NASSCO / NSRP ASE Project

Demonstration of Enhanced Filtration for Treatment of Shipyard Storm Water

(Agreement No. 20000925)

DELIVERABLE 5

Final Report

August 2002

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FINAL REPORT
DEMONSTRATION OF ENHANCED FILTRATION FOR TREATMENT OF SHIPYARD STORMWATER
SAN DIEGO, CALIFORNIA

1.0 INTRODUCTION AND EXECUTIVE OVERVIEW

National Steel and Shipbuilding Company (NASSCO), supported by Hart Crowser, Inc. and Stormwater Management, Inc. (SMI), is conducting the National Shipbuilding Research Program (NSRP)-sponsored Demonstration of Enhanced Filtration for Treatment of Shipyard Stormwater Project at its San Diego shipyard. Basis of design, equipment specifications, and installation details for the Enhanced Filtration System (EFS) were presented in the Design Report (Deliverable 1 - Hart Crowser 2000). Installation of the EFS was completed on April 20, 2001. The Installation Completion Report (Deliverable 2) documenting final design criteria and system construction was issued in May 2001 (Hart Crowser 2001a).

Performance of the EFS was tested during two seasons. The First Year Interim Report (Deliverable 3) documented the results of system testing in September 2001 (Hart Crowser 2001b). Comparison of treatment performance and cost analysis were presented in the Engineering Report (Deliverable 4 - Hart Crowser 2002). This Final Report presents testing results through April 2002 and overall project conclusions, and is Deliverable 5 of the NSRP Project.

1.1 Project Purpose and Objectives

Shipyards face increasing regulation of stormwater discharges as citizens and environmental groups pressure the EPA and the states to implement provisions of the Clean Water Act. Shipyards are among the first industries to be targeted by the states because of their high-profile waterfront locations and their necessary use of toxic antifouling compounds in hull coatings. The traditional "best management practices" (BMPs)—protocols to reduce pollution and effectively manage waste materials—that shipyards have long relied on will not be sufficient to comply with ever more stringent regulatory constraints on stormwater discharges. In response, NASSCO, in partnership with the NSRP, is studying a relatively low-cost but effective stormwater filtration technology to minimize the cost of environmental compliance at U.S. shipyards and strengthen the public's view of shipyards as environmental stewards. The main alternatives to stormwater filtration—full-scale collection and chemical treatment or diversion to the sanitary sewer—are far more costly or impose additional burdens on municipal infrastructure.

In 1997, Hart Crowser, working on behalf of a consortium of Puget Sound (Washington) shipyards, conducted a laboratory-scale study of stormwater filtration (Hart Crowser 1997). The study showed that filtration, when enhanced to remove dissolved metals through the use of an adsorbent organic medium such as the Compost Stormwater Filter (CSF®) product (manufactured by SMI), can remove up to 94 percent of dissolved copper and zinc (toxic pollutants of concern at shipyards) and is a cost-effective treatment alternative. Although long-term performance of the system remained a question, a follow-on study at Penn State University confirmed that enhanced filtration is an alternative worthy of demonstration testing (Burgos 1997). The NASSCO/Hart Crowser/SMI demonstration project completes the testing cycle by documenting field performance of enhanced filtration in a full-scale, real-world shipyard application. The objectives of the project are to provide a comparative analysis of three enhanced filtration options in a shipyard setting and to develop critical performance and cost data for the industry.

1.2 Site Description

NASSCO is the largest new construction shipyard on the West Coast. NASSCO has been building large ships for commercial customers and the U.S. Navy since 1959 while company roots date back to 1905. NASSCO's shipyard facilities are capable of building commercial cargo ships and tankers and Navy auxiliary ships up to 1,000 feet in length, and servicing or repairing any vessel sailing on the West Coast of the United States. The shipyard is located on San Diego Bay and encompasses 79 acres of land and 47 acres of water. A vicinity map is presented on Figure 1. (Tables and figures referenced in this report are presented in numerical order at the end of the main text.)

The shipyard's drainage basins have been delineated and numbered. The EFS treats surface runoff from drainage area SW-3 at the NASSCO shipyard. Enhanced filtration of runoff from other parts of the shipyard may be implemented in the future pending the results of this demonstration testing in drainage area SW-3. A site plan of drainage area SW-3 is presented on Figure 2. The areal extent of SW-3 is 9.25 acres.

1.3 Project Organization

Project roles and contact information for the key project participants are presented in Table 1. Roles and responsibilities for NASSCO and its subcontractors are as described below.

NASSCO is the primary shipyard sponsor, responsible for overall project coordination and progress reporting to the NSRP. NASSCO is coordinating several subcontractors, including engineering consultants, equipment vendors, earthwork and piping contractors, and analytical laboratories. NASSCO is also providing field labor for collection of stormwater samples. **Hart Crowser** is the project engineering firm responsible for evaluation and selection of the process options for testing, final design of the EFS, construction observation during installation, analysis of chemical and biological testing results, reporting, and presentation of technical results at industry meetings. **SMI** is providing equipment as well as engineering assistance during design, installation, and maintenance of the EFS. **AMEC Earth and Environmental, Inc**. is performing chemical and bioassay testing of stormwater samples.

An **Expert Advisory Panel** is providing review and consultation during key phases of the project. The Panel consists of Gary Minton, Ph.D., P.E., stormwater engineer with Resource Planning Associates in Seattle; Jean Nichols, Ph.D., biologist/toxicologist with JNE Associates in San Diego; James Lenhart, P.E., stormwater technology developer with SMI of Portland, Oregon; and Todd Thornburg, Ph.D., stormwater hydrologist with Hart Crowser, Inc.

1.4 Summary of Methodology

To assess the effectiveness of various treatment configurations, the EFS consists of three separate treatment trains installed in parallel. The flow from the splitter is routed to the three treatment trains. Each treatment train consists of either one or two 8- by 16-foot pre-cast concrete vaults containing StormFilter cartridges filled with CSF® media (composed of composted deciduous leaves). The CSF® media consists of three different grain size configurations:

- Relatively fine-grained media (Treatment Train 1);
- Standard or relatively coarse-grained media (Treatment Train 2); and
- A hybrid of fine and coarse grain sizes (Treatment Train 3).

Additional details of the system are shown on the flow schematic (Figure 3).

As indicated in the Design Report Operation and Monitoring Plan (Hart Crowser 2000), the stormwater filtration test units were to have been operated and monitored during at least two storm events during each of two rainy seasons. However, because of unanticipated system construction delays in 2001 and the driest rainy season on record, sampling was conducted during only three monitoring events. The first monitoring event was conducted by creating an artificial storm during the dry season. The other events utilized natural stormwater during the wet season. Influent and effluent samples were collected and analyzed during each monitoring event to assess the performance of the EFS.

1.5 Summary of Results

The EFS was operated beginning with the first monitoring event in September 2001 until the present time. Through the end of April 2002, the EFS treated approximately 40,000 gallons of artificial stormwater and 250,000 gallons of natural stormwater. The three treatment trains were efficient in removing the main pollutants of concern. The combined data indicate that the hybrid of fine- and coarse-grained media (Treatment Train No 3) was most effective in removing copper, zinc, and TSS from shipyard stormwater. Treatment Train No. 3 reduced average concentrations of total copper from 0.207 to 0.095 mg/L and total zinc from 0.834 to 0.284 mg/L.

Only Treatment Train No. 3 was able to reduce stormwater toxicity to levels required by the NPDES permit.

Analysis of the actual costs indicate that an enhanced filtration system can be purchased and constructed on a unit cost basis of approximately $40,000 per acre of drainage area or $270 per gallon per minute of peak flow capacity. Annual O&M cost would be approximately $17 per 1,000 gallons treatment.

Based on the ROI analysis, enhanced filtration is more cost-effective than the Wastewater Treatment (Chemical Process) Facility at the NASSCO Shipyard and will be cost-effective for use in similar shipyard applications. Based on the ROI analysis, the savings realized by the baseline EFS would be $1,000,000 over a 10-year period for the SW-3 drainage area and $3,700,000 over a 10-year period for a 40-acre shipyard.

1.6 Summary of Conclusions

The two main conclusions of this study are:

- Enhanced filtration was able to meet the stormwater toxicity levels required by the NPDES permit.

- Enhanced filtration is more cost-effective than standard chemical treatment.

Therefore, the results of this test indicate that enhanced filtration may be feasible at other drainages within the NASSCO shipyard and at other shipyards having similar characteristics.

A number of factors limited monitoring of real-time storm events. The enhanced filtration data collected to date are limited to an artificial storm (September 2001 Monitoring Event), stormwater which was collected and stored for a number days prior to treatment (March 2002 Monitoring Event) and one real-time storm event (April 2002 Monitoring Event). Due to the lack of rainfall, full operation and maintenance of the system as called for in the design report were not conducted. Monitoring of additional real-time storm events would allow more accurate testing. Therefore, a third year of operation and monitoring is recommended to confirm the results and conclusions of the testing presented herein.

2.0 SYSTEM DESIGN AND CONSTRUCTION

This section summarizes the design and construction of the EFS. Additional details concerning the design and construction of the EFS are presented in the Design Report (Deliverable 1 - Hart Crowser 2000) and Installation Completion Report (Deliverable 2 - Hart Crowser 2001a).

2.1 Stormwater Chemical Characterization and Regulatory Requirements

NASSCO has been collecting comprehensive stormwater data since its current NPDES permit was issued in October 1997. NASSCO typically collects stormwater samples during two storm events each year, from eight private drainages, four pier structures, and thirteen private laterals that tie into a municipal storm drain crossing the site. In total, NASSCO has collected and analyzed over 100 samples of stormwater during the last three years. Fifty-six of these samples were also tested for biological toxicity using a shrimp bioassay.

Summary statistics for NASSCO's stormwater are presented in Table 2. This table includes site-wide stormwater quality, as well as stormwater quality specific to drainage area SW-3 (the study area).

Presently, regulation of stormwater at shipyards is in various stages of development around the country. Some yards have no specific discharge limitations and only the most basic monitoring requirements, whereas other yards have technology-based limits for conventional pollutants (such as oil and grease, and total suspended solids). A few yards have discharge limits for toxic pollutants such as copper, zinc, and/or other metals. Metals limits are usually water quality-based limits intended to protect the quality of the receiving water body. With the growing emphasis on the development of Total Maximum Daily Loads (TMDLs) for regulating water-quality limited watersheds, discharge limits for metals will become more common at shipyards, just as NASSCO's limitations are in part a response to the listing of San Diego Bay as water-quality limited for copper.

NASSCO's NPDES permit, as well as those for other shipyards and Naval facilities in San Diego, is structured to regulate the quality of stormwater using toxicity limits rather than chemical concentrations or loads. It is thought that effluent toxicity tests are a more direct measure of potential impacts to aquatic life because metals are present in a variety of forms and complexes that greatly affect the toxicity of the discharge water. NASSCO's permit limitation for stormwater is extremely stringent, and specifies essentially no acute toxicity at the end of the pipe.

The permit includes the following water quality requirements:

- "Stormwater discharges shall produce greater than 70 percent survival of laboratory test species, at least 90 percent of the time, in acute effluent bioassay tests;" and

- "Stormwater discharges shall produce greater than 90 percent survival of laboratory test species, at least 50 percent of the time, in acute effluent bioassay tests."

The permit also includes the following technology requirements:

- "The discharge of the first flush (defined as the first 0.25 inch of rainfall) of stormwater from high risk areas shall be terminated (diverted to sanitary sewer);" or

- "An alternative which achieves a reduction in the discharge of pollutants to San Diego Bay equivalent to that resulting from compliance with the previous requirement for termination of the first flush (0.25-inch) shall be implemented."

Thus, the regulatory goals of the present study are to treat the stormwater to the strict stormwater toxicity limitations, and to demonstrate a lower cost technology that provides an alternative to diverting the first 0.25-inch of rainfall to the sanitary sewer. The Design Report (Deliverable 1 - Hart Crowser 2000) presented a contaminant assessment that estimated the approximate effluent concentrations of copper and zinc, which would allow the threshold toxicity limits contained in the NPDES permit to be met. A summary of the approximate estimated effluent requirements based on the calculations in the Design Report is presented in Table 2.

As of early 2001, the strategy for handling stormwater at the NASSCO shipyard called for all stormwater to be diverted rather than discharged to the bay. This new development was due to regulatory concerns over the toxicity of shipyard stormwater, and NASSCO's immediate need to comply with its permit condition, while field testing of the EFS was being conducted. The two currently approved methods of diversion are:

- Pumped to the on-site Wastewater Treatment Facility (WTF), treated, and discharged to the sanitary sewer; or

- Held for 24 hours and pumped to the sanitary sewer.

Stormwater treated and handled during start-up and initial testing of the EFS was diverted to a holding tank. Once adequate test data have been collected and analyzed, and the discharge from the EFS is confirmed to meet the requirements of the NPDES permit, the EFS discharge will be routed to the bay.

2.2 Hydrologic Analysis

The hydrologic analysis for sizing the EFS was presented in the Design Report (Deliverable 1 - Hart Crowser 2000). Two minor modifications relative to the hydrologic analysis in the Design Report were made as follows:

- The EFS received runoff from the SW-3 area of the shipyard only. Runoff from Berth 9/10 (100 gpm) was not included in the flow to be treated, since NASSCO decided to divert this stormwater elsewhere.

- The peak averaging period for estimating the design flow was changed from 15 minutes to 1 hour. Upon further analysis of the hydrographs, this approach was more appropriate for meeting the 95 percent capture criteria.

The total peak inflow to be treated is 1,350 gallons per minute (3.0 cubic feet per second [cfs]). This represents the one-year nominal design storm return period (1.2 inches or 24 hours), and results in 95 percent capture of total runoff from the SW-3 area based on the fifty-year historical record. The 5 percent of runoff not captured is associated with extreme storm events. Bypass of the system is expected to occur on average once every two years or less frequently.

2.3 System Description

The final location of the EFS is off-line from the existing 36-inch-diameter reinforced concrete storm drainage pipe, downstream from the existing terminal catch basin in drainage area SW-3 (Figure 2). Off-line placement with the existing storm drain minimized trenching for pipe placement, and minimized head losses resulting from increased pipe lengths and connections.

To assess the effectiveness of various treatment configurations, the EFS consists of three separate treatment trains installed in parallel. A flow schematic of the system is presented on Figure 3. Stormwater from drainage area SW-3 enters the high-flow bypass manhole by gravity flow. An adjustable weir in the high-flow bypass manhole allows the flow rate to the filters to be adjusted in response to changes in headloss through the filter cartridges. Flow rates exceeding the design storm maximum flow can bypass the system into the downstream side of the existing 36-inch-diameter outfall pipe and be diverted.

From the high-flow bypass manhole, the total captured flow is routed to a three-way flow splitter vault, where the flow is split, with one-third of the flow entering each treatment train by gravity flow. The inlet of the three-way flow splitter vault is equipped with a velocity-depth, continuous reading flow meter. Flow monitoring at this location allows us to measure the real-time hydrograph as it enters the treatment vaults, and provides us with a basis for flow-weighted compositing of stormwater samples.

Each outlet from the splitter vault was designed to have an identical opening and invert elevation, to ensure an exact flow split and equal hydraulic loading to each of the treatment trains. However, when constructed the outlets were not set properly and each 8-inch outlet pipe has a different invert elevation at the splitter vault. Once backfilled, it is hard to adjust the pipe elevations without cracking the pipe. The inlet pipe to Treatment Train No. 2 has the lowest invert. The invert elevations of the inlet pipes to Treatment Train Nos. 1 and 3 are higher that the inlet pipe to Treatment Train No. 2 by 2.25 inches and 0.75 inch, respectively. Based on observations and monitoring data, the effect of the variable inlet pipes does not appear to be significant. The pipes are typically submerged during operation and the treated flow is controlled by the downstream cartridge filters.

The flow from the splitter is routed to the three treatment trains. Each treatment train consists of either one or two 8- by 16-foot pre-cast concrete vaults containing StormFilter cartridges filled with CSF® media (composed of composted deciduous leaves). The CSF® media consists of three different grain size configurations:

- Relatively fine-grained media, expected to have the best metal removal characteristics;

- Standard or relatively coarse-grained media, expected to have the best hydraulic characteristics; and

- A hybrid of fine and coarse grain sizes.

Multiple vaults within trains are piped to act as parallel units, with stormwater passing through a single cartridge filter prior to exiting the system. A description of each treatment train is as follows:

- **Treatment Train No. 1** consists of two vaults, each containing 33 cartridge filters (66 total cartridges). Each cartridge contains a relatively fine gradation of CSF® media (0.05- to 0.1-inch mesh size). Treatment Train No. 1 operates at a reduced hydraulic loading rate of 7.5 gallons per minute (gpm) per cartridge, in an effort to make the throughput for each treatment train approximately uniform. The decrease in flow through each cartridge increases contact time with the media such that higher levels of pollutant removal are expected. This decrease in flow also promotes settling of solids within the vaults, such that solids loading to each cartridge is reduced. The lower solids loading will prevent accelerated plugging of the fine grain media and prolong the functional life of the cartridges.

- **Treatment Train No. 2** consists of one vault containing a total of 33 filter cartridges. Each cartridge contains a standard or relatively coarse gradation of CSF® media (0.1- to 0.4-inch mesh size). Treatment Train No. 2 operates at the standard hydraulic loading rate of 15 gpm per cartridge.

- **Treatment Train No. 3** consists of two vaults, each containing 33 cartridge filters (66 total cartridges). Each cartridge is packed radially with coarse- and fine-grained CSF® media. By passing through a single cartridge, stormwater first contacts coarse CSF® media (0.1- to 0.4-inch), followed by contact with the relatively fine CSF® media (0.05- to 0.1-inch). Treatment Train No. 3 operates at a reduced hydraulic loading of 7.5 gpm per cartridge, in an effort to make the throughput for each treatment train approximately uniform, as discussed for Treatment Train No. 1.

The patented siphon design of the StormFilter cartridge (Figure 4) increases the flow potential and distribution of pollutants across the filter media, increasing the effectiveness and useful life of the filter cartridge. Due to the siphon and flow control mechanism of the cartridge, the hydraulic loading of the system is fixed at either 7.5 or 15 gpm per cartridge.

Influent samples are collected from the three-way flow splitter vault and effluent samples from each treatment train are collected from the sampling manhole

(Figure 3), allowing collection of stormwater samples prior to treatment and following treatment by each treatment train.

The head losses across the treatment trains require that treated stormwater be pumped from the treatment trains to either the outfall pipe or to the on-site WTF. Once the effluent has been analyzed, if it has been demonstrated to pass the water quality requirements, the treated stormwater will be discharged to the existing outfall by a force main pump system. Design of the force main system considered the effects of tidal influence at the site.

2.4 Installation

The EFS was constructed during the early part of 2001. The chronology installation activities was as follows:

- January 10, 2001. Construction Kick-Off Meeting (NASSCO/Hart Crowser/Contractor), concrete treatment vaults on site;
- January 25, 2001. Begin excavation and shoring for EFS installation;
- March 5, 2001. Commenced installation of high-flow by-pass manhole;
- March 19, 2001. Complete setting all manholes and vaults, begin piping and grouting;
- March 23, 2001. Filter cartridges arrive on site;
- April 4, 2001. Complete grouting/backfilling of excavation/begin installation of filter cartridges inside vaults;
- April 5, 2001. Complete installation of filter cartridges inside vaults; and
- April 20, 2001: Complete pump station installation and site cleanup.

2.5 Startup

Following completion of system installation, start-up operations of the filtration test units and the pump station were conducted on May 1, 2001. Start-up activities included flushing of filters and observation of proper operation of pump and hydraulic control elements using plant water prior to the first storm event.

To prevent interference from fines and tannins associated with the new media, each treatment train was flushed with plant water during start-up. Flushing occurred at a nominal rate of 1,500 gpm, which is slightly above the design flow for the entire system, for a duration of 15 minutes. This process allowed the cartridges to cycle to assess system function. The 22,500 gallons from flushing were sent to the WTF. The turbidity of the effluent was monitored visually by Hart Crowser to assure clarity of the discharge. Other than real-time monitoring of turbidity, no sampling was conducted during start-up.

3.0 SYSTEM OPERATIONS AND MONITORING

As indicated in the Design Report (Deliverable 1) Operation and Monitoring Plan (Hart Crowser 2000), the EFS was to be operated and monitored during at least two storm events during each of two rainy seasons. However, because of unanticipated system construction delays in 2001 and the relatively short duration of the 2002 rainy season in Southern California, sampling was conducted during only three monitoring events. This section summarizes the operations and monitoring of the EFS during 2001 and 2002.

3.1 System Operation

The EFS was operated beginning with the first monitoring event in September 2001 until the present time. Through the end of April 2002, the EFS treated approximately 40,000 gallons of artificial stormwater and 250,000 gallons of natural stormwater. No precipitation fell during the month of May 2002.

For monitoring purposes, the first event was designated the September 2001 monitoring event, the second event was designated the March 2002 monitoring event, and the third event was designated the April 2002 monitoring event. Below is a description of system operational activities during the 2001 and 2002 monitoring events.

3.1.1 September 2001 Monitoring Event

Based on the need to construct a stormwater diversion system to comply with toxicity limitation as well as unanticipated construction delays, the system was not in place to monitor natural storms during the spring of 2001, so an artificial storm was created and sampled in September 2001 to gain initial data on system performance. The artificial storm was created within a subsection of drainage basin SW-3. The area wetted down was approximately 1.5 acres (see Figure 2). This represented the travel way and storage area within approximately 250 feet of the treatment system. Nozzle operators began wetting down the area near the treatment system with fire hoses and worked their way out to the boundaries of the test area. The objective was to wet down the entire area as uniformly as possible. Three hydrants were used, as shown on Figure 2. At each hydrant, a nozzle and 250 feet of hose were used to generate artificial stormwater.

