,500
5/30/2006	0624hrs	4.4	23.8	6.9	489	318	>7							4.8			76,667
5/30/2006	0938hrs	5.6	24	7	489	318	>7							10.6			26,000
5/30/2006	1250hrs	6.4	25.2	7.1	487	316	>7							5.5			73,846
5/30/2006	1537hrs	6.5	25.5	7	487	316	>7							4.4			22,093
5/30/2006	1828hrs	6	24.9	7	487	316	>7							6.4			20,000
Zoo Site H (Zoo Well) Station ID # 18810																	
4/24/2006	0603hrs	7	24.1	7.4	495	322	3							<4.0			142
4/24/2006	0910hrs	6.8	24.2	7.4	496	322	3		<0.06	<0.02	<0.2	<0.02	1.81	<4.0	<2.0	<10.0	464
4/24/2006	1220hrs	6.7	24.2	7.3	498	324	3							<4.0			286
4/24/2006	1520hrs	6.6	24.3	7.3	497	323	3							<4.0			357
4/24/2006	1800hrs	6.6	24.3	7.3	496	322	3							<4.0			143
5/30/2006	0912hrs	7.5	24.2	7	484	315	>7							<4.0			71
5/30/2006	1240hrs	7.5	24.3	7.1	486	316	>7							<4.0			107
5/30/2006	1515hrs	6.6	24.3	7	486	316	>7							<4.0			<71
5/30/2006	1808hrs	7.1	24.3	7.1	486	316	>7							<4.0			<71

Date	Time	DO	Temp ºC	pH	Cond.	TDS (calc)	Last Rain (days)	Q (cfs)	T-PO_4	NH_3N	TKN	NO_2N	NO_3N	TSS	CBOD	COD	Fecal Coliform
Zoo Site "I" Station ID # 18811																	
4/24/2006	0650hrs	5.9	24.1	7.4	496	322	3							<4.0			20,000
4/24/2006	0947hrs	5.4	24.1	7.4	498	324	3		0.07	0.084	0.32	<0.02	1.65	<4.0	<2	<10.0	32,000
4/24/2006	1300hrs	5.9	24.3	7.4	498	324	3							<4.0			39,000
4/24/2006	1543hrs	6.1	24.5	7.4	497	323	3							<4.0			32,000
4/24/2006	1820hrs	5.9	24.6	7.7	497	323	3							<4.0			31,000
5/30/2006	0638hrs	5.7	23.8	7	488	317	>7							<4.0			8,000
5/30/2006	1000hrs	5.8	24.1	7.1	488	317	>7							4.2			27,000
5/30/2006	1304hrs	6.4	24.6	7.1	488	317	>7							<4.0			17,500
5/30/2006	1605hrs	6.5	25.4	7.1	488	317	>7							4.6			19,333
5/30/2006	1852hrs	6.5	25.3	7.1	487	316	>7							<4.0			9,166

Runoff Survey

19-20 March 2006

Bacteria counts in org/100mL
All other concentrations mg/L

19-20 March 2006

Date	Time	Sample #	DO	Temp ºC	pH	Cond.	TDS (calc)	Last Rain (days)	Discharge (cfs)	TSS	Fecal Coliform
Primary Zoo Outfall Station ID # 15722											
3/19/06	2145hrs	607901	5.8	23.9	7.5	495	322	<1	2.5	4.2	13,334
3/20/06	0014hrs	607902	6.8	23	7.5	365	237	<1	3.6	17.5	16,000
3/20/06	0108hrs	307903	6.8	23	7.6	425	276	<1	7.6	46.6	271,000
3/20/06	1410hrs	607904	6.6	22.6	7.5	421	274	<1	3.9	180	>200,000
3/20/06	0310hrs	607905	6.2	22.6	7.5	427	278	<1	3.9	107	>200,000
Secondary Zoo Outfall Station ID #18803											
3/19/06	2205hrs	607907	3.7	23.4	7.3	527	342	<1	0.2	<4.0	<2
3/20/06	0028hrs	607908	7.4	21.4	7.5	281	183	<1	5.5	477	113,000
3/20/06	0130hrs	607909	6.7	21	7.6	363	236	<1	0.7	807	157,000
3/20/06	0225hrs	607910	5.9	21.3	7.5	376	244	<1	0.3	400	160,000
3/20/06	0335hrs	607911	4.9	21.7	7.4	416	270	<1	0.3	226	222,000

APPENDIX C: Zoo Hydrology

Zoo Hydrology

To determine the feasibility of treating storm runoff, an estimation of the peak storm flow and volume is required. For these calculations, the 2-year 24-hour storm was considered. This is the storm referenced by TCEQ Rule §3.17.4 for sizing wastewater treatment facilities. The peak flows calculated here do not include the base flows from the Zoo well house (about 4 cfs).

The first step in determining storm flows is defining the drainage area. The drainage area at the Zoo is defined as the area that drains to the Zoo's primary outfall (outflow from the rear outfall is considered negligible). For this study, the drainage area was determined primarily through field investigation and communication with Zoo staff. This process was aided by 2-foot contour data provided by SARA (2-foot vertical accuracy around the 500 year flood plain, and lesser accuracy away from flood plain). Drainage areas are approximate due to limited data and the complex nature of the Zoo drainage system. Many animal pens and their associated drainage areas are believed to be connected to the sanitary sewer system and are not included in the drainage to the Zoo's primary outfall. The Zoo's drainage area is presented in the figure on the following page. As shown, the greater drainage area is divided into a series of catchments that possess different hydraulic characteristics.

Storm flows were calculated using two methodologies. The relatively simple Rational Method was used to calculate a peak flow by treating the entire drainage area as one fairly homogenous watershed. The second method was to use the HEC-HMS computer simulation program to calculate both peak flow and volume by considering the unique characteristics of each of the watershed's catchments. Both of these methods are described below.

1. Rational Method

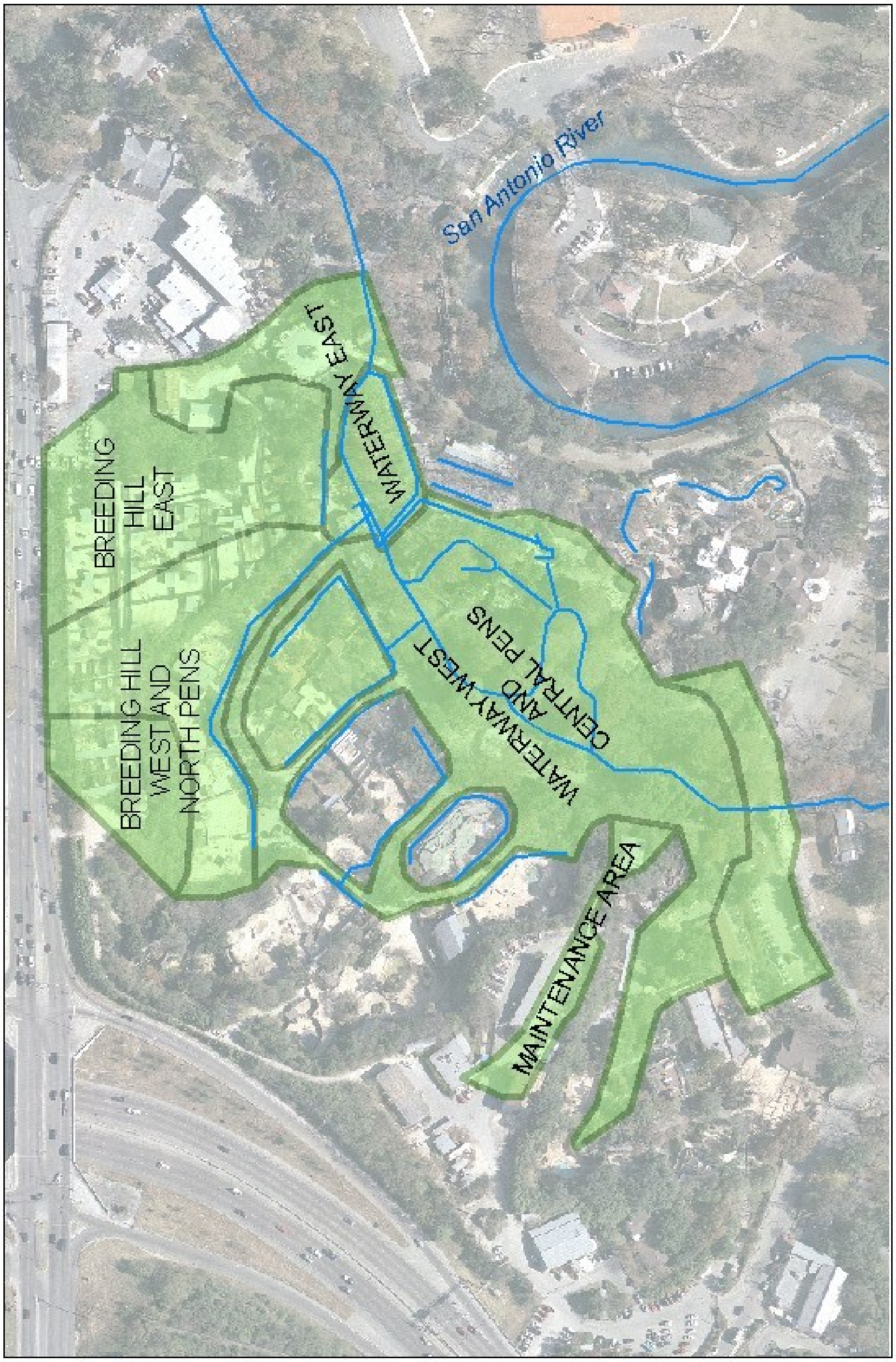
Methodology: TxDOT Hydraulic Design Manual (TxDOT, 2001)

$Q=CiA$

C = Runoff Coefficient

Typical runoff coefficients are shown in the following table. For the Zoo drainage area, a runoff coefficient of 0.75 was used. This relatively high value is appropriate because of the large amount of impervious areas (pedestrian walkways, buildings) and nearly impervious areas (animal pens) within the watershed.

Zoo Drainage Area



RUNOFF COEFFICIENTS FOR URBAN WATERSHEDS[1]	
Type of Drainage Area	Runoff Coefficient
Business:	-
¨ downtown areas	0.70-0.95
¨ neighborhood areas	0.30-0.70
Residential:	-
¨ single-family areas	0.30-0.50
¨ multi-units, detached	0.40-0.60
¨ multi-units, attached	0.60-0.75
¨ suburban	0.35-0.40
¨ apartment dwelling areas	0.30-0.70
Industrial:	-
¨ light areas	0.30-0.80
¨ heavy areas	0.60-0.90
Parks, cemeteries	0.10-0.25
Playgrounds	0.30-0.40

i = Rainfall Intensity (in/hr)

$i = b/(t_c + d)^e$

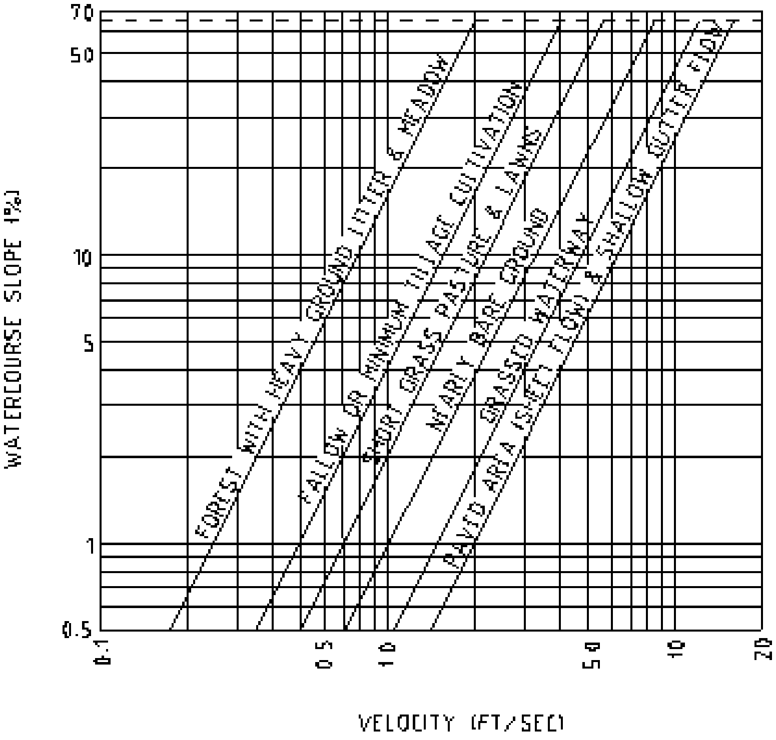
b, d, and e are county-specific rainfall frequency coefficients; for the Bexar county 2-year storm:

b = 56, d = 8.7, e = 0.798

t_c is the time of concentration, with a minimum value of 10 (min). t_c is the time that it takes runoff to travel from the most hydraulically remote location in a watershed to the watershed’s outlet. The total time of concentration can be thought to be made up of a period of sheet flow, shallow concentrated flow, and channel flow. The figure on the following page can be used to calculate the first two of these flow types. Channel flow can be calculated using Manning’s Equation, but this is not possible for the Zoo, considering the irregular nature of the Zoo’s internal waterways.

Sheet flow was calculated as flow over a large animal pen (8% slope, 100 feet, nearly bear ground) to be about 2.5 fps, or 0.67 minutes. Shallow concentrated flow was calculated as the flow over between a remote animal pen and the Zoo’s primary waterway (10% slope, 300 feet, shallow gutter flow) to be about 5 fps, or

1 minute. Channel flow was calculated as the over the remaining 850 foot length of the Zoo's primary waterway assuming 3 fps (approximated using determined peak flow and typical cross section), resulting in 4.7 minutes. Thus, the total t_c was calculated at 6.4 minutes, which is less than the minimum t_c value of 10 minutes



$i = 56/(10 + 8.7)^{0.798} = 5.4$ in/hr

A = 16.2 acres (drainage area)

Now that C, i, and A are known, we can calculate Q.

Q = 0.75*5.4*16.2 = **65.6 cfs**

2. HEC-HMS

HEC-HMS is hydrologic simulation program that converts a design storm into a runoff hydrograph through a variety of mathematical algorithms. An HMS model includes three primary components: the control file, the meteorological file, and the basin file (HEC, 2001). The control file is relatively simple; it includes the time frame and time step for the simulation. The time step was set to 1 minute which is the smallest time increment available, and the time frame was two days. The meteorological file describes the rainfall event. An SCS Type II storm was chosen because this is a commonly used and accepted synthetic storm for central Texas. The total storm depth was 4 inches, based on TCEQ Rule §3.17.9.

The basin file is the most complex component of the program. It includes the hydrologic and hydraulic characteristics of the basin. For consistency, the basin was described in terms of SCS parameters whenever possible. (SCS is an acronym for Soil Conservation Service, now known as the Natural Resources Conservation Service, NRCS). The loss rate mechanism is defined by the SCS curve number system. The table below (NRCS, 1986) shows curve number recommendations for various urban land uses and soil types.

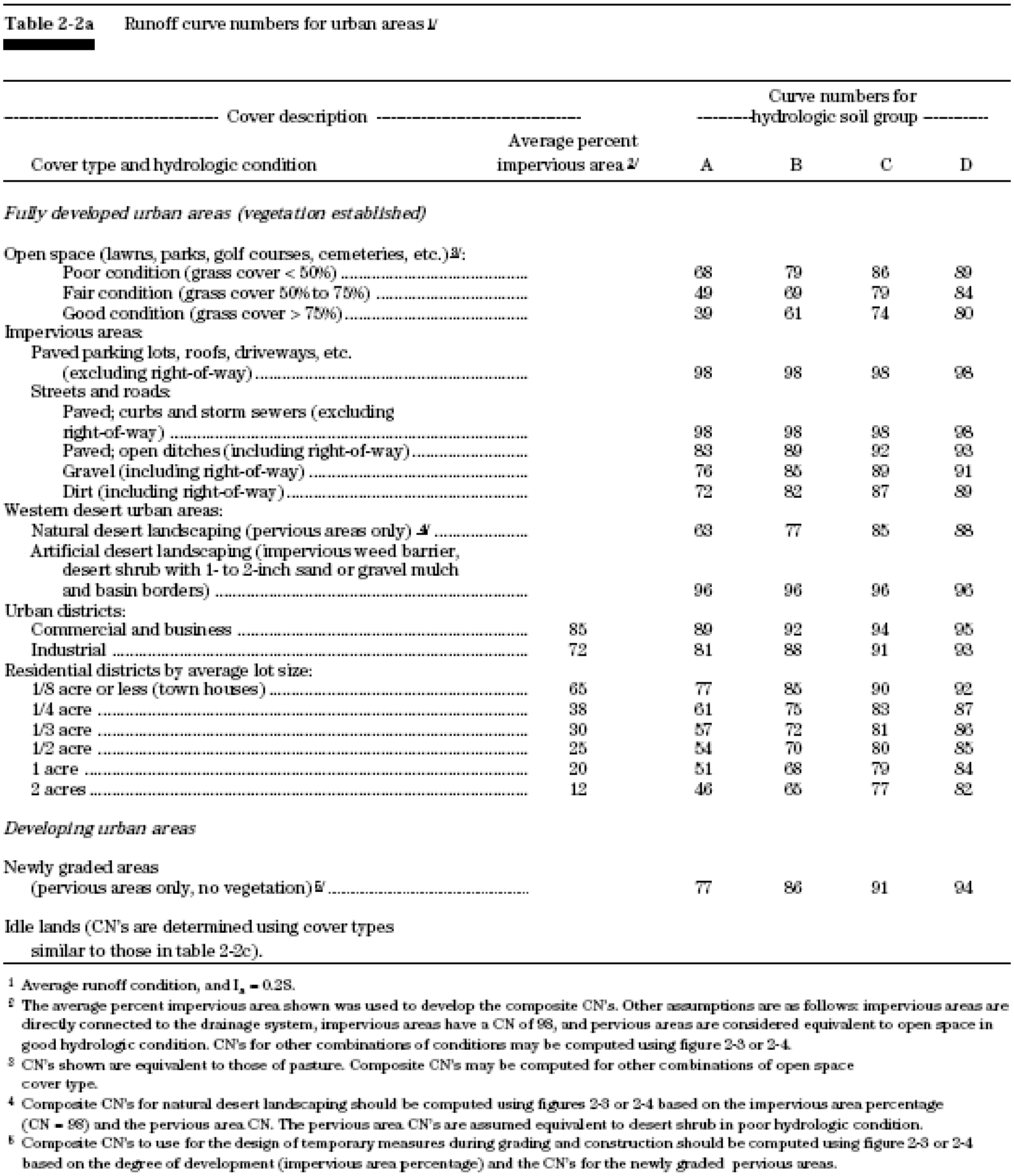


Table 2-2a Runoff curve numbers for urban areas [1]

Cover description		Curve numbers for hydrologic soil group			
Cover type and hydrologic condition	Average percent impervious area [2]	A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.)[3]:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only) [4]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation) [5]		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2c).					

[1] Average runoff condition, and $I_a = 0.2S$.

[2] The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using figure 2-3 or 2-4.

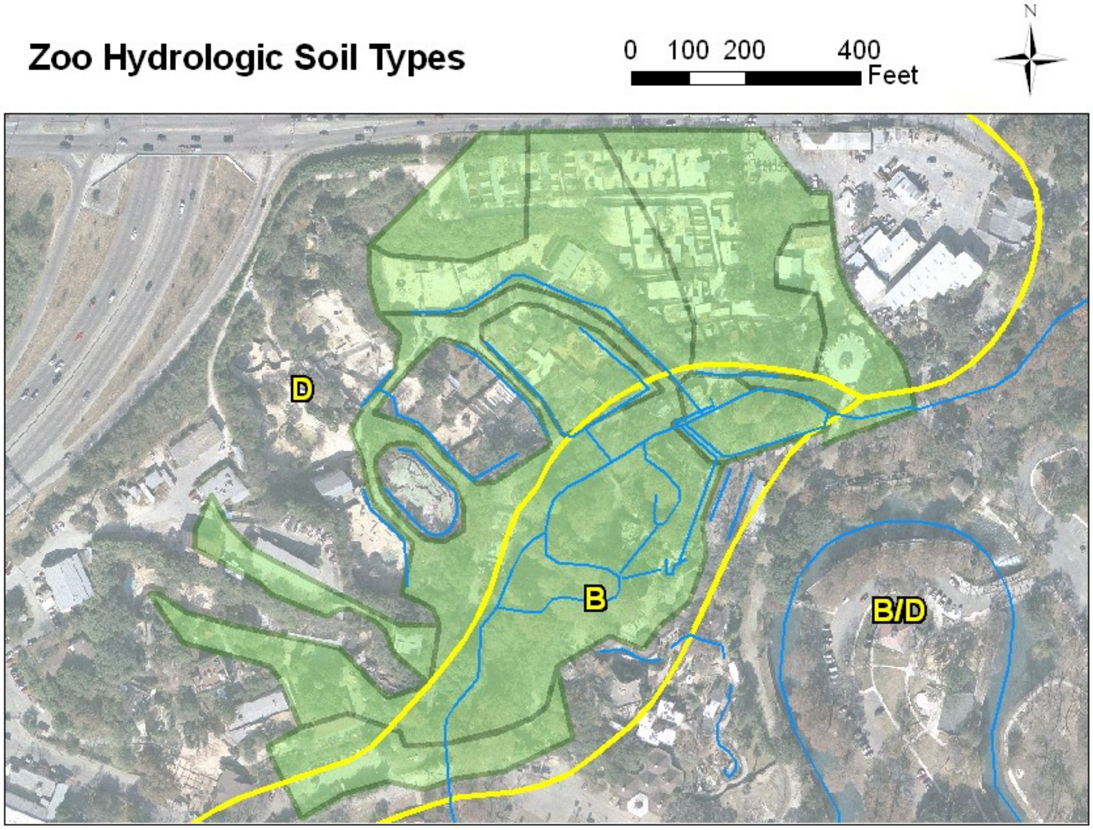
[3] CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.

[4] Composite CN's for natural desert landscaping should be computed using figures 2-3 or 2-4 based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.

[5] Composite CN's to use for the design of temporary measures during grading and construction should be computed using figure 2-3 or 2-4 based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

As shown in the figure below, both B and D soil types are found within the Zoo. The more permeable B-type soils are located along the Zoos main internal waterway, and the D-type soils are located to the north and west of the waterway. Despite the favorable soil type, most of the area along the internal waterway is paved, and was assigned a curve number of 90. The breeding hill area was assigned a curve number of 85, and the maintenance area a curve number of 95.

