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HYDRODYNAMIC SEPARATORS AS STORMWATER BEST MANAGEMENT PRACTICES

Final Report

Prepared For:

Utah Department of Transportation Research and Development Division

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NOTICE

UDOT RESEARCH & DEVELOPMENT REPORT ABSTRACT

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16. Abstract

The use of hydrodynamic separators in the treatment of stormwater runoff for UDOT basins was evaluated. This evaluation included: 1) identifying potential stormwater pollutants of concern in transportation corridors, 2) identifying documented stormwater pollutant load estimation methods, 3) prepare a listing of available proprietary treatment BMPs, 4) develop a selection methodology for water quality BMPs, 5) prepare technical specifications for hydrodynamic separators. This project reviewed published literature and existing UDOT resources.

Stormwater discharges contain constituents that can be characterized by land use activities and are largely dependent on climate patterns. Typical potential pollutants of concern for transportation use drainage basins consist of: sediment, floatables, metals and petroleum hydrocarbons. Specific land use analysis and evaluation of potential pollutants of concern is required prior to the selection and design of treatment BMPs. Total suspended solids (TSS) may be a target constituent of treatment BMPs, based on Salt Lake County's EMC measurements; the average concentration of TSS in urban stormwater in Salt Lake County is 116 mg/l whereas oil and grease concentrations are typically in the range of 5 – 10 mg/l. Hydrodynamic separators cannot treat oil and grease in stormwater runoff to lower levels.

Methods to estimate or predict pollutant loads are documented and recognized by many federal and state agencies. USGS and EPA both recognize quantitative analysis methods to estimate pollutant loads to receiving waters conveyed by stormwater runoff. Prediction of pollutant loads may be conducted to assist with the selection, operation and maintenance of stormwater treatment BMP's. These methods are highly sensitive to land use, percent impervious areas and precipitation events, and therefore produce a wide range of potential loading numbers.

To remove sediment from stormwater discharges, hydrodynamic separators may be designed to treat small storm events or the first flush produced during larger storm events. A design water quality storm event of 0.5 inches of rainfall has been identified as design criteria to size the hydrodynamic separator. Other design criteria include sediment storage capacity of the device, head loss, sediment particle size and overall efficiency of the treatment measure. Flows exceeding the design event will need to be routed around, or bypass the treatment device.

Specifications for hydrodynamic separators were developed for use by UDOT design engineers.

In conclusion, oil water/hydrodynamic separators are not recommended for use in removing oil and grease in typical urban stormwater runoff. These systems may be considered for use in spill containment, removal of oil and grease from high-risk areas, or to assist with the removal of sediments in stormwater.

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EXECUTIVE SUMMARY

The purpose of this UDOT Hydrodynamic Separator study is to work with the UDOT Technical Advisory Committee (TAC) to prepare a selection methodology and performance-based specification for hydrodynamic separators and oil-water separators as a structural control measure for stormwater treatment. These Best Management Practices (BMPs) are considered for implementation to meet water quality requirements of the UDOT Phase 1 Municipal UPDES Permit conditions (UTRS000003, Control Measure 5, post-construction water quality controls) and Utah Division of Water Quality Construction Permit requirements (R317-1-2).

The study investigated the following elements for the design and implementation of water quality BMP's:

- Identify the stormwater pollutants of concern
- Identify documented stormwater pollutant load estimation methods
- Review published literature and existing UDOT resources
- Prepare a listing of the proprietary treatment BMPSs
- Prepare a selection methodology for water quality BMPs
- Prepare technical specifications for hydrodynamic separators

These elements are documented in this final report, along with specific references and reports utilized by the TAC. Meeting agenda and minutes are included for reference.

In summary, stormwater discharges contain pollutants that can be characterized by land use activities and are largely dependent on climate patterns. Typical pollutants of concern for transportation use drainage basins consist of: sediment, floatables, metals, pesticides and herbicides and petroleum hydrocarbons. Specific land use analysis and evaluation of potential pollutants of concern is required prior to the design of treatment BMPs. Total suspended solids may be a target constituent of treatment BMPs, as the average concentration in urban stormwater is 116 mg/l, based on monitoring data by Salt Lake County, Salt Lake City and UDOT. The same data indicates that oil and grease concentrations in stormwater flows to be typically in the range of 5 – 10 mg/l. Hydrodynamic separators cannot treat oil and grease in stormwater runoff to lower levels.

Methods to estimate or predict storm event and annual pollutant loads are documented and recognized by many federal and state agencies. USGS and EPA both recognize quantitative analysis methods to estimate pollutant loads to receiving waters conveyed by stormwater runoff. Prediction of annual or storm event pollutant loads may be conducted to assist with the selection, operation and maintenance of stormwater treatment BMP's. These methods are highly sensitive to land use, percent impervious and precipitation events, and therefore produce a wide range of potential loading numbers.

To remove sediment from stormwater discharges, hydrodynamic separators may be installed to treat small storm events or the first flush produced during larger storm events. A

design water quality storm event of 0.5 inches of rainfall has been identified as design criteria to size the hydrodynamic separator. Other design criteria include sediment storage capacity of the device, head loss, sediment particle size and overall efficiency of the treatment measure. Flows exceeding the design event will need to be routed around, or bypass the treatment device.

In conclusion, hydrodynamic separators are not recommended for use in removing oil and grease in typical urban stormwater runoff. These systems may be considered for use as spill containment, removal of oil and grease from high-risk areas, or to assist with the removal of sediments.

1. Stormwater Pollutants of Concern and Seasonal Variation

1.1 Purpose

The purpose of this chapter is to identify typical pollutants and average concentrations in typical urban stormwater runoff with the intent to identify target pollutants for the Utah Department of Transportation (UDOT) to use in selecting appropriate Best Management Practices (BMPs). In addition, seasonal variation in stormwater quality is addressed. This document fulfills the requirements set in Task 1 of the UDOT Hydrodynamic Separator study. Tasks 2 (stormwater pollutant load estimation methods), Task 4 (hydrocarbon (or oil and grease) concentrations in stormwater runoff), Task 5 (evaluation of stormwater treatment technologies), and Task 6 (hydrodynamic separator specifications) are addressed are addressed in Chapters 2, 3, 4, 5 respectively.

In general, stormwater constituents are considered a pollutant when they exceed natural concentrations or water quality standards and have a detrimental effect on the beneficial uses designated for the receiving water.

1.2 Storm Water Quality

The impact on the receiving water of untreated stormwater discharges are largely dependent on climate patterns and land use activities. The frequency, duration and intensity of precipitation events relate to the quantity of stormwater runoff. The land use, population activities, industrial activities contribute to the quality of the stormwater runoff. Increases in impervious surfaces following development result in accumulated pollutants deposited from the atmosphere, leaked from vehicles, or windblown in from adjacent areas (*Schueler & Holland, 2000*). The primary non-point pollution sources that typically accompany urbanization are caused by increases in traffic, street litter, fertilizer use and pesticide use (*City of Newcastle, 1999*). The most common pollutants in urban stormwater and the sources are provided in Table 1.1.

1.2.1 National and Local Data

There are numerous studies of the nature of pollutants in urban stormwater discharges on a national level and at local levels. In the 1980's, cities across the nation sampled and analyzed urban stormwater runoff for the Nationwide Urban Runoff Program (NURP). Also, on a national level, USGS compiled stormwater runoff quality data. Finally, a Federal Highway Administration (FHWA) manual provides a compilation of available stormwater quality data. In Utah, Salt Lake City, Salt Lake County (SLCo) and UDOT have been sampling stormwater runoff since 1992. The analyses conducted in the NURP study and in Utah evaluated levels of conventional pollutants, nutrients, organics, solids and metals in urban runoff from typical storm events.

In 1995, EPA reported that the national data collected through NURP and by USGS, was consistent and suggested that sediments and metals were the most significant pollutants

Table 1.1 - Common Pollutants in Stormwater

Contaminants	Sources
Solids	Streets, lawns, driveways, roads, construction activities, atmospheric deposition, drainage channel erosion
Pesticides and Herbicides	Residential lawns and gardens, roadsides, utility right-of-ways, commercial and industrial landscaped areas, soil washoff
Organic Materials	Residential lawns and gardens, commercial landscaping, animal wastes
Metals	Automobiles, bridges, atmospheric deposition, industrial areas, soil erosion, corroding metal surfaces, combustion processes
Oil and Grease/Hydrocarbons	Roads, driveways, parking lots, vehicle maintenance areas, gas stations illicit dumping to storm drains
Bacteria and Viruses	Lawns, roads, leaky sanitary sewer lines, sanitary sewer cross-connections, animal waste, septic systems
Nitrogen and Phosphorus	Lawn fertilizers, atmospheric deposition, automobile exhaust, soil erosion, animal waste, detergents

U.S. EPA Preliminary Data Summary of Urban Storm Water Best Management Practices, August 1999

measured. Of the metals, copper, lead and zinc were the most frequently detected metals, found in at least 91 percent of the samples. The concentration of total suspended solids in urban stormwater lacking BMPs was determined to be an order of magnitude greater than discharges from wastewater treatment plants.

In 1990, the USGS developed a method for estimating stormwater runoff loads for several pollutants in urban watershed in the U.S. The USGS method is based on USGS and NURP data to predict TSS loads on an event or annual basis. Three different regions were selected based on mean annual rainfall. The intent was to use local data and a regression model to accurately predict suspended solid loads.

In 1996, the FHWA compiled documentation and research on highway stormwater runoff into a single manual on water quality impact assessment and mitigation. The FHWA reported that urban and highway runoff quality is similar for pollutant constituents and concentrations with the exception of heavy metals.

1.2.2 Stormwater Pollutants

Suspended solids are one of the most common contaminants found in urban stormwater. Solids are present in stormwater in a dissolved phase or suspended and can originate from many sources including the erosion of pervious surfaces and dust and other particles deposited on impervious surfaces from human activities and the atmosphere. Sediment in stormwater also provides a medium for the accumulation, transport and storage of other pollutants including nutrients and metals (*EPA, 1999*). Solids are removed from the stormwater discharges through sedimentation, filtration and mechanical devices, such as hydrodynamic separators.

Available studies indicate that most particles suspended in stormwater are less than 120 µm diameter. Coarser fractions, above 120 µm tend to remain in gutters or get caught in catchbasins. Sediment coarser than medium silt (~20 µm) settles rapidly, but much longer detention times are required for finer particles to settle. Particles less than 10 µm tend not to settle discretely according to Stokes Law, and flocculants are required to aid in particle settling. The particle shape, density, water viscosity, electrostatic forces and flow characteristics affect settling rates. Figure 1.1 provides information regarding particle size distribution from a study in New Zealand (Auckland, 2003).

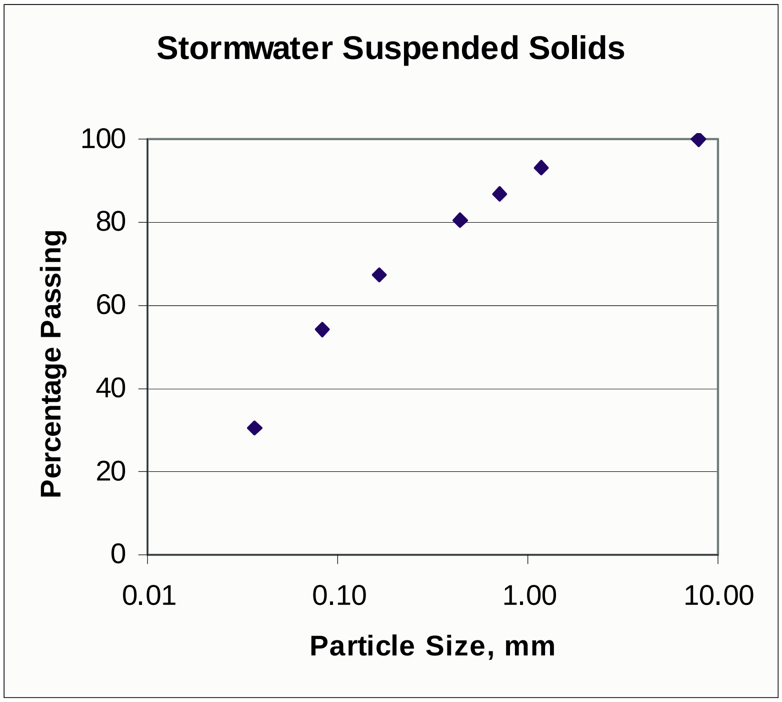

Figure 1.1 - Particle Size Distribution

Another study by the Virginia Transportation Research Council measured particle size in the inflow and outflow of a vegetated swale for one storm. This study found the following particle sizes:

Particle Size	Percent Particles	
	Inflow	Outflow
>25 µm	61.7	36.4
>8 µm	72.0	58.0
>3 µm	76.0	73.4

Litter in stormwater has been defined as manufactured objects (paper, plastic, glass, metal, etc) and not natural items (gravel, vegetation, etc.). Litter has been identified as a significant problem in urban areas in Southern California and is the major source of impairment for receiving waters. Removal of litter from stormwater can be accomplished with screens, trash racks or modification of the outlet from detention basins. Maintenance of the trash racks or screens is the required.

Metals in stormwater runoff occur as dissolved or particulate phases. As with the nutrients, the particulate phase of the metals is found attached to suspended solids. Removal of particulate metals generally involves some type of sedimentation or filtration.

Oil and grease, and petroleum hydrocarbons are found in stormwater at low concentrations both locally and nationally, with the exception of spill events and illegal discharges. Further information regarding oil and grease concentrations in stormwater runoff is presented in Chapter 3.

Nutrients, such as phosphorus and nitrogen, can impair aquatic life through the depletion of oxygen. Nutrients are transported in stormwater attached to suspended solids. Primary sources include organic matter, emulsifiers and residential fertilizer runoff. Nutrients can be present in either dissolved or particulate phases. Sedimentation is effective in removing nutrients when solids are removed from the stormwater.

1.2.3 Common Pollutants Based on Land Use

Recognizing the difference in stormwater quality given the different land uses is beneficial to developing a stormwater management plan and implementing proper BMPs. Generally, stormwater tends to contain similar pollutants, however different land uses will contribute different amounts of each contaminant. Table 1.2 provides a breakdown of typical stormwater pollutants by land use.

Stormwater discharges from construction sites were targeted as a major source of sediment to receiving waters. Currently, under the Phase 2 stormwater regulations, construction sites that disturb greater than 1 acre must be permitted and managed to reduce the discharge of pollutants to the maximum extent practicable.

Sediment, metals, oil and grease concentrations are increased in stormwater due to impervious surfaces and presence of automobiles. There have been some studies that investigated stormwater quality with relation to Average Annual Daily Traffic (AADT). It is suggested that on highly traveled roads, the pollutant loading is consistent throughout the storm event, as the cars continually travel throughout the duration of the storm.

The quality of stormwater discharges from industrial areas is difficult to generalize, based on the wide range of industrial activities in urban areas. Certain industrial activities have been permitted under the Phase 1 stormwater regulations.

Stormwater runoff from residential, commercial and industrial park land uses can be generally characterized. These land uses represent a majority of the area in urban centers

Table 1.2 - Common Pollutants by Land Use

Land Use	Pollutant
Single Family Residential	**Sediment and Floatables** Pesticides and Herbicides **Organic Materials** Metals Oil & Grease Bacteria **Nutrients**
Mixed Use	**Sediment and Floatables** **Pesticides and Herbicides** Organic Materials **Metals** **Oil & Grease** Nutrients
Transportation Corridors	**Sediment and Floatables** **Pesticides and Herbicides** **Metals** **Oil & Grease** Nutrients
Open Space/Parks	Sediment and Floatables **Pesticides and Herbicides** **Organic Materials** Metals **Nutrients**

The more predominant pollutants are in bold type

(EPA, 1995). The NURP database, as previously stated, indicates that the most prevalent pollutants from these land uses are solids, metals, floatables (litter) and nutrients.

Data from urban stormwater sampled throughout SLCo suggests that TSS levels measured are relatively consistent with average NURP TSS levels. Average concentrations of common stormwater pollutants are reported in Chapter 2 (Stormwater Pollutant Load Estimation Methods).

1.3 Stormwater Impacts

Stormwater runoff and the associated pollutants are of concern due to the potential impacts to receiving waters and habitats. Impacts to receiving waters are due to both quantity and quality of runoff. The impact of stormwater discharges is generally and briefly discussed in this chapter.

There is a direct relationship between watershed imperviousness and stream health (*Schueler and Claytor, 1995*). Habitats can be impacted by stormwater runoff by changes in both water quality and quantity. The major impact caused by stormwater runoff is the alteration of species distribution due to the fact that pollutant tolerant and less sensitive species tend to replace native species in stormwater impacted receiving waters (*EPA, 1999*). For these reasons, the intent of management and treatment of stormwater runoff is to prevent or minimize environmental impacts caused by runoff. Table 1.3 identifies physical impacts to streams associated with increased imperviousness and Table 1.4 identifies water quality impacts on habitats.

Table 1.3 - Impacts From Increases in Impervious Surfaces

Increased Imperviousness Leads to:	**Resulting Impacts**				
	Flooding	**Habitat Loss**	**Erosion**	**Channel Widening**	**Stream Bed Alteration**
Increased Volume	X	X	X	X	X
Increased Peak Flow	X	X	X	X	X
Increased Peak Duration	X	X	X	X	X
Increased Stream Temperature		X			
Decreased Base Flow		X			
Changes in Sediment Loading	X	X	X	X	X

U.S. EPA Preliminary Data Summary of Urban Storm Water Best Management Practices, August 1999

Table 1.4 - Water Quality Impacts On Habitat

Water Quality Parameter	**Habitat Effect**
Bacteria	Contamination
Heavy metals	Alteration of species distribution
Toxic organics	Alteration of species distribution
Nutrients	Eutrophication, algal blooms
Sediment	Decreased spawning areas
BOD	Reduced dissolved oxygen levels
Temperature	Reduced dissolved oxygen levels
pH	Alteration of species distribution

U.S. EPA Preliminary Data Summary of Urban Storm Water Best Management Practices, August 1999

1.4 Salt Lake County Data Comparison

Available local data can be an important component of UDOT's plan for stormwater management. With national stormwater characteristics as a basis, comparisons can be made with the SLCo-wide data and local data from other cities. As part of the stormwater permit for SLCo, stormwater sampling has been conducted since 1992 in accordance with the Sampling Plan for Representative Storm Monitoring (August 2001). In general, six stations are sampled once during the spring and fall of each year. Salt Lake City conducts similar monitoring at three stations. These stations were selected to represent various land uses throughout the County. The constituents analyzed are similar to the national studies and other local studies.

The analytical results are used to calculate Event Mean Concentrations (EMCs) for specific constituents. EMCs provide a method for examining the representative storm event concentration for an outfall in the storm drain system. EMCs are commonly used by numerous municipalities and therefore can provide an indication of how SLCo's stormwater quality compares with other municipalities. Salt Lake County calculates EMCs for six constituents for which the most data was available; it is recognized that data is available for other constituents. For comparison purposes, Table 1.5 presents SLCo's EMCs with data from other sources and indicates the SLCo data is within the ranges of the data presented from additional sources.

Figure 1.2 presents a comparison of EMCs with other municipalities and the NURP. The bar graphs indicate that SLCo has EMCs within a similar range for the municipalities compared. Salt Lake County has the lowest average EMCs for TSS, total phosphorus and total zinc.

Table 1.5 - Stormwater Data Comparison

Constituent	SLCo EMC (mg/L)	NURP Mean EMC for SLCo (mg/L)[1]	Caltrans Hwys Mean (mg/L)[2]	Caltrans Park & Rides Mean (mg/L)[2]	FHWA Hwys Median EMC (mg/L)[3]
Total Suspended Solids	116	180	94.4	45.8	142
Total Copper	0.039	0.046	0.022	0.014	0.054
Total Lead	0.031	0.220	0.022	0.006	0.400
Total Zinc	0.181	0.210	0.130	0.108	0.329
Total Phosphorus	0.39	0.6	0.3	0.4	0.4
5-day BOD	13.2	9			

[1]US EPA 1983
[2]Caltrans 2002
[3]Young, G. K., et al., 1996 (FHWA)

1.5 Seasonal and Regional Variation

As discussed previously, the duration, intensity and frequency of precipitation events directly affect the quality and quantity of urban stormwater discharges. Precipitation events vary with geography, topography and seasonally. All these variations and factors affect the quality and quantity of stormwater discharges and therefore may affect the management practice implemented. The USGS has compiled stormwater quality data and correlated this data to different geographic regions of the nation, based on average annual precipitation.

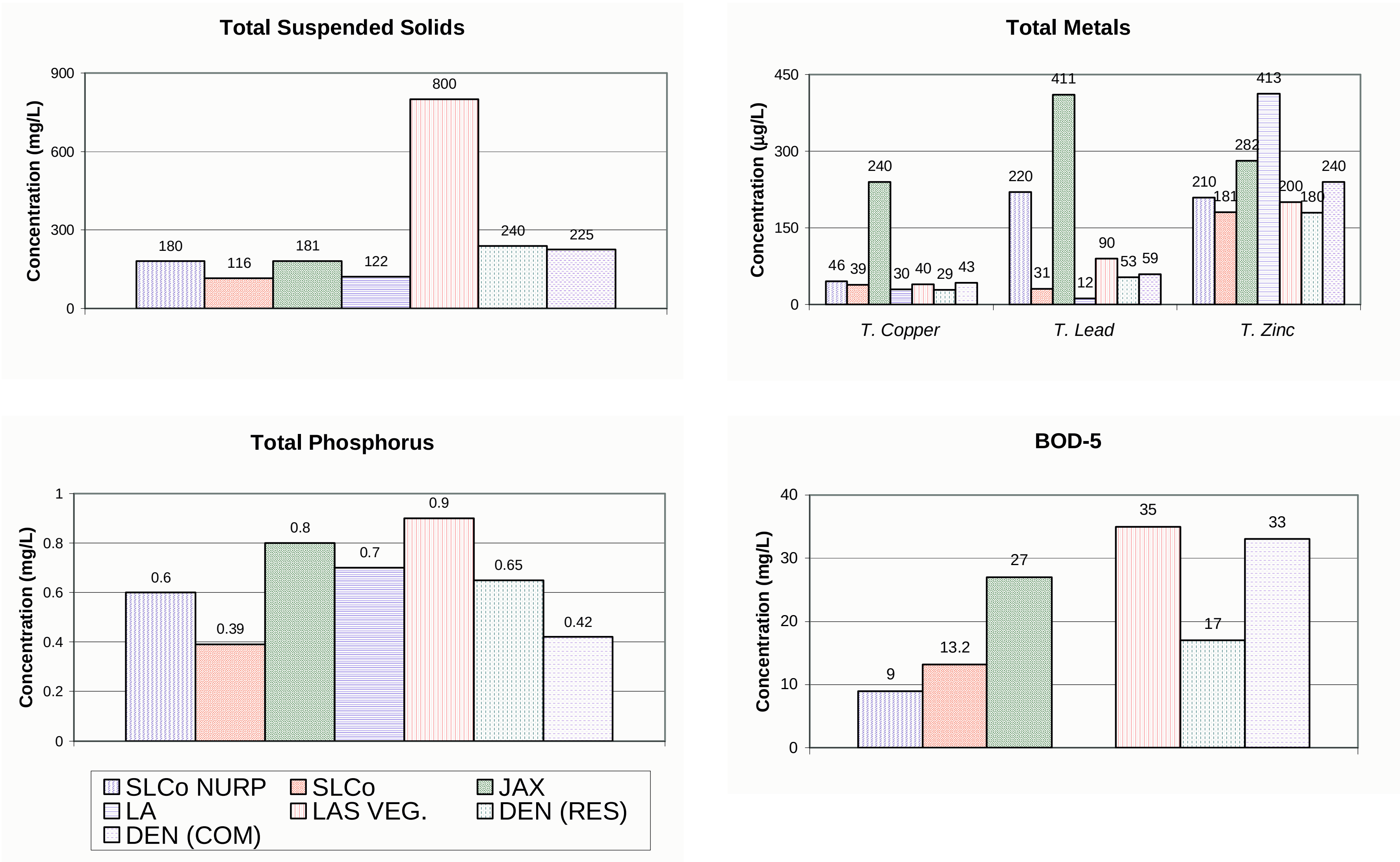

Figure 1.2 – EMC Comparisons

Few studies investigating seasonal trends in urban stormwater quality were available. However, the FHWA manual (1996) presents information that winter precipitation and subsequent spring melts can contribute higher concentrations of pollutants than spring or summer rain events. In addition, recent discussions with SLCo and Salt Lake City have focused on stormwater sample results collected from storm events occurring in early spring. A comparison of the TSS results from the March 2004 storm event to the average TSS concentration indicates that the early storm events may produce above average TSS from other storms sampled. It was noted that all stations sampled during this spring storm event were higher than the SLCo EMC for TSS (116 mg/L). The TSS results from this storm are in Table 1.6.

Table 1.6 - SLCo Spring 2004 Sample Results

Station	**Base** TSS (mg/L)	**Rise** TSS (mg/L)	**Composite** TSS (mg/L)
Decker Lake-01	7	12	170
Jordan River-03	4	10	280
Little Cottonwood-06		660	160
Milcreek-07		51	170

SLCo TSS EMC = 116 mg/L

Due to local deviations in precipitation patterns across Utah, it would be difficult to generally address seasonal or regional variations for predictive pollutant loading purposes. When evaluating a specific system for best management practices, site-specific data should be utilized, including rainfall patterns, soil erosivity and other dominant site characteristics.

1.6 BMP Selection Criteria

The process of evaluating and selecting appropriate BMPs should first determine the pollutant(s) of concern. This analysis will be based upon land use and proximity to receiving waters. From this determination, the type of treatment necessary for pollutant removal may be selected and must include an evaluation of site conditions. The final selection criteria should consider unit costs, including installation, maintenance and potential monitoring.

Potential costs of implementing structural BMPs were discussed in an engineering newsletter regarding water quality management issues related to stormwater runoff (Lee, 2002). The high cost of collection and treatment of urban runoff may affect decisions regarding system types as well as monitoring for compliance purposes. It was estimated that the installation of conventional BMPs in developed areas could cost from $1 - $3 per person per day for the population served; and from $5 - $10 per person per day for advanced BMPs. Consequently, source control BMPs become an important component in BMP selection and for water quality standards compliance purposes.

1.7 Summary

A review of the available literature identifies urban activities that contribute specific pollutants to stormwater runoff. These pollutants contribute to many water quality, habitat and aesthetic problems in receiving waters (EPA 1999). The most common pollutants urban runoff are as follows:

- Solids
- Litter & Floatables
- Organic Materials
- Metals
- Oil & grease/ hydrocarbons
- Nitrogen & Phosphorus
- Pesticides & Herbicides
- Bacteria & Viruses

It is important to recognize that the selection of BMPs must evaluate and assess site-specific factors, including land use, local weather patterns, topography and maintenance requirements. In addition, the following water quality factors should be considered:

- ♦ Does the stormwater discharge to impaired receiving waters?
- ♦ Does the stormwater discharge convey stormwater from high-risk land use?
- ♦ Are there site-specific water quality requirements for the drainage system?
- ♦ Identify stormwater pollutant(s) to be reduced by the implementation of best management practices.

From the review of available stormwater quality data, BMPs could be targeted to reduce the discharge of the following pollutants found in typical municipal stormwater runoff: suspended solids, litter and/or floatables, nutrients and metals. Removal of pollutants from stormwater discharges includes implementation of both preventative and treatment best management practices.

2. Stormwater Pollutant Load Estimation Methods

2.1 Purpose

The Utah Department of Transportation (UDOT) requires information on quantity of precipitation and runoff from their facilities as well as common pollutants contained within that stormwater runoff. This information will be utilized to accurately design stormwater runoff controls to improve stormwater quality through Best Management Practices (BMPs). The typical pollutants found in stormwater runoff from transportation, urban landtype are total suspended solids (TSS), metals, nutrients and organics (refer to Chapter 1). UDOT requested a literature review of estimation methods for urban watershed storm-runoff loads.

This chapter will focus on the estimation of TSS loads, as a pollutant indicator in stormwater runoff. It is generally believed that the removal of suspended solids will also remove metals and nutrients, as those pollutants are transported in stormwater runoff are commonly adsorbed to the suspended solids. Stormwater pollutant loads may also be affected by seasonal weather trends which lead to higher pollutant concentration in stormwater runoff during spring melts due to winter precipitation (refer to Chapter 1).

Methods for the estimation of stormwater constituent loads have been developed by the Environmental Protection Agency (EPA) and the United States Geological Survey (USGS), as well as by individual states and cities. Quantitative analysis method types for the prediction of stormwater constituent loads include (UDEQ 1994):

1. <u>Empirical</u>, empirical methods estimate pollutant loads through direct measurement of runoff and pollutant concentrations during historical storm events and relate the measured values to site-specific basin characteristics. An equation is then formed to predict pollutant loads from other basins based of site-specific characteristics and their associated weighting factors.
2. <u>Statistical</u>, statistical methods estimate pollutant loads by requiring estimates of annual rainfall, land areas, runoff coefficients for catchment basins, and representative concentrations of pollutants obtained by storm event sampling.
3. <u>Deterministic</u>, deterministic methods estimate pollutant loads by utilizing computer databases to manipulate detailed information on stormwater quantity and quality to model basin hydrology and pollutant transport.
4. <u>Hybrid</u>, hybrid methods use a combination of the above methods to estimate pollutant loads.

This section will focus on methods of estimation of total suspended solid (TSS) in stormwater runoff from an urban transportation land use type. Other pollutant loads can be predicted utilizing the same methodology, however, with different concentrations or factors as appropriate.

2.2 TSS Load Estimation Methods

Prediction of annual TSS loads from drainage basins to receiving waters may be a useful tool during the design of storm drainage systems and water quality controls. There are several methods to predict pollutant loads, they all contain two components, hydrology (precipitation and basin characteristics) and pollutant concentration. The following studies were reviewed for applicability to aid in the annual pollutant load calculations:

- USGS Regression Model Analysis
- Adjusting Regional Regression Models Using Local Data
- FHWA Method for Pollutant Load Estimation
- Salt Lake County and City Storm Monitoring EMC Data (Simple Method Loading)
- Nationwide Urban Runoff Program (NURP) Storm Monitoring Data
- California Department of Transportation (Caltrans) Storm Monitoring Data

2.2.1 USGS Storm-Runoff Loads Regression Analysis (Driver and Tasker 1990)

The USGS funded a study to develop a method for the estimate of storm-runoff loads for oxygen demand, solids, metals, and nutrients in urban watersheds in the United States. The developed method is statistical based and consists of four sets of linear regression models based on USGS and Nationwide Urban Runoff Program (NURP) data, that require information about a watersheds physical, land use, and climatic characteristics to predict TSS loads on an event or annual basis. Three different regions were selected based on mean annual rainfall; the Western United States was placed into Region I with less than 20 inches of rain annually. Region I produced the most accurate regression models but the regressions involving suspended solids (SS) were the least accurate. The most significant watershed characteristics in all the linear regression were total storm rainfall, contributing area, and impervious area. Three suspended solid estimation procedures were developed:

1. Stormwater runoff loads (includes a three-variable model)
2. Stormwater runoff mean concentration
3. Mean seasonal or annual loads

The Region I regression model (Table 1, Driver and Tasker 1990) for stormwater runoff loads of SS required information on total storm runoff (in), drainage area (mi^2), and storm duration (min). All models used a predetermined regression coefficient and bias correction factor specific to region and constituent to estimate runoff loads. An estimate of SS was done using the stormwater runoff loads regression for the Jordan 03/04 watershed in Salt Lake County. Jordan 03/04 is located by the intersection of I-15 and I-215 in Murray City, Utah; it is a transport transportation land use type with 75 acres (0.12 mi^2) of contributing area. A 2-yr 30-min storm event totaling 0.4 inches of rain was used. The Region I regression model (Table 1, Driver and Tasker 1990) yielded a value of 45 lbs of SS for a 2-yr 30-min form the Jordan 03/04 watershed. This regression has a standard error of 230% and an average prediction error of

334%. The three-variable model (Table 3, Driver and Tasker 1990) for region I SS requires total storm runoff (in), drainage area (mi^2), and percent impervious area (52% for Jordan 03/04) and yields 745 lbs of SS with a standard error of 251% for a 2-yr 30-min storm event for the Jordan 03/04 watershed. The suspended solid estimates from the stormwater runoff loads regression and the three variable model produce significantly different results. One reason for the extreme difference in SS load estimates maybe the direct relation between impervious area and SS loading within the three variable model.

The region I regression model (Table 5, Driver and Tasker 1990) for stormwater runoff mean concentration of SS requires total storm runoff (in), drainage area (mi^2), and storm duration (min). Using the Jordan 03/04 watershed and the same storm event size the regression model (table 5, Driver and Tasker 1990) produced a SS estimate of 623 mg/L with a standard error of 131%. A SS concentration of 623 mg/L does not correspond well with the predicted SS load of 45 lbs from the regression model (Table 1, Driver and Tasker 1990).

A mean annual/seasonal load was estimated using region I regression model (Table 10, Driver and Tasker 1990). The mean annual/seasonal load region I regression model has an average prediction error of 130 -156% and requires drainage area, mean annual rainfall (14.3 inches for Jordan 03/04), and mean minimum January temperature (18.7 ^{o}F for Jordan 03/04). The mean annual/seasonal load for Jordan 03/04 was predicted to be approximately 2,500 lbs. Which again does not correlate well with the other regression models for the same watershed and storm event. Appendix B contains all regression model equations and calculations.

2.2.2 Adjusting Regional Regression Models Using Local Data (Hoos and Sisolak 1993)

A procedure for adjusting regional regression models of unmonitored site's urban runoff quality using local data was developed by the USGS for use on the Driver-Tasker Models discussed above. These procedures consist of statistical functions called model adjustment procedures (MAP's) that are used to integrate local data into the Driver-Tasker regression models to improve prediction results.

For local data to improve prediction results local storm runoff monitoring sites should reflect a wide range of watershed characteristics (basin size, impervious area, and land use types), as well as a wide range of storm characteristics (total storm rainfall, duration of storm, and antecedent conditions). Also the difference between observed and predicted values for storm runoff loads should have a consistent direction of bias and the variation of observed data should be positively correlated and significantly similar to the variation of the predicted data. Statistical tests should be preformed to confirm these relationships (Hoos and Sisolak 1993).