The duration of the test was approximately 3 hours. This provided a 1-hour first-flush sampling interval and a 2-hour waning-storm sampling interval. To simulate a typical hydrograph, the flow was reduced during the second and third hours of the artificial storm. The target flows were as follows:

- Hour 1. 1,000 to 1,350 gpm
- Hours 2 and 3. 700 to 900 gpm

Prior to the start of the test, NASSCO confirmed that the system and surrounding area were prepared. NASSCO confirmed that the flow-meter probe was installed correctly. In addition, the test area was cleaned of excess soil and debris resulting from recent building demolition, as these could plug the treatment system.

3.1.2 March 2002 Monitoring Event

The relatively short duration of the 2001-2002 rainy season in Southern California limited monitoring of real-time storm events. The 2001-2002 rainy season was the driest season on record in Southern California. According to the rain gage located at the NASSCO Shipyard, the total precipitation of the 2001-2002 rainy season was 2.7 inches, much less than the average of 9 inches for San Diego.

Recycled and stored stormwater was used to create the March 2002 monitoring event to gain more representative data on system performance. The water used to test the system was natural, non-chlorinated shipyard runoff from a storm event that took place on March 11, 2002. The runoff from the original storm event passed through the EFS before being stored in Ways No. 4. Additional runoff stored in Ways No. 4 included runoff from other shipyard locations besides SW-3 and rain that fell directly into Ways No. 4. The quality of the rainwater stored within Ways No. 4 is therefore representative of shipyard runoff. Although a percentage of the rainwater had passed through the EFS, shipbuilding materials present in Ways No. 4 recontaminated it. Furthermore, runoff entering Ways No. 4 from other locations on site would yield additional volume of contaminated water. Rainwater directly entering Ways No. 4 was contaminated by similar mechanisms.

The rainwater was held in Ways No. 4 for approximately one week until pumped to a holding tank located near the EFS. This tank was the source of the rainwater for the test. Similar methods and instrumentation were used in creating, monitoring, and sampling the March 2002 Monitoring Event as was used in the September 2001 Monitoring Event, with the exception that only grab samples were collected during the March 2002 Monitoring Event due to the shorter duration.

3.1.3 April 2002 Monitoring Event

On April 24, 2002, a rain event occurred at the shipyard which provided real-time monitoring of the EFS. Total precipitation recorded at the shipyard was 0.18 inches. Due to technical difficulties, it was not possible to collect flow rate data. However, one set of grab samples were collected near the peak run-off period of the storm. The pollutant concentrations for this monitoring event generally have first flush characteristics. The preceding measurable rain event had been on April 6, when 0.11 inches of rain fell. A trace of precipitation (0.05 inches) fell on April 15.

3.2 System Monitoring

3.2.1 Flow Monitoring

During the September 2001 and March 2002 monitoring events, flow rate and water depth monitoring were performed with a velocity depth flow meter installed in the inlet pipe to the flow splitter manhole. Flow and water depth data were downloaded from the data logger during the monitoring events. First flush and waning storm flow intervals were identified.

3.2.2 Chemical and Bioassay Monitoring

Samples were generally collected and analyzed as specified in the Design Report (Deliverable 1) Operation and Monitoring Plan (Hart Crowser 2000). Sampling procedures and compositing, sample quality control, labeling, and chain of custody tracking were conducted in accordance with Monitoring Procedures (Section 3.3).

Stormwater samples were generally collected over two time intervals:

- During the initial portion of the storm (first flush—procedurally defined as the first hour of flow); and

- During the last portion of the storm (waning storm).

Stormwater samples were collected at four locations:

- An influent sample just before the three-way split; and
- Three effluent samples, one from each of the treatment lines.

All samples were analyzed for the following parameters:

- Total and dissolved metals (copper, lead, and zinc);
- Total suspended solids (TSS);
- Oil and grease; and
- pH.

In addition, influent and effluent water samples from the first-flush interval were submitted for bioassay testing. The toxicity analysis consisted of a 96-hour acute bioassay of *Mysidopsis bahia* (a marine shrimp) using a five-concentration, 0.5-geometric dilution series. The first-flush influent sample was also analyzed for aluminum and iron.

Samples from the September 2001 monitoring event were flow-weighted composite samples, with the exception of oil and grease, which was a grab sample. Samples submitted for bioassay testing were dechlorinated using sodium thiosulfate at the laboratory. A water blank was dechlorinated and underwent bioassay testing prior to the artificial storm test to confirm that the dechlorination procedure did not interfere with the bioassay (Appendix C). Because of the artificial nature of the stormwater in this test, testing of other NPDES Permit analytical parameters was not conducted.

3.3 Sampling Procedures

The following methods were used to collect stormwater samples.

1. Field notes were made as necessary on the Water Sampling Form throughout the sampling procedure to ensure thorough and accurate recordkeeping.

2. Tygon and silicone tubing was connected to the peristaltic pump and attached to the effluent sampling ports. Dedicated tubing was used for each of the three effluent locations. The tubing was kept clean between sampling times.

3. The electrodes for the peristaltic pump were connected to the battery.

4. At least 50 ml of sample were allowed to flush through the tubing before collecting a sample at each designated time interval.

5. For the influent sample, a sampling container was lowered into the flow splitter manhole.

6. One half-gallon, unpreserved, polypropylene aliquot bottle was filled at each sampling time. These bottles were forwarded to the laboratory for compositing and subsampling for chemical and bioassay testing. Subsamples were filtered and preserved as necessary at the laboratory.

7. At the 0-, 30-, 60- and 90-minute sampling times, a grab sample for oil and grease analysis was collected in a 500 ml amber glass bottle. The samples for oil and grease analysis were collected directly from the effluent sampling ports without the use of the peristaltic pump or any tubing.

8. Sample labels were completely filled out and affixed to the sample bottles.

9. All sample bottles were cleaned and stored in a cooled ice chest.

A rough calculation shows that the sampling pump flow velocity is approximately 1 foot per second. This flow rate may not capture all of the solids of concern in the effluent. Future sampling should use a higher flow rate pump to adequately characterize TSS removal.

3.3.1 Sample Labeling

All sample bottles were labeled at the time of sampling, clearly identifying the project name, sampler's initial, sample location identification, analysis to be performed, date, and time.

3.3.2 Sample Custody

After sampling, samples were maintained in custody until formally transferred to the laboratory. For purposes of this work, custody was defined as follows:

- In plain view of the field representative;

- Inside a cooler which is in plain view of the field representative; or

- Inside any locked space such as a cooler, locker, car, or truck to which the field representative has the only immediately available key(s).

A chain of custody record was initiated at the time of sampling for each sample collected. This record was signed by the field representative and others who subsequently held custody of the sample. A copy of the chain of custody with appropriate signatures was returned to the project manager.

4.0 MONITORING RESULTS

This section summarizes the hydrologic and chemical monitoring results for the first and second year of operation of the EFS.

4.1 Results of September 2001 Monitoring Event

4.1.1 Description of Monitoring Event

The monitoring event was conducted on September 20, 2001. The following narrative is a compilation of the observations made and notes taken during the first year storm by Jean Nichols (JNE & Associates), Bryan O. Wigginton (SMI), and Tyson D. Carlson (Hart Crowser). Other personnel on site included Lyn Haumschilt, Les Hansen, Bruce Charest and sampling personnel (NASSCO), and Paul J. Richter (State of California, California Regional Water Quality Control Board).

Prior to starting the test, the site was inspected to confirm that surfaces and equipment were ready for the storm event. The treatment trains, flow split vault, and the pump station manhole were opened, the sampling equipment was setup, and the fire hydrants and hoses were connected. Several vault doors still needed repair due to the damage caused by the tongue of an 18-wheel trailer. The trailers were parked next to a ship building/repair operation so needed parts could be loaded and offloaded. Yard and concrete debris had fallen into the treatment vaults. Despite initial concern that the concrete debris could affect pH, the slight increase in pH observed across the treatment system during the monitoring event was typical for the compost filtration technology (see Section 4.1.3).

Roadways within the basin adjacent to the filter system were recently paved and sub-units stored in the test area had primer paint. Trailers, fabricated metal parts, and construction materials were also present within the basin. Because they are typical components of shipyard operations, these items were wetted as part of the monitoring event to provide representative discharge.

The fire hoses were turned on to start the monitoring event at 9:20 a.m. The flow from each of the three hydrants was gradually increased to try to achieve the target flow. Hose operators wetted pavement, concrete, equipment, and materials in the basin to produce a representative storm. The target flow of 1,000 to 1,350 gpm was not possible with just the fire hoses; therefore, the direct discharge on each hydrant was also opened.

The initial water entering the flow splitter was extremely dirty, perhaps in excess of 1,000 mg/L TSS. Sheen was also observed on the surface of water entering the system. Sampling was not started until the flow splitter was full and water began entering the treatment trains; therefore, the initial flow was somewhat diluted before treatment and sampling began.

Approximately 20 minutes into the test, the storm grate at the terminal catch basin became clogged and water began to pool. Some sheet flow (approximately 50 gallons) entered Vault 1B. The grate was removed at 10:04 a.m. causing a surge in stormwater. This surge (peaking at almost 2,000 gpm) quickly overwhelmed the system hydraulically. The effluent pumps were not able to remove the treated water from the pump station; therefore, the necessary head differential was not maintained in the system. Sampling was suspended for 10 minutes to allow the effluent pumps to recover. Although water levels threatened to spill into the overflow, water levels receded before the bypass was necessary. Once the system recovered, sampling was resumed at scheduled intervals.

Personnel had some difficultly in sinking the peristaltic poly tubing in the sample streams. Asphalt, metal tubing (copper, nickel, and aluminum), and rocks were initially used to weight the tubing. Since these materials may leach constituents of concern and skew results, sampling personnel were instructed to weight the tubing with inert materials in all subsequent sampling activities.

Once the vaults had drained after the test, small amounts of miscellaneous trash and debris were scattered through the system. Trash and debris were removed from the system prior to future use to avoid clogging and plugging of the system.

The monitoring event was concluded at 12:30 p.m. on September 20, 2001.

4.1.2 Flow Data

The September 2001 Monitoring Event was monitored with a flow meter manufactured by American Sigma. The Sigma 910 was installed in the inlet pipe entering the flow splitter vault. Data were collected at 1-minute intervals. A laptop computer allowed for real-time monitoring of the storm.

The storm delivered 43,500 gallons of water to the treatment system at an average flow of about 230 gpm. The influent hydrograph is presented on Figure 5. The first flush (FF) storm was approximately 1 hour long and had an average flow of 566 gpm with a peak flow of 1,970 gpm. The peak flow was the result of the surge from clearing of the clogged storm grate. The waning storm (W) was two hours long with an average flow of 47 gpm.

Due to the backwater conditions created by the surge during the first flush, the influent hydrograph is not representative of the flow within the treatment trains. An average flow in the treatment trains was calculated using the influent hydrograph, effluent pumping rate, and storage of the system. The resulting hydrograph is displayed on Figure 6. It was assumed that the influent flow equaled the effluent flow when the influent flow was less than 900 gpm. When flow exceeded 900 gpm (maximum pumping rate of six 150 gpm effluent pumps), the exceedences went to system storage. Water held in storage was lost when influent flow was less than 900 gpm and effluent pumping continued.

Since each treatment train may not have received equal flow from the flow splitter cell, Figure 6 represents the average flow treated. As discussed in Section 2.3, the elevations of the pipes discharging from the flow splitter to the three treatment trains are at slightly different elevations. Although not a significant difference to skew results for a storm of this magnitude, a lesser storm might not deliver enough water to Treatment Train No. 1 for effective comparison of treatment.

4.1.3 Chemistry and Bioassay Data

The September 2001 Monitoring Event was sampled in accordance with the monitoring plan presented in Section 3.2. A summary of the chemical and bioassay data is presented in Table 3. The complete chemical and bioassay laboratory report is presented in Appendix B.

Inspection of Table 3 indicates that the filtration units were effective in reducing pollutants of concern as well as the acute toxicity of the stormwater. However, the Artificial Storm first flush influent had an acute toxicity of 80 percent survival. The average acute toxicity of the SW-3 Drainage based on historical data has been 56 percent survival, ranging from 35 to 68 percent survival (Table 2). The comparison indicates that the Artificial Storm was not within observed toxicity levels of previous natural storm events. Furthermore, the TSS concentration in the Artificial Storm first flush influent sample was significantly higher than typically observed, possibly due to recent construction. Finally, the chemical concentrations observed in the Artificial Storm waning storm influent sample were significantly lower than typically observed, possibly an artifact of the Artificial Storm methodology.

The influent concentrations of aluminum and iron were 5 and 15 mg/L, respectively. These concentrations may be competitive with respect to removal of the other metals although no significant effect was observed.

The influent and effluent chemistry data are graphed on Figures 7 through 11, as described below:

- For the first flush samples, the total and dissolved copper, lead, and zinc results for each treatment train are plotted on Figure 7;
- For the waning storm samples, the total and dissolved copper, lead, and zinc results for each treatment train are plotted on Figure 8;
- Total copper results showing the performance between treatment trains are plotted on Figure 9;
- Total zinc results showing the performance between treatment trains are plotted on Figure 10; and
- TSS results showing the performance between treatment trains are plotted on Figure 11.

As expected, metal and TSS concentrations are significantly higher in the first flush than in the waning portions of the storm. Individual sampling events demonstrate a clear trend of decreasing constituent concentration of all species as a result of treatment. Contaminant removal was irreversible, as the higher first flush contaminant mass had no effect on removal (i.e., did not desorb) during the waning storm, when influent concentrations were lower.

The data indicate that Treatment Train No. 3 was most effective in removing total copper and zinc, and TSS in the first flush samples compared to the other treatment trains. There was no clear difference in the waning storm samples.

4.2 Results of March 2002 Monitoring Event

4.2.1 Description of Monitoring Event

This Monitoring Event was conducted on March 21, 2002. The following narrative is a compilation of the observations made and notes taken during the second year storm by Jean Nichols (JNE & Associates). Other personnel on site included Lyn Haumschilt, Les Hansen, and Bruce Charest (NASSCO).

The water used for the test was runoff originating from a storm event on March 11, 2002. Additional details regarding the water used in the test are presented in Section 3.1.2. The valve located at the bottom of the storage tank was opened at 1:30 p.m. on March 21, 2002, to start the test. The valve was used to control flow. Stored runoff was delivered from the tank to the EFS by a hose. The hose terminated near the opening of the storm grate; therefore, SW-3 was not wetted down similar to the first artificial storm. However, a small portion of SW-3 was wetted, picking up debris, turbidity, and possible contaminants. The storm test was concluded at 2:15 p.m. on March 21, 2002.

4.2.2 Flow Data

The hydrograph of the March 2002 Monitoring Event is illustrated on Figure 12. This storm delivered nearly 9,400 gallons of water at an average flow rate of 199 gpm. Inspection of the hydrograph indicates that the flow entering into the flow-splitting vault rose quickly to a maximum flow of 402 gpm, then slowly tapering off until dropping sharply near the end of the test. The temporary decline in flow approximately 10 minutes into the test was caused by adjustment of the valve on the storage tank. This hydrograph is of influent flow rate, and is not necessarily representative of the flow rate traveling through the treatment system. The treatment hydrograph would be of similar magnitude, but would not reflect the change in flow due to adjustment of the tank valve. Otherwise, the hydrograph is representative of flow passing through the treatment system.

4.2.3 Chemistry and Bioassay Data

The March 2002 Monitoring Event was sampled in general accordance with the monitoring plan presented in Section 3.2. However, only two sets of grab samples were collected. Sample Set A was collected during the first 10 minutes of the test and Sample Set B was collected approximately 30 minutes into the test. The entire test lasted approximately 45 minutes. Due to the mixing and storage of runoff used in this test, the characteristic division of first flush and waning storm is not relevant.

A summary of the chemical and bioassay data is presented in Table 4. The complete chemical and bioassay laboratory report is presented in Appendix E. Inspection of Table 4 indicates that the filtration units were effective in reducing pollutants of concern as well as the acute toxicity of the stormwater. The influent samples had an acute toxicity of 45 and 50 percent survival, which is within the range of SW-3 historical data (35 to 68 percent survival (Table 2)).

The influent concentrations of aluminum and iron were 0.654 mg/L and 2.86 mg/L, respectively. These concentrations are lower than those in the September 2001 event and are probably more representative of storm water at the shipyard. These concentrations are likely not competitive for other metals.

The influent and effluent chemistry data are graphed on Figures 13 through 17, as described below:

- Sample A total and dissolved copper, lead, and zinc results for each treatment train are plotted on Figures 13;
- Sample B total and dissolved copper, lead, and zinc results for each treatment train are plotted on Figures 14;
- Total copper results showing the performance between treatment trains are plotted on Figure 15;
- Total zinc results showing the performance between treatment trains are plotted on Figure 16; and
- TSS results showing the performance between treatment trains are plotted on Figure 17.

Again, these data demonstrate a clear trend of decreasing constituent concentration of all species as a result of treatment. And also again, the data indicate that Treatment Train No. 3 was most effective in removing total copper and zinc, and TSS. However, the improved effectiveness was less pronounced than observed in first flush samples from the September 2001 Monitoring Event.

4.3 Results of April 2002 Monitoring Event

4.3.1 Description of Monitoring Event

This monitoring event was conducted on April 24, 2002. The following narrative was compiled by Bruce Charest (NASSCO).

This monitoring event consisted of a very short real-time storm. On April 24 rain began to fall lightly at about 9:30 a.m. Rain intensity increased at about 11:30 a.m. at which time it was decided to collect samples. The intense portion of the storm lasted about 45 minutes. Influent sampling was conducted at 12:37 p.m., when runoff intensity was decreasing. Effluent sampling was conducted between 12:45 p.m. and 1:00 p.m., at which time effluent flow from the filters still appeared maximum for the storm. The short duration of the storm prevented collection of composite samples. Additional details for the event are presented in Section 3.1.3.

4.3.2 Chemistry and Bioassay Data

The April 2002 Monitoring Event was sampled in general accordance with the monitoring plan presented in Section 3.2. However, only one set of grab samples was collected and was denoted as Sample Set A.

A summary of the chemical and bioassay data is presented in Table 5. The complete chemical and bioassay laboratory report is presented in Appendix F. Inspection of Table 5 indicates that the filtration units were effective in reducing pollutants of concern as well as the acute toxicity of the stormwater. The influent sample had an acute toxicity of 20 percent survival, which was not within observed toxicity levels of previous natural storm events at SW-3 (35 to 68 percent survival [Table 2]).

The influent and effluent chemistry data are graphed on Figures 18 through 20, as described below:

- Total and dissolved copper results for each treatment train is plotted on Figure 18.
- Total and dissolved zinc results for each treatment train is plotted on Figure 19.
- TSS results showing the performance between treatment trains are plotted on Figure 20.

Similar to the two previous monitoring events, these data demonstrate a clear trend of decreasing constituent concentration of all species as a result of treatment. The data indicate that Treatment Train No. 3 was most effective in removing total copper and zinc, and TSS.

4.4 Comparison of Influent Concentrations

The representativeness of the runoff used to test the EFS was evaluated by comparing the influent concentrations during the three monitoring events with historical runoff data for the shipyard. The comparison of influent concentrations is shown in Table 6. The data are also plotted on Figure 21. With the exception of TSS, the influent data were generally low with respect to overall historical influent range. TSS was near the high end of the historical range and the copper and zinc concentrations were below the historical averages.

4.5 Summary of Pollutant Removal

The three treatment trains were efficient in removing the main pollutants of concern. A summary of treatment performance for each treatment train is presented in Table 7. Combining the data from the September 2001, March 2002, and April 2002 monitoring events results in the following ranges:

- The fine-grained media (Treatment Train No. 1) reduced average total copper from 0.207 to 0.125 mg/L, total zinc from 0.834 to 0.452 mg/L, and TSS from 106 to 51 mg/L.

- The coarse-grained media (Treatment Train No. 2) reduced average total copper from 0.207 to 0.122 mg/L, total zinc from 0.834 to 0.441 mg/L, and TSS from 106 to 53 mg/L.

- The hybrid of fine- and coarse-grained media (Treatment Train No. 3) reduced average total copper from 0.207 to 0.095 mg/L, total zinc from 0.834 to 0.284 mg/L, and TSS from 106 to 33 mg/L.

The combined data indicate that Treatment Train No. 3 was most effective in removing copper, zinc, and TSS from shipyard stormwater. Treatment Train No. 1 appeared to be least effective, which is counter-intuitive. The fine media is expected to be most effective due to the greater surface area of the media. The treatment vaults were not inspected during testing so there is a potential that flow in Treatment Train No. 1 was backing up due to plugging and overflowing into the effluent channel. Further tests will check for this.

Due to the lack of rain and limited opportunity for monitoring the EFS, the ultimate capacity and design life of the filter cartridges was not reached during the project. The influent and effluent copper and zinc concentrations versus volume of water treated are plotted on Figures 22 and 23, respectively. It is not clear whether the increase in effluent concentrations at 250,000 gallons (the final monitoring event) is due to the increase in influent concentration or the beginning of breakthrough. Additional operation of the filters is needed to document the design life.

