In-Line Ditch Stormwater Treatment BMP Program

Final Report

December 2011

King County
Department of Transportation
Road Services Division
Roads Maintenance Section

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Stormwater Management
Implementation Grant Program

Grant Number G0900039

King County Department of Transportation
Roads Services Division
Road Maintenance Section
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Renton, Washington 98056

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In-Line Ditch Stormwater Treatment BMP Program Conducted Under the Stormwater Management Implementation Grant Program

Grant Number: G0900039

Products and Vendors

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Prepared by:

King County
Department of Transportation
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1.0. EXECUTIVE SUMMARY

The King County Roads Maintenance Section (KCRMS) is responsible for maintaining an extensive road network and the stormwater drainage system associated with those roads. A significant portion of that drainage system includes drainage ditches located within the road right-of-way. Stormwater pollution and treatment has become a significant maintenance and environmental issue for municipalities across western Washington, including King County. For this reason, KCRMS sought grant funding in 2008 to develop and evaluate stormwater treatment Best Management Practices (BMPs) that could be placed in roadside ditches to supplement, or possibly replace, more traditional roadside stormwater treatment methods such as stormwater ponds. The grant funding was provided by the Washington State Department of Ecology (Ecology).

This study, implemented in southeast King County, Washington in Puget Lowland eco-region, explores the use of ditch BMPs to promote storage, treatment and infiltration of stormwater within the existing ditch network. The BMPs were designed to function within the constraints of road engineering and safety standards while incurring the lowest possible installation and maintenance costs. Ditch BMPs were designed to provide stormwater treatment and/or flow control benefits for low to moderate intensity precipitation events, while maintaining ditch capacity and allowing conveyance of peak winter flows to minimize the risk of localized flooding.

Each BMP comprised a treatment cell encapsulated by a modified rock check dam placed in a roadside ditch. The treatment cell contained either compost or sand, depending on whether it was intended to provide water quality or flow control benefits, respectively. The rock check dam was designed to provide the armoring necessary to protect the treatment cell during peak winter flows. Together, the treatment cell and rock check dam were designed to: decrease storm flow energy and volume via ponding and infiltration; and, improve water quality via settling, adsorption and filtration.

During water years 2010 and 2011, BMPs were installed in series at a total of eight project sites (four per year). A screening process was used to generate an initial list of 21 potential project sites., The screening process assessed sites for soil type, gradient class, drainage basin characteristics and apparent hydrology. Sites with very low gradient, suspected groundwater influence, lack of hydrological indicators, or the presence of potential critical areas (streams or wetlands) were rejected. Further field review of the remaining sites, with particular focus on visual observations of dry season flow response, led to the selection of the 2010 study sites. Selection of the 2011 project sites was aided by information gained through monitoring and experiences with the first set of sites. The need to be able to successfully measure flows and collect flow-weighted composite storm samples led to a bias toward sites that were thought to be conducive to these activities, especially in regards to dry season storm flow.

To determine BMP effectiveness, stormwater monitoring was conducted upstream and downstream of the BMPs at each project site according to the project-specific Quality Assurance Project Plan (QAPP) (KCRMS 2011) prepared at the beginning of this study. Specifically, effectiveness of Water Quality BMPs was evaluated through measurement of storm flow and laboratory analyses of storm samples collected as flow-weighted composite samples and/or grab samples. Composite samples were analyzed for total suspended solids (TSS), total and dissolved metals, nitrate-nitrite nitrogen, total Kjeldahl nitrogen (TKN), orthophosphate and total phosphorus, and polycyclic aromatic hydrocarbons (PAH). Additionally, grab samples were collected during the 2010 studies for measurement of total petroleum hydrocarbons and fecal coliforms. Measurements of field parameters (dissolved oxygen (DO), pH, conductivity, temperature and turbidity) were also conducted. The project QAPP was revised for the 2011 monitoring to reflect changes in the monitoring program based on findings from the 2010 water year monitoring. The monitoring program is detailed in Section 6 Monitoring.

All parameters were monitored as before/after sample pairs through collection of matching upstream (stormwater influent) and downstream (stormwater effluent) sample pairs. BMP effectiveness therefore could only be evaluated if both the upstream and downstream parameters were successfully collected during the same storm event. Storms were sampled with a goal of comparing analytical results from twelve storms for each analytic parameter. This goal was achieved at three of the four water quality BMP project sites. Only eleven storms were analyzed at the fourth project.

Monitoring of ditch stormwater was done in accordance with storm suitability criteria specified in the project QAPP which required the use of forecasted rainfall amounts to predict storm flow responses at each ditch site. The stormwater monitoring criteria closely followed criteria defined in the county's NPDES Phase 1 Municipal Stormwater Permit, Section S8 – Monitoring (Ecology, 2007). Different storm suitability criteria were required for wet-season (October 1^{st} through April 30^{th}) and dry-season (May 1^{st} through September 30^{th}) sampling. Qualifying wet season storms were preceded by no more than 0.02 inches of rainfall in a 24 hour period. Dry season storms were preceded by a 72 hour dry period. All storms were also required to have less than a 6 hour intra-storm dry period. Storm sampling criteria for this study differed from the permit criteria in that no minimum rainfall amount was required; instead, this study only required that the storm produce enough storm flow to collect a sample with a minimum of 12 sampling aliquots for the composite sample. Sampling was biased toward wet season storms, typically experiencing higher flows. Most sampled storms produced flow that overtopped the BMPs, exceeding the maximum flow design capacity of BMPs which were targeted at treating low flows. This may have masked some of the treatment capacity of the BMPs that could be achieved during low volume storms and so the results obtained in this study may understate the treatment effectiveness of the BMPs.

Flow Control BMPs were monitored continuously for water flow for the duration of each project. Flow measurements were collected as matching upstream and downstream data sets to see the effects of the Flow Control BMPs on storm flow in the project site ditches.

Water Quality BMP Effectiveness

Beneficial water quality changes were identified through the monitoring program at one or more project sites: statistically significant reductions were observed in TSS, TKN, total metals arsenic, chromium, copper, lead, nickel, zinc; dissolved metals copper lead and zinc, PAHs, and turbidity. Hardness increased after treatment at two project sites (Projects 148 and 136); increased hardness is considered to be a water quality benefit. Results are presented in detail in Section 7 of this report.

Test results varied among the selected project sites, and the variance between tests at some sites was greater than others. Outliers (values greater than 1.5 times the inter-quartile range of the data set) are present in most data sets; outliers add to the skew of the data set. The variability of the data and presence of outliers is likely due to uncontrollable variables inherent in testing BMPs in existing ditches, moving project sites to different locations and watersheds (as opposed to testing different BMP designs in a single ditch), and the intrinsic difficulties in collecting flow-weighted composite samples based on forecasted rainfall amounts with variations in storm volume, intensity and duration, and a wide range of antecedent conditions. Other parameters that contribute to variability include soil saturation, organic and inorganic debris, vegetation and multiple storm flow input routes, just to name a few.

Despite the variance in results, beneficial treatment effects for most parameters were seen at multiple project sites with the exception of Project 136. At Project 136 most parameters including TSS, metals, organics, and nitrogen were found to be higher in BMP effluent samples. Reasons for the downstream increase include:

- Flow – Downstream effluent flow at Project 136 was almost always higher than upstream influent flow, even in the dry season. The higher flow is thought to be due to a high contribution of interflow from the yard located along the ditch in addition to sheet flow contributions from the roadway surface entering the ditch between the monitoring flumes. However, the flow was consistently higher downstream between storm events even when no sheet flow was present, indicating a watershed/groundwater contribution to ditch flow between the two monitoring stations. It should be noted that all the BMP projects measured higher wet-season flow at the downstream effluent locations while still showing reductions in some pollutant water quality parameters.

- Monitoring Design – The upstream monitoring location was selected at the outflow of a catch basin. This not an unusual situation for a roadside ditch; this catch basin routed stormwater from three upstream ditch sections into the project ditch and received and routed direct overland storm flow into the ditch. However the catch basin also worked as a treatment device itself to settle solids (and their associated pollutants) in the sump that might otherwise have been transported into the ditch.

These specific features at Project 136 may have masked some of the beneficial effects of the BMPs that were observed at the other three water quality BMP project sites.

Flow Control BMP Effectiveness

Flow control benefits included fairly uniform reductions in dry season flows that were observed at all Flow Control BMP project sites, suggesting that the BMPs were storing water and/or promoting infiltration during dry season rain events. The BMPs were designed to withstand high wet season flows that were expected to overtop (bypass) the BMPs without doing damage; wet season flows were typically higher in the effluent than in influent due to watershed inputs along the length of the BMP projects. However, the BMPs also functioned to pool storm flow in the ditch and reduce the scouring energy of both wet and dry season flows. This feature makes these BMP designs a suitable alternative for treating scoured ditch sites with high flows.

The monitoring results show that the water quality BMP designs can be effective in attenuating dry seasons flows and reducing suspended solids (measured as TSS or turbidity), along with associated chemical pollutants (total metals and PAH). These BMPs may function better in some ditches than in others. To maximize effectiveness of these BMPs, an understanding of the pollutants present and the treatment needs of a particular ditch should be evaluated before placement of this type of BMP. For example, the BMPs reduced TSS at project sites where upstream scour and, therefore, a source of turbidity, is present.

The monitoring results show that the Flow Control BMPs should be considered for ditch sites where there is a desire to attenuate dry season low flows. They should also be considered for ditches that have high flows or that are scoured to reduce the energy, and hence the erosion potential of high storm flows in those ditches. The flow control BMPs store and pond water, increasing the likelihood that sediment will also be retained by the BMPs. This suggests that these BMPs may also have water quality benefits by detaining pollutants attached to sediment particles. Flow control projects were not evaluated for water quality benefits beyond some monitoring of turbidity at one project site. These preliminary results support the hypothesis that water quality benefits may also accrue at flow control BMP sites.

Further study would be beneficial in determining the applicability of these BMPs for widespread installation. These ditch studies focused on treating sections of ditches with little prior knowledge of pollutant loads and/or storm flow hydrology. Sampling and testing of storm flow in ditches for pollutants prior to BMP installation would increase the certainty that the BMPs would achieve their objectives by targeting ditches that carry a pollutant load that could be effectively addressed by these types of BMPs.

Additional studies that could help determine applicability of these BMPs might include:

- The study results suggest that BMP effectiveness could be increased by extending the BMPs through a longer length of the ditch. This needs to be tested and verified.

- Evaluating the use of these BMPs to treat problem ditches that have obvious signs of scour or turbidity.

- Comparing results of these BMP treatments to the treatment effects of well maintained, fully vegetated ditches might demonstrate the value of retaining vegetation within the ditch as a BMP.

- Extending the study to evaluate the effects of ditch stormwater BMPs on receiving waters. This study focused on treating very short sections of ditch using varying numbers of BMP check dams. There is an active interest in installing and testing the effects of BMP installation in entire ditch networks throughout a watershed.

- Extending the study to evaluate BMP effectiveness over time and/or to determine maintenance needs for optimal BMP performance.

2.0. INTRODUCTION

The King County Department of Transportation (KCDOT) maintains an extensive road network and the stormwater drainage system associated with those roads. A significant portion of that drainage system includes drainage ditches located within the road right-of-way that are designed to collect and convey stormwater away from roadways. These drainage ditches also often provide drainage for stormwater runoff originating from properties adjacent to the road right-of-way. It is in King County's interest to manage the stormwater runoff conveyed in its ditches to protect natural resources, infrastructure and to comply with applicable regulatory requirements. Two key components of stormwater management are pollutant treatment and flow control. Stormwater treatment focuses on removal of pollutants that may be picked up by stormwater as it flows over pollution generating surfaces. Flow control seeks to detain storm flow, and minimize erosion within the ditch. Flow control also seeks to promote infiltration to help maintain ground water levels that may contribute to stream base flow in the dry season.

Traditional stormwater management has often relied on the design, installation and operation of stormwater treatment and flow control devices such as stormwater ponds and vaults. These approaches can be very effective at addressing treatment and flow control requirements in recently developed areas. However, they can be resource-intensive, occupy large areas, generally require significant changes to infrastructure and often are absent in older developed areas. They may also require the acquisition of property on which to site the structures. These limitations led King County to consider alternatives to traditional stormwater management approaches. In 2008, the King County Roads Maintenance Section (KCRMS) sought grant funding through the Washington Department of Ecology (Ecology) Stormwater Implementation Grant Program to assist in funding a study to develop affordable and effective Best Management Practice (BMP) designs to address stormwater runoff issues within existing roadside ditches. This report presents the results of this study including the BMP designs, installation process and costs, monitoring of field parameters and storm flow monitoring, and the treatment effects observed through analysis of influent and effluent stormwater samples,. Although the BMPs were designed to require minimal maintenance, the period of this report was insufficient to completely evaluate the maintenance costs of these BMPs.

This study focused on developing and testing in-line ditch stormwater treatment and flow control BMP designs intended to be simple, low-cost, and low-maintenance. The BMPs are intended to reduce or remove water quality contaminants, and attenuate and/or infiltrate storm flows. They were designed to fit within existing roadside ditches, requiring no additional land acquisition or impacts to adjacent lands. The designs are intended to be easily modified to conditions such as soil type, ditch gradient, flow regime, and pollutant type(s). The intent is that by providing research on low cost designs, installation, and maintenance of the these BMPs that this will encourage other public and private entities to retrofit multiple areas, treating stormwater locally and creating an aggregate regional decrease in pollutant and water quantity impacts from roadside ditch discharges.

The BMPs designed and tested during this study were intended to capture small storm events and "first flush" conditions from larger events primarily through detention, provide treatment via settling, adsorption and filtration, and increase opportunities for infiltration of stormwater.. BMPs were evaluated by doing paired studies of stormwater influent and effluent with analysis of stormwater samples, collection of field parameters and storm flow monitoring. To preserve the flood protection function of a ditch – allowing high storm flows to pass downstream – it was also important that the BMPs not compromise the capacity of the ditch, nor be damaged by high storm flows

This report presents the results of studies conducted at eight BMP projects sites undertaken by KCRMS to address two separate stormwater management objectives:

1. Water Quality Treatment BMPs: Four BMP projects were completed to design, install and test BMPs placed in roadside ditches to improve water quality in roadside ditch stormwater runoff.

2. Flow Control BMPs: Four BMP projects were completed to design, install and test BMPs placed in roadside ditches to provide hydrologic control for roadside ditch stormwater runoff, to help detain small storms and to promote infiltration.

3.0. GOALS AND OBJECTIVES

The goals and objectives of this study include:

- Development, installation and testing of low-cost BMP designs intended to provide a measurable level of stormwater treatment to either reduce pollutant loads or attenuate storm peak hydrographs within existing roadside ditches.

- Generation of a set of stormwater monitoring data consisting of analytical results and storm flow data that have been subject to quality assurance reviews suitable for comparison of stormwater quality and storm hydrographs upstream and downstream of each BMP. The criteria for collecting and reviewing these data are presented in the QAPP.

- Evaluation of the level of effort and costs required to design, install and maintain the BMPs.

- Provide the results of this study to the community through reports, journal articles and group presentations.

4.0. BMP PROJECTS

4.1 Conceptual Designs

Conceptual BMP designs that described the general BMP treatment concept of focusing water quality and flow control treatment within existing roadside ditches were prepared by KCRMS and presented as part of the project grant proposal. These designs borrowed from low-impact development (LID) methods providing a filter medium for treating stormwater pollutants and in-ditch detention methods to address flow control and encourage infiltration of storm flow.

4.2 Site Selection

The goal of the site selection process was to identify potential stormwater dominated ditch study sites where BMPs could be placed and evaluated. There was interest in selecting ditches representing different environmental conditions, pollutant loads and flow regimes. Information about actual pollutant loads in the ditches was limited to superficial knowledge of site conditions – general information about the land use, traffic density, observations of direct road runoff with little shoulder available for treating sheet flow from the roadway, and observations of scour in the ditch. A screening process was developed to include reviews of road, topographic and soils maps, critical areas maps, information from Roads Maintenance crews and field site visits. A checklist was developed to screen and rank potential sites. The selected ditches would need to carry flow in response to storm events well into the dry season. The selected sites were biased towards locations that were thought to carry storm flow at a volume that could be sampled well into the dry season and that were suitable for the long-term installation of monitoring equipment. Ditch sites were rejected if they appeared to have groundwater influence or might be classified as streams. The sites needed enough slope so that the storm flow would not stagnate or become a mosquito nuisance. This process generated a total of 21 potential sites; further screening for permit and engineering /safety constraints resulted in five potential sites being available for the first year study. This review process continued into the second year, with site selection being further informed by experience gained during the first year.

4.3 Water Quality BMP Project Sites

Project locations, installation dates monitoring time frame and project identifiers used in this report are presented in Table 1. Project locations are also mapped as shown in Figure 1. Projects 148 and 136 were installed in June 2009. Information gained during this study led to modifications of the BMP designs for the 2011 water year projects (Projects 192 and OP). The 192 and OP projects were installed late in the dry season of 2010.

Project 148

Project 148 is located in a ditch running along the east shoulder of 148th Ave SE (Figures 2 and 3), a collector – arterial road just south of SE 102 St as shown in Figure 2. The ditch drains an area north of SR 900 and east of 148th Ave SE that is dominated by rural residential properties. The road is crowned, has a with very limited shoulder and stormwater flows directly from the road surface into the ditch. The ditch flows to the north, draining to May Creek. The roadway has a moderate average daily traffic (ADT) volume of approximately 2,000 vehicles and has narrow shoulders on the ditch side of the road. Three water quality BMPs were installed in the spring of 2009 for monitoring during the 2010 water year.

Project 136

Project 136 is located along the north shoulder of SE 136th St, just west of 170th St SE (Figures 4 and 5). This ditch follows the north shoulder of SE 136th St draining an area of neighborhood to the north and east dominated by residential developments at 4 residences per acre. An elementary school is located north of the watershed; a high school is adjacent to the project at SE 136th St and 169th Ave SE. Flow continues north-east through a neighborhood drainage system. SE 136th St is a local road with a moderate average daily traffic (ADT) volume of approximately 1,520 vehicles and is busy with morning and early afternoon school traffic. Four water-quality treatment BMPs were installed in the early summer of 2009 and monitored during the 2010 water year.

Project 192

The Project 192 is located along the south shoulder of Petrovitsky Rd, from a culvert near 17201 SE Petrovitsky Rd downstream to SE 192 Dr (Figure 6). This ditch starts near SE 184th St and flows to the east draining forested land from the Lake Youngs watershed, rural residential properties along the west side of Petrovitsky Rd and direct runoff from the roadway. The ditch drains to Shady Lake downstream of the BMP project. Petrovitsky Rd is a major arterial with a relatively high average daily traffic (ADT) volume of approximately 8,200 vehicles. Six water quality BMPs were installed in late summer of 2010 and monitored during the 2011 water year.

Project OP

Project OP is located along the south shoulder of Petrovitsky Rd just east of the intersection of Petrovitsky Rd and Old Petrovitsky Rd (Figure 7). The ditch flows to the north and receives drainage from Petrovitsky Rd and catch basins along 162 Pl SE that are tiled under Petrovitsky Rd. The watershed along162 Pl SE includes high density residential areas and an elementary school with a storm pond. Petrovitsky Rd is a major arterial with a relatively high average daily traffic (ADT) volume of approximately 8,200 vehicles. Thirteen water quality BMPs were installed in late summer 2010 and monitored during the 2011 water year. This section of ditch was cleaned to native soil just prior to placement of the BMPs.

4.4 Flow Control BMP Project Sites

Project locations, installation dates monitoring time frame and project identifiers used in this report are presented in Table 2. Project locations are also mapped as shown in Figure 1. Four flow control BMP projects were designed, installed and monitored by KCRMS during this study.

Project PET

Project PET was located along the south shoulder of Petrovitsky Rd, across from SE 192 Dr. (Figure 6). This ditch starts near SE184th St and flows to the east, draining forested land from the Lake Youngs watershed, rural residential properties along the west side of Petrovitsky Rd and direct runoff from the roadway. The ditch drains to Shady Lake, downstream from the BMP project. Petrovitsky Rd is a major arterial with a relatively high average daily traffic (ADT) volume of approximately 8,200 vehicles. Five flow control BMPs were installed during the summer of 2009 and monitored during the 2010 water year.

Project 192DN

The 2011 flow control project, Project 192DN was located in the same reach of ditch along the south shoulder of Petrovitsky Rd as the 2010 PET flow control project (Figure 6). Project 192DN consisted of six BMPs that included the five BMPs placed for Project PET with an additional BMP placed between the upstream BMP and the upstream monitoring station. Project 192DN was also located directly downstream from the Project 192 water quality BMP project allowing for a comparison of flow attenuation between the two projects. A conceptual design showing placement of these projects is presented in Figure 8.

Project 276

Project 276 was located along the west shoulder of 276th Ave SE just north of SE 213 St (Figure 9). This ditch starts near SE 216th St and collects runoff from rural residential properties and the paved roadway. The ditch eventually drains to a stream that crosses 276th Ave SE just north of SE 208th St, flowing west toward Issaquah Creek. 276th Ave SE has a relatively high daily traffic volume (ADTV) of approximately 12,700 vehicles. Ten flow control BMPs were placed in July 2009.

Project 276DN

Project 276DN was located along 276th Ave SE just downstream from Project 276 as shown in a conceptual drawing (Figure 10). Thirteen BMPs were placed in December 2010 and monitored for the remainder of the 2011 water year. Placement of Project 276DN just below Project 276 allowed for a second year of monitoring at Project 276 and a direct comparison of low attenuation between the upstream and downstream project.

5.0. ENGINEERING

5.1 Hydrologic Analysis

Each BMP project site was evaluated by the King County Roads Design Unit (KCRDU) for stormwater capacity and to ensure that the 25 year discharge did not exceed the ditch capacity with the BMPs in place. This evaluation included a survey of the selected ditch section, delineation of the watershed boundary, review of soils maps, modeling using KCRTS hydrologic software and completion of hydraulic calculations. Once the peak storm flow for each ditch site was calculated, the water surface elevation in the ditch with the BMP in place was determined through a broad-crested weir calculation. Results from the engineering evaluation for each site are presented in Table 3 (water quality BMP projects) and Table 4 (flow control BMP projects).

5.2 Engineering Designs

Plan drawings for the BMPs can be found in Appendix D.

5.2.1 Water Quality BMP Design

Water Quality BMP structures are based on a rock check dam design, modified with the addition of an internal “treatment cell”. Commercially available coarse compost (100% passes through a 3” sieve, maximum particle length of 6 inches, tested in accordance with TMECC test method 02-02-B) was purchased from Cedar Grove Composting[1] and was used as the treatment medium. The compost was mixed by hand with washed gravel at a 2:1 compost to gravel ratio at the project site to increase porosity.

The first year water quality projects (Projects 148 and 136) BMP design plans specified the following:

- A rock check dam structure built from mix of two to four inch and four-to-eight inch crushed rock. BMPs were designed to minimize the erosive effects of flows that were expected to routinely overtop the completed structures. The resulting structures were designed and installed to withstand high winter flows that could otherwise damage both the structure and the ditch.

- An energy dissipation feature was added on the downstream end of each BMP structure consisting of a shallow pit, two feet by four feet and one foot deep filled to the invert level of the ditch with the crushed rock mix. The pit was lined with erosion control fabric prior to placement of the rock.

[1] Cedar Grove Composting, Maple Valley, Washington

- The upstream and downstream check dam slopes are 3H: 1V to conform to road safety design standards and to further minimize erosion from plunging flow.
- The maximum height of the check dam at its crest is one foot, to ensure that the residual water depth does not exceed road safety design standards (two foot maximum depth).
- The compost treatment cell was hand constructed: the mixed rock was placed into the ditch and formed into the check dam shape with a two foot gap in the middle for placement of compost. The gap was lined with erosion control fabric that extended to the upstream and downstream ends of the BMP and filled with coarse compost/washed gravel mix. The ends of the fabric were used to wrap the top of the compost cell and secured with additional rock.

Second year study designs (Projects OP and 192) focused on improving the efficiency of BMP installation through the use of pre-formed compost filled socks that could be purchased commercially, along with minor improvements to the BMP design.

BMPs for the second year of study incorporated the following changes:

- The compost treatment cell for each BMP was purchased as a pre-made “sock” from a commercial vendor, and washed gravel was not included in the compost mix. Applied Organics[2] was selected as the local vendor of Filtrexx®[3] compost socks. The socks used the same grade of coarse compost but were prepared by the vender by blowing the compost into pre-cut lengths of a high-porosity filter fabric sock. The socks can be cut to length as needed. This project specified twelve inch diameter socks six to eight feet in length[4]. The socks were placed so that the ends of the sock were higher on the ditch walls than the expected elevation of the 25 year recurrence storm flows.

- The downstream energy dissipation pad was eliminated from the BMP design. Field review of the first year BMPs showed that the downstream ramp on the check dam was sufficient to dissipate the scouring energy of flows over-topping the BMP, thereby negating the need for an erosion control pad. Eliminating the pad reduced the amount of excavation, reducing costs and saving installation time without affecting BMP performance. Erosion control fabric was pre-placed under the entire length of each planned BMP structure to prevent erosion in the ditch.

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[2] Applied Organics, Redmond, Washington
[3] Filtrexx International, LLC, Grafton, Ohio
[4] The project team, working with the maintenance crew doing the installation elected to have socks prefabricated, filled with treatment medium and delivered to KCRMS. Socks were requested in both six foot and eight foot lengths to fit the expected width of the ditches.

- The socks were placed directly onto the center of the erosion control fabric and staked into place. The socks were moved from a flat-bed trailer to the ditch using choker chains attached to the arm of an excavator and the rock check dam was then constructed around the socks.

- A two layer system of crushed rock was used to form the check dam. The lower layer was composed of two and a half inch minus crushed rock topped with an armor layer of more porous two to four inch rock. The rock layers sandwiched the treatment cell on the upstream and downstream aspects. The armor layer was designed to be stable to at least the 25 year recurrence discharge. Both courses of rock were applied using an excavator and worked into place by hand.

- The upstream and downstream check dam slopes are 3H:1V to conform to road safety design standards and to further minimize erosion from plunging flow.

- The maximum height of the check dam's weir is one foot, to ensure that the residual water depth does not exceed road safety design standards (two foot maximum depth).

- For Project OP, a single 12-inch compost sock was used in each BMP. For the Project 192 two 12-inch socks were deployed, one directly on top of the other and then staked together to increase the height of the compost treatment media in each BMP.

5.2.2. Flow Control BMP Design

The first year flow control projects (Projects PET and 276) BMP design plans used a similar rock check design but placed sand instead of compost in the fabric-wrapped treatment cell.

The second year flow control project designs (Project 276DN) and 192DN) intended to increase construction efficiency by using the compost socks instead of sand wrapped in fabric. Twelve inch socks were used with two stacked one on-top of the other and staked. The check dam was finished using layers of 2 inch minus rock around the base of the socks and 4 to 8 inch rock providing the protective outer ramps of the check dam.

Initial concerns regarding placement of roadside ditch BMPs were as follows:

- Would the structures survive the high winter storm flows intact?