There are three regression adjustment procedures, which include: the single factor regression against regional prediction, regression against regional prediction, and weighted combination of regional prediction and local regression prediction. Each procedure has different requirements for that method to be selected for the regression adjustment. A regression adjustment using local data was not preformed do to the magnitude of local data and work involved to adjust the regression models.

2.2.3 FHWA Method for Pollutant Load Estimation (Young, G. K., et al., 1996)

The Federal Highway Administration (FHWA) reviewed three methodologies for the estimate of pollutant loads: they include the USGS regression model study discussed above, a simple method that utilizes NURP data, and the FHWA estimation method. The FHWA method for pollutant load estimation uses regional data tables for obtaining model parameters along with a constituent EMC selected from a range of EMCs for an urban highway land use. This information is then used to calculate annual and event pollutant mass loads from a series of empirical equations (Young, G. K., et al., 1996). Table 2.1 lists the median TSS EMC for an urban highway landtype; refer to Chapter 1 for other constituent EMCs.

Table 2.1 - Suspended Solid Concentrations for an Urban Highway Landtype

Source	TSS (mg/L)
SLCo EMC (SLCo 2000)	116
SLCo NURP EMC (USEPA 1983)	180
Caltrans, mean conc. (Caltrans 2002)	94.4
FHWA Median EMC (Young, G. K., et al., 1996)	142

2.2.4 Salt Lake County Stormwater Monitoring (SLCo 2000)

Salt Lake County (SLCo) and Salt Lake City (SLC) stormwater runoff monitoring has been conducted since 1992 on nine outfall locations located throughout Salt Lake County (refer to Figure 2.1 for sample locations). A total of 16 storm events have been sampled up to 2003. Annual pollutant loads and event mean concentrations (EMC) were calculated through statistical methods for total suspended solids (TSS), metals, total phosphorus, and biological oxygen demand for three primary land use types residential, transportation, and commercial/industrial. An EMC for oil and grease (O&G) was not calculated because of lack of data and non-detect measurements. The method detection limit for O&G is 1 mg/L.

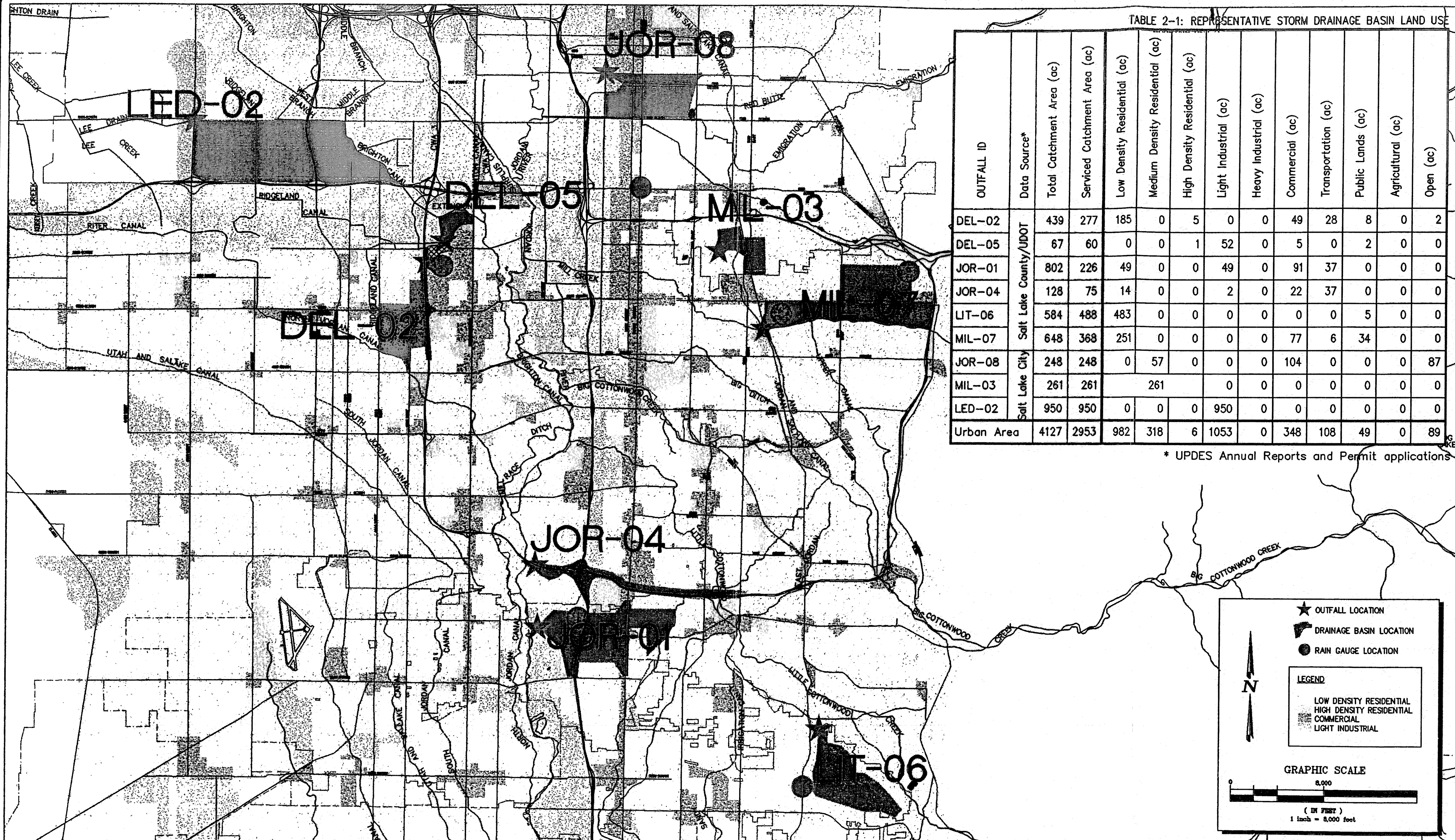

TABLE 2-1: REPRESENTATIVE STORM DRAINAGE BASIN LAND USE

OUTFALL ID	Data Source*	Total Catchment Area (ac)	Serviced Catchment Area (ac)	Low Density Residential (ac)	Medium Density Residential (ac)	High Density Residential (ac)	Light Industrial (ac)	Heavy Industrial (ac)	Commercial (ac)	Transportation (ac)	Public Lands (ac)	Agricultural (ac)	Open (ac)
DEL-02	Salt Lake County/UDOT	439	277	185	0	5	0	0	49	28	8	0	2
DEL-05		67	60	0	0	1	52	0	5	0	2	0	0
JOR-01		802	226	49	0	0	49	0	91	37	0	0	0
JOR-04		128	75	14	0	0	2	0	22	37	0	0	0
LIT-06		584	488	483	0	0	0	0	0	0	5	0	0
MIL-07		648	368	251	0	0	0	0	77	6	34	0	0
JOR-08	Salt Lake City	248	248	0	57	0	0	0	104	0	0	0	87
MIL-03		261	261		261		0	0	0	0	0	0	0
LED-02		950	950	0	0	0	950	0	0	0	0	0	0
Urban Area		4127	2953	982	318	6	1053	0	348	108	49	0	89

* UPDES Annual Reports and Permit applications

j: /s212198/2000/wq_data/report/outfall2.dwg

Project Number	FM
S212198	KKN
Filename	Plot Date
t:\...\outfalls.dwg	
Designed By	Drawn By
KKN	LAK/SGS
Checked By	Date
KKN	
Scale	Date Issued
1"=15,000'	5/1/2000

No. | Revisions | By | Date

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UPDES REPRESENTATIVE SAMPLING OUTFALL LOCATIONS,
LANDUSE, AND PRECIPITATION GAUGE LOCATIONS.

Figure Number

2-1

Salt Lake County and Salt Lake City are required to sample representative storm events for specific targeted pollutants, by their UPDES Municipal Phase 1 Stormwater Discharge Permits. Grab samples are taken before the beginning of a runoff event, rise grab samples are gathered within the first 30 minutes of runoff, and storm composite samples are collected over a 6-hour period and flow weighted for submittal to an outside laboratory for analysis. A representative storm for Salt Lake County as defined by the USEPA [40 CFR 122.21(g)(7)] was determined to have the following characteristics:

1. Accumulation of 0.62 in
2. Duration of 6.4 hrs
3. Average rate of accumulation of 0.1 in/hr
4. Wet period from March through October
5. 6-hr inter-event duration
6. Event must occur at least 72 hours after previously measurable precipitation of 0.1 in

These conditions were selected because the majority of storms in the Salt Lake County area met these criteria. A seasonal monitoring frequency of twice a year was chosen, and is spring (April 15 to July 1) and fall (September 1 to November 15).

Loading was estimated for each storm event based on area serviced, weighted runoff coefficient (0.52 for Jordan 03/04) and average concentration of constituent for that storm event given the overall land use category assigned to the basin. The load for the specific storm event for each outfall was calculated using equation 1: Table 2.2 lists estimated runoff coefficients for typical land uses.

$$L_x = 0.227 \bullet P \bullet Pj \bullet R_a \bullet A_s \bullet C_a \qquad (1)$$

Where:

Lx = load for the storm event (lbs)
P = precipitation for the storm event or annual precipitation (in)
Pj = correction factor for storms that produce no runoff = 0.9 (for annual loading estimates only)
Ra = weighted average runoff coefficient based on land use of serviced area = (∑(i=1,n) Ri·Ai)/As
As = serviced area of basin (acres)
Ca = average concentration of constituent for land use category assigned to basin (mg/L)

(0.227 is a conversion factor to convert mg/L, acres and inches to pounds)

Table 2.2 - Typical Runoff Coefficients

Land use Category	***Ri**
Light Residential	0.25
Medium Residential	0.40
Heavy Residential	0.60
Light Industrial	0.46
Heavy Industrial	0.60
Commercial	0.60
Transportation	0.75
Public Lands	0.20
Agricultural	0.10
Open	0.10

*Salt Lake County Public Works Dept. Engineering Division

The event mean concentration (EMC) for constituents were calculated at each outfall. To calculate the EMC, the calculated loading per event for each of the sampled storms was summed and divided by the total precipitation for the sampled events. The result was divided by the serviced basin area and runoff coefficient and converted to milligrams per liter. Equation 2 was used:

$$EMC = \frac{\Sigma L_x \bullet 12}{\Sigma P \bullet R_a \bullet A_s \bullet 2.72} \qquad (2)$$

Where:

Lx = load for the storm event (pounds)

P = precipitation for the storm event (inches)

Ra = weighted average runoff coefficient based on land use of serviced area = (∑(i=1,n) Ri·Ai)/As

As = serviced area of basin (acres)

(12 and 2.72 are conversion factors for pounds to mg/L)

The EMCs for each constituent were calculated on an event basis and averaged to obtain the average TSS EMC of 116 mg/L for Salt Lake County. An estimate of TSS was done using the Salt Lake County EMC for the Jordan 03/04 watershed. An average annual precipitation of 14.3 inches and a 2-yr 30-min storm event totaling 0.4 inches of rain was used with the same watershed characteristics utilized in the USGS regression models above. The predicted TSS load was 13,245 lbs annually and 411 lbs for the 2-yr 30-min storm event, yielding significantly higher TSS prediction loads that the USGS regression models. Table 2.1 lists the calculated EMC for SLCo for suspended solids. See Appendix A for Salt Lake County stormwater sampling results and Appendix B for EMC loading calculations.

2.2.5 USGS and EPA Nationwide Urban Runoff Program (NURP)

The USGS and EPA collected stormwater runoff data from 21 urban sites throughout United States during the Nationwide Urban Runoff Program (NURP). Table 2.1 lists the calculated TSS EMC for Salt Lake County determined as part of the NURP study. Concentrations for oil and grease or petroleum hydrocarbons were not reported in this study.

Equation 1 above was used to estimate TSS using the Salt Lake County NURP TSS EMC of 180 mg/L (SLC 1993) for a transportation land use. Both an annual and 2-yr 30-min storm event TSS loads were determined for the watershed Jordan 03/04. Equations 1 yielded 20,552 lbs of TSS annually and 637 lbs of TSS for a 2-yr 30-min storm event. This estimate corresponds well with the SLCo EMC and the three variable USGS regression model TSS estimates because of the direct significant relationship to impervious area. See Appendix B for EMC loading calculations.

2.2.6 California Department of Transportation Stormwater Runoff Characteristics Data

California Department of Transportation (Caltrans) conducted a multi-year study that collected stormwater runoff samples from highways, Maintenance Stations, Park and Ride facilities, rest areas and acceleration and deceleration lanes throughout the state and analyzed for a variety of pollutants (Caltrans 2002). Overall, 50 sites were monitored for a total of 323 station storm events. The following is a summary of the average concentrations found from highway facilities. Concentrations for oil and grease or petroleum hydrocarbons were not reported in this study. Table 2.1 lists the mean TSS concentration reported for Caltrans transportation facilities.

Equation 1 was used to estimate TSS using the CalTrans data for TSS of 94.4 mg/L (Caltrans 2002) for a transportation land use. Both an annual and 2-yr 30-min storm event TSS loads were determined for the watershed Jordan 03/04. Equation 1 yielded 10,778 lbs of TSS annually and 334 lbs of TSS for a 2-yr 30-min storm event. Again this estimate corresponds well with the SLCo EMC and the three variable USGS regression model TSS estimates because of the direct significant relationship to impervious area. See Appendix B for EMC loading calculations.

2.3 Conclusions

UDOT requested a review of published methods to estimate annual and single storm event constituent loads for a transportation land use in Utah. This estimation method would need to be easily applied, use available data, and be applicable to the entire state of Utah.

The method recommended for the prediction of pollutant loads in typical urban stormwater runoff is the USGS Storm-Runoff Loads Regression Analysis by Driver and Tasker

1990. Several constituent loads (TSS, oxygen demand, metals, nutrients) can be predicted utilizing this methodology, however, with different concentrations or factors as appropriate (Driver and Tasker 1990). This method could be used for a regional estimate of annual suspended solid loading and individual storm event loading where stormwater-monitoring data is not available. Salt Lake County stormwater-monitoring data could be used to adjust the USGS regression models to most accurately predict suspended solid (TSS) and other pollutant loads for unmonitored sites within the same overall watershed network using the MAP's described in Adjusting Regional Regression Models Using Local Data (Hoos and Sisolak 1993).

Salt Lake County EMC data could also be used to estimate pollutant loads for typical urban stormwater runoff.

3. Treatment of Hydrocarbon Constituents in Municipal Stormwater Discharges

3.1 Introduction

Hydrodynamic separators are treatment systems that are designed primarily to remove sediment, as well as hydrocarbons and metals associated with accumulated sediments. These systems have become popular because they are relatively inexpensive and can be easily installed at small sites without sacrificing land. These systems are typically used in high-risk areas, or “hot spots” (gas stations, auto shops, loading areas, fast-food restaurants) and provide an additional level of protection for the containment of hydrocarbon or oil spills.

This chapter documents hydrocarbon concentrations found in urban stormwater runoff from various studies and reports and discusses criteria for the design of hydrodynamic separators. This document fulfills the requirements set in Task 4 of the Utah Department of Transportation (UDOT) Hydrodynamic Separator study.

3.2 Typical Hydrocarbon Concentrations in Stormwater Runoff

In considering use of OWSs for treating stormwater, it is important to evaluate documented oil/grease or hydrocarbon concentrations in urban stormwater runoff. Current literature and/or studies indicate that oil and grease concentrations in urban stormwater runoff are generally low. Table 3.1 presents the information obtained during a literature search.

Table 3.1 - Oil & Grease and Hydrocarbon Concentrations in Stormwater Runoff

Study	Parameter	Concentration
Austin, TX study	Oil & grease	5-10 mg/L
Salt Lake County*	Oil & grease	5.75 mg/L storm first flush (average) 4.25 mg/L composite (average)
Center for Watershed Protection	Total Petroleum Hydrocarbon EMC	12.4 mg/L (based on commercial parking lot)
TxDOT	Oil & grease	2.7-27 mg/L (national concentration) 89.28 mg/L (Austin, TX[3]) 37.36 mg/L (Austin, TX[4]) 234.7 mg/L (Austin, TX[5])
FHWA	Oil & grease	2.7-27
NURP		No oil & grease or hydrocarbon data
USGS		No oil & grease or hydrocarbon data
Caltrans		No oil & grease or hydrocarbon data
SLCo Water Quality Report		No oil & grease data EMC determined

*Salt Lake County results are averages for JOR-03 (transportation landuse); majority of results were reported Non-Detect with a Method Detection Limit between 1 & 5 mg/L.

3.2.1 Oil Droplet Size

In a study designed to evaluate the performance of separators, an analysis of droplet size was provided. Oil/water mixtures are usually divided into four categories:

- Free-floating oil (droplet sizes of 250 μm or more), oil slick or film
- Oil droplets & globules ranging in size from 10-300 μm
- Emulsions (1-30 μm range)
  - Stable ; usually the result of surfactants holding droplets in solution
  - Non-stable; created by shearing forces present in mixing
- Dissolved oil (<10 μm)

*(μm=micron)

The objective of OWSs is to treat most of the flow (90-95%) from the catchment to an acceptable degree (10-15 mg/L O&G) and to remove fee oil so as not to produce a discharge that causes an on-going or recurring visible sheen. These systems are not effective at removing emulsified or dissolved oils. Oil droplets are generally characterized as emulsified or dissolved (1-30 μm range) in municipal stormwater discharges.

At this time literature that suggests typical oil droplet sizes or size distribution found in stormwater runoff has not been found. Hydrodynamic separator vendors indicate in sales and technical literature (some based on data from petroleum storage terminals) that 80% of the droplets (by volume) are greater than 90 μm and that 30% are greater than 150 μm (Auckland Regional Council Technical Publication #10).

Typically, effluent oil and grease concentrations from separators can meet 10 - 20 mg/l, which generally corresponds to the removal of droplets larger than 60 μm. Lower standards can be met by sophisticated, multi-chambered separators that incorporate coalescing plates and treat low flows (40 - 50 gpm) of a consistent influent concentration.

3.3 Separator Design

Hydrodynamic separators for municipal application are not capable of removing stable emulsions or dissolved oil. OWSs are not usually applicable for general stormwater runoff because by the time the oil reaches the device, it has emulsified or coated sediment in the runoff and is too difficult to separate.

Factors affecting separator performance are:

- Quantity of oil
- Oil density
- Water temperature
- Other wastestream characteristics

Traditionally, 150 μm separation has been used, which typically results in an effluent oil & grease concentration of 50-60 mg/L. Flow density based separators is limited to removal of "medium" sized droplets (100-140 μm) and has a low head requirement.

The following general design criteria is recommended:

Determine the following in the runoff:

- Oil & grease concentrations
- TSS concentrations
- Lowest temperature
- pH
- Empirical oil rise rates

Determine the following information about the oil:

- Viscosity
- Specific gravity
- Whether or not the oil is emulsified or dissolved

The most important characteristic affecting performance is oil droplet size, from which the critical rise rate can be determined. After determining the rise rate, design flow rate, and effective horizontal separation area, the separator can be appropriately sized. The efficiency of separators is dependent on detention time in the chamber and on droplet size.

When considering use of these systems for stormwater treatment, land use, site location and operation & maintenance should be taken into account. In addition, it is recommended that OWSs be used as follows:

√ Use as pretreatment system prior to other BMPs
√ Use in an off-line configuration
√ Catchment size should be small, one study recommended 1 acre or less

3.4 Technical Performance Standards

A variety of hydrodynamic separators were investigated to provide performance details for use in selection criteria. Hydrodynamic separators have a smaller working area than conventional gravity separators and remove debris, sediment, and surface grease and oil. Table 3.2 provides specific details regarding 11 different proprietary systems. This information will assist in the selection of a particular system depending upon the selection criteria. The data was obtained from the manufacturers specifications.

Additional information regarding hydrodynamic separators is provided in Appendix C. Manufacturers specifications for the systems reviewed are included as well as an EPA Fact Sheet for these systems.

3.5 Maintenance

Maintenance is the most overlooked aspect of these systems and is critical to pollutant removal. Re-suspension of the settled matter and flushing of the oil layer limits the removal efficiency of these units. Various papers recommend a wide range of maintenance frequency; from 1/month and after storm events, to annually. Several studies recommended monthly inspections, with maintenance and cleaning before each season. However, required maintenance varies from site to site, and should be determined on an individual basis.

Cost considerations for maintenance must be considered when evaluating these systems. Currently, UDOT estimates service visits to be approximately $379.35 or $446.60

Table 3.2 - Proprietary Hydrodynamic Separators

Company*	Hydrodynamic Separator Name	System Type	Pollutant Removed	Flow Control	TSS Removal	Free Oils	Emulsified Oils	Sizes/ Models	Overall Size	Treatment Flow (cfs)	Bypass Flow (cfs)	Storage Capacity (yd^3)	Cost (Unit)	Particle Size	Head Loss k value
Amcor	Oil Water Separator	Off-Line, w/flow bypass	Oils	weir	10-15 PPM Effluent Conc	N/A	N/A	660-CPS - 6214-SA	4'-2" X 8' X 7'	0.3 - 2 cfs	NA	-	-	0.85 oil specific gravity	-
Aqua-Swirl™ Concentrator	Aqua-Swirl™ Concentrator	Off-Line, w/flow bypass	Off-Line, w/flow bypass	orifice/weir	90%	some	none	N/A	NA	1/3 of design storm	NA	-	-	200 micron	-
Baysaver, Inc.	Baysaver	In-Line, w/flow bypass	sediments & floatable particles	trapezoidal weir	60 to 80%	some	none	1/2K	12" dia	1.1	8.5	na	$1,990	NA	NA
								1K	24" dia	2.4	10	na	$3,990	NA	NA
								3K	36"dia	7.2	24	na	$5,990	NA	NA
								5K	48" dia	11	39	na	$7,990	NA	NA
								10K	60" dia	21.8	100	na	$9,990	NA	NA
								XK	custom	custom	custom	na		NA	NA
CDS Technologies, Inc.	Continuous Deflection Separator (CDS)	Off-Line, w/flow bypass	sediments & floatable particles	orifice	84 - 52%	some	none	PSWC30_20 - CSW240_160	NA	3 - 300	NA	1.9 - 14.1 & up	NA	2700 - 4700 micron	NA
		In-Line	sediments & floatable particles	orifice	84 - 52%	some	none	PMSU20_15_4 - PMSU40_40	NA	0.7 - 10	NA	0.5 - 5.6	NA	NA	NA
Hydro International	Downstream Defender	In-Line, w/flow bypass	sediments & floatable particles	-	84%	some	none	1200 - 3000	1200 - 3000 mm	0.7 - 25	NA	0.9 - 11.4	NA	150 micron	125 - 250 mm
Practical Best Management (PBM)	Crystal Stream Oil/Grit Separator	Limited space	sediments	NA	95%	significant	none	NA	NA	NA	NA	NA	NA	NA	NA
Stormceptor	Stormceptor	In-Line, w/flow bypass	sediments & floatable particles	orifice	80%	some	none	STC 900 - STC 7200	6' dia - 14'dia	0.63-2.5	NA	2.5 - 33	NA	20-2000 micron	1.3 V2 / 2g
		two units in series	sediments & floatable particles	orifice/weir	80%	some	none	STC 9000- STC 16000	23' - 27 '	-	NA		NA		
Vortechnics, Inc.	Vortechs System	In-Line, w/flow bypass	sediments & floatable particles	orifice/weir	80%	some	none	1000 - 16000	-	1.6 - 25	100 yr flow	0.75 - 7.0	-	50 micron	1.3 (Minor Loss = 1.3 v2/2g)
	VortSentry	In-Line, w/flow bypass	sediments & floatable particles	orifice	80%	some	none	VS30 - VS80	-	-	-	-	-	150 micron	-

NA = Not Available, N/A = Not Applicable
* All information presented in this table is based on manufacturers' published documents as of 3/04

depending on whether or not enclosed space entry is required. These estimates represent minimum costs. Please refer to Appendix C for further details.

3.6 Summary of Findings

In a study conducted by the University of Texas at Austin, 35 rainfall events were simulated on a portion of highway; these results were compared with results from 23 natural storm events. This study also investigated the effectiveness of BMPs. The factors most affecting oil & grease concentrations were determined to be storm volume and number of vehicles traveling during the storm. This study determined the most effective way to minimize stormwater pollutants from highways is street sweeping.

In the *Stormwater Management Manual for Western Washington*, the use of OWS systems were recommended only for sites that typically generate high concentrations of oil due to specific activities. “High-use” for this study is defined as a road intersection with a measured average daily traffic count of 25,000 vehicles or more on the main roadway and 15,000 vehicles or more on any intersecting roadway. The report recommended an OWS with additional BMPs for this “high-use” situation.

In an article in *The Practice of Watershed Protection*, water quality analyses were conducted on an OWS serving the parking lot of a fast food restaurant. Inflow and outflow event mean concentrations (EMCs) were compared to examine pollutant removal performance. The study found that the separator did not show any capability to remove pollutants in storm runoff. In fact, net negative removal efficiency was found for suspended sediment, total organic carbon, hydrocarbons, total phosphorus, organic nitrogen, and extractable & soluble copper. The concentration of nearly every parameter was well above levels frequently encountered in “untreated” urban stormwater runoff.

In a study conducted by the Texas Transportation Institute, BMPs were analyzed for use in retrofitting TxDOT drainage structures. Three types of roadways were considered for retrofitting; limited access & urban highways, rural highways and residential & farm to market roads. An oil/grease separator with additional BMPs (ie. sand filters) was recommended only for use in limited access & urban highways areas. This study concluded that the most cost-effective technologies are extended detention basins or other surface-based technologies, such as wet ponds, wetlands and bioretention.

3.7 Recommendations

Hydrodynamic separators are not recommended for use in treating and/or reducing oil and grease concentrations in typical urban stormwater runoff. These systems may be considered for use as spill containment, oil and grease in high-risk areas (“hot spots”), or to assist with the removal of sediments.

The following criteria is recommended for UDOT purposes:

- Utilize the 60 μm sized oil droplet for the basis of design for spill containment

- Develop performance measures for oils and TSS; incorporate peak flows on small detention basins
- Develop vendor selection criteria that includes TSS and oil droplet size
- Include life-cycle maintenance costs
- Evaluate a monitoring program and evaluation criteria
- Incorporate TMDL impaired waters in the selection process
- Incorporate West Nile virus concerns

4. Evaluation of Stormwater Treatment Technologies

4.1 Purpose

UDOT design engineers must be given the following relevant information to make informed water quality improvement decisions during the design of stormwater hydraulic conveyance systems. In order to be accepted by UDOT, vendors should also provide the most recent performance criteria for specific target pollutants.

4.2 Design Storm

For the purposes of this evaluation, the treatment technologies can be designed to treat runoff from the water quality design storm, defined as 0.5 inches of rainfall with an intensity of no more than 0.5 in/hr. Approved hydrology methods should be used to identify runoff volumes and peak flow rates for design purposes. By treating this water quality design storm, approximately 70% of storm events in Salt Lake City are effectively treated.

For oil-water separator design, the Utah Division of Water Quality (DWQ) currently requires using the flow rate, which results from a “2-yr” storm event and is based on the individual “time of concentration” of the particular drainage area being evaluated. This estimated peak runoff is then divided by three to yield the water quality design flow; any flows greater than the water quality design flow are bypassed.

The UDOT method for determining the water quality design flow to a hydrodynamic separator, as addressed above will provide a measure of treatment at or above the current minimum requirements.

4.3 Required Treatment Technology Information

4.3.1 Applications:

1. How does the treatment technology work? What are the target pollutants and size distribution?

2. How are the target pollutants removed from stormwater?

3. What applications does the vendor recommend for their product? Why?

4. How many systems are installed in Utah? In the intermountain west? Provide at least three references of units owned and maintained by public municipalities or DOTs with names and telephone numbers. Provide specific model numbers.

5. Treatment technologies should be approved by the EPA ETV Program (EPA Environmental Technology Verification). Provide information regarding the status of this approval.

6. Provide history and duration of manufacturing and installation of treatment technology. The manufacturer of the system shall be regularly engaged in THE ENGINEERING DESIGN AND PRODUCTION OF SYSTEMS FOR PHYSICAL TREATMENT OF STORMWATER RUNOFF FOR A MINIMUM OF 5 YEARS.

4.3.2 Site Characteristics:

7. Please address how the following site characteristics affect performance:

- Steep slopes
- High groundwater
- Base flows (groundwater or irrigation)
- Confined space entry
- Access and safety
- Large or small drainage basins

4.3.3 Design Criteria:

8. Target pollutant removal rates and/or efficiencies at design flows. Submit pollutant removal efficiency models based on documented removal efficiency performance from full-scale tests. Testing shall include influent and effluent samples collected from storm events. Provide analysis that shows that the treatment technology shall not re-suspend trapped sediments or re-entrain floating contaminants at flow rates up to and including the specified design flow rate.

9. Provide information regarding the ability of the treatment technology to remove various sediment sizes. Complete the following table:

Particle Diameter (micron)	**Removal Rate Capability (%)**
< 1,000	
< 707 (coarse sand)	
< 595	
< 420 (medium sand)	
< 297	
< 177 (fine sand)	
< 88 (very fine sand)	
< 44 (coarse silt)	
< 16 (medium silt)	
< 8 (fine silt)	

10. Provide information regarding the size of oil droplets that the treatment technology effectively removes. Complete the following table:

Oil Droplet Size (micron)	Removal Rate Capability (%)
> 300 (free-floating)	
10-300	
1-30 (emulsions)	
< 10 (dissolved)	

11. Estimations of standing water and potential vector control concerns.

12. Please provide the following hydraulic design factors:

- Treatment flows
- Bypass flows
- Allowable entrance velocities
- Hydraulic grade line
- Head loss factor for in-line or off-line application

13. Estimations of maintenance frequency and cost (in person-hours).

14. Design life of the system or components of the treatment technology before major overhaul is projected.

15. Structural, materials, water tightness, buoyancy, constructability and maintainability.

16. Design sizing and cost information for units to perform without maintenance for one calendar year and over-designed to last three years before cleaning.

17. Pretreatment or post treatment requirements, if any.

18. What role does the vendor take during design?

4.3.4 Construction:

19. What role does the vendor take during construction? Will a vendor representative be available during construction in the field?

20. Identify the construction activities required for installation of the treatment technology.

21. How is construction installation related to pollutant removal efficiencies?

4.3.5 Operation and Maintenance:

22. Describe inspection and maintenance procedures.

23. Specify equipment and materials required for maintenance of treatment technology.

24. Provide the projected frequency of maintenance and the basis for the projection.

25. Are there confined space entry concerns?

26. What role does the vendor play in maintenance of the treatment technology?

4.3.6 Costs:

27. Provide materials costs, indicating total costs and costs per cfs treated (not per cfs of hydraulic capacity).

4.4 Selection Process

The selection process will incorporate the Hydrodynamic Separator Design Process in Appendix D.

5. HYDRODYNAMIC SEPARATOR SPECIFICATION

SPECIAL PROVISION
SECTION 02633S

PART 1 - GENERAL

1.1 SECTION INCLUDES

A. Products and procedures for selection and installation of hydrodynamic separators.

1.2 RELATED SECTIONS

A. Section 02056: Backfill
B. Section 02317: Structural Excavation
C. Section 02324: Compaction
D. Section 02610: Piping
E. Section 02721: Untreated Base Course
F. Section 03055: Portland Cement Concrete

1.3 REFERENCES

A. AASHTO M 105: Grey Iron Castings

B. ASTM B 209: Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate

C. ASTM C 857: C 858: Standard Practice for Minimum Structural Design Loading for Underground Precast Concrete Utility Structures,

D. ASTM C 858: Standard Specification for Underground Precast Concrete Utility Structures

E. ASTM C 891: Standard practice for Installation of underground pre-cast concrete utility structures

F. ASTM C 990: Specification for Joints for Concrete Pipe, Manholes, and Precast Box Sections Using Preformed Flexible Joint Sealants

G. ASTM D 3977-97, Standard Test Method for Determining Sediment Concentration in Water Samples

H. Occupational Safety and Health Association (OSHA) Regulations

1.4 GENERAL

A. Furnish and install hydrodynamic separator, all labor materials, equipment and incidentals required to meet the following requirements and in accordance with the drawings.

B. Equipment Designation. In these specifications and on the drawings, hydrodynamic separators are represented schematically and by assigned identification numbers for reference and location purposes. Hydrodynamic separators specified herein and on the drawings must be employed exclusively throughout submittals, shop drawings, data sheets, and other related documents.

C. Installation and Test. Assemble and install all equipment in strict accordance with the manufacturer's instructions. Competent craftsmen must accomplish all installations in a workmanlike manner. Prepare equipment for operational use in accordance with Manufacturer's instructions, including field-testing, where required. Final acceptance of the equipment is contingent on satisfactory operation after installation.

D. Provide a list of Manufacturer's recommended replacement parts.

E. Wrap and label all special tools and supplies.

F. Provide Engineer with operation manuals and instructions

PART 2 - PRODUCTS

2.1 GENERAL

A. Furnish and install hydrodynamic separators where shown and as called out on the drawings.

2.2 SEPARATOR SELECTION

A. Use current UDOT device selection flow chart found in the UDOT Hydrodynamic Manual to select device with lowest life cycle cost.

B. Furnish hydrodynamic separator manufactured by a UDOT approved vendor and on UDOT's approved product list (APL).

C. Route larger stormwater flows around the hydrodynamic separator. Do not allow larger flows to enter the separator.

D. Furnish a structurally sound separator for the actual burial depth. Install separator to resist buoyancy.

E. Furnish manhole or cleanout lids that carry HS-20 traffic loadings.

2.2 SUBMITTALS

A. Submit hydrodynamic separator shop drawings showing details for construction, reinforcing, joints and any appurtenances. Annotate drawings to indicate all materials used and all applicable standards for materials, required tests of materials and design assumptions for structural analysis. Submit shop drawings to Engineer for review and conformance with specifications.

PART 3 - CONSTRUCTION

3.1 GENERAL

A. Inspect hydrodynamic separator and accessory equipment upon delivery for general appearance, dimensions, soundness or damage in a manner acceptable to the Engineer.

B. Repair any defects or damage identified by the inspection or return the unit and supply new undamaged hydrodynamic separator.