4.6 Comparison with Toxicity Effluent Requirements

A summary of bioassay survival results for each treatment train is presented in Table 8. As stated in Section 2.1, the NPDES permit includes the following water quality requirements:

- Stormwater discharges shall produce greater than 70 percent survival of laboratory test species, at least 90 percent of the time; and

- Stormwater discharges shall produce greater than 90 percent survival of laboratory test species, at least 50 percent of the time.

Only Treatment Train No. 3 was able to reduce stormwater toxicity to levels required by the NPDES permit. As with metal removal, Treatment Train No. 3 was most effective in removing toxicity.

The correlation of bioassay survival with total and dissolved copper and zinc concentrations is shown on Figure 24. With the exception of the first flush influent sample of the September 2001 Monitoring Event, which was excluded from regression as an outlier because it was not representative of real stormwater, the data used to develop this correlation included all influent and effluent samples of the first flush, Sample A and Sample B, and Sample A of the September 2001, March 2002, and April 2002 Monitoring Events, respectively. These data indicate that zinc may be the controlling parameter for toxicity, based on its greater linear correlation coefficients compared to those for copper. A dissolved zinc concentration below approximately 300 ug/L appears to be needed to comply with the toxicity effluent requirement (70 to 90 percent survival).

5.0 COST ANALYSIS

A cost analysis was conducted to document the total and unit costs for the EFS and to estimate return on investment (ROI) for full-scale implementation at a typical shipyard.

5.1 Total Estimated Cost

Table 9 presents the detailed cost breakdown for the EFS, including actual capital costs and estimated annual costs. The capital costs have been separated out to provide an estimate of cost for baseline treatment where rigorous testing and effluent pumping may not be needed. Capital EFS costs are included with the exception of contaminated soil management and heavier loading costs.

These costs will be highly shipyard-specific and so are not included in the cost analysis. Annual EFS costs are included with the exception of monitoring and reporting costs. Monitoring and reporting costs will also be highly shipyard-specific and so are not included in the cost analysis.

5.2 Estimated Unit Cost

Table 10 presents a summary of unit costs. First, the capital costs detailed for each of the scenarios in Table 9 are unitized based on drainage area (9.25 acres) and peak flow rate (1,350 gpm). These unit costs can readily be used to estimate full-scale construction costs at NASSCO and other shipyards. For instance, the estimated construction cost for implementation of a full-scale baseline EFS for the remaining 70 acres of the NASSCO shipyard is $2.8 million. This estimate is based on all shipyard land and could be lower if building roof runoff can be segregated and discharged directly to the bay.

5.3 ROI Analysis

An ROI analysis was conducted to assess the cost-effectiveness of replacing or continuing to use the existing NASSCO Wastewater Treatment Facility (WTF) for treating stormwater. The NASSCO WTF is a standard physical-chemical plant having a hydraulic capacity of 240 gpm. Its primary purpose is to treat process wastewater at the shipyard. Given enough excess treatment capacity and stormwater storage volume, the WTF is currently used to treat stormwater prior to discharge to the sanitary sewer. However, it is not considered to be a long-term solution for stormwater treatment. Most U.S. shipyards treat their process wastewater, but not their stormwater, using systems similar to the NASSCO WTF.

Table 10 also presents the capital and O&M volumetric unit costs for the baseline EFS. According to NASSCO, the WTF had a capital cost of $243,000 and has an estimated unit O&M cost of approximately $100/1,000 gallons. Assuming a design life of 10 years for comparison purposes, the overall unit cost for the Wastewater Treatment Facility would be approximately $111/1,000 gallons. Of course, this assumes that sufficient treatment or storage capacity exists for the existing plant to handle 95 percent of the runoff from SW-3. Note that the WTF does not now treat this amount of stormwater, but may in the future.

The ROI for area SW-3 at the NASSCO Shipyard is presented in Table 11. The following key assumptions were used to calculate the ROI in Table 11:

- A drainage area of 9.25 acres (SW-3);

- Annual average rainfall of 9 inches (San Diego);
- Runoff requiring treatment equals 95 percent of annual average rainfall;
- EFS Unit Costs based on Baseline System in Tables 9 and 10;
- WTF Unit Costs based on current estimates provided by NASSCO for the existing 240 gpm system, assuming adequate treatment and storage capacity; and
- A 7 percent discount rate over a 10-year period.

The ROI for a generic shipyard (40 acres) is presented in Table 12. The following key assumptions were used to calculate the ROI in Table 12:

- A drainage area of 40 acres;
- Annual average rainfall of 9 inches (San Diego);
- Runoff requiring treatment equals 95 percent of annual average rainfall;
- EFS Unit Costs based on Baseline System in Tables 9 and 10, linearly factored to accommodate a drainage area of 40 acres;
- WTF Capital Unit Costs based on current estimates provided by NASSCO for the existing 240 gpm system, assuming adequate treatment and storage capacity;
- WTF O&M Unit Costs based on current estimates provided by NASSCO for the existing 240 gpm system, linearly factored to accommodate a drainage area of 40 acres; and
- A 7 percent discount rate over a 10-year period.

Based on this cost analysis, the savings realized by the baseline EFS would be $1,000,000 over a 10-year period for the SW-3 drainage area and $3,700,000 over a 10-year period for a 40-acre shipyard. Therefore, enhanced filtration is more cost-effective than the standard WTF at NASSCO Shipyard and will be cost-effective for use in similar shipyard applications.

This analysis assumes that a 240-gallon per minute standard WTF will have suitable excess capacity to treat all of the stormwater and that adequate stormwater storage capacity exists at the shipyard. The costs for expansion of the standard WTF or installation of storage are not included. Since it is highly likely that shipyards would require such improvements, the potential savings due to the EFS would be greater than the above estimated values.

6.0 CONCLUSIONS

Based on the results presented in this document, the following conclusions were developed:

- Enhanced filtration using a hybrid of fine- and coarse-grained media was able to consistently reduce stormwater toxicity to levels required by the NPDES permit during the operational period.

- The correlation of bioassay survival with total and dissolved copper and zinc concentrations showed that zinc may be the controlling parameter for toxicity and that a dissolved zinc concentration below approximately 300 ug/L appears to be needed to comply with the toxicity effluent requirement.

- Enhanced filtration using a hybrid of fine- and coarse-grained media was the most effective of the three grain sizes tested. It was effective in reducing total and dissolved concentrations of copper and zinc.

- The treatment performance was not sensitive to the rate of flow or influent chemical concentrations.

- Analysis of the actual costs indicate that an enhanced filtration system can be purchased and constructed on a unit cost basis of approximately $40,000 per acre of drainage area or $270 per gallon per minute of peak flow capacity. Annual O&M cost would be approximately $17 per 1,000 gallons treatment.

- Enhanced filtration is more cost-effective than the standard WTF at NASSCO Shipyard and will be cost-effective for use in similar shipyard applications. Based on the ROI analysis, the savings realized by the baseline EFS would be $1,000,000 over a 10-year period for the SW-3 drainage area, and $3,700,000 over a 10-year period for a 40-acre shipyard.

The need to construct a stormwater diversion system to comply with toxicity limitations, unanticipated construction delays, and the driest rainy season on record in Southern California limited monitoring of real-time storm events. The enhanced filtration data collected to date were limited to an artificial storm (September 2001 Monitoring Event), stormwater which was collected and stored for a number days prior to treatment (March 2002 Monitoring Event), and one real-time storm event (April 2002 Monitoring Event). Due to the lack of rainfall, full operation and maintenance of the system as called for in the design report were not conducted. Monitoring of additional real-time storm events would allow more accurate testing. Therefore, a third year of operation and monitoring is recommended to confirm the results and conclusions of the enhanced filtration testing presented herein.

7.0 REFERENCES

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Demonstration of Enhanced Filtration for Treatment of Shipyard Stormwater

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Table 2 - Stormwater Influent Chemical Characteristics and Effluent Requirements

	O&G in mg/L	TPH in mg/L	TSS in mg/L	Cu in mg/L	Pb in mg/L	Ni in mg/L	Zn in mg/L	TBT in ug/L	Acute Toxicity % Surviv.
NASSCO Site Wide Stormwater									
average	7	1.5	41	0.49	0.11	0.26	2.40	0.171	39
minimum	1	0.5	1	0.03	0.00	0.01	0.26	0.005	0
maximum	57	22.0	552	2.20	0.92	1.00	9.90	7.260	95
10th %ile	3	0.5	5	0.11	0.02	0.02	0.72	0.010	0
25th %ile	5	0.5	7	0.19	0.10	0.05	0.93	0.017	3
50th %ile	5	0.7	15	0.32	0.10	0.22	1.60	0.043	40
75th %ile	7	1.8	44	0.65	0.10	0.36	3.58	0.110	70
90th %ile	16	3.7	82	1.00	0.14	0.66	5.74	0.235	80
SW-3 Drainage									
average	8	1.6	26	0.34	0.09	0.28	1.45	0.061	56
minimum	2	0.5	5	0.16	0.02	0.02	0.79	0.017	35
maximum	22	6.2	49	0.76	0.17	0.57	3.30	0.110	68
Effluent Requirements									
average[a]	NA	NA	NA	0.04	NA	NA	0.30	NA	Note[a]
removal in %[b]	--	--	--	90	--	--	80	--	--

Notes:

[a] Chemical effluent requirements estimated based on required toxicity reduction.
NPDES Permit requires 70 percent survival, 90 percent of the time; and 90 percent survival, 50 percent of the time.

[b] Removal as a percent of average influent in SW-3 drainage.

NA = Not Applicable

Table 3 - Chemistry and Bioassay Results for September 2001 Monitoring Event

Interval/ Location	Sample ID	Total Copper in mg/L	Diss. Copper in mg/L	Total Lead in mg/L	Diss. Lead in mg/L	Total Zinc in mg/L	Diss. Zinc in mg/L	Oil & Grease in mg/L	TSS in mg/L	pH	Acute Toxicity % surv.
First Flush											
Influent	AS-IN-FF	0.401	0.397	0.086	0.0756	1.24	1.24	4.0	310	7.08	80
T1-Effluent	AS-EF-T1-FF	0.145	0.142	0.0302	0.0275	0.456	0.457	1.0	130	7.18	100
	% Removal	63.8	64.2	64.9	63.6	63.2	63.1	75.0	58.1	--	--
T2-Effluent	AS-EF-T2-FF	0.155	0.0525	0.0322	0.001 U	0.499	0.0672	2.0	140	7.36	95
	% Removal	61.3	86.8	62.6	98.7	59.8	94.6	50.0	54.8	--	--
T3-Effluent	AS-EF-T3-FF	0.0939	0.0868	0.0184	0.016	0.284	0.283	5.0	62	7.45	95
	% Removal	76.6	78.1	78.6	78.8	77.1	77.2	--	80.0	--	--
Waning Storm											
Influent	AS-IN-W	0.0609	0.0528	0.0143	0.00782	0.455	0.191	2.0	34	7.22	NA
T1-Effluent	AS-EF-T1-W	0.0205	0.0128	0.00239	0.001 U	0.0655	0.0391	2.0	1.0 U	7.52	NA
	% Removal	66.3	75.8	83.3	87.2	85.6	79.5	0.0	97.1	--	--
T2-Effluent	AS-EF-T2-W	0.0248	0.0135	0.00277	0.001 U	0.0794	0.0468	1.0	1.0	7.68	NA
	% Removal	59.3	74.4	80.6	87.2	82.5	75.5	50.0	97.1	--	--
T3-Effluent	AS-EF-T3-W	0.0266	0.0146	0.00321	0.001 U	0.0867	0.0456	1.0	1.0	7.71	NA
	% Removal	56.3	72.3	77.6	87.2	80.9	76.1	50.0	97.1	--	--

NA = Not analyzed.
-- = Not applicable.
Note: Percent removal calculated using full "U" value of the non detected constituents.

Table 4 - Chemistry and Bioassay Results for March 2002 Monitoring Event

Interval/ Location	Sample ID	Total Copper in mg/L	Diss. Copper in mg/L	Total Lead in mg/L	Diss. Lead in mg/L	Total Zinc in mg/L	Diss. Zinc in mg/L	Oil & Grease in mg/L	TSS in mg/L	pH	Acute Toxicity % surv.
Sample A											
Influent	I-A (I-1)	0.159	0.0924	0.0183	0.001 U	0.613	0.418	2.5	21	7.51	50
T1-Effluent	E1-A (E-1-1)	0.102	0.0754	0.00947	0.00531	0.371	0.284	1.2	20	7.4	80
	% Removal	35.8	18.4	48.3	NA	39.5	32.1	52.0	4.8	--	--
T2-Effluent	E2-A (E-2-1)	0.106	0.0723	0.0103	0.00114	0.393	0.291	1.5	18	7.4	90
	% Removal	33.3	21.8	43.7	NA	35.9	30.4	40.0	14.3	--	--
T3-Effluent	E3-A (E-3-1)	0.0885	0.0687	0.00791	0.00639	0.318	0.251	1.3	19	7.33	100
	% Removal	44.3	25.6	56.8	NA	48.1	40.0	48.0	9.5	--	--
Sample B											
Influent	I-B (I-2)	0.17	0.115	0.0244	0.001 U	0.823	0.71	1.3	27	7.25	45
T1-Effluent	E1-B (E-1-2)	0.127	0.0856	0.00618	0.001 U	0.555	0.417	1.0 U	10	7.23	65
	% Removal	25.3	25.6	74.7	NA	32.6	41.3	23.1	97.1	--	--
T2-Effluent	E2-B (E-2-2)	0.121	0.087	0.00675	0.001 U	0.59	0.46	1.0 U	17.0	7.23	80
	% Removal	28.8	24.3	72.3	NA	28.3	35.2	23.1	37.0	--	--
T3-Effluent	E3-B (E-3-2)	0.078	0.0687	0.0035	0.003	0.327	0.298	1.0 U	4.1	7.16	95
	% Removal	54.1	40.3	85.7	NA	60.3	58.0	23.1	84.8	--	--

NA = Not analyzed.
-- = Not applicable.
Note: Percent removal calculated using full "U" value of the non detected constituents.

Table 5 - Chemistry and Bioassay Results for April 2002 Monitoring Event

Interval/ Location	Sample ID	Total Copper in mg/L	Diss. Copper in mg/L	Total Lead in mg/L	Diss. Lead in mg/L	Total Zinc in mg/L	Diss. Zinc in mg/L	Oil & Grease in mg/L	TSS in mg/L	pH	Acute Toxicity % surv.
Influent	I-A (I-1)	0.244	0.179	0.0129	0.00135	1.04	0.892	14.0	140	6.34 (1)	20
T1-Effluent	E1-A (E-1-1)	0.232	0.175	0.0111	0.00152	0.814	0.633	6.9	75	6.54 (1)	55
	% Removal	4.9	2.2	14.0	NA	21.7	29.0	50.7	46.4	--	--
T2-Effluent	E2-A (E-2-1)	0.203	0.164	0.0103	0.00168	0.644	0.544	7.0	88	6.57 (1)	40
	% Removal	16.8	8.4	20.2	NA	38.1	39.0	50.0	37.1	--	--
T3-Effluent	E3-A (E-3-1)	0.189	0.145	0.0118	0.00168	0.402	0.356	6.7	79	6.60 (1)	75
	% Removal	22.5	19.0	8.5	NA	61.3	60.1	52.1	43.6	--	--

NA = Not analyzed.
-- = Not applicable.
Note: Percent removal calculated using full "U" value of the non detected constituents.
1. pH results were measured 1 to 2 hours past the 24 hour holding requirement

Table 6 - Comparison of Influent Concentrations

	O & G in mg/L	TSS in mg/L	Cu in mg/L	Pb in mg/L	Zn in mg/L	Acute Toxicity % Survival
NASSCO Site-Wide Stormwater						
Average	7	41	0.49	0.11	2.4	39
Minimum	1	1	0.03	0.00	0.26	0
Maximum	57	552	2.2	0.92	9.9	95
SW-3 Drainage						
Average	8	26	0.34	0.09	1.45	56
Minimum	2	5	0.16	0.02	0.79	35
Maximum	22	49	0.76	0.17	3.3	68
September 2001 Monitoring Event Influent						
First Flush	4	310	0.401	0.086	1.24	80
Waning Storm	2	34	0.061	0.014	0.455	NA
March 2002 Monitoring Event Influent						
Sample A	2.5	21	0.159	0.018	0.613	50
Sample B	1.3	27	0.17	0.024	0.823	45
April 2002 Monitoring Event Influent						
Sample A	14.0	140	0.244	0.0129	1.04	20
Combined 2001-2002 Monitoring Events						
Average	4.8	106	0.207	0.031	0.834	49
Minimum	1.3	21	0.061	0.013	0.455	20
Maximum	14.0	310	0.401	0.086	1.24	80

NA = Not Analyzed

Table 7 - Summary of Treatment Performance (Concentrations in mg/L)

Parameter	Influent		Effluent Fine Media (TT 1)		Effluent Coarse Media (TT 2)		Effluent Mixed Media (TT 3)	
	Range	Average	Range	Average	Range	Average	Range	Average
TSS	21 to 310	106.4	1 to 130	51	1 to 140	53	1 to 79	33
Total Copper	0.061 to 0.401	0.207	0.021 to 0.145	0.125	0.025 to 0.203	0.122	0.027 to 0.189	0.095
Dissolved Copper	0.053 to 0.397	0.167	0.013 to 0.175	0.098	0.014 to 0.164	0.078	0.015 to 0.145	0.077
Total Zinc	0.455 to 1.24	0.834	0.066 to 0.814	0.452	0.079 to 0.644	0.441	0.087 to 0.402	0.284
Dissolved Zinc	0.191 to 1.24	0.690	0.039 to 0.633	0.366	0.047 to 0.544	0.282	0.046 to 0.356	0.247

Note:
Data based on September 2001, March 2002, and April 2002 Monitoring Events, five sampling events total.

Table 8 - Summary of Bioassay Compliance Results (a)

Parameter	Treatment Train No. 1		Treatment Train No. 2		Treatment Train No. 3		Permit Requirements
	Ratio (b)	Percent (c)	Ratio (b)	Percent (c)	Ratio (b)	Percent (c)	Percent (c)
Survival > 90%	1/4	25%	2/4	50%	3/4	75%	≥50%
Survival > 70%	2/4	50%	3/4	75%	4/4	100%	≥90%

Notes:

a. NPDES Permit Compliance requires that stormwater discharges produce greater than 70 percent survival of laboratory test species at least 90 percent of the time, and greater than 90 percent survival of test species at least 50 percent of time, in accute effluent bioassay tests.

b. Fraction indicates number of samples out of total bioassay samples whose percent survival was greater than the listed criteria.

c. Percentage of samples meeting criteria.

Table 9 - Detailed EFS Cost Estimate

Site:	NASSCO	**Description:**	Enhanced filtration system (EFS) constructed April 2001; Treatment of shipyard stormwater using StormFilter cartridges in subsurface vaults. Peak flow 1,350 gpm. Flow splitter, sampling manhole, flow meter, and pump station included for testing only.
Location:	San Diego , California		
Phase:	Post Construction		
Base Year:	2001		
Date:	May 1, 2002		

CAPITAL COSTS:

DESCRIPTION	MAJOR MATERIAL COST	MINOR MATERIAL COST	LABOR & EQUIP. INSTALLATION COST	TOTAL
Baseline Filtration System				
Mobilization	0	0	20,000	$ 20,000
Sheet Pile Installation and Excavation	0	0	25,800	$ 25,800
High Flow Bypass Manhole (60"x5' deep)	4,790	2,100	9,000	$ 15,890
Concrete Vault 1A (8'x16') with 33 Filter Cartridges (fine media)	43,990	2,780	8,800	$ 55,570
Concrete Vault 1B (8'x16') with 33 Filter Cartridges (fine media)	43,990	2,780	8,800	$ 55,570
Concrete Vault 2A (8'x16') with 33 Filter Cartridges (coarse media)	40,990	2,780	8,800	$ 52,570
Concrete Vault 3A (8'x16') with 33 Filter Cartridges (mixed media)	42,490	2,780	8,800	$ 54,070
Concrete Vault 3B (8'x16') with 33 Filter Cartridges (mixed media)	42,490	2,780	8,800	$ 54,070
Piping	0	5,500	5,500	$ 11,000
Site Restoration and Paving	0	0	19,080	$ 19,080
SUBTOTAL	$ 218,740	$ 21,500	$ 123,380	$ 363,620
Filtration System with Flow Splitter				
Sheet Pile Installation and Excavation	0	0	4,300	$ 4,300
Pretreatment Flow Splitter Vault (8'x16')	15,900	5,200	10,000	$ 31,100
Site Restoration and Paving	0	0	3,180	$ 3,180
SUBTOTAL	$ 234,640	$ 26,700	$ 140,860	$ 402,200
Filtration System with Flow Splitter/Sampling Manhole/Meter				
Flow Meter	0	5,000	1,000	$ 6,000
Sheet Pile Installation and Excavation	0	0	4,300	$ 4,300
Sampling Manhole (48"x9' deep)	3,020	3,800	9,000	$ 15,820
Site Restoration and Paving	0	0	3,180	$ 3,180
SUBTOTAL	$ 237,660	$ 35,500	$ 158,340	$ 431,500
Filtration System with Flow Splitter/Sampling Manhole/Meter and Pump Station				
Sheet Pile Installation and Excavation	0	0	8,600	$ 8,600
Effluent Pump Station Manhole (84"x12' deep)	9,990	8,000	13,500	$ 31,490
Site Restoration and Paving	0	0	6,360	$ 6,360
Effluent Pump and Controls (2,000 gpm at TDH of 15ft)	0	26,000	25,700	$ 51,700
SUBTOTAL	$ 247,650	$ 69,500	$ 212,500	$ 529,650
TOTAL CAPITAL COST				**$ 530,000**

Table 9 - Detailed EFS Cost Estimate

Site:	NASSCO	**Description:**	Enhanced filtration system (EFS) constructed April 2001; Treatment of shipyard stormwater using StormFilter cartridges in subsurface vaults. Peak flow 1,350 gpm. Flow splitter, sampling manhole, flow meter, and pump station included for testing only.
Location:	San Diego , California		
Phase:	Post Construction		
Base Year:	2001		
Date:	May 1, 2002		

ANNUAL COSTS (BASELINE FILTRATION SYSTEM):

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL
Operation and Maintenance Costs				
Labor (1)	210	hr	45	$ 9,450
Operating Expenses (2)	1	ls	3,636	$ 3,636
Replace Filter Cartridges (3)	165	cartridges	115	$ 18,975
Splitter/Bypass Cleanout and Disposal (4)	1	ls	5,000	$ 5,000
Monitoring and Reporting Costs				Not Estimated
TOTAL ANNUAL COST				**$ 37,000**

Capital Cost Notes:

1 Major Material Costs based on SMI quote for concrete structures and filter cartridges dated 8/25/00, as modified in J. Holtz verbal dated 10/11/01.