Times of concentration were calculated for each catchment (the names of the catchments used in the HEC-HMS model are shown in the drainage area map). In general, a minimum time of concentration of five minutes was used. All values were adjusted up by the same amount so that the catchment with the shortest t_c met this requirement. The highest time of concentration was 11 minutes in the West Breeding Hill catchment. For routing, 4 minutes of additional lag were used for flows moving from the northeast end of the waterway to the primary outlet


Zoo Hydrologic Soil Types

The result of the HEC-HMS model was a peak flow of 55.5 cfs. The total storm volume leaving the Zoo was 3.74 ac-ft.

APPENDIX D: SAWS Wastewater Collection System BMPs

San Antonio Water System
Wastewater Collection System
Best Management Practices

Preface.

San Antonio Water System (SAWS) has instituted best management practices for the management and operation of its wastewater utility throughout the entire collection system encompassing most of Bexar County. For the purposes of this Watershed Protection Plan, the information provided herein represents SAWS' wastewater interests specifically within the geographic boundaries of the Upper San Antonio River Basin.

The river basin boundaries are defined by surface drainage into the river, as dictated by the contour elevations. The vast majority of the wastewater mains located within the river basin are subsurface gravity mains, and like the surface drainage of rainfall, the general direction of wastewater flows in the mains are inherently governed by the contour elevations at the surface. It should be noted, however, that the geographic boundaries of the "sewer shed" do not exactly coincide with the river basin boundaries. That is, the direction of sewage flow in the underground mains isn't always the same direction as the flow of rainwater or spring flow on the surface. Consequently, a portion of the mains within the Upper San Antonio River Basin contain sewage whose flows are diverted outside the river basin boundaries. Conversely, some of the wastewater mains outside the river basin divert flow to mains within the river basin boundaries. The sewer shed that is generally co-located with the Upper San Antonio River Basin is referred to as the Central Wastewater Collection System. Figure 1 is a map showing the Central Wastewater Collection System superimposed on the river basin.

SAWS is the largest wastewater utility in the Upper San Antonio River Basin. In this basin, SAWS owns and operates approximately 1700 miles of wastewater mains. 63 miles of these mains are force mains that are pressurized by 41 lift stations. Flows in the Central Wastewater Collection system average 47.5 million gallons per day (MGD) on dry days. Peak flows during dry weather average 60.0 MGD.

The wastewater collection system infrastructure in the Upper San Antonio River Basin is generally considered to be advanced in age, much of it being built before the Clean Water Act was enacted. Well over half of the mains in the Basin were built before 1972.

In addition to SAWS, there are seven other wastewater utilities, owned and operated by other entities that are located partially or entirely in the Basin and drain into SAWS' collection system. These "satellite" wastewater collection entities include the U.S. Army's Fort Sam Houston and the cities of Alamo Heights, Balcones Heights, Olmos Park, Terrell Hills, Castle Hills, and Leon Valley. Figure 1 is a map showing their geographic locations. For the years 2000-2005, the combined flows from these entities accounted for 9.5% of the sewage collected in the entire Central Watershed. SAWS has limited authority over the satellite utilities.

Additionally, SAWS has limited authority to step beyond the bounds of ownership to address problems that may be associated with private sewer laterals and private septic systems. Private sewer laterals and septic systems are governed by the cities and entities noted above and by the County, respectively.

Except for the pretreatment program and the Laterals to People program, this section of the Watershed Protection Plan addresses only the best management practices instituted by SAWS for the wastewater collection infrastructure owned by SAWS, and does not infer that these practices are adopted by the other seven wastewater utility entities, by the City, or by the County.

Looking back on history, San Antonio's processing of sewage has made a lot of progress since the days of the (water-conveying) acequias. However, while the oldest existing wastewater collection mains are, for the most part, functional from the aspect of conveying wastewater from the customer to the treatment plant, they were not built to meet today's stricter watertight standards. Furthermore, deterioration through the ages has reduced the structural integrity of some of the older mains making them more vulnerable to failure. This is typical, albeit perhaps to a lesser extent, of wastewater collection systems in many other U.S. cities.

Like all utility companies across the country, SAWS seeks to avoid or minimize rate hikes for its customers while trying to satisfy the ever stricter regulations and expectations of environmental authorities. It will take many years to thoroughly inspect the miles of old pipe in the Upper San Antonio River Basin. Until these inspections and any necessary main renewals are completed, SAWS is compelled to manage the risk in this Basin in the context of optimizing customer service while maintaining affordable rates. In order to minimize the risk, SAWS has instituted best management practices to operate and maintain the collection system.

CMOM; a.k.a. "Asset Management"

EPA issued a draft Notice of Proposed Rulemaking dated January 4, 2001, for their Sanitary Sewer Overflow Rule, but it was never published in the Federal Register. If EPA's yet to be enacted Sanitary Sewer Overflow rule enters the rulemaking process and moves to promulgation, EPA is likely to establish NPDES permit conditions requiring capacity assurance, management, operations and maintenance (CMOM) programs be developed, implemented and periodically reviewed.

CMOM is synonymous with the concept of "asset management". CMOM is not prescriptive; rather it simply provides a framework for utilities to adopt a common sense business approach to efficiently manage wastewater collection assets in order to optimize their performance and maximize their life cycle. CMOM is EPA's way of encouraging wastewater utility companies to become more proactive in predicting maintenance and renewal.

Although compliance with CMOM is not yet required by regulatory mandate, SAWS nevertheless entered into a multi-year contract agreement in 2002 with a wastewater industry expert to conduct an ongoing CMOM gap analysis using the EPA Region 4 Self Assessment document. Starting that same year, SAWS made a commitment to implement an aggressive, long term investment strategy to modernize equipment, to expand in-house resources, to increase productivity, and to supplement in-house capabilities with contracted services for the purpose of becoming more proactive in the planning, operation, maintenance and renewal of the wastewater collection system.

The best management practices that resulted from SAWS' assessments, strategies and investments are described in this section of the WPP.

BMP1: Sanitary Sewer Overflow (SSO) Emergency Response

It is the goal of every wastewater utility to eliminate SSOs. Realistically, however, SSOs inevitably occur due to vandalism, accidental ruptures caused by construction activity, and other unforeseen manmade or natural causes. Therefore, it is imperative that a wastewater utility be poised and ready to respond quickly to the inevitable SSO in order to contain and stop the overflow, thereby minimizing the volume of sewage spilled and mitigating the damaging effects of the spill.

SAWS has published emergency response procedures and spill reporting procedures. These procedures are practiced when spills occur and are continually reviewed and updated.

SAWS is organized, staffed, trained, equipped and supplied to respond quickly to SSOs when they occur. There are 62 maintenance and repair crews that work staggered shifts so that crews are on duty 24 hours a day, seven days a week. Their primary purpose is to ensure the contents of the water distribution and wastewater collection systems are contained and to ensure they flow. These multi-functional crews are assigned at four service centers located strategically in the City to provide preventive maintenance and repairs. In addition to the 62 maintenance and repair crews, there are 16 sewer main cleaning crews who operate specialized equipment to remove blockages and obstructions from the wastewater mains.

On those few occasions when a high volume spill exceeds SAWS' capability to respond with in-house forces, contractors are hired to supplement their efforts.

Detection of leaks or failures has improved at the lift stations with the use of SCADA monitoring, and quick response is facilitated by an alarm system which automatically notifies the control center.

Responding to urgent failures is the top priority of all the crews in order to preserve water resources, to protect the health and safety of the public, and to enhance the quality of life for the community. Their performance is measured currently with performance indicators that reflect timeliness of response, duration of repair, and restoration of service.

BMP2: Pretreatment Program.

Fats, oils and grease (otherwise known as FOG, or merely "grease"), is the leading cause of SSOs among wastewater utilities in the country. SAWS develops, administers and enforces a pretreatment program which addresses grease. In accordance with Section 34-472 of the City of San Antonio Code of Ordinances, users of the wastewater collection system are restricted from discharging into the system fats, oils, or greases of animal, mineral or vegetable origin in concentrations greater than two hundred (200) mg/L.

The City of San Antonio has adopted the International Plumbing Code which governs the requirement to install grease traps. In addition to plumbing code requirements, SAWS expects its customers to develop their own best management practices for the purpose of minimizing the discharge of grease into the wastewater collection system. This expectation is communicated by SAWS through 1.) Inspection and monitoring, 2.) Enhanced surveillance and enforcement, and 3.) Residential and commercial partnerships.

Significant industrial users are inspected at least twice per year and are monitored through sampling and/or zero discharge verification from two to twelve times per year based upon the permit requirement and compliance history. Specifically for grease, SAWS will inspect the grease traps for proper function and for the necessary cleaning. SAWS will also check manifests to ensure the grease is properly disposed. SAWS has also developed a capability to perform investigations of civil or criminal allegations associated with pollutant discharges into the collection system as a basis to take enforcement action when warranted. SAWS prefers, however, to partner with their customers by establishing a shared purpose through collaboration and by offering incentives for compliance through public recognition for outstanding efforts.

In 2002, SAWS received National Second Place Clean Water Act Recognition for its pretreatment program. SAWS' pretreatment program is audited every five years by TCEQ, the most recent audit being conducted in May 2006.

BMP3: Odor/Corrosion Control Program

As a result of anaerobic bacterial decomposition of sulfur compounds found in sewer collection systems, sulfide ions are diffused into the wastewater. These sulfide ions combine with hydrogen from the water and yield hydrogen sulfide (H_2S) gas, which has a rotten egg odor. In addition to controlling the unpleasant odor, a more compelling reason to reduce H_2S in the system is the chemical process at the wall of the pipe that turns H_2S into sulfuric acid (H_2SO_4), which has a corrosive effect on concrete pipes. Corrosion over a period of time reduces the structural integrity of a concrete wastewater main and will eventually cause its failure.

SAWS implemented an odor/corrosion control program in January 2000. Two 2-person crews are dedicated for this program. Annually, \$1.2 million worth of ferrous sulfate ($FeSO_4$) is injected into the collection system at strategic locations as the means to chemically bind the dissolved sulfides in the system, preventing the formation of H_2S, thus reducing the noxious odors and inhibiting the corrosion process. The injection station locations in the Upper San Antonio River Basin are referred to as Hart, Mission Trails, 34th Street, Basin, Zarzamora, and Baetz. These injection stations are shown on the map in Figure 2.

Efforts to study and optimize the effects of this program are ongoing. An Odor/Corrosion Control Master Plan is currently being drafted.

BMP4: Maintenance Program

Industry studies have shown that fewer sanitary sewer overflows occur when the mains are cleaned frequently. For this reason, SAWS has committed to increase the frequency of cleaning its small diameter mains by enhancing its in-house main cleaning capabilities. Beginning in

2003, SAWS embarked on a multi-year investment strategy to 1.) modernize its aging fleet of combination trucks used to clean the mains, 2.) to expand the fleet, and 3.) to optimize the productivity of the maintenance crews by centralizing the cleaning function within the organization and by instituting an improved training program focused on operating the cleaning equipment. Within the last three years, SAWS acquired eight new combination trucks at an investment of $1.8 million. Supplementing the cleaning capabilities of the combination trucks are seven pressure cleaning trucks. With recent advances in mapping, coupled with the deployment of laptop computers in the field, SAWS is now able to better document the main cleaning history and the productivity of its maintenance crews.

Concurrently, and driven by the need to internally inspect the large diameter wastewater collection mains, SAWS necessarily began a cleaning program for the large mains in 2005 in order to facilitate their internal inspection. Cleaning large diameter mains is more suitable for an experienced contractor with specialized equipment for this unique type of work. In the first year of the program, SAWS' contractor cleaned approximately 8.5 miles of mains in the Upper San Antonio River Basin removing approximately 285 tons of debris from the mains. SAWS has committed to cleaning a portion of the approximately 231 miles of large diameter mains in the entire system annually.

BMP5: Inspection Program

SAWS owns six vans equipped with television (CCTV) equipment and has dedicated the necessary trained personnel to conduct internal TV inspections of the small diameter mains in the entire collection system. Two TV vans are dedicated exclusively to the collection system in the EARZ in order to satisfy the TCEQ Chapter 213 regulations, while the other four vans are dedicated to the remainder of the collection system.

A contract was completed on April 30, 1998, to conduct a condition survey of the small wastewater collection mains in a broad area of the Central Wastewater Service Area. The purpose of the survey was to locate pipe defects as potential sources of inflow and infiltration. Mains up to a distance of 15' from the manholes were visually inspected using video cameras. Smoke testing was the other primary method used for identifying defective mains. High capacity smoke blowers induced smoke into the mains, and wherever a defect existed, the smoke would ordinarily travel from the pipe defect to the ground surface. A total of 2,243,623 linear feet of sanitary sewer lines and 6,970 manholes were inspected during this project. Those main segments found to be in generally poor condition have been selected for a thorough internal visual inspection over their entire length using a TV camera to conclusively assess their structural condition. A strategy has been developed and implemented to prioritize the TV inspections of the selected mains. Based upon the specific results of the TV inspections, determinations will be made and strategies developed to repair, rehabilitate, or replace the mains.

BMP6: Risk Management

Because of their vulnerability and the potential consequence of extensive damage due to their failure, the large diameter wastewater collection mains pose a high risk. Recognizing this risk, SAWS has adopted and applied a risk-based asset management strategy for the large diameter wastewater collection mains.

The key element of this strategy is the practice of conducting internal TV inspections of the large diameter mains in order to determine their remaining useful life, upon which investment decisions will be made to optimize their life cycle costs. In other words, it is the intent to renew mains at or near the end of their useful life rather than paying the higher expense of renewing them during emergency situations when they fail.

In 2005, a concerted program was initiated to televise the large diameter mains thought to have the highest risk. Eight and a half miles of large mains were inspected in the downtown area of San Antonio during the inaugural year of the program because they were determined to pose the highest risk. Subsequent to the inspection, an assessment of the mains' structural conditions will result in the creation and future execution of CIP projects to renew some of the mains. A multi-year contract was awarded in 2006 to continue the large diameter cleaning and inspection program using the risk-based approach.

BMP7: Sewer Lift Station Assessments

Inspections of the lift stations are performed by SAWS employees in conjunction with their routine maintenance. Additionally, SAWS has embarked upon a multi-year program to perform comprehensive assessments of all its sewer lift stations to assure compliance with current TCEQ requirements, as well as industry BMPs.

In 2004, SAWS hired a consultant to conduct a comprehensive assessment of the 46 existing lift stations in the EARZ and three critical lift stations outside the EARZ. Many of these lift stations are located in the Central Wastewater Collection system. The lift stations are being assessed for their physical condition, for adequate capacity and for regulatory compliance. Construction contract documents for necessary repairs and improvements to the lift stations are currently under design.

Phase II of this lift station assessment program is ongoing. A consultant is performing assessment of an additional 29 lift stations. Like the previous project, this assessment will ultimately result in the complete rehabilitation of these 29 stations.

BMP8: Edwards Aquifer Recharge Zone (EARZ)

The northernmost portion the Upper San Antonio River Basin is located in the EARZ. Forty five miles of wastewater collection mains are located in that small area of the EARZ. Figure 2 is a map depicting the geographic location of the EARZ in relation to the Upper San Antonio River Basin. Those 45 miles of mains, and any new construction, are regulated by 30 TAC Chapter 213. SAWS is in compliance with the Chapter 213 regulations.

Under Chapter 213, the State requires owners of sewage collection systems to ensure that all existing sewer lines having a diameter greater than or equal to six inches, including private service laterals, manholes, and connections, are tested to determine types and locations of structural damage and defects such as offsets, open joints, or cracked or crushed lines that would allow exfiltration to occur. Testing of all sewage collection systems must be conducted every five years after being put into use. Any sewage collection system in place as of March 21, 1990 must have commenced and completed the first round of five-year testing. Every five years, existing sewage collection systems must be tested to determine types and locations of structural damage and defects such as offsets, open joints, or cracked or crushed lines that would allow exfiltration to occur. These test results must be certified by a Texas licensed professional engineer. The test results must be retained by the plan holder for five years and made available to the executive director upon request.

In SAWS' wastewater service area, the EARZ is divided into five geographic sub-areas as a means to apportion and account for the inspection work. Each sub-area is inspected every five years, with one sub-area inspected each year. The portion of the Upper San Antonio River Basin in the EARZ is located in Sub-Areas II and III. Mains six inches through twelve inches in diameter in Sub-Area III were cleaned and televised by in-house forces in 1997-1998 and again in 2002-2003. Similarly, mains of this size in Sub-Area II were cleaned and inspected in 2001-2002, and are currently being cleaned and inspected in its second 5-year cycle. Since the beginning of the EARZ inspection program in 1997, a total of 2,182 defects were identified and corrected by SAWS forces by year end 2005, some of which were located in the Upper San Antonio River Basin.

In order to comply with the demanding 5-year inspection schedule, the cleaning and inspection of mains 15" and greater was outsourced to an engineering consulting firm. The consultant also provided engineering design services to correct identified defects. Construction contracts were then awarded to accomplish the necessary repairs, rehabilitation and replacements. Since the award of the consulting contract in 2003, the consultant cleaned and inspected 316,000 L.F. of mains, and deficiencies were corrected by construction contractors costing over $16 million, some of which were located in the Upper San Antonio River Basin.

BMP9: Information Management Practices

Timely, relevant information plays a critical role in an effective CMOM program. A dynamic CMOM program focuses on planning, implementing, reviewing, evaluating and taking appropriate actions in response to available information. The ability of a utility to effectively manage its collection system is directly related to its ability to maintain and have access to the most up-to-date information concerning its facilities. Data is critical to a number of internal and external processes that are conducted by SAWS everyday. Operations, Finance, Engineering and Planning are just a few of the SAWS departments that are end users of wastewater collection system data.

Understanding the criticality of information and data, SAWS has undertaken to leverage the power of new technology in the form of computer hardware and software. In February 2003, SAWS launched Maximo as its computerized maintenance management system (CMMS). Maximo is used to capture, store and retrieve a variety of information associated with SAWS' human and physical assets. For the purposes of the wastewater collection system, it stores information that defines and characterizes each of the many thousands of wastewater infrastructure assets that exist in the system. Furthermore, it chronicles all the operation, maintenance and repair activities associated with the assets, and it relates costs to those activities.

To facilitate the efficient flow of information from the field to the computer server, laptop computers have been acquired and are deployed with the maintenance and repair crews in the field. Current infrastructure asset information, including mapping information, is downloaded to the laptop computers for ready reference by the crews. Maintenance and repair activity is documented on electronic work orders in the laptop computer and uploaded to Maximo on the server each day.

A third of SAWS' six television inspection vans have modern state of the art digital recording equipment. This new technology for digitizing televising video of collection mains drastically improves the efficiency of cataloging, retrieving and managing the video records and the condition assessment data. Linked to Maximo and to GIS, this inspection data is essential to the creation of SAWS' condition-based asset management program. The other four vans use VHS recording technology and are scheduled to be replaced with digital recording technology in the future.

SAWS has made great strides and has nearly completed the arduous process of converting the legacy mapping system to a geographic information system (GIS) for the wastewater collection infrastructure. With the recent creation of the enterprise GIS database, SAWS has the new ability to analyze the data in Maximo geo-spatially, a huge improvement to SAWS' analytical capabilities and a giant step toward the creation of a robust asset management program.

Since 2003, Maximo has been continually improved with expanded capabilities. It currently has many elements of an enterprise information system and has become a template for the development of SAWS' newly acquired enterprise resource software system.

BMP10: Decision Tree Model – A Risk-Based Asset Management Tool for Large Mains

As previously mentioned, SAWS recognizes that the large diameter wastewater collection mains pose a high risk. Because it will take many years to thoroughly inspect and renew the miles of old pipe in the Upper San Antonio River Basin, the risk must be managed. Thus, SAWS has adopted and applied a risk-based asset management strategy for the large diameter wastewater collection mains.

SAWS must be selective in choosing which mains to inspect and which mains to renew, in order to have a high level of confidence that limited funding is spent on the mains most at risk. Therefore, SAWS was compelled to develop an intelligent approach to target funds on the neediest mains. Because intelligence is based upon information, capturing the right information is imperative.

The most widely accepted definition of risk centers on "vulnerability" and "consequence". In other words, the wastewater collection mains possessing the highest risk are those that 1.) are most vulnerable to failure, and 2.) result in greatest customer dissatisfaction and/or most severe environmental damage as a consequence of failure. Based upon experience, SAWS has identified several vulnerability factors that contribute to the cause of a main failure and that indicate a main is nearing failure. SAWS has also identified certain significant geographic areas where the consequence of a failure would be great. Twenty information attributes have been identified that determine the level of risk of a wastewater main, the most important ones being age, size, material type, proximity to a river or stream, and structural condition.

Considering only the large diameter wastewater collection mains, there are over 5,000 pipe segments in the system. Multiply this by the twenty information attributes associated with each segment and one can readily comprehend the magnitude of the effort needed to manage and analyze all the data. This is where the Decision Tree Model (DTM) comes in. The DTM is a computer model created and customized exclusively for SAWS with the capability to automatically retrieve the attribute information from existing SAWS databases. It contains built-in logic, based upon engineering experience, to determine if the attribute data meet certain conditions. The model applies scores to the data according to the condition met, it weights the scores with multipliers based upon the importance of the attribute, and then the model tabulates the final scores in order to quantify the risk associated with each and every main segment.

In addition to providing the attribute data and scores in tabular form, the DTM data and scores are also presented graphically using a GIS platform to facilitate geo-spatial analysis of the risk in order to provide a comprehensive knowledge of all the large diameter mains in the entire wastewater collection system. For example, a map can be produced showing the mains color coded by level of risk according to the tabulated attribute scores, illustrating the mains that should be inspected first.

By quantifying risk, the DTM serves two purposes for SAWS' decision makers: 1.) it assists in prioritizing mains to be inspected (i.e. televised), and 2.) it assists in prioritizing CIP main renewal projects.

The fact that the Upper San Antonio River is considered "impaired" caused SAWS to weight the scores for mains in this Basin more heavily, indicating higher risk, thus demanding a higher priority.