C. Complete required repairs or adjustments of separator in accordance with Manufacturer's recommendations. Manufacture's Representative and Engineer will inspect repairs before installation.

3.2 EXCAVATION

A. Prepare and excavate the site for the unit installation in accordance with section 02137. Comply with Occupational Safety and Health Association (OSHA) regulations and the manufacture's requirements and specifications.

B. Prior to the excavation, verify bottom of excavation elevation against separator dimensions and connecting storm drain invert elevations. Adjust bottom of excavation elevation must be adjusted to insure installation in accordance with Manufacture's Specifications.

C. In the event of unsuitable material at the bottom of the excavation, remove at least 8-inches of the unsuitable material and replace it with granular borrow material approved by the Engineer.

   a. Unsuitable material is defined as soils consisting of organic soils or materials such as peat, moss and bog, or fine-grained soils (silts or clays) and un-cemented sands.
   b. Compact material on which the hydrodynamic separator is to be placed must be compacted to a relative density of not less than 96 percent (AASHTO T180).

D. Provide a level foundation, which fully supports the hydrodynamic separator meeting manufacture's recommendations.

3.3 INSTALLATION

A. Conform with ASTM C891 and the manufacture's recommendations.

B. Lift and place separator into position in strict accordance with manufacture's recommendations. Use equipment to lift and place the separator that is of adequate size to avoid damaging the separator. Do not drag the separator along the ground or drop during installation.

C. Install hydrodynamic separator plumb, level and align both vertically and horizontally with inlet and outlet piping.

D. Connect the inlet and outlet piping in accordance with the Manufacture's Recommendations and to insure uniform flows with no obstructions.

E. Provide watertight connections with inlet and outlet pipes.

F. Install manhole or clean out port frames and lids, set at the grade required as necessary to be within 0.125-0.25 inches lower than finished grade of roadway. Provide locking manhole covers when required.

G. Install anchoring systems to resist buoyancy forces.

H. Provide that a Manufacture's Representative inspects, prior to backfill. Complete all required post-installation testing as prescribed by the manufacture. Make all repairs or adjustments will be made as directed by the manufacture's representative.

3.4 BACKFILL

A. Comply with Section 02056.

B. Do not damage unit during compaction.

END OF SECTION

6. Conclusions and Recommendations

6.1 Conclusions

The purpose of this UDOT Hydrodynamic Separator study is to assist the UDOT Technical Advisory Committee (TAC) in the preparation of a selection methodology and performance-based specification for hydrodynamic separators and oil-water separators as a structural control measure for stormwater treatment. Current State of Utah and federal stormwater discharge permits require the implementation of Best Management Practices (BMPs) to reduce the discharge of pollutants to the maximum extent practicable (R317-8). Current State of Utah Division of Water Quality rules (R317-1-2) require storm sewer discharges, that discharge greater than 5 cfs into a receiving water, obtain a Stormwater Permit for Construction Activities and implement controls.

These Best Management Practices (BMPs) are considered for implementation to meet water quality requirements of the UDOT Phase 1 Municipal UPDES Permit conditions (UTRS000003, Control Measure 5, post-construction water quality controls) and Utah Division of Water Quality Construction Permit requirements (R317-1-2).

Stormwater discharges from urban areas contain potential pollutants that can be characterized by land use activities and are largely dependent on climate patterns. Typical pollutants of concern for transportation use drainage basins consist of: sediment, floatables, metals, pesticides and herbicides and petroleum hydrocarbons. Specific land use analysis and evaluation of potential pollutants of concern is required prior to the design of treatment BMPs. Total suspended solids may be a target constituent of treatment BMPs, as the average concentration in local urban stormwater is 116 mg/l, based on monitoring data by Salt Lake County, Salt Lake City and UDOT. The same data indicates that oil and grease concentrations in stormwater flows to be typically in the range of 5 – 10 mg/l. Hydrodynamic separators cannot treat oil and grease in stormwater runoff to lower levels.

Methods to estimate or predict pollutant loads are documented and recognized by many federal and state agencies. USGS and EPA both recognize quantitative analysis methods to estimate pollutant loads to receiving waters conveyed by stormwater runoff. Prediction of annual or storm event pollutant loads may be conducted to assist with the selection, operation and maintenance of stormwater treatment BMP’s. These methods are highly sensitive to land use, percent impervious areas and precipitation events, and therefore produce a wide range of potential loading numbers.

6.2 Recommendations

To remove sediment from stormwater discharges, hydrodynamic separators may be considered to treat small storm events or the first flush produced during larger storm events. A design water quality storm event of 0.5 inches of rainfall has been identified as design criteria to size the water quality control measure.

If hydrodynamic separators are chosen as the treatment control, additional design criteria include sediment storage capacity of the device, head loss, sediment particle size and overall efficiency of the treatment measure. Flows exceeding the design event will need to be routed around, or bypass the treatment device. The hydrodynamic separator also provides some capacity to contain spills and litter (floatables) that occur within the basin or in hot spot areas. However, due to the high removal efficiency of solids, these treatment devices must be maintained on a regular basis; otherwise, re-suspension of settled particles will occur. It is recommended that a strong maintenance program be implemented if these devices are utilized. It is also recommended that some monitoring be conducted on the units, to document removal efficiencies and collection of floatables.

It is recommended that new or redeveloped drainage basins be evaluated for potential pollutant discharges, in accordance with state and federal requirements. If structural control measures are determined to be necessary, the measures should be chosen based on the following criteria:

- Target pollutants and removal efficiencies
- Assess end of pipe treatment and/or upper basin controls measures
- Water quality design flow (or volume) to be treated
- Evaluation of land based or proprietary control measures
- Forecasted operation and maintenance costs

Hydrodynamic separators should be considered as a structural control measure, along with other measures as infiltration basins, extended detention basins, constructed wetlands and biofiltration ditches and swales.

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APPENDIX A

Chapter 1 - Supporting Documents

Salt Lake County Stormwater Sampling Results

Salt Lake City Stormwater Sampling Results

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SUMMARY OF RESPRESENTATIVE SAMPLING ANALYSES
DEL-02/DEL-01 OUTFALL-COMMERCIAL/ RAW LAB RESULTS

	EPA		DEL-02																									DEL-01														
			STORM COMPOSITE	STORM COMPOSITE	BASEFLOW GRAB	STORM COMPOSITE	STORM COMPOSITE	STORM GRAB	STORM COMPOSITE	(sampler problems)	BASEFLOW GRAB	STORM GRAB	STORM COMPOSITE (2)	BASEFLOW GRAB	STORM GRAB	STORM COMPOSITE	BASEFLOW GRAB	STORM GRAB	STORM COMPOSITE	(lack of precipitation)	BASEFLOW GRAB	STORM GRAB	STORM COMPOSITE	(not sampled)	BASEFLOW GRAB	STORM GRAB	(not sampled)	(not sampled/being relocated)	STORM GRAB	STORM COMPOSITE	STORM GRAB	STORM COMPOSITE	STORM COMPOSITE	BASEFLOW GRAB	STORM GRAB	STORM COMPOSITE	STORM COMPOSITE	COMPOSITE DUPLICATE	(not sampled)	BASEFLOW GRAB	STORM GRAB	STORM COMPOSITE
			Event 1	Event 2	Event 3		Event 4	Event 5		Event 6	Event 7			Event 8			Event 9			Event 10	Event 11			Event 12	Event 13		Event 14	Event 15	Event 16		Event 17		Event 18	Event 19			Event 20		Event 21	Event 22		
CONSTITUENT	Method	Method Limit	9/14/92	4/1/93	6/18/93	6/18/93	10/14/94	9/29/95	9/29/95	5/16/96	9/26/97	9/26/97	9/26/97	10/11/97	10/11/97	10/11/97	6/4/98	6/4/98	6/4/98	10/16/98	4/20/99	4/20/99	4/20/99	5/13/99	6/2/99	6/2/99	11/17/99	5/10/00	10/10/00	10/10/00	5/16/01	5/16/01	10/9/01	4/15/02	4/15/02	4/15/02	5/8/03	5/8/03	11/3/03	3/26/04	3/26/04	3/26/04
METALS (mg/l)																																										
Selenium	270.3	0.005 mg/l	<0.005	<0.005	ND	ND	<0.005																																			
Selenium-Dissolved	270.3	0.005 mg/l	<0.005	<0.005	0.005	0.008																																				
Antimony	204.2	0.005 mg/l	<0.005	<0.01	ND	ND	<0.01																																			
Antimony-Dissolved	240.2	0.01 mg/l	<0.005	<0.01	ND	ND																																				
Arsenic	206.2	0.01 mg/l	<0.01	<0.01	0.01	<0.01	<0.01																																			
Arsenic-Dissolved	206.2	0.01 mg/l	<0.01	<0.01	<0.01	<0.01																																				
Beryllium	210.2	0.00025 mg/l	<0.0005	<0.00025	ND	ND	<0.005																																			
Beryllium-Dissolved	7091	0.00025 mg/l	<0.0005	<0.00025	ND	ND																																				
Cadmium	213.2	0.0005 mg/l	0.0009	0.0006	ND	0.0009	<0.004	<0.02	<0.02						<0.020	<0.020		0.002	<0.004		0.002	0.003	0.003		0.002	0.004			<0.003	<0.003	<0.0005		<0.0005	<0.004	<0.004	<0.004	<0.004	<0.004		< 0.004	< 0.004	< 0.004
Cadmium-Dissolved	200.7	0.0005 mg/l	<0.0005	0.0011	ND	ND																							<0.006	<0.003	<0.0005	<0.0005	<0.0005	<0.004	<0.004	<0.004	<0.004	<0.004		< 0.004	< 0.004	< 0.004
Chrominum	218.2	0.0015 mg/l	0.0073	0.009	ND	0.0039	<0.006																																			
Chrominum-Dissolved	218.2	0.002 mg/l	0.0053	0.008	ND	0.0028																																				
Copper	220.2	0.002 mg/l	0.021	0.037	0.003	0.037	0.018	0.02	0.03						<0.050	<0.050		0.15	0.04		0.009	0.053	0.036		0.007	0.027			0.021	0.033	0.02		0.02	<0.01	0.04	0.037	0.018	0.032		0.0042	0.0044	0.042
Copper-Dissolved	200.7	0.002 mg/l	0.014	0.035	0.003	0.025																							<0.2	0.015	0.01	0.011	0.01	<0.01	<0.01	<0.01	0.0066	0.0062		< 0.004	< 0.004	0.008
Lead	239.2	0.003 mg/l	0.034	0.052	ND	0.034	0.007	<0.15	<0.15						<0.20	<0.20		0.1	<0.05		0.04	0.10	0.06		<0.03	0.03				<0.03	<0.005		<0.005	<0.03	<0.03	<0.03	0.0089	0.016		< 0.005	< 0.005	0.023
Lead-Dissolved	200.7	0.003 mg/l	0.014	0.05	ND	0.004																								<0.03	<0.005	<0.005	<0.005	<0.03	<0.03	<0.03	<0.005	<0.005		< 0.005	< 0.005	< 0.005
Nickel	249.2	0.002 mg/l	0.004	<0.002	ND	0.003	<0.02																																			
Nickel-Dissolved	249.2	0.002 mg/l	0.003	0.002	ND	ND																																				
Silver	272.2	0.001 mg/l	<0.005	<0.0005	0.001	ND	<0.003																																			
Silver-Dissolved	272.2	0.0005 mg/l	<0.005	<0.0005	ND	ND																																				
Zinc	289.2	0.0025 mg/l	0.06	0.139	0.00237	0.121	0.034	<0.3	<0.30						<0.15	<0.15		0.6	0.136		<0.18	<0.18	<0.18		<0.18	<0.18			<0.08	0.11	0.03		0.03	<0.05	0.17	0.17	0.065	0.12		0.06	0.06	0.19
Zinc-Dissolved	200.7	0.0005 mg/l	0.04	0.123	0.00218	0.0717																							<0.16	<0.08	0.05	0.04	0.05	<0.05	<0.05	<0.05	0.017	0.017		0.045	0.04	0.034
Thallium	279.2	0.01 mg/l	<.002	<0.01	ND	ND	<0.01																																			
Thallium-Dissolved	279.2	0.01 mg/l	<0.002	<0.01	ND	ND																																				
Mercury	245.1	0.0005 mg/l	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005																																			
Mercury-Dissolved	245.1	0.0005 mg/l	<0.0005	<0.0005	<0.0005	<0.0005																																				
FECAL STREPTOCOCCI (cfu/100 ml)	SM 910A	1		1,000 CFU		1,800 CFU		TNTC			TNTC	TNTC						TNTC			72	168																		< 1,000	7,800	
FECAL COLIFORMS (cfu/100 ml)	SM909C	1		30 CFU		7,000 CFU		TNTC			TNTC	TNTC						TNTC			100	>800																		3,000	1,200	
pH	150.1	0.01			7.93	7.94	7.65	7.77	8.02		7.97	7.89			8.27	8.25		8.09	8.05		8.15	8.13	8.27		8.19	8.11			7.93	7.26	7.57	7.48	7.57	8.67	8.1	8.03	7.9	7.9		7.92	8.02	8.08
TSS (mg/l)	160.2	4 mg/l	50	114	<4	87	20	145	63						52	34		625	242		7.2	22.8	126		7.6	116			78.9	51	77.0	22	77.0	42.4	335	206	67	28		7	12	170
TDS (mg/l)	160.1	10 mg/l	520	440	1850	360	124	632	288						1230	795		233	409		930	807	788		898	818			1450	439	154	322	154	2500	2230	1040	140	140		2,600	2,600	310
HARDNESS (mg/l)	130.2	5 mg/l	188		910			310	140						528	380		188	220		460	412	416		444	452			564	176	72.0		72.0	766	642	295	72	98		720	700	120
TKN (mg/l)	351.2	0.2 mg/l			<0.5										1.6	1.6		3	1		<2.0	<2.0	<2.0		<2.0	<2.0			5.04		2.46	1.68	2.46	1.6	5.38	4.2	1.2	0.95		2.1	3.3	6.6
N (nitrate) (mg/l)	353.3	0.05 mg/l			3.79		0.42								1.9	1.4		0.79	1.08		1.24	1.61			1.24	1.61			1.9	1.9	0.53	0.607	0.53	5.72	6.09	4.49	0.7	0.7		4.30	4.2	0.83
N (nitrite) (mg/l)	300.0	0.02 m/gl													<0.2	<0.2		<0.05	<0.05		<0.01	<0.01			<0.01	<0.01			<0.05	<0.02	<0.02	<0.02	<0.02	<0.075	<0.075	2.86						
N (ammonia) (mg/l)	350.2	0.1 mg/l			<0.5										<1	<1		0.4	0.2		0.2	0.2	0.3		0.4	0.2			1.06		1.06		1.06	0.4	1.68	1.57	0.31	0.29		0.15	0.18	0.93
N (organic) (mg/l)	350.3	.15 mg/l			<0.5		<0.5	2.1	1.8						<2	<2		2	0.9																							
Orthophosphate P (mg/l)	365.3	.02 mg/l			0.06		0.16	0.15	0.09						<0.5	<0.5		<0.3	<0.3		<0.1	<0.1	<0.1		<0.1	<0.02			<0.5	<0.2	<0.2	<0.2	<0.2	<0.5	<0.5	<0.5	0.11	0.097		0.14	0.14	0.26
P (total P) (mg/l)	365.3	.02 mg/l			0.07		0.24	0.39	0.18						0.13	0.19		0.84	0.2		0.2	0.3	0.3		0.14	0.3			1.24	0.62	0.527	0.378	0.527	0.187	0.818	0.638	0.18	0.14		0.31	0.31	0.49
P (soluable P) (mg/l)	365.3	.02 mg/l			0.06		0.22																																			
Total Recoverable Phenolics	420.1	.05 mg/l			<0.05			0.002																																		
BOD (total) (mg/l)	405.1	2 mg/l	9	7	<2	13	5	22	9		24	7			<6	7		6	4		<12	10	6		2	16			22	51	24.6	12.5	24.6	5.32	>36.8	25	6	6		< 5	< 5	26
COD (mg/l)	410.1	20 mg/l		20	<20		71	121	58						63	66		217	89		37	71	73		2	16			172	123	92.7	88.5	92.7	71.1	243	193	43	36		28	38	130
Cyanide (total) (mg/l)	335.2	.005 mg/l			<0.005		<0.005																																			
Oil and Grease (mg/l)	413.2	1 mg/l		5	1.1	<1.0	2.4	7							<5			10			<4	<4			<4				<1.9		<2.1		<2.1	<1.8	1.9					3.9	< 3	
TPH (mg/l)	418.1	1 mg/l		<2.0	<1.0	<1.0	<1.0	<1																																		

ND Not Detected
TNTC To Numerous to Count
(1) No priority pollutant constituents were detected (mg/l)
(2) Not enough precipitation for composite
(3) DEL-02 Station moved in 2000 due to difficulties w/ existing station
Highlighted area indicates this data was not included in load or EMC calculations (see annual report text for further description)

SUMMARY OF RESPRESENTATIVE SAMPLING ANALYSES
DEL-05 OUTFALL-INDUSTRIAL/ RAW RESULTS

DEL-05

	EPA		Event 1	Event 2	Event 3		Event 4	Event 5		Event 6			Event 7			Event 8			Event 9			Event 10
			STORM COMPOSITE	STORM COMPOSITE	BASEFLOW GRAB	STORM COMPOSITE	STORM COMPOSITE	STORM GRAB	STORM COMPOSITE	BASEFLOW GRAB	STORM GRAB	STORM COMPOSITE	BASEFLOW GRAB	STORM GRAB	STORM COMPOSITE (2)	BASEFLOW GRAB	STORM GRAB	STORM COMPOSITE	BASEFLOW GRAB	STORM GRAB	STORM COMPOSITE	(lack of precipitation)
CONSTITUENT	Method	Method Limit	9/14/92	4/1/93	6/18/93	6/18/93	10/14/94	9/29/95	9/29/95	5/16/96	5/16/96	5/16/96	9/26/97	9/26/97	9/26/97	10/11/97	10/11/97	10/11/97	6/4/98	6/4/98	6/4/98	10/16/98
METALS (mg/l)																						
Selenium	270.3	0.005 mg/l		<0.005		ND	<0.005															
Selenium-Dissolved	270.3	0.005 mg/l		<0.005		<0.005																
Antimony	204.2	0.005 mg/l		<0.01		ND	<0.01															
Antimony-Dissolved	240.2	0.01 mg/l		<0.01		ND																
Arsenic	206.2	0.01 mg/l		<0.01		<0.01	<0.01															
Arsenic-Dissolved	206.2	0.01 mg/l		<0.01		<0.01																
Beryllium	210.2	0.00025 mg/l		<0.00025		ND	<0.005															
Beryllium-Dissolved	7091	0.00025 mg/l		<0.00025		ND																
Cadmium	213.2	0.0005 mg/l		0.0008		0.0009	<0.004	<0.02	<0.02	<0.02	<0.02	<0.02					<0.020	<0.020		<0.002	<0.004	
Cadmium-Dissolved	200.7	0.0005 mg/l		0.001		ND																
Chrominum	218.2	0.0015 mg/l		0.01		0.0077	<0.006															
Chrominum-Dissolved	218.2	0.002 mg/l		0.009		0.0019																
Copper	220.2	0.002 mg/l		0.018		0.043	0.024	0.02	0.05	<0.1	<0.1	<0.1					<0.050	<0.050		0.06	0.04	
Copper-Dissolved	200.7	0.002 mg/l		0.017		0.024																
Lead	239.2	0.003 mg/l		0.017		0.031	0.023	<0.15	<0.15	<0.15	<0.15	<0.15					<0.20	<0.20		0.1	<0.05	
Lead-Dissolved	200.7	0.003 mg/l		0.015		0.003																
Nickel	249.2	0.002 mg/l		<0.005		0.004	<0.02															
Nickel-Dissolved	249.2	0.002 mg/l		<0.002		0.002																
Silver	272.2	0.001 mg/l		<0.0005		0.003	<0.003															
Silver-Dissolved	272.2	0.0005 mg/l		<0.0005		ND																
Zinc	289.2	0.0025 mg/l		0.0766		0.189	0.11	<0.3	0.32	<0.25	0.4	0.32					<0.15	<0.15		0.3	0.194	
Zinc-Dissolved	200.7	0.0005 mg/l		0.0732		0.0546																
Thallium	279.2	0.01 mg/l		<0.01		ND	<0.01															
Thallium-Dissolved	279.2	0.01 mg/l		<0.01		ND																
Mercury	245.1	0.0005 mg/l		<0.0005		<0.0005	<0.0005															
Mercury-Dissolved	245.1	0.0005 mg/l		<0.0005		0.0005																
FECAL STREPTOCOCCI (cfu/100 ml)	SM 910A	1		11,000 CFU		1,700 CFU		2940 CFU		400 CFU	230 CFU		TNTC	TNTC						TNTC		
FECAL COLIFORMS (cfu/100 ml)	SM909C	1		20 CFU		5,000 CFU		TNTC		240 CFU	160 CFU		TNTC	TNTC						TNTC		
pH	150.1	0.01				7.95	8.38	8.06	7.92	8.25	8.02	7.99	7.86	8.02			7.38	7.68		8.88	8.32	
TSS (mg/l)	160.2	4 mg/l		60		102	188	119	144	<20	206	117					64			296	652	
TDS (mg/l)	160.1	10 mg/l		410		190	130	808	348	3030	200	318					120			75	124	
HARDNESS (mg/l)	130.2	5 mg/l						487	140	530	112	110					60	56		96	84	
TKN (mg/l)	351.2	0.2 mg/l															<1.5	<1.5		1.0	1.0	
N (nitrate) (mg/l)	353.3	0.05 mg/l					0.42			2	<0.2	<0.5					0.40	0.29		0.39	0.41	
N (nitrite) (mg/l)	300.0	0.02 mg/l															<0.2	<0.2		<0.05	0.05	
N (ammonia) (mg/l)	350.2	0.1 mg/l															<1	<1		0.5	0.2	
N (organic) (mg/l)	350.3	.15 mg/l						1.5		<3	<2	<2					<2	<2		0.7	0.7	
Orthophosphate P (mg/l)	365.3	.02 mg/l						0.18	0.15	0.29	0.18	0.12					<0.1	<0.5		<0.3	<0.3	
P (total P) (mg/l)	365.3	.02 mg/l						0.49		0.35	0.62	0.49					0.17	0.17		0.44	0.24	
P (soluable P) (mg/l)	365.3	.02 mg/l																				
Total Recoverable Phenolics	420.1	.05 mg/l						<0.001														
BOD (total) (mg/l)	405.1	2 mg/l		<6		25	8	26	30	5.9	12.1	14.3	20	20			11			5	4	
COD (mg/l)	410.1	20 mg/l		20		120		125		<50	<50	<50					68	62		82	78	
Cyanide (total) (mg/l)	335.2	.005 mg/l																				
Oil and Grease (mg/l)	413.2	1 mg/l		6		3.8	2.1	2		<5	7	<5					<4			3		
TPH (mg/l)	418.1	1 mg/l		2.4		2.1	1.3	<1														

	Event 11			Event 12	Event 13			Event 14	Event 15			Event 16		Event 17		Event 18		Event 19			Event 20	Event 21	Event 22
	BASEFLOW GRAB	STORM GRAB	STORM COMPOSITE	(not sampled)	BASEFLOW GRAB	STORM GRAB	STORM COMPOSITE	(not sampled)	BASEFLOW GRAB	STORM GRAB	STORM COMPOSITE	STORM GRAB	STORM COMPOSITE	STORM GRAB	STORM COMPOSITE	STORM GRAB	STORM COMPOSITE	BASEFLOW GRAB	STORM GRAB	STORM COMPOSITE	STORM COMPOSITE	(not sampled)	(station not active)
CONSTITUENT	4/20/99	4/20/99	4/20/99	5/13/99	6/2/99	6/2/99	6/2/99	11/17/99	5/10/00	5/10/00	5/10/00	10/10/00	10/10/00	5/16/01	5/16/01	10/9/01	10/9/01	4/15/02	4/15/02	4/15/02	5/8/03	11/3/03	3/26/04
METALS (mg/l)																							
Selenium																							
Selenium-Dissolved																							
Antimony																							
Antimony-Dissolved																							
Arsenic																							
Arsenic-Dissolved																							
Beryllium																							
Beryllium-Dissolved																							
Cadmium	0.002	0.003	0.003		<0.002	0.004	0.004		<0.003	<0.003	<0.003	<0.003	0.003	0.0005		<0.004	<0.004	<0.004	0.0046	<0.004	<0.004		
Cadmium-Dissolved												<0.006	<0.003	<0.0005	<0.0005	<0.004	<0.004			<0.004	<0.004		
Chrominum																							
Chrominum-Dissolved																							
Copper	0.034	0.078	0.051		0.014	0.112	0.123		0.07	0.042	0.027	0.027	0.042	0.02		<0.01	0.053	0.05	0.161	0.0516	0.076		
Copper-Dissolved												0.028	0.027	0.008	0.012	<0.01	<0.01			0.013	<0.004		
Lead	0.03	0.06	0.04		<0.03	0.12	0.1		0.077	0.06	0.039		0.071	0.02		<0.03	<0.03	0.05	0.14	0.047	0.073		
Lead-Dissolved													<0.03	<0.005	<0.005	<0.03	<0.03			<0.03	<0.005		
Nickel																							
Nickel-Dissolved																							
Silver																							
Silver-Dissolved																							
Zinc	0.2	0.4	0.25		<0.18	0.5	0.6		0.384	0.365	0.17	0.21	0.2	0.17		<0.05	0.351	0.2	0.685	0.329	0.49		
Zinc-Dissolved												<0.16	<0.08	0.02	0.03	<0.05	0.091			<0.05	0.016		
Thallium																							
Thallium-Dissolved																							
Mercury																							
Mercury-Dissolved																							
FECAL STREPTOCOCCI (cfu/100 ml)	80	60																					
FECAL COLIFORMS (cfu/100 ml)	300	>800																					
pH	8.10	7.85	8.39		7.62	8.2	7.84		8.13	8.4	8.01	8.97	7.69	8.90	8.09	8.45	8.00	8.08	8.31		7.89		
TSS (mg/l)	<5	<12.5	182		38.8	483	81.2		185	182	64	58	52	71.0	44	9.6	162	217	1630	353	300		
TDS (mg/l)	1660	623	259		808	146	449		205	456	262	490	482	333	292	1050	369	2500	1310	932	250		
HARDNESS (mg/l)	340	240	104		268	184	200		120	112	76	136	108	64.0				478	762	258	130		
TKN (mg/l)	<2.0	4.7	33		2.24	<2	3.7		<2.0	<2.0	<2.0	2.35	2.18	1.51		0.90	3.47	6.1	9.8	3.92	2.8		
N (nitrate) (mg/l)	0.37	0.48	0.44		0.37	0.48	0.44		0.92	0.05	0.47	0.63	0.99	0.47	0.534			5.58	4.53	4.55	0.6		
N (nitrite) (mg/l)	<0.01	<0.01	<0.01		<0.01	<0.02	<0.01		0.17	<0.03	<0.05	0.27	0.33	<0.02	<0.02			<0.075	<0.075	<0.075			
N (ammonia) (mg/l)	0.2	2	1		0.3	0.5	4		0.78	0.53	5.82	1.06		0.896		<0.1		6.72	2.46	1.51	0.44		
N (organic) (mg/l)																							
Orthophosphate P (mg/l)	0.1	0.4	<0.1		<0.1	<0.02	<0.1		<0.1	<0.3	<0.1	<0.1	<0.2	<0.2	<0.2	<1.2	<1.2	<0.5	<0.5	<0.5	0.11		
P (total P) (mg/l)	0.5	0.9	0.3		0.3	0.6	0.7		0.68	0.58	0.46	0.36	0.42	0.213	0.243	3.49	1.93	1.4	0.771	0.779	0.64		
P (soluable P) (mg/l)																							
Total Recoverable Phenolics																							
BOD (total) (mg/l)	9	35	10		5	9	14		29.4	11.9	17.2	19	21	9.54	10.3	<2	23.9	>34.7	66.7	20.9	10		
COD (mg/l)	81	272	107		57	178	230		70.4	53.5	57.8	119	103	53	65.7	46.8	141	344	434	216	130		
Cyanide (total) (mg/l)																							
Oil and Grease (mg/l)	<4	<4			<4	33			<1.9	<2.7		<1.9		4.6		2.3		4.9	6.1				
TPH (mg/l)																							

ND Not Detected
TNTC To Numerous to Count
(1) No priority pollutant constituents were detected (mg/l)
(2) Not enough precipitation for composite
Highlighted area indicates this data was not included in load or EMC calculations (see annual report text for further description)

SUMMARY OF RESPRESENTATIVE SAMPLING ANALYSES
JOR-01 OUTFALL-REPRESENTATIVE MIX/ RAW LAB RESULTS

JOR-01

CONSTITUENT	EPA Method	Method Limit	Event 1 9/14/92 STORM COMPOSITE	Event 2 4/1/93 STORM COMPOSITE	Event 3 6/18/93 BASEFLOW GRAB	Event 3 6/18/93 STORM COMPOSITE	Event 4 10/14/94 STORM COMPOSITE	Event 5 9/29/95 STORM GRAB	Event 5 9/29/95 STORM COMPOSITE	Event 6 5/16/96 BASEFLOW GRAB	Event 6 5/16/96 STORM GRAB	Event 6 5/16/96 STORM COMPOSITE	Event 7 9/26/97 BASEFLOW GRAB	Event 7 9/26/97 STORM GRAB	Event 7 9/26/97 STORM COMPOSITE (2)
METALS (mg/l)															
Selenium	270.3	0.005 mg/l	0.005	<0.005	ND	ND	<0.005								
Selenium-Dissolved	270.3	0.005 mg/l	<0.005	<0.005	ND	<0.005									
Antimony	204.2	0.005 mg/l	<0.005	<0.01	ND	ND	<0.01								
Antimony-Dissolved	240.2	0.01 mg/l	<0.005	<0.01	ND	ND									
Arsenic	206.2	0.01 mg/l	<0.01	<0.01	ND	<.010	<0.01								
Arsenic-Dissolved	206.2	0.01 mg/l	<0.01	<0.01	ND	<0.01									
Beryllium	210.2	0.00025 mg/l	<0.0005	<0.00025	ND	ND	<0.005								
Beryllium-Dissolved	7091	0.00025 mg/l	<0.0005	<0.00025	ND	ND									
Cadmium	213.2	0.0005 mg/l	0.0009	0.0024	ND	0.0013	<0.004	<0.02	<0.02	<0.02	<0.02	<0.02			
Cadmium-Dissolved	213.2	0.0005 mg/l	0.0008	0.0024	ND	ND									
Chrominum	218.2	0.0015 mg/l	0.005	0.0032	0.0018	0.0098	<0.006								
Chrominum-Dissolved	218.2	0.002 mg/l	0.0052	0.0035	0.0016	0.0021									
Copper	220.2	0.002 mg/l	0.018	0.043	ND	0.072	0.031	0.08	0.05	<0.1	0.14	<0.1			
Copper-Dissolved	220.2	0.002 mg/l	0.02	0.043	ND	0.023									
Lead	239.2	0.003 mg/l	0.05	0.131	ND	0.143	0.06	0.18	<0.15	<0.15	<0.15	<0.15			
Lead-Dissolved	239.2	0.003 mg/l	0.047	0.12	ND	0.013									
Nickel	249.2	0.002 mg/l	0.003	0.002	ND	0.005	<0.02								
Nickel-Dissolved	249.2	0.002 mg/l	0.003	0.002	ND	0.002									
Silver	272.2	0.001 mg/l	<0.005	<0.0005	ND	ND	<0.003								
Silver-Dissolved	272.2	0.0005 mg/l	<0.005	<0.0005	ND	0.005									
Zinc	289.2	0.0025 mg/l	0.08	0.206	0.0098	0.252	0.146	0.52	<0.3	<0.25	0.64	0.33			
Zinc-Dissolved	289.2	0.0005 mg/l	0.1	0.201	0.0089	0.0599									
Thallium	279.2	0.01 mg/l	<0.002	<0.01	ND	ND	<0.01								
Thallium-Dissolved	279.2	0.01 mg/l	<0.002	<0.01	ND	ND									
Mercury	245.1	0.0005 mg/l	<0.002	<0.01	ND	ND	<0.0005								
Mercury-Dissolved	245.1	0.0005 mg/l	<0.0005	<0.0005	<0.0005	<0.0005									
FECAL STREPTOCOCCI (cfu/100 ml)	SM 910A	1		2,000 CFU	44 CFU	3,500 CFU		TNTC		31 CFU	2,000 CFU				
FECAL COLIFORMS (cfu/100 ml)	SM909C	1		360 CFU	24 CFU	4,000 CFU		TNTC		80 CFU	1,800 CFU				
pH	150.1	0.01			8.1	7.96	7.86	7.89	7.57	8.31	7.77	8.28	7.51	7.61	
TSS (mg/l)	160.2	4 mg/l	57	189	9	194	124	552	207	65	224	348			
TDS (mg/l)	160.1	10 mg/l	810	130	260	170	106	352	260	458	248	162			
HARDNESS (mg/l)	130.2	5 mg/l	106		140			220	155	220	178	166			
TKN (mg/l)	351.2	0.2 mg/l			<0.5										
N (nitrate) (mg/l)	353.3	0.05 mg/l			0.97		0.59			<1.0	<0.5	0.7			
N (nitrite) (mg/l)	300.0	0.02 mg/l													
N (ammonia) (mg/l)	350.2	0.1 mg/l			<0.5										
N (organic) (mg/l)	350.3	.15 mg/l			<0.5		0.9	4	1.6	<2	3	<2			
Orthophosphate P (mg/l)	365.3	.02 mg/l			<0.02		0.09	0.19	0.14	<0.02	0.48	0.15			
P (total P) (mg/l)	365.3	.02 mg/l			<0.02		0.31	0.91	0.44	<0.08	1.1	0.94			
P (soluable P) (mg/l)	365.3	.02 mg/l			<0.02		0.26								
Total Recoverable Phenolics	420.1	.05 mg/l			<0.05		0.047	0.01							
BOD (total) (mg/l)	405.1	2 mg/l	12.1	7	<2	19	7	33	19	4.6	12	18	18	17	
COD (mg/l)	410.1	20 mg/l		<20	<20	160	80	315	146	<50	115	170			
Cyanide (total) (mg/l)	335.2	.005 mg/l			<0.005		<0.005								
Oil and Grease (mg/l)	413.2	1 mg/l		<2	1.4	3.2	2.6	24		68	14	<5			
TPH (mg/l)	418.1	1 mg/l		2.4	1.3	2.6	<1.0	8.9							