- Would the BMPs contribute to flooding?

- Would the BMPs degrade the ditch by increasing scouring flows downstream of the BMPs?

- Would the BMPs result in damage to the roadway?

- Would there be a measurable treatment effect from BMP monitoring?

The BMPs passed all of these tests, with the exception that Project 136 demonstrated only very limited water quality improvements. The initial designs were reviewed for the 2011 water year projects with a focus on creating an easier BMP installation and addressing some design issues.

The second year flow control BMP projects sought to build on the first year monitoring results and to incorporate economies by installing these BMPs adjacent other projects. The 192DN flow control study incorporated the existing BMPs from the first year flow control study with the addition of one new BMP. This flow control project was located just downstream from the newly installed Project 192 water quality BMP study site. This allowed for monitoring flow at three points – upstream and downstream at the 192 water quality projects; and upstream and downstream of the 192DN flow control project with a comparison of the flow attenuation effects of twelve BMPs between the 192 upstream and 192DN monitoring points (Figure 1).

The 276DN project installed 13 new BMPs using the compost sock design directly downstream from the first year (2010 water year) 276 study. Flow monitoring was done at the original upstream station, a mid-point station that represented the downstream end of the 2010 study and the upstream end of the 2011 water year study and downstream from the thirteen newly installed BMPs (Figure 2).

5.3 BMP Costs

5.3.1 Direct Installation Costs

Installation costs for the water quality and flow control BMP projects are presented in Table 5. The eight projects (four water quality and four flow control projects) consisted of between three and thirteen individual BMPs, treating 100 feet to 400 feet of ditch. Costs for installing the BMPs were well within the initial target cost estimate of $5,000 to $10,000 per BMP project, with the focus on producing a design that would be cost effective, simple to install and maintain and produce measureable water quality or flow control improvements. Total costs for BMP installation at each project ranged from approximately $3,000 to $7,500. The average cost for a single water quality BMP structure was just under $900; the average cost for a flow control structure was $500. The BMP cost, averaged among all projects was $700 per BMP. The most significant driver of variation in costs was the number of BMPs placed wherein the larger projects cost more to install. However, due to fairly fixed mobilization costs, the cost per BMP decreased as the number of BMPs installed increased. Projects with up to six BMPs (148, 136 and 192) were installed in a single day; projects with ten and thirteen BMPs required under a day and a half to complete. The OP water quality BMP project and the 276DN flow control project required installation of the largest number of BMPs at 13 placed for each project. The average BMP cost for these two projects was $587 and $460 respectively.

These costs assume the ditch to be treated is currently meeting road design standards – that the ditch will not require cleaning before placement of BMPs. If the ditch does require cleaning there would be an additional cost for that aspect of the project. However, ditch cleaning would be done by the same equipment and crew as required for the BMP installation, and so additional costs could be minimized. The designs are not complicated; the intent is that once a ditch site has been evaluated for permits, hydrological analysis and design specifics (number and location of each BMP structure), an experienced municipal construction crew should be capable of installing these BMPs with minimal guidance and supervision.

5.3.2 Crew and Equipment

All BMP projects were installed by King County Road Maintenance crews. Each BMP project required an excavator for soil removal and placement of rock, dump trucks for material import and export, utility workers to manually place fabric, create or adjust the rock BMP structure, and flaggers for traffic control and safety.

5.3.3 BMP Materials

BMP construction materials included:

- **Erosion Control Cloth:** Non-woven filter fabric (Geotex 801 Non-woven, purchased as an equivalent to Amoco non-woven #4553 filter fabric) was cut into strips wide and long enough to completely underlie the finished BMP. The fabric was purchased in bulk (15 x 300 feet) and cut into sheets by the utility workers to fit the individual site conditions. The sheets were approximately 3 feet wide by 8 to 10 feet long.
- **Crushed Ledge Rock:**
    - **4 to 8 inch rock** (with or without a mix of 2 to 4 inch rock) up to 1 yard per BMP
    - **2 inch minus rock** up to 0.5 yards per BMP
- **Compost:**
    - First year projects**:** These projects used coarse compost purchased in bulk from Cedar Grove Composting. About a yard was purchased for each BMP. The compost was mixed with washed gravel at a 2 to 1 mix, placed into the BMP using hand tools and wrapped with an erosion control cloth wrapping.
    - Second year projects: These projects used twelve inch diameter Filtrexx® compost socks prepared by Applied Organics of Redmond, Washington. The socks were filled with coarse compost from Cedar Grove Composting; the added porosity intended by the addition of gravel was thought to be minimal and no washed gravel was used in the second year socks. The socks for both the 192 and OP projects were pre-seeded with an erosion grass mix. The socks used at Project 192 included a patented Filtrexx® metals treatment medium.
    - The vendor delivered pre-filled compost socks to the KCRMS maintenance facility in Renton where they were stored for a short period and later taken to the installation site by King County crews. The crews installed the socks at each ditch site location using a choker attached to the bucket of the excavator. The vendor can also fill the socks with compost directly on site.
    - Wooden stakes were used to secure the compost socks in place. Three stakes; one at each end and one in the middle of the sock were used.

5.4 Maintenance

5.4.1 Maintenance Costs

The in-line ditch BMPs are intended to function with minimal maintenance requirements. The primary construction materials are simple: crushed ledge rock that was sized to withstand high winter flows and protect the internal treatment medium. The compost socks were seen as an improvement over the hand-built treatment cells both in creation of the BMP and as an easier item for future replacement. Replacement of the treatment cell would require a backhoe to remove either the sock or compost, and place a new sock in the BMP structure (socks could also be filled with compost on site by the vendor). A utility worker would be required to move and reform the rock check-dam structure. Maintenance issues to date at the BMP project sites have been minimal, requiring only minor repairs to the structure of the rock check dams that form the BMPs and contain the treatment media.

Costs for completely replacing or removing the BMP structures would be similar to the installation costs, requiring an excavator or backhoe to remove the BMP and install a replacement structure. Material costs would be lower, assuming that the existing rock for the check dam could be re-used.

The life-span of this monitoring project has been insufficient to determine the life-time effectiveness of the filter media. However, much of the treatment effects of the BMPs come from reducing the energy of untreated storm flow and so some benefits are expected to continue even after the filtration capacity of the BMP is exhausted

5.4.2 Maintenance Plan

The following recommendations for maintenance of the in-line ditch BMPs are based on observations of the BMPs during the time period of this study. This operation time was insufficient to completely assess the lifespan and full maintenance requirements of these structures.

Recommended annual assessment of BMP project sites:

- Integrity of the BMP structure:
    - Rock check dam structure is intact according to its original design elements and the treatment cell is still present and protected.
    - Visual inspection of the treatment cell to determine if the cell (filter fabric and/or compost sock) is still intact. This may require temporarily moving and replacing some of the rock structure by hand.

    - Treatment cells found to be damaged (compost or other media exposed and/or lost from the BMP) or occluded by sediment should be uncovered and replaced.

- Sediment loading in the BMP forbay:

    - Sediment buildup in excess of approximately one-third of the height of the BMP should be removed.

- Condition of the ditch: The ditch should be inspected for scour, erosion or undercutting that could result from high flows overtopping the BMPs.

- Other concerns in the ditch: Excessive debris, e.g., wind-blow debris such as tree limbs and excessive leaves should be removed as soon as they are reported.

- Vegetation Management:

    - Ditch vegetation can be mowed using roadside mowing equipment provided the operators are aware of the rock BMP structures in the ditch. Coordination with maintenance staff or installation of warning signs may be necessary. Alternatively, hand mowing by utility workers may appropriate. During the first year studies the project sites were hand-mowed by crews using weed-eaters. During the second year studies the ditches were allowed to be mowed by mechanical mowers that were able to work around the BMPs.

Sediment removal at the project BMP sites has been unnecessary to date. Due to the fairly small volume of the BMP forebay, a vacuum flush truck (eductor truck) is recommended for sediment removal

Maintenance issues identified during field inspections for this project recommended some additional rock to be added to two check dams at Project 192 where the rock had been moved by the high winter flows. This site has compost socks; the socks were still intact. The BMPs did not require sediment removal by the end of the monitoring period.

5.5 Design and Permitting Considerations

Permitting review should include a field visit and site evaluation by the permit specialist. Basic surveying is required to establish the ditch profile and cross-section(s). Design aspects, including hydrological analysis, should require about a day’s time for a qualified engineer unless a higher level of design plan is deemed necessary by the engineer. These permitting and design considerations should be part of any road drainage project that includes grading or filling activities and are not exclusive to BMP installation. The level of effort in completing these preconstruction elements will vary slightly with the site and the length of ditch targeted for treatment.

5.5.1 Permitting Considerations

Prior to installing BMPs the project sites should be assessed for permit requirements or constraints, including the following: identification and avoidance of critical areas (streams and wetlands); determination of whether or not Army Corps of Engineers permits would be required for placement of fill in waters of the USA; completion of a cultural resources screening and archeological review; compliance with Road Safety and Design Standards. If critical areas are present, federal, state and local government permits may be required. Due to costs associated with some of these permits, it is preferable to avoid these areas where possible until programmatic permits for these types of projects are in place. Permit costs and associated project delays can be minimized by avoiding or minimizing impacts to critical areas. Working within the existing ditch and minimizing sub-surface work will minimize concerns about impacts to archeological and historic cultural resources and right-of-way issues. The permit inspection and review will typically require a minimum of four hours of the permit specialist's time.

5.5.2 Design Considerations

- Level survey of the ditch:
  - Cross-sectional area and side slope of the ditch
  - Profile slope of the ditch
  - Establish/verify right-of-way limits
  - Location and type of existing drainage features (crossings, culverts, etc)
- Hydrological Analysis/Broad-crested weir calculations
  - Delineate watershed on topographic maps
  - Calculate percentage of pervious/impervious watershed
  - Review soils maps for soil classification
  - Run flow model
  - Broad-crested weir calculation will establish the storm recurrence capacity of the ditch with BMPs in place.
  - Map out spacing interval of the BMPs based on slope of the ditch.

A surveyed profile and cross-section of the ditch will establish the basic ditch geometry and the slope of the ditch. Each BMP should project no more than 1 foot above the bottom of the ditch. The crest of a downstream BMP should be at the same elevation as the toe of the next upstream BMP so that water is ponded between BMPs. Using the one-foot height standard for the BMP structure, the survey can be used to establish the distance between BMPs placements and hence the total number of BMPs per site. Other useful information in planning a ditch BMP project includes the location of structures (culverts, etc) that interrupt the ditch, an assessment of the condition of the ditch, and right-of-way location. Survey information will aid in completing a hydraulic analysis to asses the stormwater carrying capacity of the ditch with the BMPs in place.

Temporary erosion and sediment control plans that detail how construction site runoff and erosion will be addressed will be required during project construction activities.

The BMP plans that were developed for this pilot project required review and approval at the 90% design level by Ecology, requiring a greater level of detail than may be needed for many subsequent projects.

6.0. BMP MONITORING

6.1 Monitoring Design

The BMP monitoring design, analytical parameters and quality assurance protocols are detailed in the QAPP (King County, 2008) prepared at the start of this project. Water quality BMP projects were evaluated though analysis of stormwater samples and measurement of field parameters. Both water quality and flow control projects were evaluated through continuous measurement of flow. At the end of the 2010 studies the project QAPP was revised with changes to the monitoring parameters for the 2011 water year projects. Monitoring parameters and the revisions to monitoring are described in Section 6.2 and shown in Tables 6 and 7.

The water quality BMP study was designed as a "before and after" treatment study with data collected from stormwater influent and effluent monitoring sites as paired sample sets. The evaluations included measurement of storm flow, flow-weighted composite samples, grab samples, discrete measurements of field parameters, continuous temperature monitoring and, during selected storm events, continuous turbidity monitoring.

Flow-weighted composite samples were collected to evaluate the event mean concentration (EMC) of analytical parameters for each sampled storm event. Composite sampling criteria established in the project QAPP called for a minimum of twelve constant volume subsamples or aliquots of storm flow collected on a flow-weighted basis to cover a period that represented at least fifty percent of the total storm flow. The aliquots were directed into a single sample container and thoroughly mixed before splitting into separate sample containers for analysis. Collecting composite samples required estimating the expected storm flow (based on forecasted rainfall totals) and appropriate programming of autosamplers staged at the influent and effluent monitoring locations of each BMP project.

> Programming example: a storm forecast of 0.3 inches of rainfall was estimated to produce 10,000 gallons of storm flow at a project site (based on rainfall/flow comparisons). The autosampler might be set to collect a sample every 250 gallons to obtain a flow-weighted composite sample consisting of 40 aliquots. The actual storm flow would be dependant on a number of factors, including the actual rainfall amount, intensity, and soil saturation conditions – all factors that are not known at the time of sample set-up. Difficulties in meeting either the minimum number of aliquots or sampling the minimum duration of the storm arise if the resulting storm flow is significantly different from the estimated storm flow.

Grab samples were collected during 2010 studies for total petroleum hydrocarbons (TPH) and fecal coliform bacteria, parameters that could not be collected using automated equipment. Grab samples are single samples collected by manually dipping sampling containers directly into the storm flow "early" during the storm event.

Discrete measurements – Field parameters were collected by taking single measurements of storm flow parameters for dissolved oxygen (DO), pH, temperature, turbidity, and conductivity.

These measurements were made using hand-held data sondes and were typically collected immediately following collection of grab samples.

Continuous monitoring parameters. Flow was recorded continuously using automated data loggers and primary flow measurement devices at all sites. Temperature was monitored continuously at all water quality project sites. Turbidity was monitored continuously during selected storm events at water quality project sites 148, 192, OP and flow control project sites PET and 192DN

Rainfall, used to evaluate storm flow, was recorded by real-time gages maintained by the King County Hydrologic Information Center (KCHIC) at gages located near each project site. An on-site rain gage was also located at each water quality project site.

6.2 Parameters

6.2.1 Analytical Parameters

Samples were tested for the analytical parameters listed in Tables 6 and 7. Parameters tested for 2010 studies included total suspended solids (TSS), hardness, nitrate-nitrite (nitrogen), total Kjeldahl nitrogen (TKN), ortho-phosphate phosphorus, dissolved metals (arsenic, chromium, cadmium, copper, lead, nickel, selenium, tin and zinc), seventeen polycyclic aromatic hydrocarbons (PAHs) (Table 7), Project locations, installation dates, monitoring time frame and project identifiers used for water quality BMP projects in this report are presented in Table 1. Project locations are also mapped as shown in Figure 1. TPH and fecal coliform bacteria. Parameters were collected as flow-weighted composite samples except for TPH and fecal coliform which were collected as discrete grab samples. The project QAPP was revised for the 2011 studies with the addition of total metals (arsenic, chromium, copper, lead, nickel and zinc), and total phosphorus collected as flow-weighted composite samples. Collection of dissolved cadmium, selenium, and tin, grab sampling for TPH and fecal coliform bacteria and discrete measurements of field parameters were discontinued.

6.2.2 Field Parameters

Field parameters (DO, pH, conductivity, temperature and turbidity), shown in Table 8, were measured as discrete readings using YSI multi-probe sondes during the first year of monitoring at Projects148 and 136. The intent of this monitoring was to evaluate these single-point measurements early during storm events. Examination of the resulting data showed no discernable difference between influent and effluent readings, perhaps due in part to the logistical difficulties in getting to the projects sites during the early portion of storm events. As an alternative method, continuous turbidity was also measured by deploying sondes during select storm events at Project 148 water quality site and Project PET flow control site. The use of sondes was expanded during 2011 monitoring of the 192 and OP water quality project sites.

6.3 Storm Sampling

Each ditch BMP study site was evaluated via the collection of data from twelve flow-weighted composite samples collected as matched influent/effluent pairs (at Project 148, only eleven storms were successfully sampled). The list of storms sampled, including the storm date, laboratory IDs, antecedent dry period, intra-storm dry period, total storm flow, and sampled storm flow are presented in Tables 9, 10, 11 and 12. Storm sampling followed criteria established in the project QAPP as described below:

Wet Season storm sampling criteria: Antecedent dry period of 24 hours, less than a 6 hour intra-storm dry period, storm volume sufficient to produce adequate flow in the ditch, composite sampling representing greater than 50% of the storm hydrograph.

Dry Season storm sampling criteria: Antecedent dry period of 72 hours, less than a 6 hour intra-storm dry period, storm volume sufficient to produce adequate flow in the ditch, composite sampling representing greater than 50% of the storm hydrograph.

Storm Sampling Figures: Storm sampling summary charts were prepared for each sampled storm event. These charts include storm hydrographs with storm flow in gallons, rainfall hyetograph, and timing of sample aliquots for each successful storm event. These charts are presented in Appendix A (Storm Summary Figures).

Field Monitoring Summary Tables: Spreadsheets detailing site monitoring records were kept throughout the project (see Tables B-1 through B-4 Appendix B). These records included storm sampling attempts and routine site visits to audit field monitoring equipment. These tables include the date of field visits, antecedent and mid-storm dry periods, comparison of flume and meter readings, storm start and stop times, total flow, and total rainfall. The comments section was used to document issues with the sampling or operation of the meters. These tables were used as a tool to audit field sampling activities, review the field forms for completeness and errors and to document conditions that resulted in deviations from the QAPP.

6.4 Flow Monitoring

6.4.1 Baseline Flow Monitoring

Pre-project baseline flow monitoring was used to develop the methods and equipment that would be used during the BMP studies and to start developing rainfall/storm flow relationships for use in composite sampling at each location (KCRMS unpublished data). These studies are summarized below.

Baseline Flow data were collected at the following water quality monitoring stations:

- 148UP: October 30th 2008 through June 3rd 2009. A 1.0 foot HS flume (Dawson & Grant 1997) was originally installed at this monitoring station in late October 2008. This flume was destroyed when a car ran off the road during a snow event on January 4th 2009. The HS flume was replaced with an extra-large 60° V trapezoidal flume on January 27th 2009. The trapezoidal flume was removed on June 3rd 2009 and moved approximately ten feet closer to the upstream ditch culvert during BMP installation on June 4th 2009.

- 148DN: A trapezoidal flume (Dawson & Grant 1997) was installed on February 19th 2009. A site visit on February 26th 2009 found that the meter was set two hours late and was adjusted appropriately (flow peaks for this time period are off by two hours). During the baseline flow monitoring period, some flow was observed leaking around the flume at the ditch backslope. Therefore, this flume was removed on June 3rd 2009, prior to installation of BMPs on June 4th 2009, and the ditch backslope was re-built. The flume was replaced in the same location after BMP installation and ditch repair; the repaired ditch backslope prevented the loss of flow around the flume.

- 136UP**:** Baseline flow data were collected using a Thel-Mar weir from March 3rd 2009 until BMPs were installed on June 11th 2009.

- 136DN: Baseline flow data were collected using a Thel-Mar weir from March 23rd 2009 until BMPs were installed on June 11th 2009.

- PET UP Baseline data were collected from November 20th 2008 until January 30th 2009 using a 1.0 foot HS flume and Isco bubble meter. Additional baseline data were collected from March 31st 2009 into June 2009 using a Campbell Scientific® data logger and pressure transducer. Monitoring was continued into June 2009 until the ditch was dry.

- PETDN: Baseline data were collected from November 20th 2008 until January 27th 2009 using a 1.0 foot HS flume and Isco bubble meter. No baseline data were collected from January 28th until March 31st 2009, at which time a Campbell Scientific® data logger and pressure transducer were installed at the site. Monitoring was continued into June 2009 until the ditch was dry. The downstream flume was moved about 100 feet father downstream to a point below the last BMP after BMPs were installed on June 30th 2009.

Experience with baseline flow monitoring was used to guide development of the BMP monitoring protocols used in subsequent studies.

6.5 BMP Flow and Rainfall Monitoring

6.5.1 Flow Monitoring

Flow was monitored using extra-large 60°V trapezoidal flumes (Dawson & Grant 1997) installed in the ditches at the 148, 192 and OP project sites. At the 136 site, Thel-Mar weirs were installed in existing culverts just upstream and downstream of the BMP installations.

Water Quality BMP Projects:

Continuous paired flow monitoring records for water quality BMP projects include:

Project 148 flow monitoring records from June 17th 2009 through September 30th 2010.

Project 136 flow monitoring records from August 11 2009 through September 1st 2010.

Project 192 flow monitoring records from October 1st 2010 through September 30th 2011.

Project OP flow monitoring records from September 3rd 2010 through September 30th 2011.

Water Quality BMP Projects

Continuous paired flow monitoring records for Flow BMP projects include:

Project PET flow monitoring records from August 10th 2009 through September 29th 2010.

Project 192DN flow monitoring records from September 30th 2010 through September 26th 2011 (a period of record is missing from October 25th 2010 to November 4th 2010 due to instrument malfunction).

Project 276 flow monitoring records from August 10th 2009 through September 28th 2011 and October 1st 2010 through September 28th 2011

Project 276DN flow monitoring records from December 16th 2010 through September 28th 2011.

6.5.2 Rainfall Monitoring

Project rain gages are telemeter equipped gages with real-time records available online, operated by the KCHIC. Historical and real-time rainfall records in increments of 15 minutes, one hour, daily, and monthly are available at: http://green.kingcounty.gov/WLR/Waterres/hydrology/GaugeMap.aspx?TabDefault=Map.

The project rain gage for the 148 and 136 projects was 31UN – Renton Roads rain gage. The 31UN gage has been in operation at this location since October 10th 2000. Project 148 is two and a half miles east-northeast of the 31UN gage, and Project 136 is just over two miles east of the 31UN gage.

The project rain gage for the 192 and OP projects was 31Y2 - Fairwood rain gage. The 31Y2 real-time rain gage has been at this location since October 16th 2009, when it replaced a non-telemeter equipped gage (31Y) that had been in operation since October 1st 1994. Both the OP and 192 projects are approximately one-half mile east-southeast of the 31Y2 rain gage.

7.0. BMP MONITORING RESULTS

7.1 Statistical Analysis of Water Quality Analytical Data

7.1.1 Hypothesis Testing

The BMP study was designed as a "before and after" treatment study. The goal of the study was to create paired sample sets of influent vs. effluent stormwater data that would be evaluated to determine if a statistically significant difference could be identified and if this difference indicated improved downstream water quality. Hypothesis testing (t-tests) were run to determine if the differences in the mean values of the data sets were significant.

Improvement to stormwater effluent quality were assessed as reductions in the event mean concentration of each analytical parameter measured in flow weighted composite samples. This analysis was also performed on grab samples. The reductions are described as BMP percent efficiency calculated as:

$$\frac{(\text{Influent Value} - \text{Effluent Value})}{\text{Influent Value}} \times 100$$

Results of the hypothesis tests, along with mean reduction or BMP efficiencies for data sets with values all reported above the laboratory method detection limit (MDL) are presented in Table 13. Mean percent efficiency values and confidence intervals (CIs) for those reductions were calculated using bootstrapping techniques at a 95 percent CI and are included in Table 13. Hypothesis testing and bootstrapping techniques used for this analysis are described below.

7.1.1.1 Non-parametric t-test Evaluation

The function of each BMP project was evaluated by testing the null hypothesis that there is no statistically significant difference between the means of influent vs. effluent data sets (and, therefore, the BMPs have no effect on water quality). This hypothesis was rejected at a 95% CI when a paired sample test resulted in a unitless p value of less than 0.05. The Wilcoxon signed rank test, a two sided test for non-parametric paired samples, was selected to evaluate the BMP data. A Student's t-test was not deemed suitable for testing these data because the Student t-test requires a normal or Gaussian distribution of data around a sample mean. The data sets collected during this study do not follow a normal distribution. This is typical of environmental data, especially when data sets are small (less than 20 data points per test). The assumption of non-normality was evaluated on TSS data using a Kolmogorov-Smirnov (KS) test. The KS test reported that data for TSS was unlikely to follow a normal distribution, although this data set was consistent with a log-normal distribution. The data sets could be evaluated using a t-test on data transformed to log-normal values but transformed results cannot be easily un-transformed. An alternative was to use a non-parametric test that does not rely on the assumption that the data are drawn from a given probability distribution.

The Wilcoxon test does not rely on the sample distribution, but computes the difference between sets of paired samples and analyzes the differences. This test was suitable for evaluating all paired sample data collected during this study regardless of the distribution. In addition to computing a p value at a 95% CI, the test computed an estimated mean of the difference between the influent and effluent values and calculated the upper and lower CIs of the difference. The p value, estimated median, CI and the upper and lower values for the CI are presented in Table 13. The estimated median and CI results have the same units as the analytical test results. Negative values for the estimated mean and CIs show the parameter values increasing in effluent samples collected downstream of the BMPs. The Wilcoxon Signed Rank test computations were accomplished using Minitab® software and a Minitab® macro for the Wilcoxon signed rank test[5].

7.1.1.2 Bootstrapped Mean Efficiency and Confidence Intervals

Mean percent efficiency values for each parameter were calculated using a "bootstrapping evaluation". The bootstrapping process estimates the sampling distribution of a data set and computes nonparametric CIs on the mean and median through multiple iterations of a statistical re-sampling of the data as shown in Figure 11. A Minitab® bootstrap macro was used to run 1,000 re-sampling iterations to produce the bootstrapped means and CIs for percent efficiency values for each parameter[6]. One thousand bootstrap iterations were selected as a sufficiently large number to calculate a reasonable mean value; increasing the number of iterations over this amount was felt to produce a negligible increase in the accuracy of the mean.

[5] Wilcoxon Signed Rank Test for Paired Data macro downloaded at http://www.minitab.com/en-US/support/macros/view-macro.aspx?action=display&cat=non

[6] Bootstrap Macro downloaded at http://www.minitab.com/en-US/support/macros/default.aspx?q=bootstrap&collection=Macros

7.1.1.3 Data Sets with Non-detected Values

Data sets with non-detects (i.e., results reported as less than the MDL) occurred for dissolved lead, chromium, cadmium, selenium and tin, orthophosphate phosphorus, TPH and fecal coliform. Non-detected data are considered left-censored; the <MDL values cannot be directly presented but are not zero. In order to test the null hypothesis for data sets with less than 90% non-detects (dissolved lead and chromium, orthophosphate phosphorus and fecal coliform) a substitution of ½ MDL was made. While ½ MDL does not represent the true value of those test results it was considered to be a suitable surrogate for use in comparing influent to effluent results. The Wilcoxon signed rank test was then run on the data sets with substitutions. Data sets with greater than 90% of results reported as <MDL (dissolved cadmium, selenium and tin and TPH) could not be evaluated through these methods, and were not further evaluated. Results of hypothesis testing on data sets with non-detects are presented in Table 14.

7.1.2 Descriptive Statistics

Descriptive statistics calculated for data sets included the number of tests, mean, standard error of the mean, standard deviation, minimum, 25th percentile, median, 75th percentile, maximum, inter-quartile range (IQR) and skewness. Minitab® software was used to calculate these statistics on datasets without non-detects. Results are presented in Table 15.