BMP11: Asset Management Strategy for Small Mains

SAWS has adopted a vision based upon the concept of condition-based asset management for the small diameter mains. Essentially, the vision involves the collection, management and analysis of information through the use of digital technology. The cornerstone of realizing this vision includes a strategy to invest in digital televising equipment for in-house inspection, linking the digital televising data to the Computerized Maintenance Management System (currently Maximo), and also linking it to GIS for geo-spatial analysis.

The product of the vision will be the capability to create maps of the small diameter mains, color-coded to show the high-maintenance mains and to show mains that are in poor structural condition, based upon NASSCO's PACP scores. These maps would facilitate maintenance and renewal decisions for the small diameter mains.

BMP12: Capacity (Management) Master Plan Program

One of the major causes of SSOs are peak flows into the wastewater collection system. Flows in wastewater collection systems can be described in terms of base flows (during dry weather), inflow, and infiltration.

Base flow is the wastewater that a collection system is intended to convey from the customers. ***Inflow*** generally refers to water other than wastewater, typically rainfall that directly enters a sewer system. Inflow connections to wastewater collection systems are unauthorized; however, it is possible that many inflow connections may exist on private property without the knowledge or consent of SAWS. The volume of inflow in a wastewater collection system typically depends on the magnitude and duration of storm events. ***Infiltration*** generally refers to other water that enters a sewer system through defects in the sewer system. Infiltration can be long term seepage of water into a sewer system from the water table or short term seepage from saturated ground due to storm events. Inflow and infiltration (I&I) would not exist in an ideal, watertight collection system. Realistically, however, it would be extremely difficult and expensive to eliminate all I&I and maintain a perfectly watertight system. Therefore, in addition to base flow, wastewater collection systems are typically designed to accommodate a certain amount of I&I.

Potential capacity problems arise when additional customer hookups occur that add to the base flows, when grease and debris accumulate in the system restricting flow, and when actual I&I levels exceed the projected design levels.

SAWS initiated a flow monitoring program in 1995. In addition to SAWS' other three wastewater collection basins, an extensive hydraulic assessment was conducted specifically for the Central Wastewater Collection system. The purpose of the assessment was to identify system capacity inadequacies due to rainfall derived inflow and infiltration, to forecast future population growth, and to develop system improvement recommendations to mitigate sanitary sewer overflows. The assessment involved the installation of metering devices to measure wastewater flows during dry and wet weather events. The collection mains were modeled using computer software to assess the performance of all mains 12" and larger in the Central Wastewater Collection system. The drainage area was also modeled to simulate the storm water runoff and resultant I&I into the collection system.

The hydraulic assessment was concluded with the results published in a detailed report dated February 9, 2005. As a result of the findings during the assessment, a wastewater capacity master plan was developed as a living document that is continually assessed and refined. The master plan includes several capacity improvement CIP projects, estimated to cost over $50 million, prioritized for execution over the course of time, with the first two capacity improvement projects scheduled in the Central Wastewater System for construction in 2007.

SAWS has acquired the modeling software, and has dedicated the personnel and training, for maintaining the hydraulic model of the wastewater collection system. Used primarily for capacity management, the model allows for better planning, engineering, operations and maintenance decisions regarding the collection system. With this in-house modeling capability, SAWS has achieved the ability to simulate the collection system's response to current and future conditions. The software tool is bolstered through GIS integration, and validated through field measurements of rainfall and wastewater flow.

BMP13: Capital Improvement Program (CIP)

The foregoing discussions about the creation, planning and execution of CIP projects as a result of condition and capacity assessments represent SAWS' best management practices for addressing the deficiencies of the existing infrastructure. As old infrastructure is replaced, new infrastructure must be designed and constructed for high performance and long life. In that regard, SAWS developed and continues to improve its own design, construction and material standards based upon industry practice and local experience, in order to meet and exceed all State and Federal government regulations. The internet address for SAWS specifications is www.saws.org/business_center/specs/index.shtml. Bid advertisements and past bid openings for SAWS wastewater construction projects may be found at http://www.saws.org/business_center/bids. More information about existing and upcoming wastewater construction projects may be found at http://www.saws.org/infrastructure/construction.

Likewise, as the growth of San Antonio adds to the demand for additional sewer service, building developers must construct new wastewater systems to meet certain design and construction quality standards. Authority has been vested in SAWS to establish policies governing service extensions to SAWS customers for wastewater. These policies are published in the Utility Service Regulations and can be referenced at http://www.saws.org/business_center/developer/.

A key strategy of SAWS is to renew the wastewater infrastructure in conjunction with the City's street maintenance program. Because most wastewater mains are located in the street right of way, an opportune time to replace deteriorated mains is during a street maintenance project. By coordinating (i.e. joint bidding) a main replacement with a City street project, SAWS avoids the cost of the street work. Otherwise, all the street work would be paid by SAWS if the main was replaced unilaterally. This governmental coordination results in a significant cost avoidance, allowing SAWS to efficiently replace mains at a lower unit cost. To facilitate the quick response necessary to design such main replacements on relatively short notice, SAWS awards an annual "unspecified services" engineering contract whereby several engineering firms are on retainer to provide engineering design services when street project schedules are announced by the City. Bids for the City of San Antonio capital improvement projects are advertised at http://www.sanantonio.gov/capprog/rep/bid_data/pdf/bidopen.pdf.

BMP14: Sewer Laterals Practices

Inside property owners' buildings, the plumbing fixtures (toilets, sinks, etc.) drain into sewer laterals. Sewer laterals drain into SAWS' wastewater mains and are the means by which SAWS collects the wastewater from their customers. The property owner is responsible for the sewer lateral from the building to the property line, and SAWS is responsible for the lateral from the property line to the main. When a blockage occurs and a sewer backup is experienced by a property owner, there is inherently a question as to where the blockage is located. SAWS encourages customers to call SAWS immediately when they experience a sewer backup. When SAWS receives such a call, a crew will check the main via a manhole in the street to determine if a blockage in the main is causing the backup. If the main is flowing normally, then the problem is assumed to be in the lateral. The property owner will then hire a licensed plumber to inspect his/her lateral and correct the problem. If the blockage is determined by the property owner's plumber to be beyond the property line in SAWS' portion of the lateral, then SAWS will correct the problem and reimburse the property owner for the plumber's inspection costs.

In those cases when an impoverished homeowner cannot afford to correct a malfunctioning sewer lateral that becomes a health threat, SAWS will correct the problem for the homeowner at SAWS' expense. In 2003, SAWS and the City of San Antonio executed a Memorandum of Agreement that establishes the process for the City to determine eligibility for the "Laterals to People" program and to refer the homeowner to SAWS for assistance.

BMP15: Recycled Water Program

In 2001, SAWS began using high quality recycled water to augment the flow in the San Antonio River and Salado Creek. Since the highest potential for DO and fecal coliform concerns are in low flow, stagnant conditions, increasing the flow with recycled water that nearly meets drinking water standards, greatly enhances the overall water quality in the Upper San Antonio River Basin. SAWS has committed 4,250 AF/yr to augment flow in the Brackenridge Park area and will add another 723 AF/yr at the Convention Center later in 2006.

In addition to direct stream flow augmentation, the Recycled Water Program has other significant beneficial impacts to the water quality in the basin. SAWS provides 8,272 AF/yr of recycled water for irrigation of golf courses, parks and cemeteries. This amount of water equals the amount of reduced pumping from the Edwards Aquifer, thus protecting the natural spring flows that are the source of the San Antonio River.

BMP16: Waste Hauler Program

In 2001, SAWS relocated the disposal station for liquid waste haulers from a point in the collection system near the Central Sewer shed to the Dos Rios Water Recycling Center (WRC). Prior to that, this waste, pumped from septic tanks and chemical toilets, was discharged into a manhole and allowed to flow many miles through the collection system. This high strength waste had the potential of spilling out into the watershed in incidents such as main breaks and SSOs. The substantial amount of rags and solids in the waste could also be the cause of overflows in the collection system. By moving the disposal site to Dos Rios, there is no longer any impact to the collection system and the potential for the waste to spill in the watershed is eliminated.

BMP17: Partnership for Public Health

According to County records, it is estimated that approximately 108 active septic systems exist in the Upper San Antonio River Basin (not including the septic systems in the other utility entities). In response to the need to eliminate a health threat associated with septic systems in the Espada area, SAWS partnered with several agencies to provide wastewater utility service to this area.

On December 18, 2001 the San Antonio Metropolitan Health District, the Public Health Authority for the City of San Antonio, declared the Espada area to be a significant public health risk to warrant immediate attention and expenditure of public funds for the purpose of correcting and eliminating such risks from the community. The Espada area is located south of Stinson Air Field, and is bounded by Loop 410, Roosevelt Avenue, Ashley Road, and the San Antonio River.

The area does not currently have an organized sewage collection system. Most of the residences are served by septic tanks, many of which are substandard or no longer working, and cesspools.

In view of these conditions, SAWS committed to provide the Espada area a wastewater collection system as part of its 2003 Capital Improvements Program. On February 4, 2003, SAWS awarded a contract for professional engineering services to design a sewer utility improvement to eliminate the septic tanks and cesspools. To date SAWS has committed $487,598.95 in design funds. The engineering design phase services included a cultural resources survey, a geotechnical engineering study, a preliminary environmental report, and a Phase I environmental site assessment of the necessary land acquisition for this project. Easement acquisition, environmental investigations, archeological issues and multiple agency coordination and approval impacted the schedule for this project.

On May 24, 2005, SAWS awarded a construction contract in the amount of $3,627,540.44 in connection with the Espada Unsewered Area Sanitary Sewer Project. The project includes the installation of approximately 23,300 linear feet of 8, 10, 12, and 15-inch diameter sanitary sewer mains, one lift station, and 7,000 feet of 6-inch force main. This contract provides for 540 days for the completion of this project. Notice to proceed was issued to the contractor on June 13, 2005. SAWS anticipates the construction to be complete by November 2006.

The private service laterals for qualified residents will be constructed through a joint effort of Los Vecinos de las Misiones, Merced of Texas, and the City of San Antonio.

BMP18: San Antonio Zoological Society Activities

As a result of past Edwards Aquifer withdrawal permitting meetings with the Edwards Aquifer Authority (EAA), San Antonio Zoological Society and SAWS, SAWS dedicated efforts to aid the Zoo in identifying BMPs and help resolve issues pertaining to water quality.

Recognizing the need for BMPs to address the issue of animal wastes, the Zoo requested that SAWS assist them with a capital improvement project to divert a portion of their animal waste into SAWS' wastewater collection system instead of the storm drainage system. The primary concern in this case was the wastewater from the hippo house which was emptied daily.

A project was initiated by SAWS to re-route this wastewater flow — which has historically been released from the Zoo into the storm drainage and ultimately into San Antonio River — into SAWS' sanitary sewer main. All the animal husbandry waste streams in a specific area were re-routed to a new 6-foot diameter wet well. The large size of the wet well was installed to accommodate the hippo holding tank, which is emptied daily and releases approximately 5000 gallons of water at a rate of 475 gallons per minute. The project was completed in 2004.

FIGURE 1

Upper San Antonio River Basin Relative to the Central Wastewater Collection System and Satellite Wastewater Utility Entities

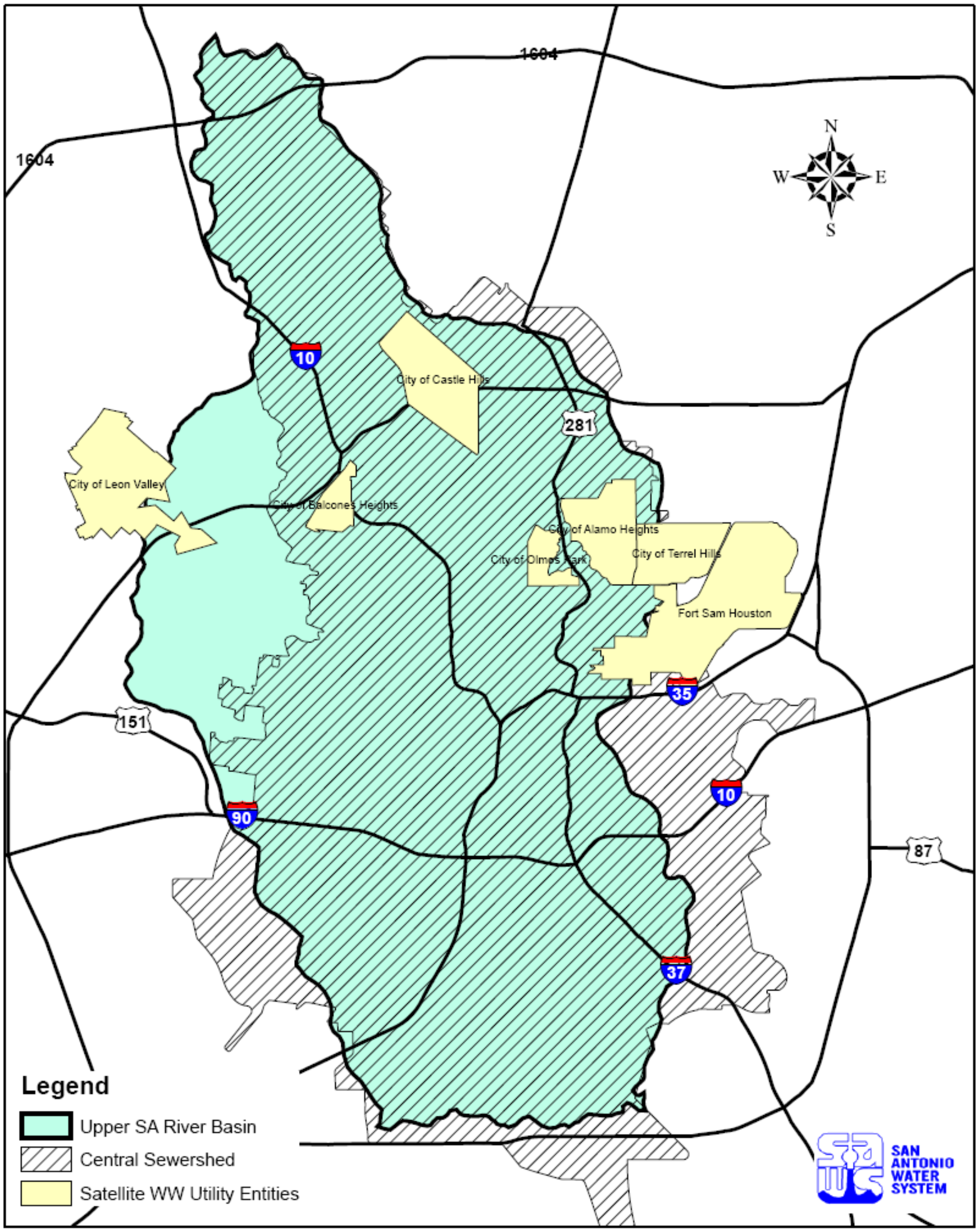
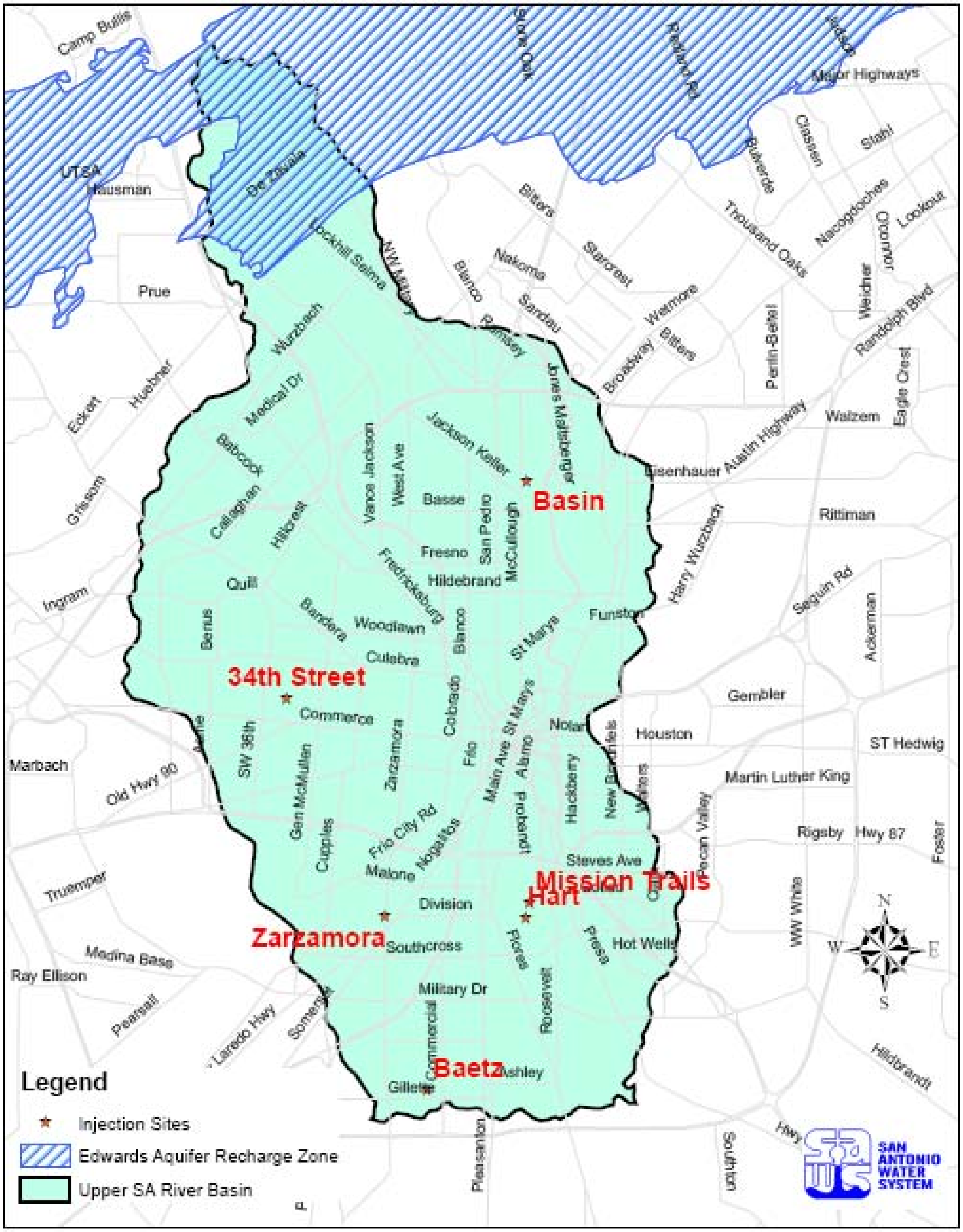


Figure 2

Ferrous Sulfate Injection Sites
and
Edwards Aquifer Recharge Zone



APPENDIX E: City of San Antonio Water Quality BMPs

(1) Program Title: Drainage Channel Mowing & ROWs

(2) Division/Section: Vegetation Control

(3) Program Element: **(a) TPDES**

1. Storm Water Controls & Collection System Operations

(4) Statement of Purpose:

This activity is associated with a TPDES permit requirement. The Permit's Storm Water Management Program Requirement (1) states that the municipal separate storm sewer system and any storm water structural controls shall be operated in a manner to reduce the discharge of pollutants to the maximum extent practicable. Observations have shown that a well-maintained channel helps to discourage illegal dumping. Floatable debris is removed from the channel prior to mowing activities. Vegetative cover of earthen channels holds the soil in place and reduces the sediment transport into local rivers and streams that can have a negative impact to water quality.

In addition the drainage channels were designed with an "n" value. Exceeding this value reduces the conveyance capacity of the channels. Weeds along street rights of way can reach over 6' tall causing a visual obstruction if not managed. Regular vegetation control by mowing reduces noxious weeds, visual obstructions and vector (mosquitoes, etc) problems to the surrounding areas.

(5) Description of Actions (Statement of Services):

Mowing of the established vegetation on all improved drainage channels and selected street rights-of-way. Inventory associated with activity includes earthen channels and tops of bank right-of-way vegetation associated with concrete channels. Improved channels have been engineered and constructed to convey a quantity of storm water. Select street rights-of-way include those along arterial & collector streets or street right-of-way where an identifiable property owner is not responsible.

Scheduled frequency of mowing is 3 times per year. Mowing occurs during the growing season and excludes the months of November through February. Personnel and equipment are assigned to one of four quadrants of the City. Quadrants are determined by equalizing infrastructure and difficulty. Each crew consists of a hand crew for areas where equipment cannot cut.

(1) Program Title: Flood Buy-Out Property Maintenance

(2) Division/Section: Vegetation Control

(3) Program Element: **(a) NFIP**

(4) Statement of Purpose:

Maintenance of the private property that was acquired using federal funds is a requirement for compliance with the City's Vegetation Ordinance. These properties are located in established neighborhoods. Citizens are required to maintain grass to a height not to exceed 15"; therefore the City property should also be maintained at this restriction. Per conditions of the FEMA grant, property purchased with federal grant money must remain as open space in perpetuity.

(5) Description of Actions (Statement of Services):

Maintenance activities include mowing established vegetation and debris removal from 74 acres of property. The properties are non-contiguous and are parceled out similar to residential lots. Frequency of maintenance is approximately every 6 weeks during the growing season, February through November. For a manicured look to be consistent with surrounding residence, zero-turn grooming mowers are used. Each crew also consists of maintenance workers for handwork such as edging.

(1) Program Title: Herbicide Application Program

(2) Division/Section: Vegetation Control

(3) Program Element: **(a) TPDES**

1. Pesticide, Herbicide & Fertilizer Application

(4) Statement of Purpose:

This activity is a TPDES permit requirement. The Permit's Storm Water Management Program Requirement (5) states that each permittee shall implement controls to reduce the discharge of pollutants related to the application of pesticides, herbicides, and fertilizers applied by employees to public rights-of-way, parks and other municipal property. The City's Storm Water Management Plan states the City's herbicide operators are licensed under the Texas Structural Pest Control Board. This helps ensure that correct products and quantities are used for the different applications. The Management Plan requires that low volume spraying occur to reduce run-off and drift control agents are used to prevent spray applications from drifting off target.

(5) Description of Actions (Statement of Services):

Herbicide is applied to earthen channels, concrete channels, medians (limited use) and curb line of streets. Frequency of application is based upon need. To control noxious weeds, herbicide application is a scheduled maintenance activity on earthen channels only. Spraying occurs two weeks prior to earthen channel mowing. The Street Cleaning supervisor identifies street curb lines that have excessive vegetative growth two weeks prior to street cleaning schedule. These areas are scheduled for herbicide application prior to sweeping operations. Based upon inspections, herbicide is applied to cracks and joints of concrete channels to eliminate vegetation growth. This is accomplished on an "as-needed" basis. Operators are required to assess the weather conditions for appropriate spray conditions and refrain from application under adverse conditions.