CONSTITUENT	Event 8 10/11/97 BASEFLOW GRAB	Event 8 10/11/97 STORM GRAB	Event 8 10/11/97 STORM COMPOSITE	Event 9 6/4/98 BASEFLOW GRAB	Event 9 6/4/98 STORM GRAB	Event 9 6/4/98 STORM COMPOSITE	Event 10 10/16/98 BASEFLOW GRAB	Event 10 10/16/98 STORM GRAB	Event 10 10/16/98 STORM COMPOSITE	Event 11 4/20/99 (<0.1 predicted)	Event 12 5/13/99 (sampler failed)	Event 13 6/2/99 BASEFLOW GRAB	Event 13 6/2/99 STORM GRAB	Event 13 6/2/99 STORM COMPOSITE	Event 14 11/17/99 (lack of precipitation)
METALS (mg/l)															
Selenium															
Selenium-Dissolved															
Antimony															
Antimony-Dissolved															
Arsenic															
Arsenic-Dissolved															
Beryllium															
Beryllium-Dissolved															
Cadmium	<0.020	<0.020	<0.020	<0.004	0.004	0.004	<0.004	0.006	<0.004			0.002	0.006	0.003	
Cadmium-Dissolved															
Chrominum															
Chrominum-Dissolved															
Copper	<0.050	<0.050	0.051	0.0100	0.27	0.08	0.022	0.312	0.075			0.064	0.097	0.081	
Copper-Dissolved															
Lead			<0.20	<0.05	0.36	0.08	<0.050	0.414	0.089			<0.03	0.11	0.11	
Lead-Dissolved															
Nickel															
Nickel-Dissolved															
Silver															
Silver-Dissolved															
Zinc	0.1600	0.21	<0.15	0.0500	1.07	0.302	0.121	1.02	0.286			0.5	0.6	0.43	
Zinc-Dissolved															
Thallium															
Thallium-Dissolved															
Mercury															
Mercury-Dissolved															
FECAL STREPTOCOCCI (cfu/100 ml)				752	TNTC										
FECAL COLIFORMS (cfu/100 ml)				>400	>2000										
pH	8.72	9.04	8.53	8.19	8.54	8.13	7.94	8.36	8.21			8.31	8.22	7.67	
TSS (mg/l)	450	660	324	22	2170	426	70	3070	222			39.2	447	33.2	
TDS (mg/l)	151	116	153	293	247	163	207	212	112			1080	153	137	
HARDNESS (mg/l)	160	148	104	148	472	124	180	2650	112			192	132	120	
TKN (mg/l)	<1.5	<1.5	<1.5	<1	4	2	1	4				2.24	3.02		
N (nitrate) (mg/l)	0.80	0.5	0.7	1.47	0.78	0.57	0.60	1.73	0.74			2.83	0.48	0.92	
N (nitrite) (mg/l)	<0.2	<0.2	<0.2	<0.05	0.1	<0.05	0.046	0.17	0.10			<0.04	0.08	0.28	
N (ammonia) (mg/l)	<1	<1	<1	0.3	0.9	0.1	0.2	1.8				2	1		
N (organic) (mg/l)	<2	<2	<2	<0.1	3	2	0.6	2							
Orthophosphate P (mg/l)	<0.5	<0.1	<0.5	<0.3	0.5	<0.3	<0.2	<0.2	<0.2			22.7	0.2	<0.2	
P (total P) (mg/l)	0.64	0.88	0.62	0.09	1.55	0.54	0.14	2	0.54			0.4	0.7	0.6	
P (soluable P) (mg/l)															
Total Recoverable Phenolics															
BOD (total) (mg/l)	29	19	9	2	14	8	4	2	17			5	26	18	
COD (mg/l)	98	84	73	46	338	130	67	454	166			306	256		
Cyanide (total) (mg/l)															
Oil and Grease (mg/l)	<5	<5		3	9		<4.0	8.2				<4	<4		
TPH (mg/l)															

CONSTITUENT	Event 15 5/10/00 BASEFLOW GRAB	Event 15 5/10/00 STORM GRAB	Event 15 5/10/00 STORM COMPOSITE	Event 16 10/10/00 (missed storm peak)	Event 17 5/16/01 STORM GRAB	Event 17 5/16/01 STORM GRAB DUPLICATE	Event 17 5/16/01 STORM COMPOSITE	Event 18 10/8/01 (sampler malfunction)	Event 19 4/15/02 BASEFLOW GRAB	Event 19 4/15/02 STORM GRAB	Event 19 4/15/02 STORM COMPOSITE	Event 20 5/7/03 (station not active)	Event 21 11/13/03 (station not active)	Event 22 3/26/04 (sampler malfunction)
METALS (mg/l)														
Selenium														
Selenium-Dissolved														
Antimony														
Antimony-Dissolved														
Arsenic														
Arsenic-Dissolved														
Beryllium														
Beryllium-Dissolved														
Cadmium	<0.003	<0.003	<0.003		0.0006	0.0007	0.0012		<0.004	0.0048	<0.004			
Cadmium-Dissolved					<0.0005	<0.0005	<0.0005		<0.004	<0.004	<0.004			
Chrominum														
Chrominum-Dissolved														
Copper	0.046	0.062	0.037		0.035	0.037	0.048		<0.01	0.183	0.111			
Copper-Dissolved					0.017	0.015	0.037		<0.01	0.019	<0.01			
Lead	0.043	0.061	0.034		0.025	0.03	0.04		<0.03	0.14	0.15			
Lead-Dissolved					0.005	<0.005	<0.005		<0.03	<0.03	<0.03			
Nickel														
Nickel-Dissolved														
Silver														
Silver-Dissolved														
Zinc	0.239	0.33	0.163		0.26	0.27	0.31		0.12	0.991	0.783			
Zinc-Dissolved					0.13	0.12	0.09		0.068	<0.05	0.067			
Thallium														
Thallium-Dissolved														
Mercury														
Mercury-Dissolved														
FECAL STREPTOCOCCI (cfu/100 ml)														
FECAL COLIFORMS (cfu/100 ml)														
pH	8.21	8.21	7.54		7.50	7.52	7.31		8.44	8.46	7.96			
TSS (mg/l)	87	352	92		108	19	126		<22	1210	342			
TDS (mg/l)	396	241	186		252	215	239		322	880	532			
HARDNESS (mg/l)	188	144	96		120	124	120		183	500	220			
TKN (mg/l)	2.24	2.02	<2.0		3.30	3.47	4.20		<0.62	8.43	6.55			
N (nitrate) (mg/l)	0.6	0.5	0.22		0.634	0.757	0.542		4.47	4.53	3.54			
N (nitrite) (mg/l)	0.4	0.43	<0.03		<0.02	<0.02	<0.02		<0.075	<0.075	2.17			
N (ammonia) (mg/l)	<0.2	0.73	0.56		1.01	1.51			0.19	2.91	2.24			
N (organic) (mg/l)														
Orthophosphate P (mg/l)	<0.3	<0.3	<0.3		<0.2	<0.2	<0.2		<0.5	<0.5	<0.4			
P (total P) (mg/l)	0.78	0.98	0.56		0.564	0.574	0.723		0.606	0.065	0.995			
P (soluable P) (mg/l)														
Total Recoverable Phenolics														
BOD (total) (mg/l)	15.5	26.8	11.5		25.0	28.7	33.5		<2	84.3	36.7			
COD (mg/l)	74.7	78.9	47.2		120	128	151		31	520	270			
Cyanide (total) (mg/l)														
Oil and Grease (mg/l)	3.02	<1.9							5.4	8.9				
TPH (mg/l)														

ND Not Detected
TNTC To Numerous to Count
(1) No priority pollutant constituents were detected (mg/l)
(2) Not enough precipitation for composite
Highlighted area indicates this data was not included in load or EMC calculations (see annual report text for further description)

SUMMARY OF RESPRESENTATIVE SAMPLING ANALYSES
JOR-04/JOR-03[3] OUTFALL-TRANSPORTATION/ RAW LAB RESULTS

	EPA		STORM COMPOSITE	STORM COMPOSITE	BASEFLOW GRAB	STORM COMPOSITE	STORM COMPOSITE	STORM GRAB	STORM COMPOSITE	BASEFLOW GRAB	STORM GRAB	STORM COMPOSITE	BASEFLOW GRAB	STORM GRAB	STORM COMPOSITE (2)
			JOR-04												
			Event 1	Event 2	Event 3		Event 4	Event 5		Event 6			Event 7		
CONSTITUENT	Method	Method Limit	9/14/92	4/1/93	6/18/93	6/18/93	10/14/94	9/29/95	9/29/95	5/16/96	5/16/96	5/16/96	9/26/97	9/26/97	9/26/97
METALS (mg/l)															
Selenium	270.3	0.005 mg/l	<0.005	<0.005	ND	ND	<0.005								
Selenium-Dissolved	270.3	0.005 mg/l	<0.005	<0.0005	0.006	<0.005									
Antimony	204.2	0.005 mg/l	0.005	<0.01	ND	ND	<0.01								
Antimony-Dissolved	240.2	0.01 mg/l	<0.005	<0.01	ND	ND									
Arsenic	206.2	0.01 mg/l	<0.01	<0.01	ND	<0.01	<0.01								
Arsenic-Dissolved	206.2	0.01 mg/l	<0.01	<0.01	ND	<0.01									
Beryllium	210.2	0.00025 mg/l	<0.0005	<0.00025	ND	ND	<0.005								
Beryllium-Dissolved	7091	0.00025 mg/l	<0.0005	<0.00025	ND	ND									
Cadmium	213.2	0.0005 mg/l	0.0008	0.0022	ND	0.0016	<0.004	<0.02	<0.02	<0.02	<0.02	<0.02			
Cadmium-Dissolved	213.2	0.0005 mg/l	0.0012	0.0025	ND	ND									
Chrominum	218.2	0.0015 mg/l	0.0091	0.013	0.0025	0.0058	<0.01								
Chrominum-Dissolved	218.2	0.002 mg/l	0.0082	0.011	0.0019	0.0042									
Copper	220.2	0.002 mg/l	0.04	0.072	0.01	0.09	0.057	<0.02	0.05	<0.1	0.2	0.17			
Copper-Dissolved	220.2	0.002 mg/l	0.057	0.114	0.009	0.028									
Lead	239.2	0.003 mg/l	0.046	0.111	ND	0.11	0.03	<0.15	<0.15	<0.15	0.150	<0.15			
Lead-Dissolved	239.2	0.003 mg/l	<0.005	0.114	ND	0.008									
Nickel	249.2	0.002 mg/l	0.005	0.003	ND	0.01	<0.02								
Nickel-Dissolved	249.2	0.002 mg/l	0.007	0.002	ND	0.002									
Silver	272.2	0.001 mg/l	<0.005	<0.0005	ND	0.003	<0.003								
Silver-Dissolved	272.2	0.0005 mg/l	<0.005	0.0008	ND	ND									
Zinc	289.2	0.0025 mg/l	0.1	0.236	0.0317	0.283	<3.5	<0.3	<0.3	<0.25	0.83	0.603			
Zinc-Dissolved	289.2	0.0005 mg/l	0.15	0.242	0.04	0.0938									
Thallium	279.2	0.01 mg/l	<0.002	<0.01	ND	ND	<0.01								
Thallium-Dissolved	279.2	0.01 mg/l	<0.002	<0.01	ND	ND									
Mercury	245.1	0.0005 mg/l	<0.005	0.0018	<0.0005	<0.0005	<0.0005								
Mercury-Dissolved	245.1	0.0005 mg/l	0.0006	<0.0005	<0.0005	<0.0005									
FECAL STREPTOCOCCI (cfu/100 ml)	SM 910A	1		7,000	20	1,600		1070		23	2,000		TNTC	TNTC	
FECAL COLIFORMS (cfu/100 ml)	SM909C	1		500	16	22,000		TNTC		70	900		TNTC	TNTC	
pH	150.1	0.01			8.32	8.06	7.96	8.26	8.13	8.24	7.77	7.81	8.04	7.96	
TSS (mg/l)	160.2	4 mg/l	118	142	<4	193	121	33	163	<20	380	323			
TDS (mg/l)	160.1	10 mg/l	500	350	1200	460	208	1040	814	834	660	328			
HARDNESS (mg/l)	130.2	5 mg/l	120		570			470	395	378	462	174			
TKN (mg/l)	351.2	0.2 mg/l			<0.5										
N (nitrate) (mg/l)	353.3	0.05 mg/l			5.3		0.81			4	1.2	0.87			
N (nitrite) (mg/l)	300.0	0.02 mg/l													
N (ammonia) (mg/l)	350.2	0.1 mg/l			<0.5										
Orthophosphate P (mg/l)	365.3	.02 mg/l			0.04		0.22	0.05	<0.08	0.05	0.41	0.18			
P (total P) (mg/l)	365.3	.02 mg/l			0.03		0.4	0.11	0.32	<0.08	1.25	0.9			
P (soluable P) (mg/l)	365.3	.02 mg/l			0.02		0.35								
Total Recoverable Phenolics	420.1	.05 mg/l			<0.05		0.052	<0.001							
BOD (total) (mg/l)	405.1	2 mg/l	14.5	6	<2	17	5	6	17	13.6	39.8	15.5	14	17	
COD (mg/l)	410.1	20 mg/l		<20	<20	100	74	<50	201	<50	<50	<50			
Cyanide (total) (mg/l)	335.2	.005 mg/l			<0.005		0.007								
Oil and Grease (mg/l)	413.2	1 mg/l		<2.0	<1.0	<1.0	1.5	<2		52	11	7			
TPH (mg/l)	418.1	1 mg/l		<1.0	<1.0	<1.0	1.5	<1							

	BASEFLOW GRAB	STORM GRAB	STORM COMPOSITE	BASEFLOW GRAB	STORM GRAB	STORM COMPOSITE	BASEFLOW GRAB	STORM GRAB	STORM COMPOSITE	COMPOSITE DUPLICATE	(<0.1 predicted)	BASEFLOW GRAB	STORM GRAB	STORM COMPOSITE	(w/in 45 day criteria)	(lack of precipitation)
	JOR-04															
	Event 8			Event 9			Event 10				Event 11	Event 12			Event 13	Event 14
CONSTITUENT	10/11/97	10/11/97	10/11/97	6/4/98	6/4/98	6/4/98	10/16/98	10/16/98	10/16/98	10/16/98	4/20/99	5/13/99	5/13/99	5/13/99	6/2/99	11/17/99
METALS (mg/l)																
Selenium																
Selenium-Dissolved																
Antimony																
Antimony-Dissolved																
Arsenic																
Arsenic-Dissolved																
Beryllium																
Beryllium-Dissolved																
Cadmium	<0.020		<0.020	<0.002	<0.002	<0.004	0.004	<0.004	<0.004			0.002	<0.002	0.003		
Cadmium-Dissolved																
Chrominum																
Chrominum-Dissolved																
Copper	<0.050		0.051	0.98	0.03	0.12	0.011	<0.01	0.075			0.009	0.027	0.083		
Copper-Dissolved																
Lead	<0.20		<0.20	0.02	0.03	0.12	<0.050	<0.050	0.081			<0.03	0.04	0.10		
Lead-Dissolved																
Nickel																
Nickel-Dissolved																
Silver																
Silver-Dissolved																
Zinc	<0.15		<0.15	1.3	0.1	0.387	0.045	0.053	0.356			<0.18	<0.18	0.29		
Zinc-Dissolved																
Thallium																
Thallium-Dissolved																
Mercury																
Mercury-Dissolved																
FECAL STREPTOCOCCI (cfu/100 ml)				628	>800											
FECAL COLIFORMS (cfu/100 ml)				106	TNTC											
pH	8.19	8.13	8.25	8.20	8.15	8.05	8.20	8.19	8.18	8.25		8.12	7.98	8.09		
TSS (mg/l)	<10	302	228	10	51	944	2.4	7.6	254	380		<5	130	259		
TDS (mg/l)	1050	723	216	1200	1100	461	1030	1050	508	516		1250	902	522		
HARDNESS (mg/l)	512		148	560	516	128	544	552	312	316		556	432	264		
TKN (mg/l)	<1.5	2.4	<1.5	<1	1	1	<1	<1	3			<2	<2	<2		
N (nitrate) (mg/l)	7	5.5	1.3	8.30	7.52	2.30	7.13	7.05	3.53	3.61		7.24	5.13	2.48		
N (nitrite) (mg/l)	<0.2	<0.5	<0.2	<0.05	<0.05	0.07	<0.03	<0.03	0.10	0.10		<0.05	<0.05	<0.05		
N (ammonia) (mg/l)	<1	<1	<1	0.1	0.2	0.3	0.2	<0.1	0.8			<0.2	0.2	0.4		
Orthophosphate P (mg/l)	<0.5	<0.5	<0.5	<0.3	<0.3	0.5	<0.2	<0.2	<0.2	<0.2		<0.5	<0.5	<0.2		
P (total P) (mg/l)	<0.08	0.48	0.64	<0.08	0.17	0.59	<0.08	1.27	0.56	0.51		0.07	0.13	0.6		
P (soluable P) (mg/l)																
Total Recoverable Phenolics																
BOD (total) (mg/l)	<6	21	10	2	2	8	2	2	17	19		3	16	7		
COD (mg/l)	<50	109	75	80	191	137	46	46	158	148		<14	25	57		
Cyanide (total) (mg/l)																
Oil and Grease (mg/l)	199	8		2	2		<4.0	<4.0				<4	<4	NA		
TPH (mg/l)																

	BASEFLOW GRAB	STORM GRAB	STORM COMPOSITE	(missed storm peak)	STORM GRAB	STORM COMPOSITE	(missed peak storm)	BASEFLOW GRAB	STORM GRAB	STORM COMPOSITE	STORM COMPOSITE	(only MIL07 sampled)	BASEFLOW GRAB	STORM GRAB	STORM COMPOSITE
	JOR-03														
	Event 15			Event 16	Event 17		Event 18	Event 19			Event 20	Event 21	Event 22		
CONSTITUENT	5/10/00	5/10/00	5/10/00	10/10/00	5/16/01	5/16/01	10/8/01	4/15/02	4/15/02	4/15/02	5/8/03	11/13/03	3/26/04	3/26/04	3/26/04
METALS (mg/l)															
Selenium															
Selenium-Dissolved															
Antimony															
Antimony-Dissolved															
Arsenic															
Arsenic-Dissolved															
Beryllium															
Beryllium-Dissolved															
Cadmium	<0.003	<0.003	<0.003		0.0023	0.0011		<0.004	0.019	<0.004	<0.004		< 0.004	< 0.004	< 0.004
Cadmium-Dissolved					0.0009	<0.0005		<0.004	0.0096	<0.004	<0.004		< 0.004	< 0.004	< 0.004
Chrominum															
Chrominum-Dissolved															
Copper	0.018	0.02	0.036		0.082	0.046		<0.01	0.0572	0.106	0.052		< 0.004	0.0047	0.10
Copper-Dissolved					0.036	0.027		<0.01	0.015	0.022	0.0077		< 0.004	< 0.004	0.023
Lead	<0.03	<0.03	<0.03		0.04	0.01		<0.03	<0.03	0.069	0.029		< 0.005	< 0.005	0.059
Lead-Dissolved					<0.005	<0.005		<0.03	<0.03	<0.03	<0.005		< 0.005	< 0.005	0.007
Nickel															
Nickel-Dissolved															
Silver															
Silver-Dissolved															
Zinc	0.129	<0.08	0.141		0.49	0.19		0.16	0.513	0.673	0.31		0.06	0.085	0.61
Zinc-Dissolved					0.15	0.07		<0.05	0.065	<0.05	0.029		0.042	0.045	0.085
Thallium															
Thallium-Dissolved															
Mercury															
Mercury-Dissolved															
FECAL STREPTOCOCCI (cfu/100 ml)													< 100	100	
FECAL COLIFORMS (cfu/100 ml)													< 100	300	
pH	8.40	8.04	8.13		7.84	7.82		8.37	8.16	8.17	7.84		8.33	8.33	8.14
TSS (mg/l)	64	16.4	56		208	52		19	318	390	150		4	10	280
TDS (mg/l)	598	588	403		440	381		784	820	938	120		890	850	400
HARDNESS (mg/l)	316	316	184		232	180		418	406	282	89		420	420	170
TKN (mg/l)	<2.0	<2.0	<2.0		5.66	2.35		0.59	4	3.36	1.2		0.1	0.7	4
N (nitrate) (mg/l)	1.90	2	1.1		1.75	1.44		5.44	5.15	4.53	0.8		4.00	4.1	0.85
N (nitrite) (mg/l)	<0.03	<0.03	0.39		<0.02	<0.02		<0.075	<0.075	<0.075					
N (ammonia) (mg/l)	<0.2	0.28	0.25		1.57	0.504		0.28	1.4	1.9	0.23		0.08	0.12	0.44
Orthophosphate P (mg/l)	<0.3	<0.3	<0.3		<0.2	<0.2		<0.5	<0.5	<0.5	0.13		< 0.05	< 0.05	0.11
P (total P) (mg/l)	0.046	0.06	0.49		0.476	0.312		1.59	<0.02	0.686	0.25		< 0.05	0.11	0.36
P (soluable P) (mg/l)															
Total Recoverable Phenolics															
BOD (total) (mg/l)	2.75	5.29	10.7		25.9	17.2		2.03	>36.8	15.8	5		< 5	< 5	15
COD (mg/l)	70.4	32.4	57.8		159	107		35.4	268	203	71		< 10	< 10	140
Cyanide (total) (mg/l)															
Oil and Grease (mg/l)	<2.6	<2.5			2.0			<1.8	5.8				< 3	< 3	
TPH (mg/l)															

TNTC To Numerous to Count
(1) No priority pollutant constituents were detected (mg/l)
(2) Not enough precipitation for composite
(3) JOR-04 Station moved in 2000 due to difficulties w/ existing station
Highlighted area indicates this data was not included in load or EMC calculations (see annual report text for further description)

SUMMARY OF RESPRESENTATIVE SAMPLING ANALYSES
LIT-06 OUTFALL-RESIDENTAL/ RAW LAB RESULTS

LIT-06

CONSTITUENT	EPA Method	Method Limit	Event 1 9/14/92 STORM COMPOSITE	Event 2 4/1/93 STORM COMPOSITE	Event 3 6/18/93 BASEFLOW GRAB	Event 3 6/18/93 STORM COMPOSITE	Event 4 10/14/94 STORM COMPOSITE	Event 5 9/29/95 STORM GRAB	Event 5 9/29/95 STORM COMPOSITE	Event 6 5/16/96 BASEFLOW GRAB	Event 6 5/16/96 STORM GRAB	Event 6 5/16/96 STORM COMPOSITE
METALS (mg/l)												
Selenium	270.3	0.005 mg/l	<0.005	<0.005		ND	<0.005					
Selenium-Dissolved	270.3	0.005 mg/l	<0.005	<0.005		0.018						
Antimony	204.2	0.005 mg/l	<0.005	<0.01		ND	<0.01					
Antimony-Dissolved	240.2	0.01 mg/l	<0.005	<0.01		ND						
Arsenic	206.2	0.01 mg/l	<0.01	<0.01		<0.01	<0.01					
Arsenic-Dissolved	206.2	0.01 mg/l	<0.01	<0.01		<0.01						
Beryllium	210.2	0.00025 mg/l	<0.0005	<0.00025		ND	<0.005					
Beryllium-Dissolved	7091	0.00025 mg/l	<0.0005	<0.00025		ND						
Cadmium	213.2	0.0005 mg/l	<0.0005	<0.0005		0.0006	<0.004	<0.02	<0.02	<0.02	<0.02	<0.02
Cadmium-Dissolved	200.7	0.0005 mg/l	<0.0005	<0.0005		ND						
Chrominum	218.2	0.0015 mg/l	0.003	0.012		0.006	<0.006					
Chrominum-Dissolved	218.2	0.002 mg/l	0.0046	0.011		<0.0015						
Copper	220.2	0.002 mg/l	0.009	0.014		0.028	0.019	<0.02	0.04	<0.1	0.19	<0.1
Copper-Dissolved	200.7	0.002 mg/l	0.014	0.012		0.01						
Lead	239.2	0.003 mg/l	0.012	0.013		0.023	0.006	<0.15	<0.15	<0.15	0.220	<0.15
Lead-Dissolved	200.7	0.003 mg/l	0.016	0.01		0.003						
Nickel	249.2	0.002 mg/l	<0.002	<0.002		0.003	<0.02					
Nickel-Dissolved	249.2	0.002 mg/l	0.003	<0.002		ND						
Silver	272.2	0.001 mg/l	<0.005	<0.0005		0.004	<0.003					
Silver-Dissolved	272.2	0.0005 mg/l	<0.005	<0.0005		ND						
Zinc	289.2	0.0025 mg/l	0.05	0.063		0.117	0.051	<0.3	<0.3	<0.25	0.71	0.27
Zinc-Dissolved	200.7	0.0005 mg/l	0.07	0.051		0.0466						
Thallium	279.2	0.01 mg/l	<.002	<0.01		ND	<0.01					
Thallium-Dissolved	279.2	0.01 mg/l	<0.002	<0.01		ND						
Mercury	245.1	0.0005 mg/l	<0.002	<0.01		ND	<0.0005					
Mercury-Dissolved	245.1	0.0005 mg/l	<0.0005	<0.0005		<0.0005						
FECAL STREPTOCOCCI (cfu/100ml)	SM 910A	1		2,800		TNTC		2890		370	2,000	
FECAL COLIFORMS (cfu/100 ml)	SM909C	1		240		TNTC		TNTC		90	24,000	
pH	150.1	0.01				7.36	8.85	8.46	8.49	8.04	7.65	7.68
TSS (mg/l)	160.2	4 mg/l	57	189		89	27	<4	128	<20	892	135
TDS (mg/l)	160.1	10 mg/l	810	130		80	60	264	150	192	216	<100
HARDNESS (mg/l)	130.2	5 mg/l	106					200	103	140	264	80
TKN (mg/l)	351.2	0.2 mg/l										
N (nitrate) (mg/l)	353.3	0.05 mg/l		0.45		0.66	0.19			<0.2	<0.2	<0.2
N (nitrite) (mg/l)	300.0	0.02 mg/l										
N (ammonia) (mg/l)	350.2	0.1 mg/l		0.5		0.6						
N (organic) (mg/l)	365.3	.02 mg/l		0.13								
Orthophosphate P (mg/l)	365.3	.02 mg/l		0.03		0.11	0.34	0.09	0.17	0.04	0.31	0.12
P (total P) (mg/l)	365.3	.02 mg/l		0.17		0.41	2.65	0.13	0.54	<0.08	1.3	0.56
P (soluable P) (mg/l)	365.3	.02 mg/l		0.13			2.48					
Total Recoverable Phenolics	420.1	.05 mg/l						<0.001				
BOD (total) (mg/l)	405.1	2 mg/l	7.5	8		13	10	<6	19	6.6	12	11.7
COD (mg/l)	410.1	20 mg/l		<20		100	126	<50	149	<50	163	<50
Cyanide (total) (mg/l)	335.2	.005 mg/l					<0.005					
Oil and Grease (mg/l)	413.2	1 mg/l		10		3.3	2.4	4		44	13	<5
TPH (mg/l)	418.1	1 mg/l		2.5		1.7	1.1	<1				

CONSTITUENT	Event 7 9/26/97 (station relocated)	Event 8 10/11/97 (station relocated)	Event 9 6/4/98 (not sampled/gage data)	Event 10 10/16/98 BASEFLOW GRAB	Event 10 10/16/98 STORM GRAB	Event 10 10/16/98 STORM COMPOSITE	Event 11 4/20/99 (<0.1 predicted)	Event 12 5/13/99 BASEFLOW GRAB	Event 12 5/13/99 STORM GRAB	Event 12 5/13/99 STORM COMPOSITE	Event 13 6/2/99 (w/in 45 day criteria)	Event 14 11/17/99 (sampling cancelled)	Event 15 5/10/00 STORM GRAB	Event 15 5/10/00 STORM COMPOSITE
METALS (mg/l)														
Selenium														
Selenium-Dissolved														
Antimony														
Antimony-Dissolved														
Arsenic														
Arsenic-Dissolved														
Beryllium														
Beryllium-Dissolved														
Cadmium				<0.004	<0.004			<0.002	0.004	0.005			<0.003	<0.003
Cadmium-Dissolved														
Chrominum														
Chrominum-Dissolved														
Copper				<0.01	0.035			0.005	0.08	0.15			0.017	0.026
Copper-Dissolved														
Lead				<0.050	<0.050			<0.03	0.06	0.14			<0.03	<0.03
Lead-Dissolved														
Nickel														
Nickel-Dissolved														
Silver														
Silver-Dissolved														
Zinc				0.036	0.155			<0.18	0.29	0.35			<0.08	0.082
Zinc-Dissolved														
Thallium														
Thallium-Dissolved														
Mercury														
Mercury-Dissolved														
FECAL STREPTOCOCCI (cfu/100ml)														
FECAL COLIFORMS (cfu/100 ml)														
pH				7.75	7.79	7.77		7.60	7.34	7.62			7.71	7.74
TSS (mg/l)				2.4	172	54		<5	159	1500			21	114
TDS (mg/l)				415	260	120		562	171	156			482	103
HARDNESS (mg/l)				348	280			400	148	232			240	80
TKN (mg/l)				1	2	3		<2	4.2	5			3.98	<2.0
N (nitrate) (mg/l)				0.92	1.72	0.79		2.6	1.63	0.71			2.9	0.59
N (nitrite) (mg/l)				<0.03	0.065	0.061		<0.05	<0.05	0.270			0.47	<0.03
N (ammonia) (mg/l)				0.1	0.3	0.6		<0.2	1	1			0.9	<0.29
N (organic) (mg/l)														
Orthophosphate P (mg/l)				<0.2	<0.2	<0.2		<0.5	<0.5	<0.2			2.6	<0.3
P (total P) (mg/l)				<0.08	0.68	0.44		0.11	0.5	1.3			0.49	0.1
P (soluable P) (mg/l)														
Total Recoverable Phenolics														
BOD (total) (mg/l)				2	9	13		<4.87	4	22			9.4	11.2
COD (mg/l)				135	205	153		<14	83	663			66.2	66.2
Cyanide (total) (mg/l)														
Oil and Grease (mg/l)				<4.0	5.8			<4	<4	NA			2.9	
TPH (mg/l)														

CONSTITUENT	Event 16 10/10/00 STORM GRAB	Event 16 10/10/00 STORM COMPOSITE	Event 17 5/16/01 STORM GRAB	Event 17 5/16/01 STORM COMPOSITE	Event 18 10/8/01 STORM COMPOSITE	Event 19 4/15/02 BASEFLOW GRAB	Event 19 4/15/02 STORM GRAB	Event 19 4/15/02 STORM COMPOSITE	Event 20 5/7/03 (sampler problems)	Event 21 11/13/03 (station inactive)	Event 22 3/26/04 STORM GRAB	Event 22 3/26/04 STORM COMPOSITE	Event 22 3/26/04 STORM COMPOSITE (2)
METALS (mg/l)													
Selenium													
Selenium-Dissolved													
Antimony													
Antimony-Dissolved													
Arsenic													
Arsenic-Dissolved													
Beryllium													
Beryllium-Dissolved													
Cadmium	<0.003	<0.003	<0.0005	<0.0005		<0.004	0.009	<0.004			< 0.004	< 0.004	< 0.004
Cadmium-Dissolved	<0.003	<0.003	<0.0005	<0.0005	<0.004	0.0051	<0.004	<0.004			< 0.004	< 0.004	< 0.004
Chrominum													
Chrominum-Dissolved													
Copper	0.084	0.043	0.015	0.014		<0.01	0.335	0.653			0.095	0.035	0.038
Copper-Dissolved	0.02	0.022	0.01	0.029	0.013	<0.01	0.027	0.011			0.025	0.0064	0.0067
Lead		<0.03	<0.005	<0.005		<0.03	0.349	0.047			0.053	0.019	0.047
Lead-Dissolved		<0.03	<0.005	<0.005	<0.03	<0.03	<0.03	<0.03			< 0.005	< 0.005	< 0.005
Nickel													
Nickel-Dissolved													
Silver													
Silver-Dissolved													
Zinc	0.26	0.13	0.06	0.04		<0.05	1.25	0.238			0.6	0.15	0.17
Zinc-Dissolved	<0.08	<0.08	0.03	0.03	0.05	<0.05	<0.05	<0.05			0.095	0.014	0.019
Thallium													
Thallium-Dissolved													
Mercury													
Mercury-Dissolved													
FECAL STREPTOCOCCI (cfu/100ml)											3,000		
FECAL COLIFORMS (cfu/100 ml)											< 1,000		
pH	9.2		7.57	7.57	7.65	8.09	7.66	8.04			7.28	7.92	7.93
TSS (mg/l)	152	130	43	20	142	<7.1	2580	337			660	160	130
TDS (mg/l)	172	98.5	89.5	180	<5600	641	965	265			330	24	20
HARDNESS (mg/l)	100	64	60.0	100		459	475	154			160	44	53
TKN (mg/l)	3.5		2.80	1.96	2.86	0.7	16.9				14	3.8	9.9
N (nitrate) (mg/l)	0.4	0.2	0.712	1.26		6.72	<0.12	3.92			1.9	0.36	0.36
N (nitrite) (mg/l)	0.18	<0.02	<0.02	<0.02		<0.075	<0.075	2.53					
N (ammonia) (mg/l)	0.73			<0.1		<0.1	5.04	269			1.7	0.61	0.58
N (organic) (mg/l)													
Orthophosphate P (mg/l)	<0.1	<0.2	<0.2	<0.2	<0.5	<0.5	<0.5	<0.5			0.46	0.16	0.16
P (total P) (mg/l)	0.51	0.67	0.432	0.314	1.46	<0.02	1.99	0.947			1.0	0.42	0.44
P (soluable P) (mg/l)													
Total Recoverable Phenolics													
BOD (total) (mg/l)	67	18	<2	12.6		2.15	>185	22.7			58	15	14
COD (mg/l)	276	127	145	86.4	102	12	685	214			450	100	120
Cyanide (total) (mg/l)													
Oil and Grease (mg/l)	<1.9		2.0			<2	4.7				69		
TPH (mg/l)													