Descriptive statistics for data sets that included non-detects that represented less than 90% of the data were calculated using the Minitab® macro KMSTATS v. 1.8[7]. This macro uses the Kaplan-Meier method for computing descriptive statistics for left-censored data. The macro “flips” the data to a right-censored format then computes the statistics and "unflips" the resulting statistics back into their original units. It uses the Efron bias correction when the lowest value in the data set is censored. The number of tests, mean, standard error of the mean, standard deviation, 25 percentile, median, 75th percentile and 90th percentile are presented in Table 16.

7.1.3 Graphical Analysis using Box Plot Figures

Box plot graphics allow for a visual comparison of data sets. For each parameter the influent/effluent sample pairs collected at each BMP project site are displayed in a single graphic. This allows for viewing the treatment effects from multiple study sites simultaneously.

The box plot graphics, as demonstrated in Figure 13, consist of a ‘box’ drawn around the 25th and 75th percentile values of a single data set, defining the IQR and enclosing fifty percent of

[7] Helsel, D.R., 2005, Nondetects And Data Analysis, Wiley and Sons, 252 p.
KMSTATS v 1.8 Copyright (c) 2004-2009 by Dennis R. Helsel

values from the set. Horizontal lines or 'whiskers' above and below the box represent the minimum and maximum values within 1.5 times the IQR. The median value is shown as a bold horizontal line at the narrowest part or waist of the box. If the median is not centered vertically it shows the direction of sample skewness and indicates that the data sets have a non-normal distribution. Outliers – data points that extend more than 1.5 times the inter-quartile range are shown as small circles not connected to the box.

Box plot graphics for each analytical parameter are presented in Figures 14 through 33. Plots for data sets that included non-detected results (dissolved lead, chromium, orthophosphate phosphorus, and fecal coliform) at less than 90% of the data set were created by first substituting ½ the MDL for non-detected values. No plots were created for data sets with greater than 90% non-detected values (cadmium, selenium tin, and TPH).

7.2 Summary of Water Quality Results

7.2.1 Laboratory Analytical Data

Laboratory analytical results of influent vs. effluent stormwater samples collected at the four Water Quality BMP projects are presented in this section. Analytical results are presented in Tables 17, 18, 19 and 20. A summary of the mean BMP efficiencies for parameters with measured treatment effects is provided in Figure 12. Evaluation of these data suggests improvements in the following water quality parameters at one or more BMP project sites:

- Decreased TSS
- Decreased TKN
- Decreased total metals: arsenic, chromium, copper, lead, nickel, zinc
- Decreased dissolved metals: lead, nickel and zinc
- Decreased PAH was measured as the sum of the results from the seventeen PAH parameters tested for each sample in Table 7.
- Increased hardness (increased hardness is considered to be a water quality benefit)
- Decreased turbidity, monitored as continuous turbidity during targeted storm events, was seen at Projects 148, 192 and OP

Hypothesis testing (t-tests) (described in Section 7.1. Statistical Analysis), was done to determine if the observed reductions were statistically significant. Results of the hypothesis testing, along with mean reductions or BMP efficiencies are presented in Tables 13 through 16.

A statistical technique known as "bootstrapping" (discussed further under Section 7.1) was used to compute mean efficiency values along with CI values. The CIs are a range around a measurement that conveys precision of the measurement. Mean percent efficiency values calculated using bootstrapping techniques are also reviewed in Section 7.1.

Laboratory analytical results varied between project sites and the variance between tests at some sites is greater than others. In particular, water quality improvements were not seen at Project 136 where BMP effluent test results were typically higher than influent results. This is thought to be due to difficulties with collecting representative samples in ditches that carry significantly more water than the BMPs were designed to treat, along with the effects of watershed and roadway inputs into the ditch between the influent and effluent measuring stations. Outliers (values greater than 1.5 times the IQR of the data set) are present in most data sets; outliers add to the skew of the data set. The variability of the data and presence of outliers is likely due to uncontrollable variables inherent in testing BMPs in existing ditches (soil saturation, organic and inorganic debris and vegetation, and lack of an exclusive storm flow input location, just to name a few), moving test sites to different locations and watersheds (as opposed to testing different BMP designs in a single ditch), and the intrinsic difficulties with collecting flow-weighted composite samples based on forecasted rainfall amounts with variations in storm volume, intensity and duration, and a wide range of antecedent conditions.

Graphical presentations of BMP treatment effects are presented in Figures 14 through 33 (TSS, presented in Figure 14A, is also presented as a detail in Figure 14B). A box plot comparison of influent and effluent flows measured during sampling events is presented in Figure 34. This comparison shows that flows were often higher downstream during sampling events, but is not representative of the dry season flow regime at these sites.

The treatment percent efficiencies for parameters showing water quality improvement (i.e., the null hypothesis was rejected and pollutant presence in paired sample sets was reduced in effluent samples) are listed below.

TSS

- Project 148: TSS was reduced in 10 out of 11 sample pairs with a mean percent reduction of 44.6%. The upper and lower 95% CI values for the percent reduction ranged from 23.7% to 61.6%.
- Project 192: TSS was reduced in 9 out of 12 sample pairs with a mean percent reduction of 13.1%. The upper and lower 95% CIs of the percent reduction ranged from -21.3% (TSS was higher downstream in some cases) to 40.4%.
- Project OP: TSS was reduced in 9 out of 12 sample pairs with a mean percent reduction of 37.7%. The upper and lower 95% CIs of the percent reduction ranged from 11.3% to 60.4%

TKN

- Project 192: TKN was reduced in 10 out of 12 sample pairs with a mean percent reduction of 12.9%. The upper and lower 95% CIs of the percent reduction ranged from 4.0% to 20.6%.

- Project OP: TKN was reduced in 10 out of 12 sample pairs with a mean percent reduction of 14.2%. The upper and lower 95% CIs of the percent reduction ranged from -4.9% (TKN was higher downstream) to 28.8%.

Arsenic, total

- Project 192: total arsenic was reduced in 10 out of 12 sample pairs with a mean percent reduction of 17.1%. The upper and lower 95% CIs of the percent reduction ranged from 2.3% to 28.5%.

- Project OP: total arsenic was reduced in 10 out of 12 sample pairs with a mean percent reduction of 14.2%. The upper and lower 95% CIs of the percent reduction ranged from 13.0% to 37.9%

Chromium, total

- Project 192: total chromium was reduced in 11 out of 12 sample pairs with a mean percent reduction of 23.2%. The upper and lower 95% CIs of the percent reduction ranged from 14.1% to 31.8%.

- Project OP: total chromium was reduced in 11 out of 12 sample pairs. However, the mean percent reduction was -5.1% indicating an overall increase in total chromium in effluent samples. Hypothesis testing calculated p value at a 94.5 CI of 0.065 and the null hypothesis could not be rejected. Examination of the data showed that effluent chromium was reduced in all but one sample pair and the data set was skewed by outliers. The upper and lower 95% CIs of the reduction ranged from -85.4% (total chromium was higher downstream) to 44.9%.

Copper, total

- Project 192: total copper was reduced in 10 out of 12 sample pairs with a mean percent reduction of 7.9%. The upper and lower 95% CIs of the percent reduction ranged from 3.2% to 20.6%.

- Project OP: total copper was reduced in 10 out of 12 sample pairs with a mean percent reduction of 28.6%. The upper and lower 95% CIs of the percent reduction ranged from 14.4% to 44.1%.

Copper, dissolved

- Project 192: dissolved copper was reduced in 9 out of 12 sample pairs with a mean percent reduction of 15.1%. Data includes one upstream outlier. The upper and lower 95% CIs of the percent reduction ranged from 3.3% to 29.7%. The hypothesis test resulted in a p value of 0.053. The cutoff for rejecting the null hypothesis that there is no difference in influent and effluent sample sets at a 95% CI is a p value 0.05. The result for dissolved copper at Project 192 is right at this value. The box plot comparison indicates a small reduction in dissolved copper at this project site.

- **Lead, total**

- Project 192: total lead was reduced in 11 out of 12 sample pairs with a mean percent reduction of 27.2%. The upper and lower 95% CIs of the percent reduction ranged from 14.9% to 39.2%.

- Project OP: total lead was reduced in 10 out of 12 sample pairs with a mean percent reduction of 33.7%. The upper and lower 95% CIs of the percent reduction ranged from 2.4% to 59.2%.

Lead, dissolved

- Project 192: dissolved lead was reduced in 8 out of 12 sample pairs with a mean percent reduction of 24.8%. This data set included non-detected values; ½ of the MDL was used as a surrogate for the non-detected results[8]. The upper and lower 95% CIs of the percent reduction ranged from 10.4% to 40.2%.

Nickel, total

- Project 192: total nickel was reduced in 11 out of 12 sample pairs with a mean percent reduction of 18.9%. The upper and lower 95% CIs of the percent reduction ranged from 9.2% to 27.7%.

- Project OP: total nickel was reduced in 11 out of 12 sample pairs with a mean percent reduction of 10.5%. The upper and lower 95% CIs of the percent reduction ranged from -36.8% to 41.3% (nickel was higher downstream).

Nickel, dissolved

- Project 192: dissolved nickel was reduced in 9 out of 12 sample pairs with a mean percent reduction of 7.8%. The upper and lower 95% CIs of the percent reduction ranged from 0.9% to 15.0%.

Zinc, total

- Project 192: total zinc was reduced in 9 out of 12 sample pairs with a mean percent reduction of 17.6%. The upper and lower 95% CIs of the percent reduction ranged from 4.0% to 34.7%.

Zinc, dissolved

- Project 148: dissolved zinc was reduced in 9 out of 11 sample pairs with a mean percent reduction of 20.5%. The upper and lower 95% CI values for the percent reduction ranged from 2.2% to 38.9%.

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[8] See Section 5.2.1.3 for a description of statistical analysis of data sets with non-detects

- Project OP: dissolved zinc was reduced in 11 out of 12 sample pairs with a mean percent reduction of 16.1%. The upper and lower 95% CIs of the percent reduction ranged from -27.0 % (zinc was higher downstream) to 41.9%

Hardness (increased hardness was evaluated as a water quality benefit)

- Project 148: hardness increased in 11 out of 11 sample pairs with a mean percent increase of 57.0%. The upper and lower 95% CI values for the percent increase ranged from 29.2% to 92.2%

- Project 136: hardness increased in 10 out of 12 sample pairs with a mean percent increase of 8.6%. upper and lower 95% CI values for the percent increase ranged from -1.3 (hardness was lower downstream) to 17.8%.

PAH

PAH detection results were typically very low, with most results below the reporting limit of 0.1 ug/L. Typically only a few PAHs from the 17 PAH parameters analyzed (Table 7) were detected. However, when taken as a sum of all detected PAHs the results at Projects 148, 192, and OP were found to be reduced in BMP effluent samples.

- Project 148: total PAH was reduced in 11 out of 11 sample pairs with a mean percent reduction of 63.1 percent. The upper and lower 95% CI values for the percent reduction ranged from 50.6% to 75.7%.

- Project 192: total PAH was reduced in 7 out of 12 sample pairs with a mean percent reduction of 21.3%. The upper and lower 95% CIs of the percent reduction ranged from 6.5% to 38.4%.

- Project OP: total PAH was reduced in 12 out of 12 sample pairs with a mean percent reduction of 43.5%. The upper and lower 95% CIs of the reduction percent ranged from 28.0 % to 58.1% .

7.3 Field Parameters

Discrete Measurements

Results from monitoring discrete measurements of water quality parameters DO, pH, temperature, turbidity and conductivity are presented in Table 21. This monitoring did not find any significant differences between influent and effluent measurements. However, these observations from single-point sampling differed from the results obtained by continuous monitoring for turbidity (described below) where data sondes were left in place through entire storm events and where an effect of the BMPs on turbidity was observed.

Continuous Turbidity Measurement

Turbidity, monitored using continuous recording data sondes set to log turbidity values in ten minute increments during selected storms, demonstrated that turbidity values were typically lower in BMP effluent. Monitoring results including average and maximum turbidity during the monitoring period for Project 192 are summarized in Table 22, results for Project OP are summarized in Table 23. At Project 192, turbidity monitoring included placement of turbidity sensors at the effluent monitoring site of Project 192DN (the flow control BMP project located directly downstream). Some continuous turbidity monitoring was also done at the 2010 PET flow control study. These results are summarized in Table 24. Figure 35 demonstrates typical results obtained during continuous turbidity monitoring during a storm event at Project OP. Box plot comparisons of mean and maximum turbidity results are presented in Figures 36 through 39.

Continuous Temperature Measurement

Temperature was monitored using continuously recording data-loggers at all water quality BMP project sites. Results from continuous temperature monitoring were summarized as average daily temperature. Periods where no flow was recorded in the ditch were deleted from the data set. The results are shown graphically as box plot comparisons in Figure 40. No significant difference was observed between influent and effluent temperature.

7.4 Flow

Figure 41 demonstrates the relationship between influent and effluent flows at water quality BMP projects during sampled storm events. Storm flow monitored during the wet season and hence a majority of sampled events, showed higher flow in the BMP effluent than at influent monitoring stations due to watershed inputs along the length of the BMP projects. In contrast, a reduction in effluent flows was seen at most BMP project sites during the dry season, particularly in the July to September time frame as shown in Figure 41. Storm flow reductions at water quality BMP project sites were most significant at Project OP which contained the greatest number of BMPs (thirteen BMPs). Comparisons between upstream and downstream total monthly flows for Project OP are presented in Table 25, and graphically in Figures 42 and 43.

8.0. FLOW CONTROL RESULTS

Effluent flow was typically found to be reduced relative to influent flow during the mid to late dry season months (July through early October). Water quality and flow control BMPs were built for different purposes, but function in a similar fashion to treat flow by detaining water, decreasing flow energy, and increasing opportunities for infiltration. Projects with more BMPs (Flow Control Projects 276 and 276DN and water quality Project OP) showed a greater decrease in effluent flow. In 2011, locating later projects immediately adjacent to existing projects (Project 276DN was located immediately downstream of Project 276 and Project 192DN was located immediately downstream of Project 192) allowed for direct comparison of the effects of increasing the number of BMPs on flow. Not unexpectedly, most projects showed higher effluent flows during the wet season when storm flows are highest and the watershed soils are typically saturated.

Typical dry season flow attenuation effects are presented in Tables 26 and 27. Total monthly flows are presented in Figures 44 through 47. Table 26 and Figures 44 and 45 present the results from combined flow monitoring at water quality BMP project 192 and flow control project 192DN. As demonstrated in these charts, the reduction in flow increases with the increasing number of BMPs. A similar comparison showing significant dry-season flow reduction was also seen at Projects 276 and 276DN (Table 27 and Figures 44 and 45).

The combined Projects 276 (ten BMPs) and 276DN (13 BMPs) downstream of Project 276 demonstrated flow reductions at greater than 10 percent during the months of June through September 2011. In June, influent flows of 675,000 gallons were reduced by almost 23 percent. In July and August, influent flows averaged approximately 30,000 gallons each month but were reduced by almost 100 percent. During this time period the majority of the flow reduction was seen within the upper project, Project 276. September demonstrated a reduction in Flows monitored in Project 276, but an increased in effluent flows at Project 276DN, possibly due to watershed input along the length of the downstream project.

Results at the combined water quality Project 192 (6 BMPs) and flow control Project 192DN (6 BMPs) downstream of Project 192 was similar, with effluent flow reductions seen during the dry season months of July, August and September 2011. Additional flow reductions were seen during October at Project 192DN and November 2010. In November, a 1 percent flow reduction was observed between 192UP and 192M, while a 20 percent reduction in flow was observed between 192M and 192DN.

9.0. SUMMARY AND CONCLUSIONS

The studies summarized in this report examined the effects of installing stormwater treatment BMPs in roadside ditches at eight project sites. Four project sites focused on water quality treatment BMPs and four project sites focused on flow control BMPs. The selected ditches all carry significant amounts of wet season storm flow. During the duration of these studies, no storms produced flows that exceeded the design capacity of the ditch. No flooding or damage to the ditch was observed within the vicinity of the BMPs. BMP installation costs were low and little or no maintenance was required during this two year study. The BMPs provided reductions in stormwater pollutants and exhibited flow control benefits by reducing dry season flows. In addition, the BMPs at all sites reduced the scouring energy from high flows that can lead to erosion and instability of the ditch. The effect of these BMPs was examined on a small scale in this study. Interest has been expressed in expanding a study of flow control BMPs to examine the effects of wide spread installation of these BMPs on receiving waters in watersheds with a long history of hydrologic and stormwater monitoring.

9.1 Water Quality BMPs

This study was implemented to design and install BMPs that would be low cost, low maintenance structures placed directly into existing roadside ditches. The BMPs would utilize existing road rights-of-way to improve stormwater quality or provide flow control. The studies were designed as before/after treatments, generating paired data sets of influent/effluent stormwater chemistry and measurements of field parameters (flow, turbidity, temperature, DO, pH, and conductivity) to assess the BMPs effect on stormwater quality and flow control.

Water quality benefits described in this report were seen as modest decreases in pollutants including TSS, TKN, total metals (arsenic, chromium, copper, lead, nickel, zinc), dissolved metals (copper, lead and zinc), PAHs, and turbidity. Hardness increased after treatment at two project sites; increased hardness is considered to be a water quality benefit. Water quality benefits were achieved by detention, adsorption and filtering of stormwater through a filtration medium (coarse compost) placed directly into a treatment cell within the BMP. It is unclear how much of these benefits are due directly to filtering and/or adsorption and how much is due to the water quality benefits obtained through stormwater detention by the BMP structure itself. The addition of a compost treatment cell inside the rock check dam structure of the BMP increased the stormwater detention. Stormwater detention could provide water quality benefits by decreasing TSS (and TSS related pollutants such as metals and PAH) through settling. In general, the baseline concentrations measured for pollutants, especially metals and PAH were low in stormwater influent.

Limitations. Limitations in the effectiveness of water quality treatment include the amount, or cross-sectional area of compost that could be placed securely in the ditch relative to the volume of stormwater that the ditch carried. For example, ditches at one project site conveyed over a half million gallons of storm flow per day during winter storm events. This limitation was addressed in part by increasing the number of BMP structures placed with in the study area.

In general, stormwater pollutant concentrations measured during these studies were relatively low. The ability to measure treatment effects required untreated stormwater influent with a detectable level of pollutants against which a treatment effect could be measured. These BMP designs would be best utilized by placing them throughout an entire section of ditch, thereby minimizing the opportunities for pollutants and solids to accrue in the storm flow. Increasing the length of the ditch treated by BMPs allowed for increased storm flow input between the influent and effluent monitoring stations which complicates the assessment of BMP effectiveness, since pollutant input could also occur between the monitoring stations.

Uncontrolled variables that affect stormwater flow and pollutant loads include antecedent dry periods, soil saturation, total rain fall (vs. forecasted rainfall) and, more importantly, rainfall intensity. These uncontrolled variables make stormwater sampling a very difficult undertaking and affect both discrete and continuous sampling protocols. Composite sampling evaluates the entire storm event whereas grab sampling can easily miss the parts of the storm with the highest pollutant concentrations. This was amply demonstrated by our experience comparing the results of discrete sampling of turbidity vs. continuous turbidity monitoring. Evaluation of the effect of the BMPs was also limited by the low frequency of the “perfect storm”; numerous storms were sampled that resulted in flows that overtopped the BMPs (and their intended performance level).

9.2 Flow Control BMPs

Flow control benefits described in this report were seen as decreases in dry season effluent flows, particularly from July through September and into early October. This was presumed to occur by increased infiltration during these dry season storms. Typically, wet season flows were higher at effluent monitoring stations due to water inputs between the monitoring stations. However, the BMPs decrease the erosive energy in higher volume storm flows even when the BMPs are overtopped and so some benefits to water quality are also expected from flow control BMPs.

Limitations. The project was successful at monitoring continuous storm flow at all flow control project sites. Limitations in the ability to assess flow control aspects of BMP projects were primarily due to an inability to control watershed inputs along the length of the projects that resulted in higher effluent flows particularly during wet season storms.

Site Suitability. BMPs should be considered for installations in locations that meet the following criteria:

- Ditch sections with known water quality issues such as scour, high pollutant concentrations, ditches that are adjacent to high volume roads, long sections of roadside ditch, and ditch sites that experience high flow conditions.
- Locations where opportunities for other water quality treatment options are limited, such as areas too constrained for treatment ponds.

Lessons Learned.

Lack of a control ditch. The BMP studies described in this report were assessed as a before/after treatment, but the study lacked a control ditch with upstream and downstream monitoring to assess the effects of no BMPs placed in the ditch.

Baseline water quality. While some flow monitoring was done at some project sites, an alternative to a control study would have included collection of baseline or pre-BMP influent and effluent chemistry sample pairs.

Parameter selection. First year studies monitored for dissolved metals but did not include analysis of total metals. Reductions in total metals were seen during second year studies.

Site Selection. The selected sites were representative of the various roadside watershed drainage features found in unincorporated King County, and provided adequate flows for assessing BMP function. However, a more detailed assessment of stormwater conditions in existing ditches is needed to better understand the optimal conditions (location, condition of ditch, flows, etc.) for installation of the BMPs.

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FIGURES

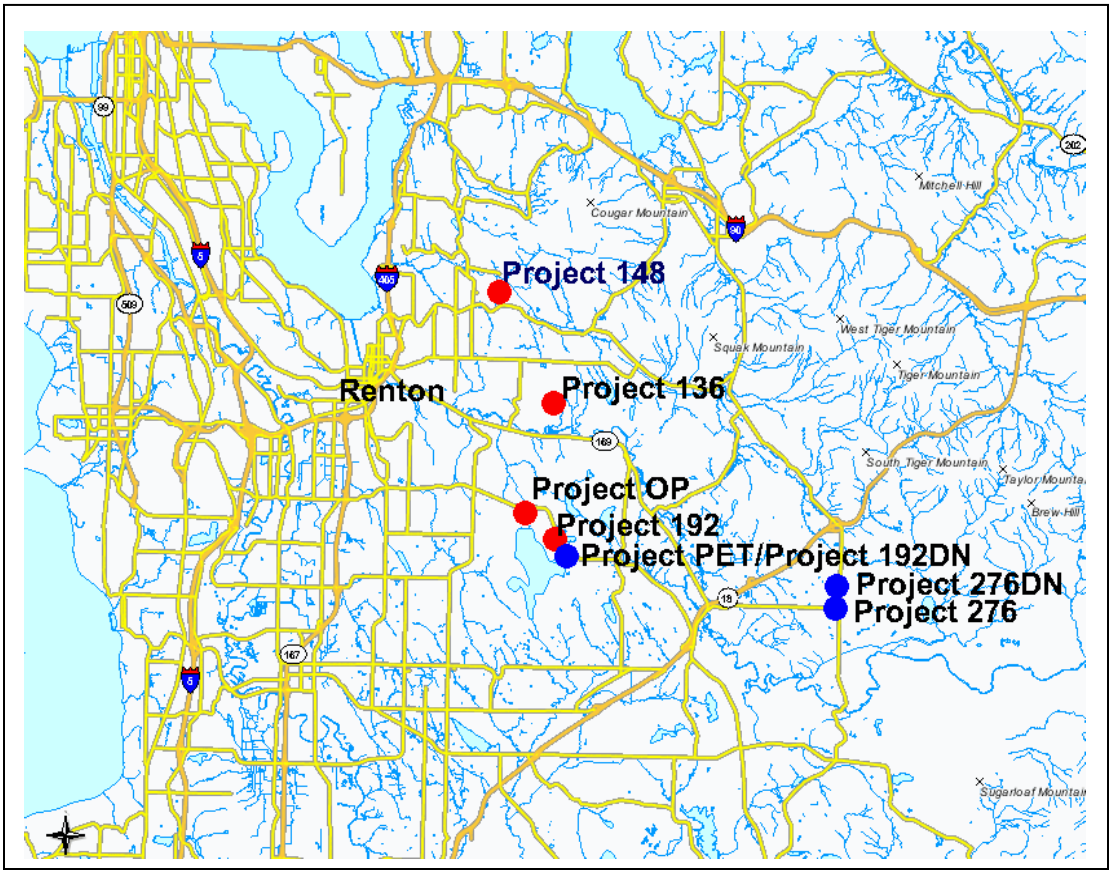
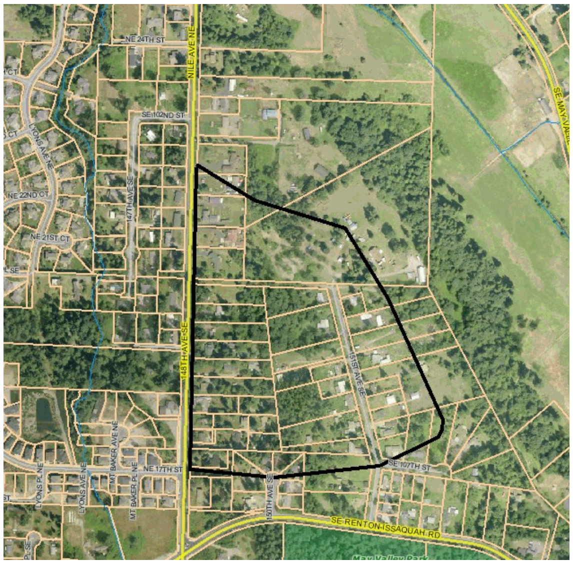


Figure 1. Study Locations

- 🔴 **Water Quality Study Site**
- 🔵 **Blue Dot = Flow Control Study Site**



Watershed

Study Location (red line)

Figure 2. Project 148 watershed

Figure 3. Project 148 study site

Watershed

Study Site (red lines)

Figure 4. Project 136 watershed

Figure 5. Project 136 study site

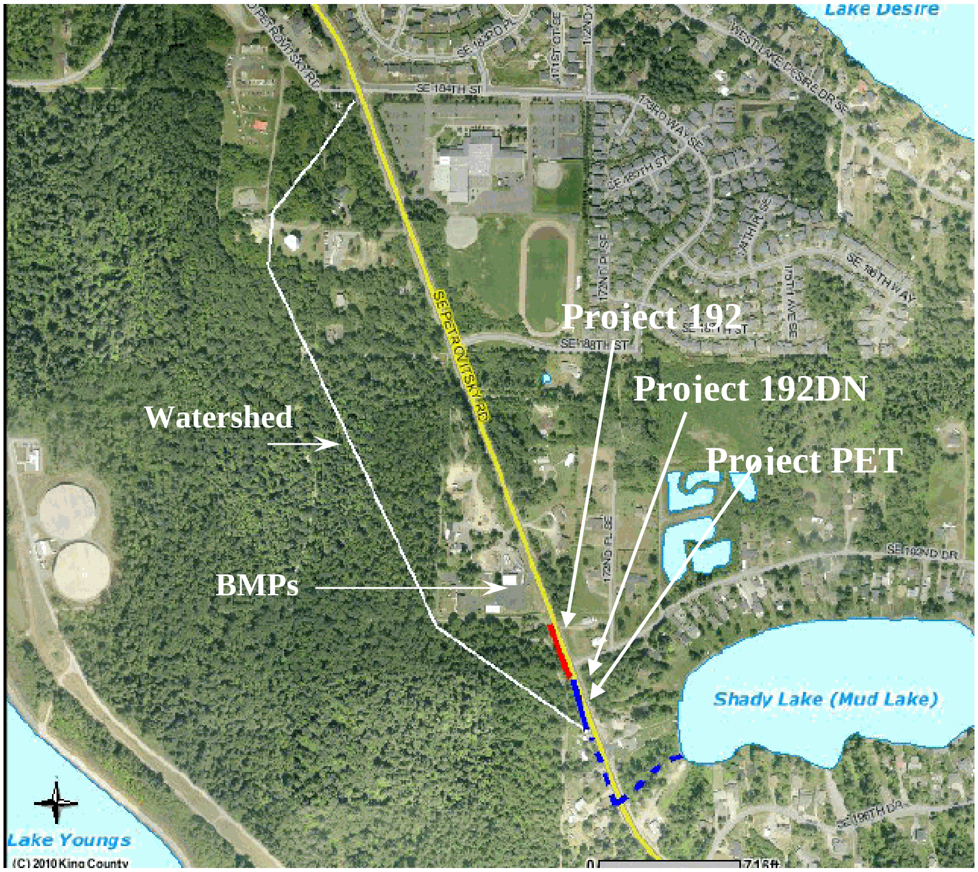


Figure 6. Water Quality Project 192 and Flow Control Projects PET and 192DN

- **Project 192 water quality BMP study site (red line)**
- **Project PET and Project 192DN Flow Control study sites (blue line)**