2 Minor Material (pump, piping, valves, fittings, conduit, control panel, ballast, rock, weir and flow meter) and Labor/Equipment Costs based on total actual cost of $282,000 per L. Hansen e-mail dated 10/2/01,distributed per Ledsam quote dated 8/21/00.

3 The following costs are not included:

a. Contaminated soil handling and disposal

b. Upgrading of structures and paving for loading greater than H20.

Annual Cost Notes

1 Labor cost is based on 2 weekly inspections during the 6-month wet season.

2 Operating expenses are calculated as 1 percent of the baseline capital costs.

3 Annual frequency to be confirmed through testing. Unit cost per cartridge is for the mixed media (fine/coarse) cartridge. Cost includes supply of new media and disposal of spent media. Fine media cartridges cost $130, and coarse media cartridges cost $65.

4 Semi-annual cleanout of solids; off-site disposal as non-hazardous waste.

Table 10 - Unit Cost Summary

Enhanced Filtration System	Unit Capital Cost per acre (a)	Unit Capital Cost per gpm (b)	Unit Capital Cost per 1000 gal. (c)	Unit O&M Cost per 1000 gal. (d)	Total Unit Cost per 1000 gal. (e)
Baseline Filtration System	$ 40,000	$ 270	$ 11	$ 17	$ 29
- With Flow Splitter	$ 44,000	$ 300	$ 12	--	--
- With Flow Splitter/Sampling Manhole/Meter	$ 47,000	$ 320	$ 13	--	--
- With Flow Splitter/Sampling Manhole/Meter and Pump Station	$ 58,000	$ 400	$ 16	--	--

Notes:

a. Based on detailed capital cost data in Table 1, divided by drainage area of SW-3, 9.25 acres

b. Based on detailed capital cost data in Table 1, divided by hydraulic capacity of EFS, 1,350 gallons per minute (gpm).

c. Based on detailed capital cost data in Table 1, divided by design life of EFS, 15 years, and volume of stormwater to be treated in 1,000s of gallons

- Average rainfall in San Diego, 9 inches per year
- Drainage area of SW-3, 9.25 acres
- EFS runoff efficiency, 95 percent capture

d. Based on detailed O&M cost data in Table 1, divided by volume of stormwater to be treated in 1,000's of gallons (see note 3)

e. Total unit cost is equal to unit capital cost plus unit O&M cost.

Table 11 - ROI Evaluation for NASSCO Shipyard SW-3 (In Thousands of Dollars)

PROJECT YEAR	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	TOTAL
Enhanced Filtration System (EFS) Capital Cost	364	0	0	0	0	0	0	0	0	0	
EFS Operation and Maintenance (O&M) Cost	0	37	37	37	37	37	37	37	37	37	
Total EFS Cost	364	37	37	37	37	37	37	37	37	37	
Present Value of EFS Cost	364	35	32	30	28	26	25	23	22	20	605
Savings											
Capital Cost Avoidance	243	0	0	0	0	0	0	0	0	0	
O & M Cost Avoidance	0	215	215	215	215	215	215	215	215	215	
Total Savings	243	215	215	215	215	215	215	215	215	215	
Present Value of Total Savings	243	201	188	176	164	153	143	134	125	117	1,644
Net Benefit	-121	178	178	178	178	178	178	178	178	178	
Present Value of the Net Benefit	-121	166	155	145	136	127	119	111	104	97	1,039
Discount Factors	1.0000	0.9346	0.8734	0.8163	0.7629	0.7130	0.6664	0.6228	0.5820	0.5439	
Cumulative Present Net Value	-121	45	201	346	482	609	727	838	942	1,039	
Net Present Value(a)	1,039										

General Notes:

a. Equal to the Cumulative Present Net Value at the end of the 10 year period at a 7% discount rate.

b. Presumes adequate storage tankage exists at the shipyard.

c. Based on drainage area of SW-3, 9.25 acres

d. Based on average rainfall in San Diego, 9 inches per year

e. Based on EFS runoff efficiency, 95 percent capture

Table 12 - ROI Calculation for Medium Sized Commercial Shipyard (in Thousands of Dollars)

PROJECT YEAR	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	TOTAL
Enhanced Filtration System (EFS) Capital Cost	1,574	0	0	0	0	0	0	0	0	0	
EFS Operation and Maintenance (O&M) Cost	0	160	160	160	160	160	160	160	160	160	
Total EFS Cost	1,574	160	160	160	160	160	160	160	160	160	
Present Value of EFS Cost	1,574	150	140	131	122	114	107	100	93	87	2,616
Savings											
Capital Cost Avoidance	243										
O & M Cost Avoidance		930	930	930	930	930	930	930	930	930	
Total Savings	243	930	930	930	930	930	930	930	930	930	
Present Value of Total Savings	243	869	812	759	709	663	620	579	541	506	6,302
Net Benefit	-1,331	770	770	770	770	770	770	770	770	770	
Present Value of the Net Benefit	-1,331	720	673	629	587	549	513	480	448	419	3,686
Discount Factors	1.0000	0.9346	0.8734	0.8163	0.7629	0.7130	0.6664	0.6228	0.5820	0.5439	
Cumulative Present Net Value	-1,331	-611	61	690	1,277	1,826	2,339	2,819	3,267	3,686	
Net Present Value(a)	3,686										

General Notes:

a. Equal to the Cumulative Present Net Value at the end of the 10 year period at a 7% discount rate.

b. Presumes adequate storage tankage exists at the shipyard.

c. Based on drainage area of 40 acres

d. Based on average rainfall in San Diego, 9 inches per year

e. Based on EFS runoff efficiency, 95 percent capture

Vicinity Map

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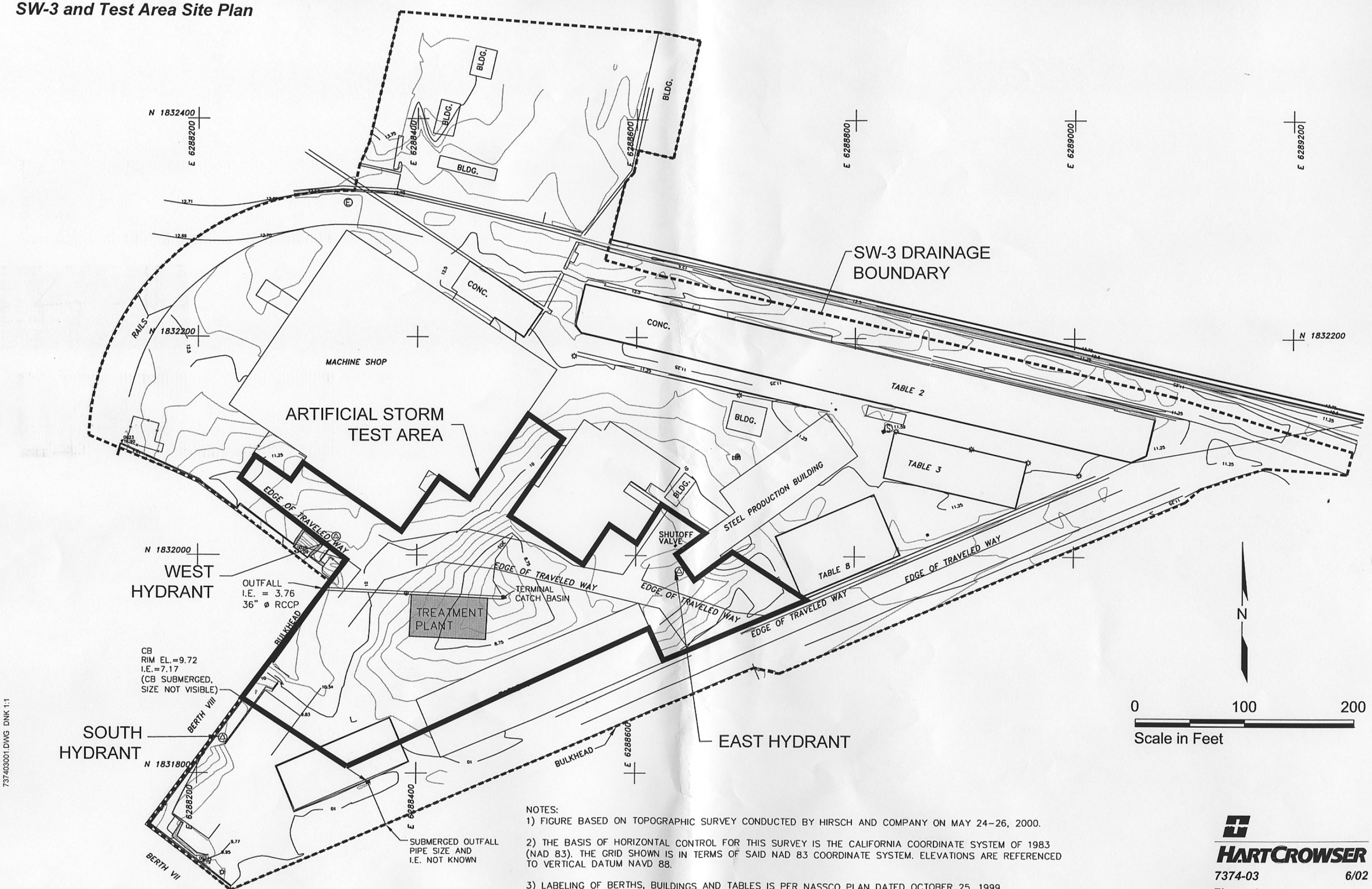
Figure 1

SW-3 and Test Area Site Plan



NOTES:
1) FIGURE BASED ON TOPOGRAPHIC SURVEY CONDUCTED BY HIRSCH AND COMPANY ON MAY 24–26, 2000.

2) THE BASIS OF HORIZONTAL CONTROL FOR THIS SURVEY IS THE CALIFORNIA COORDINATE SYSTEM OF 1983 (NAD 83). THE GRID SHOWN IS IN TERMS OF SAID NAD 83 COORDINATE SYSTEM. ELEVATIONS ARE REFERENCED TO VERTICAL DATUM NAVD 88.

3) LABELING OF BERTHS, BUILDINGS AND TABLES IS PER NASSCO PLAN DATED OCTOBER 25, 1999.