ND Not Detected
TNTC To Numerous to Count
(1) No priority pollutant constituents were detected (mg/l)
(2) Station out of order due to relocation
Highlighted area indicates this data was not included in load or EMC calculations (see annual report text for further description)

SUMMARY OF RESPRESENTATIVE SAMPLING ANALYSES

MIL-07 OUTFALL-RESIDENTAL/ RAW LAB RESULTS

MIL-07

CONSTITUENT	EPA Method	Method Limit	Event 1	Event 2	Event 3		Event 4	Event 5		Event 6			Event 7	Event 8			Event 9			Event 10		
			STORM COMPOSITE	STORM COMPOSITE	BASEFLOW GRAB	STORM COMPOSITE	STORM COMPOSITE	STORM GRAB	STORM COMPOSITE	BASEFLOW GRAB	STORM GRAB	STORM COMPOSITE	(lack of precipitation)	BASEFLOW GRAB	STORM GRAB	STORM COMPOSITE (3)	BASEFLOW GRAB	STORM GRAB	STORM COMPOSITE	BASEFLOW GRAB	STORM GRAB	STORM COMPOSITE
			9/14/92	4/1/93	6/18/93	6/18/93	10/14/94	9/29/95	9/29/95	5/16/96	5/16/96	5/16/96	9/26/97	10/11/97	10/11/97	10/11/97	6/4/98	6/4/98	6/4/98	10/16/98	10/16/98	10/16/98
METALS (mg/l)																						
Selenium	270.3	0.005 mg/l	<0.005			ND	<0.005															
Selenium-Dissolved	270.3	0.005 mg/l	<0.005			<0.005																
Antimony	204.2	0.005 mg/l	<0.005			ND	<0.01															
Antimony-Dissolved	240.2	0.01 mg/l	<0.005			ND																
Arsenic	206.2	0.01 mg/l	<0.01			<0.01	<0.01															
Arsenic-Dissolved	206.2	0.01 mg/l	<0.01			<0.01																
Beryllium	210.2	0.00025 mg/l	<0.0005			ND	<0.005															
Beryllium-Dissolved	7091	0.00025 mg/l	<0.0005			ND																
Cadmium	213.2	0.0005 mg/l	0.0012			0.001	<0.004	<0.02	<0.02	<0.02	<0.02	<0.02			<0.020						<0.004	<0.004
Cadmium-Dissolved	200.7	0.0005 mg/l	0.0011			0.0005																
Chrominum	218.2	0.0015 mg/l	0.0082			0.0076	<0.006															
Chrominum-Dissolved	218.2	0.002 mg/l	0.0084			0.0026																
Copper	220.2	0.002 mg/l	0.037			0.04	0.012	0.04	0.08	<0.1	0.25	<0.1			<0.050						0.063	0.035
Copper-Dissolved	200.7	0.002 mg/l	0.031			0.017																
Lead	239.2	0.003 mg/l	0.08			0.036	0.009	<0.15	<0.15	<0.15	0.450	<0.15			<0.20						0.068	<0.050
Lead-Dissolved	200.7	0.003 mg/l	0.057			0.0005																
Nickel	249.2	0.002 mg/l	0.006			0.004	<0.02															
Nickel-Dissolved	249.2	0.002 mg/l	0.005			0.004																
Silver	272.2	0.001 mg/l	<0.005			0.001	<0.003															
Silver-Dissolved	272.2	0.0005 mg/l	<0.005			ND																
Zinc	289.2	0.0025 mg/l	0.17			0.153	0.033	<0.30	0.4	<0.25	1.5	0.33			0.22						0.333	0.268
Zinc-Dissolved	200.7	0.0005 mg/l	0.16			0.0586																
Thallium	279.2	0.01 mg/l	<.002			ND	<0.01															
Thallium-Dissolved	279.2	0.01 mg/l	<0.002			ND																
Mercury	245.1	0.0005 mg/l	<0.002			ND	<0.0005															
Mercury-Dissolved	245.1	0.0005 mg/l	<0.0005			0.0005																
FECAL STREPTOCOCCI (cfu/100 ml)	SM 910A	1	3,000			2,900		4,230		19												
FECAL COLIFORMS (cfu/100 ml)	SM909C	1	90			5,000		TNTC		130												
pH	150.1	0.01				7.81	7.25	7.88	7.97	8.15	6.91	7.99		7.83	7.59					8.27	7.70	7.52
TSS (mg/l)	160.2	4 mg/l	101			112	54	100		<20	1050	277			182						190	134
TDS (mg/l)	160.1	10 mg/l	360			140	66	244		260	508	138			225						246	34
HARDNESS (mg/l)	130.2	5 mg/l	66					140		152	376	122			72						250	68
TKN (mg/l)	351.2	0.2 mg/l													2.5						6	3
N (nitrate) (mg/l)	353.3	0.05 mg/l					0.26			0.9	<0.2	<0.5		0.8	0.8						1.95	0.78
N (nitrite) (mg/l)	300.0	0.02 mg/l												<0.2	<0.2						0.16	0.10
N (ammonia) (mg/l)	350.2	0.1 mg/l													<1						2.0	
Orthophosphate P (mg/l)	365.3	.02 mg/l						0.19		0.03	0.21	0.2		<0.5	<0.5						<0.2	<0.2
P (total P) (mg/l)	365.3	.02 mg/l					1.72	0.42	0.63	<0.08	<2	0.77			0.36						0.48	0.53
P (soluable P) (mg/l)	365.3	.02 mg/l					1.65															
Total Recoverable Phenolics	420.1	.05 mg/l						0.008														
BOD (total) (mg/l)	405.1	2 mg/l	12.9			17	6	32	23	7.1	24	24.5		43	41						2	18
COD (mg/l)	410.1	20 mg/l				150	55	218	205	<50	200	<50			181						355	213
Cyanide (total) (mg/l)	335.2	.005 mg/l																				
Oil and Grease (mg/l)	413.2	1 mg/l	8			1.6	2.4	5		<5	28	9		7	<5						<4.0	
TPH (mg/l)	418.1	1 mg/l	<2.0			<1.0	1.2	2.6														

CONSTITUENT	Event 11	Event 12			Event 13	Event 14			Event 15			Event 16		Event 17		Event 18	Event 19			Event 20	Event 21		Event 22	
	(<0.1 predicted)	BASEFLOW GRAB	STORM GRAB	STORM COMPOSITE	(w/in 45 day criteria)	BASEFLOW GRAB	STORM GRAB	STORM COMPOSITE	BASEFLOW GRAB	STORM GRAB	STORM COMPOSITE	STORM GRAB	STORM COMPOSITE	STORM GRAB	STORM COMPOSITE	STORM COMPOSITE	BASEFLOW GRAB	STORM GRAB	STORM COMPOSITE	STORM COMPOSITE	STORM GRAB	STORM COMPOSITE	STORM GRAB	STORM COMPOSITE
	4/20/99	5/13/99	5/13/99	5/13/99	6/2/99	11/17/99	11/17/99	11/17/99	5/10/00	5/10/00	5/10/00	10/10/00	10/10/00	5/16/01	5/16/01	10/8/01	4/15/02	4/15/02	4/15/02	5/7/03	11/13/03	11/13/03	3/26/04	3/26/04
METALS (mg/l)																								
Selenium																								
Selenium-Dissolved																								
Antimony																								
Antimony-Dissolved																								
Arsenic																								
Arsenic-Dissolved																								
Beryllium																								
Beryllium-Dissolved																								
Cadmium			<0.002	NA			<0.002	<0.002	<0.003	<0.003	<0.003	<0.003	<0.003	<0.0005	<0.0005	<0.004	<0.004	0.009	<0.004	<0.004	<0.004	<0.004	< 0.004	< 0.004
Cadmium-Dissolved												<0.003	<0.003	<0.0005	<0.0005	<0.004	0.0051	<0.004	<0.004	<0.004	<0.004	<0.004	< 0.004	< 0.004
Chrominum																								
Chrominum-Dissolved																								
Copper			0.013	NA			0.084	0.04	0.027	0.037	0.018	0.032	0.049	0.028	0.023	0.0565	<0.01	0.335	0.653	0.036	0.0057	<0.004	0.13	0.045
Copper-Dissolved												0.029	0.027	0.007	0.018	0.015	<0.01	0.027	0.011	0.0062	<0.004	<0.004	0.019	0.0076
Lead			<0.03	NA			0.105	0.044	<0.03	<0.03	<0.03		0.038	0.029	0.014	0.043	<0.03	0.349	0.047	0.038	0.026	0.019	0.13	0.049
Lead-Dissolved													<0.03	<0.005	<0.005	<0.03	<0.03	<0.03	<0.03	<0.005	<0.005	<0.005	< 0.005	< 0.005
Nickel																								
Nickel-Dissolved																								
Silver																								
Silver-Dissolved																								
Zinc			<0.18	NA			0.441	0.234	0.095	0.152	0.097	0.13	0.1	0.16	0.09	0.242	<0.05	1.25	0.238	0.15	0.28	0.14	0.64	0.24
Zinc-Dissolved												<0.16	<0.08	0.03	0.04	0.07	<0.05	<0.05	<0.05	0.013	0.086	0.047	0.034	0.023
Thallium																								
Thallium-Dissolved																								
Mercury																								
Mercury-Dissolved																								
FECAL STREPTOCOCCI (cfu/100 ml)																							< 1,000	
FECAL COLIFORMS (cfu/100 ml)																							28,000	
pH			8.01	7.29			7.77	7.86	7.67	7.79	7.54	7.87		7.43	7.25	7.46	8.09	7.66	8.04	7.59	7.88	7.87	8.05	8.1
TSS (mg/l)			10	59.2			453	223	35	95	42	62.8	71.2	144	47	195	<7.1	2580	337	180	88	66	51	170
TDS (mg/l)			520	76			216	113	194	118	97	91.5	96.5	40	31	<5600	641	965	265	44	430	270	280	60
HARDNESS (mg/l)			252	NA			152	74	56	44	40	104	60	52.0	40.0		459	475	154	51	83	47	160	51
TKN (mg/l)			2.1	<2.0			4.59	2.18	<2.0	<2.0	<2.0	<2.0		2.63	2.30	3.08	0.7	16.9		1.6			11	4.4
N (nitrate) (mg/l)			1.48	0.6			1.3	0.59	0.67	0.3	0.27	0.1	0.2	0.35	0.40		6.72	<0.12	3.92	0.47	0.74	0.48	0.8	0.3
N (nitrite) (mg/l)			<0.02	0.25			0.5	0.15	0.4	0.38	<0.03	<0.01	<0.02	<0.02	<0.02		<0.075	<0.075	2.53					
N (ammonia) (mg/l)			1.0	0.3			11.4	0.9	0.56	0.5	<0.2	0.9		0.17	0.784	1.12	<0.1	5.04	2.69		0.52	0.44	1.5	0.56
Orthophosphate P (mg/l)			<0.2	<0.2			0.18	<0.1	<0.3	<0.3	<0.3	<0.1	<0.2	<0.2	<0.2	<0.5	<0.5	<0.5	<0.5	0.097	0.09	0.14	0.36	0.18
P (total P) (mg/l)			0.2	0.3			0.96	0.59	0.47	0.34	0.28	0.49	0.52	0.522	0.353	1.52	<0.02	1.99	0.947	0.34	0.28	0.29	1.2	0.45
P (soluable P) (mg/l)																								
Total Recoverable Phenolics																								
BOD (total) (mg/l)			10	8			70	34	13.2	13	13.8	25	17	17.5	16.3	28.1	2.15	>185	22.7	8	35	24	38	14
COD (mg/l)			35	57			240	119	113	102	85.2	117	109	78.1	92.7	106	12	685	214	94	200	120	520	110
Cyanide (total) (mg/l)																								
Oil and Grease (mg/l)			<4	NA			5.48	NA	4.2	2.42		<2.1		2.6			<2	4.7			9.3		14	
TPH (mg/l)																								

ND Not Detected
TNTC To Numerous to Count
(1) No priority pollutant constituents were detected (mg/l)
(2) Not enough precipitation for composite
(3) Machine failure
Highlighted area indicates this data was not included in load or EMC calculations (see annual report text for further description)

Table VI-I
Gale Street Base Flow Samples 1995-1999

Salt Lake City Base Flow Monitoring Data							
UPDES Permit No. UTS000002							
Gale Street Base Flow Composite/Grab - JOR-08							
Parameter	**Units**	**8/31/1995**	**8/8/1996**	**9/10/1997**	**9/3/1998**	**7/19/1999**	**Average**
BOD	mg/L	<4	7	<4	<4	52.5	11.9
COD	mg/L	<20	39	<20	<20	40	15.8
TSS	mg/L	13	15	13	3.2	3.6	9.56
TDS	mg/L	720	453	397	846	776	638.4
Total Nitrogen	mg/L	<0.5	1.52	0.15	*No data	<0.020	0.417
TKN	mg/L	0.06	1.52	0.15	0.64	<0.18	0.47
Total Phosphorus	mg/L	0.26	0.91	0.34	0.12	0.12	0.35
Dissolved Phosphorus	mg/L	0.26	0.77	<0.04	0.10	0.14	0.25
Oil and Grease	mg/L	<1	3.3	2.8	<1.0	<1.0	1.22
Total Cadmium	mg/L	<0.02	0.002	<0.001	<0.003	<0.001	0.0004
Dissolved Cadmium	mg/L	<0.02	0.002	<0.001	<0.003	<0.001	0.0004
Total Copper	mg/L	<0.02	0.019	0.014	0.005	<0.003	0.008
Dissolved Copper	mg/L	<0.02	0.012	0.004	<0.0125	<0.003	0.0032
Total Lead	mg/L	<0.003	0.012	0.005	<0.005	<0.004	0.003
Dissolved Lead	mg/L	<0.003	0.01	0.005	<0.005	<0.004	0.003
Total Zinc	mg/L	<0.080	0.091	0.023	<0.018	0.015	0.026
Dissolved Zinc	mg/L	<0.080	0.087	0.044	<0.018	0.009	0.028
Total Arsenic	mg/L	0.005	<0.005	<0.005	0.026	<0.011	0.006
Dissolved Arsenic	mg/L	0.07	<0.005	<0.005	<0.012	<0.011	0.014
Total Chromium	mg/L	<0.08	0.037	<0.005	<0.007	<0.001	0.007
Dissolved Chromium	mg/L	<0.08	<0.005	<0.005	<0.007	<0.001	<0.080
Total Cyanide	mg/L	<0.005	<0.001	<0.0005	<0.005	<0.0013	<0.050
Total Nickel	mg/L	<0.060	<0.005	<0.005	<0.007	0.002	<0.060
Dissolved Nickel	mg/L	<0.060	<0.005	<0.005	<0.007	0.002	<0.060
Total Selenium	mg/L	<0.02	<0.005	<0.007	<0.025	<0.012	<0.02
Dissolved Selenium	mg/L	<0.05	<0.005	<0.007	<0.025	<0.012	<0.05
Total Silver	mg/L	<0.02	0.005	<0.002	<0.008	<0.002	0.001
Dissolved Silver	mg/L	<0.02	0.002	<0.002	<0.008	<0.002	<0.002
pH	std. u	8.36	7.5	7.5	7.2	8.0	7.71

Table VI-2
Gale Street Storm Event Grab Samples 1995-1999

Salt Lake City Storm Event Monitoring												
UPDES Permit No. UTS000002												
Gale Street Grab Samples - JOR-08												
Parameter	**Units**	**11/9/1995**	**3/23/1996**	**10/19/1996**	**4/23/1997**	**9/26/1997**	**10/11/1997**	**5/13/1998**	**9/10/1998**	**4/7/1999**	**10/29/1999**	**Average**
BOD	mg/L	>35	54.3	40	67.3	28	41.0	27.5	38.4	41.1	71.2	40.9
COD	mg/L	152	295	107	160	135	134	167	159.3	310	230	184.9
TSS	mg/L	102	234	81	353	36	153	205	236	384	214	199.8
TDS	mg/L	580	338	474	402	436	280	208	218	368	150	345.4
Total Nitrogen	mg/L	0.6	4.34	1.91	2.98	1.68	1.76	0.440	0.88	0.74	0.87	1.62
TKN	mg/L	0.6	4.9	2.53	3.83	1.92	2.29	2.550	3.2	4.59	3.55	3.00
Total Phosphorus	mg/L	0.55	1	0.75	2.24	0.13	0.8	0.540	0.58	0.57	0.88	0.80
Dissolved Phosphorus	mg/L	0.22	0.44	0.6	1.15	0.15	0.51	0.280	0.24	0.11	0.39	0.41
Oil and Grease	mg/L	13	<2	<2	3.3	<2	2.7	<2.0	51.9	5.9	4.2	8.10
Total Cadmium	mg/L	<0.02	<0.001	0.001	0.003	0.002	0.005	<0.001	<0.003	0.001	0.001	0.001
Dissolved Cadmium	mg/L	<0.02	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.003	<0.001	<0.001	0.000
Total Copper	mg/L	0.06	0.095	0.077	0.144	0.013	0.044	0.049	0.052	0.057	0.047	0.064
Dissolved Copper	mg/L	<0.02	0.023	0.019	0.032	<0.005	0.007	0.015	0.066	0.010	0.013	0.019
Total Lead	mg/L	0.04	0.093	0.031	0.144	0.01	0.047	0.093	<0.005	0.059	0.047	0.056
Dissolved Lead	mg/L	0.003	<0.003	<0.002	0.009	<0.003	0.009	0.005	<0.005	<0.004	<0.004	0.003
Total Zinc	mg/L	<0.30	0.403	0.159	0.496	0.141	0.243	0.331	0.219	0.311	0.233	0.254
Dissolved Zinc	mg/L	<0.30	0.24	0.112	0.107	0.09	0.043	0.117	0.048	0.052	0.045	0.085
Total Arsenic	mg/L	0.011	0.013	0.009	0.024	0.005	0.023	0.016	<0.012	<0.011	<0.011	0.010
Dissolved Arsenic	mg/L	0.014	<0.005	<0.006	<0.005	<0.005	<0.005	0.011	<0.012	<0.011	<0.011	0.003
Total Chromium	mg/L	<0.02	0.017	0.007	0.031	<0.005	0.013	0.018	<0.007	0.014	0.011	0.011
Dissolved Chromium	mg/L	<0.02	<0.005	0.001	0.005	<0.005	<0.005	0.008	<0.007	0.001	0.002	0.002
Total Cyanide	mg/L	<0.005	0.011	0.002	0.016	0.002	0.002	0.005	0.0025	0.0191	0.002	0.006
Total Nickel	mg/L	<0.060	0.009	0.007	0.019	<0.005	0.019	0.008	0.009	0.005	0.009	0.009
Dissolved Nickel	mg/L	<0.060	<0.005	0.002	0.005	<0.005	<0.005	<0.003	<0.007	<0.002	0.006	0.001
Total Selenium	mg/L	<0.05	<0.005	<0.007	<0.005	<0.005	<0.005	<0.010	<0.025	<0.012	<0.012	0.000
Dissolved Selenium	mg/L	0.16	<0.005	<0.007	<0.005	<0.005	<0.005	<0.010	<0.025	<0.012	<0.012	0.016
Total Silver	mg/L	<0.02	<0.002	0.011	<0.002	0.004	0.005	<0.003	<0.008	<0.002	<0.002	0.002
Dissolved Silver	mg/L	<0.02	<0.002	<0.002	<0.002	<0.002	<0.002	<0.003	<0.008	<0.002	<0.002	0.000
pH	std. u	8.06	8.1	7.7	6.8	6.8	7.0	7.4		7.4	7.7	7.4

TABLE VI - 3
GALE STREET STORM EVENT COMPOSITE SAMPLES 1995-1999

Salt Lake City Storm Event Monitoring Data												
UPDES Permit No. UTS000002												
Gale Street Composite Samples - JOR-08												
		1	2	3	4	5	6	7	8	10	11	
Parameter	**Units**	**11/9/1995**	**3/23/1996**	**10/19/1996**	**4/24/1997**	**9/26/1997**	**10/12/1997**	**5/13/1998**	**9/10/1998**	**4/7/1999**	**10/29/1999**	**Average**
BOD	mg/L	>35	18.9	36.5	38.6	<4	17	21.1	32.8	10.3	96.0	27.1
COD	mg/L	312	128	114	112	98	34	127	160.5	67.0	249	140.2
TSS	mg/L	226	104	93	202	40	44	105	150	116	304	138.4
TDS	mg/L	266	172	240	222	238	166	130	154	104	208	190.0
Total Nitrogen	mg/L	1.8	2.53	1.83	1.59	1.43	0.73	0.44	0.59	0.19	1.36	1.25
TKN	mg/L	1.8	2.53	2.33	1.92	1.61	0.97	2.55	2.46	1.26	0.48	1.79
Total Phosphorus	mg/L	0.71	0.38	0.69	0.66	0.24	0	0.25	0.5	0.26	0.98	0.47
Dissolved Phosphorus	mg/L	0.12	0.2	0.52	0.27	0.21	0.5	0.24	0.19	0.10	0.48	0.28
Total Cadmium	mg/L	<0.02	<0.001	0.001	0.002	<0.001	0.5	<0.001	<0.003	<0.001	<0.001	0.050
Dissolved Cadmium	mg/L	<0.02	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.003	<0.001	<0.001	0.000
Total Copper	mg/L	0.13	0.043	0.047	0.054	0.01	0.018	0.027	0.045	0.024	0.044	0.044
Dissolved Copper	mg/L	<0.02	0.014	0.015	0.016	<0.005	0.005	0.011	0.034	0.006	0.01	0.011
Total Lead	mg/L	0.12	0.048	0.04	0.082	0.008	0.021	0.033	<0.005	0.027	0.03	0.041
Dissolved Lead	mg/L	0.007	<0.003	0.002	0.006	<0.005	<0.003	0.007	<0.005	<0.004	<0.004	0.002
Total Zinc	mg/L	0.51	0.219	0.161	0.24	0.088	0.113	0.144	0.206	0.101	0.21	0.199
Dissolved Zinc	mg/L	<0.30	0.112	0.081	0.037	0.054	0.03	0.076	0.053	0.017	0.055	0.052
Total Arsenic	mg/L	0.014	<0.005	0.009	0.016	<0.005	0.01	0.014	0.016	<0.011	<0.011	0.008
Dissolved Arsenic	mg/L	0.01	<0.005	0.006	0.006	<0.005	<0.005	0.013	0.016	<0.011	<0.011	0.005
Total Chromium	mg/L	0.02	0.01	0.006	0.018	<0.005	<0.005	0.012	0.007	0.008	0.008	0.009
Dissolved Chromium	mg/L	<0.02	<0.005	0.001	<0.005	<0.005	<0.005	0.0070	<0.007	0.002	0.001	0.001
Total Nickel	mg/L	<0.060	0.005	0.007	0.005	<0.005	<0.005	0.003	0.008	0.004	0.0089	0.004
Dissolved Nickel	mg/L	<0.060	<0.005	0.003	<0.005	<0.005	<0.005	<0.003	<0.007	<0.002	0.003	0.001
Total Selenium	mg/L	<0.05	<0.005	<0.007	<0.005	<0.005	<0.007	<0.010	<0.025	<0.012	<0.012	0.000
Dissolved Selenium	mg/L	<0.05	<0.005	<0.007	<0.005	<0.005	<0.007	<0.010	<0.025	<0.012	<0.012	0.000
Total Silver	mg/L	<0.02	<0.002	0.01	<0.002	<0.002	<0.002	<0.003	<0.008	<0.002	0.002	0.001
Dissolved Silver	mg/L	<0.02	<0.002	<0.002	<0.002	<0.002	<0.002	<0.003	<0.008	<0.002	<0.002	0.000

Table VI-4
Forest Dale Base Flow Samples 1995-1998

Salt Lake City Base Flow Monitoring Data							
UPDES Permit No. UTS000002							
Forest Dale Base Flow: Composite/Grab - MIL-03							
	Units	**8/31/1995**	**8/14/1996**	**8/29/1997**	**9/1/1998**	**7/19/1999**	**Average**
BOD	mg/L	<4	<2	<2	<4	47.5	9.5
COD	mg/L	31	9	<20	5.5	20	13.1
TSS	mg/L	14	17	6	9.2	7.5	10.74
TDS	mg/L	392	446	428	470	412	429.6
Total Nitrogen	mg/L	0.8	<1.0	<0.013	*No data	<0.020	0.16
TKN	mg/L	0.8	<0.3	<0.10	<0.3	<0.18	0.16
Total Phosphorus	mg/L	0.04	<0.1	<0.04	<0.1	0.1	0.028
Dissolved Phosphorus	mg/L	0.06	<0.1	<0.04	<0.1	0.065	0.025
Oil and Grease	mg/L	<1	3.5	2.8	7.6	11.9	5.16
Total Cadmium	mg/L	<0.02	<0.001	<0.007	0.003	<0.01	0.0006
Dissolved Cadmium	mg/L	<0.02	<0.001	0.003	0.003	<0.01	0.0012
Total Copper	mg/L	<0.02	0.01	0.036	0.028	0.05	0.0248
Dissolved Copper	mg/L	<0.02	<0.005	<0.002	0.005	0.05	0.011
Total Lead	mg/L	<0.003	<0.003	0.006	<0.005	0.009	0.003
Dissolved Lead	mg/L	<0.003	<0.003	<0.002	<0.005	<0.004	0
Total Zinc	mg/L	<0.08	0.019	0.015	0.042	0.057	0.0266
Dissolved Zinc	mg/L	<0.08	0.005	0.03	0.027	0.015	0.0154
Total Arsenic	mg/L	0.006	<0.005	0.006	<0.012	<0.011	0.0024
Dissolved Arsenic	mg/L	<0.005	<0.005	<0.006	<0.012	<0.011	0
Total Chromium	mg/L	<0.08	<0.005	0.001	<0.007	0.003	0.0008
Dissolved Chromium	mg/L	<0.08	<0.005	0.004	<0.007	<0.01	0.0008
Total Cyanide	mg/L	<0.005	<0.001	<0.005	0.002	<0.0013	0.0004
Total Nickel	mg/L	<0.06	<0.005	0.006	<0.007	0.009	0.003
Dissolved Nickel	mg/L	<0.06	<0.005	<0.0006	<0.007	0.002	0.0004
Total Selenium	mg/L	<0.05	<0.005	<0.007	<0.025	<0.012	0
Dissolved Selenium	mg/L	<0.05	<0.005	<0.007	<0.025	<0.012	0
Total Silver	mg/L	<0.02	<0.002	0.003	<0.008	0.003	0.0012
Dissolved Silver	mg/L	<0.02	<0.002	<0.0009	<0.008	<0.002	0
pH	std. u	8.51	7.6	8	8.30	8.50	8.2

Table VI-4
Forest Dale Storm Event Grab Samples 1995-1999

Salt Lake City Storm Event Monitoring Data												
UPDES Permit No. UTS000002												
Forrest Dale Grab Samples - MIL-03												
Parameter	**Units**	**11/9/1995**	**3/23/1996**	**10/1/1996**	**4/23/1997**	**9/26/1997**	**10/11/1997**	**5/13/1998**	**9/10/1998**	**4/7/1999**	**10/29/1999**	**Average**
BOD	mg/L	>35	37.9	58	45	14.6	24	27.0	58.4	53.0	76.3	39.4
COD	mg/L	681	254	164	164	42	103	144.0	162.7	270	224	220.9
TSS	mg/L	882	342	205	681	32	77	159.0	512	424	149	346.3
TDS	mg/L	570	195	192	194	276	200	108.0	170	268	174	234.7
Total Nitrogen	mg/L	1.3	3.72	3.56	3.95	0.77	1.53	0.360	0.56	4.66	2.89	2.3
TKN	mg/L	1.3	4.46	4.31	4.51	0.9	1.89	2.730	4.53	5.47	3.59	3.37
Total Phosphorus	mg/L	4.92	0.76	1.01	1.34	<0.1	0.54	0.480	1.12	0.89	0.91	1.197
Dissolved Phosphorus	mg/L	0.09	0.3	0.64	0.18	<0.1	0.49	0.220	0.31	0.19	0.6	0.302
Oil and Grease	mg/L	11	<2	<2	<2	3.2	<1.0	<2.0	<1.0	8.8	<1.0	2.3
Total Cadmium	mg/L	0.1	0.003	0.001	0.003	<0.001	<0.001	<0.001	<0.003	0.001	<0.001	0.0108
Dissolved Cadmium	mg/L	<0.02	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.003	<0.001	<0.001	0.0002
Total Copper	mg/L	0.26	0.057	0.089	0.069	0.011	0.017	0.023	0.104	0.06	0.027	0.0717
Dissolved Copper	mg/L	0.02	0.036	0.016	0.007	<0.005	0.007	0.011	0.013	0.012	0.012	0.0134
Total Lead	mg/L	0.17	0.071	0.051	0.151	<0.003	0.011	0.033	<0.005	0.063	0.026	0.0576
Dissolved Lead	mg/L	0.006	0.036	0.009	0.003	<0.003	<0.003	<0.002	<0.005	<0.004	<0.004	0.0054
Total Zinc	mg/L	0.82	0.378	0.173	0.384	0.029	0.089	0.140	0.399	0.26	0.107	0.2779
Dissolved Zinc	mg/L	<0.30	0.295	0.085	0.059	0.011	0.045	0.065	0.029	0.040	0.030	0.0659
Total Arsenic	mg/L	0.037	0.031	0.013	0.04	<0.005	0.008	0.025	<0.012	<0.011	<0.011	0.0154
Dissolved Arsenic	mg/L	0.014	0.016	0.007	<0.005	<0.005	<0.005	0.009	<0.012	<0.011	<0.011	0.0046
Total Chromium	mg/L	0.1	0.023	0.009	0.03	<0.005	<0.005	0.011	0.017	0.015	0.006	0.0211
Dissolved Chromium	mg/L	<0.02	0.018	<0.005	<0.005	<0.005	<0.005	0.008	<0.007	0.002	<0.001	0.0028
Total Cyanide	mg/L	<0.005	0.008	0.002	0.007	0.002	0.001	0.003	<0.005	0.0272	0.009	0.0059
Total Nickel	mg/L	0.104	0.013	0.008	0.016	<0.005	<0.005	0.003	0.014	0.006	0.005	0.0169
Dissolved Nickel	mg/L	<0.060	0.01	<0.005	<0.005	<0.005	<0.005	<0.003	<0.007	<0.002	0.002	0.0012
Total Selenium	mg/L	<0.05	<0.007	<0.007	<0.005	<0.005	<0.005	<0.010	<0.025	<0.012	<0.012	0.0000
Dissolved Selenium	mg/L	<0.005	<0.007	<0.007	<0.005	<0.005	<0.005	0.012	<0.025	<0.012	0.022	0.0034
Total Silver	mg/L	<0.02	0.003	0.008	0.005	<0.002	<0.002	<0.003	<0.008	<0.002	<0.002	0.0016
Dissolved Silver	mg/L	<0.02	0.002	<0.002	<0.002	<0.002	<0.002	<0.003	<0.008	<0.002	<0.002	0.0002
pH	std.u	8.18	8.4	8.3	6.3	7.9	8.2	7.9	7.5	7.3	8	7.8

Table VI-6
Forest Dale Storm Event Composite Samples 1995-1998

Salt Lake City Storm Event Monitoring Data												
UPDES Permit No. UTS000002												
Forrest Dale Composite Samples - MIL-03												
		1	2	3	4	5	6	7	8	10	11	
Parameter	**Units**	**11/9/1995**	**3/23/1996**	**10/19/1996**	**4/23/1997**	**9/26/1997**	**10/11/1997**	**5/13/1998**	**9/10/1998**	**4/7/1999**	**10/29/1999**	**Average**
BOD	mg/L	>35	12	36.5	53	12	17	23.4	70	23.7	91	33.9
COD	mg/L	405	114	93	145	37	46	111	161.6	146.2	235	149.4
TSS	mg/L	513	103	226	256	32	34	93	434	206	254	215.1
TDS	mg/L	314	103	358	132	224	204	102	144	152	202	193.5
Total Nitrogen	mg/L	1.3	2.03	1.66	2.34	0.68	0.68	0.290	0.58	0.46	0.85	1.087
TKN	mg/L	1.3	2.03	1.95	2.68	0.73	0.87	2.370	3.97	2.79	4.44	2.31
Total Phosphorus	mg/L	15.7	0.36	0.75	0.72	0.1	0.60	0.480	0.7	0.43	1.12	2.10
Dissolved Phosphorus	mg/L	0.15	0.2	0.34	0.24	<0.10	0.58	0.220	0.29	0.10	0.56	0.2680
Total Cadmium	mg/L	<0.02	0.002	0.002	0.002	<0.001	<0.001	<0.001	<0.003	0.002	<0.001	0.0008
Dissolved Cadmium	mg/L	<0.02	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.003	<0.001	<0.001	0.0000
Total Copper	mg/L	0.12	0.027	0.036	0.054	<0.005	0.01	0.021	0.104	0.056	0.039	0.0467
Dissolved Copper	mg/L	<0.02	0.015	0.009	0.016	<0.005	<0.005	0.011	0.013	0.009	0.011	0.0084
Total Lead	mg/L	0.13	0.032	0.028	0.065	<0.003	0.009	0.018	<0.005	0.072	0.046	0.0400
Dissolved Lead	mg/L	0.006	0.008	0.004	0.005	<0.003	0.003	0.003	<0.005	0.008	<0.004	0.0037
Total Zinc	mg/L	0.44	0.289	0.092	0.21	0.03	0.047	0.085	0.399	0.279	0.167	0.2038
Dissolved Zinc	mg/L	<0.30	0.114	0.052	0.062	0.012	0.027	0.076	0.018	0.026	0.031	0.0418
Total Arsenic	mg/L	0.027	0.015	0.016	0.025	<0.005	0.009	0.015	<0.012	<0.011	<0.011	0.0107
Dissolved Arsenic	mg/L	0.008	<0.005	<0.005	0.005	<0.005	<0.005	0.010	<0.012	<0.011	<0.011	0.0023
Total Chromium	mg/L	0.05	0.01	0.009	0.017	<0.005	<0.005	0.010	0.017	0.016	0.009	0.0138
Dissolved Chromium	mg/L	<0.02	<0.005	<0.005	<0.005	<0.005	<0.005	0.007	<0.007	0.003	0.002	0.0012
Total Nickel	mg/L	<0.060	0.007	0.008	0.005	<0.005	<0.005	0.003	0.014	0.008	0.008	0.0053
Dissolved Nickel	mg/L	<0.060	<0.005	<0.005	<0.005	<0.005	<0.005	<0.003	<0.007	0.002	0.004	0.0006
Total Selenium	mg/L	<0.05	<0.005	<0.005	<0.005	<0.005	<0.005	<0.010	<0.025	<0.012	<0.012	0.0000
Dissolved Selenium	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.010	<0.025	0.018	<0.012	0.0018
Total Silver	mg/L	<0.02	0.003	0.028	<0.002	0.009	<0.002	<0.003	<0.008	<0.002	<0.002	0.0040
Dissolved Silver	mg/L	<0.02	0.003	<0.002	<0.002	<0.002	<0.002	<0.003	<0.008	0.002	<0.002	0.0005