(1) Program Title: **Median Maintenance and Wildflower Program**

(2) Division/Section: **Vegetation Control**

(3) Program Element:
(a) TPDES
1. Roadways
2. Pesticide, Herbicide & Fertilizer Applications

(4) Statement of Purpose:

This activity is associated with a TPDES permit requirement. The Permit's Storm Water Management Program Requirement (3) states that public streets and roads be operated and maintained in a manner to minimize pollutants. Since medians are a component of the road system, they are subject to the same requirements. The Permit's Storm Water Management Program Requirement (5) states that each permittee shall implement controls to reduce the discharge of pollutants related to the application of pesticides, herbicides, and fertilizers applied by employees to public rights-of-way, parks and other municipal property. Floatable debris is removed from the medians as part of the maintenance activities. Vegetative cover holds the soil in place and reduces the sediment transport into local rivers and streams that can have a negative impact to water quality. Vegetative cover also helps promote local water quality by providing a filter for the water versus runoff that would occur as result of non-pervious material. The Wildflower Program while providing an esthetic quality to the surrounding area helps reduce the need for herbicide application to the medians to help control noxious weed growth. The wildflowers, during growth are a thick vegetative cover that has a natural life cycle from which they reseed themselves.

Weeds along street rights of way can reach over 6' tall causing a visual obstruction if not managed. Regular vegetation control reduces noxious weeds and visual obstructions.

(5) Description of Actions (Statement of Services):

Maintenance of medians consists of mowing and debris removal from 156 acres of city-owned medians.

Scheduled frequency of maintenance is 20 times per year. Mowing occurs during the growing season and excludes the months of November through February on medians without wildflowers. Medians with wildflowers are maintained by debris removal and spot mowing along gutter lines. These medians do not receive mowing while the wildflowers are in bloom and until after they seed, February through May. Five to seven species of native wildflowers are selected for planting. Personnel and equipment are assigned to one of three crews (North, Central and South).

(1) Program Title: Maintenance of Trees in Public Rights-of-Way

(2) Division/Section: Vegetation Control

(3) Program Element:

(a) TPDES

1. SW Controls & Collection System Operations

(b) NFIP

(c) Mandate/Public Safety

(4) Statement of Purpose:

This activity is associated with a TPDES permit requirement. The Permit's Storm Water Management Program Requirement (1) states that the municipal separate storm sewer system and any storm water structural controls shall be operated in a manner to reduce the discharge of pollutants to the maximum extent practicable. Studies have shown that trees help improve water quality by increasing the dissolved oxygen. Trees help keep the water cooler which increases dissolved oxygen levels. Trees also can help reduce the amount of storm water infrastructure necessary for a community by absorbing some of the storm run-off. Trees require maintenance to stay health and not become an obstruction due to excessive canopy growth. After a storm event, downed trees must be removed from the streets so as not to cause a traffic hazard. This would include rain events and ice storms.

(5) Description of Actions (Statement of Services):

Tree canopies are trimmed to a minimum of 7 feet above the ground in drainage channels to provide clearance for the mowers. Tree branches are also trimmed along the City's street rights-of-way to prevent visual obstructions or interference with motor vehicles. While the City does not have a tree inventory at this time, inventory identified is based upon an estimated 15% of all earthen drainage channels have trees that require trimming. It takes approximately one hour/acre to trim trees. This crew is also required to remove trees that have established within 2 feet of concrete drainage structures. Over time, tree roots will damage the concrete and require early repairs. The tree crew consists of a 4-person crew. This crew is on call 24 hours/day 7days/week to remove trees that have caused a traffic hazard. Personnel that have received training within the Vegetation Control section supplement the crew during storm events.

(1) Program Title: Debris Removal from Channels

(2) Division/Section: River Maintenance

(3) Program Element: **(a) TPDES**

(1) Storm Water Controls & Collection System Operations
(2) Improper Disposal

(4) Statement of Purpose:

This activity is a TPDES permit requirement. The Permit's Storm Water Management Program Requirement (1) states that the municipal separate storm sewer system and any storm water structural controls shall be operated in a manner to reduce the discharge of pollutants to the maximum extent practicable and (6) eliminate improper disposal practices to include the expeditious removal of the discharge. The City's Storm Water Management Program specifies that the drainage channels receive regularly scheduled maintenance.

In addition, this activity aids in the conveyance of storm water. Debris in channels changes the design characteristics of the channels and reduces the conveyance capacity of the waterways.

(5) Description of Actions (Statement of Services):

All concrete and improved earthen drainage channels are inspected at a minimum every two years. The removal of illegally dumped debris is scheduled based on a degradation priority system (1-4). Currently priority 1 projects receive necessary maintenance within a 3 month period. Priority two projects are maintained within 6 months. Scheduling is predicated by required equipment availability. In addition the Storm Water Community Service/Restitution program provides necessary hand crews to aid in the removal of floatable debris at minimal cost to the Utility.

(1) Program Title: De-silting Earthen & Concrete Channels

(2) Division/Section: River Maintenance

(3) Program Element: **(a) TPDES**

1. Storm Water Controls & Collection System Operations

(4) Statement of Purpose:

This activity is associated with a TPDES permit requirement. The Permit's Storm Water Management Program Requirement (1) states that the municipal separate storm sewer system and any storm water structural controls shall be operated in a manner to reduce the discharge of pollutants to the maximum extent practicable. Total suspended solids (TSS) are one of the major contributors to poor water quality. Silt enters earthen and concrete channels as a result of construction site runoff, erosive velocities resulting from storm events and poorly vegetated areas. The City's Storm Water Management Program specifies that the drainage channels receive regularly scheduled de-silting maintenance.

In addition, this activity aids in the conveyance of storm water. Silt build-up changes the design characteristics of the channels and reduces the conveyance capacity of the channel.

(5) Description of Actions (Statement of Services):

All concrete and improved earthen drainage channels are inspected at a minimum every two years. Maintenance is scheduled based on a degradation priority system (1-4). Currently priority 1 projects receive necessary maintenance within a 3 month period. Priority two projects are maintained within 6 months. Scheduling is predicated by required equipment availability.

(1) Program Title: Inspections of Channels & Customer Service

(2) Division/Section: River Maintenance

(3) Program Element: **(a) TPDES**

1. Storm Water Controls & Collection System Operations

(4) Statement of Purpose:

This activity is associated with a TPDES permit requirement. The Permit's Storm Water Management Program Requirement (1) states that the municipal separate storm sewer system and any storm water structural controls shall be operated in a manner to reduce the discharge of pollutants to the maximum extent practicable. This program provides for inspection of all channels to identify pollutants in the channels. The City's Storm Water Management Program specifies that the drainage channels receive regularly scheduled maintenance to remove pollutants.

In addition, this activity aids in the conveyance of storm water. Silt build-up, floatable debris and erosion changes the design characteristics of the channels and reduce the conveyance capacity of the channel.

(5) Description of Actions (Statement of Services):

All concrete, improved earthen drainage channels and natural rivers and creeks are inspected at a minimum every two years. Maintenance is scheduled based on a degradation priority system (1-4). Currently priority 1 projects receive necessary maintenance within a 3 month period. Priority two projects are maintained within 6 months. Priority 3 projects receive maintenance with 12 months of identification. Priority 4 projects are scheduled, however they are mostly addressed only when there is a higher priority project requiring similar equipment are in the vicinity.

(1) Program Title: Lake De-silting

(2) Division/Section: River Maintenance

(3) Program Element: **(a) TPDES**

1. Storm Water Controls & Collection System Operations

(4) Statement of Purpose:

This activity is associated with a TPDES permit requirement. The Permit’s Storm Water Management Program Requirement (1) states that the municipal separate storm sewer system and any storm water structural controls shall be operated in a manner to reduce the discharge of pollutants to the maximum extent practicable. Total suspended solids (TSS) are one of the major contributors to poor water quality. Silt enters area lakes and ponds as a result of construction site runoff, erosive velocities in upstream earthen channels resulting from storm events and poorly vegetated areas. The City’s Storm Water Management Program specifies that the drainage infrastructure receive regularly scheduled de-silting maintenance. In addition, this activity aids in the conveyance of storm water. Silt build-up reduces the potential storm water capacity of area lakes and ponds that take surface run-off.

(5) Description of Actions (Statement of Services):

Seven area lakes and ponds have been identified to receive de-silting operations. These lakes and ponds are: Woodlawn Lake, Davis Lake, Elmendorf Lake, Southside Lions Park, Miller’s Pond, San Antonio River, and Friesenhahn Pond. Evaluation of the sediment must be conducted prior to de-silting operations to identify composition of material and to develop effective removal process and appropriate disposal procedures. In addition, all necessary regulatory permits must be applied and received prior to maintenance activities. It is anticipated that de-silting operations will be accomplished by mechanical methods and entails dewatering of the lake/pond.

(1) Program Title: Re-Grading Earthen Channels

(2) Division/Section: River Maintenance

(3) Program Element: **(a) TPDES**

1. Storm Water Controls & Collection System Operations

(4) Statement of Purpose:

This activity is associated with a TPDES permit requirement. The Permit's Storm Water Management Program Requirement (1) states that the municipal separate storm sewer system and any storm water structural controls shall be operated in a manner to reduce the discharge of pollutants to the maximum extent practicable. Total suspended solids (TSS) are one of the major contributors to poor water quality. Silt enters earthen channels as a result of construction site runoff, erosive velocities resulting from storm events and poorly vegetated areas. The City's Storm Water Management Program specifies that the drainage channels receive regularly scheduled de-silting maintenance.

In addition, this activity aids in the conveyance of storm water. Silt build-up changes the design characteristics of the channels and reduces the conveyance capacity of the channel.

(5) Description of Actions (Statement of Services):

This activity is associated with a TPDES permit requirement. The Permit's Storm Water Management Program Requirement (1) states that the municipal separate storm sewer system and any storm water structural controls shall be operated in a manner to reduce the discharge of pollutants to the maximum extent practicable. Total suspended solids (TSS) are one of the major contributors to poor water quality. Silt enters earthen channels as a result of construction site runoff, erosive velocities resulting from storm events and poorly vegetated areas. The City's Storm Water Management Program specifies that the drainage channels receive regularly scheduled de-silting maintenance.

In addition, this activity aids in the conveyance of storm water. Silt build-up changes the design characteristics of the channels and reduces the conveyance capacity of the channel.

(1) Program Title: Restoring Earthen Channels

(2) Division/Section: River Maintenance

(3) Program Element:

(a) TPDES

1. Storm Water Controls & Collection System Operations

(b) Mandate

(4) Statement of Purpose:

This activity is associated with a TPDES permit requirement. The Permit's Storm Water Management Program Requirement (1) states that the municipal separate storm sewer system and any storm water structural controls shall be operated in a manner to reduce the discharge of pollutants to the maximum extent practicable. Total suspended solids (TSS) are one of the major contributors to poor water quality. Silt enters earthen channels as a result of erosive velocities resulting from storm events and poorly vegetated areas. The City's Storm Water Management Program specifies that the drainage channels receive regularly scheduled de-silting and erosion repair maintenance.

In addition, this activity aids in the conveyance of storm water. Silt build-up as a result of erosion changes the design characteristics of the channels and reduces the conveyance capacity of the channel.

(5) Description of Actions (Statement of Services):

Channel restoration entails a reshaping of the channel to bring it back to the original shape and conveyance capacity based on design criteria. This activity normally consist of removal of vegetation during the course of reshaping the channel. Vegetation must then be re-established before the project is considered completed. All improved earthen drainage channels are inspected at a minimum every two years. Maintenance is scheduled based on a degradation priority system (1-4). Currently priority 1 projects receive necessary maintenance within a 3 month period. Priority two projects are maintained within 6 months. Scheduling is predicated by required equipment availability.

(1) Program Title: Natural Creek Maintenance

(2) Division/Section: River Maintenance

(3) Program Element: **(a) TPDES**

1. Improper Disposal

(4) Statement of Purpose:

This activity is a TPDES permit requirement. The Permit's Storm Water Management Program (6) eliminate improper disposal practices to include the expeditious removal of the discharge. The City's Storm Water Management Program specifies that improper disposal and floatable debris be removed from the City's drainage facilities.

In addition, this activity aids in the conveyance of storm water. Debris in natural creeks changes the characteristics of the rivers and creeks and reduces the conveyance capacity of the waterways.

(5) Description of Actions (Statement of Services):

All rivers and creeks within the permit area are inspected at a minimum every two years. The removal of illegally dumped debris is scheduled based on potential impact to impair upstream and downstream infrastructure and cause flooding of the surrounding community. Maintenance consists of debris removal only. In addition the Storm Water Community Service/Restitution program provides necessary hand crews to aid in the removal of floatable debris at minimal cost to the Utility.

(1) Program Title: Removal of Un-permitted Fill in the Floodplain

(2) Division/Section: River Maintenance

(3) Program Element:

(a) Mandate

(b) Unified Development Code

(c) NFIP

(4) Statement of Purpose:

This activity is necessary for compliance with the City's Unified Development Code and to maintain the integrity of the Flood Insurance Program.

In addition, this activity aids in the conveyance of storm water. Un-permitted fill decreases the capacity of drainage infrastructure.

(5) Description of Actions (Statement of Services):

Areas to remove un-permitted fill are identified by the Storm Water Utility and scheduled for removal based on available funding. Projects are designed to restore the area to pre-fill conditions. Evaluation of the un-permitted fill must be conducted prior to removal operations to identify composition of material and to develop effective removal process and appropriate disposal procedures. In addition, all necessary regulatory permits must be applied and received prior to maintenance activities.

(1) Program Title: Support Personnel for River Maintenance

(2) Division/Section: River Maintenance

(3) Program Element: **(a) TPDES**

1. Storm Water Controls & Collection System Operations

(4) Statement of Purpose:

This activity is associated with a TPDES permit requirement. The Permit's Storm Water Management Program Requirement (1) states that the municipal separate storm sewer system and any storm water structural controls shall be operated in a manner to reduce the discharge of pollutants to the maximum extent practicable. This personnel and equipment is necessary to ensure the maximum productivity of maintenance activities.

In addition, this activity aids in the conveyance of storm water by aiding in the maintenance activities associated with maintaining the design characteristics of the channels and the conveyance capacity of the channel.

(5) Description of Actions (Statement of Services):

The activity provides pre-maintenance of all heavy equipment and field re-fueling activities of River Maintenance equipment to include such items as pumps etc. The haul truck is tasked with moving all "track" and oversized equipment to jobsites that are prohibited from operating on City streets.

(1) Program Title: Arterial and Collector Street Cleaning

(2) Division/Section: Street Cleaning

(3) Program Element: **(a) TPDES**
(1) Roadways

(4) Statement of Purpose:

This activity is a requirement of the TPDES permit. The Permit's Storm Water Management Program Requirement (3) states that public streets, roads, and highways shall be operated and maintained in a manner to minimize discharges of pollutants, including those pollutants related to de-icing or sanding activities. The approved storm water management program states the minimum frequency that must be accomplished each year. Street cleaning also removes floatable debris that accumulates in the curb lines. Removal of this material prevents floatable material from entering the drainage systems and potential causes blockages in the channels that could lead to flooding of area residences.

(5) Description of Actions (Statement of Services):

Arterial and collector streets are swept a minimum of four times per year to meet TPDES permit requirements. Regenerative air sweepers are used versus broom sweepers to remove pollutants from the road surfaces. Debris is staged at designated areas around town to be consolidated and transported to an approved landfill. All debris is removed from the staging areas within 24 hours. Sweepers use re-use water versus potable water except over the recharge zones.

(1) Program Title: Residential Street Cleaning

(2) Division/Section: Street Cleaning

(3) Program Element: **(a) TPDES**

1. Roadways

(4) Statement of Purpose:

This activity is a requirement of the TPDES permit. The Permit’s Storm Water Management Program Requirement (3) states that public streets, roads, and highways shall be operated and maintained in a manner to minimize discharges of pollutants, including those pollutants related to de-icing or sanding activities. The approved storm water management program states the minimum frequency that must be accomplished each year. Street cleaning also removes floatable debris that accumulates in the curb lines. Removal of this material prevents floatable material from entering the drainage systems and potential causes blockages in the channels that could lead to flooding of area residences.

(5) Description of Actions (Statement of Services):

Residential streets are swept a minimum of two times per year to meet TPDES permit requirements. Regenerative air sweepers are used versus broom sweepers to remove pollutants from the road surfaces. Debris is staged at designated areas around town to be consolidated and transported to an approved landfill. All debris is removed from the staging areas within 24 hours. Sweepers use re-use water versus potable water except over the recharge zones.

(1) Program Title: Central Business District – Day

(2) Division/Section: Street Cleaning

(3) Program Element: **(a) TPDES**

1. Roadways
2. Illicit Discharges & Improper Disposal

(4) Statement of Purpose:

This activity is associated with a TPDES permit requirement. The Permit’s Storm Water Management Program Requirement (6) states that non-storm water discharges to the municipal storm sewer system shall be effectively prohibited and the permittee shall ensure the implementation of a program to reduce the discharge of floatable (i.e. litter and other human generated solid refuse). The Street Cleaning activity requirement (3) states that public streets, roads, and highways shall be operated and maintained in a manner to minimize discharge of pollutants. Due to the close proximity of the central business district trash receptacles to the San Antonio Riverwalk and San Pedro Creek, trash receptacles should not be allowed to overflow.

(5) Description of Actions (Statement of Services):

Empty 86 trash receptacles within the Central Business District area on an as-needed basis. They are check during the day. Sidewalks are cleaned on a regular basis in the 3.5 miles of the central business district. Streets in the central business district are swept approximately 163 times per year to meet TPDES Permit requirement.

(1) Program Title: Central Business District - Night

(2) Division/Section: Street Cleaning

(3) Program Element: **(a) TPDES**

1. Roadways
2. Illicit Discharges & Improper Disposal

(4) Statement of Purpose:

This activity is associated with a TPDES permit requirement. The Permit's Storm Water Management Program Requirement (6) states that non-storm water discharges to the municipal storm sewer system shall be effectively prohibited and the permittee shall ensure the implementation of a program to reduce the discharge of floatable (i.e. litter and other human generated solid refuse).The Street Cleaning activity requirement (3) states that public streets, roads, and highways shall be operated and maintained in a manner to minimize discharge of pollutants. Due to the close proximity of the central business district trash receptacles to the San Antonio Riverwalk and San Pedro Creek, trash receptacles should not be allowed to overflow.

(5) Description of Actions (Statement of Services):

All 171-trash receptacles within the Central Business District area are emptied on an as-needed basis. They are check during the night. All sidewalks are cleaned on a regular basis in the 13 miles of the central business district. All streets in the central business district are swept approximately 363 times per year to meet TPDES Permit requirement.

(1) Program Title: Graffiti Abatement Program

(2) Division/Section: Street Cleaning

(3) Program Element: **(a) Mandate**

(4) Statement of Purpose:

This activity is a requirement to be in compliance with the City's Graffiti ordinance. Graffiti is required to be removed from infrastructure so as not to become a public nuisance.

(5) Description of Actions (Statement of Services):

Graffiti is removed from public infrastructure as soon as possible once identified. Public infrastructure consists of sidewalks, curbs, retaining walls, streets and concrete drainage infrastructure. Abatement consists of either painting over the graffiti or by power washing. Paint is obtained from the City's recycled paint bank and is matched as close as possible to the existing infrastructure. Community volunteers and court ordered restitutioners are utilized to supplement the two person crew who is responsible for this activity. On the average, graffiti is removed with 30 days of identification.

(1) Program Title: Mission Trails Maintenance

(2) Division/Section: Street Cleaning

(3) Program Element: (a) Mandate

(4) Statement of Purpose:

This activity is a cooperative effort between the City's Park & Recreation and Public Works Department. The upkeep of the Mission Trails is to making it safe and enjoyable for its participants.

(5) Description of Actions (Statement of Services):

Crew leader on a weekly basis will conduct a visual inspection of the Mission Trails system. If any discrepancy is located, the crew leader will forward the problem to the appropriate department or section for resolution. The Mission Hike & Bike Trails are swept and cleaned 26 times annually, removing all litter, trash or debris. The maintenance includes the upkeep of the street surface of the Mission Parkway.

(1) Program Title: NAD Sweeps (Neighborhood Action Department)

(2) Division/Section: Street Cleaning

(3) Program Element: (a) Mandate

(4) Statement of Purpose:

This activity is associated with the Neighborhood Action Department Management Program. The program consists of 24 residential sweeps annually. Neighborhoods that participate in this program help clean-up the area by removing trash and cleaning surrounding property of insightly messes. The neighborhood sweep program provides for City services in a comprehensive, fast paced effort.

(5) Description of Actions (Statement of Services):

During the course of the sweep, mowing of public rights of way and debris removal is accomplished. Once the sweep is complete, the streets are swept to help minimize the discharge of pollutants that resulted from the cleanup operations. Removal of this material prevents it from entering the drainage systems.

(1) Program Title: Special Events

(2) Division/Section: Street Cleaning

(3) Program Element: **(a) TPDES**

1. Illicit Discharges & Improper Disposal

(4) Statement of Purpose:

This activity is associated with a TPDES permit requirement. There are 19 scheduled special events annually. The Street Cleaning Section removes trash that is left as a result of the City sponsored events. Removal of this material prevents material from entering the drainage systems and potential causes blockages in the channels that could lead to flooding of the central business district or nearby residents.

(5) Description of Actions (Statement of Services):

Regenerative air sweepers are used versus broom sweepers to remove debris from the road and sidewalk surfaces. Trash is collected and transported to an approved landfill. Special Events: includes Thanksgiving Holiday Parade, Blue Santa Parade, Alamo Bowl, New Year’s Eve Celebration, Martin Luther King March, City Wide Cleanup, Market Square Carnival, Night in Old San Antonio (N.I.O.S.A.), River Parade, Battle of Flowers, Fiesta Flambeau Parade, King William Festival, Cattleman Square, Folk Live Festival, July 4th Celebration, Independence Day Parade, JAZZ Alive and the Diez de Septiembre Parade.