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Figure 2

Flow Schematic

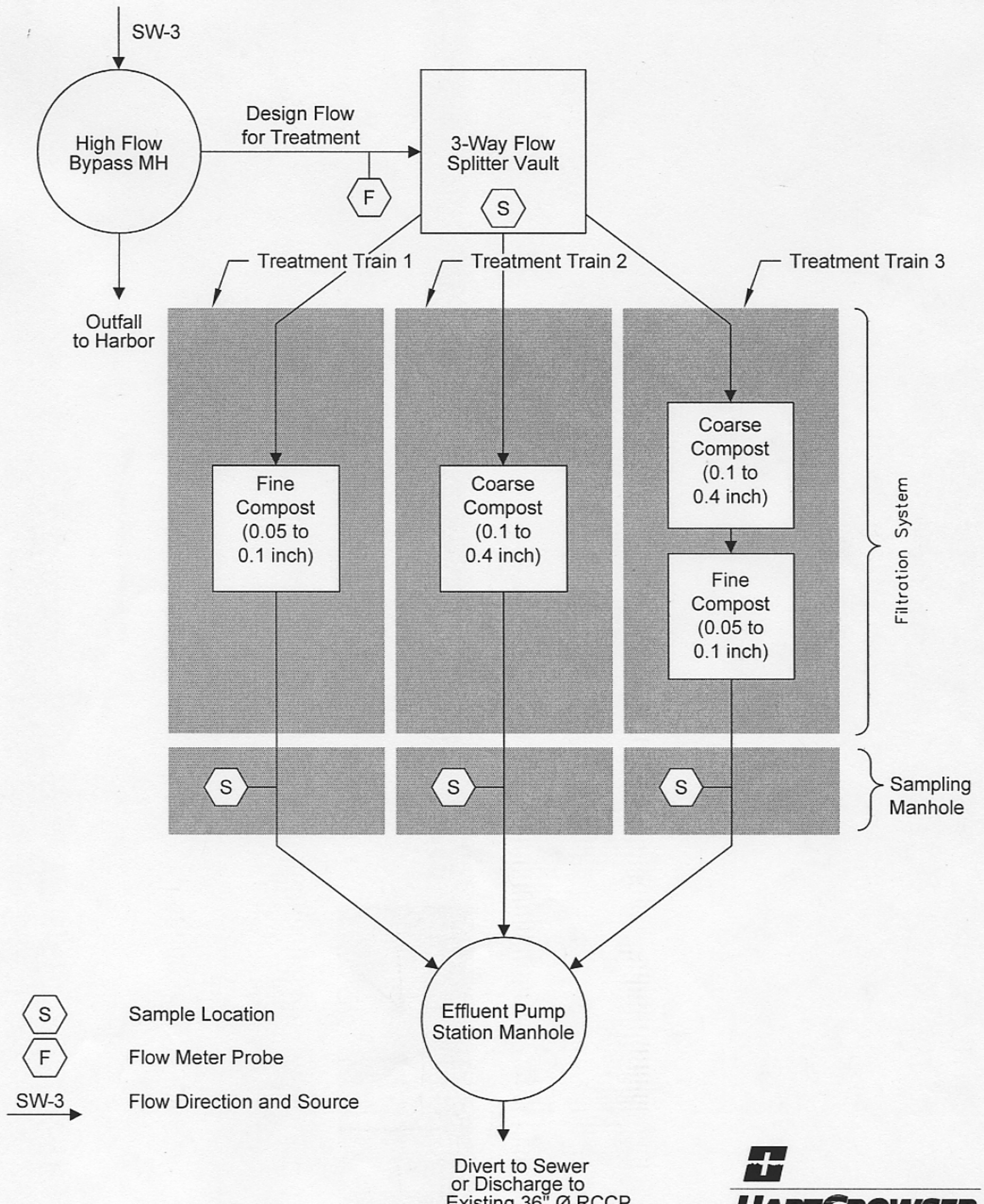

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Figure 3

Cartridge Schematic

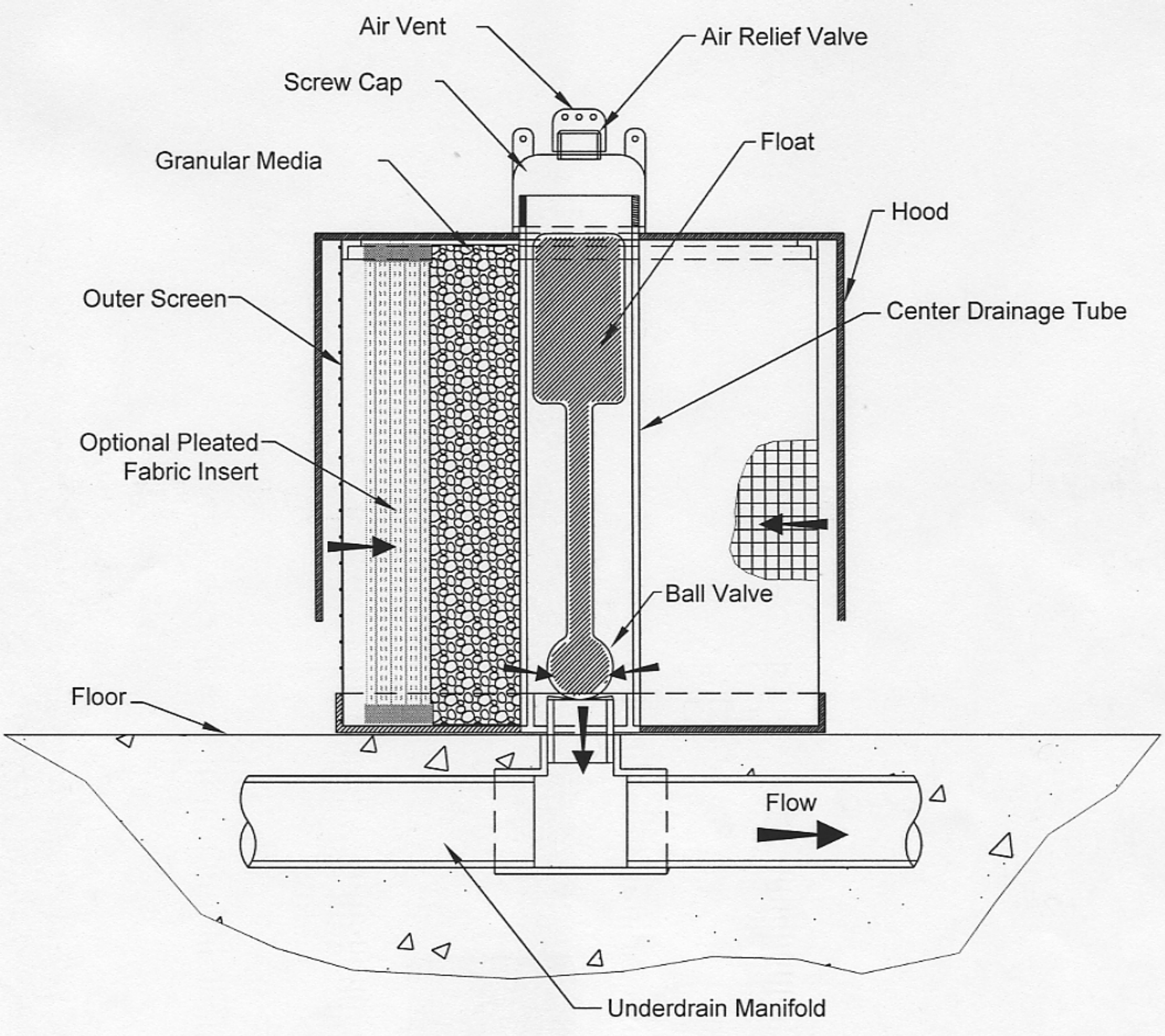

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Figure 4

Influent Flow Hydrograph for September 2001 Monitoring Event

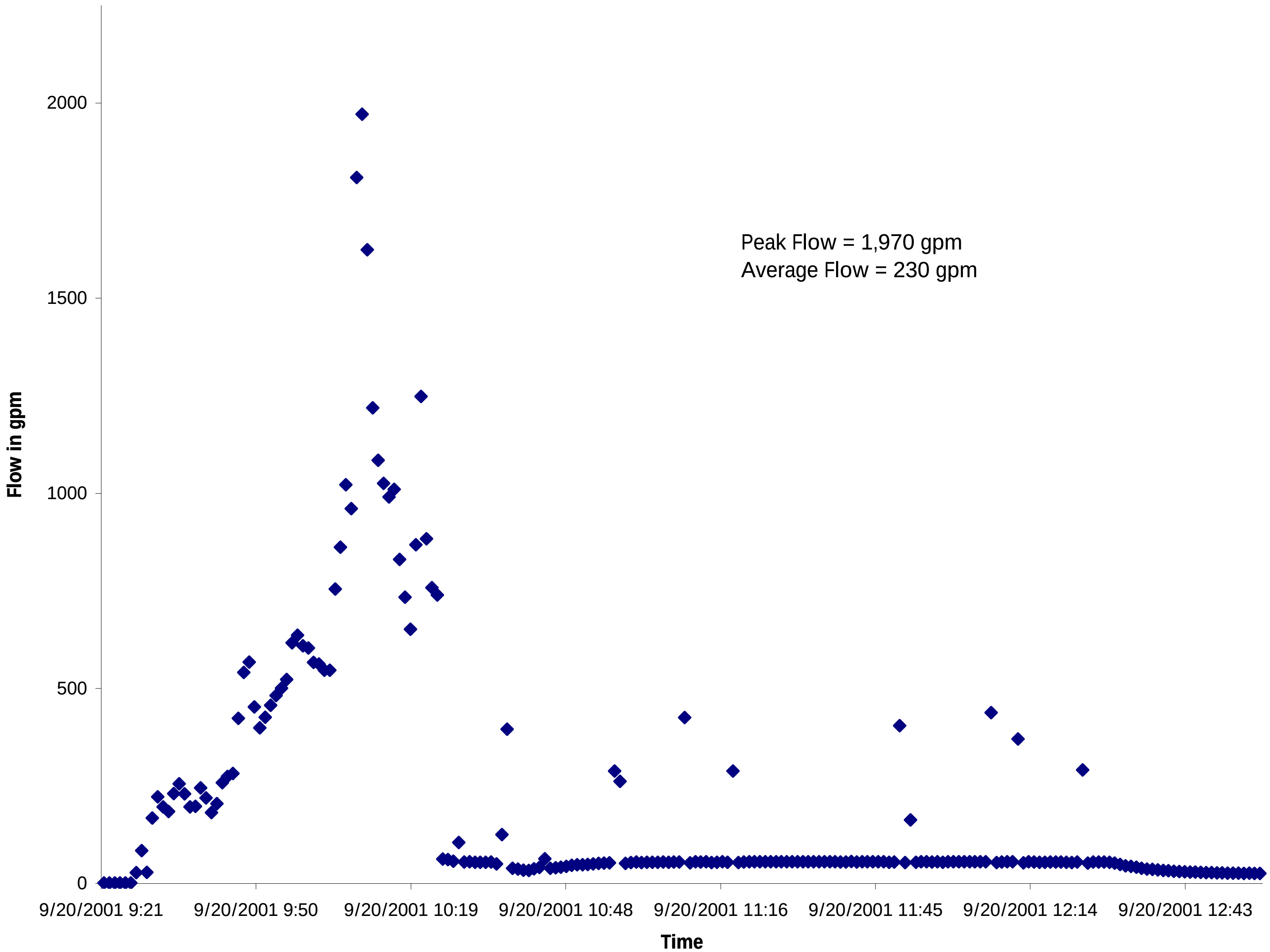

Figure 5
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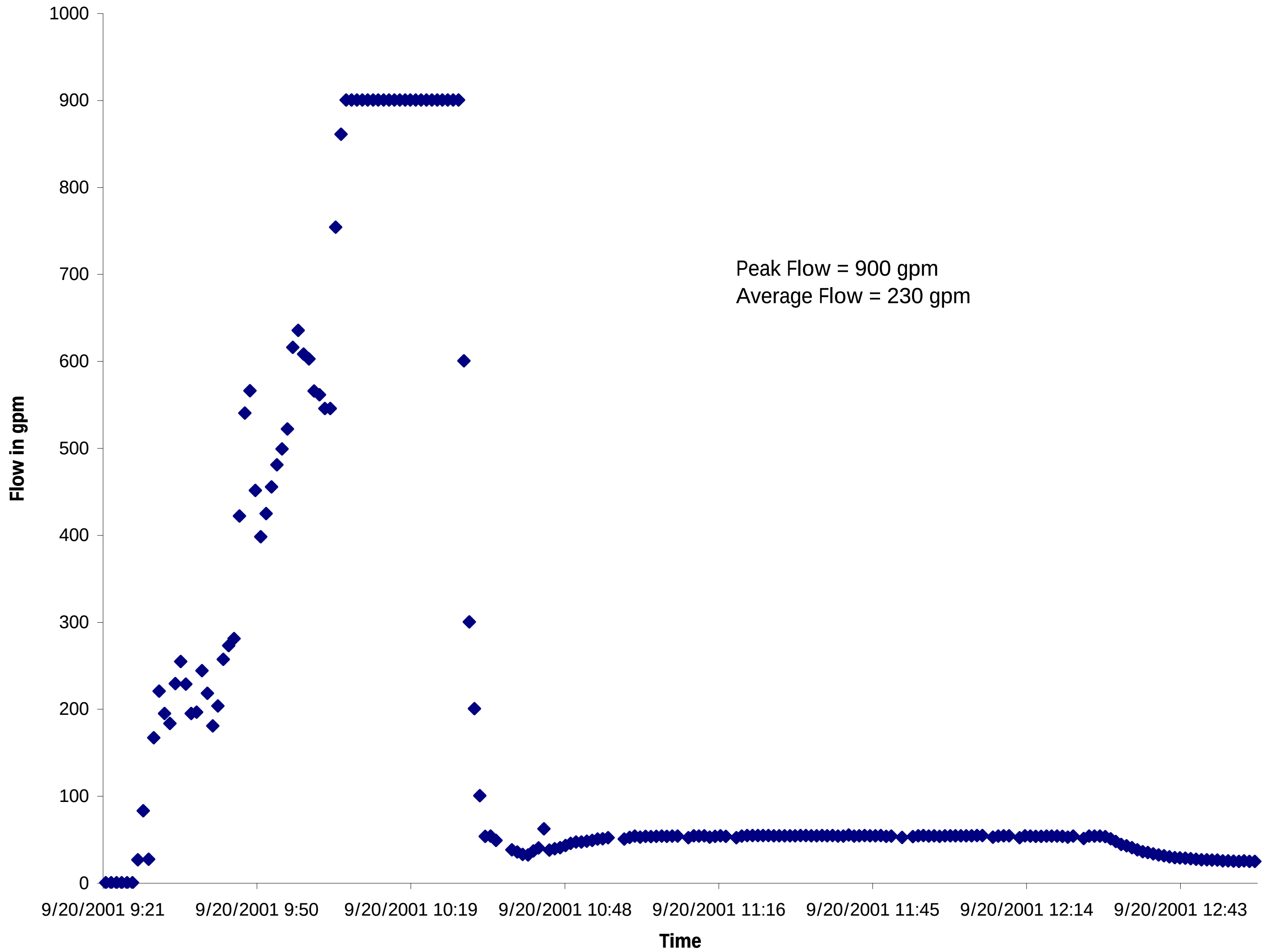
737403_FIG5-11.XLS CAS 6/13/02

Treated Flow Hydrograph for September 2001 Monitoring Event



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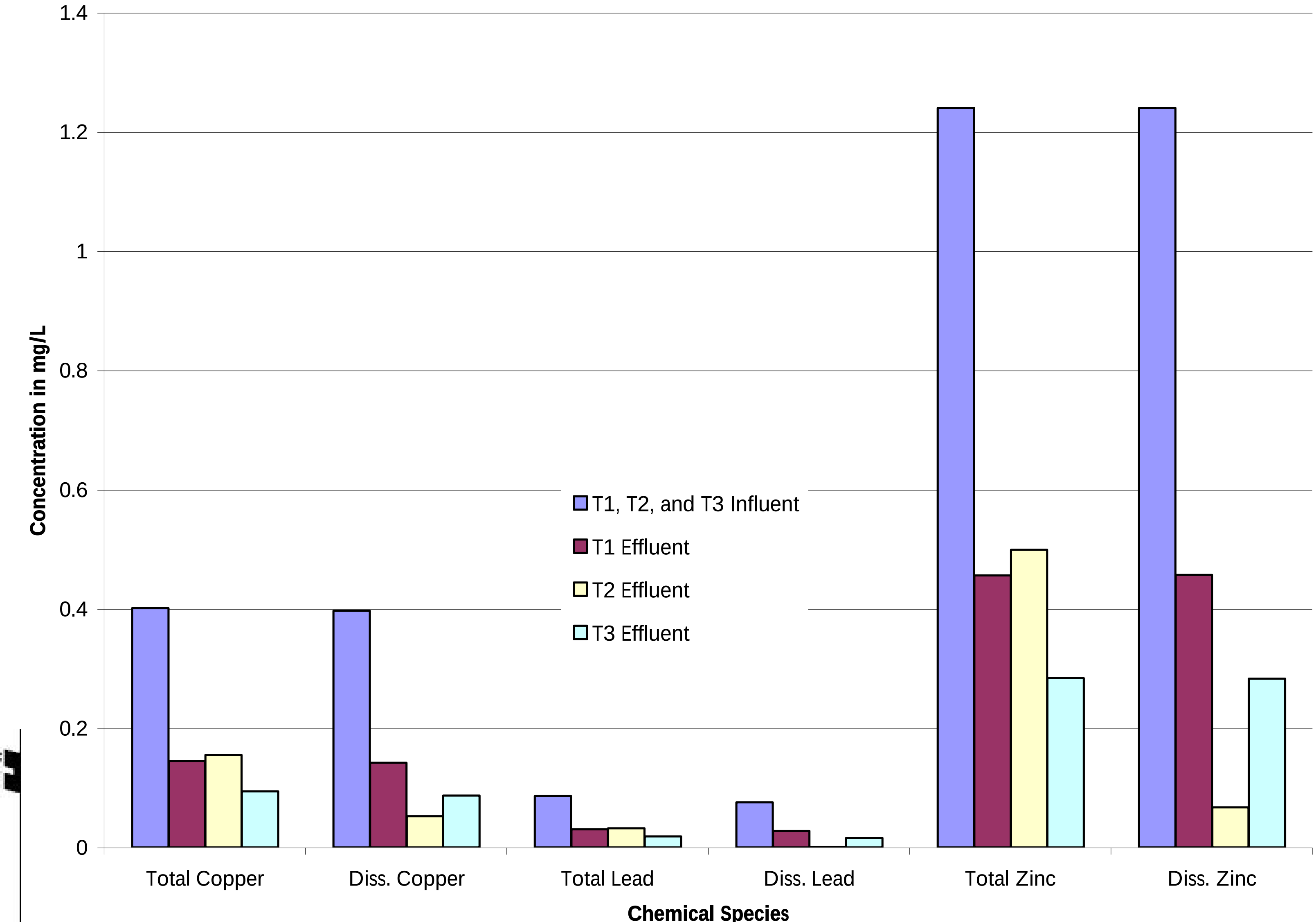
6/02
Figure 6

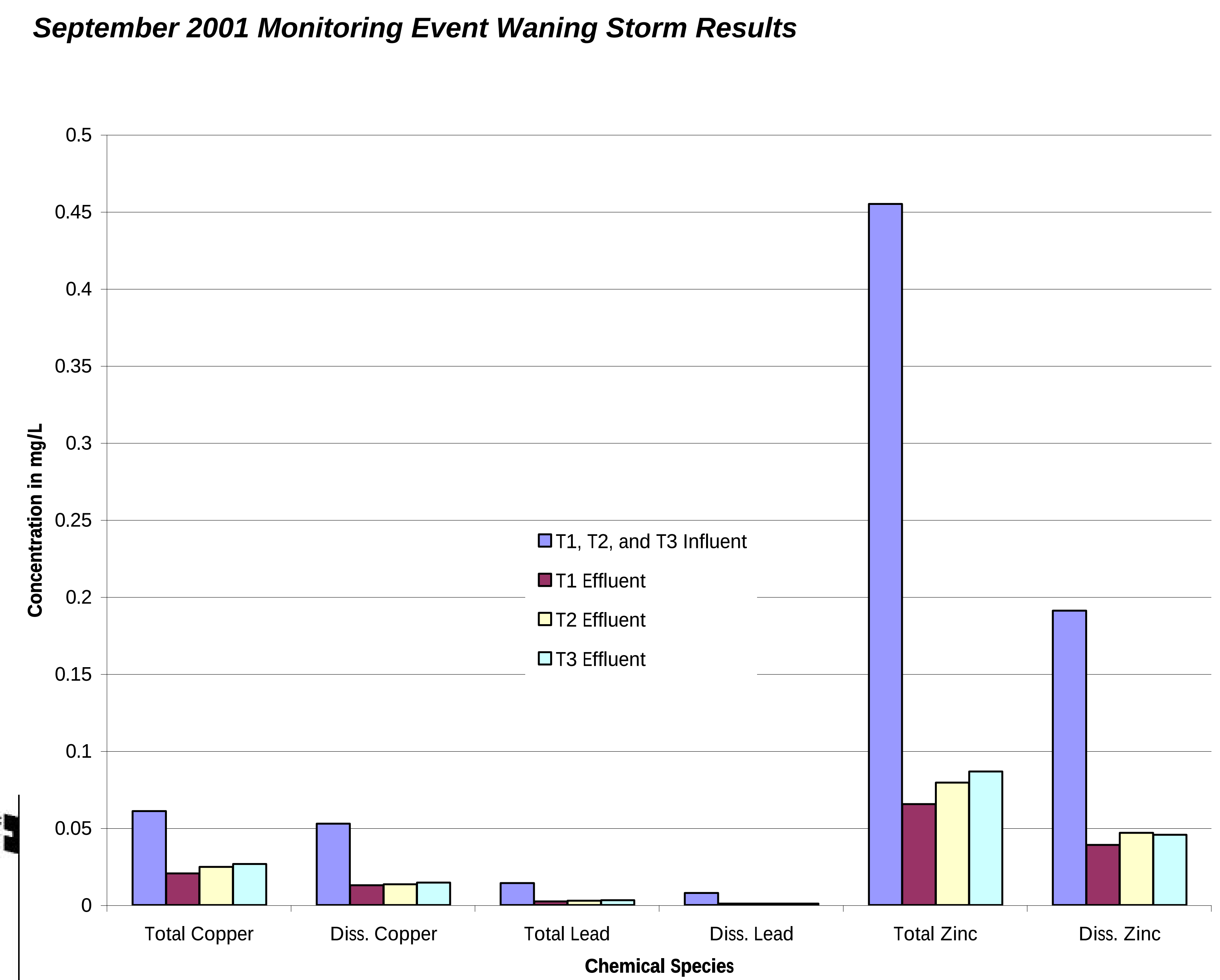
737403_FIG5-11.XLS HEL 6/26/02

September 2001 Monitoring Event First Flush Results



HARTCROWSER
7374-03 6/02
Figure 7

737403_FIG5-11.XLS CAS 6/13/02



I737403_FIG5-11.XLS CAS 6/13/02

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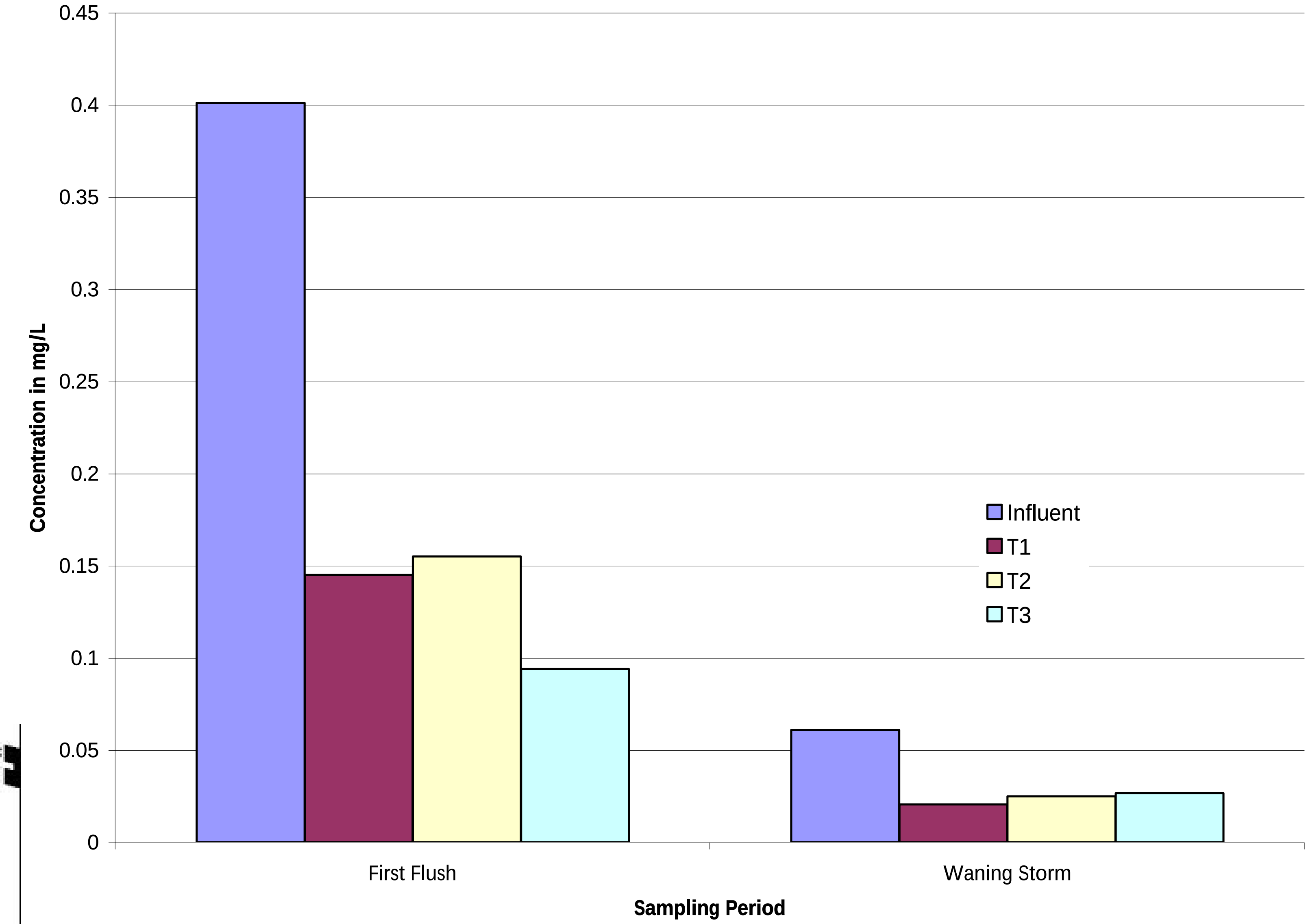
7374-03
Figure 8
6/02

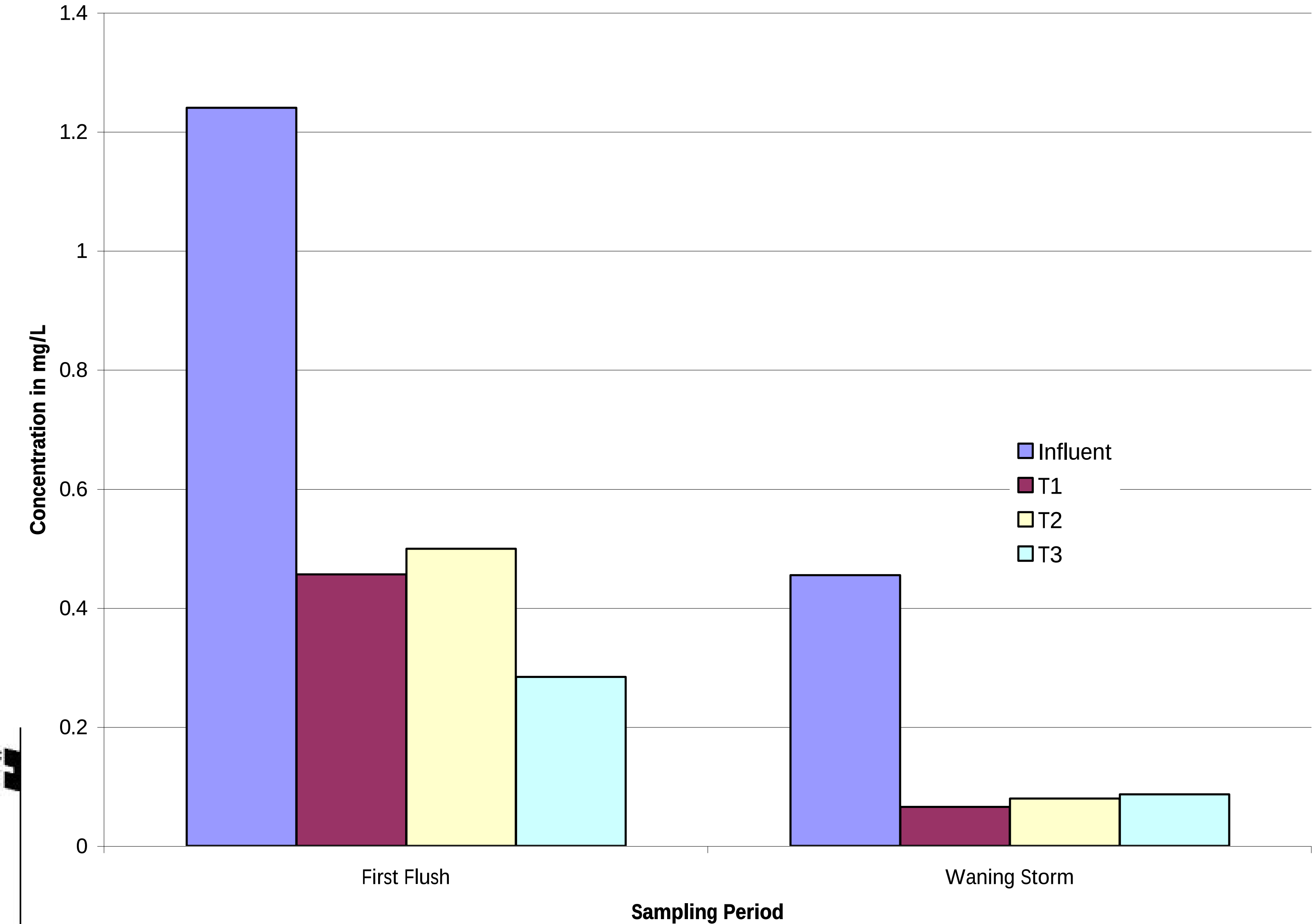
September 2001 Monitoring Event Comparison of Total Copper Results