Table VI-7
Lee Drain Base Flow Samples 1995-1999

Salt Lake City Base Flow Monitoring Data							
UPDES Permit No. UTS000002							
Lee Drain Base Flow Composite/Grab - LED-02							
Parameter	**Units**	**4/6/1995**	**9/6/1996**	**10/17/1997**	**9/3/1998**	**9/9/1999**	**Average**
BOD	mg/L	11	9.6	12	*No data	6.0	7.7
COD	mg/L	64	82	37	48.4	57.0	57.7
TSS	mg/L	20	76	16.5	17.2	21.0	30.1
TDS	mg/L	5,820	1530	478	2266.0	2636.0	2546.0
Total Nitrogen	mg/L	3.2	1.93	0.79	*No data	0.10	1.204
TKN	mg/L	3.2	1.93	0.97	1.45	0.05	1.520
Total Phosphorus	mg/L	0.2	0.62	0.82	0.24	0.29	0.434
Dissolved Phosphorus	mg/L	0.2	0.4	0.53	0.13	0.13	0.278
O&G	mg/L	<2	<2	<2	<1	5.1	1.020
Total Cadmium	mg/L	<0.004	<0.001	<0.001	<0.003	<0.001	0.000
Dissolved Cadmium	mg/L	<0.005	<0.001	<0.001	<0.003	<0.001	0.000
Total Copper	mg/L	0.01	0.019	0.007	0.009	0.007	0.010
Dissolved Copper	mg/L	<0.02	<0.005	<0.005	0.007	0.005	0.002
Total Lead	mg/L	0.007	0.005	0.003	<0.005	0.015	0.006
Dissolved Lead	mg/L	0.004	<0.003	<0.003	<0.005	0.017	0.004
Total Zinc	mg/L	0.05	0.057	0.03	0.0260	0.0250	0.038
Dissolved Zinc	mg/L	0.04	0.03	0.025	<0.018	0.020	0.023
Total Arsenic	mg/L	0.04	0.032	0.059	<0.012	0.026	0.031
Dissolved Arsenic	mg/L	0.004	0.038	0.051	0.051	0.030	0.035
Total Chromium	mg/L	<0.010	0.012	<0.005	<0.007	0.005	0.003
Dissolved Chromium	mg/L	<0.010	<0.005	<0.005	<0.007	0.002	0.000
Total Cyanide	mg/L	<0.005	<0.001	<0.005	<0.05	<0.0013	0.000
Total Nickel	mg/L	0.02	0.009	0.01	0.013	0.008	0.012
Dissolved Nickel	mg/L	<0.04	0.006	0.007	<0.007	0.006	0.004
Total Selenium	mg/L	<0.005	<0.005	<0.007	<0.025	<0.012	0.000
Dissolved Selenium	mg/L	<0.005	<0.005	<0.007	<0.025	<0.012	0.000
Total Silver	mg/L	<0.004	0.008	0.002	<0.008	<0.002	0.002
Dissolved Silver	mg/L	<0.01	<0.002	<0.002	<0.008	<0.002	0.000
pH	std. u	8.71	8.5	7.8	8.4	8.2	8.3

Table VI-8
Lee Drain Storm Event Grab Samples 1995-1999

Salt Lake City Storm Event Monitoring Data												
UPDES Permit No. UTS000002												
Lee Drain Grab Sample - LED-02												
Parameter	**Units**	**11/9/1995**	**4/12/1996**	**10/19/1996**	**4/23/1997**	**9/26/1997**	**10/11/1997**	**9/10/1998**	**10/29/1998**	**4/7/1999**	**9/3/1999**	**Average**
BOD	mg/L	24	30	16	34	25	11.7	29	15.2	22.9	7.3	21.5
COD	mg/L	<50	189	47	83	77	78	111.6	75.2	96.2	72	82.9
TSS	mg/L	79	682	164	382	543	503	790.0	640	980	204	496.7
TDS	mg/L	3790	1892	2924	1926	1316	1100	1668	454	2206	1868	1914.4
Total Nitrogen	mg/L	<0.05	4.18	2.25	3.19	1.3	2.66	0.830	0.21	2.67	0.245	1.75
TKN	mg/L	<0.5	4.18	2.25	3.43	1.55	2.71	4.360	3.1	3.15	1.14	2.59
Total Phosphorous	mg/L	0.28	1.97	0.9	1.35	0.64	1.1	1.310	1.66	1.55	0.55	1.13
Dissolved Phosphorous	mg/L	0.27	0.29	0.42	0.33	0.2	0.51	0.23	0.104	0.13	<0.03	0.248
O&G	mg/L	2	<2	<2	<2	<2	<2	1.1	1.4	1.9	7.8	1.4
Total Cadmium	mg/L	<0.02	0.003	0.0007	0.001	0.002	<0.001	<0.003	<0.003	0.003	0.002	0.001
Dissolved Cadmium	mg/L	<0.02	<0.001	<0.0007	<0.001	<0.001	<0.001	<0.003	<0.003	<0.001	<0.001	0.000
Total Copper	mg/L	<0.02	0.106	0.33	0.04	0.022	0.044	0.0730	<0.013	0.079	0.03	0.072
Dissolved Copper	mg/L	<0.02	0.007	0.007	<0.005	<0.005	<0.005	0.0360	<0.013	0.006	0.018	0.007
Total Lead	mg/L	0.008	0.059	0.017	0.014	<0.003	0.005	<0.005	<0.005	0.049	0.014	0.017
Dissolved Lead	mg/L	0.004	<0.003	0.002	<0.003	<0.003	<0.003	<0.005	<0.005	0.007	0.006	0.002
Total Zinc	mg/L	<0.30	0.218	0.068	0.157	0.106	0.111	0.2950	<0.018	.0.277	0.07	0.103
Dissoved Zinc	mg/L	<0.30	0.021	0.052	0.081	0.049	0.042	0.0340	<0.018	0.02	0.028	0.033
Total Arsenic	mg/L	0.058	0.08	0.06	0.056	0.073	0.069	<0.012	0.016	<0.011	0.011	0.042
Dissolved Arsenic	mg/L	0.053	0.019	0.054	0.038	0.02	0.036	<0.012	0.015	0.02	<0.011	0.026
Total Chromium	mg/L	<0.02	0.037	0.013	0.013	0.017	0.008	0.0200	<0.007	0.033	0.007	0.015
Dissolved Chromium	mg/L	<0.02	<0.005	0.001	<0.005	<0.0005	<0.005	<0.007	<0.007	0.0030	0.0030	0.001
Total Cyanide	mg/L	<0.005	0.001	<0.001	<0.001	0.001	<0.001	<0.005	<0.005	0.00284		0.000
Total Nickel	mg/L	<0.060	0.025	0.014	0.027	0.016	0.015	0.0240	<0.007	0.026	0.012	0.016
Dissolved Nickel	mg/L	<0.060	<0.005	0.009	0.008	<0.0005	0.006	<0.007	<0.007	0.006	0.006	0.004
Total Selenium	mg/L	0.06	<0.005	<0.007	<0.005	<0.005	<0.005	<0.025	<0.025	<0.012	<0.012	0.006
Dissolved Selenium	mg/L	<0.05	<0.005	<0.007	<0.005	<0.005	<0.005	<0.025	<0.025	0.014	0.017	0.003
Total Silver	mg/L	<0.02	<0.002	0.01	<0.002	<0.002	<0.002	0.0080	0.008	<0.002	<0.002	0.003
Dissolved Silver	mg/L	<0.02	<0.002	<0.0009	<0.002	<0.002	<0.002	0.0	<0.008	0.004	0.002	0.001
pH	std. u	8.27	8.3	8.7	8.4	8	7.9	8.0	8.19	8.4	8.2	8.2

Table VI-9
Lee Drain Storm Event Composite Samples
1995-1999

Salt Lake City Storm Event Monitoring Data												
UPDES Permit No. UTS000002												
Lee Drain Composite Samples - LED-02												
		1	2	3	4	5	6	8	9	10	11	
Parameter	**Units**	**11/9/1995**	**4/12/1996**	**10/19/1996**	**4/24/1997**	**9/26/1997**	**10/12/1997**	**9/10/1998**	**10/29/1998**	**4/7/1999**	**9/3/1999**	**Average**
BOD	mg/L	30	20	18.5	23.5	20	10	26.9	13.1	12.0	15.6	18.96
COD	mg/L	193	1,115	81	58	51	24	96.2	46.7	54.4	70	178.9
TSS	mg/L	286	286	246	462	64	90	60.0	198	302	121	211.5
TDS	mg/L	1,030	1,600	684	1346	1222	620	160.0	1054	1020	1206	994.2
Total Nitrogen	mg/L	0.6	2.77	2.26	2.38	1.05	0.84	<0.10	0.16	0.24	0.26	1.056
TKN	mg/L	0.6	2.77	2.64	2.68	1.05	1.02	1.820	2	1.71	0.92	1.72
Total Phosphorous	mg/L	1.07	1.03	1.13	1.1	<0.1	0.55	0.430	0.672	0.63	0.44	0.705
Dissolved Phosphorus	mg/L	0.2	<0.10	0.61	0.33	<0.1	0.53	0.150	0.237	0.13	0.18	0.237
Total Cadmium	mg/L	<0.02	0.002	0.002	0.003	<0.001	<0.001	<0.003	<0.003	0.003	<0.001	0.001
Dissolved Cadmium	mg/L	<0.02	<0.001	<0.0007	0.002	<0.001	<0.001	<0.003	<0.003	<0.001	<0.001	0.000
Total Copper	mg/L	0.08	0.064	0.066	0.079	<0.005	0.018	0.024	0.032	0.056	0.021	0.044
Dissolved Copper	mg/L	<0.02	0.006	0.005	0.036	<0.005	0.006	0.090	<0.013	0.003	0.007	0.015
Total Lead	mg/L	0.04	<0.003	0.027	0.033	<0.003	<0.003	<0.005	0.009	0.038	0.014	0.016
Dissolved Lead	mg/L	0.006	<0.003	<0.002	0.006	<0.003	<0.003	<0.005	<0.005	<0.004	0.004	0.002
Total Zinc	mg/L	<0.30	0.158	0.149	0.22	0.049	0.062	0.076	0.107	0.166	0.061	0.105
Dissolved Zinc	mg/L	<0.30	0.023	0.067	0.16	0.036	0.038	0.041	0.018	0.012	0.020	0.042
Total Arsenic	mg/L	0.043	0.051	0.033	0.057	0.029	0.036	0.040	0.049	<0.011	<0.011	0.034
Dissolved Arsenic	mg/L	0.024	0.023	0.019	0.029	0.023	0.015	0.016	0.02	<0.011	0.015	0.018
Total Chromium	mg/L	0.04	0.018	0.021	0.026	<0.005	<0.005	<0.007	0.009	0.02	0.005	0.014
Dissolved Chromium	mg/L	<0.02	<0.005	0.001	<0.005	<0.005	<0.005	<0.007	<0.007	<0.001	0.002	0.000
Total Nickel	mg/L	<0.060	0.016	0.015	0.013	0.006	0.006	0.012	0.011	0.013	0.007	0.010
Dissolved Nickel	mg/L	<0.060	<0.005	0.004	0.005	<0.005	<0.005	<0.007	<0.007	<0.002	0.004	0.001
Total Selenium	mg/L	<0.05	<0.005	<0.007	<0.005	<0.005	<0.007	<0.025	<0.025	<0.012	<0.012	0.000
Dissolved Selenium	mg/L	<0.05	<0.005	<0.007	<0.005	<0.005	<0.007	<0.025	<0.025	<0.012	0.015	0.002
Total Silver	mg/L	<0.02	<0.002	0.011	0.002	<0.002	<0.002	<0.008	<0.008	0.003	<0.002	0.002
Dissolved Silver	mg/L	<0.02	<0.002	<0.0009	<0.0002	<0.002	<0.002	<0.008	<0.008	<0.002	<0.002	0.000

APPENDIX B

Chapter 2 - Supporting Documents

TSS Load Calculations

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TSS Load Calculations

Input Parameters	
Storm Event (in) =	0.40
Serviced Drainage Area (acre) =	75
Storm Duration (min) =	30
Estimated Impervious Area % =	52
Weighted Avg Runoff Coefficient (R_a) =	0.52
Mean # of storms per season =	23
Mean Annual Rainfall (in)=	14.3
Runoff correction factor (annual loading only)=	0.9
Minimun January Temperature (^oF)=	18.7

Precipitation Frequency Estimates (inches)

MIDVALE, UTAH (42-5610) 40.6ºN 111.9167ºW 4281 feet, ESTIMATES FROM NOAA ATLAS 14

Return Period	5 min	10 min	15 min	30 min	60 min	120 min	3 hr	6 hr	12 hr	24 hr
2	0.16	0.24	0.30	0.40	0.49	0.62	0.71	0.92	1.14	1.32
5	0.21	0.33	0.41	0.55	0.68	0.80	0.89	1.11	1.37	1.57
10	0.27	0.41	0.51	0.68	0.84	0.98	1.05	1.29	1.58	1.78
25	0.36	0.55	0.68	0.91	1.12	1.27	1.32	1.55	1.89	2.07
50	0.44	0.67	0.83	1.12	1.39	1.54	1.57	1.77	2.14	2.30
100	0.54	0.82	1.02	1.37	1.70	1.86	1.87	2.03	2.42	2.54

Conversions

1.0 lb	=	453,592 mg
1.0 acre	=	6,272,665 in^2
1.0 in^3	=	0.016 L
1.0 acre	=	1.6E-3 mi^2

$L_x = 0.227 \cdot P \cdot P_j \cdot R_a \cdot A_s \cdot C_a$

0.227 conversion factor		**0.227**		
Precipitation of Storm Event	in	**P**		
Weighted Avg Runoff Coefficient		**R_a**		
Drainage Area	acre	**A_s**		
Concentration (EMC) of Consituent	mg/L	**C_a**		

Using SLCo EMC		TSS = 411 lbs
Ra =	0.52	[1] 116 mg/L
EMC =	116 mg/L	
As =	75.0 acre	
	Annual TSS =	13,245 lbs

Using NURP EMC		TSS = 637 lbs
Ra =	0.52	[6] 180 mg/L
EMC =	180 mg/L	
As =	75.0 acre	
	Annual TSS =	20,552 lbs

Using CalTrans Data		TSS = 334 lbs
Ra =	0.52	[9] 94.6 mg/L
Hwy TSS Conc =	94.4 mg/L	
As =	75.0 acre	
	Annual TSS =	10,778 lbs

Characteristics of Stormwater Runoff from Caltrans Facilities, 2002

USGS Water-Supply Paper 2363

Driver, N. E. and G. D. Tasker. 1990. Techniques for Estimation of Storm-Runoff Loads, Volumes, and Selected Constituent Concentrations in Urban Watersheds in the United States. Washington, D.C., U.S. Geological Survey, Washington, D.C., USGS Water-Supply Paper 2363

$Y = \beta_o' \cdot X_1^{\beta 1} \cdot X_2^{\beta 2} \cdot \ldots\ldots X_n^{\beta n} \cdot BCF$ — Eq. 3 USGS Table 1, 3, & 5

Region I: Areas that have a mean annual rainfall less than 20 in.

			Regression Model for Mean Loads, Table 1				Three-Variable Model, Table 3				Regression Model for Mean Concentrations, Table 5			
			Needed	SS Region I	Value X_n	Value β_n	Needed	SS Region I	Value X_n	Value β_n	Needed	SS Region I	Value X_n	Value β_n
Regression coefficient		$\beta_o' = 10^{\beta o}$	*	1,518			*	1,778			*	2,041		
Total Storm Rainfall	in	TRN	*		0.4	1.211	*		0.4	0.867	*		0.4	0.143
Total Drainage Area	mi^2	DA	*		0.12	0.735	*		0.12	0.728	*		0.12	0.108
Impervious Area + 1	%	IA+1					*		53	0.157				
Industrial Landuse + 1	%	LUI+1												
Commercial Landuse + 1	%	LUC+1												
Residential Landuse + 1	%	LUR+1												
Nonurban Landuse + 2	%	LUN+2												
Population Density	people/mi^2	PD												
Duration of each storm	min	DRN	*		30	-0.463					*		30	-0.370
Max 2-yr 24-hr Precip Intensity	in	INT												
Mean Annual Rainfall	in	MAR												
Bias correction factor		BCF	*			2.112	*			2.367	*			1.543
Suspended Solids	mg/L		SS =	45 lbs	R^2 =	0.55	SS =	745 lbs	R^2 =	0.52	SS =	623 mg/L	R^2 =	0.13
				[2] 7 mg/L	%Error =	334		[3] 211 mg/L	%Error =	251		[4] 4,233 lbs	%Error =	131
							Annual SS =	16,575 lbs						

$W = 10^{[\beta o' + \beta 1 SQRT(DA) + \beta 2 IA + \beta 3 MAR + \beta 4 MJT + \beta 4 X2]} \cdot BCF$ — USGS Table 10

Region I: Areas that have a mean annual rainfall less than 20 in.

			Model for Annual Mean Loads, Table 10 (OLS)				Model for Mean Annual Loads, Table 10 (GLS)			
			Needed	SS Region I	Value	Value β_n	Needed	SS Region I	Value	Value β_n
Regression coefficient		β_o'	*	1.4627			*	1.5430		
Total Drainage Area	mi^2	DA	*		0.12	1.6021	*		0.12	1.5906
Impervious Area	%	IA								
Mean Annual Rainfall	in	MAR	*		14.3	0.0299	*		14.3	0.0264
Minimun January Temperature	^oF	MJT	*		18.7	-0.0342	*		18.7	-0.0297
Indicator Var, Com + Ind LU exceeding 75%		X_2								
Bias correction factor		BCF	*			1.670	*			1.521
Suspended Solids	mg/L		Annual SS =	2,424 lbs	R^2 =	0.43	Annual SS =	2,846 lbs	R^2 =	0.43
				[7] 10 mg/L	%Error =	156		[8] 12 mg/L	%Error =	130

Example uses Jordan 03/04

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APPENDIX C

Chapter 3 - Supporting Documents

Proprietary System Details

EPA Stormwater Technology Fact Sheet – Hydrodynamic Separators

UDOT Site Visit Cost Estimates

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STORMWATER TREATMENT SYSTEMS

BAYSAVER

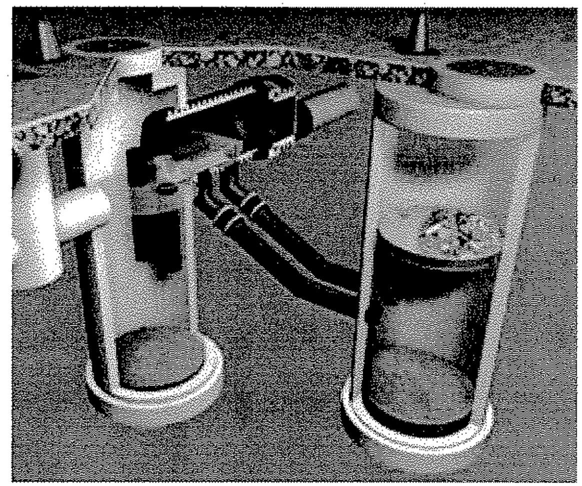
Your Best Value Per Treated CFS

HOME | SYSTEM INFO | DESIGN-SPECIFY | FAQ | GET INFO | NEWS & LINKS | COMPANY INFO

The BaySaver Separation System is a structural stormwater Best Management Practice (BMP) that:

- Removes pollutants from stormwater runoff
- Meets regulatory requirements
- Is your best value per treated cfs

See the system in action!
View System Animation
Curious about installation?
View Installation- Flash Version



NPDES Stormwater Permit Planning:

BaySaver understands, and can help you identify and effectively manage, municipal stormwater infrastructures.

Whether you are regulated by Phase I of the stormwater program, or are still planning permit coverage for Phase II, BaySaver can help you meet the 5th program element (minimum control measure) for stormwater treatment where:

- Optimal land development is desired
- A cost effective BMP is needed
- Pretreatment or stand alone treatment is desired

News So You're Not Confused

Diversion Structure Use: A lesson in fuzzy math

2004 Events Include Las Vegas, New Orleans

Distributor & Rep Opportunities Available ....

Daily Industry News ....

Vortechs® Animation | Maintenance | Case Histories | Technical Bulletins

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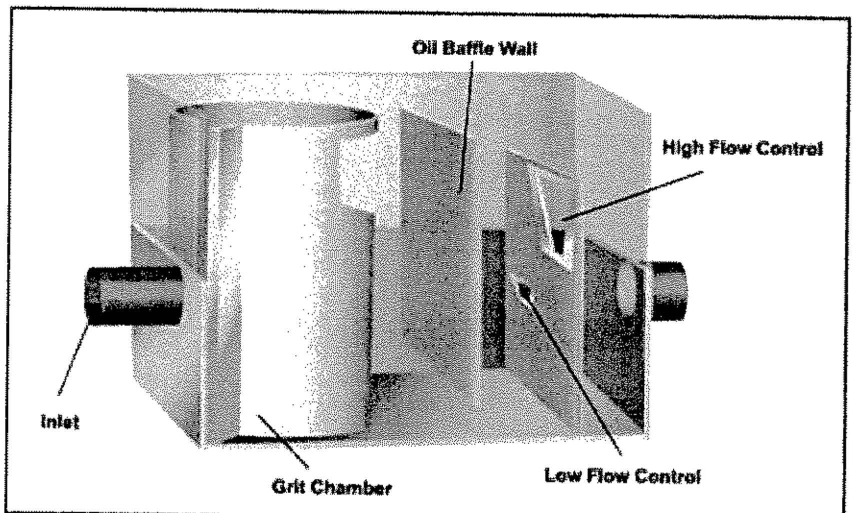
Vortechs® System

EPA award-winning design efficiently removes contaminated sediment, floating oil and debris from surface runoff. It is a compact, below grade system that is fabricated near the jobsite from precast concrete and marine grade aluminum. Its unique design allows for easy inspection and unobstructed maintenance access. Features include low capital cost per unit of treatment and a shallow excavation depth that reduces installation costs.

The Vortechs® System's swirl-concentrator and flow-controls work together to prevent pollutant re-suspension and washout - even during high-intensity storm events. System performance has been documented with both laboratory and field data. Annual TSS removal efficiencies have been shown to be 80% for typical urban runoff particle distributions. Each system is custom-designed to suit site conditions and local regulatory requirements, treating design flows from 1.6 CFS to 25 CFS. Larger flows are treated using Vortechs Systems that are cast-in-place. Animated phases of operation.



The sizing chart below describes precast Vortechs® Systems and peak design flow rates treated by each. These models are sized to treat infrequent peak design flows (e.g. 10 year storms) without bypassing. Stormwater flows can also be treated using off-line (bypassed) Vortechs® Systems or cast-in-place Vortechs® Systems. Please refer to Technical Bulletin 3 for a complete explanation of our sizing criteria (or contact your local sales office for assistance.).

Vortechs® Model	Grit Chamber Diam./Area ft/ft^2	Peak Design Flow (A) cfs.	Sediment Storage (B) yds.	Approx. Size (C) L x W ft.
1000	3/7	1.6	0.75	9 x 3
2000	4/13	2.8	1.25	10 x 4
3000	5/20	4.5	1.75	11 x 5
4000	6/28	6.0	2.5	12 x 6
5000	7/38	8.5	3.25	13 x 7
7000	8/50	11.0	4.0	14 x 8
9000	9/64	14.0	4.75	15 x 9
11000	10/79	17.5	5.5	16 x 10
16000	12/113	25.0	7.0	18 x 12

click here for metric conversion

Engineering Notes:

A) For on-line Vortechs® Systems without a bypass, sizing criteria is based on providing one square foot of grit chamber surface area for each 100 gpm of peak design storm flow rate (e.g., 10-year storm).

B) Sediment storage volumes assume a 3-foot sump and a 1-foot opening under baffle.

C) The sizing information above is representative of typical Vortechs® Systems. Construction details may vary depending on the specific application. Any alterations to the sizing chart specifications will appear on Vortechnics dimensional and shop drawings. Please contact Vortechnics for the weight of specific Vortechs® Systems if needed.

Special Note: Oil storage capacity, when it is needed to meet a specific requirement for spill containment, can be sized to meet the storage requirement with the selected model. Vortechnics technical staff will optimize system geometry to meet containment requirements within a correctly size Vortechs® System.

"When you are ready to specify a Vortechs® System, please complete our Specifier's Worksheet and e-mail or fax to Vortechnics or contact a local Vortechnics Sales Office for assistance."

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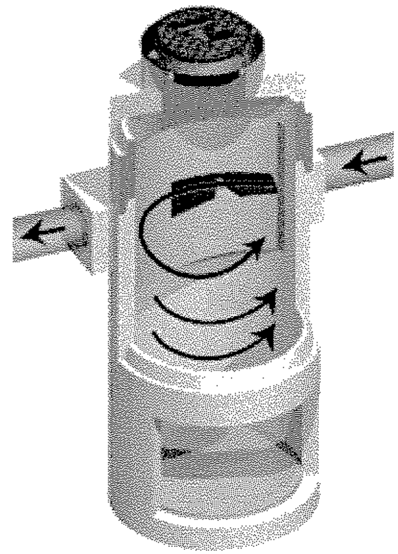
VortSentry™

The new alternative in hydrodynamic separation

The VortSentry™ is a new, engineered Vortechnics solution for the primary treatment of stormwater flows. It utilizes a round concrete manhole as the host for the treatment components and is specifically designed to remove sediment and free-floating pollutants from stormwater runoff. The design is the result of rigorous CFD (Computational Fluid Dynamics) modeling and full-scale laboratory testing. Its lightweight, round construction offers easy installation, and its compact design is well suited for congested sites.

Ideally suited for applications where stormwater regulations require that pollutants are reduced to the maximum extent practicable, the VortSentry™ can be used as a standalone best management practice (BMP) or as a pre-treatment system used in conjunction with other stormwater treatment devices. All VortSentry™ models are configured with a flow partition to ensure that the rate of flow through the treatment chamber will not cause pollutant re-entrainment, even as the total flow rate through the system



VortSentry™ at a Glance

- Round, lightweight construction offers easy installation
- Compact design ideal for congested sites
- Backed by full-scale laboratory testing
- Capable of diverting high flows without pollutant washout
- Unobstructed access and no moving parts ensures easy

increases. maintenance

VortSentry™ Models & Dimensions

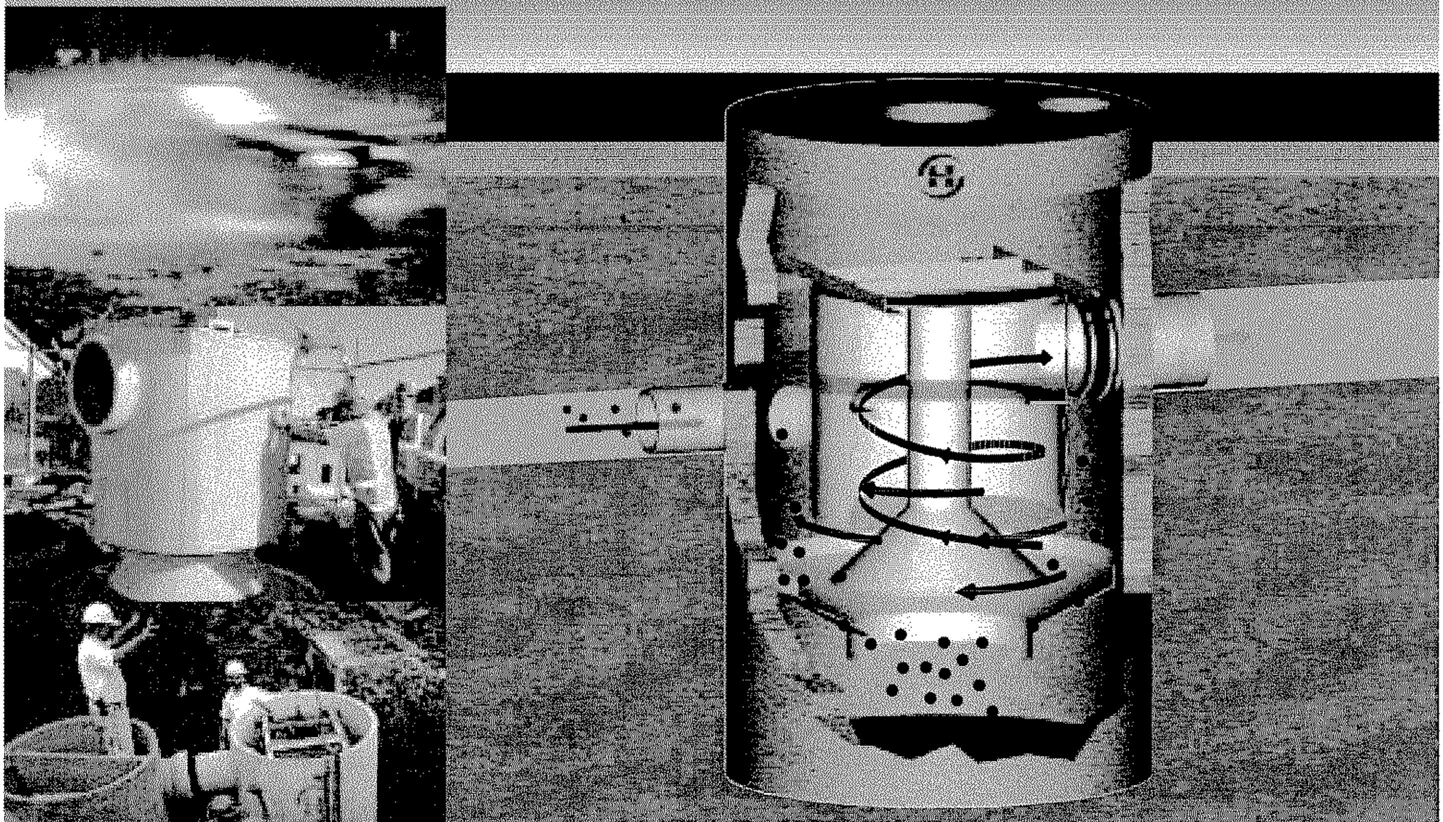
Model	Diameter		Depth (below invert)		Typical Inlet/Outlet Pipe Size*	
	ft	mm	ft	m	in	mm
VS30	3	900	5.4	1.7	12	300
VS40	4	1,200	6.5	2.0	12	300
VS50	5	1,500	7.4	2.3	15	375
VS60	6	1,800	8.3	2.5	18	450
VS70	7	2,100	9.1	2.8	21	525
VS80	8	2,400	10.0	3.0	24	600

***To ensure that the most appropriate VortSentry™ model size is slected, please contact a Vortechnics representative.**

When you are ready to specify a VortSentry™, please complete our Specifier's Worksheet and e-mail or fax to Vortechnics or contact a local Vortechnics Sales Office for assistance.

Downstream Defender

Environmental Stormwater Treatment Systems



PROTECTING OUR ENVIRONMENT

INTRODUCTION

The Hynds Downstream Defender is an advanced Hydrodynamic Vortex Separator that is specifically designed to provide high removal efficiencies of settleable solids and floatables over a wide range of flow rates.

Its flow-modifying internal components have been developed from extensive full scale testing, CFD modelling and over thirty years of hydrodynamic separation experience in wastewater, combined sewer and stormwater applications.

These internal components distinguish the Hynds Downstream Defender from simple swirl-type devices and conventional oil/grit separators by minimising turbulence and headlosses, enhancing separation, and preventing re-suspension of previously stored pollutants.

The high removal efficiencies and inherent low headlosses of the Hynds Downstream Defender allow for a small footprint making it a compact and economical solution for non-point source pollution.

ADVANTAGES

- Removes sediment, floatables, oils and grease
- Small footprint
- No pollutant re-entrainment
- No loss of treatment capacity between clean-outs
- Low head loss
- Efficient over a wide range of flows
- Easy to install
- Low maintenance
- Easy to specify

REFERENCE: EV.06.02

APPLICATIONS

The Hynds Downstream Defender's small footprint makes it an ideal choice wherever stormwater treatment is required. Installation locations include:

- Streets and roadways
- Parking Areas
- New Developments
- Construction Sites
- Vehicle Maintenance Yards
- Industrial and Commercial Facilities
- Airports, truck stops, shopping malls, restaurants, supermarkets, etc....

The Hynds Downstream Defender can also be used as a pretreatment device for detention systems, mitigating wetlands, swales, filters or other polishing systems.

NO POLLUTANT RE-ENTRAINMENT

Most stormwater treatment devices collect sediment within the treatment vessel. This reduces treatment capacity, compromises removal efficiency, and increases the risk of re-entrainment between clean-outs.

The Hynds Downstream Defender is unique in that the internal components create isolated zones for pollutant capture and storage. Separate oil and sediment storage areas are thereby established outside the main treatment flow path. Isolating the storage zones maintains treatment capacity and removal efficiency and prevents pollutant re-entrainment between cleanouts.