(1) Program Title: High Water Detection Alert System

(2) Division/Section: Tunnel Maintenance

(3) Program Element: (a) Mandate

(4) Statement of Purpose:

The High Water Detection System must be maintained to ensure operability during storm events. These systems use flashing lights to warn motorist of water over the road conditions in selected high profile areas of the City.

The system has an associated status board located at Station 1 to give advance notice to Public Works' dispatchers during a storm of locations of heavy rain and flooding streets so barricade trucks can be dispatched to appropriate parts of the City.

(5) Description of Actions (Statement of Services):

The high water detection system must be inspected monthly and necessary maintenance performed on the components of the system. This consist of replacing light bulbs, ensuring battery integrity, radio frequency operation and if necessary replacing systems that have been knocked down by vehicles.

(1) Program Title: Drainage Inlet and HazMat Trap Cleaning

(2) Division/Section: Tunnel Maintenance

(3) Program Element: **(a) TPDES**

1. Storm Water Controls & Collection System Operations
2. Illicit Discharge & Improper Disposal

(4) Statement of Purpose:

This activity is a requirement of the TPDES permit. The Permit's Storm Water Management Program Requirement (1) states that the municipal separate storm sewer system and any storm water structural controls shall be operated in a manner to reduce the discharge of pollutants to the maximum extent practicable and (6) states that non-storm water discharges to the municipal storm sewer system shall be effectively prohibited and the permittee shall ensure the implementation of a program to reduce the discharge of floatables (i.e. litter).

Drainage inlet cleaning ensures that all storm drain inlets and the five HazMat traps are free and clear of debris and floatable material.

(5) Description of Actions (Statement of Services):

Remove all obstructions and floatable debris from inlets and clean out the material collected in the five HazMat traps. These five HazMat traps are located in the Edwards Aquifer region. The inlet cleaning program provides for 20% of the City's storm sewer inlets to receive yearly inspection and necessary cleaning. In addition, four of the City's Street Sweepers have been equipped with a vacuum hose so they can help support this activity. The HazMat traps are required to be inspected once per month for necessary cleaning. This activity is performed with the vacuum inductor trucks

(1) Program Title: Flood Control Facility Operation and Maintenance

(2) Division/Section: Tunnel Maintenance

(3) Program Element: **(a) TPDES**

1. Storm Water Controls & Collection System Operations
2. Illicit Discharge/ Improper Disposal

(b) NFIP

(4) Statement of Purpose:

This activity is a requirement of the TPDES permit. The Permit's Storm Water Management Program Requirement (1) states that the municipal separate storm sewer system and any storm water structural controls shall be operated in a manner to reduce the discharge of pollutants to the maximum extent practicable and (6) states that non-storm water discharges to the municipal storm sewer system shall be effectively prohibited and the permittee shall ensure the implementation of a program to reduce the discharge of floatables (i.e. litter).

Maintain the operation readiness of the infrastructure and associated equipment of two flood control tunnels, four dams, and the Pearsall Landfill Lift station.

(5) Description of Actions (Statement of Services):

The San Antonio River Tunnel is monitored and set to different modes depending on the needs of the City. Operators monitor the system to ensure that proper settings are maintained. The San Antonio River and San Pedro River tunnel facilities consist of numerous mechanical parts that must be exercised and maintained on a daily basis. This includes testing of the emergency generators, oiling moving mechanical parts of the equipment, providing recommended maintenance to the various pumps associated with the system.

The gates at the City's 4 dams must be kept operational to ensure proper operations if necessary during a flood event and the dam structures must be maintained to ensure structural integrity. The four City owned dams are: Olmos, Woodlawn, Elmendorf and Espada. The lift station located near the Pearsall Rd. Landfill is inspected monthly and necessary maintenance is performed pump and electrical system.

(1) Program Title: Infrastructure Repairs (Pipes & Concrete)

(2) Division/Section: Tunnel Maintenance

(3) Program Element:

(a) TPDES

1. Storm Water Controls & Collection System Operations
2. Illicit Discharge/ Improper Disposal

(b) NFIP

(4) Statement of Purpose:

This activity is a requirement of the TPDES permit. The Permit's Storm Water Management Program Requirement (1) states that the municipal separate storm sewer system and any storm water structural controls shall be operated in a manner to reduce the discharge of pollutants to the maximum extent practicable and (6) states that non-storm water discharges to the municipal storm sewer system shall be effectively prohibited and the permittee shall ensure the implementation of a program to reduce the discharge of floatables (i.e. litter).

In addition, the underground storm sewer pipes must be maintained to ensure maximum capacity during a rain event.

(5) Description of Actions (Statement of Services):

Repair or replace concrete infrastructure such as concrete drainage channel aprons and wing walls, box culverts, and concrete drainage channels. It is estimated that 15% of the existing concrete drainage structures are severely damaged and requiring spot repairs to maintain integrity of the structure. Underground collapsed storm sewer pipes are identified and replaced on an as-needed basis. Approximately 1,300 linear feet of under pipes are replaced yearly.

(1) Program Title: Pipeline Inspection & Survey

(2) Division/Section: Tunnel Maintenance

(3) Program Element: (a) TPDES

1. Storm Water Controls & Collection System Operations
2. Illicit Discharge/ Improper Disposal

(4) Statement of Purpose:

This activity is a requirement of the TPDES permit. The Permit's Storm Water Management Program Requirement (1) states that the municipal separate storm sewer system and any storm water structural controls shall be operated in a manner to reduce the discharge of pollutants to the maximum extent practicable and (6) states that non-storm water discharges to the municipal storm sewer system shall be effectively prohibited and the permittee shall ensure the implementation of a program to reduce the discharge of floatables (i.e. litter).

In addition, the underground storm sewer pipes must be maintained to ensure maximum capacity during a rain event.

(5) Description of Actions (Statement of Services):

Inspect the underground storm sewer system to identify illicit connections to the system and document damages to include collapsed pipe requiring replacement to the estimated 499 miles of underground system. Approximately 20% of the system is inspected yearly. This program also provides inspections on newly constructed infrastructure to ensure compliance with plans and specifications. .

(1) Program Title: Fiscal Operations

(2) Division/Section: Fiscal

(3) Program Element:
- **(a) NFIP**
- **(b) TPDES**
- **(c) Mandates**

(4) Statement of Purpose:

Assist the Utility Administrator, Operations Division Manager, and Chief Storm Water Engineer in managing a $25 million annual budget and $46.8 million capital improvement program.

(5) Description of Actions (Statement of Services):

With assigned staff, insure timely and accurate payment of daily invoices, compile performance measures on current budget, track and recover special project expenses, prepare all necessary documentation for proposed budget, and coordinate with Department Fiscal Operations Manager and outside agencies as required.

(1) Program Title: Personnel Services

(2) Division/Section: Human Resources

(3) Program Element:

(a) NFIP
(b) TPDES
(c) Mandates

(4) Statement of Purpose:

Assist the Utility Administrator, Operations Division Manager, and Chief Storm Water Engineer in managing employee services for all personnel within the Utility. Provide oversight of all administrative actions throughout the Utility.

(5) Description of Actions (Statement of Services):

With assigned staff, insure timely and accurate payroll submission. Processes all personnel actions dealing with recruitment, retirement, performance appraisals, awards, workman's compensation, disabilities, and disciplinary actions within the Utility.

(1) Program Title: Volunteer/Restitution Program Personnel Services

(2) Division/Section: Administration

(3) Program Element: **TPDES**

1. Illicit Discharges and Improper Disposal

(4) Statement of Purpose:

This activity is associated with a TPDES permit requirement. The Permit's Storm Water Management Program Requirement (6) states that a program be established to eliminate improper disposal practices to include the expeditious removal of the discharge. The Storm Water Volunteer/Restitution Program is utilized to remove floatable debris from the City's drainage infrastructure and to maintain the infrastructure in good condition by removing graffiti.

(5) Description of Actions (Statement of Services):

In cooperation with the Parks and Recreation Department and Bexar County Justice Department, individuals assessed by the courts to serve their community as a result of an offense are utilized by the Utility to perform routine hand labor work that otherwise would require operations personnel. These people are assigned to crews to pick up debris from street rights-of-way, drainage channels, waterways and medians. They are also used to remove graffiti from the drainage infrastructure.

In addition to the restitution workers, community volunteer groups to address a specific concern in an area also contact the Utility. These volunteers are also used to pick up floatable debris and remove graffiti.

(1) Program Title: Municipal Infrastructure Capital Improvement Projects Review

(2) Division/Section: Storm Water Engineering

(3) Program Element:

(a) Flood Insurance Program

(b) TPDES

1. Areas of New Development and Significant Redevelopment

(4) Statement of Purpose:

Review of proposed municipal infrastructure improvements to maintain high community rating in National Flood Insurance Program and to insure compliance with TPDES permit requirements.

(5) Description of Actions (Statement of Services):

Review of proposed municipal infrastructure improvements to maintain high community rating in National Flood Insurance Program and to insure compliance with TPDES permit requirements.

(1) Program Title: Floodplain Management

(2) Division/Section: Storm Water Engineering

(3) Program Element:

(a) Flood Insurance Program

(c) TPDES

1. Areas of New Development and Significant Redevelopment

(4) Statement of Purpose:

Under the direction of the Floodplain Administrator, implement a community program of corrective and preventive measures for reducing flood damage and improve surface water quality to the maximum extent practical.

(5) Description of Actions (Statement of Services):

Perform technical review of Floodplain Development Permits for approval or denial by the Floodplain Administrator. Review all submittals of Flood Insurance Rate Map revisions to FEMA. Identify, notify and help prosecute floodplain violators. Perform storm water management plan reviews of Master Development Plans, Planned Unit Developments, Tax Increment Reinvestment Zones, plats, and building permits to insure compliance with UDC floodplain ordinances and storm water management requirements. Coordinate all actions with Development Services Department.

(1) Program Title: Storm Water Design Engineering

(2) Division/Section: Storm Water Engineering

(3) Program Element: **(a) Flood Insurance Program**

(b) Mandates

(4) Statement of Purpose:
Program is set to allow Storm Water Engineering the capacity to provide construction plans for the repair of City infrastructure within the capabilities of in-house forces to repair.

(5) Description of Actions (Statement of Services):
Provides mitigation plans to in-house City forces (Street Maintenance or Storm Water Operations) to allow for construction of needed projects.

(1) Program Title: Citizen Request for Service Response

(2) Division/Section: Storm Water Engineering

(3) Program Element:

(a) Flood Insurance Program

(b) Mandates

(4) Statement of Purpose:
Customer First Service.

(5) Description of Actions (Statement of Services):
Respond to citizens' request for storm water engineering services. Provide floodplain information to individual citizens for flood insurance applications. Prepare and present informative engineering analysis and recommended solutions for neighborhood drainage issues.

(1) Program Title: Regional Storm Water Management Plan Implementation

(2) Division/Section: Storm Water Engineering

(3) Program Element:

(a) Flood Insurance Program

(c) TPDES

1. Flood Control Projects

(4) Statement of Purpose:

Administer and implement the Regional Storm Water Management Program (RSWMP) as described in the UDC. Participate in the development and implementation of the Regional Flood Control, Drainage and Storm Water Management Program in partnership with the County, SARA suburban cities, and federal installations.

(5) Description of Actions (Statement of Services):

Review requests for participation in the RSWMP by reviewing and evaluating storm water management plans submitted by private developers. Provide storm water review of Prop 3 acquisitions. Participate in the selection of consultants to prepare regional hydraulic/hydrologic and water quality models for the Regional Management Program. Coordinate with other agencies as required.

(1) Service Community Outreach

(2) Division/Section Community Outreach

(3) Program Element **(a) TPDES**

1. Public education/public participation
2. Illicit discharges and improper disposal NFIP

(4) Statement of Purpose

The Clean Water Act of 1972 charged the Federal Government with taking charge of regulating the surface water quality of the nation's waterways. It set maximum extent practical standards for all non-point source discharges into the regulated waterways, and required such discharges to receive a permit through the National Pollutant Discharge Elimination System (NPDES). Storm Water runoff is a non-point source discharge. San Antonio received an NPDES permit in February of 1996. Surface water quality education is a required portion of this permit. The permit's Storm Water Management Program requirement (6)(c) states that the permittees shall ensure the implementation of a program to reduce the discharge of floatables. (6)(d) The discharge or disposal of used motor vehicle fluids, household hazardous wastes, grass clippings, leaf litter, and animal wastes into separate storm sewers shall be prohibited. (10) States that a public education program with the following elements shall be implemented: a program to promote, publicize and facilitate public reporting of the presence of illicit discharges or improper disposal of materials, the proper management and disposal of used oil and household hazardous wastes and the proper use, application and disposal of pesticides, herbicides and fertilizers. Public education performed by Community Outreach, consists of brochures, pamphlets, training sessions and public meetings to educate the adult community on storm water related activities and services, TPDES permitting responsibilities, flood insurance, floodplain development requirements, and drainage projects and services specific to individual watersheds. There exists a memorandum of agreement with SAWS that delineates responsibilities for public education in order to eliminate unnecessary redundancy.

Public education is also a vital requirement as participants in the National Flood Insurance Program and is necessary to participate in the Community Rating System.

(5) Description of Actions (Statement of Services)

Compliance with the public education requirement of the NPDES permit is achieved through coordination with other city departments as well as outside organizations. Approximately 140 educational presentations per fiscal year to include community meetings, school presentations, City of San Antonio employee education and special events are conducted. Presentations consist of distribution of written materials, demonstration of a watershed model, videos or open discussion.

APPENDIX F: Cost Estimates for Structural Stormwater BMPs

Narrative

The rough order of magnitude (ROM) cost estimates provided in the attached tables were prepared by Parsons Water & Infrastructure during August and September 2006 as screening level estimates only, to be used primarily for assessing the comparative costs of the different BMPs described. The cost estimates were only one factor considered when evaluating different BMPs for use in the San Antonio area. The costs presented are not suitable for use as design cost estimates and should be revised once planning level work has identified specific areas and BMPs for future consideration. If necessary, the estimates may also be used at a broad planning level although, once more precise details of any planned BMPs are known (e.g., size, location, etc.), the estimates should be updated using that information as well as updated construction and materials and labor costs. The costs presented include design fees, permitting fees, erosion control, fencing, grubbing, excavation and hauling, contractor construction and profit, materials, and vegetation installation and/or repair. Costs do not include land acquisition or annual maintenance.

The BMP cost estimates are separated into two main categories based on general size of BMP or volume treated. Within each of these two categories each BMP type is then further divided into three approximately equal sizes to allow comparison between BMP types and for assessing cost. The large scale BMPs include infiltration basins (simple ponds with permeable bottom, typically dry), retention ponds (wet ponds with vegetation on the shoreline), and constructed wetlands (always wet, typically shallow except during storms, long residence time). The small scale BMPs include sand filters (structures to settle and filter pollutants in baffles, followed by a filter media (sand) with the sand being replaced), infiltration trenches (gravel or sand filled trenches to infiltrate water, requiring media replacement), and bioretention (using a planted soil bed and vegetation to mimic an ecosystem for filtering pollutants - typically in a roadway island or in a parking lot island).

Areas where a municipality could decrease costs from these ROM estimates include performing design, permitting, and construction themselves and teaming up with nearby city projects minimizing excavation and hauling of soil. The estimates include a percentage multiplier on construction cost for contractor profit, management, contingency, and bonding. For BMPs with estimated construction costs of less than or equal to $150,000, a 30-percent multiplier was used for construction management and profit. For BMPs with construction costs of greater than $150,000, a 25-percent multiplier was used. Design and permitting costs on estimated construction costs of less than or equal to $150,000, use a 25-percent multiplier. For BMPs with construction costs of greater than $150,000, a 15-percent multiplier was utilized for design and permitting.

References utilized in the cost estimates include:

- RS Means Building Construction Cost Data 2006.
- CalTransCostEstimateData - compilation of costs for multiple projects of seven BMP types across the U.S.
- EPA 821-R-99-012 Preliminary Data Summary of Urban Stormwater BMPs Aug 1999
- (EPA 832-F-99-007, Sept 1999) Sand Filters

- (CASQA TC-10 1-2003) Infiltration Trenches, California Stormwater BMP Handbook (cabmphandbooks.com)
- (CASQA TC-11 1-2003) Infiltration Basins, California Stormwater BMP Handbook (cabmphandbooks.com)
- (EPA 832-F-99-025) Storm Water Wetlands
- Structural BMP Fact Sheet SFWMD-BMP-DS-3 Constructed Wetlands, South Florida Water Management District, April 2002 (sfwmd.gov)

		Rough Order of Magnitude Estimated Construction Cost	Surface Area of BMP (sq ft)	Treatment Volume of BMP (cu ft)	BMP ROM Construction Cost ($ per cu ft)
Large Scale BMPs (large volume of water treated)					
Infiltration Basin (shallow impoundment, slow infiltration)					
1.75 Surface Acre Basin approximately 5 ft deep (1' of sand base, 2' of treatment, 2' of freeboard)		$ 286,173	76,230	152,460	$ 1.88
3.5 Surface Acre Basin approximately 5 ft deep (1' of sand base, 2' of treatment, 2' of freeboard)		$ 561,234	152,460	304,920	$ 1.84
35 Surface Acre Basin approximately 5 ft deep (1' of sand base, 2' of treatment, 2' of freeboard)		$ 4,782,864	1,524,600	3,049,200	$ 1.57
Retention Pond (wet pond - veg on shoreline)					
1/2 Surface Acre Pond, approximately 7 ft deep (1' of retained water, 4' of treatment, 2' of freeboard)		$ 166,963	21,780	87,120	$ 1.92
1 Surface Acre Pond, approximately 7 ft deep (1' of retained water, 4' of treatment, 2' of freeboard)		$ 292,643	43,560	174,240	$ 1.68
10 Surface Acre Pond, approximately 7 ft deep (1' of retained water, 4' of treatment, 2' of freeboard)		$ 1,721,196	435,600	1,742,400	$ 0.99
Constructed Wetlands (constant shallow water, storm retention, veg in pond and on shoreline)					
1/2 Surface Acre Wetland, approximately 7 ft deep (1' of retained water, 4' of treatment, 2' of freeboard)		$ 184,563	21,780	87,120	$ 2.12
1 Surface Acre Wetland, approximately 7 ft deep (1' of retained water, 4' of treatment, 2' of freeboard)		$ 323,093	43,560	174,240	$ 1.85
10 Surface Acre Wetland, approximately 7 ft deep (1' of retained water, 4' of treatment, 2' of freeboard)		$ 1,960,446	435,600	1,742,400	$ 1.13
Small Scale BMPs (small volume of water treated)					
Sand Filter					
1) Austin Sand Filter	~20,000 cu ft System, approximately 5 ft deep	$ 119,555	4,000	20,000	$ 5.98
	~80,000 cu ft System, approximately 5 ft deep	$ 336,426	16,000	80,000	$ 4.21
	~160,000 cu ft System, approximately 5 ft deep	$ 632,755	32,000	160,000	$ 3.95
2) Washington DC Sand Filter	~20,000 cu ft System, approximately 6 ft deep	$ 180,824	3,333	20,000	$ 9.04
	~80,000 cu ft System, approximately 6 ft deep	$ 491,077	13,333	80,000	$ 6.14
	~160,000 cu ft System, approximately 6 ft deep	$ 776,796	26,667	160,000	$ 4.85
3) Delaware Sand Filter (estimated costs are similar to Washington DC Sand Filter)					
Infiltration Trench					
Infiltration Trench	3,400 sq ft Surface Area System, approximately 4 ft deep	$ 55,194	3,400	4,760	$ 11.60
Infiltration Trench	13,400 sq ft Surface Area System, approximately 4 ft deep	$ 148,361	13,400	18,760	$ 7.91
Infiltration Trench	26,700 sq ft Surface Area System, approximately 4 ft deep	$ 243,036	26,700	37,380	$ 6.50
Bioretention/Biofiltration (parking lot edges and traffic-island buffer/planter areas)					
Bioretention	1/4 Acre Surface Area System, approximately 2 ft deep	$ 50,321	10,900	21,800	$ 2.31
Bioretention	0.9 Acre Surface Area System, approximately 2 ft deep	$ 166,919	39,200	78,400	$ 2.13
Bioretention	1.8 Acre Surface Area System, approximately 2 ft deep	$ 293,551	78,400	156,800	$ 1.87

Infiltration Basin

1.75 Surface Acre Basin approximately 5 ft deep (1' of sand base, 2' of treatment, 2' of freeboard)

	Units	Number	Cost/Unit $	Cost	Area sq ft	Volume cubic ft	
Land: area/volume info	acre	1.750			76230	152460	
Survey	acre	1.750	3275	$5,731			2006 Means, 01103 700 0100 Survey, Maximum $3,275/ac (use 1/2 acre as a minimum area)
Temporary Erosion Control		1104.4	0.8	$2,000			2006 Means, 02270 700 1000 Silt Fence $0.80 L.F. (use $2,000 min for 1 acre area or less)
Grubbing/Debris	acre	1.750	3300	$5,775			2006 Means, 02230 100 0020 Grubbing
Excavation (5 feet depth)							
Mob/Demob		4	300	$2,200			2006 Means, 02305 250 0100 Mob one piece of equipment one way $300, plus $1,000 general mob
Excavation, Dozer, 80 hp, 50' haul	C.Y.	14117	3.86	$54,490			2006 Means, 02315 432 2040 Excavation dozer, clay $3.86/B.C.Y.
Loading/Excavation, Front End Loader, 2 1/4 C.Y.	C.Y.	14117	1.19	$16,799			2006 Means, 02315 424 1600 Excavation $1.19/C.Y.
Haul, 20 C.Y. Dump Truck, 1 mi RT	C.Y.	7058	2.48	$17,505			2006 Means, 02315 490 1150 Haul half of soil excavated volume, use other half onsite. $2.48/C.Y. (use $1,000 min)
Compaction	C.Y.	7058	0.65	$4,588			2006 Means, 02315 315 5600 Compact the half of total soil excavated remaining on site grounds $0.65/C.Y. (use $1,000 min)
Materials Concrete (inflow bay, walls, outflow structure)		1	5000	$5,000			Use $100 per cu yd (Capitol Aggregates 7-2006 quote) times a factor of 5 for reinforcing steel, formwork, labor
Materials (Sand)	C.Y.	2823	15	$42,350			Use 1 foot of sand depth
Materials Other (pipeworks)		1	5000	$5,000			
Security/Safety							
Fencing, chain link, 4' tall	lin ft	0	7.75	$0			2006 Means, 02820 140 0050
Gate and gate posts	each	0	820	$0			2006 Means, 02820 130 5010
Signs	each	4	500	$2,000			
Revegetation after construction		76.23	445	$33,922			2006 Means, 02920 400 0300 Sod <1000 S.F.; $445 / M.S.F. (thousand sq ft)
	Construction Sub Total			**$197,360**			
Construction Mgmt/Profit/Contingency		25%	0.25	$49,340			2006 Means, CM:01103 200 0050 7.5%, Profit: 01300 620 0300 25 - 30%: using sum of 30% for constructed cost < $150,000, else 25%.
Design/Permitting		15%	0.15	$29,604			Using 25% on constructed cost <= $150,000, else 15%.
Bonding/Insurance		5%	0.05	$9,868			Use 5%
CM,Profit,Design,Permiting,Contingency,Bonding Sub Total				**$88,812**			
			Total	**$286,173**			