HARTCROWSER
7374-03
Figure 9
6/02

I737403_FIG5-11.XLS CAS 6/13/02

September 2001 Monitoring Event Comparison of Total Zinc Results



737403_FIG5-11.XLS CAS 6/13/02

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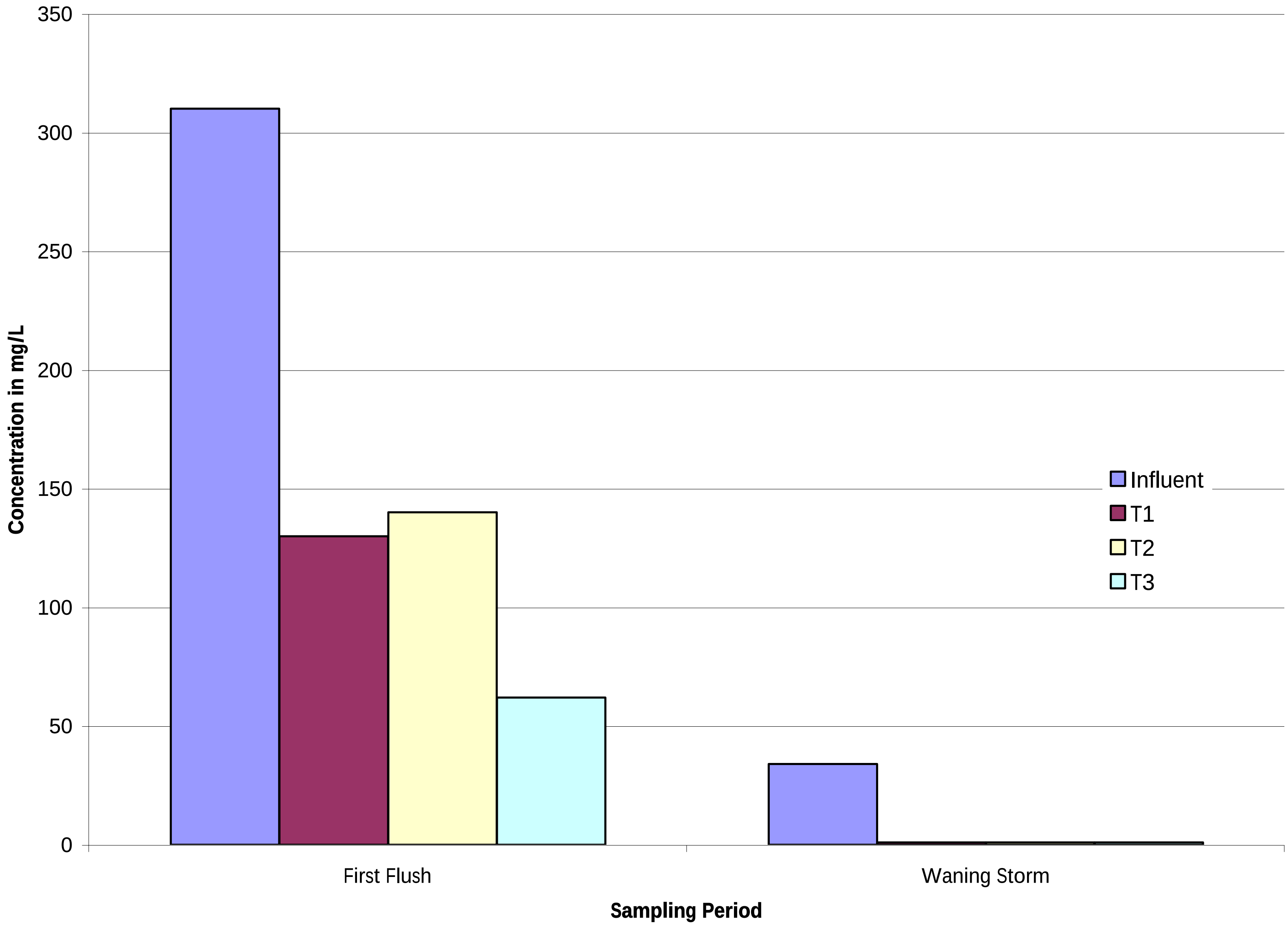
7374-03 6/02
Figure 10

September 2001 Monitoring Event Comparison of Total Suspended Solids (TSS) Results



737403_FIG5-11.XLS HEL 6/26/02

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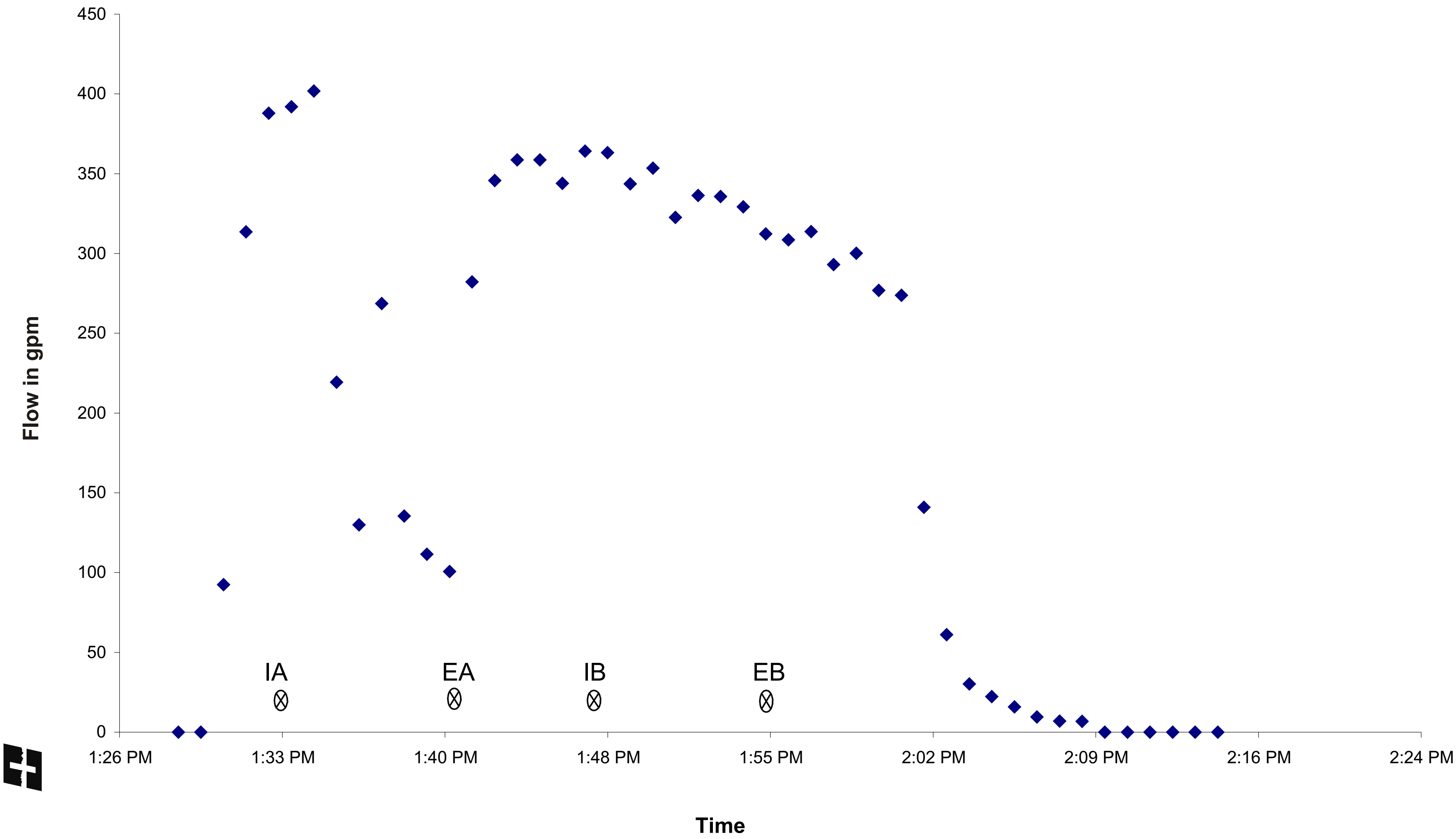
7374-03 6/02
Figure 11

Influent Flow Hydrograph for March 2002 Monitoring Event



Peak Flow = 402 gpm
Average Flow = 199 gpm
IA ⊗ = Sample Collection Time and Designation

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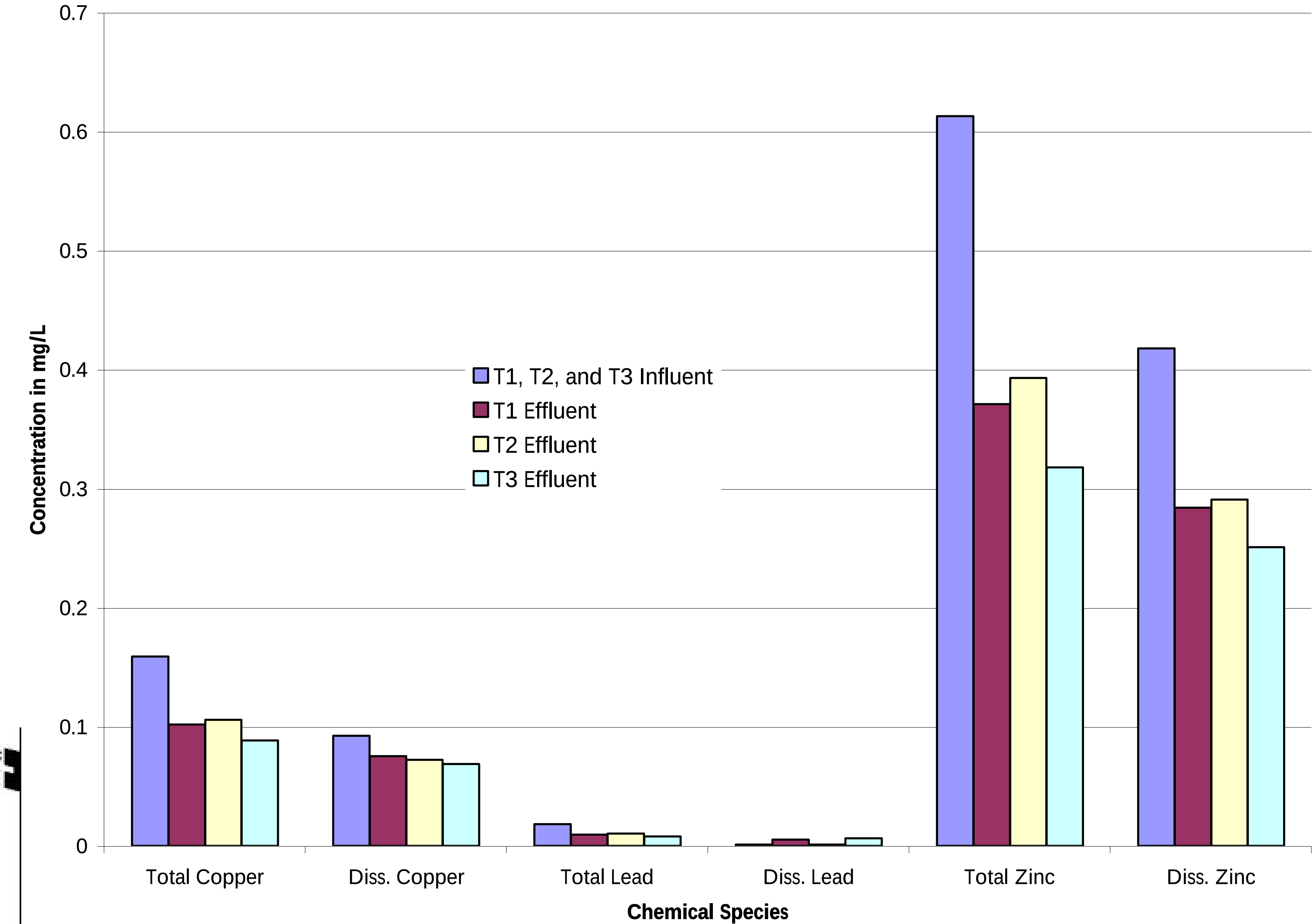
7374-03 6/02
Figure 12

March 2002 Monitoring Event Sample A Results



737403_FIG12-25.XLS CAS 6/13/02

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7374-03
Figure 13
6/02

March 2002 Monitoring Event Sample B Results

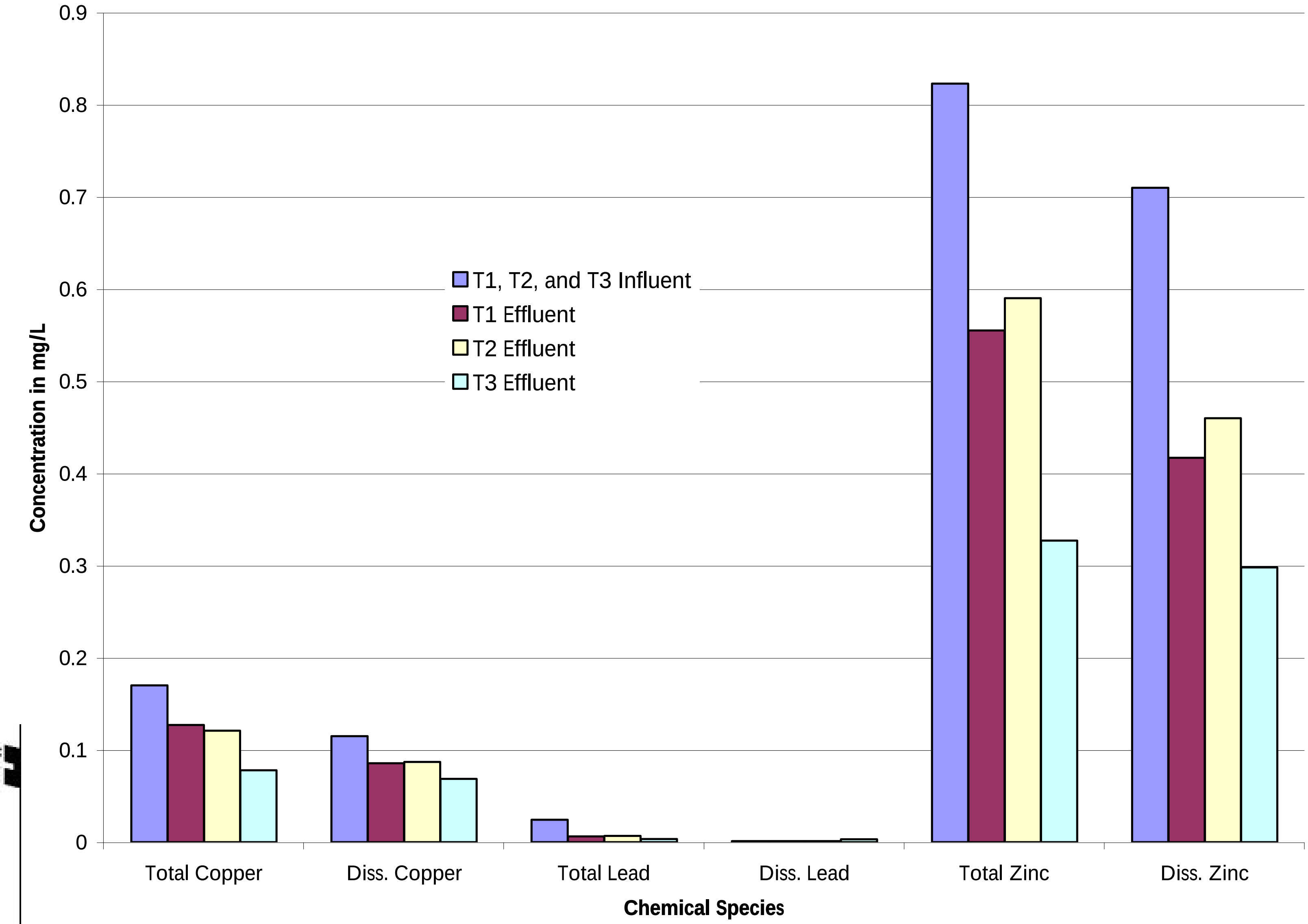

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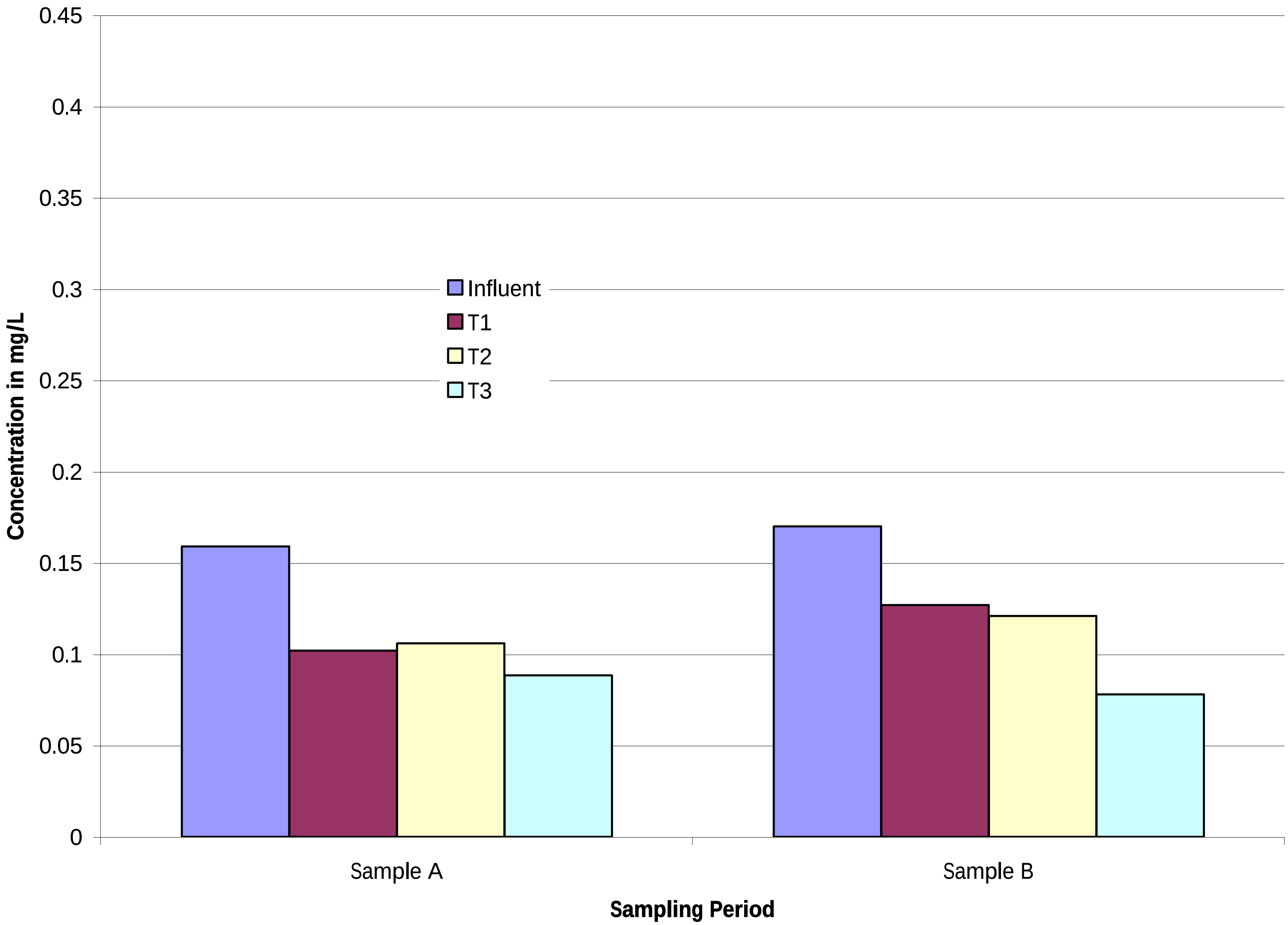
Figure 14

737403_FIG12-25.XLS CAS 6/13/02

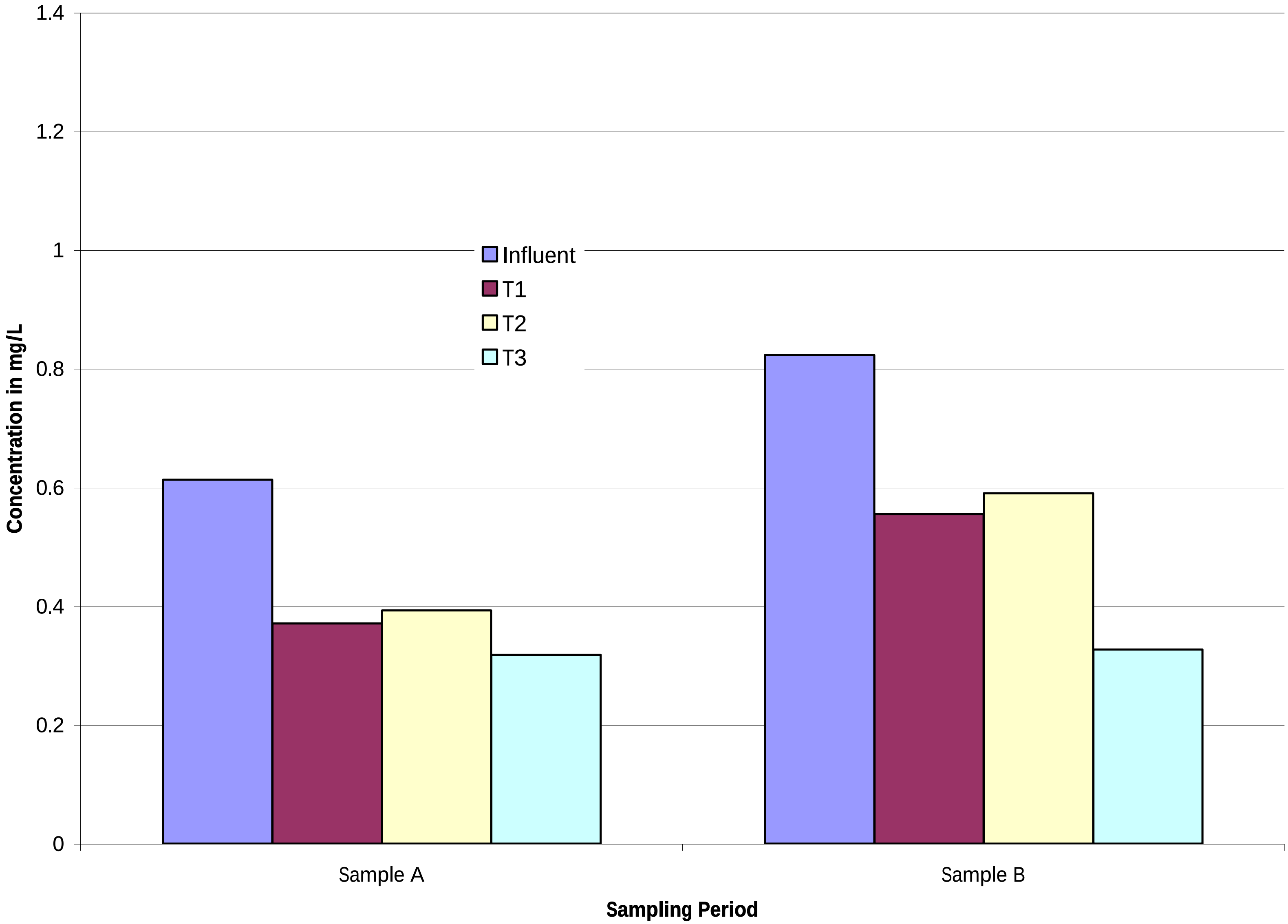
March 2002 Monitoring Event Comparison of Total Copper Results