Figure 7. Project OP

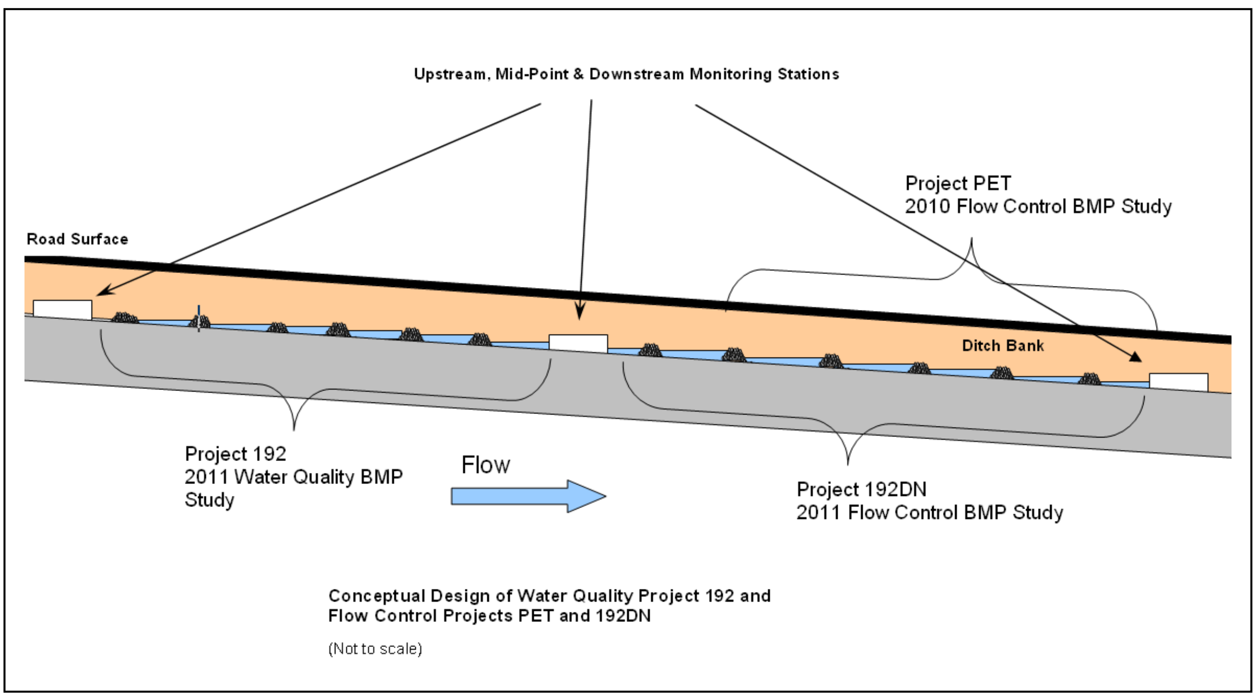


Figure 8. Conceptual Design of Water Quality BMP Project 192 and Flow Control Projects PET and 192DN

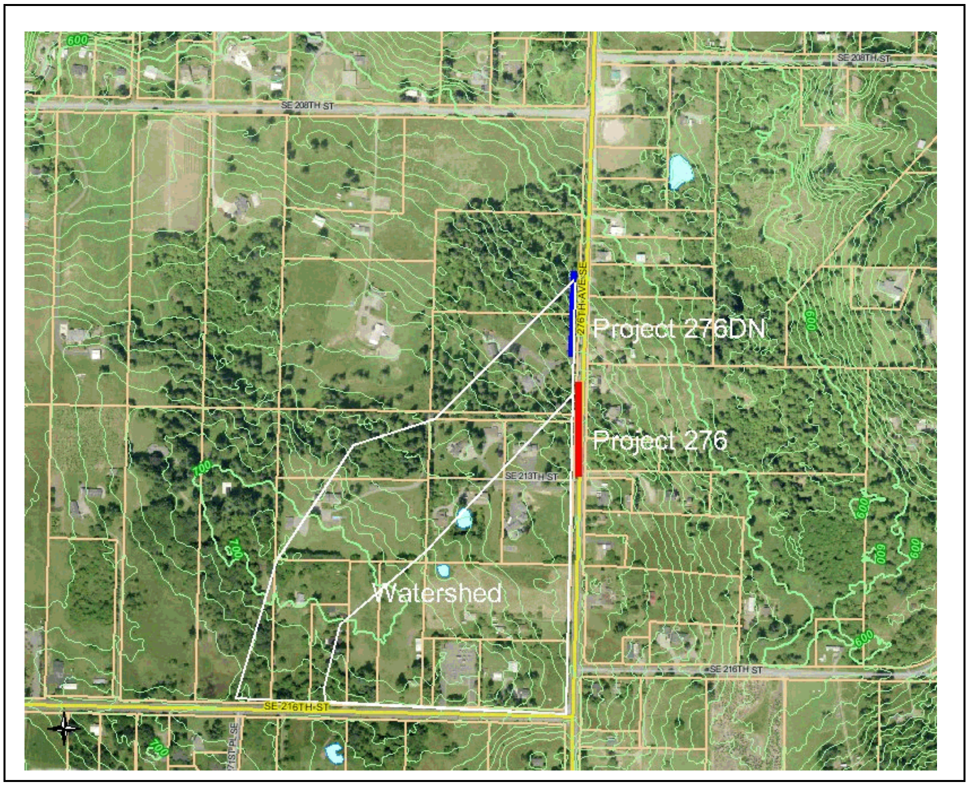


Figure 9. Projects 276 and 276 DN Study Sites

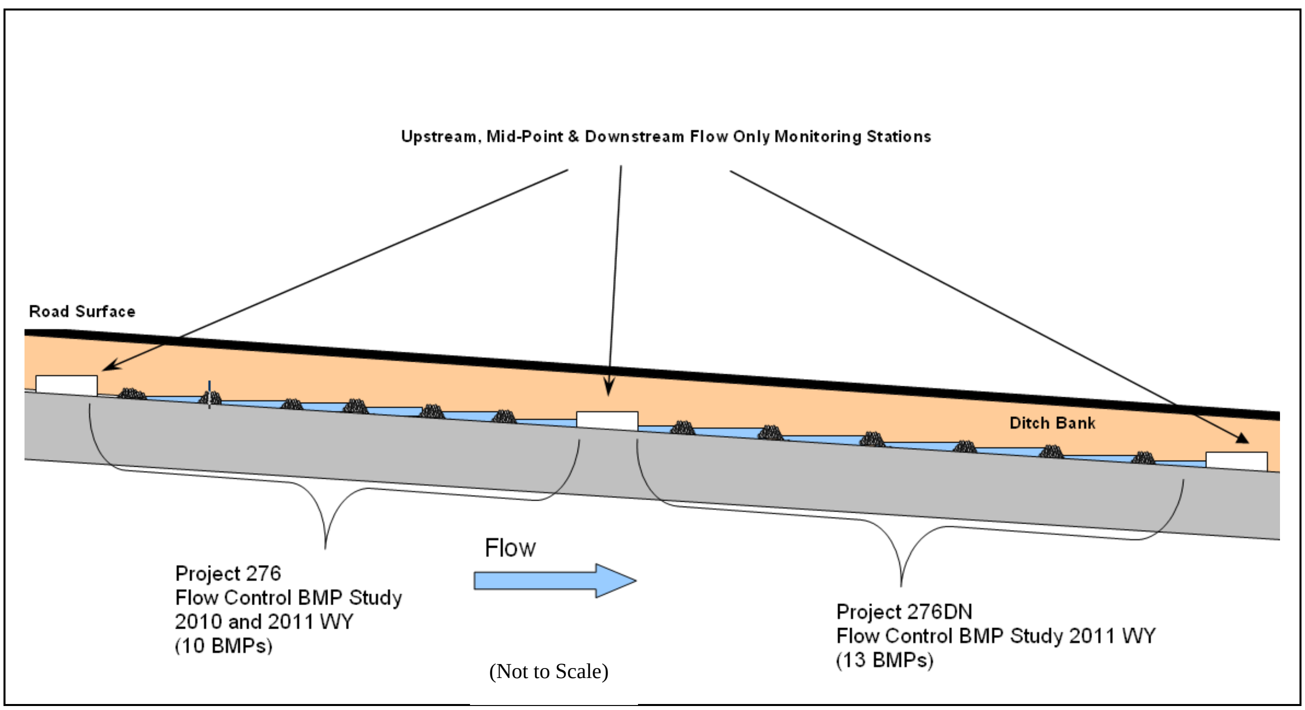
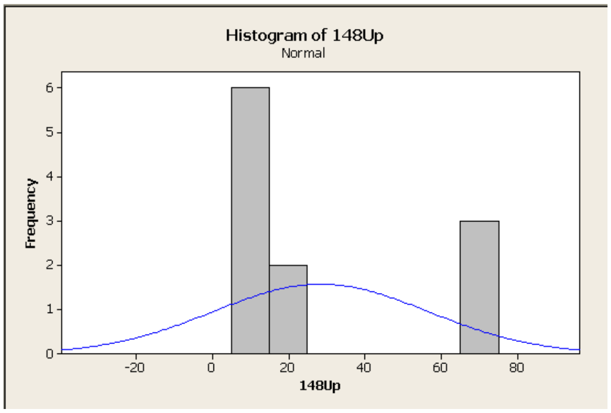


Figure 10. Conceptual Design of Flow Control Projects 276 and 276DN



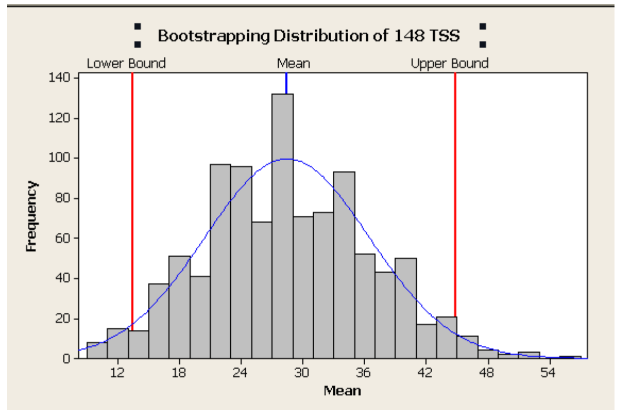


Figure 11. Bootstrapping Example. Histogram distribution of Project 148 influent TSS is shown on the left, the bootstrapping distribution (1000 iterations) of the same data set is shown on the right.

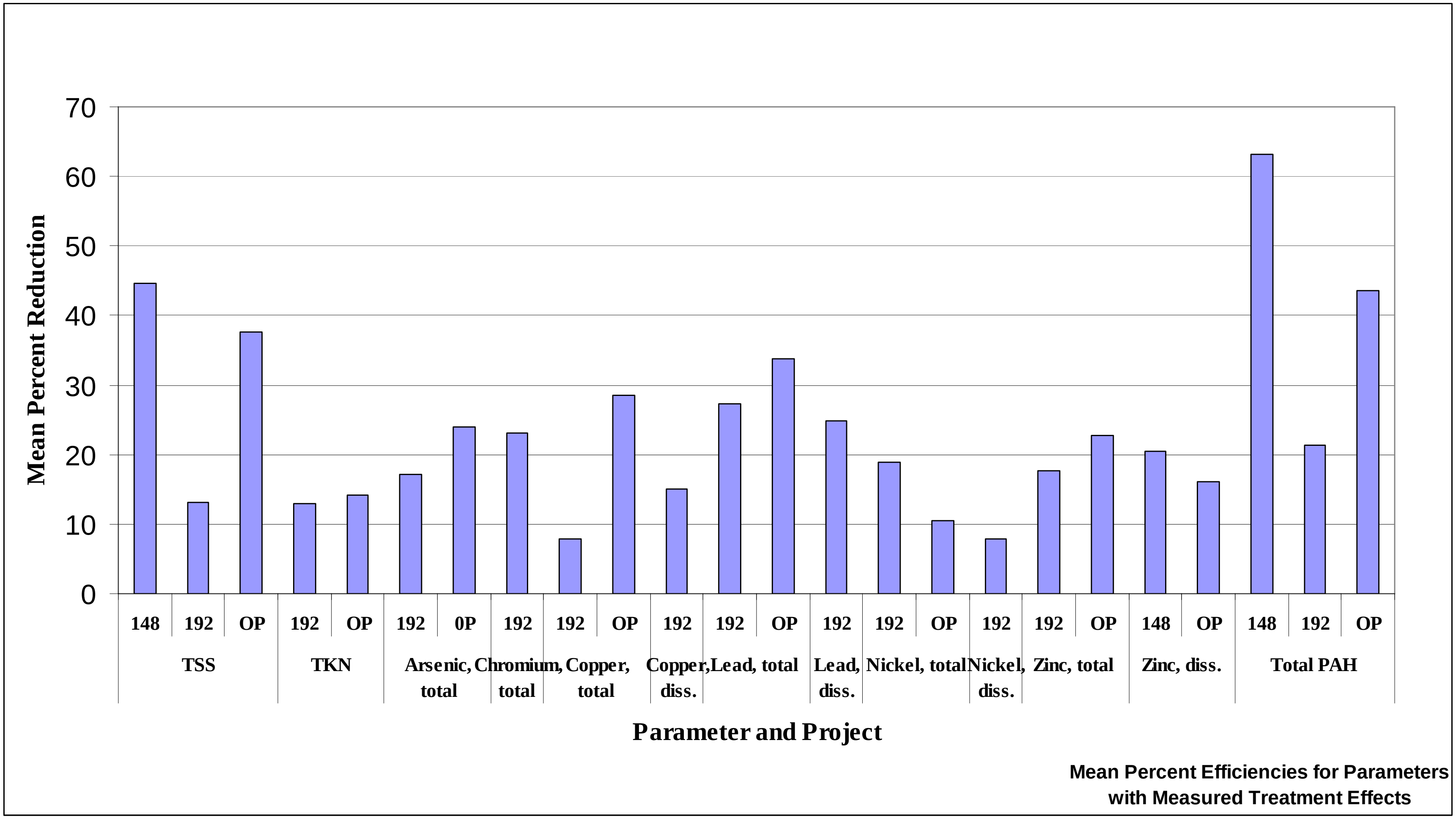


Figure 12. Percent Efficiencies for Parameters with Measured Treatment Effects

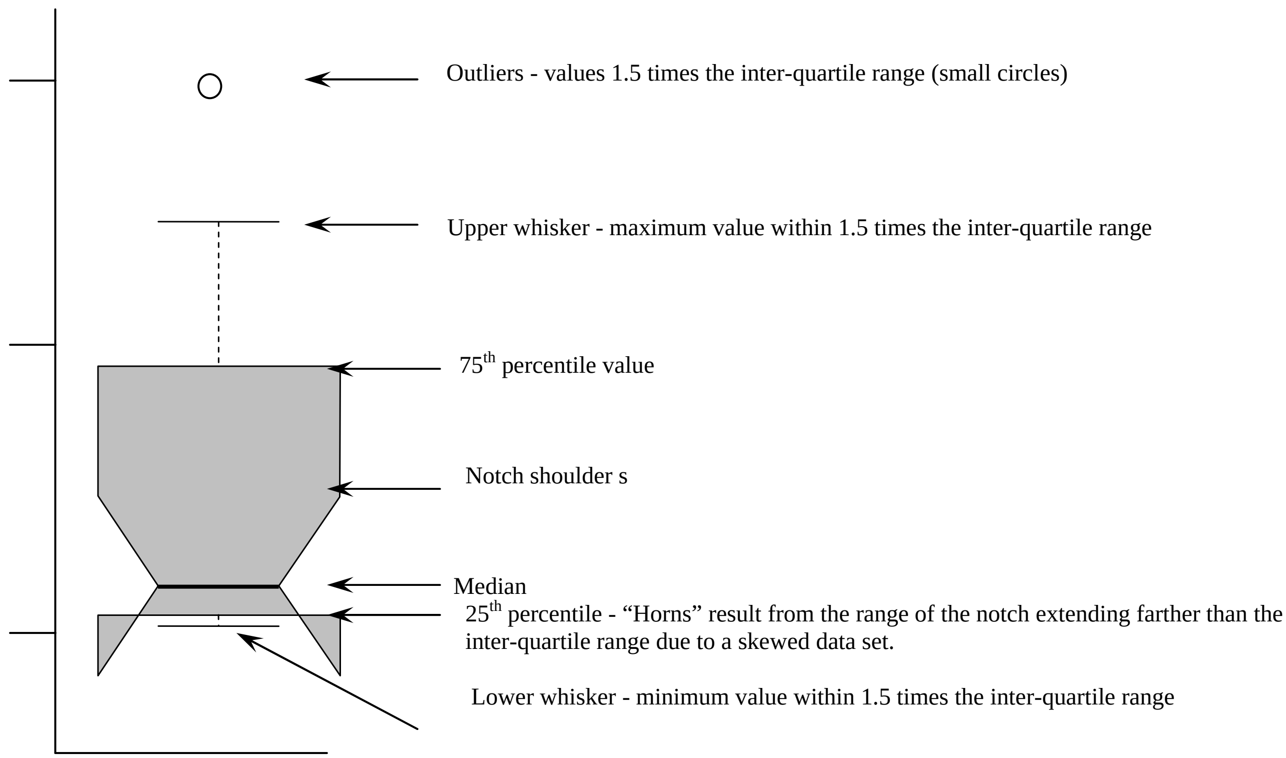


Figure 13. Notched Box Plot Example

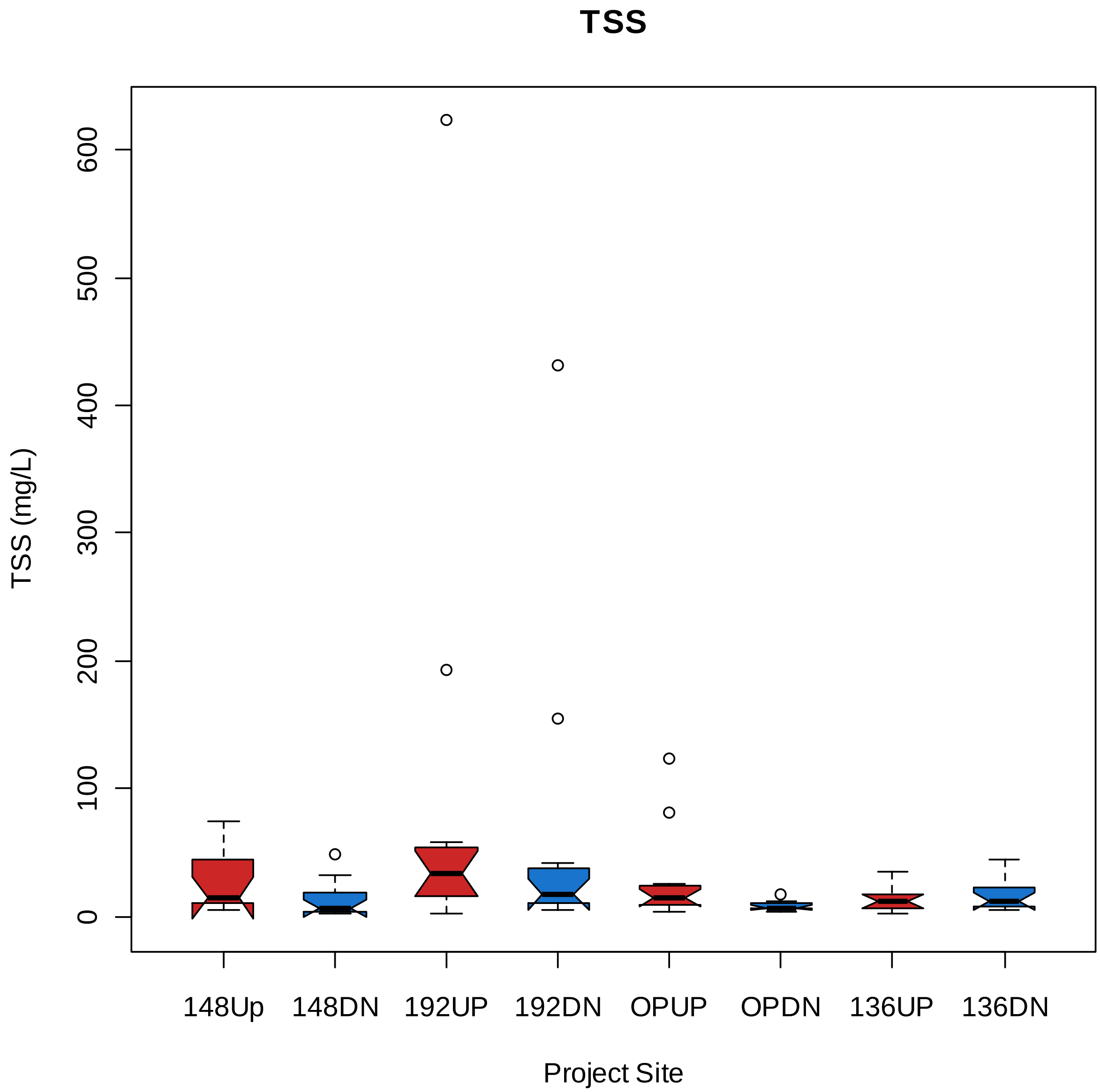


Figure 14A. TSS (mg/L)

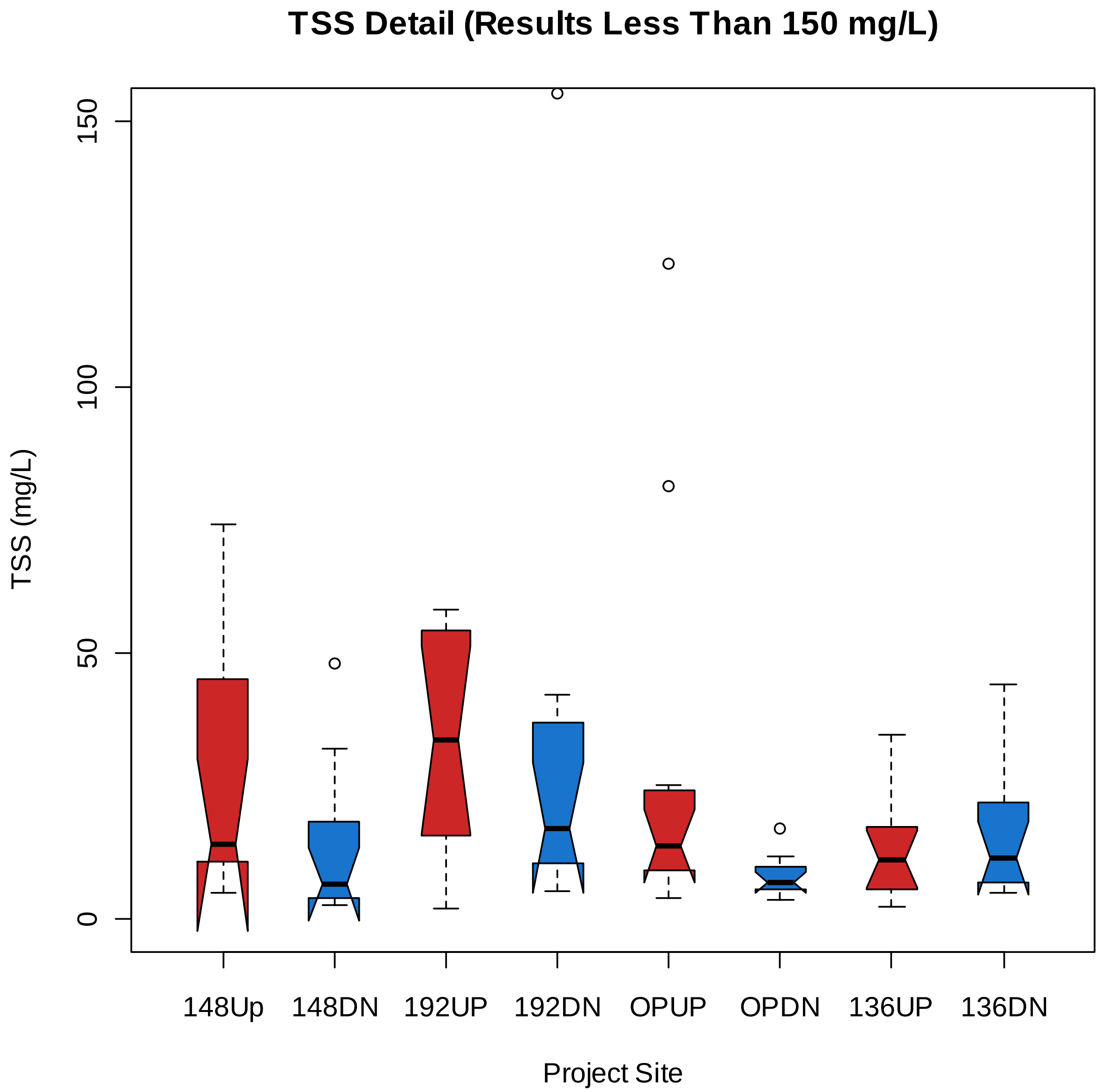


Figure 14B. TSS (mg/L) Detail. Outlier values greater than 150 mg/L are not shown in this figure.