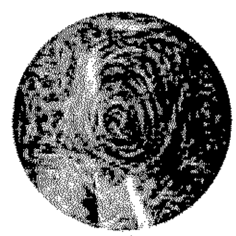
HOW THEY WORK (See diagram below)

The Hynds Downstream Defender consists of a concrete cylindrical vessel with a sloping base and internal components. Raw liquid is introduced tangentially into the side of the cylinder and spirals down the perimeter allowing heavier particles to settle out by gravity and the drag forces on the wall and base of the vessel.

The base of the Hynds Downstream Defender is formed at a 30 degree angle. As the flow rotates about the vertical axis, solids are directed towards the base of the vessel where they are stored in a collection facility. The internal components direct the main flow away from the perimeter and back up the middle of the vessel as a narrower spiralling column rotating at a slower velocity than the downward flow.

By the time the flow reaches the top of the vessel, it is virtually free of solids and is discharged through the outlet pipe.

HYDRAULIC FLOW P



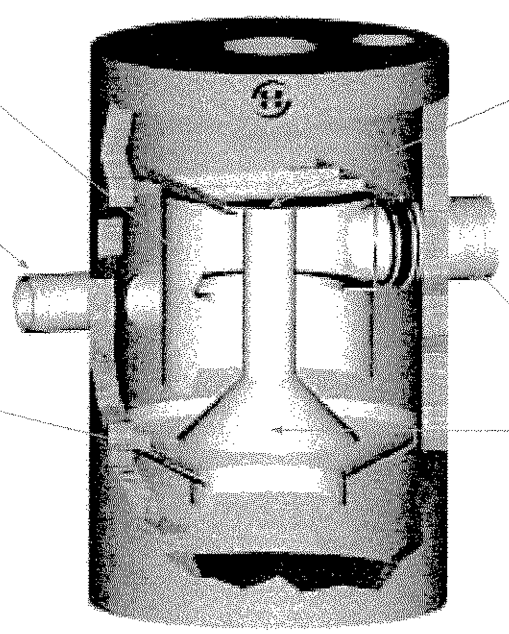
Flow pattern of a simple swirl type device

HYNDS DOWNSTREAM DEFENDER INTERIOR VIEW

The dip plate cylinder acts as an oil/floatables baffle.

The tangential inlet pipe generates rotational flow.

As the flow spirals around the vertical axis, sediment settles towards the base and is swept inward, along the benching skirt. Sediment then passes under the centre cone into the quiescent storage facility, beneath the vortex chamber.



The **floatables lid** covers the treated effluent in the inner annulus between the dip plate and centre shaft. It isolates the oil/floatables collection zone, located between the dip plate and the manhole wall, from the treated affluent.

The **outlet pipe** discharges treated effluent from the inner annulus.

As the main flow is directed inwards and upwards, the centre cone provides shelter for stored sediment, preventing re-entrainment.

LOW HEADLOSS

The Hynds Downstream Defender has large clear openings and no internal restrictions. Without internal orifice plates or weirs, hydraulic losses are minimised. The results are:

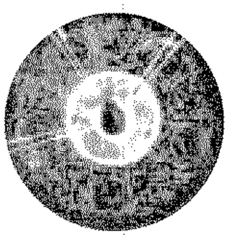
- Low Headlosses (see table below)
- Reduced risk of blockage
- No upstream flooding

PERFORMANCE

The device operates over a wide range of flows. At design flow the Hynds Downstream Defender is designed to remove 90% of all particles larger than 150 microns (0.15mm) with a specific gravity of 2.65. At lower flows this performance will increase.

The system also captures a large proportion of floatables, oils and grease and features a bypass system for flows greater than the capacity flow.

'ATTERNS



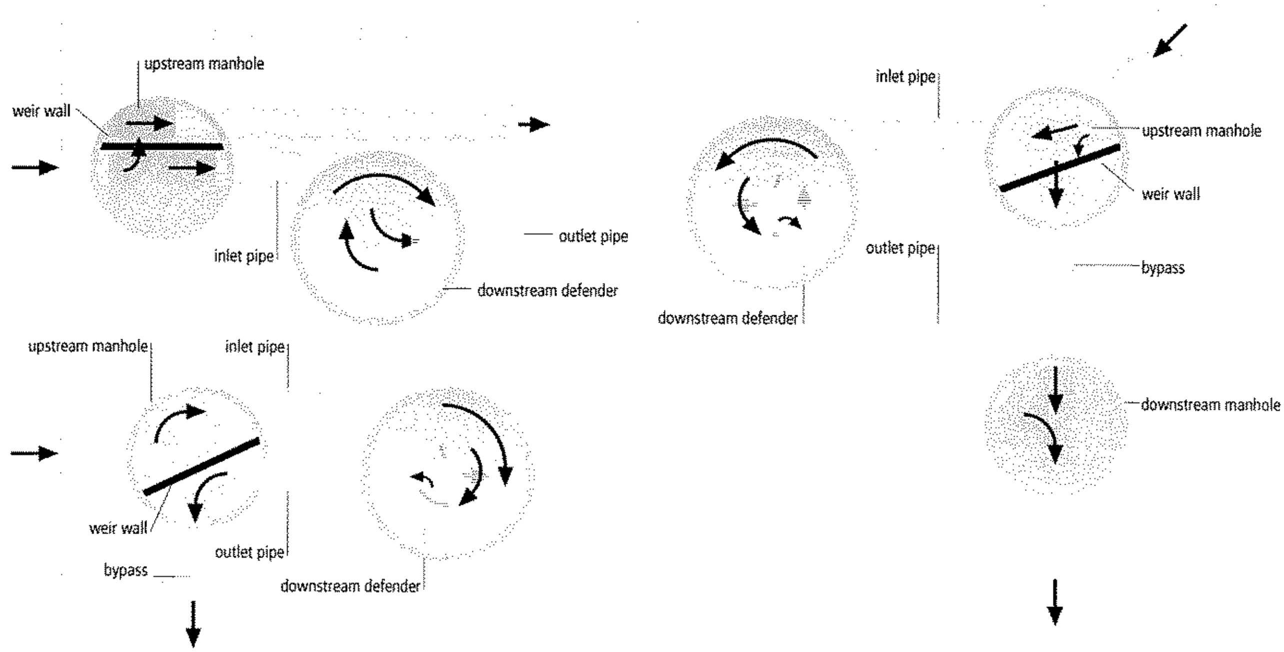
Flow pattern observed in the Hynds Downstream Defender

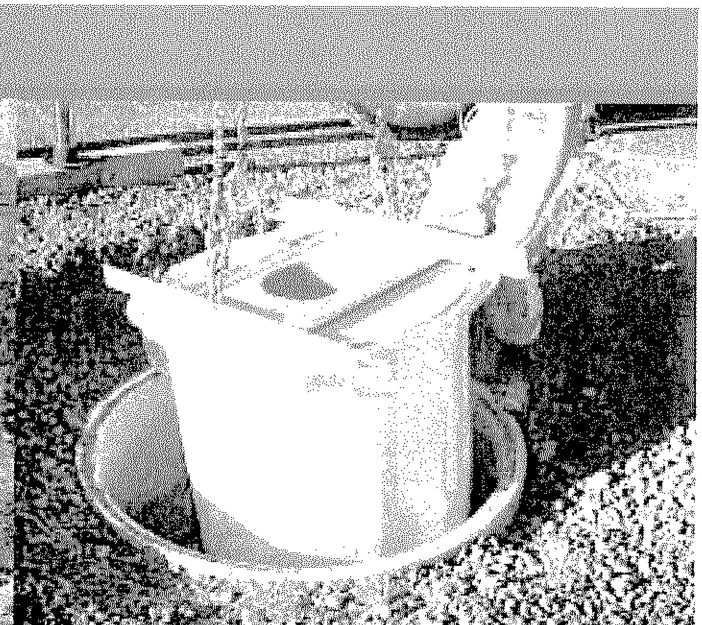
SIZING AND DESIGN

Unit Size (mm)	Design Flow (l/s)	Capacity Flow (l/s)	Inlet Pipe Diameter (mm)	Outlet Pipe Diameter (mm)	Headloss at Design Flow (mm)	Headloss at Capacity (mm)	Minimum Sediment Storage (m^3)
1200	20	85	225	300	75	575	0.55
1800	85	200	300	450	175	825	1.60
2550	200	425	450	600	225	575	4.05
3000	370	700	600	750	250	550	6.65

The sizing of a Hynds Downstream Defender is generally based on treating a 1 in 3 month storm or the "first flush".
The capacity through the system is shown above. At flows greater than capacity, the stormwater will bypass the Hynds Downstream Defender via an upstream manhole.
Typical layout plans for Hynds Downstream Defender Systems with a bypass are shown below.

TYPICAL INSTALLATION LAYOUTS FOR THE HYNDS DOWNSTREAM DEFENDER





INSTALLATION

Installing a Hynds Downstream Defender is as simple as installing a standard manhole. It typically requires significantly less excavation than other flow through systems.

The Hynds Downstream Defender is delivered to site in a kit set form, ready to be installed into the excavated hole and connected to the stormwater system. Its compact size allows it to fit within an excavation trench guard.

Installation time for a 1200 Series Hynds Downstream Defender is typically between one and two hours.

MAINTENANCE

Units are typically installed in locations that are easily accessible for a maintenance vehicle. A simple vactor procedure is used to periodically remove the pollutants.

Two ports at ground level provide access for inspection and clean-out of stored floatables and sediment. In most situations, bi-annual clean-outs are recommended.

Hynds Environmental offers maintenance contracts. Detailed maintenance instructions and maintenance logs are also available.

Hynds Environmental Systems Limited
Telephone 09 571 0090 Facsimile 09 571 0091
Email sales@hyndsenv.co.nz
Suite 2, 37 Wilkinson Road Ellerslie
PO Box 17 388 Greenlane, Auckland

HYNDS ENVIRONMENTAL

www.hynds.co.nz

Hynds Pipe Systems Ltd manufactures the Downstream Defender under license from Hydro International. New Zealand Patent Number 197894.

Hydro International

14th May, 2004

Don't know how CDS units work?

Copa LIMITED

LOGIN NAME:

PASSWORD:

PROCEED...

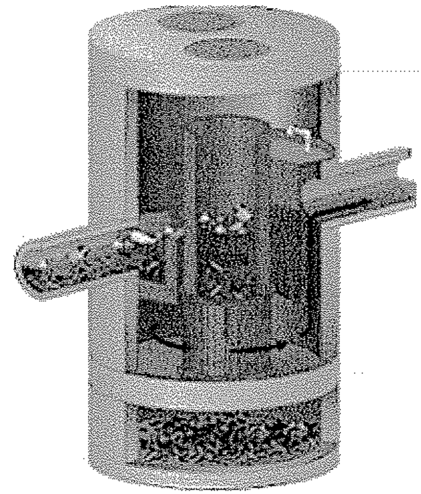
Not Registered?

Continuous Deflective Separation (CDS).

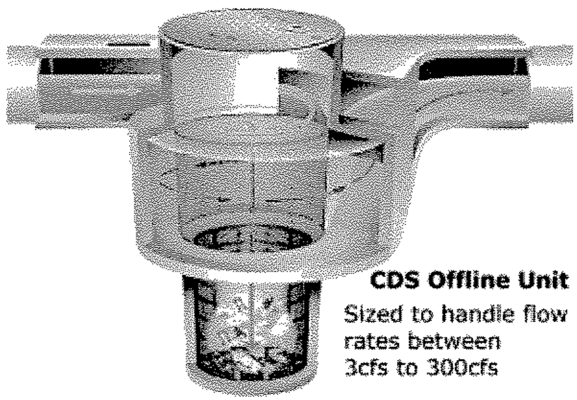
An effective treatment technology utilizing a non-blocking, non-mechanical screening process to remove pollutants from stormwater flows and combined sewer overflows (CSO).

Where do you want to go?? Capacities & Physical Features

Contact Us...



CDS Inline Unit
Sized to handle flows rates between 0.7cfs to 10cfs



CDS Offline Unit
Sized to handle flow rates between 3cfs to 300cfs

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Stormceptor®

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Sizing Tool

The Stormceptor Group of Companies is proud to introduce Version 4.0.0 of the Stormceptor® Sizing Program. Use our sizing program to accurately size the correct Stormceptor® unit to meet the site conditions for your project.

Please register to receive information on the Stormceptor® System or to download a copy of the Stormceptor® Sizing Program Version 4.0.0.

Learn How Stormceptors Work

- No Flow
- Low Flow
- High Flow

Stormceptor® Oil and Sediment Separator for Stormwater Runoff and Spill Control.

The Stormceptor is an engineered stormwater treatment structure that removes oil and sediment from storm runoff. Comprised of a round precast concrete tank and fibreglass partition, the patented Stormceptor replaces a maintenance hole in the storm sewer. By capturing oil spills and suspended solids, the system prevents non-point source pollution from entering downstream lakes and rivers. In the stormwater management industry it is commonly referred to as an:

- Oil-grit separator or Oil and grit separator (OGS), or
- Oil-sediment separator, or Oil and sediment separator (OSS)

The key advantage of Stormceptor over other stormwater treatment structures is its simplicity - treatment based on gravity separation. An internal weir directs 80-95% of annual runoff into the lower chamber where gravity separates oil and sediment from water. The weir forces a portion of the peak flow during infrequent storm events to bypass the treatment chamber. All OGS systems must bypass peak flows to prevent high velocities in the treatment chamber from re-suspending previously captured pollutants. Because Stormceptor has an internal bypass, only one structure is required. Other OGS systems must use external structures for a bypass, resulting in additional costs.

AquaShield
STORM WATER TREATMENT SOLUTIONS

PDA Client Login
founded on 20 years experience

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PDA System Registration

AquaSwirl Introduction

The Aqua-Swirl™ Concentrator provides a highly effective means for the removal of sediment, floating debris and free-oil . Swirl technology, or vortex separation, is a proven form of pollutant removal utilized in the stormwater industry to accelerate gravitational separation. Independent university laboratory performance evaluations have shown the TSS removal of 91% calculated for a net annual basis. See the "Perfomance and Testing" Section for details.

Each Aqua-Swirl™ is constructed of High-Density Polyethylene (HDPE), and is therefore modular, lightweight and durable, eliminating the need for heavy lifting equipment during installation. Inspection and maintenance are made easy, with large risers that allow for both examination and cleanout without entering the chamber.

Aqua Swirl Links

- Aqua Swirl Intro
- Inspection & Maintenance
- AquaSwirl Installation
- AquaSwirl Fabrication
- AquaSwirl Operation

Introducing Our PDA

We have completed our intuitive on-line PDA system to assist you in finding the proper system based on environmental conditions & regulatory concerns.

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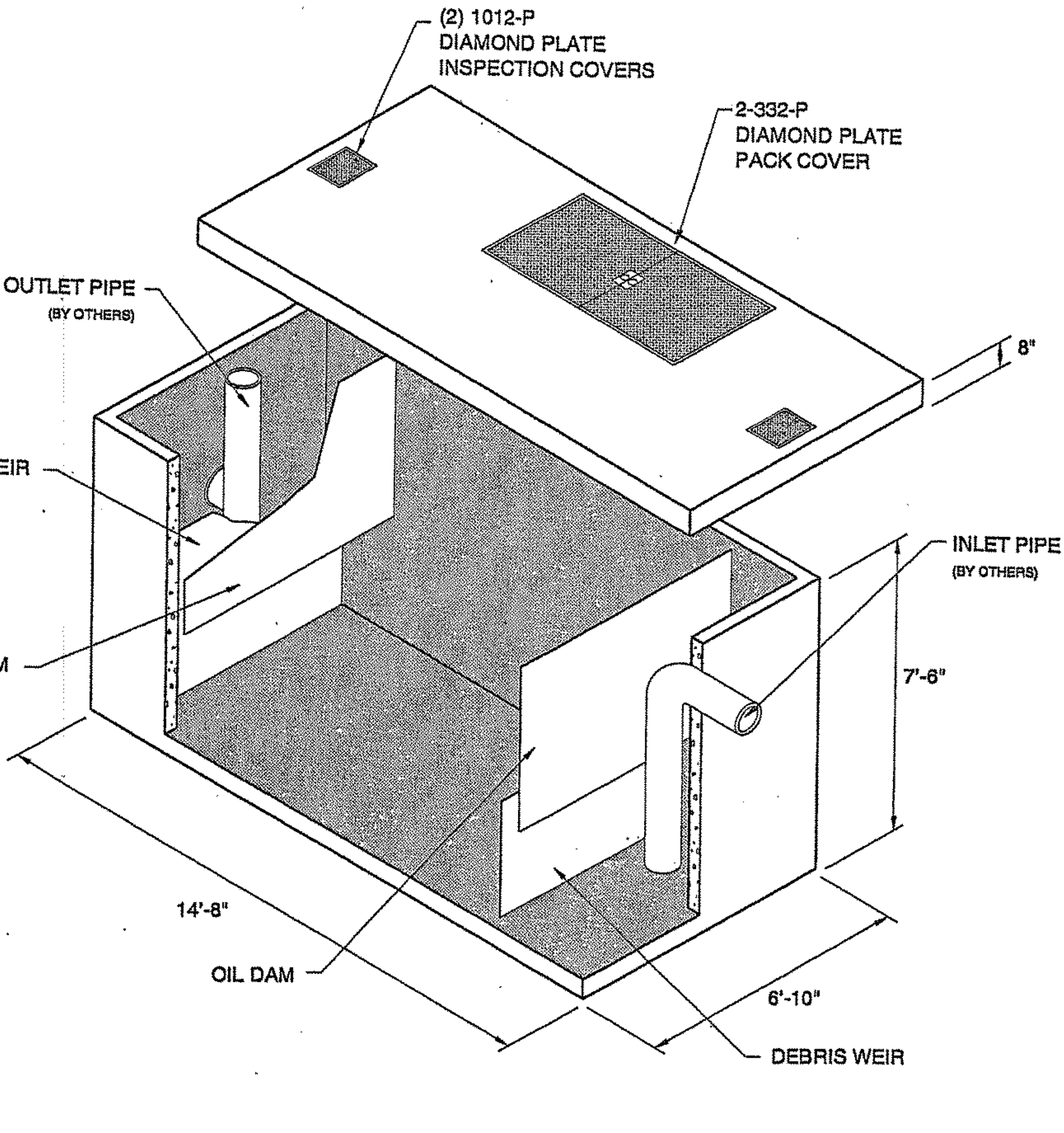
AMCOR Precast

OIL/WATER SEPARATOR

6214-SA



FOR DETAILS SEE REVERSE SIDE.

NOTES:
1. CONTRACTOR TO SUPPLY ALL PIPING.
2. LIQUID LEVEL = 4'-8".
3. CONTRACTOR TO VERIFY SIZE AND LOCATION OF INLET AND OUTLET HOLES.
4. INSIDE DIMENSIONS = 4'-2" x 8'-0" x 7'-0".

DESIGN INFORMATION
OIL SPECIFIC GRAVITY = .85
OPERATING TEMPERATURE = 40°
INFFLUENT OIL CONCENTRATION = 2000 PPM
EFFLUENT CONCENTRATION = 15 PPM
FLOW RATE = 800 GPM

OW250

2/93

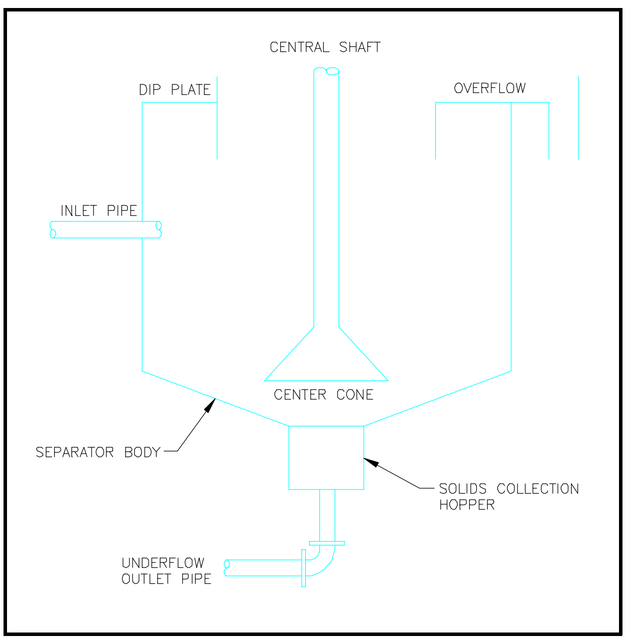
801 West 12th Street, Ogden, Utah 84404 • (801) 399-1171 • FAX 801-392-7849 • WATTS 800-776-8760

United States Environmental Protection Agency | Office of Water Washington, D.C. | EPA 832-F-99-017 September 1999

Storm Water Technology Fact Sheet
Hydrodynamic Separators

DESCRIPTION

Hydrodynamic separators are flow-through structures with a settling or separation unit to remove sediments and other pollutants that are widely used in storm water treatment. No outside power source is required, because the energy of the flowing water allows the sediments to efficiently separate. Depending on the type of unit, this separation may be by means of swirl action or indirect filtration. A generalized schematic of a unit is shown in Figure 1. Variations of this unit have been designed to meet specific needs.



Source: Fenner and Tyack, 1997.

FIGURE 1 GENERALIZED HYDRODYNAMIC SEPARATOR

Hydrodynamic separators are most effective where the materials to be removed from runoff are heavy particulates - which can be settled - or floatables - which can be captured, rather than solids with poor settleability or dissolved pollutants.

In addition to the standard units, some vendors offer supplemental features to reduce the velocity of the flow entering the system. This increases the efficiency of the unit by allowing more sediments to settle out.

APPLICABILITY

This technology may be used by itself or in conjunction with other storm water BMPs as part of an overall storm water control strategy. Hydrodynamic separators come in a wide size range and some are small enough to fit in conventional manholes. This makes hydrodynamic separators ideal for areas where land availability is limited. Also, because they can be placed in almost any specific location in a system, hydrodynamic separators are ideal for use in potential storm water "hotspots"--areas such as near gas stations, where higher concentrations of pollutants are more likely to occur.

The need for hydrodynamic separators is growing as a result of decreasing land availability for the installation of storm water BMPs. This fact sheet discusses hydrodynamic separator systems from four vendors. Although there are many hydrodynamic separation systems available, these four address the major types.

They are the following:

- Continuous Deflective Separation (CDS).

- Downstream Defender™.
- Stormceptor®.
- Vortechs™.

Continuous Deflective Separation (CDS)

CDS' hydrodynamic separator technology is suitable for gross pollutant removal. The system utilizes the natural motion of water to separate and trap sediments by indirect filtration. As the storm water flows through the system, a very fine screen deflects the pollutants, which are captured in a litter sump in the center of the system. Floatables are retained separately. This non-blocking separation technique is the only technology covered in this fact sheet that does not rely on secondary flow currents induced by vortex action.

The processing capacities of CDS units vary from 3 to 300 cubic feet per second (cfs), depending on the application. Precast modules are available for flows up to 62 cfs, while higher flow processing requires cast-in-place construction. Every unit requires a detailed hydraulic analysis before it is installed to ensure that it achieves optimum solids separation. The cost per unit (including installation) ranges from $2,300 to $7,200 per cfs capacity, depending on site-specific conditions and does not include any required maintenance.

Maintenance of the CDS technology is site-specific but the manufacturer recommends that the unit be checked after every runoff event for the first 30 days after installation. During this initial installation period the unit should be visually inspected and the amount of deposition should be measured, to give the operator an idea of the expected rate of sediment deposition. Deposition can be measured with a calibrated "dip stick". After this initial operation period, CDS Technologies recommends that the unit should be inspected at least once every thirty days during the wet season. During these inspections, the floatables should be removed and the sump cleaned out (if it is more than 85 percent full). It is also recommended that the unit be pumped out and the screen inspected for damage at least once per year.

A recently completed study by UCLA for CDS Technologies evaluating the effectiveness of four different sorbent materials in removing used motor oil at concentrations typically found in storm water runoff. They applied the sorbents in a CDS unit separation chamber and reported captures of 80-90 percent. The test found that polypropylene or co-polymer sorbents to be the most effective in the capture of the used motor oil.

Downstream Defender

The Downstream Defender, manufactured by H.I.L. Technology, Inc., regulates both the quality and quantity of storm water runoff. The Downstream Defender is designed to capture settleable solids, floatables, and oil and grease. It utilizes a sloping base, a dip plate and internal components to aid in pollutant removal. As water flows through the unit, hydrodynamic forces cause solids to begin settling out. A unique feature of this unit is its sloping base (see Figure 1), which is joined to a benching skirt at a 30-degree angle. This feature helps solids to settle out of the water column. The unit's dip plate encourages solids separation and aids in the capture of floatables and oil and grease. All settled solids are stored in a collection facility, while flow is discharged through an outlet pipe. H.I.L. Technology reports that this resulting discharge is 90 percent free of the particles greater than 150 microns that originally entered the system.

The Downstream Defender comes in predesigned standard manhole size, typically ranging from 4 to 10 feet in diameter. These units have achieved 90 percent removal for flows from 0.75 cfs to 13 cfs. To meet specific performance criteria, or for larger flow applications, units may be custom designed up to 40 feet in diameter. (These are not able to fit in conventional manholes.) The approximate capital and installation costs, range from $10,000 to $35,000 per pre-cast unit.

Inspecting the Downstream Defender periodically (once a month) over the first year of operation will aid in determining the rate of sediment and floatables accumulation. A probe (or dipstick) may be used to help determine the sediment depth in the collection facility. (With this inspection information a maintenance schedule may be established.) A sump vac (commercial or municipally-owned) may be used to remove captured floatables and solids. With proper upkeep, H.I.L. Technology reports the Downstream Defender will treat storm water for more than 30 years.

Stormceptor

Stormceptor Corporation is based in Canada and has licensed manufacturers throughout Canada and the United States. Stormceptor is designed to trap and retain a variety of non-point source pollutants, using a by-pass chamber and treatment chamber. Stormceptor reports that it is capable of removing 50 to 80 percent of the total sediment load when used properly.

Stormceptor units are available in prefabricated sizes up to 12 feet in diameter by 6 to 8 feet deep. Customized units are also available for limited spaces. Stormceptor recommends its units for the following areas:

- Redevelopment projects of more than 2,500 square feet where there was no previous storm water management (even if the existing impervious area is merely being replaced).

- Projects that result in doubling the impervious area.

- Projects that disturb at least half of the existing site.

The cost of the Stormceptor unit is based on the costs of two important system elements:

- A treatment chamber and by-pass insert.

- Access way and fittings.

Typically, the cost for installation of a unit for a one acre drainage area is $9,000. This cost will vary depending on site-specific conditions. Stormceptor units range from 900 to 7,200 gallons and cost between $7,600 and $33,560. Cleaning costs depend on several factors, including the size of the installed unit and travel costs for the cleaning crew. Cleaning usually takes place once per year and costs approximately $1,000 per structure.

Vacuum trucks are used to clean out the Stormceptor unit. Although annual maintenance is recommended, maintenance frequency will be based on site-specific conditions. The need for maintenance is indicated by sediment depth; typically, when the unit is filled to within one foot of capacity, it should be cleaned. Visual inspections may also be performed and are especially recommended for units that may capture petroleum-based pollutants. The visual inspection is accomplished by removing the manhole cover and using a dipstick to determine the petroleum or oil accumulation in the unit.

If the Stormceptor unit is not maintained properly, approximately 15 percent of its total sediment capacity will be reduced each year.

Vortechs

The Vortechs™ storm water treatment system, manufactured by Vortechnics™ of Portland, Maine, has been available since 1988. Like the other hydrodynamic separators, Vortechs removes floating pollutants and settleable solids from surface runoff. This system combines swirl-concentrator and flow-control technologies to separate solids from the flow. Constructed of precast concrete, Vortechs uses four structures to optimize storm water treatment through its system. These are:

- *Baffle wall*: Situated permanently below the water line, this structure helps to contain floating pollutants during high flows and during clean outs.

- *Circular grit chamber*: This structure aids in directing the influent into a vortex path. The vortex action encourages sediment to be caught in the swirling flow path and to settle out later, when the storm event is complete.

- *Flow control chamber*: This device helps keep pollutants trapped by reducing the forces that encourage resuspension and washout. This chamber also helps to eliminate turbulence within the system.

- *Oil chamber*: This structure helps to contain floatables.

Vortechnics manufactures nine standard-sized units. These range from 9 feet by 3 feet to 18 feet by 12 feet. The unit sizes depend on the estimated runoff volume to be treated. For specific applications, dimensions of the runoff area are used to customize the unit. Vortechnics reports that Vortechs systems are able to treat runoff flows ranging from 1.6 cfs to 25 cfs. The cost for these units ranges from $10,000 to $40,000, not including shipment or installation.

As with other hydrodynamic separator systems, maintenance of the Vortechs system is site-specific. Frequent inspections (once a month) are recommended during the first year and whenever there may be heavy contaminant loadings: after winter sandings, soil disturbances, fuel spills, or sometimes, intense rain or wind.

The Vortechs unit requires cleaning only when the system has nearly reached capacity. This occurs when the sediment reaches within one foot of the inlet pipe. The depth may be gauged by measuring the sediment in the grit chamber with a rod or dipstick. To clean out the system, the manhole cover above the grit chamber is lifted and the sediment is removed using as vacuum truck. Following sediment removal, the manhole cover is replaced securely to ensure that runoff does not leak into the unit.

Hydrodynamic separators are most effective where the separation of heavy particulate or floatable from wet weather runoff is required. (The typical concentrations of heavy particulate and floatable pollutants found in storm water are shown in Table 1.) They are designed to remove settleable solids and capture floatables; however, suspended solids are not effectively removed. Most units are small (depending on the flow entering needing to be treated) and may be able to fit into pre-existing manholes. For this reason, this technology is particularly well suited to locations where there is limited land available.

TABLE 1 CONCENTRATION OF POLLUTANTS IN STORM WATER

Pollutant	Concentration
TSS	100 mg/L
Total P	0.33 mg/L
TKN	1.50 mg/L
Total Cu	34 µg/L
Total Pb	144 µg/L
Total Zn	160 µg L

Source: U.S. EPA, 1995.

The units designed for hydrodynamic separators are generally prefabricated in set sizes up to twelve feet in diameter, but they may be customized for a specific site if needed. Some structures are available in concrete or fiberglass. (Fiberglass is recommended for areas of potential hazardous material spills.) These materials are both suitable for retrofit applications.

Hydrodynamic separators are also good for potential storm water "hotspots" or sites that fall under industrial NPDES storm water requirements. "Hotspots" are areas such as gas stations, where a higher concentration of pollutants is more likely to be found.

ADVANTAGES AND DISADVANTAGES

The use of hydrodynamic separators as wet weather treatment options may be limited by the variability of net solids removal. While some data suggest excellent removal rates, these rates often depend on site-specific conditions, as well as other contributing factors. Pollutants such as nutrients, which adhere to fine particulates or are dissolved, will not be significantly removed by the unit.

Site constraints, including the availability of suitable land, appropriate soil depth, and stable soil to support the unit structurally, may also limit the applicability of the hydrodynamic separator. The slope of the site or collection system may necessitate the use of an underground unit, which can result in an extensive excavation.

Observable improvements in waterways are often attributable to the use of hydrodynamic separators. This is due to the reduction of sediments, floatables, and oil and grease in the flow out of the unit. These positive impacts are only achievable when proper design and O&M of the unit are implemented.

PERFORMANCE

Hydrodynamic separators are designed primarily for removing floatable and gritty materials; they may have difficulty removing the less-settleable solids generally found in storm water. The reported removal rates of sediments, floatables, and oil and grease differ depending on the vendor. Proper design and maintenance also affect the unit's performance.

OPERATION AND MAINTENANCE

Hydrodynamic separators do not have any moving parts, and are consequently not maintenance intensive. However, maintaining the system properly is very important in ensuring that it is operating as efficiently as possible. Proper maintenance involves frequent inspections throughout the first year of installation. The unit is full when the sediment level comes within one foot of the unit's top. This is recognized through experience or the use of a "dip stick" or rod for measuring the sediment depth. When the unit has reached capacity, it must be cleaned out. This may be performed with a sump vac or vacuum truck, depending on which unit is used. In general, hydrodynamic separators require a minimal amount of maintenance, but lack of attention will lower their overall efficiency.

COSTS

The capital costs for hydrodynamic separators depend on site-specific conditions. These costs are based on several factors including the amount of runoff (in cfs) required to be treated, the amount of land available, and any other treatment technologies that are presently being used. Capitol costs can range from $2,300 to $40,000 per pre-cast unit. Units which are site-specifically designed, typically cost more and the price is based on the individual site.

Total costs for hydrodynamic separators often include predesign costs, capital costs, and operation and maintenance (O&M) costs. Again, these costs are site-specific. The predesign costs depend upon the complexity of the intended site. O&M costs vary based on the company contracted to clean out the unit, and may depend on travel distances and cleaning frequency. These costs generally are low (maximum of $1,000 a year) and vary from year to year.

The individual unit prices are discussed in the current status section previously mentioned. This covers a more in depth price range of the various systems.