HARTCROWSER
7374-03 6/02
Figure 15

737403_FIG12-25.XLS HEL 6/26/02

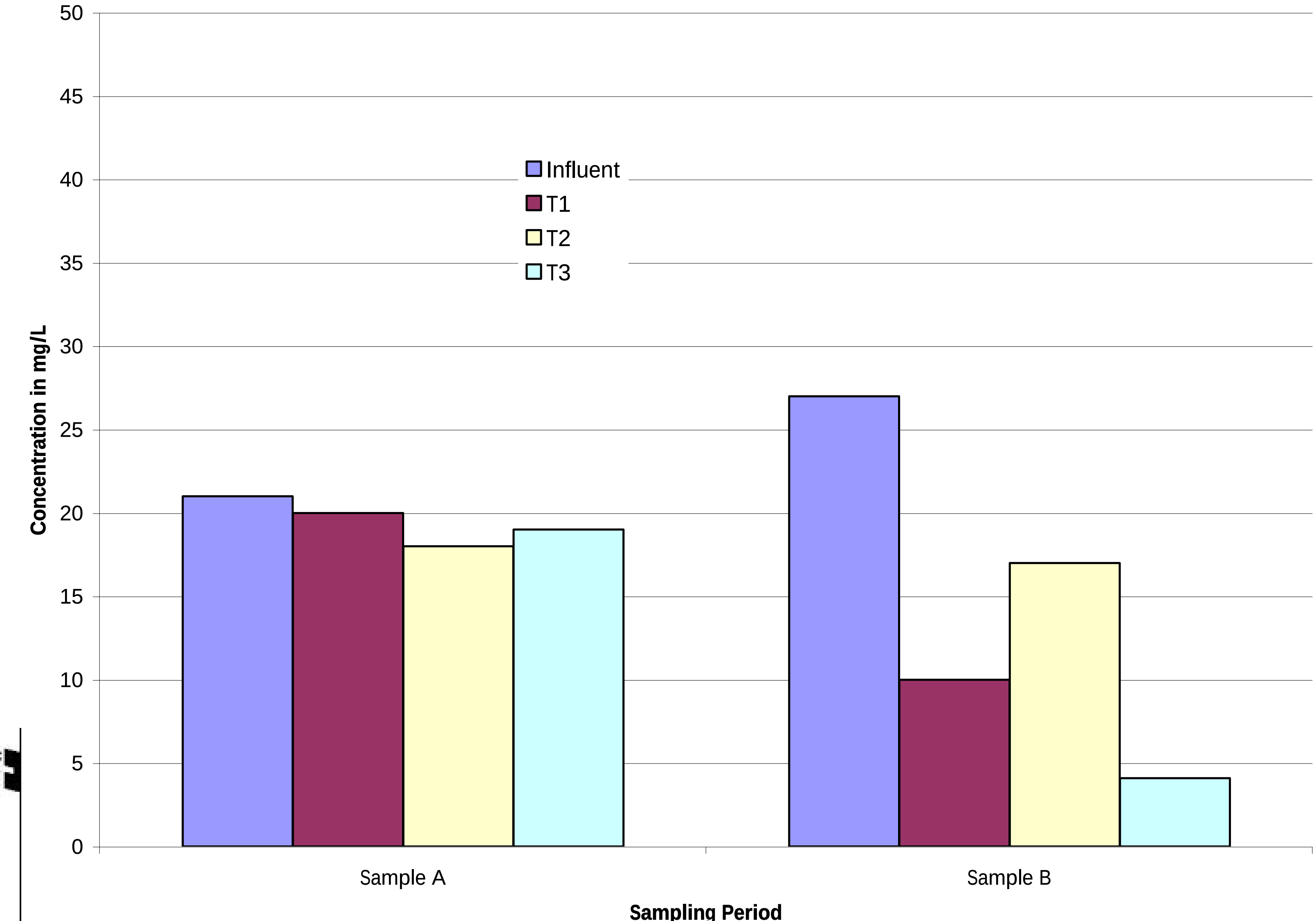
March 2002 Monitoring Event Comparison of Total Zinc Results



HARTCROWSER
7374-03 6/02
Figure 16

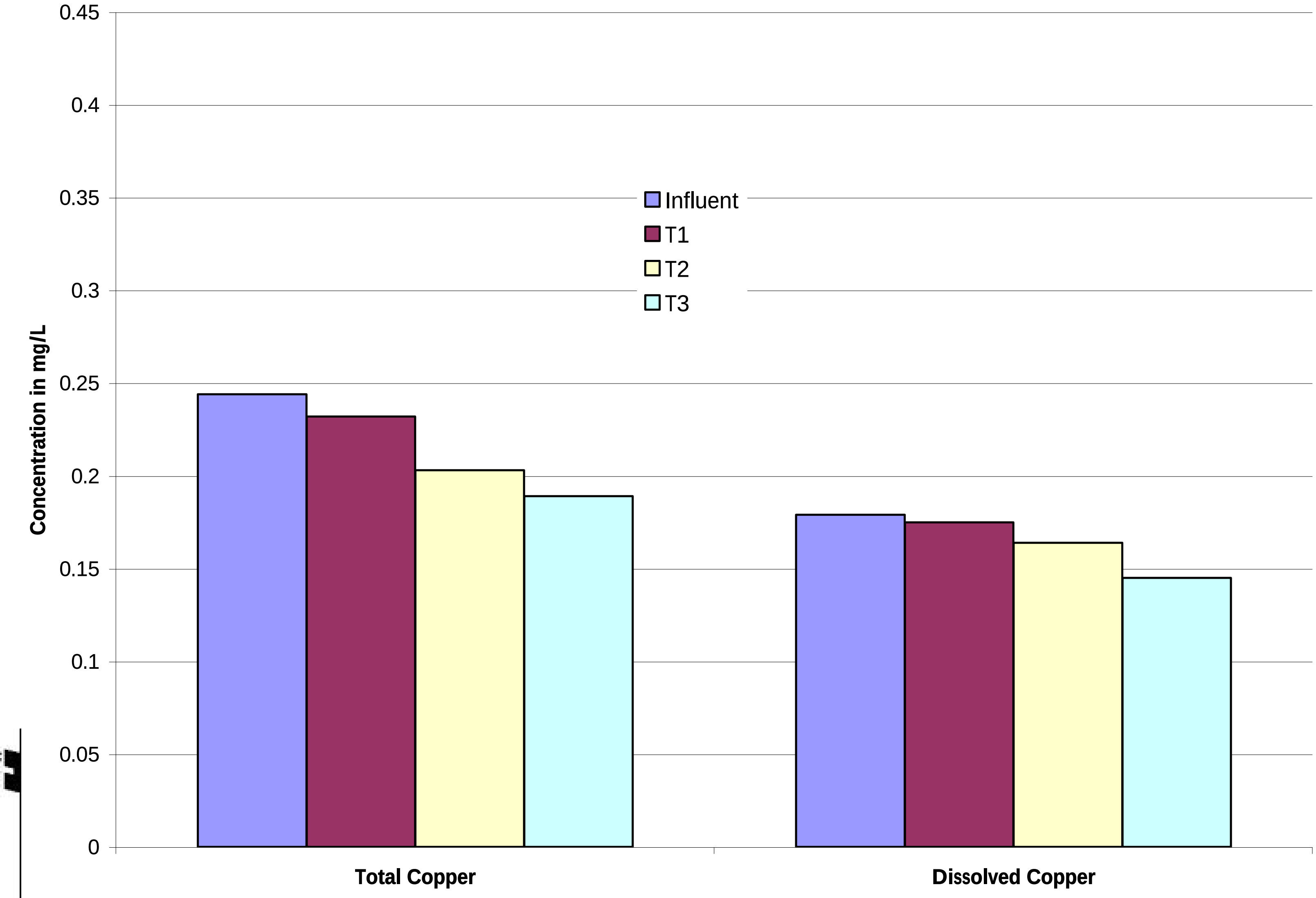
737403_FIG12-25.XLS CAS 6/13/02

March 2002 Monitoring Event Comparison of Total Suspended Solids (TSS) Results



HARTCROWSER
7374-03 6/02
Figure 17

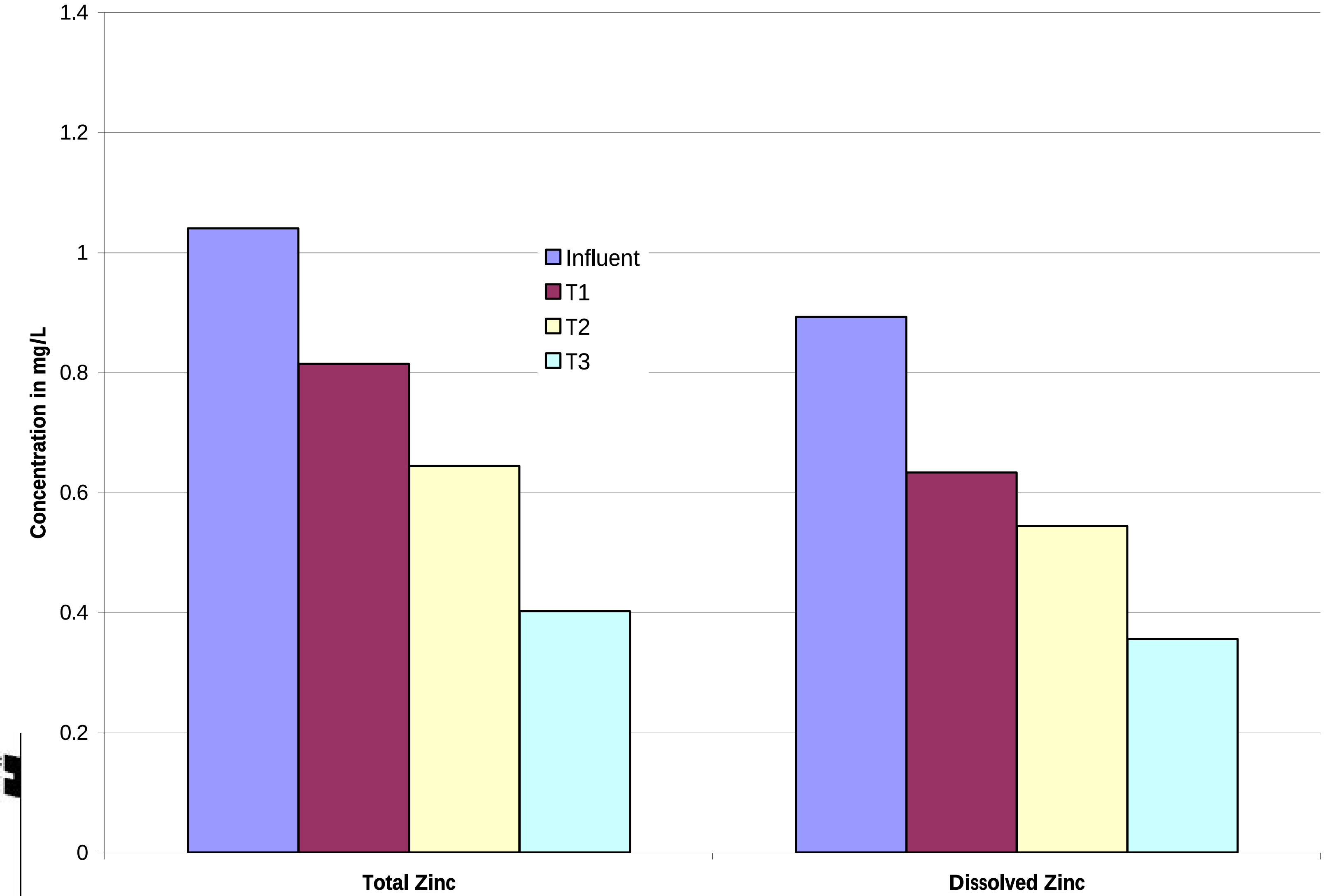
April 2002 Monitoring Event Comparison of Total and Dissolved Copper Results



HARTCROWSER
7374-03
Figure 18
6/02

737403_FIG12-25.XLS CAS 6/13/02

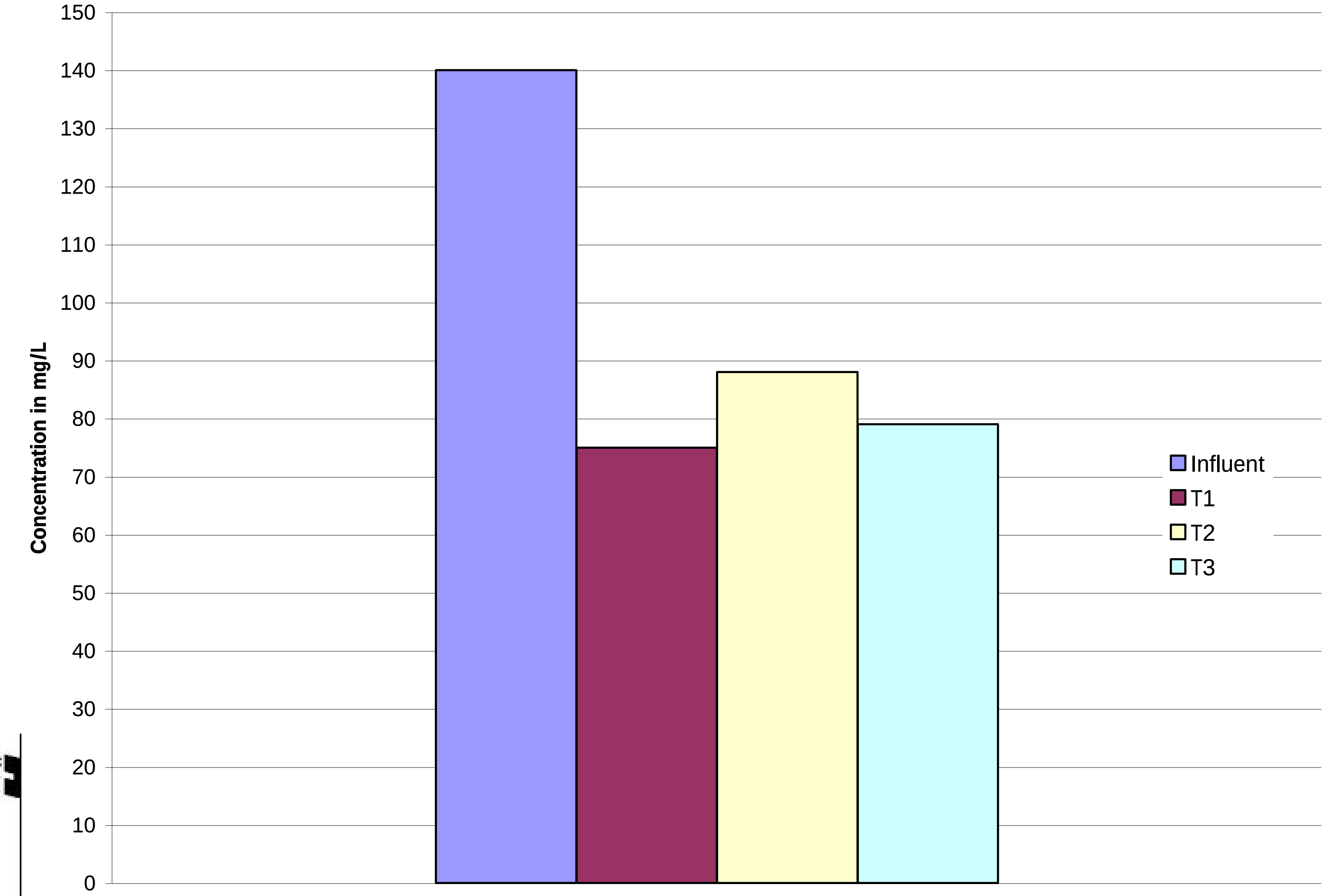
April 2002 Monitoring Event Comparison of Total and Dissolved Zinc Results



HARTCROWSER
7374-03 6/02
Figure 19

737403_FIG12-25.XLS CAS 6/13/02

April 2002 Monitoring Event Comparison of Total Suspended Solids (TSS) Results



737403_FIG12-25.XLS CAS 6/13/02

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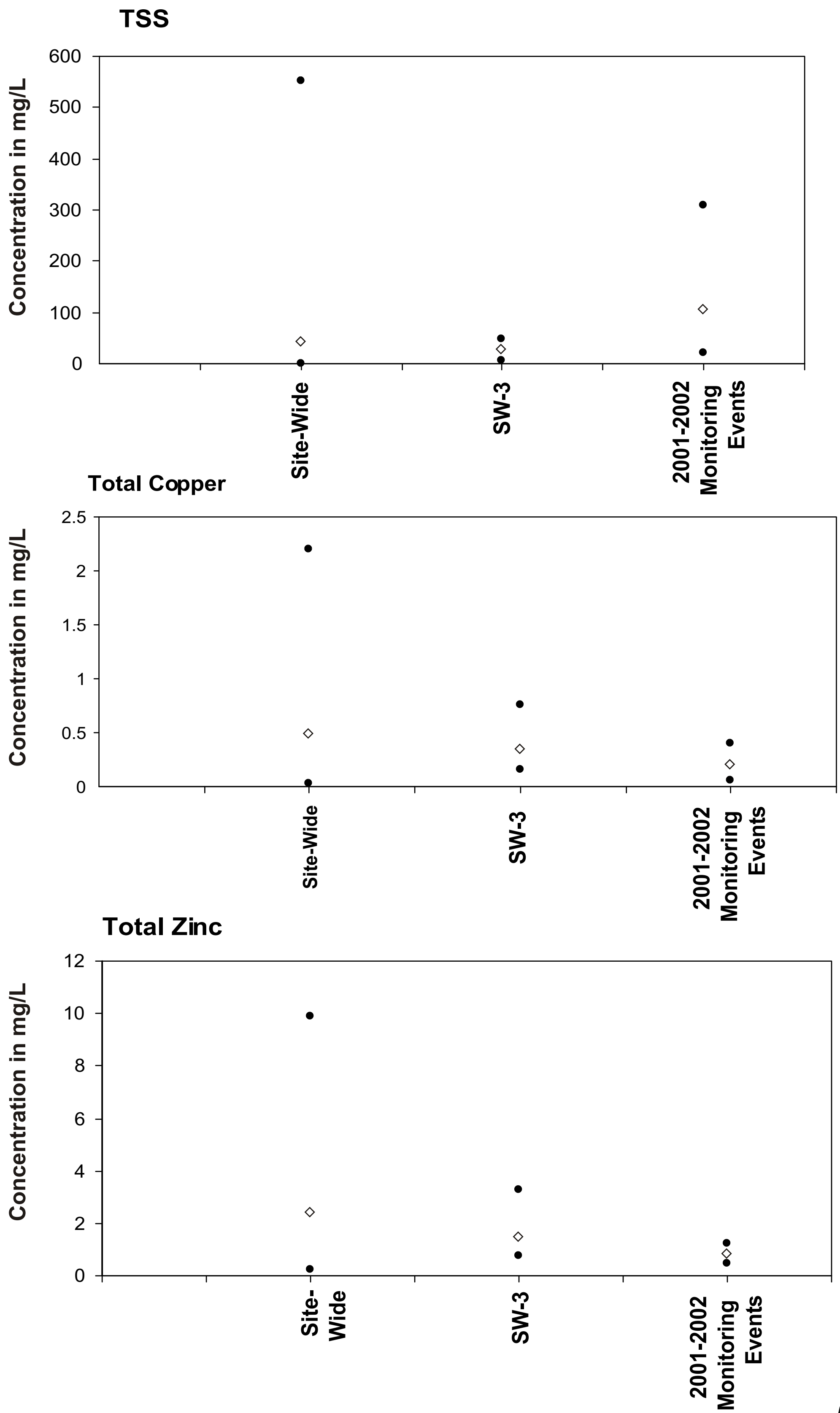
7374-03 6/02
Figure 20