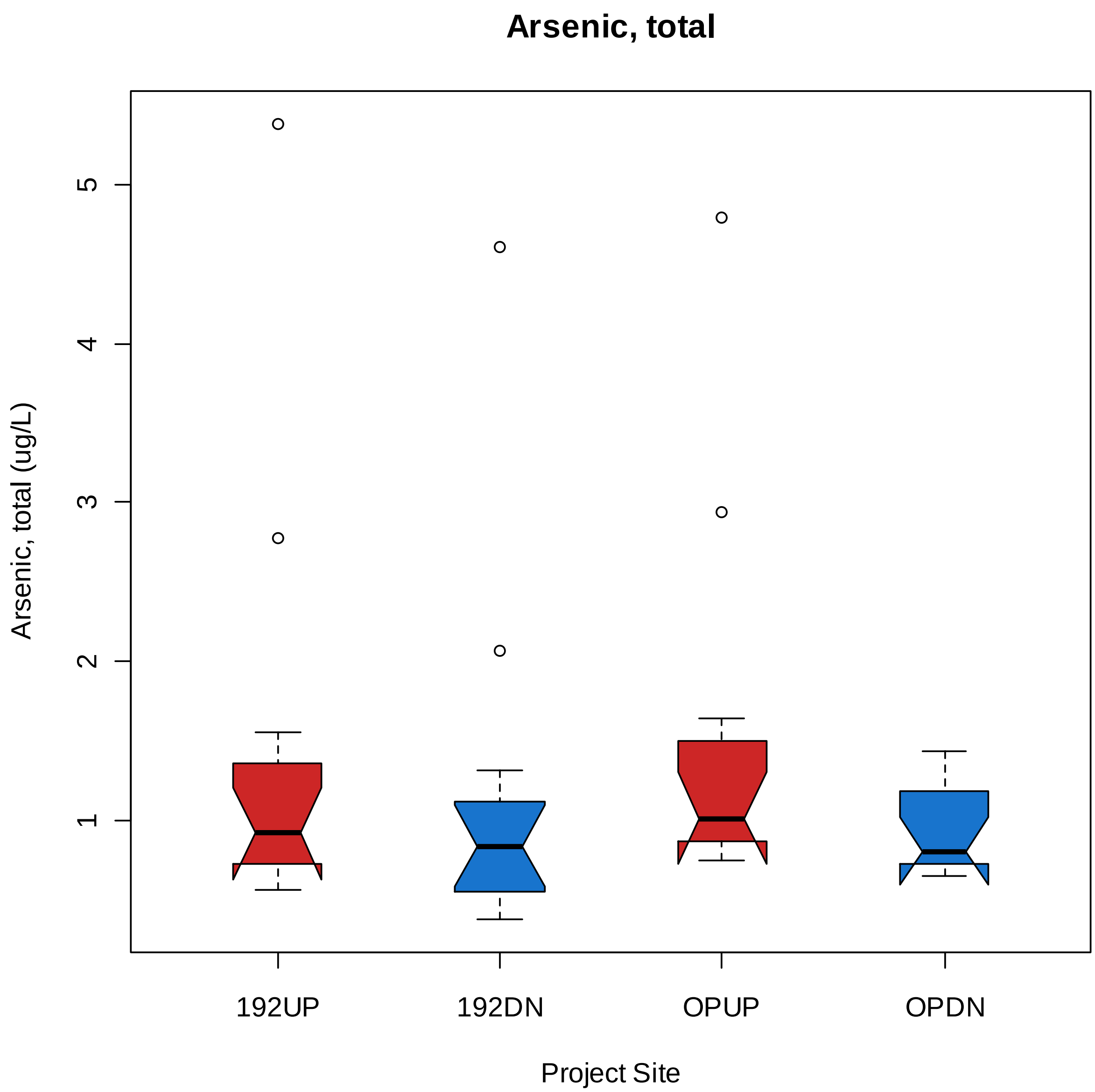


Figure 15. Arsenic, Total (ug/L)

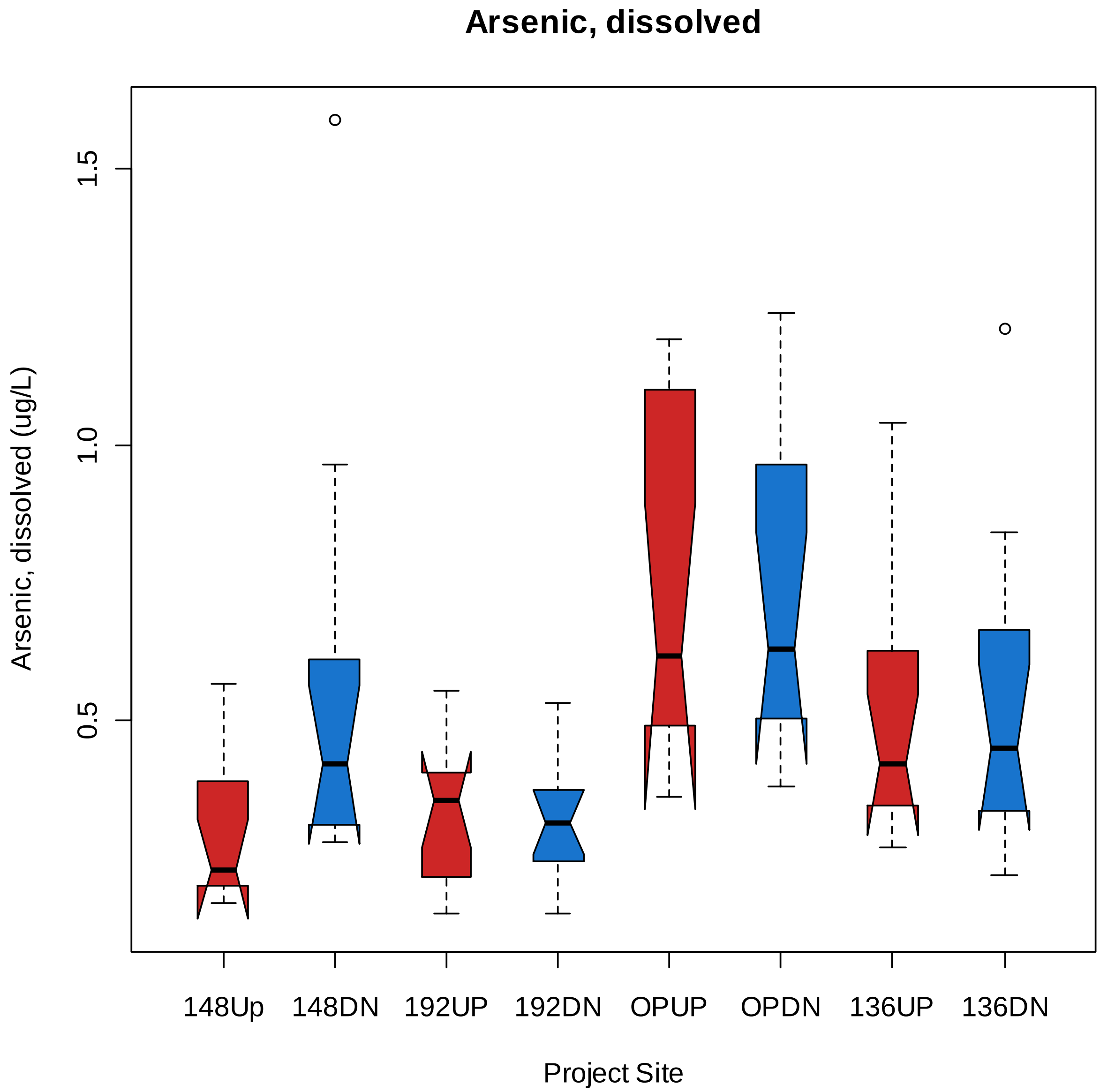


Figure 16. Arsenic, Dissolved (ug/L)

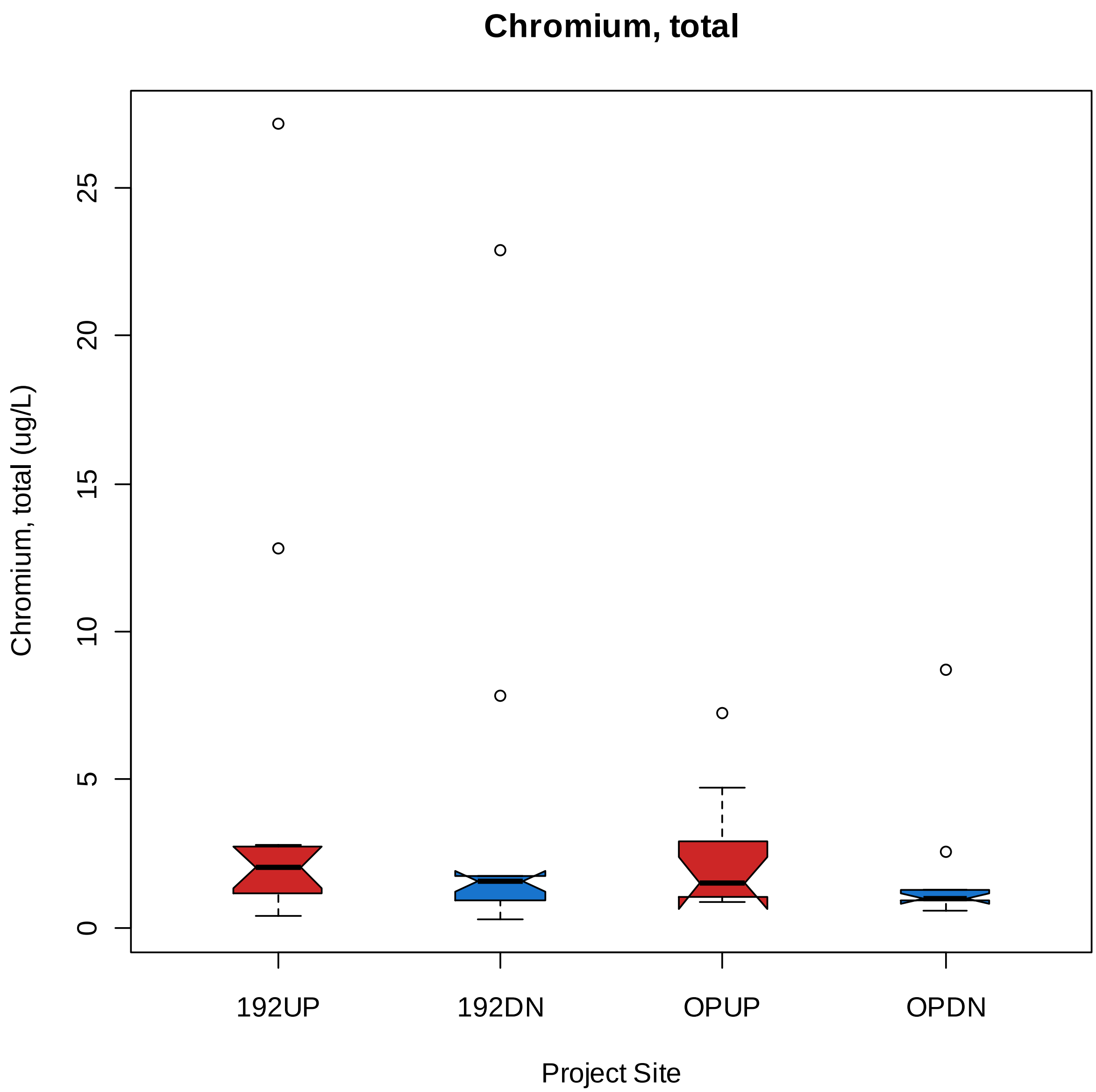


Figure 17. Chromium, total (ug/L)

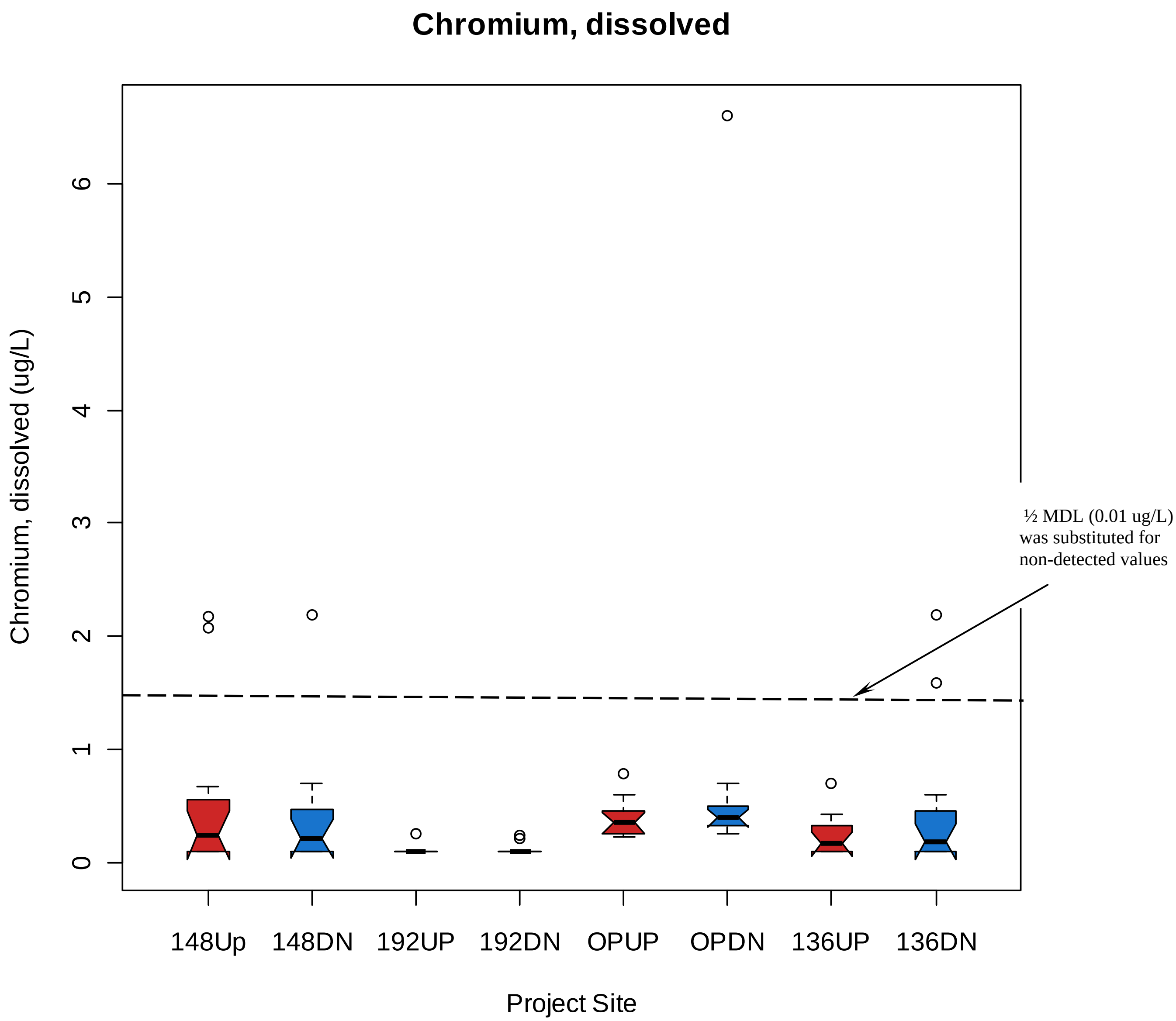


Figure 18. Chromium, dissolved (ug/L)

Chromium, dissolved results include values reported as below the MDL of 0.2 ug/L. This graphic was prepared using one-half of the MDL as a placeholder for these <MDL values.

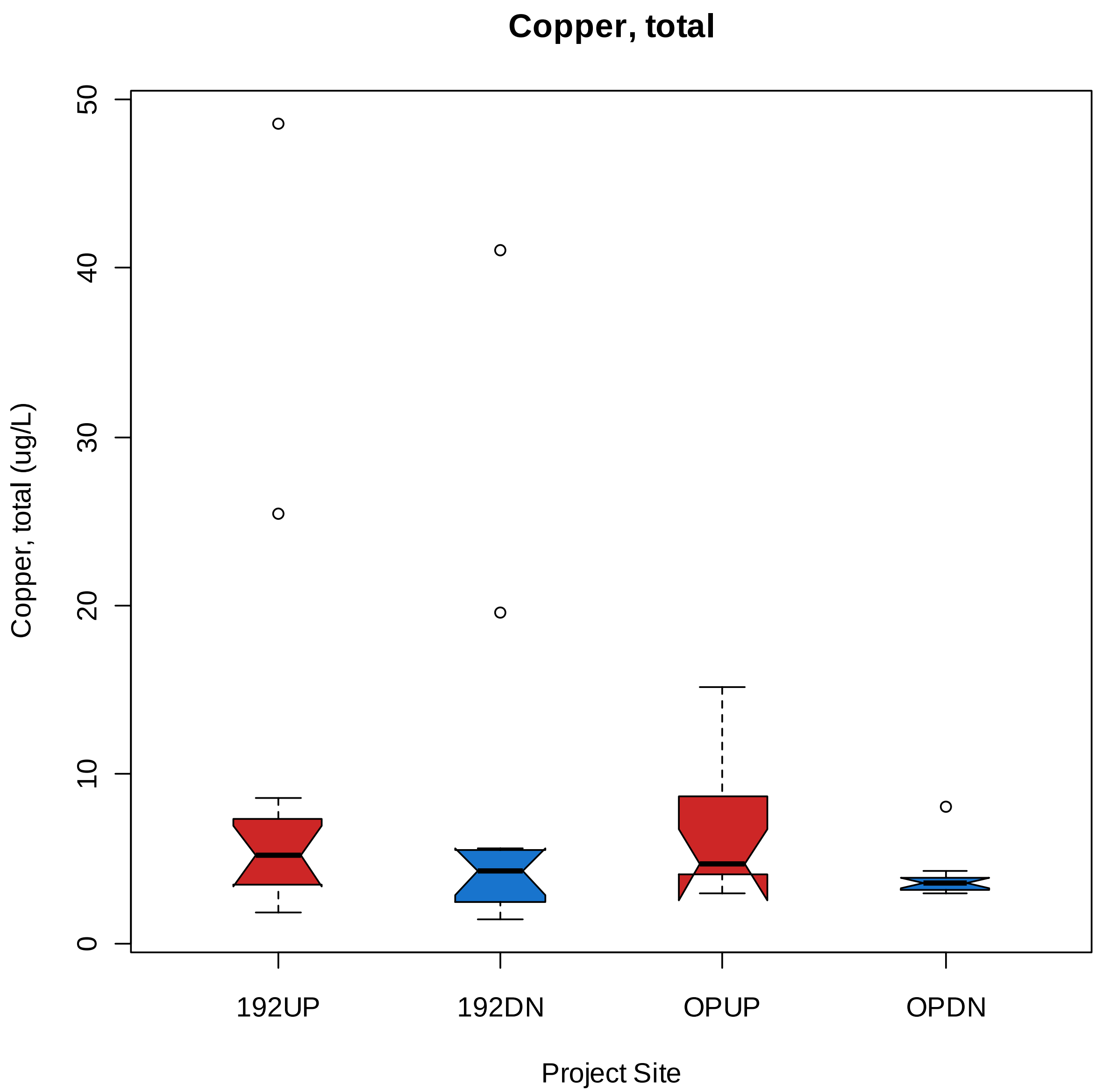


Figure 19. Copper, total (ug/L)

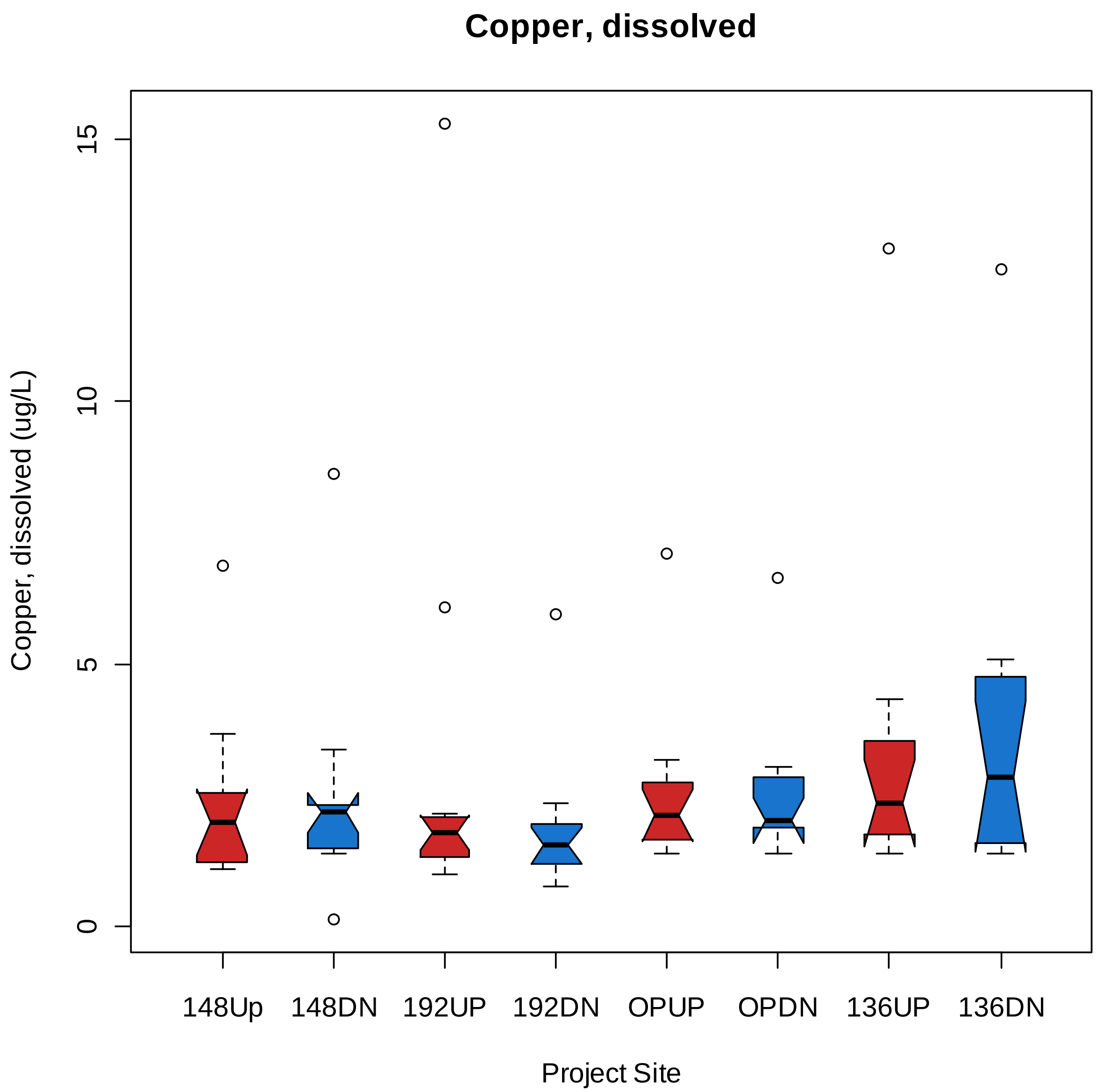


Figure 20. Copper, dissolved (ug/L)

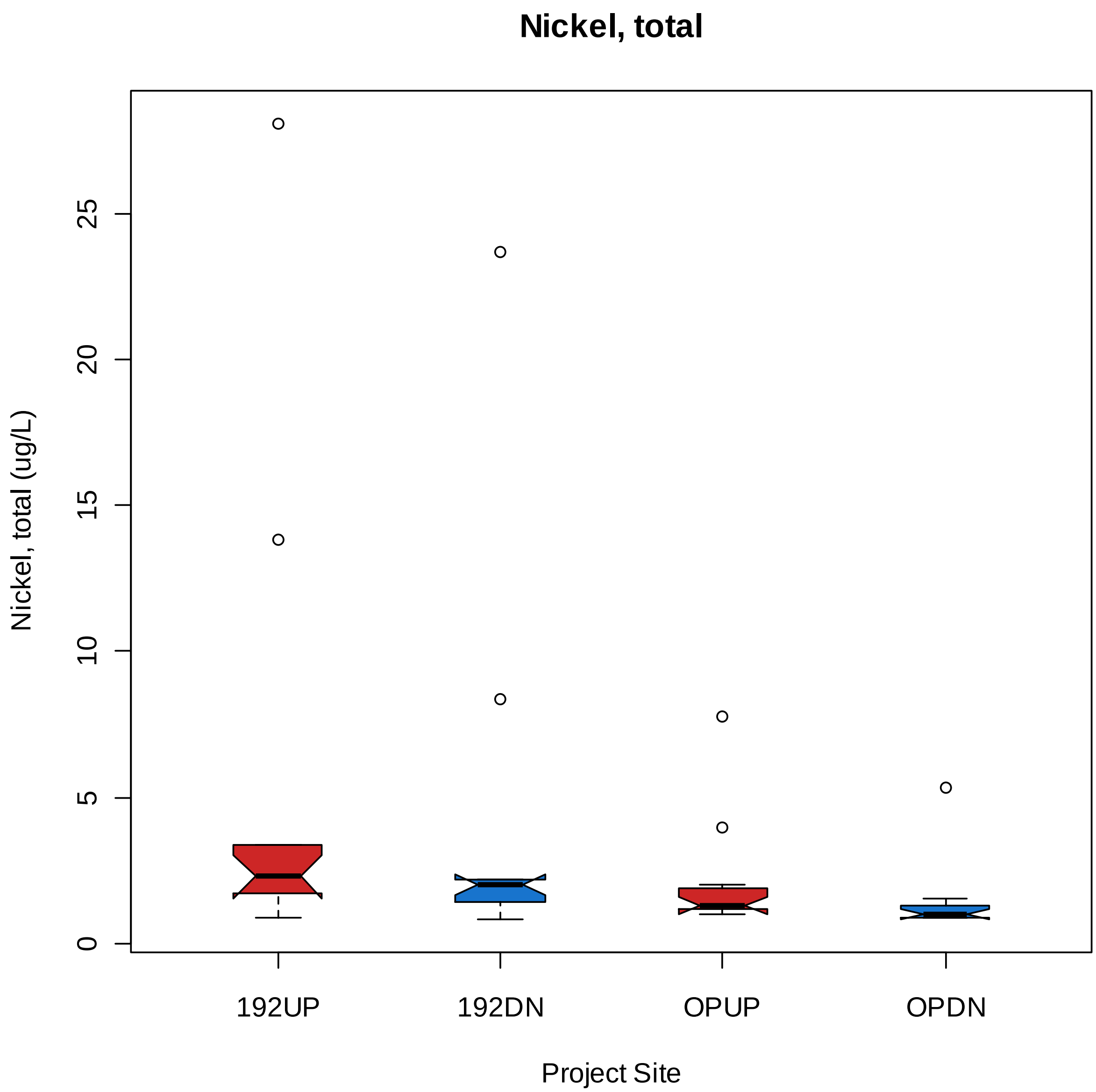


Figure 21. Nickel, total (ug/L)