Infiltration Basin

3.5 Surface Acre Basin approximately 5 ft deep (1' of sand base, 2' of treatment, 2' of freeboard)

	Units	Number	Cost/Unit $	Cost	Area sq ft	Volume cubic ft	
Land: area/volume info	acre	3.500			152460	304920	
Survey	acre	3.500	3275	$10,000			2006 Means, 01103 700 0100 Survey, Maximum $3,275/ac (use 1/2 acre as a minimum area), use $10,000 as maximum
Temporary Erosion Control		1561.8	0.8	$2,000			2006 Means, 02270 700 1000 Silt Fence $0.80 L.F. (use $2,000 min for 1 acre area or less)
Grubbing/Debris	acre	3.500	3300	$11,550			2006 Means, 02230 100 0020 Grubbing
Excavation (5 feet depth)							
Mob/Demob		4	300	$2,200			2006 Means, 02305 250 0100 Mob one piece of equipment one way $300, plus $1,000 general mob
Excavation, Dozer, 80 hp, 50' haul	C.Y.	28233	3.86	$108,981			2006 Means, 02315 432 2040 Excavation dozer, clay $3.86/B.C.Y.
Loading/Excavation, Front End Loader, 2 1/4 C.Y.	C.Y.	28233	1.19	$33,598			2006 Means, 02315 424 1600 Excavation $1.19/C.Y.
Haul, 20 C.Y. Dump Truck, 1 mi RT	C.Y.	14117	2.48	$35,009			2006 Means, 02315 490 1150 Haul half of soil excavated volume, use other half onsite. $2.48/C.Y. (use $1,000 min)
Compaction	C.Y.	14117	0.65	$9,176			2006 Means, 02315 315 5600 Compact the half of total soil excavated remaining on site grounds $0.65/C.Y. (use $1,000 min)
Materials Concrete (inflow bay, walls, outflow structure)		1	15000	$10,000			Use $100 per cu yd (Capitol Aggregates 7-2006 quote) times a factor of 5 for reinforcing steel, formwork, labor
Materials (Sand)	C.Y.	5647	15	$84,700			Use 1 foot of sand depth
Materials Other (pipeworks)		1	10000	$10,000			
Security/Safety							
Fencing, chain link, 4' tall	lin ft	0	7.75	$0			2006 Means, 02820 140 0050
Gate and gate posts	each	0	820	$0			2006 Means, 02820 130 5010
Signs	each	4	500	$2,000			
Revegetation after construction		152.46	445	$67,845			2006 Means, 02920 400 0300 Sod <1000 S.F.; $445 / M.S.F. (thousand sq ft)
	Construction Sub Total			**$387,058**			
Construction Mgmt/Profit/Contingency		25%	0.25	$96,765			2006 Means, CM:01103 200 0050 7.5%, Profit: 01300 620 0300 25 - 30%: using sum of 30% for constructed cost < $150,000, else 25%.
Design/Permitting		15%	0.15	$58,059			Using 25% on constructed cost <= $150,000, else 15%.
Bonding/Insurance		5%	0.05	$19,353			Use 5%
	CM,Profit,Design,Permiting,Contingency,Bonding Sub Total			**$174,176**			
			Total	**$561,234**			

Infiltration Basin

35 Surface Acre Basin approximately 5 ft deep (1' of sand base, 2' of treatment, 2' of freeboard]

	Units	Number	Cost/Unit $	Cost	Area sq ft	Volume cubic ft	
Land: area/volume info	acre	35.000			1524600	3049200	
Survey	acre	35.000	3275	$10,000			2006 Means, 01103 700 0100 Survey, Maximum $3,275/ac (use 1/2 acre as a minimum area), use $10,000 as maximum
Temporary Erosion Control		4939.0	0.8	$3,951			2006 Means, 02270 700 1000 Silt Fence $0.80 L.F. (use $2,000 min for 1 acre area or less)
Grubbing/Debris	acre	35.000	3300	$30,000			2006 Means, 02230 100 0020 Grubbing, $3300 per acre, use $30,000 maximum
Excavation (5 feet depth)							
Mob/Demob		4	300	$2,200			2006 Means, 02305 250 0100 Mob one piece of equipment one way $300, plus $1,000 general mob
Excavation, Dozer, 80 hp, 50' haul	C.Y.	282333	3.86	$1,089,807			2006 Means, 02315 432 2040 Excavation dozer, clay $3.86/B.C.Y.
Loading/Excavation, Front End Loader, 2 1/4 C.Y.	C.Y.	282333	1.19	$335,977			2006 Means, 02315 424 1600 Excavation $1.19/C.Y.
Haul, 20 C.Y. Dump Truck, 1 mi RT	C.Y.	141167	2.48	$350,093			2006 Means, 02315 490 1150 Haul half of soil excavated volume, use other half onsite. $2.48/C.Y. (use $1,000 min)
Compaction	C.Y.	141167	0.65	$91,758			2006 Means, 02315 315 5600 Compact the half of total soil excavated remaining on site grounds $0.65/C.Y. (use $1,000 min)
Materials Concrete (inflow bay, walls, outflow structure)		1	15000	$15,000			Use $100 per cu yd (Capitol Aggregates 7-2006 quote) times a factor of 5 for reinforcing steel, formwork, labor
Materials (Sand)	C.Y.	56467	15	$847,000			Use 1 foot of sand depth
Materials Other (pipeworks)		1	10000	$10,000			
Security/Safety							
Fencing, chain link, 4' tall	lin ft	0	7.75	$0			2006 Means, 02820 140 0050
Gate and gate posts	each	0	820	$0			2006 Means, 02820 130 5010
Signs	each	4	500	$2,000			
Revegetation after construction		1524.6	335	$510,741			2006 Means, 02920 400 0300 Sod <1000 S.F.; $445 / M.S.F. (thousand sq ft); >8 M.S.F $335/ M.S.F.
	Construction Sub Total			**$3,298,527**			
Construction Mgmt/Profit/Contingency		25%	0.25	$824,632			2006 Means, CM:01103 200 0050 7.5%, Profit: 01300 620 0300 25 - 30%: using sum of 30% for constructed cost < $150,000, else 25%.
Design/Permitting		15%	0.15	$494,779			Using 25% on constructed cost <= $150,000, else 15%.
Bonding/Insurance		5%	0.05	$164,926			Use 5%
CM,Profit,Design,Permiting,Contingency,Bonding Sub Total				**$1,484,337**			
Total				**$4,782,864**			

Retention Pond (wet pond)

1/2 Surface Acre Pond, approximately 7 ft deep (1' of retained water, 4' of treatment, 2' of freeboard)

	Units	Number	Cost/Unit $	Cost	Area sq ft	Volume cubic ft	
Land: area/volume info	acre	0.500			21780	87120	
Survey	acre	0.500	3275	$1,638			2006 Means, 01103 700 0100 Survey, Maximum $3,275/ac (use 1/2 acre as a minimum area)
Temporary Erosion Control			1	$2,000			2006 Means, 02270 700 1000 Silt Fence $0.80 L.F. (use $2,000 min for 1 acre area or less)
Grubbing/Debris	acre	0.500	3300	$1,650			2006 Means, 02230 100 0020 Grubbing
Excavation (estimate 7 feet depth)							
Mob/Demob		4	300	$2,200			2006 Means, 02305 250 0100 Mob one piece of equipment one way $300, plus $1,000 general mob
Excavation, Dozer, 80 hp, 50' haul	C.Y.	5647	3.86	$21,796			2006 Means, 02315 432 2040 Excavation dozer, clay $3.86/B.C.Y.
Loading/Excavation, Front End Loader, 2 1/4 C.Y.	C.Y.	5647	1.19	$6,720			2006 Means, 02315 424 1600 Excavation $1.19/C.Y.
Haul, 20 C.Y. Dump Truck, 1 mi RT	C.Y.	2823	2.48	$7,002			2006 Means, 02315 490 1150 Haul half of soil excavated volume, use other half onsite. $2.48/C.Y. (use $1,000 min)
Compaction	C.Y.	2823	0.65	$1,835			2006 Means, 02315 315 5600 Compact the half of total soil excavated remaining on site grounds $0.65/C.Y. (use $1,000 min)
Materials Concrete (inflow bay, walls, outflow structure)		1	20000	$20,000			Use $100 per cu yd (Capitol Aggregates 7-2006 quote) times a factor of 5 for reinforcing steel, formwork, labor
Materials (Shoreline Veg.)		1	4000	$4,000			
Materials Other (pipeworks)		1	20000	$20,000			
Security/Safety							
Fencing, chain link, 4' tall	lin ft	590.3219	7.75	$4,575			2006 Means, 02820 140 0050
Gate and gate posts	each	2	820	$1,640			2006 Means, 02820 130 5010
Signs	each	4	500	$2,000			
Revegetation after construction	M.S.F.	21.78	335	$7,296			2006 Means, 02920 400 0300 Sod <1000 S.F.; $445 / M.S.F. (thousand sq ft); >8 M.S.F $335/ M.S.F.
	Construction Sub Total			**$104,352**			
Construction Mgmt/Profit/Contingency		30%	0.30	$31,306			2006 Means, CM:01103 200 0050 7.5%, Profit: 01300 620 0300 25 - 30%: using sum of 30% for constructed cost < $150,000, else 25%.
Design/Permitting		25%	0.25	$26,088			Using 25% on constructed cost <= $150,000, else 15%.
Bonding/Insurance		5%	0.05	$5,218			Use 5%
CM,Profit,Design,Permiting,Contingency,Bonding Sub Total				**$62,611**			
			Total	**$166,963**			

Retention Pond (wet pond)

1 Surface Acre Pond, approximately 7 ft deep (1' of retained water, 4' of treatment, 2' of freeboard)

	Units	Number	Cost/Unit $	Cost	Area sq ft	Volume cubic ft	
Land: area/volume info	acre	1.000			43560	174240	
Survey	acre	1.000	3275	$3,275			2006 Means, 01103 700 0100 Survey, Maximum $3,275/ac (use 1/2 acre as a minimum area)
Temporary Erosion Control			1	$2,000			2006 Means, 02270 700 1000 Silt Fence $0.80 L.F. (use $2,000 min for 1 acre area or less)
Grubbing/Debris	acre	1.000	3300	$3,300			2006 Means, 02230 100 0020 Grubbing
Excavation (estimate 7 feet depth)							
Mob/Demob		4	300	$2,200			2006 Means, 02305 250 0100 Mob one piece of equipment one way $300, plus $1,000 general mob
Excavation, Dozer, 80 hp, 50' haul	C.Y.	11293	3.86	$43,592			2006 Means, 02315 432 2040 Excavation dozer, clay $3.86/B.C.Y.
Loading/Excavation, Front End Loader, 2 1/4 C.Y.	C.Y.	11293	1.19	$13,439			2006 Means, 02315 424 1600 Excavation $1.19/C.Y.
Haul, 20 C.Y. Dump Truck, 1 mi RT	C.Y.	5647	2.48	$14,004			2006 Means, 02315 490 1150 Haul half of soil excavated volume, use other half onsite. $2.48/C.Y. (use $1,000 min)
Compaction	C.Y.	5647	0.65	$3,670			2006 Means, 02315 315 5600 Compact the half of total soil excavated remaining on site grounds $0.65/C.Y. (use $1,000 min)
Materials Concrete (inflow bay, walls, outflow structure)		1	40000	$40,000			Use $100 per cu yd (Capitol Aggregates 7-2006 quote) times a factor of 5 for reinforcing steel, formwork, labor
Materials (Shoreline Veg.)		2	4000	$8,000			
Materials Other (pipeworks)		1	40000	$40,000			
Security/Safety							
Fencing, chain link, 4' tall	lin ft	834.8413	7.75	$6,470			2006 Means, 02820 140 0050
Gate and gate posts	each	4	820	$3,280			2006 Means, 02820 130 5010
Signs	each	8	500	$4,000			
Revegetation after construction		43.56	335	$14,593			2006 Means, 02920 400 0300 Sod <1000 S.F.; $445 / M.S.F. (thousand sq ft); >8 M.S.F $335/ M.S.F.
	Construction Sub Total			**$201,823**			
Construction Mgmt/Profit/Contingency		25%	0.25	$50,456			2006 Means, CM:01103 200 0050 7.5%, Profit: 01300 620 0300 25 - 30%: using sum of 30% for constructed cost < $150,000, else 25%.
Design/Permitting		15%	0.15	$30,273			Using 25% on constructed cost <= $150,000, else 15%.
Bonding/Insurance		5%	0.05	$10,091			Use 5%
CM,Profit,Design,Permiting,Contingency,Bonding Sub Total				**$90,820**			
			Total	**$292,643**			

Retention Pond (wet pond)

10 Surface Acre Pond, approximately 7 ft deep (1' of retained water, 4' of treatment, 2' of freeboard)

	Units	Number	Cost/Unit $	Cost	Area sq ft	Volume cubic ft	
Land: area/volume info	acre	10.000			435600	1742400	
Survey	acre	10.000	3275	$10,000			2006 Means, 01103 700 0100 Survey, Maximum $3,275/ac (use 1/2 acre as a minimum area), use $10,000 as maximum
Temporary Erosion Control		2640.0	0.8	$2,112			2006 Means, 02270 700 1000 Silt Fence $0.80 L.F. (use $2,000 min for 1 acre area or less)
Grubbing/Debris	acre	10.000	3300	$30,000			2006 Means, 02230 100 0020 Grubbing, $3300 per acre, use $30,000 maximum
Excavation (estimate 7 feet depth)							
Mob/Demob		4	300	$2,200			2006 Means, 02305 250 0100 Mob one piece of equipment one way $300, plus $1,000 general mob
Excavation, Dozer, 80 hp, 50' haul	C.Y.	112933	3.86	$435,923			2006 Means, 02315 432 2040 Excavation dozer, clay $3.86/B.C.Y.
Loading/Excavation, Front End Loader, 2 1/4 C.Y.	C.Y.	112933	1.19	$134,391			2006 Means, 02315 424 1600 Excavation $1.19/C.Y.
Haul, 20 C.Y. Dump Truck, 1 mi RT	C.Y.	56467	2.48	$140,037			2006 Means, 02315 490 1150 Haul half of soil excavated volume, use other half onsite. $2.48/C.Y. (use $1,000 min)
Compaction	C.Y.	56467	0.65	$36,703			2006 Means, 02315 315 5600 Compact the half of total soil excavated remaining on site grounds $0.65/C.Y. (use $1,000 min)
Materials Concrete (inflow bay, walls, outflow structure)		1	80000	$80,000			Use $100 per cu yd (Capitol Aggregates 7-2006 quote) times a factor of 5 for reinforcing steel, formwork, labor
Materials (Shoreline Veg.)		15	4000	$60,000			
Materials Other (pipeworks)		1	80000	$80,000			
Security/Safety							
Fencing, chain link, 4' tall	lin ft	2640	7.75	$20,460			2006 Means, 02820 140 0050
Gate and gate posts	each	4	820	$3,280			2006 Means, 02820 130 5010
Signs	each	12	500	$6,000			
Revegetation after construction		435.6	335	$145,926			2006 Means, 02920 400 0300 Sod <1000 S.F.; $445 / M.S.F. (thousand sq ft); >8 M.S.F $335/ M.S.F.
	Construction Sub Total			**$1,187,032**			
Construction Mgmt/Profit/Contingency		25%	0.25	$296,758			2006 Means, CM:01103 200 0050 7.5%, Profit: 01300 620 0300 25 - 30%: using sum of 30% for constructed cost < $150,000, else 25%.
Design/Permitting		15%	0.15	$178,055			Using 25% on constructed cost <= $150,000, else 15%.
Bonding/Insurance		5%	0.05	$59,352			Use 5%
CM,Profit,Design,Permiting,Contingency,Bonding Sub Total				**$534,164**			
			Total	**$1,721,196**			

Constructed Wetlands

1/2 Surface Acre Wetland, approximately 7 ft deep (1' of retained water, 4' of treatment, 2' of freeboard)

	Units	Number	Cost/Unit $	Cost	Area sq ft	Volume cubic ft	
Land: area/volume info	acre	0.500			21780	87120	
Survey	acre	0.500	3275	$1,638			2006 Means, 01103 700 0100 Survey, Maximum $3,275/ac (use 1/2 acre as a minimum area)
Temporary Erosion Control			1	$2,000			2006 Means, 02270 700 1000 Silt Fence $0.80 L.F. (use $2,000 min for 1 acre area or less)
Grubbing/Debris	acre	0.500	3300	$1,650			2006 Means, 02230 100 0020 Grubbing
Excavation (estimate 7 feet depth)							
Mob/Demob		4	300	$2,200			2006 Means, 02305 250 0100 Mob one piece of equipment one way $300, plus $1,000 general mob
Excavation, Dozer, 80 hp, 50' haul	C.Y.	5647	3.86	$21,796			2006 Means, 02315 432 2040 Excavation dozer, clay $3.86/B.C.Y.
Loading/Excavation, Front End Loader, 2 1/4 C.Y.	C.Y.	5647	1.19	$6,720			2006 Means, 02315 424 1600 Excavation $1.19/C.Y.
Haul, 20 C.Y. Dump Truck, 1 mi RT	C.Y.	2823	2.48	$7,002			2006 Means, 02315 490 1150 Haul half of soil excavated volume, use other half onsite. $2.48/C.Y. (use $1,000 min)
Compaction	C.Y.	2823	0.65	$1,835			2006 Means, 02315 315 5600 Compact the half of total soil excavated remaining on site grounds $0.65/C.Y. (use $1,000 min)
Materials Concrete (inflow bay, walls, outflow structure)		1	20000	$20,000			Use $100 per cu yd (Capitol Aggregates 7-2006 quote) times a factor of 5 for reinforcing steel, formwork, labor
Materials (Aquatic Veg)		1	15000	$15,000			
Materials Other (pipeworks)		1	20000	$20,000			
Security/Safety							
Fencing, chain link, 4' tall	lin ft	590.3219	7.75	$4,575			2006 Means, 02820 140 0050
Gate and gate posts	each	2	820	$1,640			2006 Means, 02820 130 5010
Signs	each	4	500	$2,000			
Revegetation after construction	M.S.F.	21.78	335	$7,296			2006 Means, 02920 400 0300 Sod <1000 S.F.; $445 / M.S.F. (thousand sq ft); >8 M.S.F $335/ M.S.F.
	Construction Sub Total			**$115,352**			
Construction Mgmt/Profit/Contingency		30%	0.30	$34,606			2006 Means, CM:01103 200 0050 7.5%, Profit: 01300 620 0300 25 - 30%: using sum of 30% for constructed cost < $150,000, else 25%.
Design/Permitting		25%	0.25	$28,838			Using 25% on constructed cost <= $150,000, else 15%.
Bonding/Insurance		5%	0.05	$5,768			Use 5%
CM,Profit,Design,Permiting,Contingency,Bonding Sub Total				**$69,211**			
			Total	**$184,563**			

Constructed Wetlands

1 Surface Acre Wetland, approximately 7 ft deep (1' of retained water, 4' of treatment, 2' of freeboard)

	Units	Number	Cost/Unit $	Cost	Area sq ft	Volume cubic ft	
Land: area/volume info	acre	1.000			43560	174240	
Survey	acre	1.000	3275	$3,275			2006 Means, 01103 700 0100 Survey, Maximum $3,275/ac (use 1/2 acre as a minimum area)
Temporary Erosion Control			1	$2,000			2006 Means, 02270 700 1000 Silt Fence $0.80 L.F. (use $2,000 min for 1 acre area or less)
Grubbing/Debris	acre	1.000	3300	$3,300			2006 Means, 02230 100 0020 Grubbing
Excavation (estimate 7 feet depth)							
Mob/Demob		4	300	$2,200			2006 Means, 02305 250 0100 Mob one piece of equipment one way $300, plus $1,000 general mob
Excavation, Dozer, 80 hp, 50' haul	C.Y.	11293	3.86	$43,592			2006 Means, 02315 432 2040 Excavation dozer, clay $3.86/B.C.Y.
Loading/Excavation, Front End Loader, 2 1/4 C.Y.	C.Y.	11293	1.19	$13,439			2006 Means, 02315 424 1600 Excavation $1.19/C.Y.
Haul, 20 C.Y. Dump Truck, 1 mi RT	C.Y.	5647	2.48	$14,004			2006 Means, 02315 490 1150 Haul half of soil excavated volume, use other half onsite. $2.48/C.Y. (use $1,000 min)
Compaction	C.Y.	5647	0.65	$3,670			2006 Means, 02315 315 5600 Compact the half of total soil excavated remaining on site grounds $0.65/C.Y. (use $1,000 min)
Materials Concrete (inflow bay, walls, outflow structure)		1	40000	$40,000			Use $100 per cu yd (Capitol Aggregates 7-2006 quote) times a factor of 5 for reinforcing steel, formwork, labor
Materials (Aquatic Veg)		2	15000	$30,000			
Materials Other (pipeworks)		1	40000	$40,000			
Security/Safety							
Fencing, chain link, 4' tall	lin ft	834.8413	7.75	$6,470			2006 Means, 02820 140 0050
Gate and gate posts	each	4	820	$3,280			2006 Means, 02820 130 5010
Signs	each	6	500	$3,000			
Revegetation after construction		43.56	335	$14,593			2006 Means, 02920 400 0300 Sod <1000 S.F.; $445 / M.S.F. (thousand sq ft); >8 M.S.F $335/ M.S.F.
	Construction Sub Total			**$222,823**			
Construction Mgmt/Profit/Contingency		25%	0.25	$55,706			2006 Means, CM:01103 200 0050 7.5%, Profit: 01300 620 0300 25 - 30%: using sum of 30% for constructed cost < $150,000, else 25%.
Design/Permitting		15%	0.15	$33,423			Using 25% on constructed cost <= $150,000, else 15%.
Bonding/Insurance		5%	0.05	$11,141			Use 5%
CM,Profit,Design,Permiting,Contingency,Bonding Sub Total				**$100,270**			
			Total	**$323,093**			