Comparison of Influent Concentrations



737403AC.CDR DNK 7/24/02

Legend

◇ Average

• Minimum and Maximum Sample Result Indicating Range of Concentrations

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7374-03 *6/02*

Figure 21

Influent and Effluent Copper Concentrations Versus Volume of Water Treated

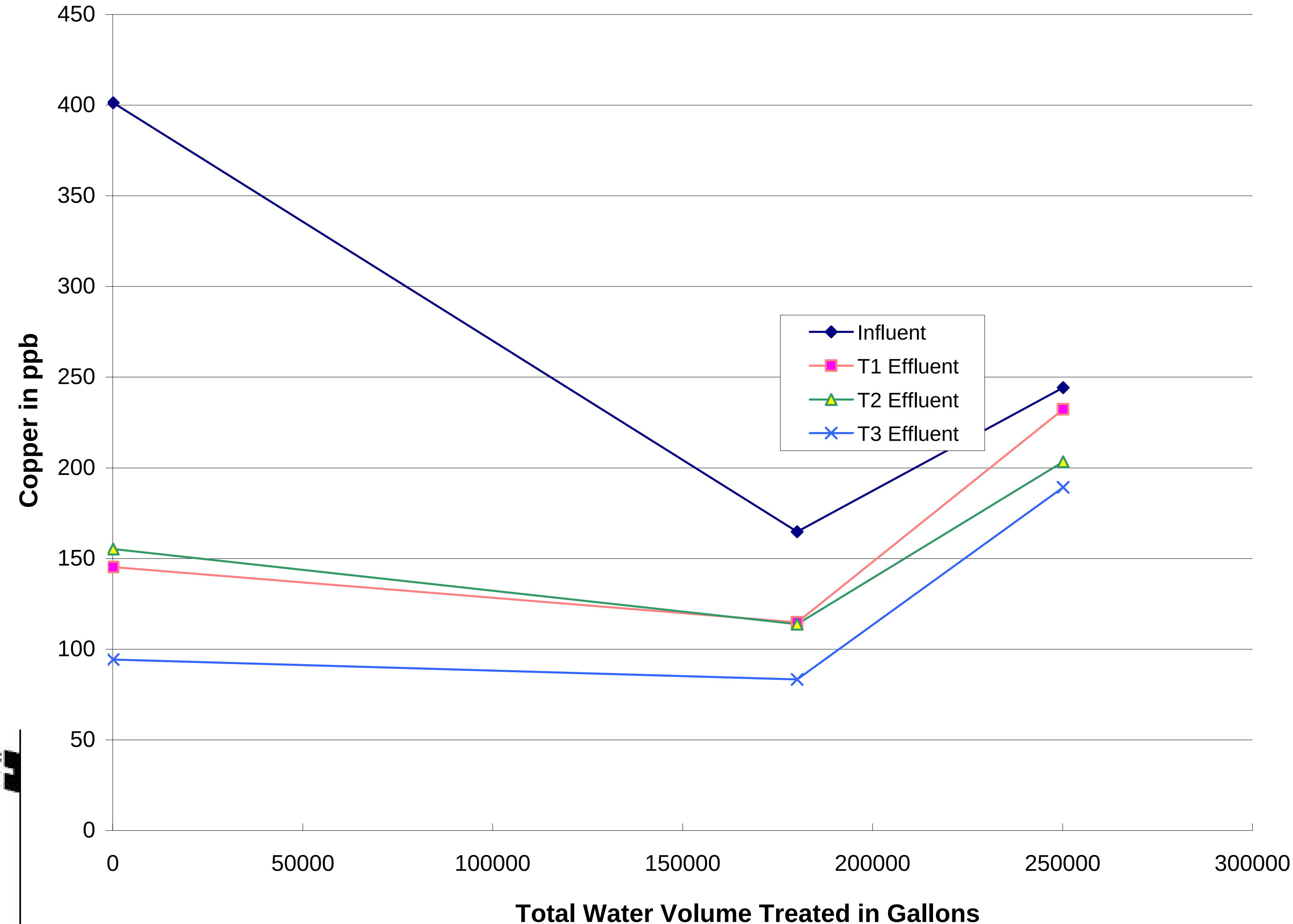

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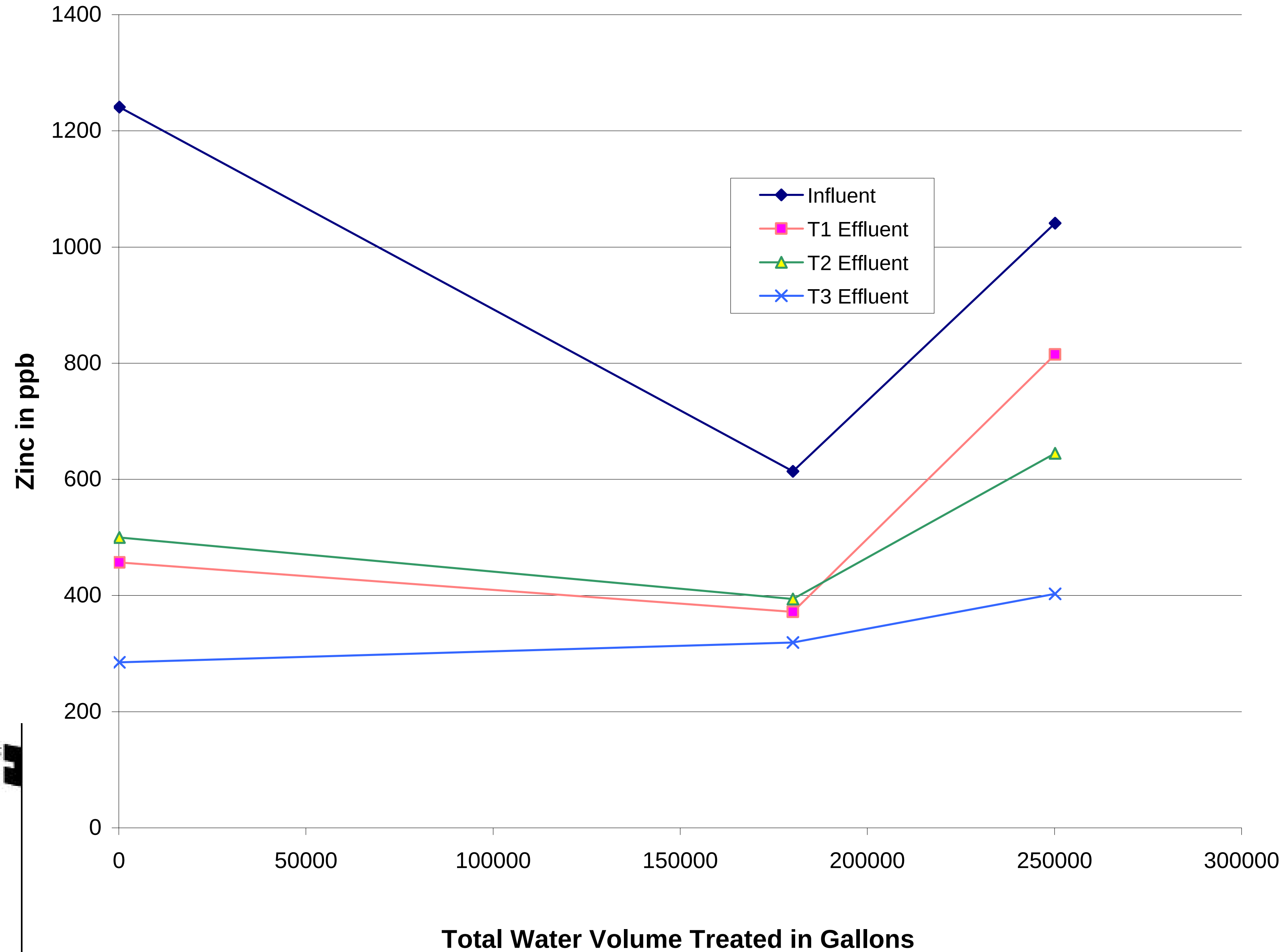
Figure 22

737403_FIG12-25.XLS CAS 6/13/02

Influent and Effluent Zinc Concentrations Versus Volume of Water Treated



737403_FIG12-25.XLS CAS 6/13/02

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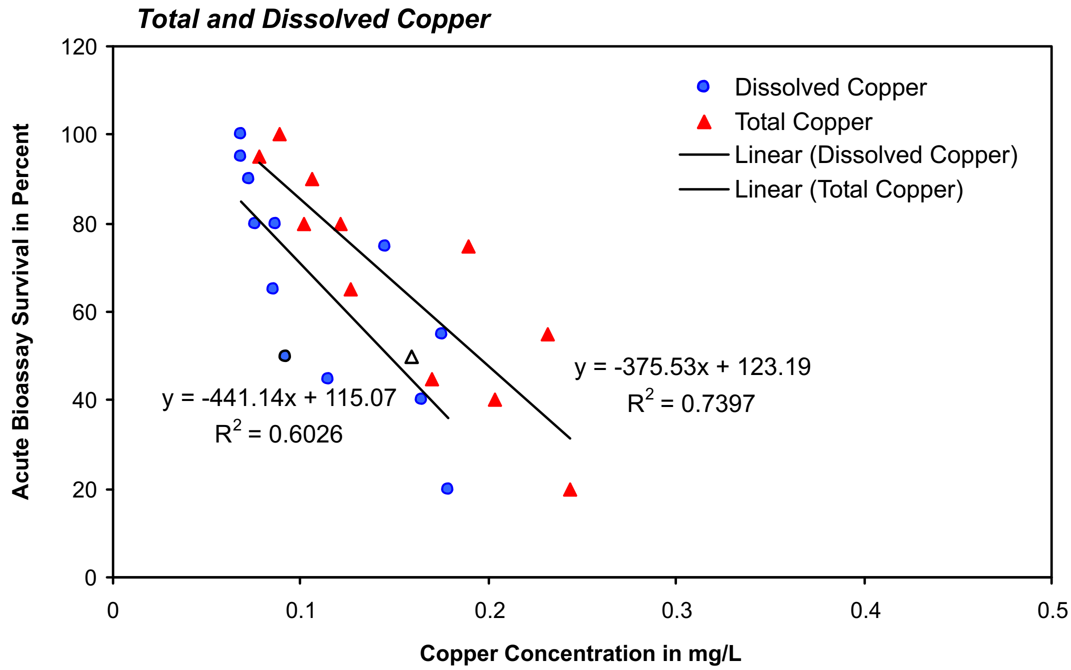
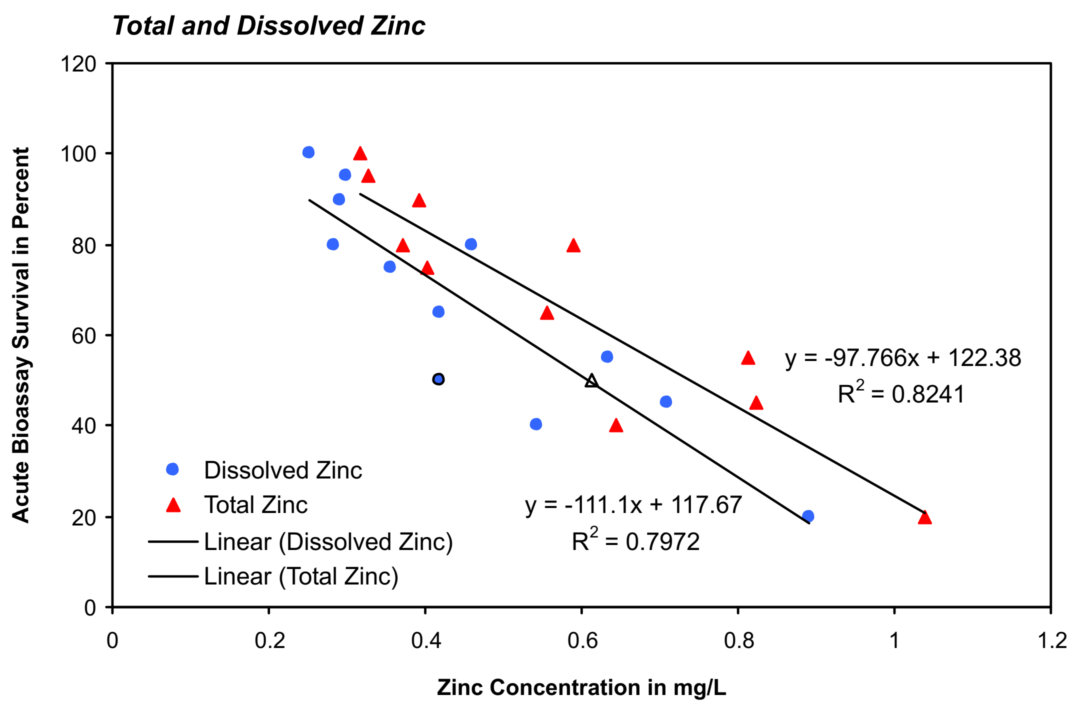
Figure 23

Correlation of Copper and Zinc Bioassay Survival





737403AB.CDR DNK 7/24/02

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7374-03 6/02

Figure 24

APPENDIX A
SEPTEMBER 2001 MONITORING EVENT PHOTOGRAPHS

Photograph 1 – Creating Artificial Storm

Photograph 2 – Creating Artificial Storm

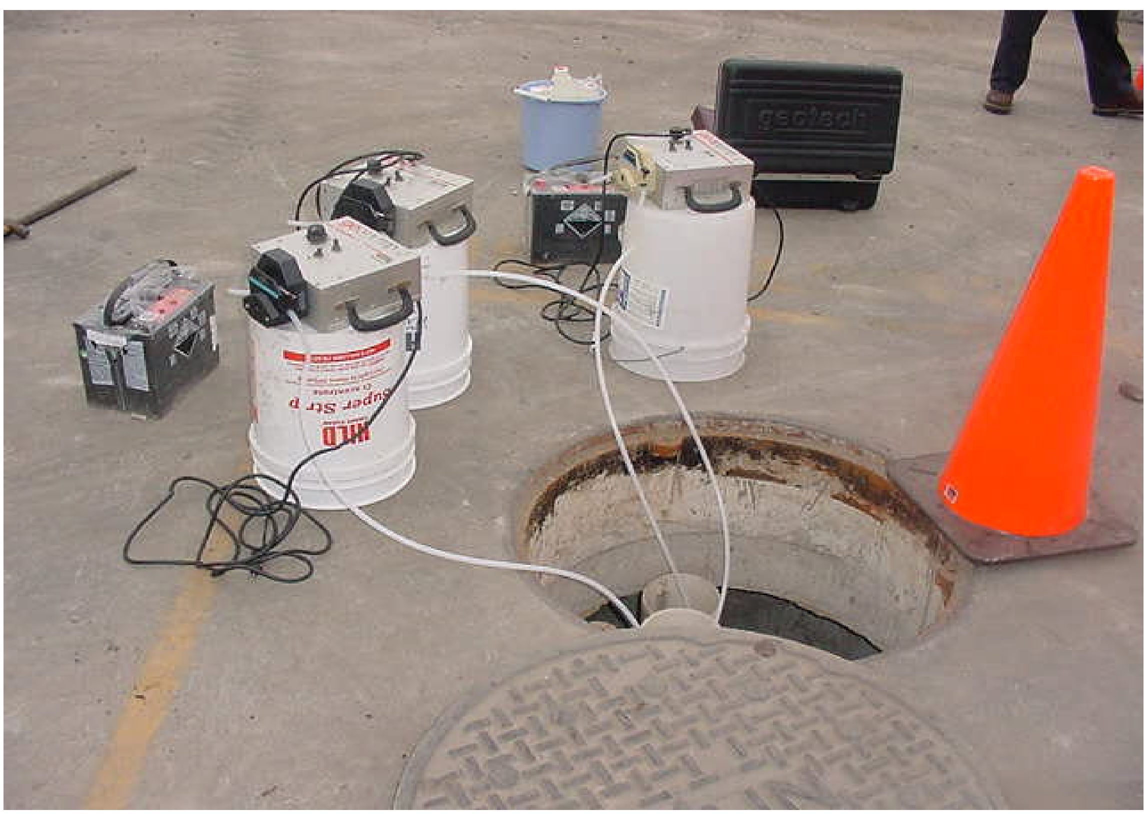
Photograph 3 – Creating Artificial Storm

Photograph 4 – Creating Artificial Storm, taken at high-flow bypass manhole.

Photograph 5 – Ponding due to plugged storm grate.

Photograph 6 – Inlet pipe to Train No. 1, flow-split manhole.

Photograph 7 – Inlet pipes to Train Nos. 2 and 3, flow-split manhole.



Photograph 8 – Effluent sampling apparatus

APPENDIX B
SEPTEMBER 2001 MONITORING EVENT
CHEMICAL AND BIOASSAY LABORATORY REPORT
(Not included in electronic deliverable)

APPENDIX C
SEPTEMBER 2001 MONITORING EVENT BIOASSAY TEST OF DECHLORINATED SAMPLE

AMEC Earth and Environmental
San Diego Bioassay Laboratory
AMEC Test Nos.: 0108-126 (Internal test)

SUMMARY REPORT
Results Prepared: 12 September 2001
Sample ID: NASSCO Storm Study Pre-Test Blank

Sample Information

Sample Date:	27-Aug-01
Sample Time:	approx. 1400
Sample Receipt Date at Laboratory:	28-Aug-01
Test Material Matrix:	Liquid
Sampling Method:	Grab
Sample Containers:	4-liter poly cubitainers

Toxicity Testing Specifications

Test Series Initiation Date:	28-Aug-01
Test Series Termination Date:	1-Sep-01
Test Organism:	*Mysidopsis bahia*
Test Organism Source:	Aquatic Biosystems
Acute Organism Age:	4 days
Dilution Water:	Natural Scripps Seawater
Test Concentrations:	100% test material; Laboratory and salt controls
Protocol Used:	EPA 1991 (Acute)
Statistical Analysis Software:	TOXCALC, version 5.0

Mysid Toxicity Testing Results Summary

Test Exposure	Acute 96-hr Percent Survival	Acute TU Value
Laboratory Control	100	
Artificial Salt Control	95	
100% Test Material	100	<1.0

Summary Results of Chemical Analyses

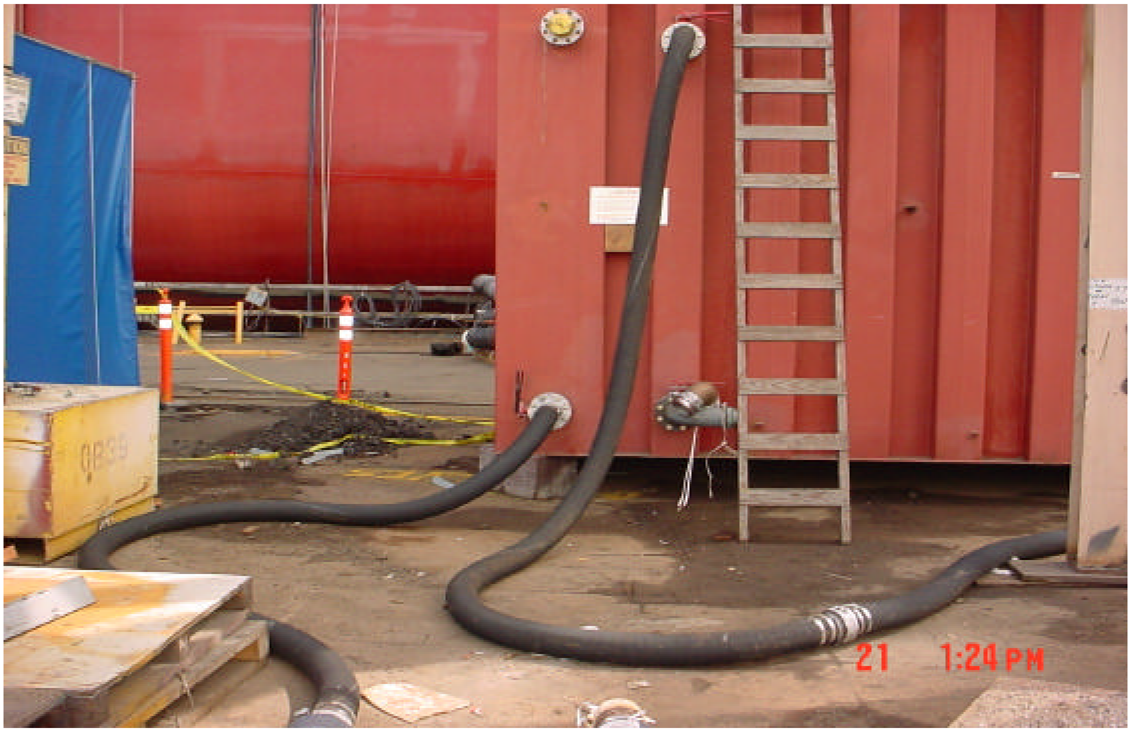
Analyte	Sample Result	Reporting Limit	Units
Total Chlorine	1.69	0.01	mg/L (ppm)
Free Chlorine	0.31	0.01	mg/L (ppm)
Final Free Chlorine (post-dechlorination)	0.01	0.01	mg/L (ppm)

Results Verification/Date:

APPENDIX D
MARCH 2002 MONITORING EVENT PHOTOGRAPHS

Photograph 1 – Discharge pipes from Flow Splitter to Treatment Train Nos. 1 and 2.

Photograph 2 – Discharge pipes from Flow Splitter to Treatment Train Nos. 1 and 2.



Photograph 3 – Baker Tank.

Photograph 4 – Sampling from effluent manhole.

Photograph 5 – Discharge from Baker Tank.

Photograph 6 – Discharge flow into storm grate.

Photograph 7 – Effluent Flow into Pump Station.

Photograph 8 – Effluent Flow into Pump Station.

Photograph 9 – Collection of second set of samples.

APPENDIX E
MARCH 2002 MONITORING EVENT CHEMICAL AND BIOASSAY LABORATORY REPORT
(Not included in electronic deliverable)

APPENDIX F
APRIL 2002 MONITORING EVENT CHEMICAL AND BIOASSAY LABORATORY REPORT
(Not included in electronic deliverable)