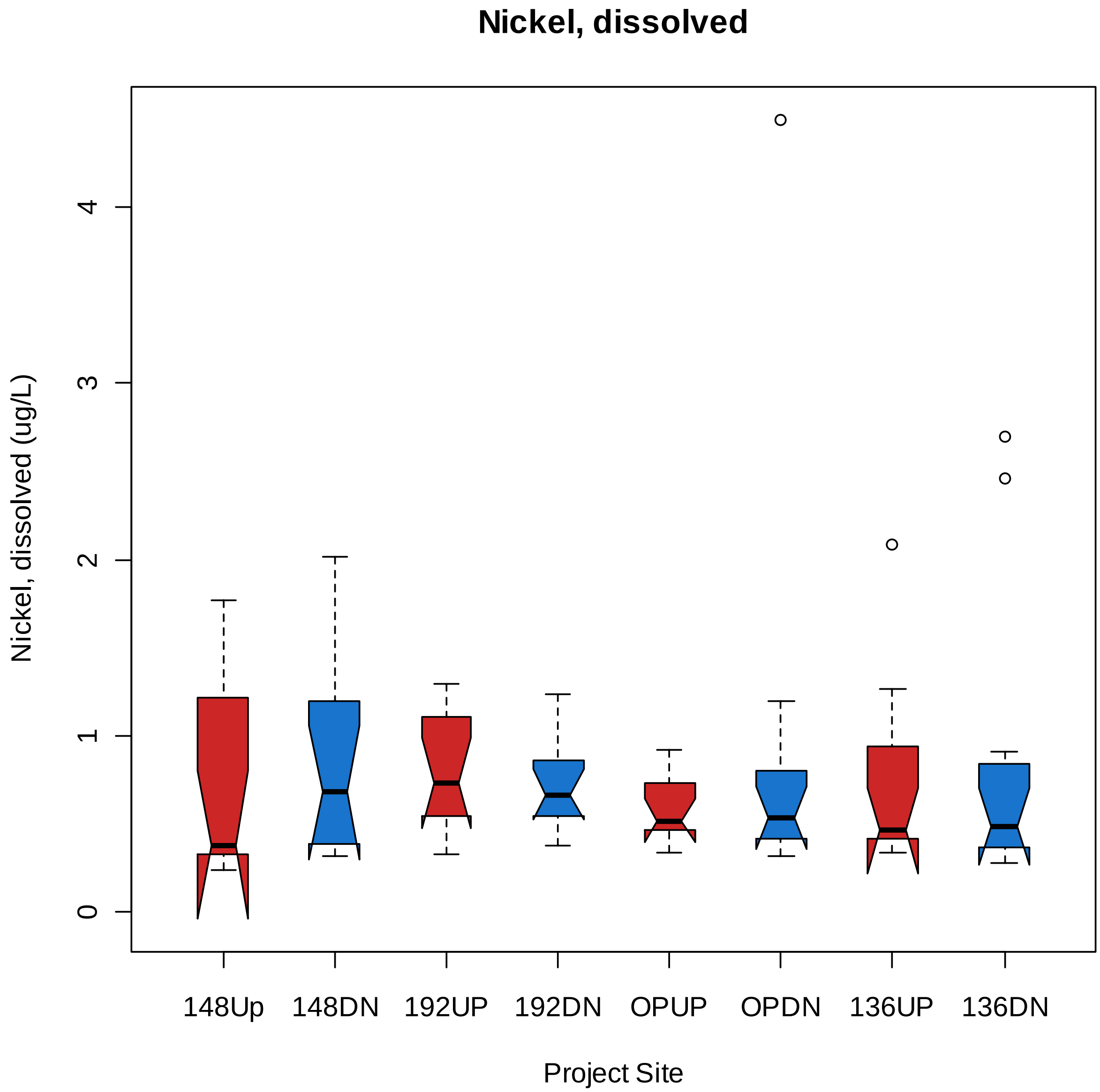


Figure 22. Nickel, dissolved (ug/L)

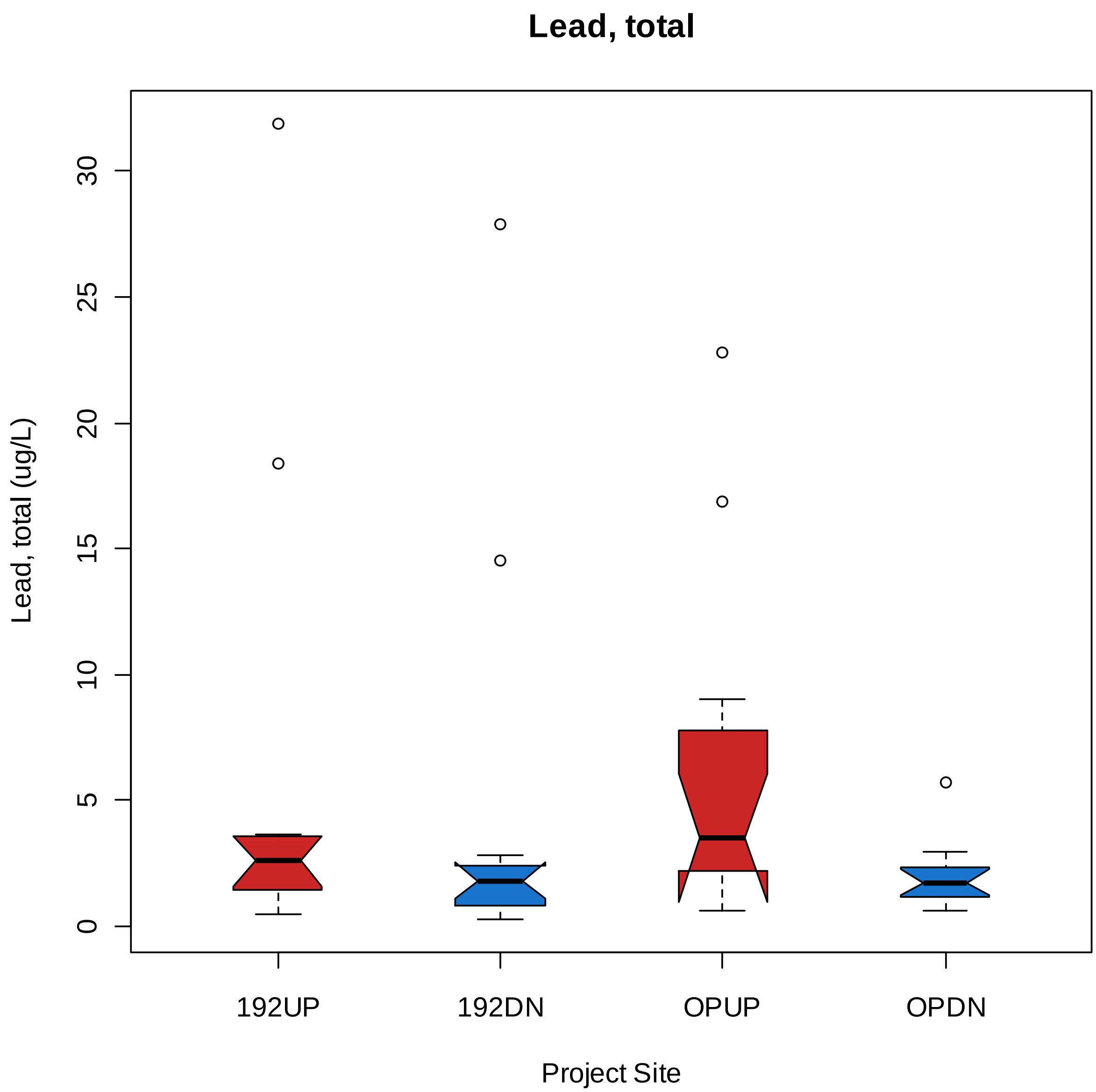


Figure 23. Lead, total (ug/L)

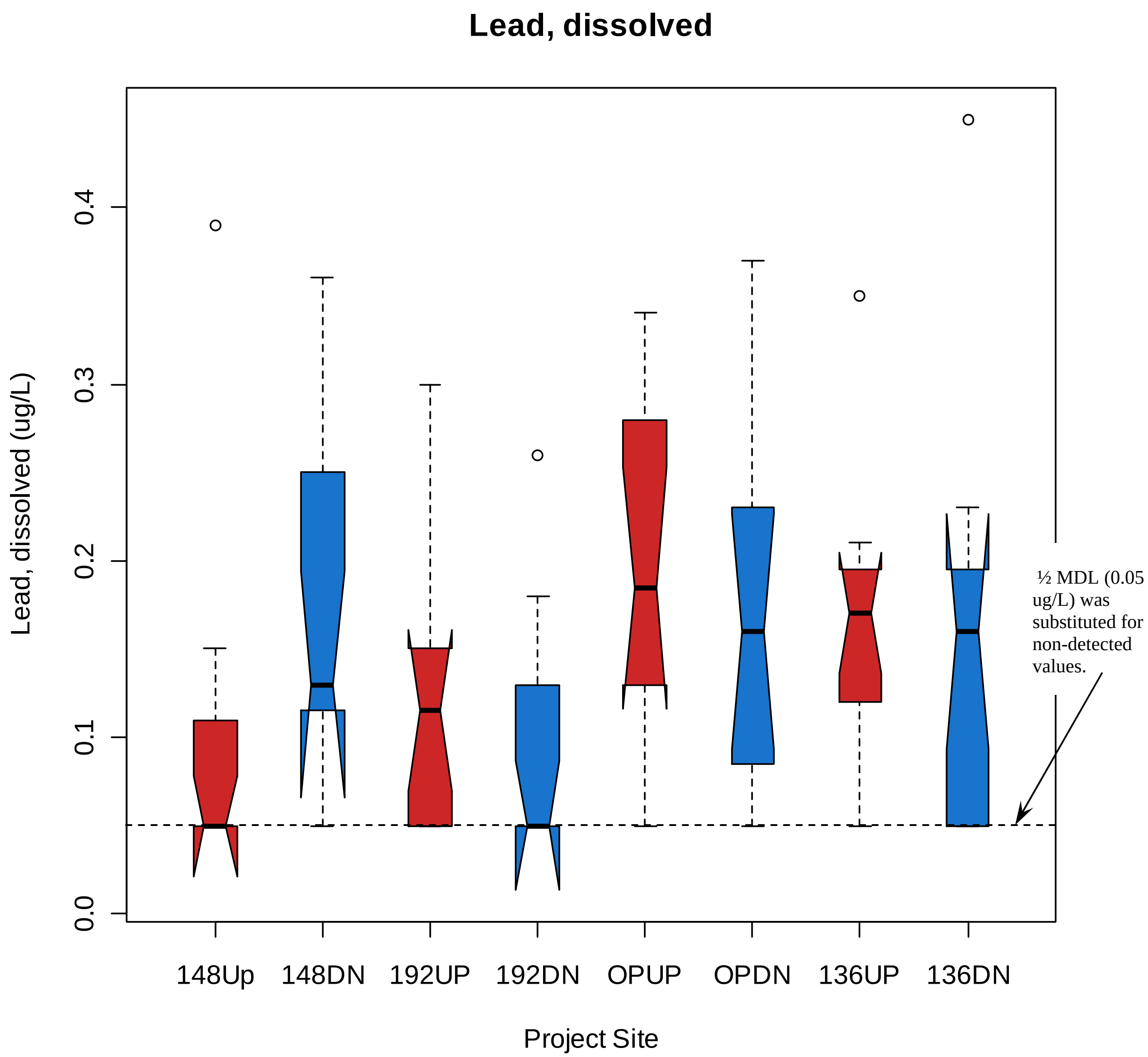


Figure 24. Lead, dissolved (ug/L)

Lead, dissolved results include values reported at below the MDL of 0.1 ug/L. This graphic was prepared using one-half of the MDL (0.05 ug/L) as a placeholder for these <MDL values.

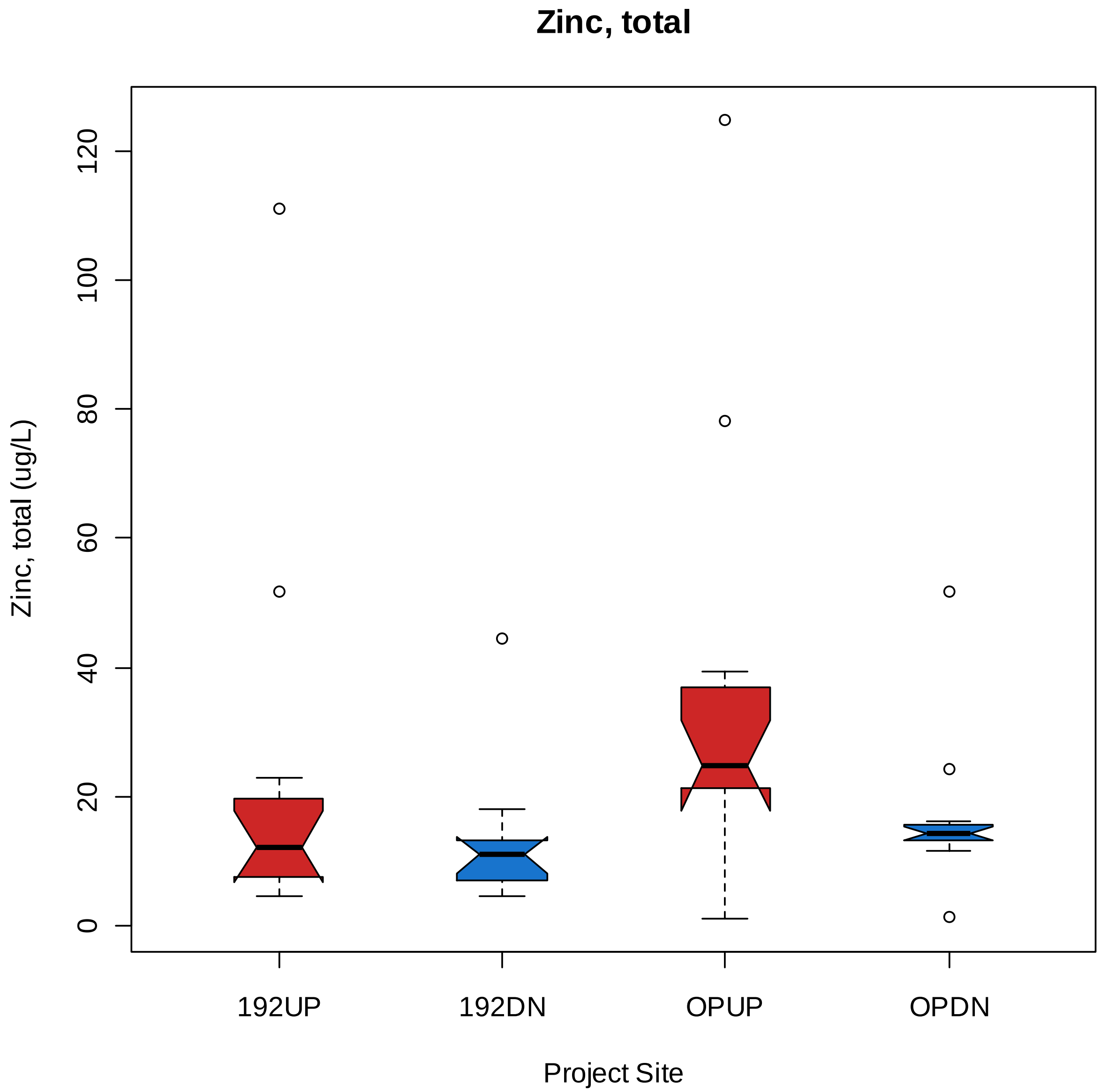


Figure 25. Zinc, total (ug/L)

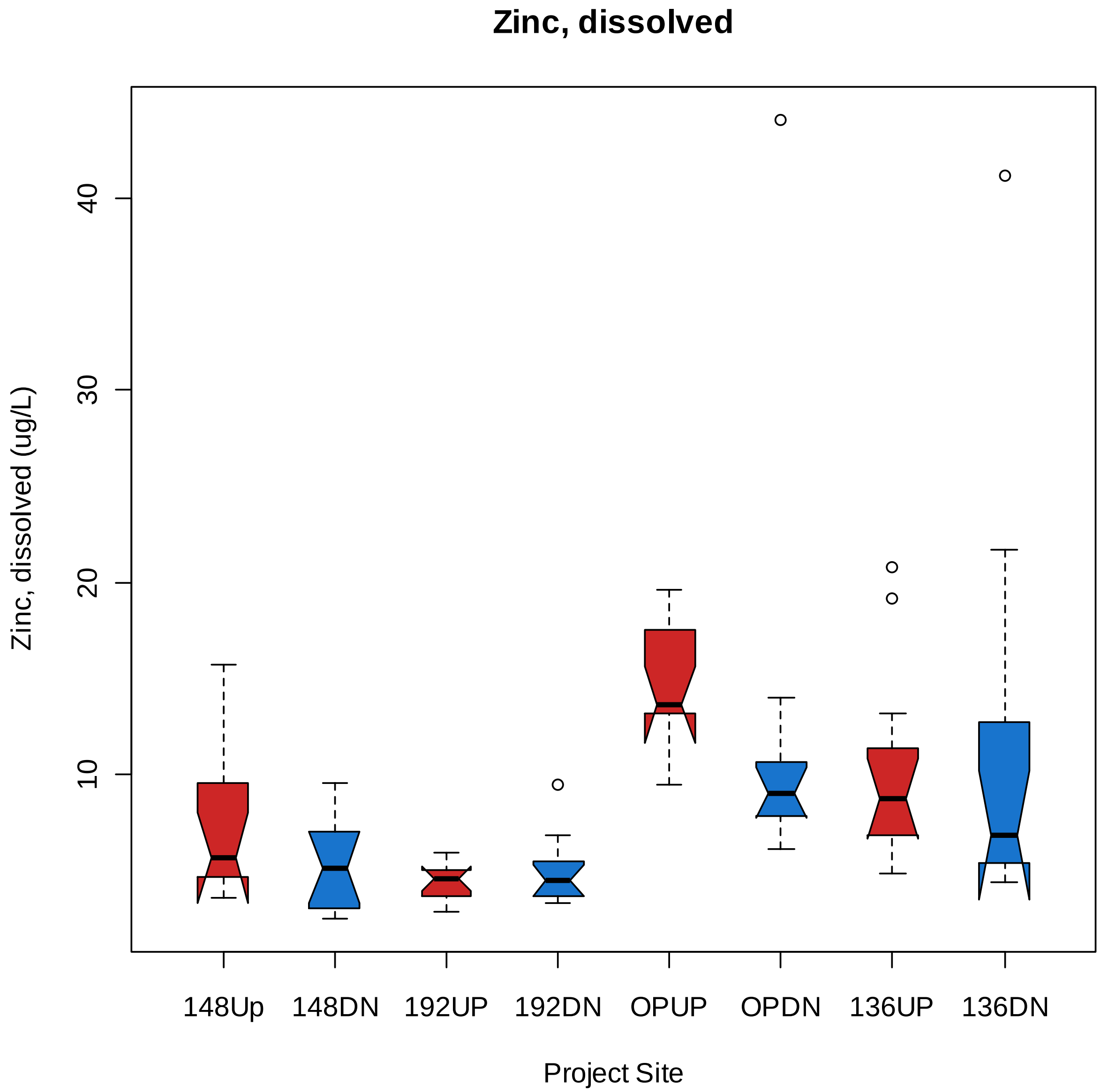


Figure 26. Zinc, dissolved (ug/L)

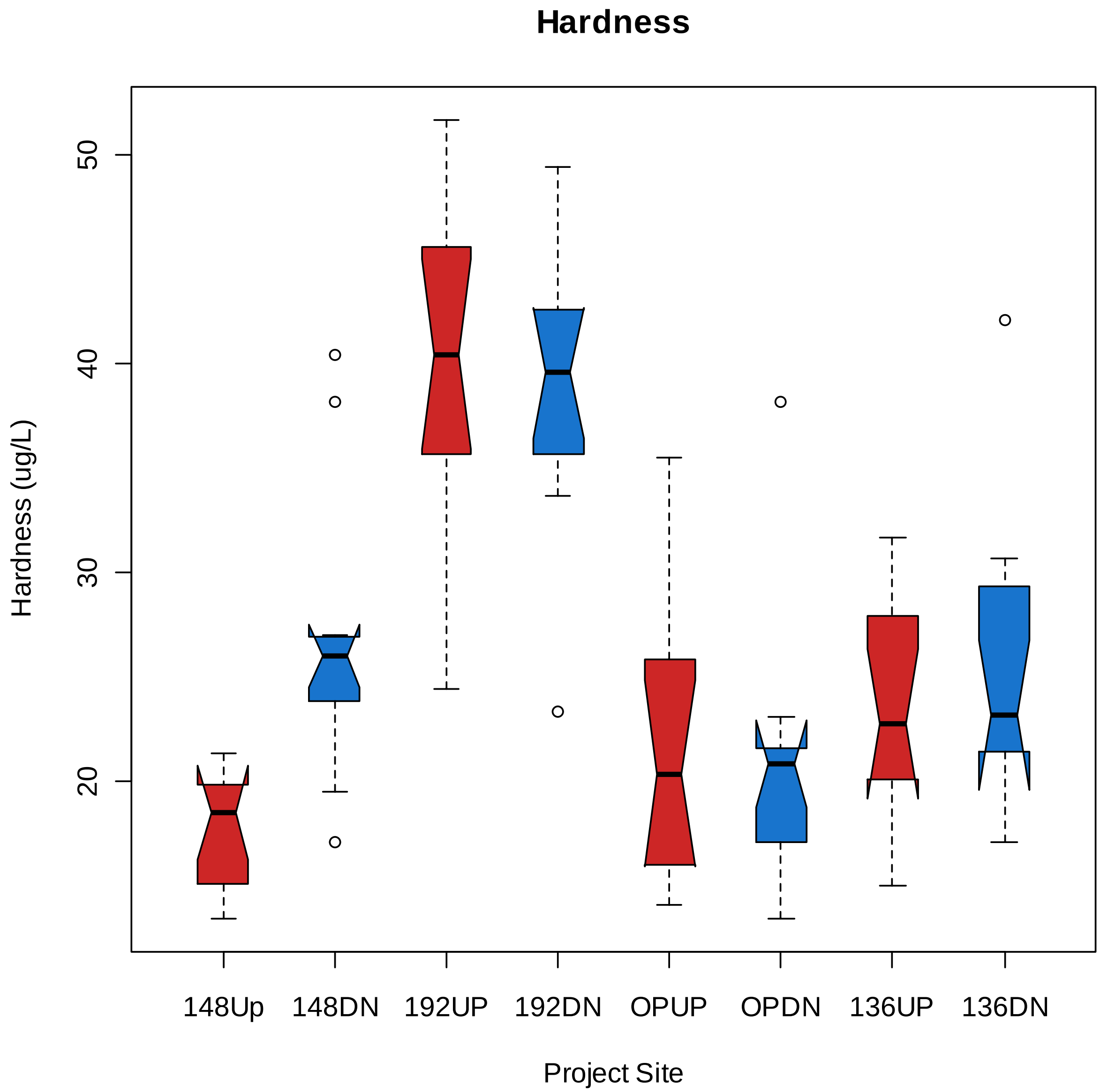


Figure 27. Hardness (mg/L)

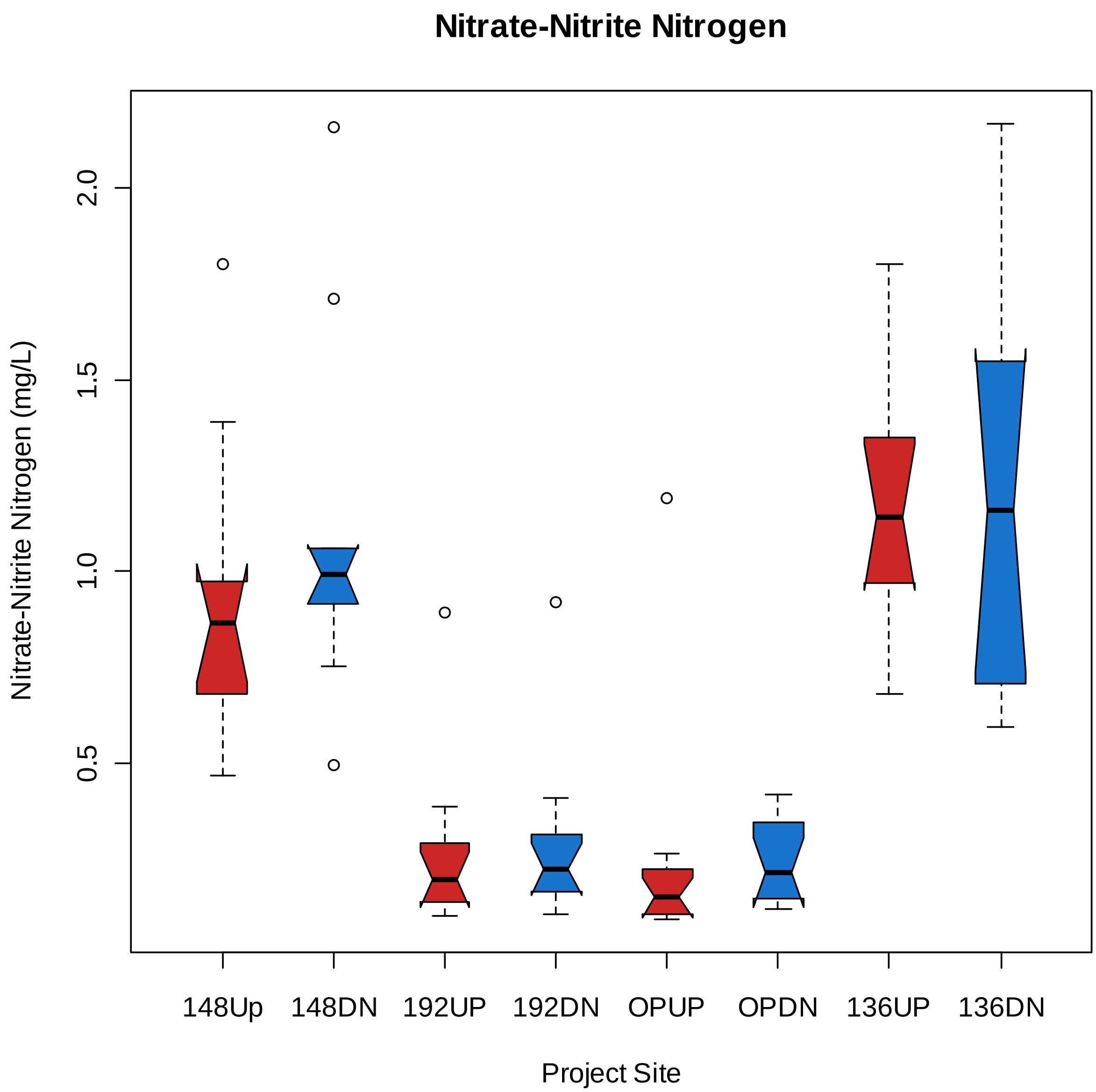


Figure 28. Nitrate-Nitrite Nitrogen (mg/L)