Constructed Wetlands

10 Surface Acre Wetland, approximately 7 ft deep (1' of retained water, 4' of treatment, 2' of freeboard)

	Units	Number	Cost/Unit $	Cost	Area sq ft	Volume cubic ft	
Land: area/volume info	acre	10.000			435600	1742400	
Survey	acre	10.000	3275	$10,000			2006 Means, 01103 700 0100 Survey, Maximum $3,275/ac (use 1/2 acre as a minimum area), use $10,000 as maximum
Temporary Erosion Control		2640.0	0.8	$2,112			2006 Means, 02270 700 1000 Silt Fence $0.80 L.F. (use $2,000 min for 1 acre area or less)
Grubbing/Debris	acre	10.000	3300	$30,000			2006 Means, 02230 100 0020 Grubbing, $3300 per acre, use $30,000 maximum
Excavation (estimate 7 feet depth)							
Mob/Demob		4	300	$2,200			2006 Means, 02305 250 0100 Mob one piece of equipment one way $300, plus $1,000 general mob
Excavation, Dozer, 80 hp, 50' haul	C.Y.	112933	3.86	$435,923			2006 Means, 02315 432 2040 Excavation dozer, clay $3.86/B.C.Y.
Loading/Excavation, Front End Loader, 2 1/4 C.Y.	C.Y.	112933	1.19	$134,391			2006 Means, 02315 424 1600 Excavation $1.19/C.Y.
Haul, 20 C.Y. Dump Truck, 1 mi RT	C.Y.	56467	2.48	$140,037			2006 Means, 02315 490 1150 Haul half of soil excavated volume, use other half onsite. $2.48/C.Y. (use $1,000 min)
Compaction	C.Y.	56467	0.65	$36,703			2006 Means, 02315 315 5600 Compact the half of total soil excavated remaining on site grounds $0.65/C.Y. (use $1,000 min)
Materials Concrete (inflow bay, walls, outflow structure)		1	80000	$80,000			Use $100 per cu yd (Capitol Aggregates 7-2006 quote) times a factor of 5 for reinforcing steel, formwork, labor
Materials (Aquatic Veg)		15	15000	$225,000			
Materials Other (pipeworks)		1	80000	$80,000			
Security/Safety							
Fencing, chain link, 4' tall	lin ft	2640	7.75	$20,460			2006 Means, 02820 140 0050
Gate and gate posts	each	4	820	$3,280			2006 Means, 02820 130 5010
Signs	each	12	500	$6,000			
Revegetation after construction		435.6	335	$145,926			2006 Means, 02920 400 0300 Sod <1000 S.F.; $445 / M.S.F. (thousand sq ft); >8 M.S.F $335/ M.S.F.
	Construction Sub Total			**$1,352,032**			
Construction Mgmt/Profit/Contingency		25%	0.25	$338,008			2006 Means, CM:01103 200 0050 7.5%, Profit: 01300 620 0300 25 - 30%: using sum of 30% for constructed cost < $150,000, else 25%.
Design/Permitting		15%	0.15	$202,805			Using 25% on constructed cost <= $150,000, else 15%.
Bonding/Insurance		5%	0.05	$67,602			Use 5%
CM,Profit,Design,Permiting,Contingency,Bonding Sub Total				**$608,414**			
			Total	**$1,960,446**			

Sand Filter
Austin Sand Filter

~20,000 cu ft System, approximately 5 ft deep

	Units	Number	Cost/Unit $	Cost	Area sq ft	Volume cubic ft	
Land: area/volume info	acre	0.092			4000	20000	
Survey	acre	0.092	3275	$1,638			2006 Means, 01103 700 0100 Survey, Maximum $3,275/ac (use 1/2 acre as a minimum area)
Temporary Erosion Control				$2,000			2006 Means, 02270 700 1000 Silt Fence (use $2,000 min for 1 acre area or less)
Grubbing/Debris	acre	0.092	3300	$303			2006 Means, 02230 100 0020 Grubbing
Excavation (estimate 7 feet depth with slab)							
Mob/Demob		4	300	$2,200			2006 Means, 02305 250 0100 Mob one piece of equipment one way $300, plus $1,000 general mob
Excavation, Dozer, 80 hp, 50' haul	C.Y.	741	3.86	$2,859			2006 Means, 02315 432 2040 Excavation dozer, clay $3.86/B.C.Y.
Loading/Excavation, Front End Loader, 2 1/4 C.Y.	C.Y.	741	1.19	$881			2006 Means, 02315 424 1600 Excavation $1.19/C.Y.
Haul, 20 C.Y. Dump Truck, 1 mi RT	C.Y.	370	2.48	$919			2006 Means, 02315 490 1150 Haul half of soil excavated volume, use other half onsite. $2.48/C.Y. (use $1,000 min)
Compaction	C.Y.	370	0.65	$241			2006 Means, 02315 315 5600 Compact the half of total soil excavated remaining on site grounds $0.65/C.Y. (use $1,000 min)
Materials Concrete (inflow bay, walls, outflow structure)		1	54605	$54,605			Use $100 per cu yd (Capitol Aggregates 7-2006 quote) times a factor of 5 for reinforcing steel, formwork, labor
Materials (Sand)	C.Y.	49	15	$741			Use 1/15 volume as sand
Materials Other (pipeworks)		1	5000	$5,000			
Security/Safety							
Fencing, chain link, 4' tall	lin ft	0	7.75	$0			2006 Means, 02820 140 0050
Gate and gate posts	each	0	820	$0			2006 Means, 02820 130 5010
Signs	each	4	500	$2,000			
Revegetation after construction		3	445	$1,335			2006 Means, 02920 400 0300 Sod <1000 S.F.; $445 / M.S.F. (thousand sq ft)
	Construction Sub Total			**$74,722**			
Construction Mgmt/Profit/Contingency		30%	0.30	$22,417			2006 Means, CM:01103 200 0050 7.5%, Profit: 01300 620 0300 25 - 30%: using sum of 30% for constructed cost < $150,000, else 25%.
Design/Permitting		25%	0.25	$18,681			Using 25% on constructed cost <= $150,000, else 15%.
Bonding/Insurance		5%	0.05	$3,736			Use 5%
CM,Profit,Design,Permiting,Contingency,Bonding Sub Total				**$44,833**			
Total				**$119,555**			

Sand Filter
Austin Sand Filter

~80,000 cu ft System, approximately 5 ft deep

	Units	Number	Cost/Unit $	Cost	Area sq ft	Volume cubic ft	
Land: area/volume info	acre	0.367			16000	80000	
Survey	acre	0.367	3275	$1,638			2006 Means, 01103 700 0100 Survey, Maximum $3,275/ac (use 1/2 acre as a minimum area)
Temporary Erosion Control				$2,000			2006 Means, 02270 700 1000 Silt Fence (use $2,000 min for 1 acre area or less)
Grubbing/Debris	acre	0.367	3300	$1,212			2006 Means, 02230 100 0020 Grubbing
Excavation (estimate 7 feet depth with slab)							
Mob/Demob		4	300	$2,200			2006 Means, 02305 250 0100 Mob one piece of equipment one way $300, plus $1,000 general mob
Excavation, Dozer, 80 hp, 50' haul	C.Y.	2963	3.86	$11,437			2006 Means, 02315 432 2040 Excavation dozer, clay $3.86/B.C.Y.
Loading/Excavation, Front End Loader, 2 1/4 C.Y.	C.Y.	2963	1.19	$3,526			2006 Means, 02315 424 1600 Excavation $1.19/C.Y.
Haul, 20 C.Y. Dump Truck, 1 mi RT	C.Y.	1481	2.48	$3,674			2006 Means, 02315 490 1150 Haul half of soil excavated volume, use other half onsite. $2.48/C.Y. (use $1,000 min)
Compaction	C.Y.	1481	0.65	$963			2006 Means, 02315 315 5600 Compact the half of total soil excavated remaining on site grounds $0.65/C.Y. (use $1,000 min)
Materials Concrete (inflow bay, walls, outflow structure)		1	183285	$183,285			Use $100 per cu yd (Capitol Aggregates 7-2006 quote) times a factor of 5 for reinforcing steel, formwork, labor
Materials (Sand)	C.Y.	198	15	$2,963			Use 1/15 volume as sand
Materials Other (pipeworks)		1	10000	$10,000			
Security/Safety							
Fencing, chain link, 4' tall	lin ft	0	7.75	$0			2006 Means, 02820 140 0050
Gate and gate posts	each	0	820	$0			2006 Means, 02820 130 5010
Signs	each	4	500	$2,000			
Revegetation after construction		16	445	$7,120			2006 Means, 02920 400 0300 Sod <1000 S.F.; $445 / M.S.F. (thousand sq ft)
	Construction Sub Total			**$232,018**			
Construction Mgmt/Profit/Contingency		25%	0.25	$58,004			2006 Means, CM:01103 200 0050 7.5%, Profit: 01300 620 0300 25 - 30%: using sum of 30% for constructed cost < $150,000, else 25%.
Design/Permitting		15%	0.15	$34,803			Using 25% on constructed cost <= $150,000, else 15%.
Bonding/Insurance		5%	0.05	$11,601			Use 5%
CM,Profit,Design,Permiting,Contingency,Bonding Sub Total				**$104,408**			
			Total	**$336,426**			

Sand Filter
Austin Sand Filter

~160,000 cu ft System, approximately 5 ft deep

	Units	Number	Cost/Unit $	Cost	Area sq ft	Volume cubic ft	
Land: area/volume info	acre	0.735			32000	160000	
Survey	acre	0.735	3275	$2,406			2006 Means, 01103 700 0100 Survey, Maximum $3,275/ac (use 1/2 acre as a minimum area)
Temporary Erosion Control				$2,000			2006 Means, 02270 700 1000 Silt Fence $0.80 L.F. (use $2,000 min for 1 acre area or less)
Grubbing/Debris	acre	0.735	3300	$2,424			2006 Means, 02230 100 0020 Grubbing
Excavation (estimate 7 feet depth with slab)							
Mob/Demob		4	300	$2,200			2006 Means, 02305 250 0100 Mob one piece of equipment one way $300, plus $1,000 general mob
Excavation, Dozer, 80 hp, 50' haul	C.Y.	5926	3.86	$22,874			2006 Means, 02315 432 2040 Excavation dozer, clay $3.86/B.C.Y.
Loading/Excavation, Front End Loader, 2 1/4 C.Y.	C.Y.	5926	1.19	$7,052			2006 Means, 02315 424 1600 Excavation $1.19/C.Y.
Haul, 20 C.Y. Dump Truck, 1 mi RT	C.Y.	2963	2.48	$7,348			2006 Means, 02315 490 1150 Haul half of soil excavated volume, use other half onsite. $2.48/C.Y. (use $1,000 min)
Compaction	C.Y.	2963	0.65	$1,926			2006 Means, 02315 315 5600 Compact the half of total soil excavated remaining on site grounds $0.65/C.Y. (use $1,000 min)
Materials Concrete (inflow bay, walls, outflow structure)		1	345987	$345,987			Use $100 per cu yd (Capitol Aggregates 7-2006 quote) times a factor of 5 for reinforcing steel, formwork, labor
Materials (Sand)	C.Y.	395	15	$5,926			Use 1/15 volume as sand
Materials Other (pipeworks)		1	20000	$20,000			
Security/Safety							
Fencing, chain link, 4' tall	lin ft	0	7.75	$0			2006 Means, 02820 140 0050
Gate and gate posts	each	0	820	$0			2006 Means, 02820 130 5010
Signs	each	4	500	$2,000			
Revegetation after construction		32	445	$14,240			2006 Means, 02920 400 0300 Sod <1000 S.F.; $445 / M.S.F. (thousand sq ft)
	Construction Sub Total			**$436,383**			
Construction Mgmt/Profit/Contingency		25%	0.25	$109,096			2006 Means, CM:01103 200 0050 7.5%, Profit: 01300 620 0300 25 - 30%: using sum of 30% for constructed cost < $150,000, else 25%.
Design/Permitting		15%	0.15	$65,457			Using 25% on constructed cost <= $150,000, else 15%.
Bonding/Insurance		5%	0.05	$21,819			Use 5%
CM,Profit,Design,Permiting,Contingency,Bonding Sub Total				**$196,372**			
			Total	**$632,755**			

Sand Filter
Washington DC Sand Filter

~20,000 cu ft System, approximately 6 ft deep

	Units	Number	Cost/Unit $	Cost	Area sq ft	Volume cubic ft	
Land: area/volume info	acre	0.077			3333.333	20000	
Survey	acre	0.077	3275	$1,638			2006 Means, 01103 700 0100 Survey, Maximum $3,275/ac (use 1/2 acre as a minimum area)
Temporary Erosion Control				$2,000			2006 Means, 02270 700 1000 Silt Fence (use $2,000 min for 1 acre area or less)
Grubbing/Debris	acre	0.077	3300	$253			2006 Means, 02230 100 0020 Grubbing
Excavation (estimate 7 feet depth with slab)							
Mob/Demob		4	300	$2,200			2006 Means, 02305 250 0100 Mob one piece of equipment one way $300, plus $1,000 general mob
Excavation, Dozer, 80 hp, 50' haul	C.Y.	741	3.86	$2,859			2006 Means, 02315 432 2040 Excavation dozer, clay $3.86/B.C.Y.
Loading/Excavation, Front End Loader, 2 1/4 C.Y.	C.Y.	741	1.19	$881			2006 Means, 02315 424 1600 Excavation $1.19/C.Y.
Haul, 20 C.Y. Dump Truck, 1 mi RT	C.Y.	370	2.48	$919			2006 Means, 02315 490 1150 Haul half of soil excavated volume, use other half onsite. $2.48/C.Y. (use $1,000 min)
Compaction	C.Y.	370	0.65	$241			2006 Means, 02315 315 5600 Compact the half of total soil excavated remaining on site grounds $0.65/C.Y. (use $1,000 min)
Materials Concrete (inflow bay, walls, outflow structure)		1	93319	$93,319			Use $100 per cu yd (Capitol Aggregates 7-2006 quote) times a factor of 5 for reinforcing steel, formwork, labor
Materials (Sand)	C.Y.	148	15	$2,222			Use 1/5 of volume as sand/aggregate
Materials Other (pipeworks)		1	5000	$5,000			
Security/Safety							
Fencing, chain link, 4' tall	lin ft	0	7.75	$0			2006 Means, 02820 140 0050
Gate and gate posts	each	0	820	$0			2006 Means, 02820 130 5010
Signs	each	0	500	$0			
Revegetation after construction		3.33	445	$1,483			2006 Means, 02920 400 0300 Sod <1000 S.F.; $445 / M.S.F. (thousand sq ft)
	Construction Sub Total			**$113,015**			
Construction Mgmt/Profit/Contingency		30%	0.30	$33,905			2006 Means, CM:01103 200 0050 7.5%, Profit: 01300 620 0300 25 - 30%: using sum of 30% for constructed cost < $150,000, else 25%.
Design/Permitting		25%	0.25	$28,254			Using 25% on constructed cost <= $150,000, else 15%.
Bonding/Insurance		5%	0.05	$5,651			Use 5%
CM,Profit,Design,Permiting,Contingency,Bonding Sub Total				**$67,809**			
			Total	**$180,824**			

Sand Filter
Washington DC Sand Filter

~80,000 cu ft System, approximately 6 ft deep

	Units	Number	Cost/Unit $	Cost	Area sq ft	Volume cubic ft	
Land: area/volume info	acre	0.306			13333.33	80000	
Survey	acre	0.306	3275	$1,638			2006 Means, 01103 700 0100 Survey, Maximum $3,275/ac (use 1/2 acre as a minimum area)
Temporary Erosion Control				$2,000			2006 Means, 02270 700 1000 Silt Fence (use $2,000 min for 1 acre area or less)
Grubbing/Debris	acre	0.306	3300	$1,010			2006 Means, 02230 100 0020 Grubbing
Excavation (estimate 7 feet depth with slab)							
Mob/Demob		4	300	$2,200			2006 Means, 02305 250 0100 Mob one piece of equipment one way $300, plus $1,000 general mob
Excavation, Dozer, 80 hp, 50' haul	C.Y.	2963	3.86	$11,437			2006 Means, 02315 432 2040 Excavation dozer, clay $3.86/B.C.Y.
Loading/Excavation, Front End Loader, 2 1/4 C.Y.	C.Y.	2963	1.19	$3,526			2006 Means, 02315 424 1600 Excavation $1.19/C.Y.
Haul, 20 C.Y. Dump Truck, 1 mi RT	C.Y.	1481	2.48	$3,674			2006 Means, 02315 490 1150 Haul half of soil excavated volume, use other half onsite. $2.48/C.Y. (use $1,000 min)
Compaction	C.Y.	1481	0.65	$963			2006 Means, 02315 315 5600 Compact the half of total soil excavated remaining on site grounds $0.65/C.Y. (use $1,000 min)
Materials Concrete (inflow bay, walls, outflow structure)		1	285404	$285,404			Use $100 per cu yd (Capitol Aggregates 7-2006 quote) times a factor of 5 for reinforcing steel, formwork, labor
Materials (Sand)	C.Y.	593	15	$8,889			Use 1/5 of volume as sand/aggregate
Materials Other (pipeworks)		1	10000	$10,000			
Security/Safety							
Fencing, chain link, 4' tall	lin ft	0	7.75	$0			2006 Means, 02820 140 0050
Gate and gate posts	each	0	820	$0			2006 Means, 02820 130 5010
Signs	each	4	500	$2,000			
Revegetation after construction		13.33	445	$5,933			2006 Means, 02920 400 0300 Sod <1000 S.F.; $445 / M.S.F. (thousand sq ft)
	Construction Sub Total			**$338,674**			
Construction Mgmt/Profit/Contingency		25%	0.25	$84,668			2006 Means, CM:01103 200 0050 7.5%, Profit: 01300 620 0300 25 - 30%: using sum of 30% for constructed cost < $150,000, else 25%.
Design/Permitting		15%	0.15	$50,801			Using 25% on constructed cost <= $150,000, else 15%.
Bonding/Insurance		5%	0.05	$16,934			Use 5%
CM,Profit,Design,Permiting,Contingency,Bonding Sub Total				**$152,403**			
			Total	**$491,077**			

Sand Filter
Washington DC Sand Filter

~160,000 cu ft System, approximately 6 ft deep

	Units	Number	Cost/Unit $	Cost	Area sq ft	Volume cubic ft	
Land: area/volume info	acre	0.612			26666.67	160000	
Survey	acre	0.612	3275	$2,005			2006 Means, 01103 700 0100 Survey, Maximum $3,275/ac (use 1/2 acre as a minimum area)
Temporary Erosion Control				$2,000			2006 Means, 02270 700 1000 Silt Fence (use $2,000 min for 1 acre area or less)
Grubbing/Debris	acre	0.612	3300	$2,020			2006 Means, 02230 100 0020 Grubbing
Excavation (estimate 7 feet depth with slab)							
Mob/Demob		4	300	$2,200			2006 Means, 02305 250 0100 Mob one piece of equipment one way $300, plus $1,000 general mob
Excavation, Dozer, 80 hp, 50' haul	C.Y.	5926	3.86	$22,874			2006 Means, 02315 432 2040 Excavation dozer, clay $3.86/B.C.Y.
Loading/Excavation, Front End Loader, 2 1/4 C.Y.	C.Y.	5926	1.19	$7,052			2006 Means, 02315 424 1600 Excavation $1.19/C.Y.
Haul, 20 C.Y. Dump Truck, 1 mi RT	C.Y.	2963	2.48	$7,348			2006 Means, 02315 490 1150 Haul half of soil excavated volume, use other half onsite. $2.48/C.Y. (use $1,000 min)
Compaction	C.Y.	2963	0.65	$1,926			2006 Means, 02315 315 5600 Compact the half of total soil excavated remaining on site grounds $0.65/C.Y. (use $1,000 min)
Materials Concrete (inflow bay, walls, outflow structure)		1	548260	$548,260			Use $100 per cu yd (Capitol Aggregates 7-2006 quote) times a factor of 5 for reinforcing steel, formwork, labor
Materials (Sand)	C.Y.	1185	15	$17,778			Use 1/5 of volume as sand/aggregate
Materials Other (pipeworks)		1	20000	$20,000			
Security/Safety							
Fencing, chain link, 4' tall	lin ft	0	7.75	$0			2006 Means, 02820 140 0050
Gate and gate posts	each	0	820	$0			2006 Means, 02820 130 5010
Signs	each	4	500	$2,000			
Revegetation after construction		26.67	445	$11,867			2006 Means, 02920 400 0300 Sod <1000 S.F.; $445 / M.S.F. (thousand sq ft)
	Construction Sub Total			**$647,330**			
Constr Construction Mgmt/Profit/Contingency			0.30	$0	$0		2006 Means, CM:01103 200 0050 7.5%, Profit: 01300 620 0300 25 - 30%: using sum of 30% for constructed cost < $150,000, else 25%.
Design/Permitting		15%	0.15	$97,099			Using 25% on constructed cost <= $150,000, else 15%.
Bonding/Insurance		5%	0.05	$32,366			Use 5%
CM,Profit,Design,Permiting,Contingency,Bonding Sub Total				**$129,466**			
			Total	**$776,796**			