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Oil-Water Separator Service Visit

Task	Duration - minutes	Labor - hrs	Labor - cost	Equipment - hrs	Equipment - cost	Materials	Cost	Total Cost
Travel to Site	**10**	0.33	$10.05	0.3				
Remove Cover	**5**	0.17	$5.03	0.2			$5.03	
Evacuate debris	**20**	0.67	$20.10	0.7			$20.10	
Inspect Installation	**15**	0.50	$15.08	0.5			$15.08	
replace cover	**5**	0.17	$5.03	0.2		$5.00	$10.03	
Debris Disposal	**15**	0.50	$15.08	0.5		$25.00	$40.08	
Document Visit	**5**	0.17	$5.03	0.2			$5.03	
Equipment	**---**			3.5	$284.03		$284.03	
				ESTIMATED COST PER VISIT				**$379.35**

Equipment Needed	**One-ton truck with boom**		$20.50	per hour	$81.15
	Hand tools		$0.50	per hour	
	Heavy duty lamp		$0.15	per hour	
	Vactor		$60.00	per hour	
if entry into device is required					
	Ventilation fan		$2.50	per hour	$3.75
	Harness		$0.25	per hour	
	Oxygen Meter		$1.00	per hour	
Crew Size	**2 workers**	2	$30.15	per hour	
	Personal Protective Equipment				
Materials	**Sealant**		$5.00	per site	
Disposal	**Based on 8 units per day and $200/truck load disposal fee**				

Oil-Water Separator Service Visit

Task	Duration - minutes	Labor - hrs	Labor - cost	Equipment - hrs	Equipment - cost	Materials	Cost	Total Cost
Travel to Site	**10**	0.33	$10.05	0.3				
Remove Cover/Set up								
Enclosed Space Entry	**20**	0.67	$20.10	0.7	$2.25		$20.10	
Evacuate debris	**45**	1.50	$45.23	1.5	$5.06		$45.23	
Inspect Installation	**15**	0.50	$15.08	0.5	$1.69		$15.08	
replace cover	**5**	0.17	$5.03	0.2		$5.00	$10.03	
Debris Disposal	**15**	0.50	$15.08	0.5		$25.00	$40.08	
Document Visit	**5**	0.17	$5.03	0.2			$5.03	
Equipment	**---**			3.8	$311.08		$311.08	
				ESTIMATED COST PER VISIT				**$446.60**

Equipment Needed	**One-ton truck with boom**	$20.50	per hour	$81.15
	Hand tools	$0.50	per hour	
	Heavy duty lamp	$0.15	per hour	
	Vactor	$60.00	per hour	
if entry into device is required				
	Ventilation fan	$4.00	per hour	$6.75
	Generator	$1.50	per hour	
	Harness	$0.25	per hour	
	Oxygen Meter	$1.00	per hour	
Crew Size	**2 workers** 2	$30.15	per hour	
	Personal Protective Equipment			
Materials	**Sealant**	$5.00	per site	
Disposal	**Based on 8 units per day and $200/truck load disposal fee**			

APPENDIX D

Chapter 4 - Supporting Documents

Hydrodynamic Separator Design Process

Example Selection Process

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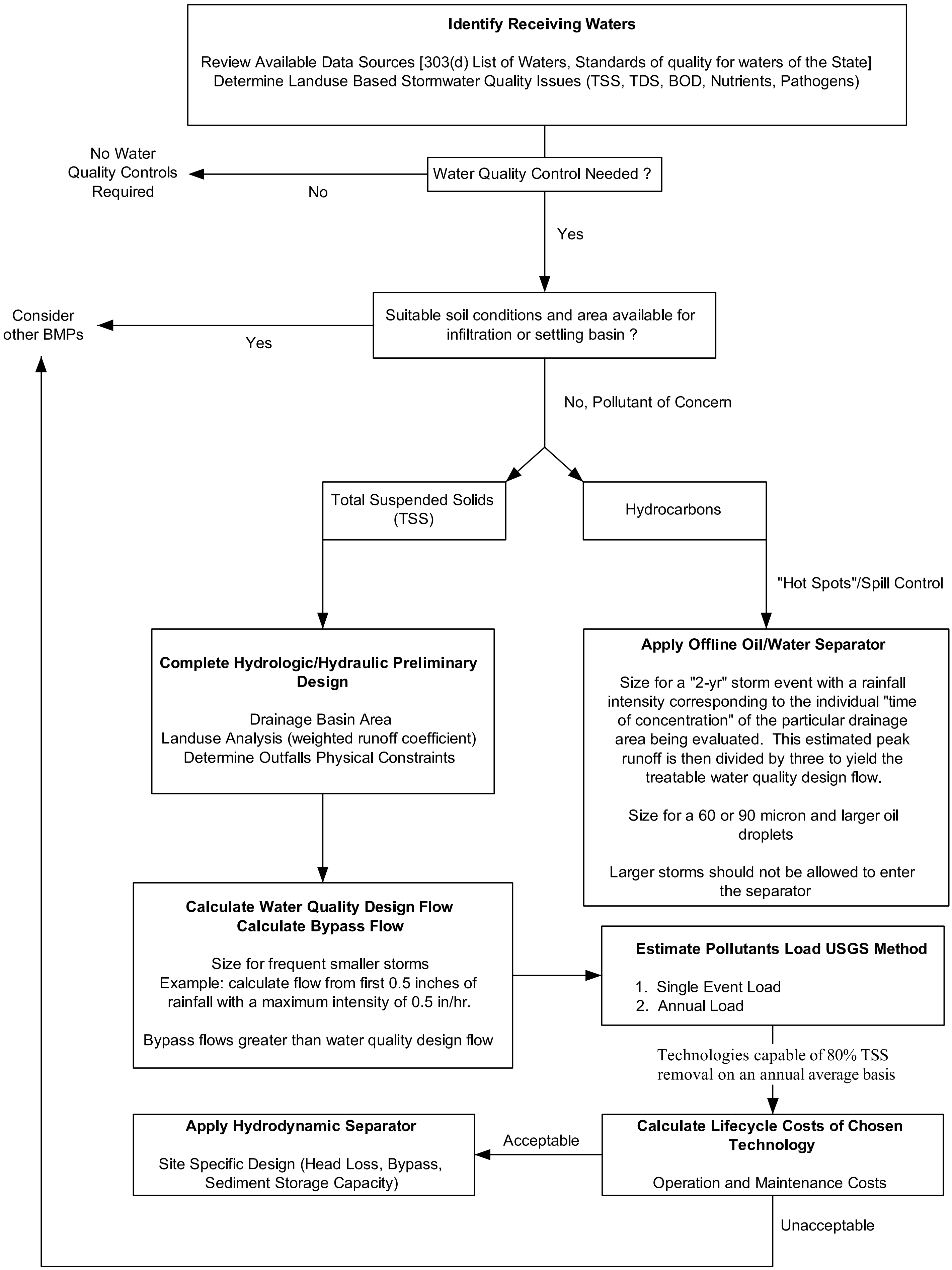
HYDRODYNAMIC SEPARATOR DESIGN PROCESS



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EXAMPLE

STORM WATER ANALYSIS FOR WATER QUALITY IMPROVEMENTS

The following analysis is an example of the steps and procedures for the water quality evaluation of stormwater flows from a specific urban drainage basin. The purpose of the analysis is to complete the following:

1. Predict the single design storm and annual pollutant load to be discharged.

2. Determine water quality design flow for a drainage basin.

3. Select appropriate water quality treatment device to remove target pollutants.

STEP 1: Inventory Drainage Basin for Land use and Potential Pollutant Sources

For this example a drainage basin was chosen in the Salt Lake Valley. The drainage basin was chosen due to the transportation land use and the fact that specific storm water quantity and quality data is available through the UDOT/SLCounty permit program. Through the UDOT/SL County monitoring program this basin is referred to as JOR 03 and/or JOR 20.13.

LAND USE. The drainage basin conveys stormwater flows from approximately 128 acres consisting of the following land use breakdown:

Transportation	73.5 acres (serviced area)
Residential	27.2 acres
Commercial	19.4 acres
Public	7.8 acres

The basin conveys flows from the intersection of I-15 and South I-215, see Figure 1. The receiving water for this basin is the Jordan River. There is currently no TMDL for this receiving water.

POLLUTANTS OF CONCERN. Due to the basin's mixed land use, the pollutants of concern were determined to be total suspended solids (TSS) and trace metals. There are no heavy industry or other large hot spot concerns.

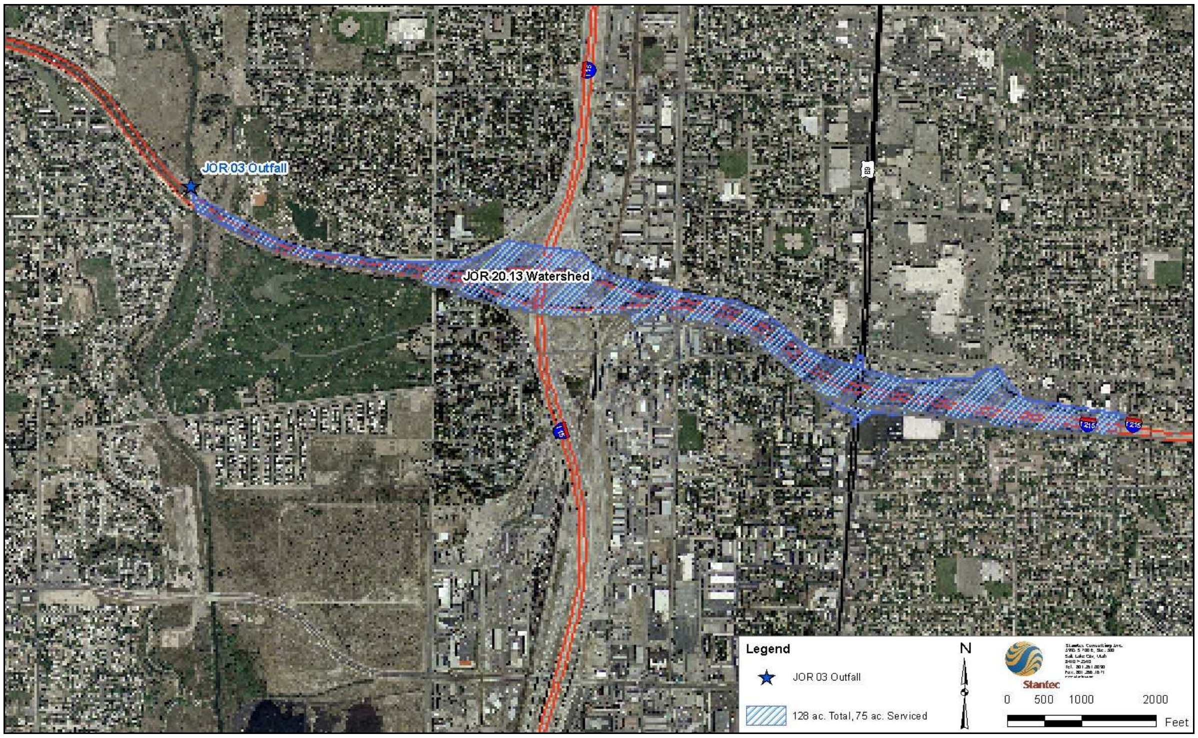

Figure 1. Drainage Basin Delineation JOR 03 (transportation land use).

STEP 2: Conduct Basin Hydrology and Hydraulic Calculations

For water quality treatment purposes the peak discharge to be treated by a control measure, is normally based on a smaller precipitation event than a 10-yr or 25-yr event. Therefore, sizing the treatment device for smaller flows, a high flow bypass system will be required to convey the nominal stormwater conveyance peaks around the treatment unit.

The peak water quality design flow for the JOR 03 basin was obtained using the Rational Method. A smaller rain event was used to calculate the water quality design peak, 0.5" of rainfall with a maximum intensity of 0.5 in/hr versus the conveyance design event, normally a 10-yr event. The following hydrologic parameters were utilized:

- One half inch (0.5") of rainfall with a maximum intensity of 0.5 in/hr
- Time of concentration about 1 hour (see attached Tc calculations for this specific basin)
- To capture and treat the first 0.5" of rainfall (first flush) a maximum rainfall intensity of 0.5 in/hr was used.
- Average weighted runoff coefficient for the basin 0.52
- Drainage basin area was assumed to be the serviced area approximately 75 acres

The water quality design peak flow for JOR 03 basin was estimated to be 19.5 cfs. A water quality design volume of 1.6 ac-ft was predicted for the same 0.5 inches of rainfall (see attached flow calculations). These two quantities, flow and volume will be utilized to determine the most appropriate BMP, for this specific basin.

Also attached is the flow hydrograph for the March 2004 storm event (0.66 inches) that was measured, sampled and analyzed for the UDOT UPDES permit, JOR 03 basin.

STEP 3: Predict Annual and Event Pollutant Loads

The basin conveys stormwater to the Jordan River. Annual pollutant loads are predicted to assist with the selection of treatment technologies and to estimate operation and maintenance requirements

For this example, the pollutant loads will be calculated by the various methods discussed during this study. The purpose of using multi-methods is to show the designer the variability of the methods and the range of results. The purpose for predicting annual and storm event loads would be to evaluate operation and maintenance costs for the treatment technology.

The following methods will be used:

SINGLE STORM EVENT LOADS

1. USGS Method Mean Loads Regression Model

2. USGS Method—Three Variable Model

ANNUAL LOADS

1. EPA Simple Method—Based on SLCo EMC (Table 1)

Two USGS methods were used to estimate a single storm event load for TSS on the JOR 03 basin for a design storm based on the capture and treatment of the first 0.5" of rainfall (first flush). The mean loads regression model (USGS, Table 1), and the three-variable model (USGS, Table 3) were uses to predict TSS. The large difference in TSS prediction between the mean loads regression model and the three-variable model is the significant correlation between impervious area and runoff volume in the three-variable model. The EPA Simple Method was used to calculate the annual TSS loading for JOR 03; results are shown in Table 1.

The EPA Simple Method was used to calculate the annual TSS loading for JOR 03; results are shown in Table 1.

Loading was estimated for the year based on area serviced, weighted runoff coefficient (0.52 for Jordan 03) and average concentration of constituent for that storm event given the overall land use category assigned to the basin. The annual load for the outfall was calculated using equation 1: Chapter 2, Table 2.2 lists estimated runoff coefficients for typical land uses.

$$L_x = 0.227 \bullet P \bullet Pj \bullet R_a \bullet A_s \bullet C_a \qquad (1)$$

Where:

Lx = load for the storm event (lbs)

P = annual precipitation (in)

Pj = correction factor for storms that produce no runoff = 0.9 (for annual loading estimate only)

Ra = weighted average runoff coefficient based on land use of serviced area = $(\sum(i=1,n)Ri \cdot Ai)/As$

As = serviced area of basin (acres)

Ca = average concentration of constituent for land use category assigned to basin (mg/L)

(0.227 is a conversion factor to convert mg/L, acres and inches to pounds)

Table 1. Estimated TSS Loads for JOR 03 Drainage Basin. (see attached loading calculations)

UDOT JOR 03 BASIN			
Method	**Estimated Single Event TSS Load (lbs)**	**Estimated Annual Event TSS Load (lbs)**	**[3]TSS Load (yd^3)**
[1]Mean Loads Regression Model (USGS, Table 1)	43	-	0.02
[1]Three Variable Model (USGS, Table 3)	904	-	0.43
[2]EPA Simple Method (annual estimate)	-	13,245	6.29

[1]Based on the capture and treatment of the first 0.5" of rainfall (first flush).
[2]Annual load JOR 03 mean annual rainfall of 14.3"
[3]Assumed Soil Bulk density of 1.25 g/cm^3

STEP 4: Integration of BMP into Hydraulic Design

The subject drainage basin is a highly developed transportation and mixed use corridor with little available land for an area intensive post construction BMP (i.e. infiltration pond, constructed wetland, wet pond). A hydrodynamic separator is selected for retrofitting on the existing JOR 03 basin storm drain system, for the following reasons:

- Lack of land available for basins
- High removal efficiency for target pollutant (TSS)
- Provides spill containment for the basin prior to discharging to the Jordan River

The separator will be placed upstream and off-line of the main basin outfall.

A common particulate size for a transportation land use type is typically less than 120 µm. UDOT approve product list (APL) proprietary treatment technologies that should be considered for implementation are (see Chapter 3, Table 3.2):

Potential suppliers of hydrodynamic separators are listed below:

- Aqua-Swirl™ Concentrator
- Baysaver
- Continuous Deflection Separator by CDS Technologies
- Downstream Defender by Hydro International
- Vortechs System

All listed proprietary treatment technologies will submit particle diameter removal capability prior to selection process. The treatment technology chosen should be EPA ETV approved and able to treat the water quality design flow, remove 60-80% of the design particle size on an annual average basis, and have the storage capacity for annual maintenance procedures.

BMP HYDRAULIC DESIGN. The selection of a hydrodynamic separator will be driven by the water quality design flow of 19.5 cfs; this is the maximum flow to be routed through the treatment technology. Flows greater than the water quality design flow should by-pass hydrodynamic separator. Note the water quality design flow is significantly less then the design capacity of the storm drain system, which is generally designed the convey a 10-yr storm. Also any design restrictions due to head loss through the hydrodynamic separator should be considered. Individual vendors should supply head losses for listed proprietary treatment technologies.

Note: The water quality design flow of 19.5 cfs falls on the high end of the range of treatable flows for the devices. This will be a large treatment unit, with potentially an overall reduction of pollutant removal efficiency. This may cause the designer to reduce the storm event that is treated, to allow a smaller design flow for treatment, with more flows routed to by-pass.

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```
::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
TIME OF CONCENTRATION CALCULATOR
::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::


------------------------------------------------------------------------


Segment #1:  Tc: TR-55 Sheet

Mannings n           .0110
Hydraulic Length   300.00 ft
2yr, 24hr P          .4000 in
Slope              .005000 ft/ft

Avg.Velocity           .35 ft/sec

                                         Segment #1 Time:     .2395 hrs
------------------------------------------------------------------------

Segment #2:  Tc: TR-55 Shallow

Hydraulic Length  1000.00 ft
Slope              .005000 ft/ft
Paved

Avg.Velocity          1.44 ft/sec

                                         Segment #2 Time:     .1932 hrs
------------------------------------------------------------------------

Segment #3:  Tc: TR-55 Channel

Flow Area           6.8500 sq.ft
Wetted Perimeter      7.80 ft
Hydraulic Radius       .88 ft
Slope              .005000 ft/ft
Mannings n           .0170
Hydraulic Length 11700.00 ft

Avg.Velocity          5.68 ft/sec

                                         Segment #3 Time:     .5718 hrs
------------------------------------------------------------------------

                                               =========================
                                                Total Tc:    1.0046 hrs
                                               =========================
```

Tc Equations used...

==== SCS TR-55 Sheet Flow ==

```
Tc = (.007 * ((n * Lf)**0.8)) / ((P**.5) * (Sf**.4))

Where:  Tc = Time of concentration, hrs
        n  = Mannings n
        Lf = Flow length, ft
        P  = 2yr, 24hr Rain depth, inches
        Sf = Slope, %
```

==== SCS TR-55 Shallow Concentrated Flow ==============================

```
Unpaved surface:
V  = 16.1345 * (Sf**0.5)

Paved surface:
V  = 20.3282 * (Sf**0.5)

Tc = (Lf / V) / (3600sec/hr)

Where:  V  = Velocity, ft/sec
        Sf = Slope, ft/ft
        Tc = Time of concentration, hrs
        Lf = Flow length, ft
```

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==== SCS Channel Flow ==

```
R  = Aq / Wp
V  = (1.49 * (R**(2/3)) * (Sf**-0.5)) / n

Tc = (Lf / V) / (3600sec/hr)

Where:  R  = Hydraulic radius
        Aq = Flow area, sq.ft.
        Wp = Wetted perimeter, ft
        V  = Velocity, ft/sec
        Sf = Slope, ft/ft
        n  = Mannings n
        Tc = Time of concentration, hrs
        Lf = Flow length, ft
```

Flow Calculations

STORM RUNOFF by the RATIONAL METHOD

Q = C I A

Q = rate of runoff in cubic feet per second (1 cfs = 1 acre inch / hour)

C = runoff coefficient representing the ratio of runoff to rainfall (always < 1.0)

I = intensity or rainfall in inches per hour for duration = to time of concentrating "**Tc**" *

A = drainage area in acres

* **Tc** = Time of concentration is time required for runoff from the most remote corner of the watershed to reach the outlet of the watershed.

Precipitation Frequency Estimates (inches)

MIDVALE, UTAH (42-5610) 40.6ºN 111.9167ºW 4281 feet, ESTIMATES FROM NOAA ATLAS 14

Return Period	5 min	10 min	15 min	30 min	60 min	120 min	3 hr	6 hr	12 hr	24 hr
2	0.16	0.24	0.30	0.40	0.49	0.62	0.71	0.92	1.14	1.32
5	0.21	0.33	0.41	0.55	0.68	0.80	0.89	1.11	1.37	1.57
10	0.27	0.41	0.51	0.68	0.84	0.98	1.05	1.29	1.58	1.78
25	0.36	0.55	0.68	0.91	1.12	1.27	1.32	1.55	1.89	2.07
50	0.44	0.67	0.83	1.12	1.39	1.54	1.57	1.77	2.14	2.30
100	0.54	0.82	1.02	1.37	1.70	1.86	1.87	2.03	2.42	2.54

frequency	duration	C	I	A =	Q	
2	1.0	0.52	0.50	75.0	19.50	cfs
* **Tc** =	1.0	See Tc Calcs			1170	gpm

POND VOLUME, Vcf = 3600 Q x D = 70200 ft^3

VOLUME in acre feet = Vcf / 43560 = 1.612 ac. ft.

VOLUME in cubic yards = Vcf / 27 = 2600 yd^3

Storm Event Summary

Date:	26-Mar-04
Storm event manager:	Chris Browne
Sample Team:	Steve Burgon - Salt Lake County
	Chris Browne, Phyllis Mayhew, Bruce Eloff, Karen Nichols - Stantec

Pre-storm tracking:
The National Weather Service (NWS) predicted precipitation as a result of a cold front moving across the Salt Lake Valley
Widespread precipitation was forecasted to begin in the early morning of March 26.

Mobilization:
Sample teams mobilized between 6:30 & 7:00 am with showers beginning
Samplers set up and programmed to start

During storm coordination:
Samplers activated 2nd tray between 10am & 11am, dependant on location. 2nd tray set for 5 min per bottle due to lab time constraints
Eastern sites received rain sooner and in greater quantity than western sites
Rain continued as drizzle/light rain into the afternoon
3/26/04 11:20 am - grab samples delivered to lab
3/26/04 12:30 pm - downloaded data
3/26/04 3:30 pm and 4:40 pm - composite samples delivered to lab
NOTES:
1. All sampler second trays set to sample 1 bottle every 5 minutes
2. DEL05 Station not active because of construction of new culvert
3. JOR01 Station was not able to pump water into the sampler - sampling was aborted

Description	DEL 01	DEL 05	JOR 01	JOR 03	LIT 06	MIL 07
Team	Chris Browne	Not active	Phyllis Mayhew	Bruce Eloff	Steve Burgon	Karen Nichols
Storm Amount, inches	0.59			0.66	1.11	0.94
Storm Peak flow, cfs	11.136			25.205	11.062	21.504
Cum. flow with baseflow, cf	135,003			372,121	145,440	332,141
Cum. flow without baseflow, cf	135,003			361,321	145,440	332,141
Base flow, cfs	0			0.50	0	0
COMPOSITE SAMPLES						
No. samples taken, total	36			36	36	48
Volume Available for Comp. (L)	14.14			8.43	14.23	19.57
Samples submitted to lab?	Yes			Yes	Yes	Yes
GRAB SAMPLES (BASE)						
Samples taken?	Yes			Yes	No	No
Site rain, inches*						
BOD, TDS, taken?	Yes			Yes		
Total/ Fecal	Yes			Yes		
Samples submitted to lab?	Yes			Yes		
GRAB SAMPLES (RISE)						
Samples taken?	Yes			Yes	Yes	Yes
Site rain, inches*						
BOD, TDS taken?	Yes			Yes	Yes	Yes
Total/ Fecal	Yes			Yes	Yes	Yes
Samples submitted to lab?	Yes			Yes	Yes	Yes

(yellow)	Hydrograph was adjusted
(blue)	Sampler set to sample 1 bottle every 5 minutes for both trays

Storm Event Summary

Date: 26-Mar-04

Precipitation at Midvale JOR03

Time	Total Precip (in)
7:15	0.02
7:45	0.03
8:00	0.05
8:15	0.06
8:30	0.09
8:45	0.12
9:00	0.17
9:15	0.24
9:30	0.29
9:45	0.36
10:00	0.40
10:15	0.42
10:30	0.44
10:45	0.45
11:00	0.47
11:15	0.49
11:30	0.50
11:45	0.52
12:00	0.53
12:15	0.55
12:30	0.56
12:45	0.58
13:00	0.60
13:15	0.62
13:30	0.63
13:45	0.64
14:00	0.65
14:15	0.66

Willow Creek LIT06

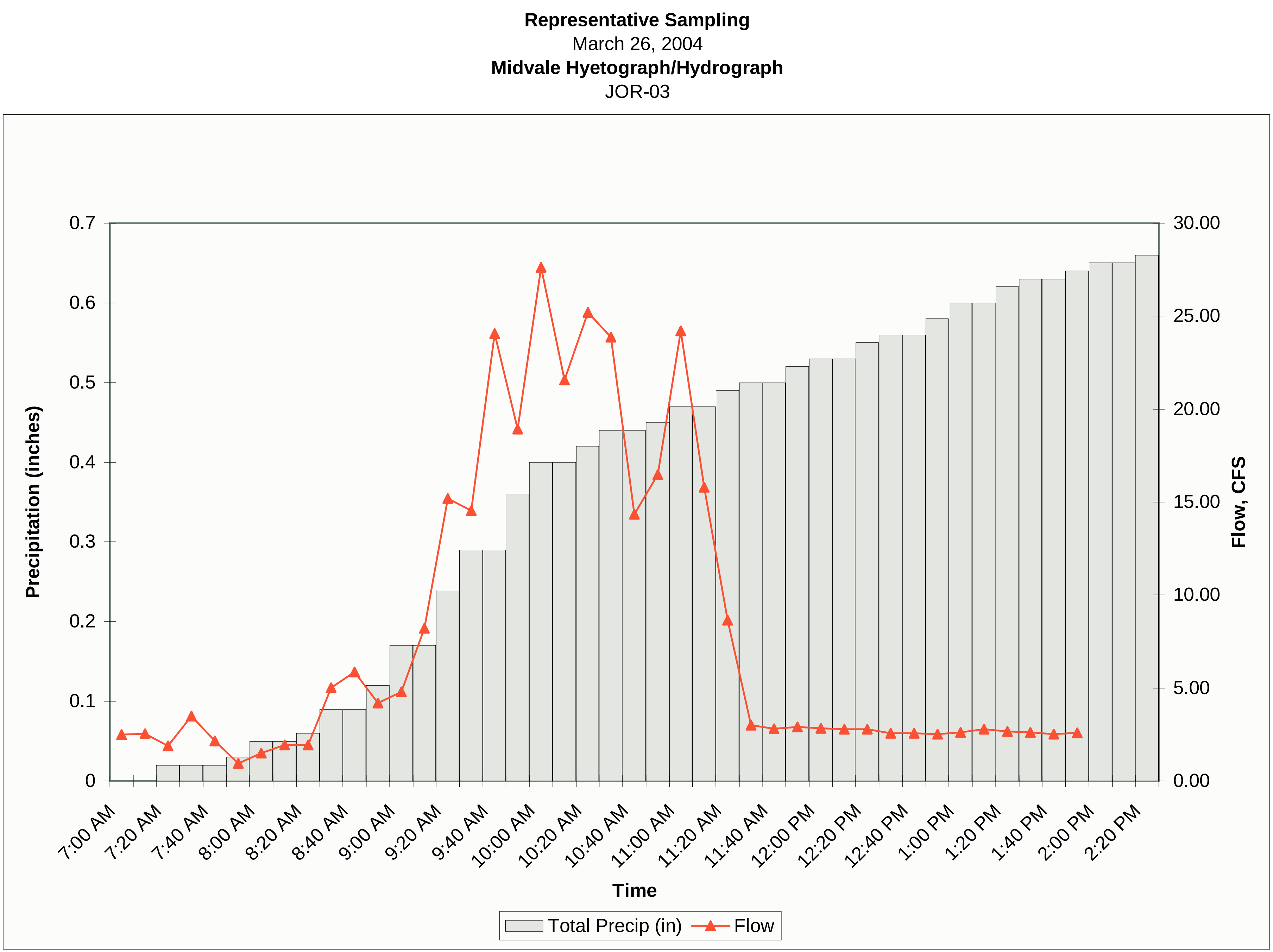
Time	Total Precip (in)
6:30	0.03
6:45	0.09
7:00	0.12
7:15	0.13
7:30	0.18
7:45	0.27
8:00	0.32
8:15	0.37
8:30	0.42
8:45	0.46
9:00	0.51
9:15	0.56
9:30	0.62
9:45	0.69
10:00	0.72
10:15	0.75
10:30	0.76
10:45	0.78
11:00	0.80
11:15	0.82
11:30	0.84
11:45	0.85
12:00	0.87
12:15	0.89
12:30	0.92
12:45	0.97
13:00	1.00
13:15	1.02
13:30	1.06
13:45	1.08
14:00	1.10
14:15	1.11

MILFIRE MIL07

Time	Total Precip (in)
6:00	0.01
6:30	0.05
6:45	0.07
7:00	0.11
7:15	0.13
7:30	0.16
7:45	0.23
8:00	0.29
8:15	0.34
8:30	0.40
8:45	0.47
9:00	0.52
9:15	0.57
9:30	0.61
9:45	0.64
10:00	0.66
10:15	0.68
10:30	0.70
10:45	0.71
11:00	0.73
11:15	0.74
11:30	0.76
11:45	0.78
12:00	0.80
12:15	0.82
12:30	0.84
12:45	0.87
13:00	0.90
13:15	0.92
13:30	0.93
14:15	0.94

Granger Hunter DEL01

Time	Total Precip (in)
7:45	0.01
8:00	0.04
8:15	0.07
8:30	0.11
8:45	0.14
9:00	0.18
9:15	0.23
9:30	0.26
9:45	0.3
10:00	0.32
10:15	0.34
10:30	0.36
10:45	0.38
11:15	0.40
11:30	0.41
11:45	0.43
12:00	0.45
12:15	0.46
12:30	0.48
12:45	0.50
13:00	0.53
13:15	0.55
13:30	0.56
13:45	0.57
14:00	0.58
14:15	0.59



Representative Sampling
March 26, 2004
Midvale Hyetograph/Hydrograph
JOR-03
Precipitation (inches)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Flow, CFS
30.00
25.00
20.00
15.00
10.00
5.00
0.00
7:00 AM
7:20 AM
7:40 AM
8:00 AM
8:20 AM
8:40 AM
9:00 AM
9:20 AM
9:40 AM
10:00 AM
10:20 AM
10:40 AM
11:00 AM
11:20 AM
11:40 AM
12:00 PM
12:20 PM
12:40 PM
1:00 PM
1:20 PM
1:40 PM
2:00 PM
2:20 PM
Time
Total Precip (in)
Flow

JOR 03 Loading Calculations

Input Parameters	
Storm Event (in) =	0.5
Serviced Drainage Area (acre) =	75
Storm Duration (min) =	60
Estimated Impervious Area % =	52
Weighted Avg Runoff Coefficient (R_a) =	0.52
Mean # of storms per season =	23
Mean Annual Rainfall (in)=	14.33
Runoff correction factor (annual loading only)=	0.9
Minimun January Temperature (^oF)=	18.7

Precipitation Frequency Estimates (inches)										
MIDVALE, UTAH (42-5610) 40.6ºN 111.9167ºW 4281 feet, ESTIMATES FROM NOAA ATLAS 14										
Return Period	5 min	10 min	15 min	30 min	60 min	120 min	3 hr	6 hr	12 hr	24 hr
2	0.16	0.24	0.30	0.40	0.49	0.62	0.71	0.92	1.14	1.32
5	0.21	0.33	0.41	0.55	0.68	0.80	0.89	1.11	1.37	1.57
10	0.27	0.41	0.51	0.68	0.84	0.98	1.05	1.29	1.58	1.78
25	0.36	0.55	0.68	0.91	1.12	1.27	1.32	1.55	1.89	2.07
50	0.44	0.67	0.83	1.12	1.39	1.54	1.57	1.77	2.14	2.30
100	0.54	0.82	1.02	1.37	1.70	1.86	1.87	2.03	2.42	2.54

Conversions		
1.0 lb	=	453,592 mg
1.0 acre	=	6,272,665 in^2
1.0 in^3	=	0.016 L
1.0 acre	=	1.6E-3 mi^2

$L_x = 0.227 \cdot P \cdot P_j \cdot R_a \cdot A_s \cdot C_a$

0.227 conversion factor		0.227
Precipitation of Storm Event	in	P
Weighted Avg Runoff Coefficient		R_a
Drainage Area	acre	A_s
Concentration (EMC) of Consituent	mg/L	C_a

Using SLCo EMC		
	TSS =	462 lbs
	[1]	105 mg/L
Ra = 0.52		
EMC = 116 mg/L		
As = 75.0 acre		
	Annual TSS =	13,245 lbs
		6.29 yd^3

USGS Water-Supply Paper 2363

Driver, N. E. and G. D. Tasker. 1990. Techniques for Estimation of Storm-Runoff Loads, Volumes, and Selected Constituent Concentrations in Urban Watersheds in the United States. Washington, D.C., U.S. Geological Survey, Washington, D.C., USGS Water-Supply Paper 2363

$Y = \beta_o' \cdot X_1^{\beta 1} \cdot X_2^{\beta 2} \cdot .....X_n^{\beta n} \cdot BCF$ Eq. 3 USGS Table 1, 3, & 5

Region I: Areas that have a mean annual rainfall less than 20 in.

			Regression Model for Mean Loads, Table 1				Three-Variable Model, Table 3				Regression Model for Mean Concentrations, Table 5			
			Needed	SS Region I	Value X_n	Value β_n	Needed	SS Region I	Value X_n	Value β_n	Needed	SS Region I	Value X_n	Value β_n
Regression coefficient		$\beta_o' = 10^{\beta o}$	*	1,518			*	1,778			*	2,041		
Total Storm Rainfall	in	TRN	*		0.5	1.211	*		0.5	0.867	*		0.5	0.143
Total Drainage Area	mi^2	DA	*		0.12	0.735	*		0.12	0.728	*		0.12	0.108
Impervious Area + 1	%	IA+1					*		53	0.157				
Industrial Landuse + 1	%	LUI+1												
Commercial Landuse + 1	%	LUC+1												
Residential Landuse + 1	%	LUR+1												
Nonurban Landuse + 2	%	LUN+2												
Population Density	people/mi^2	PD												
Duration of each storm	min	DRN	*		60	-0.463					*		60	-0.37
Max 2-yr 24-hr Precip Intensity	in	INT												
Mean Annual Rainfall	in	MAR												
Bias correction factor		BCF	*			2.112	*			2.367	*			1.543
Suspended Solids	mg/L		SS =	43 lbs	R^2 =	0.55	SS =	904 lbs	R^2 =	0.52	SS =	497 mg/L	R^2 =	0.13
			[2]	5 mg/L	% Error =	334	[3]	204 mg/L	% Error =	251	[4]	4,227 lbs	% Error =	131
				0.02 yd^3			Annual SS =	15,128 lbs				0.24 yd^3		
								0.43 yd^3						