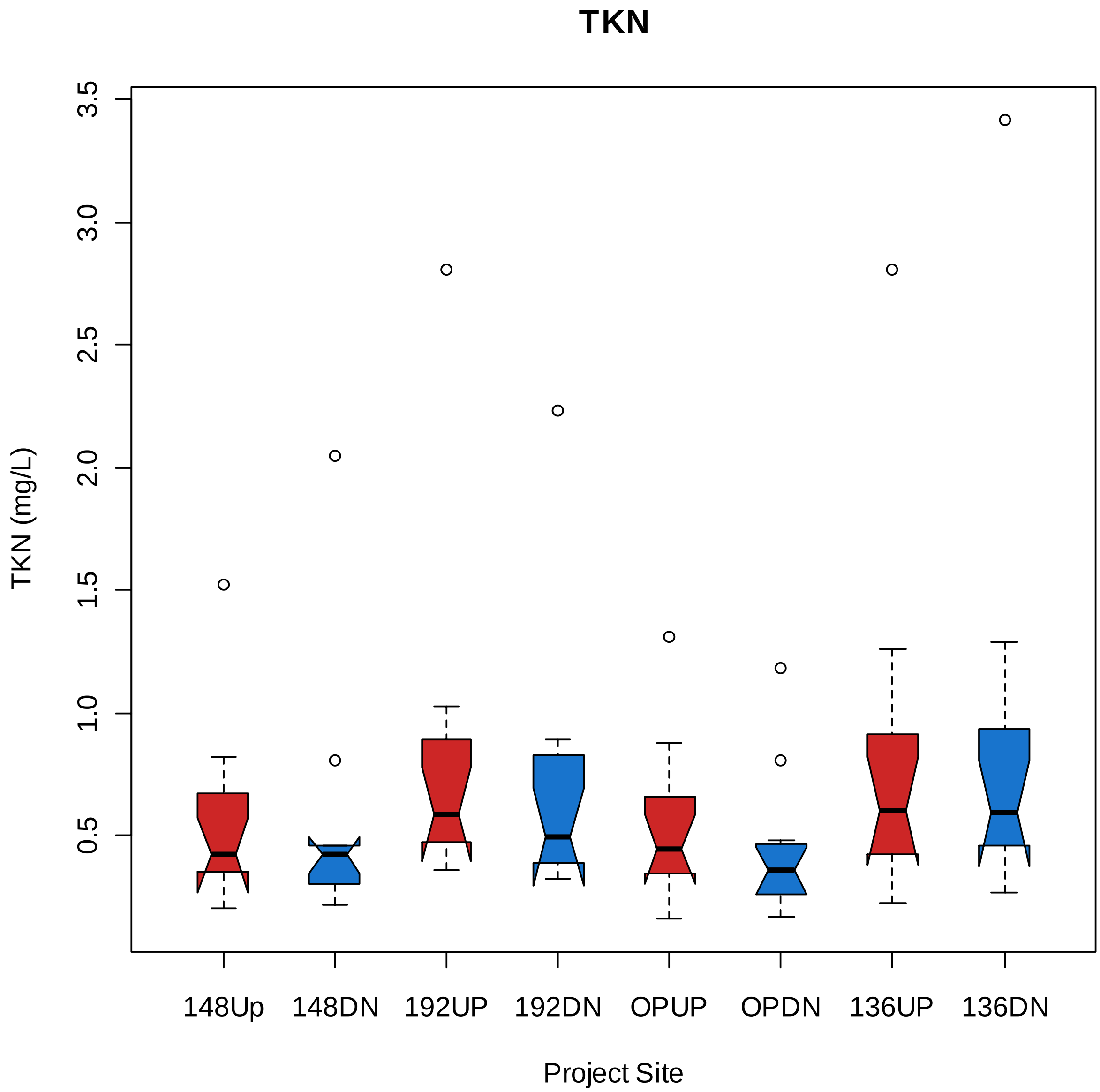


Figure 29. TKN (mg/L)

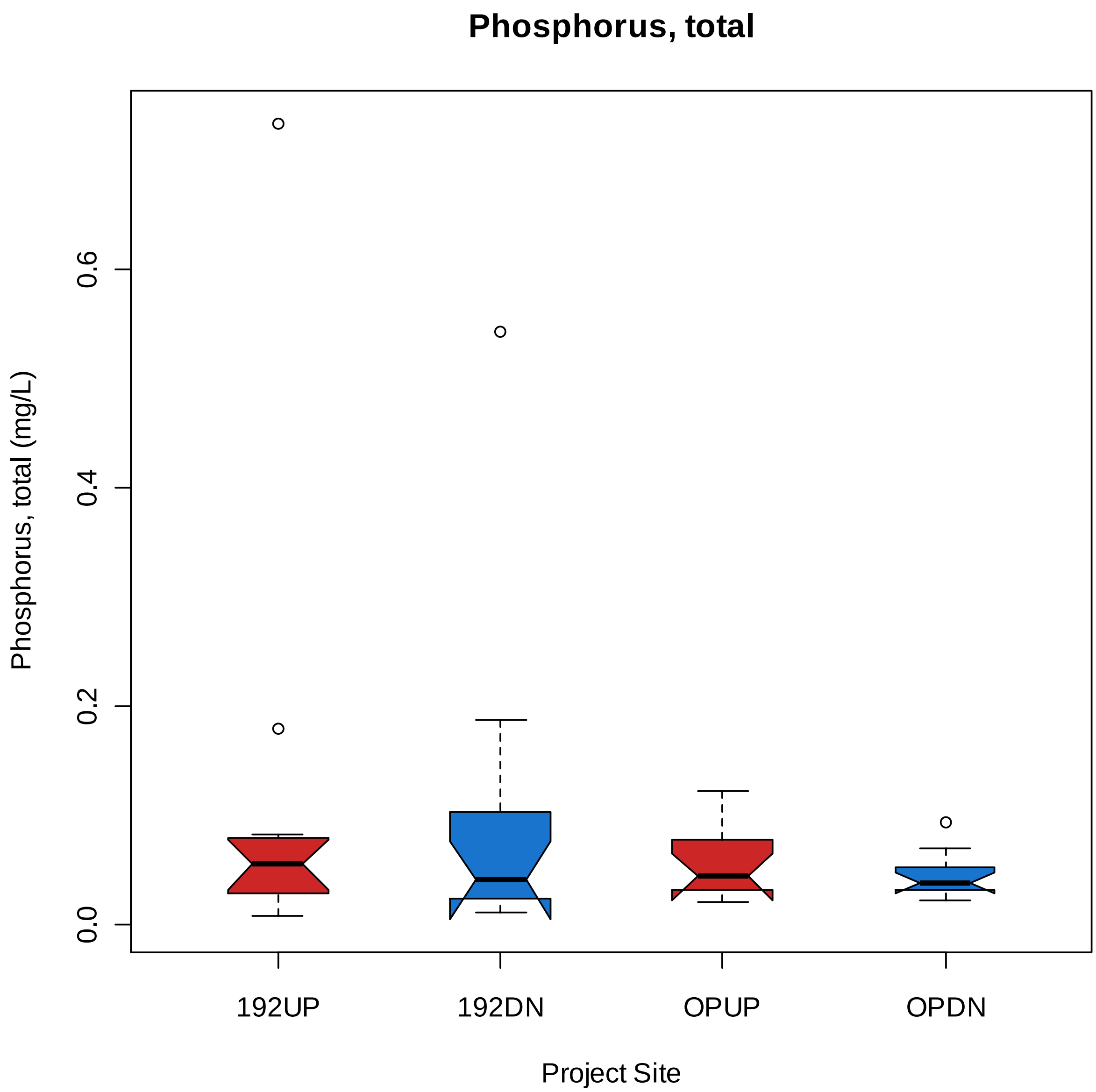


Figure 30. Phosphorous, total (mg/L)

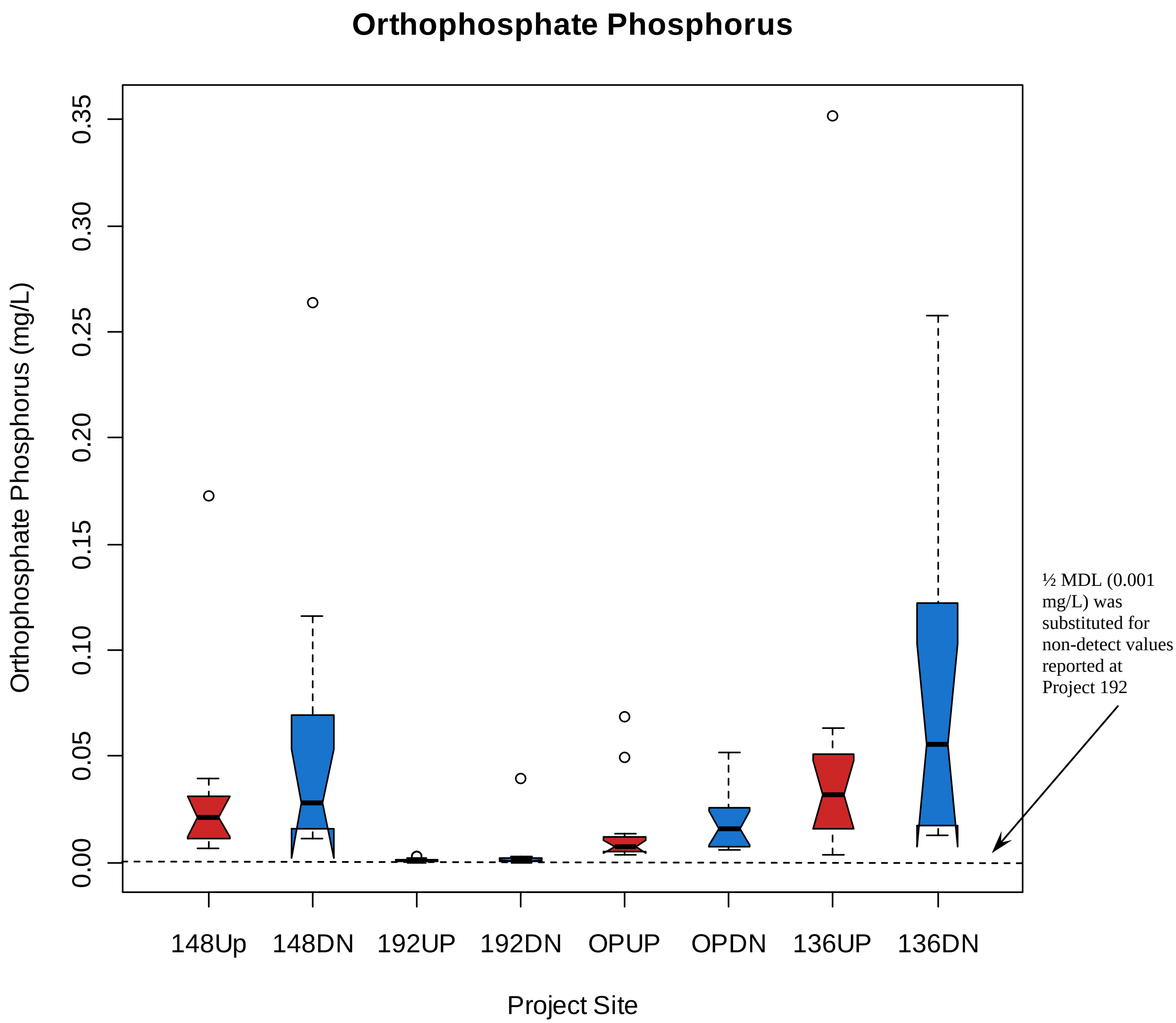


Figure 31. Orthophosphate phosphorus (mg/L)

Orthophosphate phosphorous results for Project 192 include values reported as below the MDL of 0.002 mg/L. A substitution of 0.001mg/L (1/2 the MDL) was used for values at Project192 reported as <MDL.

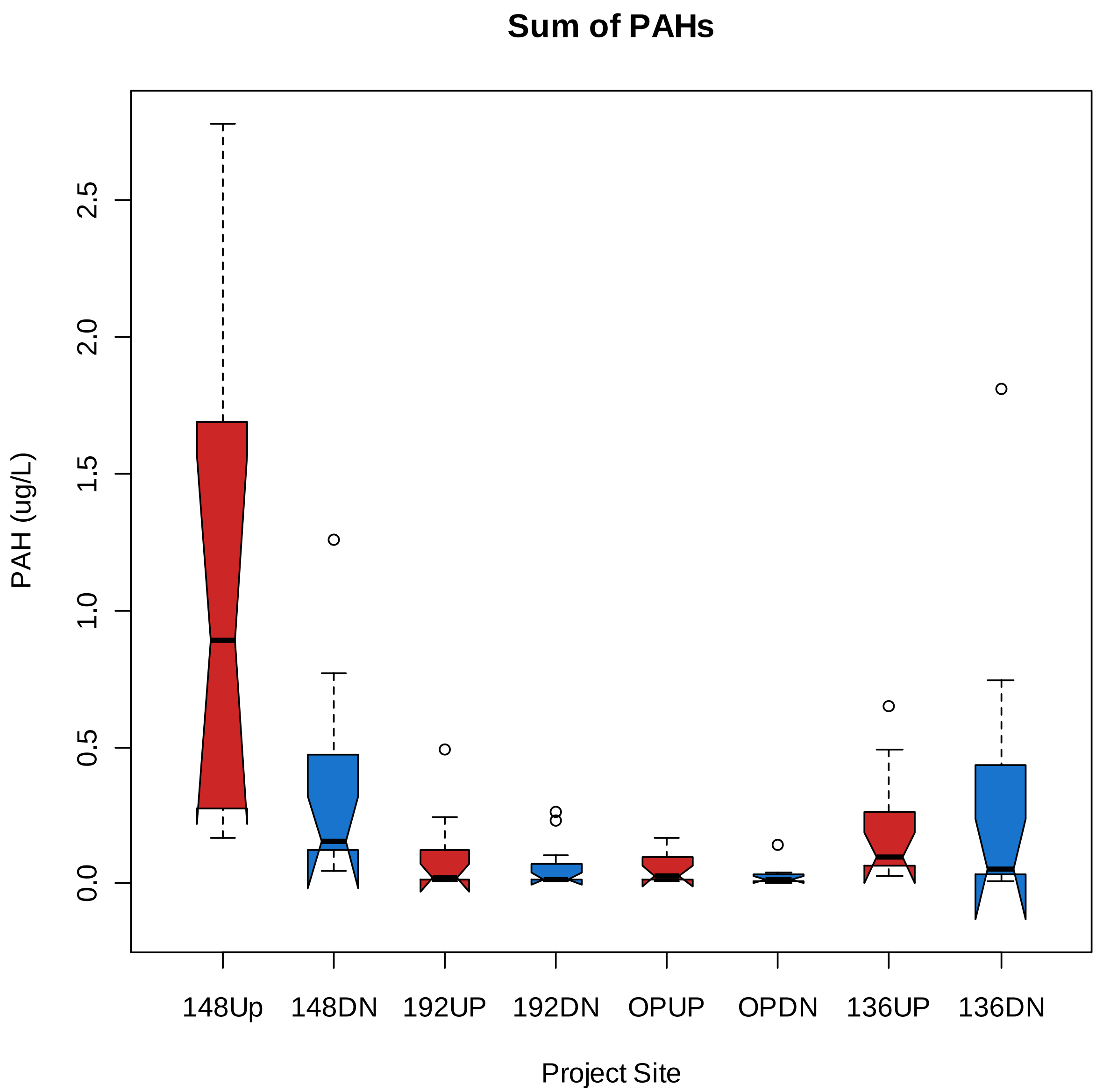


Figure 32. Sum of PAHs (ug/L)

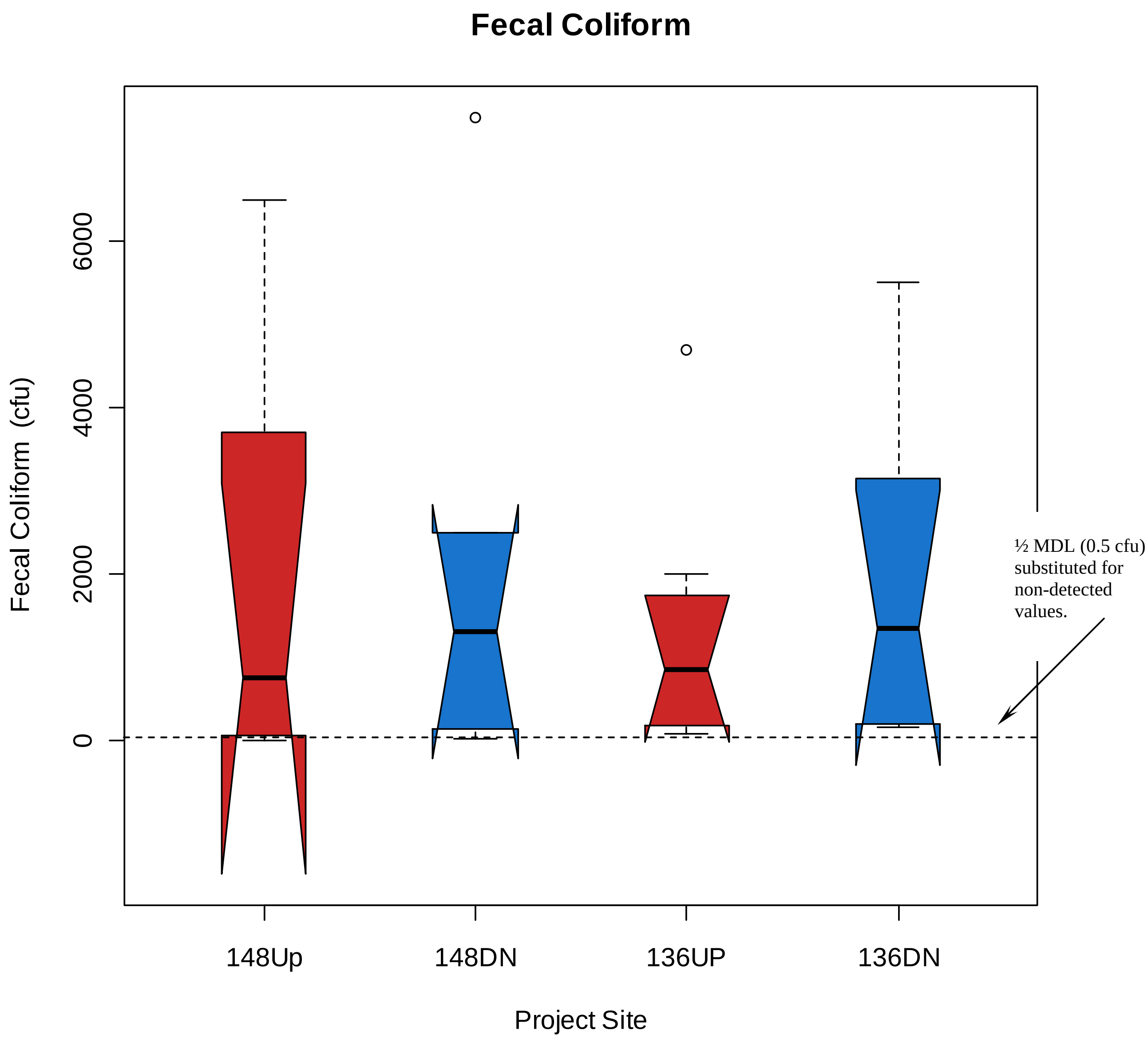


Figure 33. Fecal coliform (cfu)

Fecal coliform results include values reported as below the MDL of 1 cfu A substitution of 1/2 the MDL (0.5 cfu) was used for values at reported at <MDL.

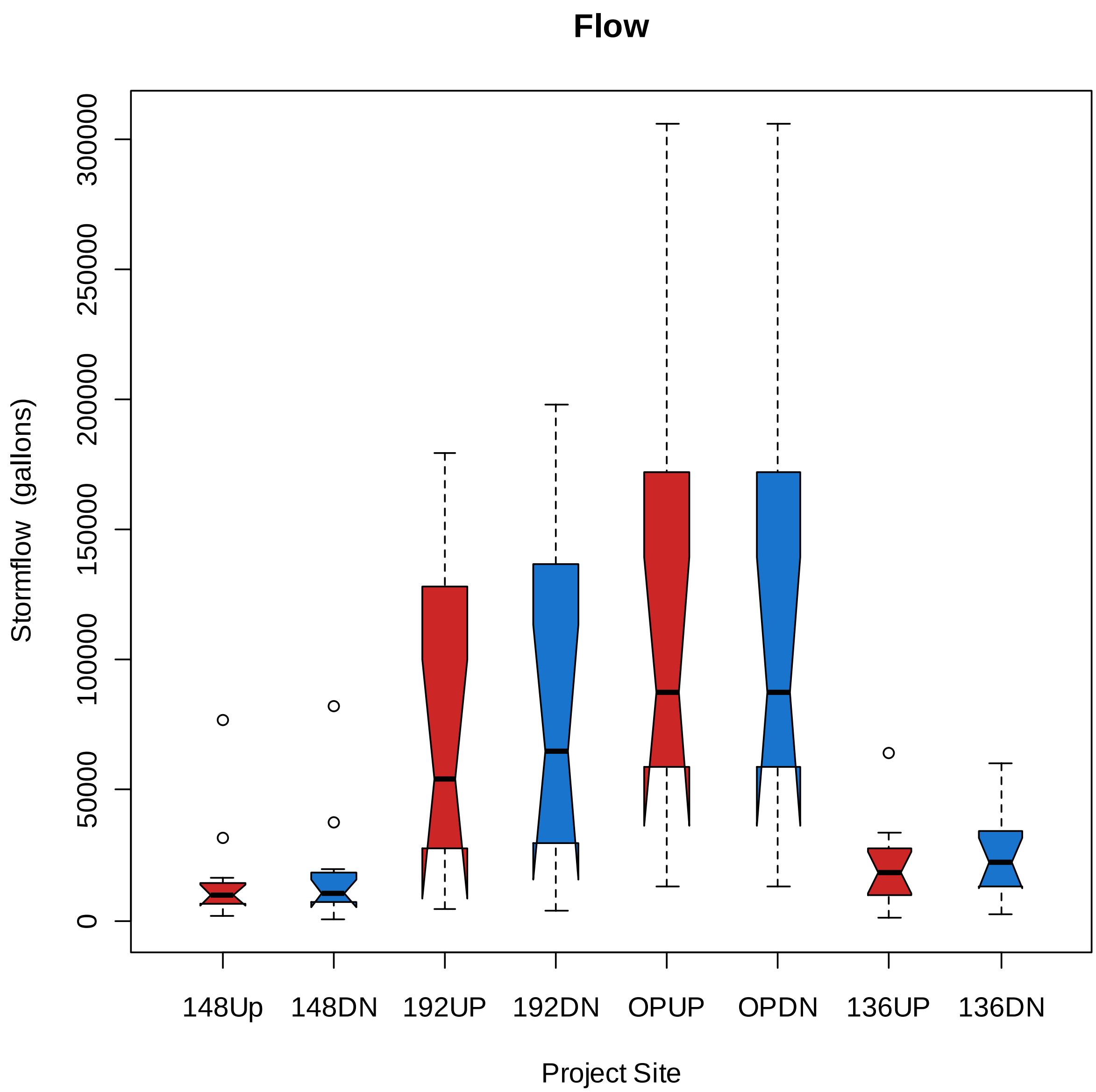


Figure 34. Total Flow During Sampled Storm Events

Box plots demonstrate the range of flows during sampled storm events and provide a comparison of influent to effluent flow during those events. This figure demonstrates the increased downstream flows typical of sampling biased to wet-season storm events where most of the successful sampling events occurred. These flows are not representative of the dry season influent/effluent flow regimes at the ditch project sites.