Infiltration Trench

3,400 sq ft Surface Area System, approximately 4 ft deep

	Units	Number	Cost/Unit $	Cost	Area sq ft	Volume cubic ft	
Land: area/volume info	acre	0.078			3400	4760	Treatment volume due to void space of gravel (35%)
						13600	Actual volume for excavation and materials
Survey	acre	0.078	3275	$1,638			2006 Means, 01103 700 0100 Survey, Maximum $3,275/ac (use 1/2 acre as a minimum area)
Temporary Erosion Control				$2,000			2006 Means, 02270 700 1000 Silt Fence (use $2,000 min for 1 acre area or less)
Grubbing/Debris	acre	0.078	3300	$258			2006 Means, 02230 100 0020 Grubbing
Excavation (4 feet depth)							
Mob/Demob		4	300	$2,200			2006 Means, 02305 250 0100 Mob one piece of equipment one way $300, plus $1,000 general mob
Excavation, Dozer, 80 hp, 50' haul	C.Y.	504	3.86	$1,944			2006 Means, 02315 432 2040 Excavation dozer, clay $3.86/B.C.Y.
Loading/Excavation, Front End Loader, 2 1/4 C.Y.	C.Y.	504	1.19	$599			2006 Means, 02315 424 1600 Excavation $1.19/C.Y.
Haul, 20 C.Y. Dump Truck, 1 mi RT	C.Y.	252	2.48	$625			2006 Means, 02315 490 1150 Haul half of soil excavated volume, use other half onsite. $2.48/C.Y. (use $1,000 min)
Compaction	C.Y.	252	0.65	$164			2006 Means, 02315 315 5600 Compact the half of total soil excavated remaining on site grounds $0.65/C.Y. (use $1,000 min)
Materials Concrete (inflow bay, walls, outflow structure)		1	4000	$4,000			Use $100 per cu yd (Capitol Aggregates 7-2006 quote) times a factor of 5 for reinforcing steel, formwork, labor
Materials (Gravel)	C.Y.	504	15	$7,556			
Materials Other (pipeworks)		1	10000	$10,000			
Security/Safety							
Fencing, chain link, 4' tall	lin ft	0	7.75	$0			2006 Means, 02820 140 0050
Gate and gate posts	each	0	820	$0			2006 Means, 02820 130 5010
Signs	each	4	500	$2,000			
Revegetation after construction		3.4	445	$1,513			2006 Means, 02920 400 0300 Sod <1000 S.F.; $445 / M.S.F. (thousand sq ft)
	Construction Sub Total			**$34,496**			
Construction Mgmt/Profit/Contingency		30%	0.30	$10,349			2006 Means, CM:01103 200 0050 7.5%, Profit: 01300 620 0300 25 - 30%: using sum of 30% for constructed cost < $150,000, else 25%.
Design/Permitting		25%	0.25	$8,624			Using 25% on constructed cost <= $150,000, else 15%.
Bonding/Insurance		5%	0.05	$1,725			Use 5%
CM,Profit,Design,Permiting,Contingency,Bonding Sub Total				**$20,698**			
			Total	**$55,194**			

Infiltration Trench

13,400 sq ft Surface Area System, approximately 4 ft deep

	Units	Number	Cost/Unit $	Cost	Area sq ft	Volume cubic ft	
Land: area/volume info	acre	0.308			13400	18760	Treatment volume due to void space of gravel (35%)
						53600	Actual volume for excavation and materials
Survey	acre	0.308	3275	$1,638			2006 Means, 01103 700 0100 Survey, Maximum $3,275/ac (use 1/2 acre as a minimum area)
Temporary Erosion Control				$2,000			2006 Means, 02270 700 1000 Silt Fence (use $2,000 min for 1 acre area or less)
Grubbing/Debris	acre	0.308	3300	$1,015			2006 Means, 02230 100 0020 Grubbing
Excavation (4 feet depth)							
Mob/Demob		4	300	$2,200			2006 Means, 02305 250 0100 Mob one piece of equipment one way $300, plus $1,000 general mob
Excavation, Dozer, 80 hp, 50' haul	C.Y.	1985	3.86	$7,663			2006 Means, 02315 432 2040 Excavation dozer, clay $3.86/B.C.Y.
Loading/Excavation, Front End Loader, 2 1/4 C.Y.	C.Y.	1985	1.19	$2,362			2006 Means, 02315 424 1600 Excavation $1.19/C.Y.
Haul, 20 C.Y. Dump Truck, 1 mi RT	C.Y.	993	2.48	$2,462			2006 Means, 02315 490 1150 Haul half of soil excavated volume, use other half onsite. $2.48/C.Y. (use $1,000 min)
Compaction	C.Y.	993	0.65	$645			2006 Means, 02315 315 5600 Compact the half of total soil excavated remaining on site grounds $0.65/C.Y. (use $1,000 min)
Materials Concrete (inflow bay, walls, outflow structure)		1	10000	$10,000			Use $100 per cu yd (Capitol Aggregates 7-2006 quote) times a factor of 5 for reinforcing steel, formwork, labor
Materials (Gravel)	C.Y.	1985	15	$29,778			
Materials Other (pipeworks)		1	25000	$25,000			
Security/Safety							
Fencing, chain link, 4' tall	lin ft	0	7.75	$0			2006 Means, 02820 140 0050
Gate and gate posts	each	0	820	$0			2006 Means, 02820 130 5010
Signs	each	4	500	$2,000			
Revegetation after construction		13.4	445	$5,963			2006 Means, 02920 400 0300 Sod <1000 S.F.; $445 / M.S.F. (thousand sq ft)
	Construction Sub Total			**$92,726**			
Construction Mgmt/Profit/Contingency		30%	0.30	$27,818			2006 Means, CM:01103 200 0050 7.5%, Profit: 01300 620 0300 25 - 30%: using sum of 30% for constructed cost < $150,000, else 25%.
Design/Permitting		25%	0.25	$23,181			Using 25% on constructed cost <= $150,000, else 15%.
Bonding/Insurance		5%	0.05	$4,636			Use 5%
CM,Profit,Design,Permiting,Contingency,Bonding Sub Total				**$55,636**			
			Total	**$148,361**			

Infiltration Trench

26,700 sq ft Surface Area System, approximately 4 ft deep

	Units	Number	Cost/Unit $	Cost	Area sq ft	Volume cubic ft	
Land: area/volume info	acre	0.613			26700	37380	Treatment volume due to void space of gravel (35%)
						106800	Actual volume for excavation and materials
Survey	acre	0.613	3275	$2,007			2006 Means, 01103 700 0100 Survey, Maximum $3,275/ac (use 1/2 acre as a minimum area)
Temporary Erosion Control				$2,000			2006 Means, 02270 700 1000 Silt Fence (use $2,000 min for 1 acre area or less)
Grubbing/Debris	acre	0.613	3300	$2,023			2006 Means, 02230 100 0020 Grubbing
Excavation (4 feet depth)							
Mob/Demob		4	300	$2,200			2006 Means, 02305 250 0100 Mob one piece of equipment one way $300, plus $1,000 general mob
Excavation, Dozer, 80 hp, 50' haul	C.Y.	3956	3.86	$15,268			2006 Means, 02315 432 2040 Excavation dozer, clay $3.86/B.C.Y.
Loading/Excavation, Front End Loader, 2 1/4 C.Y.	C.Y.	3956	1.19	$4,707			2006 Means, 02315 424 1600 Excavation $1.19/C.Y.
Haul, 20 C.Y. Dump Truck, 1 mi RT	C.Y.	1978	2.48	$4,905			2006 Means, 02315 490 1150 Haul half of soil excavated volume, use other half onsite. $2.48/C.Y. (use $1,000 min)
Compaction	C.Y.	1978	0.65	$1,286			2006 Means, 02315 315 5600 Compact the half of total soil excavated remaining on site grounds $0.65/C.Y. (use $1,000 min)
Materials Concrete (inflow bay, walls, outflow structure)		1	20000	$20,000			Use $100 per cu yd (Capitol Aggregates 7-2006 quote) times a factor of 5 for reinforcing steel, formwork, labor
Materials (Gravel)	C.Y.	3956	15	$59,333			
Materials Other (pipeworks)		1	40000	$40,000			
Security/Safety							
Fencing, chain link, 4' tall	lin ft	0	7.75	$0			2006 Means, 02820 140 0050
Gate and gate posts	each	0	820	$0			2006 Means, 02820 130 5010
Signs	each	4	500	$2,000			
Revegetation after construction		26.7	445	$11,882			2006 Means, 02920 400 0300 Sod <1000 S.F.; $445 / M.S.F. (thousand sq ft)
	Construction Sub Total			**$167,611**			
Construction Mgmt/Profit/Contingency		25%	0.25	$41,903			2006 Means, CM:01103 200 0050 7.5%, Profit: 01300 620 0300 25 - 30%: using sum of 30% for constructed cost < $150,000, else 25%.
Design/Permitting		15%	0.15	$25,142			Using 25% on constructed cost <= $150,000, else 15%.
Bonding/Insurance		5%	0.05	$8,381			Use 5%
CM,Profit,Design,Permiting,Contingency,Bonding Sub Total				**$75,425**			
			Total	**$243,036**			

Bioretention System

1/4 Acre Surface Area System, approximately 2 ft deep

	Units	Number	Cost/Unit $	Cost	Area sq ft	Volume cubic ft	
Land: area/volume info	acre	0.250			10900	21800	
Survey	acre	0.250	3275	$1,638			2006 Means, 01103 700 0100 Survey, Maximum $3,275/ac (use 1/2 acre as a minimum area)
Temporary Erosion Control				$2,000			2006 Means, 02270 700 1000 Silt Fence (use $2,000 min for 1 acre area or less)
Grubbing/Debris	acre	0.250	3300	$826			2006 Means, 02230 100 0020 Grubbing
Excavation (2 feet depth)							
Mob/Demob		4	300	$2,200			2006 Means, 02305 250 0100 Mob one piece of equipment one way $300, plus $1,000 general mob
Excavation, Dozer, 80 hp, 50' haul	C.Y.	807	3.86	$3,117			2006 Means, 02315 432 2040 Excavation dozer, clay $3.86/B.C.Y.
Loading/Excavation, Front End Loader, 2 1/4 C.Y.	C.Y.	807	1.19	$961			2006 Means, 02315 424 1600 Excavation $1.19/C.Y.
Haul, 20 C.Y. Dump Truck, 1 mi RT	C.Y.	404	2.48	$1,001			2006 Means, 02315 490 1150 Haul half of soil excavated volume, use other half onsite. $2.48/C.Y. (use $1,000 min)
Compaction	C.Y.	404	0.65	$262			2006 Means, 02315 315 5600 Compact the half of total soil excavated remaining on site grounds $0.65/C.Y. (use $1,000 min)
Materials Concrete (inflow bay, walls, outflow structure)		1	2000	$2,000			Use $100 per cu yd (Capitol Aggregates 7-2006 quote) times a factor of 5 for reinforcing steel, formwork, labor
Materials (Mulch/Sand)	C.Y.	807	15	$12,111			Use 1/2 volume as sand, 1/2 volume as mulch
Materials Other (pipeworks)		1	2000	$2,000			
Security/Safety							
Fencing, chain link, 4' tall	lin ft	0	7.75	$0			2006 Means, 02820 140 0050
Gate and gate posts	each	0	820	$0			2006 Means, 02820 130 5010
Signs	each	4	500	$2,000			
Revegetation after construction		3	445	$1,335			2006 Means, 02920 400 0300 Sod <1000 S.F.; $445 / M.S.F. (thousand sq ft)
	Construction Sub Total			**$31,451**			
Construction Mgmt/Profit/Contingency		30%	0.30	$9,435			2006 Means, CM:01103 200 0050 7.5%, Profit: 01300 620 0300 25 - 30%: using sum of 30% for constructed cost < $150,000, else 25%.
Design/Permitting		25%	0.25	$7,863			Using 25% on constructed cost <= $150,000, else 15%.
Bonding/Insurance		5%	0.05	$1,573			Use 5%
CM,Profit,Design,Permiting,Contingency,Bonding Sub Total				**$18,871**			
			Total	**$50,321**			

Bioretention System

0.9 Acre Surface Area System, approximately 2 ft deep

	Units	Number	Cost/Unit $	Cost	Area sq ft	Volume cubic ft	
Land: area/volume info	acre	0.900			39200	78400	
Survey	acre	0.900	3275	$2,947			2006 Means, 01103 700 0100 Survey, Maximum $3,275/ac (use 1/2 acre as a minimum area)
Temporary Erosion Control				$2,000			2006 Means, 02270 700 1000 Silt Fence (use $2,000 min for 1 acre area or less)
Grubbing/Debris	acre	0.900	3300	$2,970			2006 Means, 02230 100 0020 Grubbing
Excavation (2 feet depth)							
Mob/Demob		4	300	$2,200			2006 Means, 02305 250 0100 Mob one piece of equipment one way $300, plus $1,000 general mob
Excavation, Dozer, 80 hp, 50' haul	C.Y.	2904	3.86	$11,208			2006 Means, 02315 432 2040 Excavation dozer, clay $3.86/B.C.Y.
Loading/Excavation, Front End Loader, 2 1/4 C.Y.	C.Y.	2904	1.19	$3,455			2006 Means, 02315 424 1600 Excavation $1.19/C.Y.
Haul, 20 C.Y. Dump Truck, 1 mi RT	C.Y.	1452	2.48	$3,601			2006 Means, 02315 490 1150 Haul half of soil excavated volume, use other half onsite. $2.48/C.Y. (use $1,000 min)
Compaction	C.Y.	1452	0.65	$944			2006 Means, 02315 315 5600 Compact the half of total soil excavated remaining on site grounds $0.65/C.Y. (use $1,000 min)
Materials Concrete (inflow bay, walls, outflow structure)		1	6000	$6,000			Use $100 per cu yd (Capitol Aggregates 7-2006 quote) times a factor of 5 for reinforcing steel, formwork, labor
Materials (Mulch/Sand)	C.Y.	2904	15	$43,556			Use 1/2 volume as sand, 1/2 volume as mulch
Materials Other (pipeworks)		1	6000	$6,000			
Security/Safety							
Fencing, chain link, 4' tall	lin ft	0	7.75	$0			2006 Means, 02820 140 0050
Gate and gate posts	each	0	820	$0			2006 Means, 02820 130 5010
Signs	each	4	500	$2,000			
Revegetation after construction		39.2	445	$17,444			2006 Means, 02920 400 0300 Sod <1000 S.F.; $445 / M.S.F. (thousand sq ft)
	Construction Sub Total			**$104,324**			
Construction Mgmt/Profit/Contingency		30%	0.30	$31,297			2006 Means, CM:01103 200 0050 7.5%, Profit: 01300 620 0300 25 - 30%: using sum of 30% for constructed cost < $150,000, else 25%.
Design/Permitting		25%	0.25	$26,081			Using 25% on constructed cost <= $150,000, else 15%.
Bonding/Insurance		5%	0.05	$5,216			Use 5%
CM,Profit,Design,Permiting,Contingency,Bonding Sub Total				**$62,595**			
			Total	**$166,919**			

Bioretention System

1.8 Acre Surface Area System, approximately 2 ft deep

	Units	Number	Cost/Unit $	Cost	Area sq ft	Volume cubic ft	
Land: area/volume info	acre	1.800			78400	156800	
Survey	acre	1.800	3275	$5,894			2006 Means, 01103 700 0100 Survey, Maximum $3,275/ac (use 1/2 acre as a minimum area)
Temporary Erosion Control				$2,000			2006 Means, 02270 700 1000 Silt Fence $0.80 L.F. (use $2,000 min for 1 acre area or less)
Grubbing/Debris	acre	1.800	3300	$5,939			2006 Means, 02230 100 0020 Grubbing
Excavation (2 feet depth)							
Mob/Demob		4	300	$2,200			2006 Means, 02305 250 0100 Mob one piece of equipment one way $300, plus $1,000 general mob
Excavation, Dozer, 80 hp, 50' haul	C.Y.	5807	3.86	$22,417			2006 Means, 02315 432 2040 Excavation dozer, clay $3.86/B.C.Y.
Loading/Excavation, Front End Loader, 2 1/4 C.Y.	C.Y.	5807	1.19	$6,911			2006 Means, 02315 424 1600 Excavation $1.19/C.Y.
Haul, 20 C.Y. Dump Truck, 1 mi RT	C.Y.	2904	2.48	$7,201			2006 Means, 02315 490 1150 Haul half of soil excavated volume, use other half onsite. $2.48/C.Y. (use $1,000 min)
Compaction	C.Y.	2904	0.65	$1,887			2006 Means, 02315 315 5600 Compact the half of total soil excavated remaining on site grounds $0.65/C.Y. (use $1,000 min)
Materials Concrete (inflow bay, walls, outflow structure)		1	12000	$12,000			Use $100 per cu yd (Capitol Aggregates 7-2006 quote) times a factor of 5 for reinforcing steel, formwork, labor
Materials (Mulch/Sand)	C.Y.	5807	15	$87,111			Use 1/2 volume as sand, 1/2 volume as mulch
Materials Other (pipeworks)		1	12000	$12,000			
Security/Safety							
Fencing, chain link, 4' tall	lin ft	0	7.75	$0			2006 Means, 02820 140 0050
Gate and gate posts	each	0	820	$0			2006 Means, 02820 130 5010
Signs	each	4	500	$2,000			
Revegetation after construction		78.4	445	$34,888			2006 Means, 02920 400 0300 Sod <1000 S.F.; $445 / M.S.F. (thousand sq ft)
	Construction Sub Total			**$202,449**			
Construction Mgmt/Profit/Contingency		25%	0.25	$50,612			2006 Means, CM:01103 200 0050 7.5%, Profit: 01300 620 0300 25 - 30%: using sum of 30% for constructed cost < $150,000, else 25%.
Design/Permitting		15%	0.15	$30,367			Using 25% on constructed cost <= $150,000, else 15%.
Bonding/Insurance		5%	0.05	$10,122			Use 5%
			CM,Profit,Design,Permiting,Contingency,Bonding Sub Total	**$91,102**			
			Total	**$293,551**			

APPENDIX G: Meetings

Meetings where WPP was discussed, ordered by date:

Date	Description
5/16/2005 5/27/2005	A presentation outlining the WPP was made to the Committee of Seven (a member of the multi-governmental effort known as the Bexar Regional Watershed Management program (BRWM)), and later to the Water Quality Focus Group of the BRWM.
7/29/2005 8/26/2005	The Bexar Regional Watershed Management program (BRWM) Water Quality Focus Group met to discuss the WPP.
6/29/2005	The WPP was presented to the BRWM Watershed Improvement and Advisory Committee (WIAC).
6/27/2005 8/29/2005	The WPP was discussed during the SARA managers meetings.
7/12/2005	WPP was discussed during the SARA Exec meeting.
8/30/2005 9/28/2005 10/28/2005	The Bexar Regional Watershed Management program (BRWM) Water Quality Focus Group met to discuss the WPP.
9/15/2005 10/6/2005 11/15/2005	The WPP was discussed during the SARA Watershed Management meetings. – No agenda
9/2/2005	The WPP was discussed during the SARA managers meeting. – No agenda
10/17/2005	The WPP was presented to the BRWM Watershed Improvement and Advisory Committee (WIAC).
10/26/2005	The WPP was presented to the Committee of Seven.
10/27/2005	The WPP was discussed at a Bexar County Law & Environmental Enforcement Network (BCLEEN) meeting. – No agenda
11/29/2005	The first of three public meetings was held in the SARA board room.
2/28/2006	The public notice for the second of three WPP public meetings was posted. – Notice available.
12/30/2005 1/27/2006 2/24/2006	The Bexar Regional Watershed Management program (BRWM) Water Quality Focus Group met to discuss the WPP. – Agendas available, but no Power Point presentations.
2/15/2006	The WPP was presented to the BRWM Watershed Improvement and Advisory Committee (WIAC). – Agenda and Power Point presentation available.
1/30/2006 2/27/2006	The WPP was discussed during the SARA managers meetings. – No agendas or Power Point presentations.
1/23/2006	The WPP was presented to the San Antonio Parks & Recreation Board. - Power Point presentation available, but no agenda.

Date	Description
12/13/2005 2/21/2006	The WPP was presented to the Committee of Seven. – Agendas and Power Point presentations available.
12/12/2005 2/13/2006	The WPP was presented to the River Oversight Committee. – Agendas and Power Point presentations available.
3/9/2006	WPP was presented to the Watershed Coordination Steering Committee of the Texas State Soil and Water Conservation Board (TSSWCB). - Agenda and presentation available.
3/29/2006	The second of three public meetings was held in the SARA board room. - Agenda and presentations available.
3/31/2006	The Bexar Regional Watershed Management program (BRWM) Water Quality Focus Group met to discuss the WPP. – Agendas available, but no Power Point presentations.
4/12/2006	A presentation was made to at the 2006 Water Quality Monitoring & Assessment Seminar in Bandera, Texas. The WPP was a component of the presentation titled "A History of Water Quality in the Upper San Antonio River/Plans for Restoration". - Agenda available.
4/25/2006	The WPP was presented to the Committee of Seven. - Agendas and Power Point presentations available.
5/26/2006	The Bexar Regional Watershed Management program (BRWM) Water Quality Focus Group met to discuss the WPP. – Agendas available, but no Power Point presentations.
6/6/2006	A WPP presentation was made at the Bexar Regional Watershed Management (BRWM) Public Management Committee meeting. – Agenda and presentation available.
6/13/2003	The Texas State Soil & Water Conservation Board (TSSWCB) held a meeting of their Watershed Coordination Steering Committee where an update of the Upper San Antonio River WPP was presented. – No agenda or presentation.
7/13/2006	A presentation of the WPP was made at the Bexar County Commissioners Court meeting. – Presentation available, but no agenda.
6/24/2006	The third of three public meetings was held in the SARA board room. - Agenda and presentations available.
7/26/2006	A radio interview conducted at KZEP, which addressed water quality in the San Antonio River. The Upper San Antonio River Watershed Protection Plan was discussed. – No agenda or presentation available.
7/28/2006	The Bexar Regional Watershed Management (BRWM) Water Quality Focus Group met to discuss the WPP. - Agenda is available, but no presentation.

Date	Description
8/7/2006	A presentation was made on the draft WPP to the SARA Operations Committee (Sub-group of the board of directors). – Agenda and presentation available.
8/8/2006	A presentation was made to the BRWM Committee of Seven, which summarized the draft WPP. – Agenda and presentation available.
8/9/2006	A presentation was made to the BRWM Watershed Improvement Advisory Committee (WIAC), which summarized the draft WPP. – Agenda and presentation available.
8/14/2006	A briefing on the draft WPP was made to the San Antonio River Oversight Committee (SAROC). – Agenda and presentation available.
8/25/2006	A special meeting of the BRWM Water Quality Focus Group was held to discuss the draft WPP and the comments from TCEQ, San Antonio Water System, Edwards Aquifer Authority, City of San Antonio, and SARA. - Agenda available, but no presentation.

Upper San Antonio River
Watershed Protection Plan