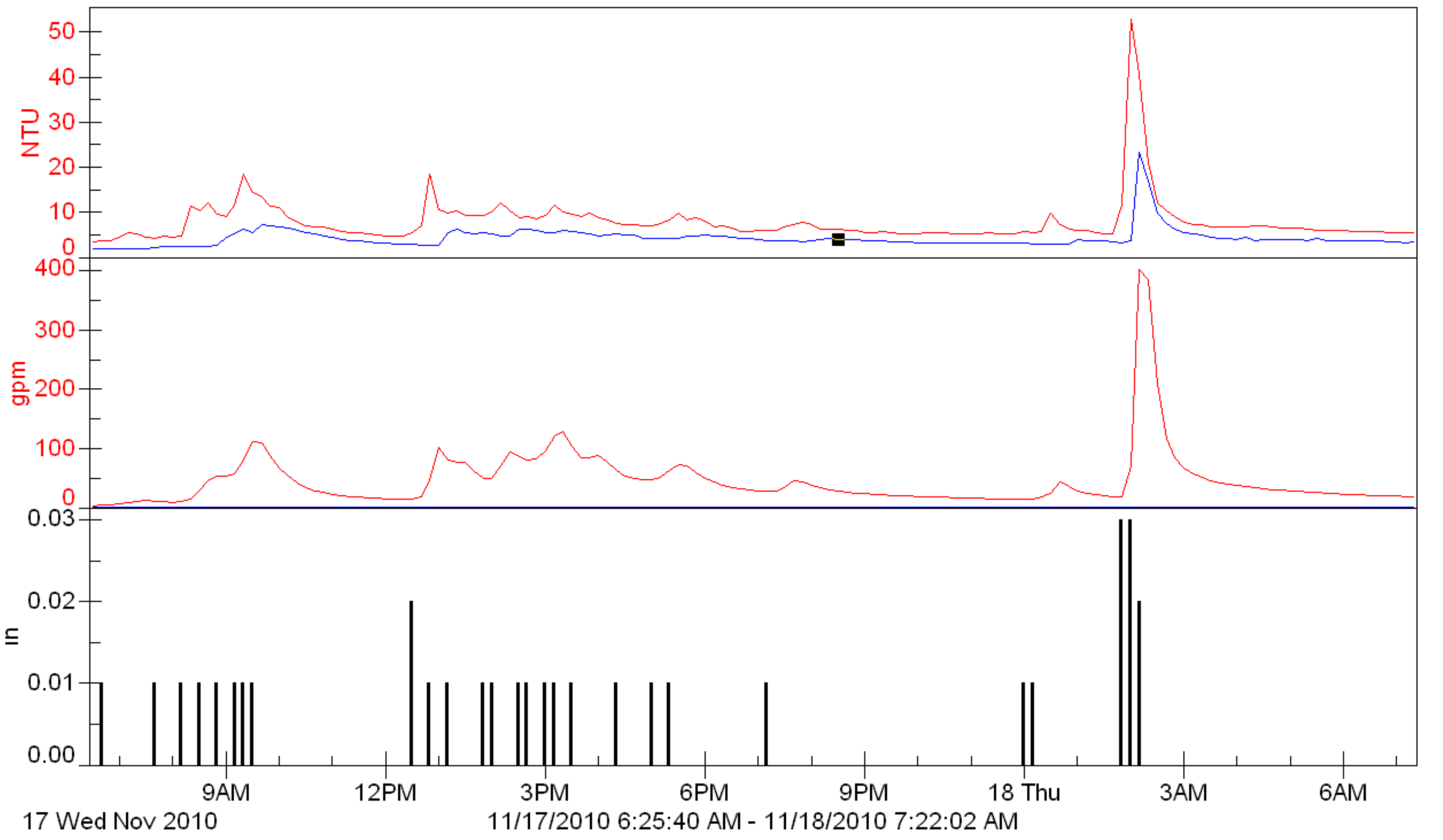


Figure 35. Turbidity, Flow and Rainfall, Project OP November 17, 2010

Red line = Influent

Blue Line = Effluent

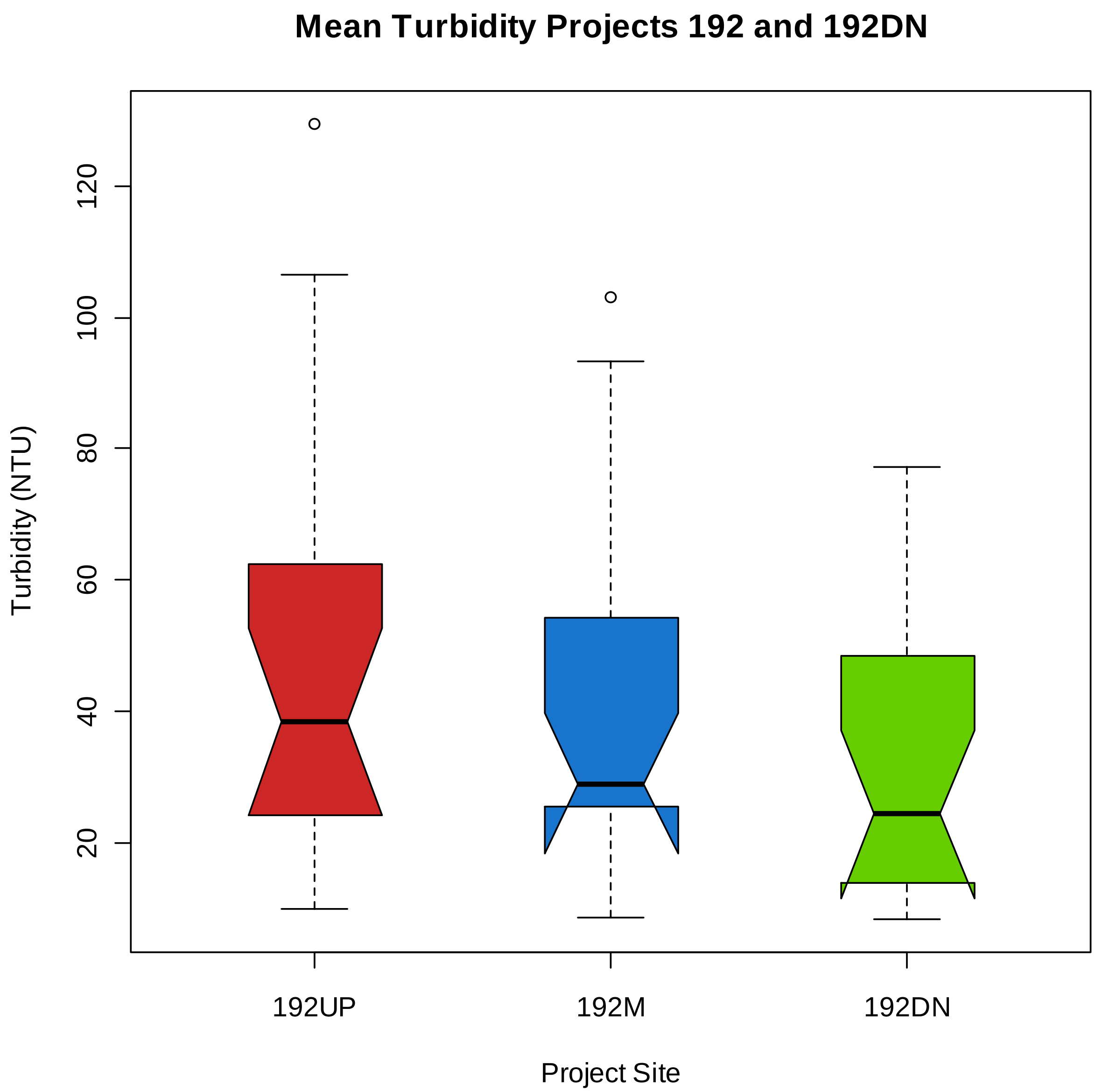


Figure 36. Mean Turbidity at Water Quality Project 192 and Flow Control Project 192DN (continuous monitoring)

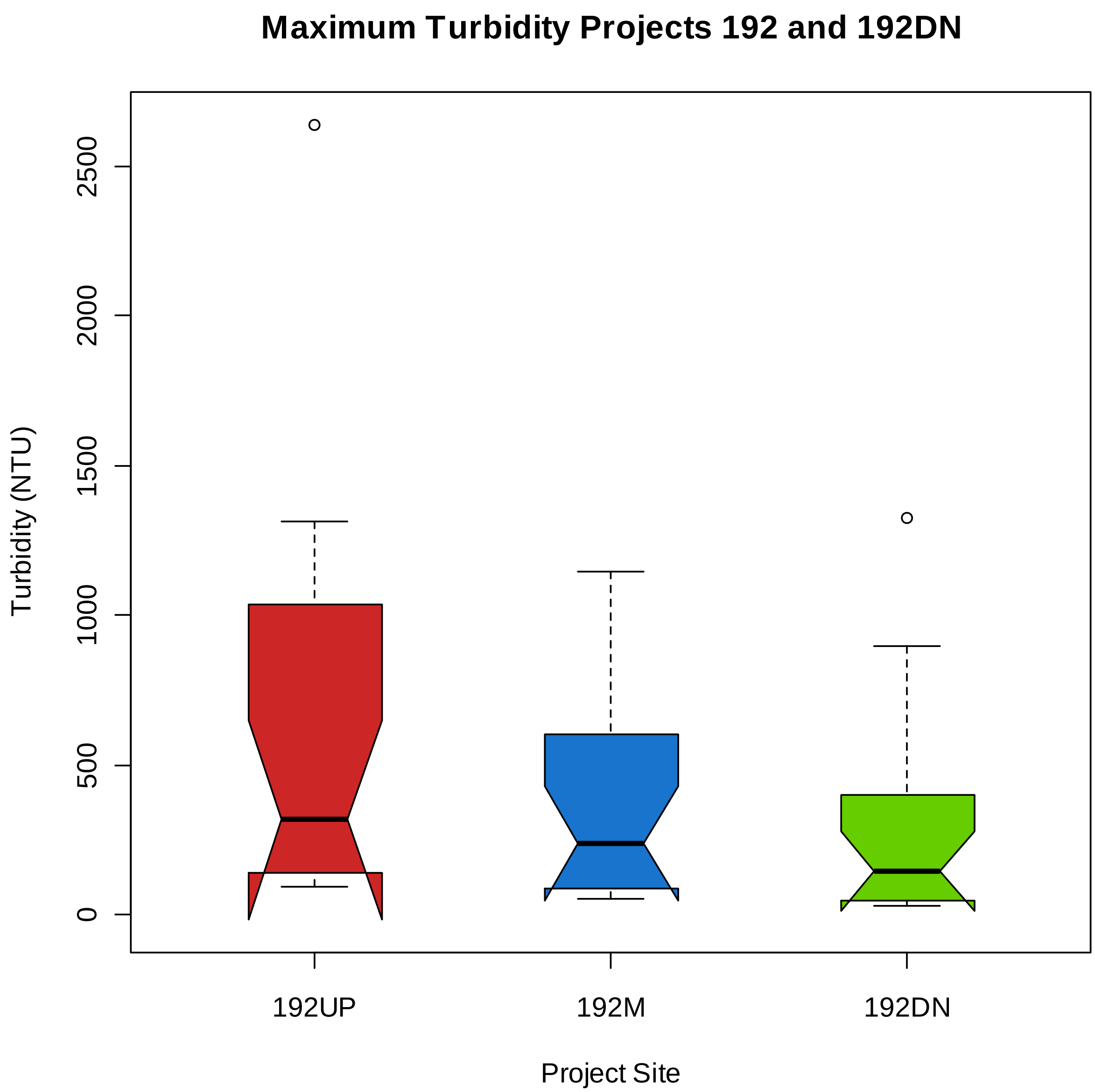


Figure 37. Maximum Turbidity at Water Quality Project 192 and Flow Control Project 192DN (continuous monitoring)

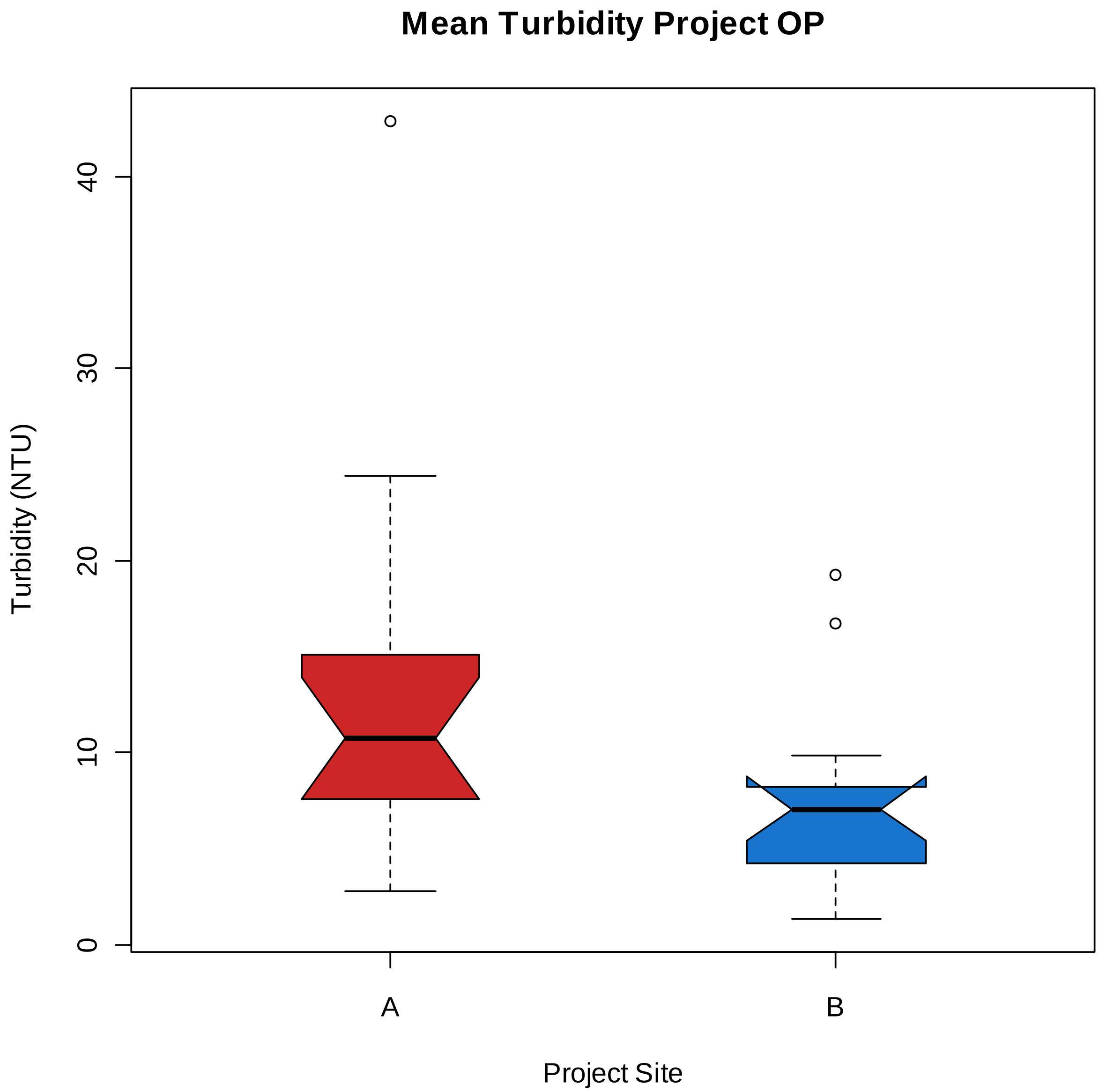


Figure 38. Mean Turbidity at Water Quality Project OP (continuous monitoring)

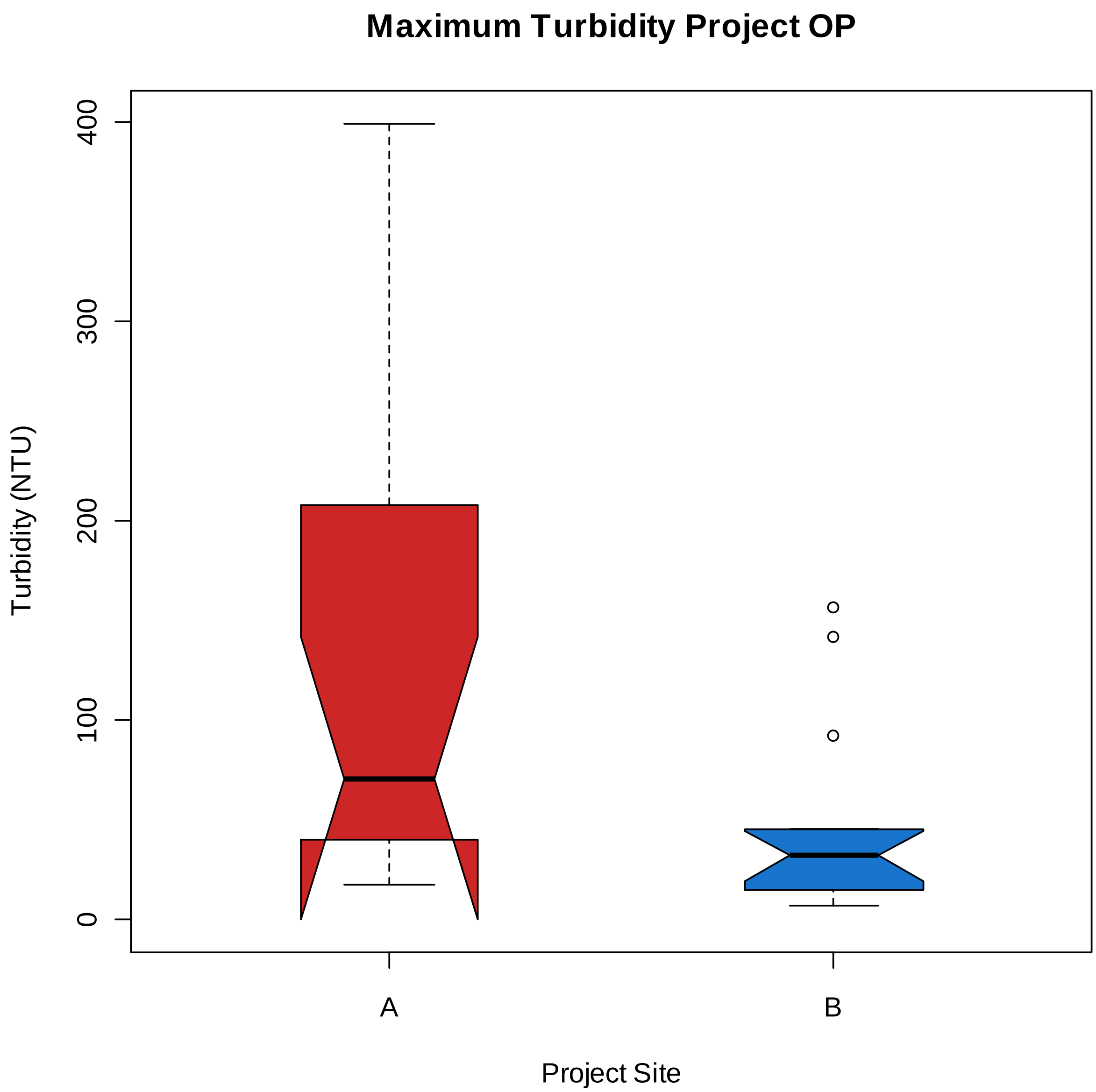


Figure 39. Maximum Turbidity at Water Quality Project OP (continuous monitoring)

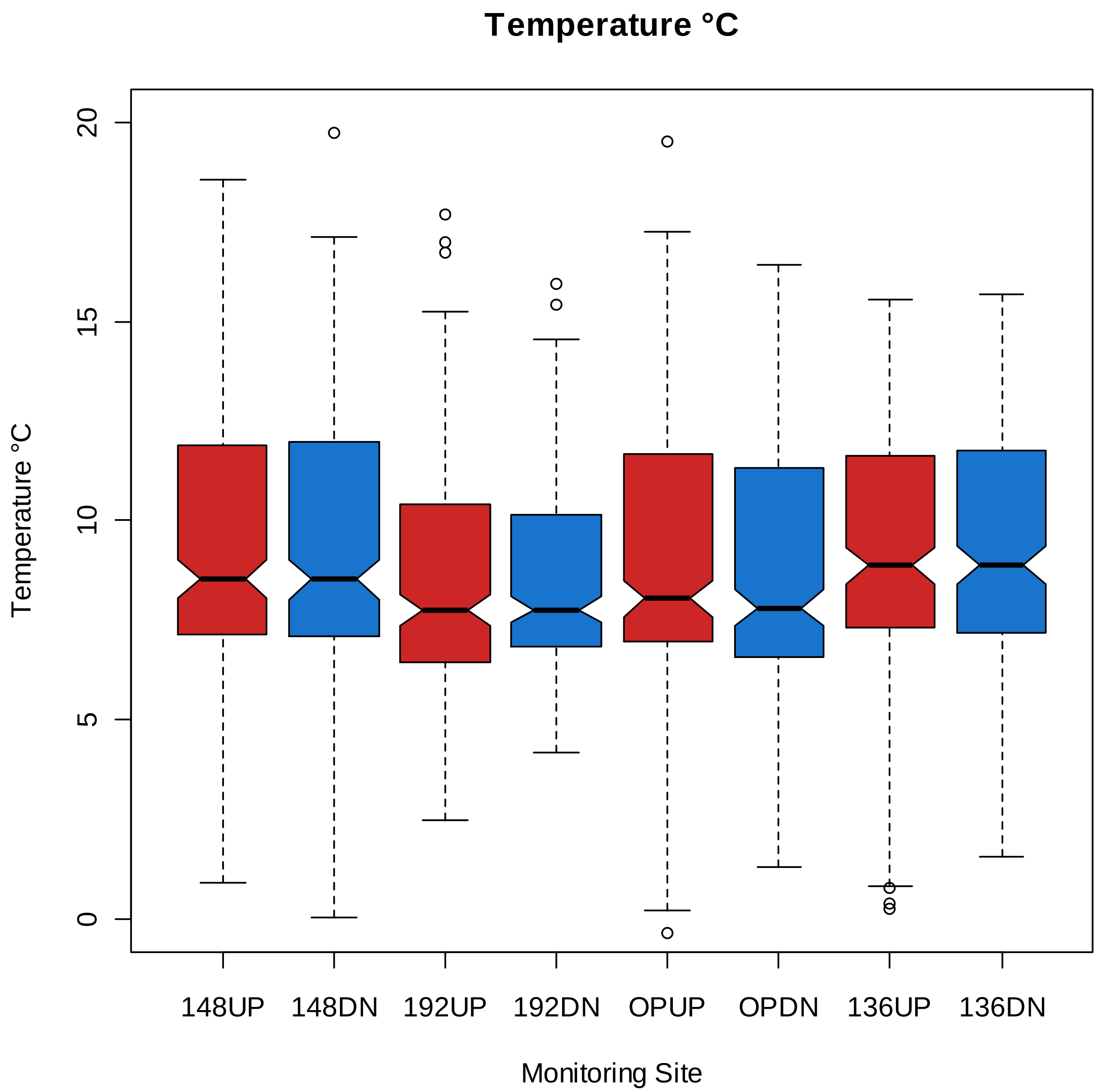


Figure 40. Temperature Monitoring Results (continuous monitoring)

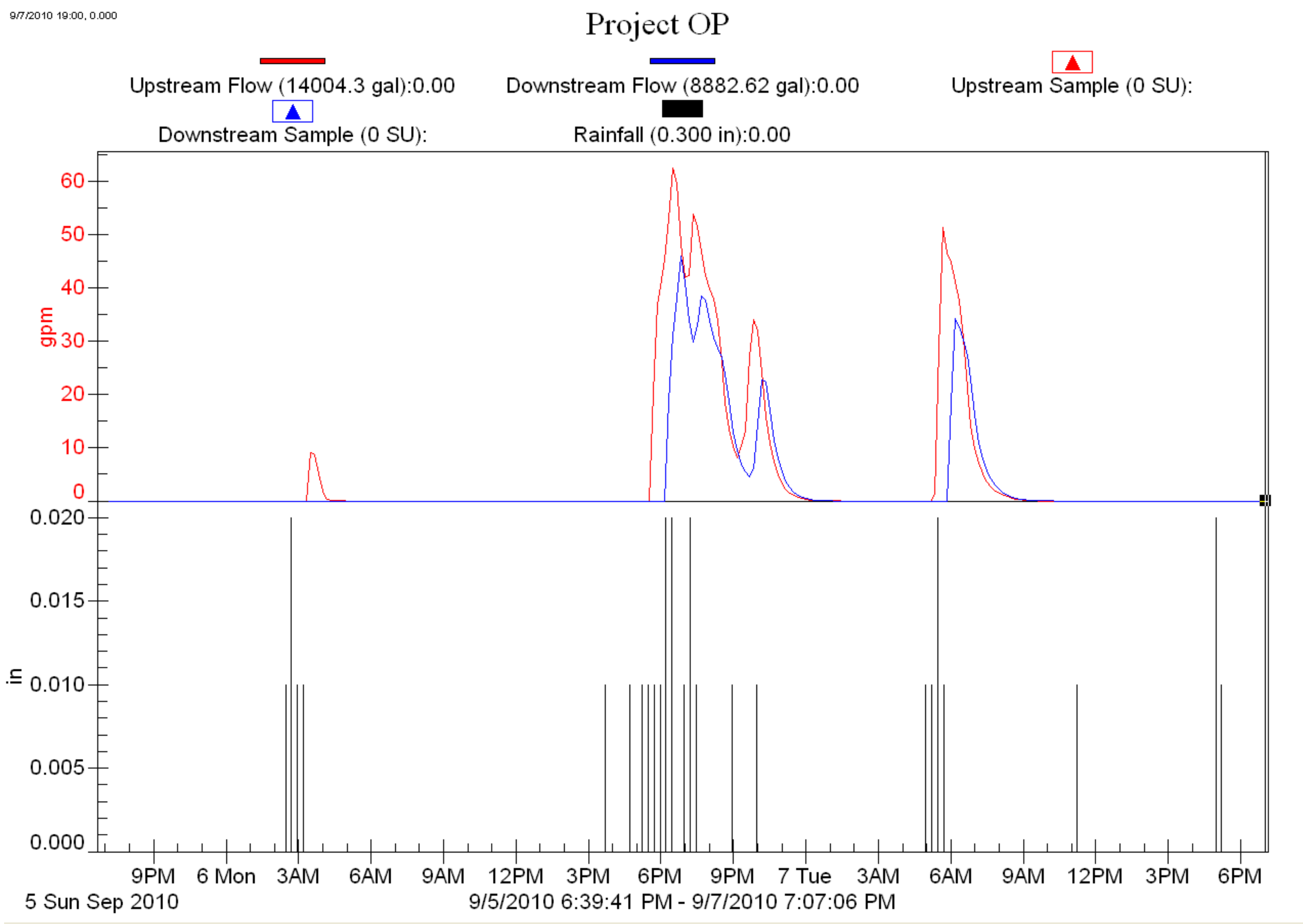


Figure 41. Flow Comparison, Project OP September 5, 2010

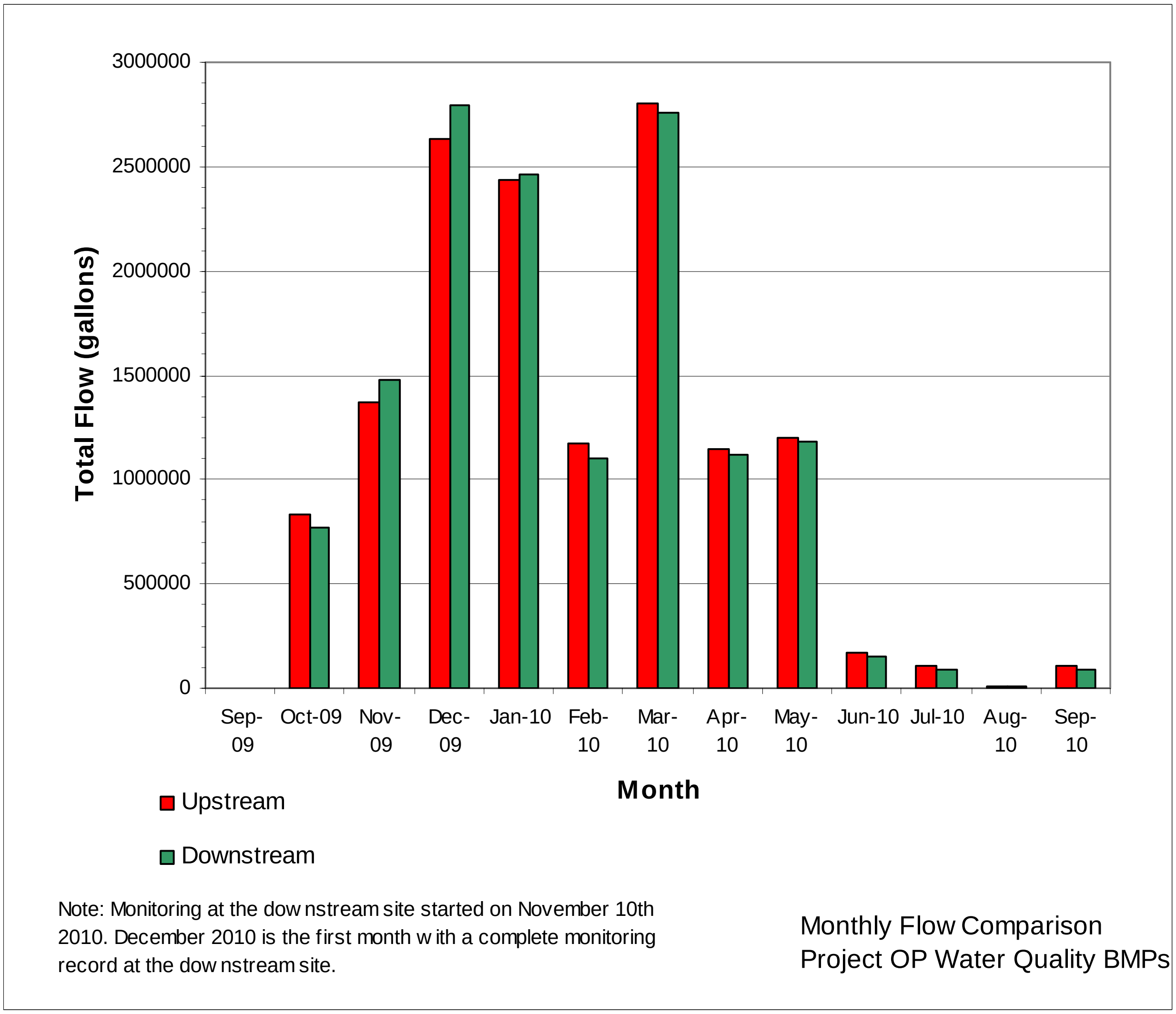


Figure 42. Monthly Flow Comparison Project OP

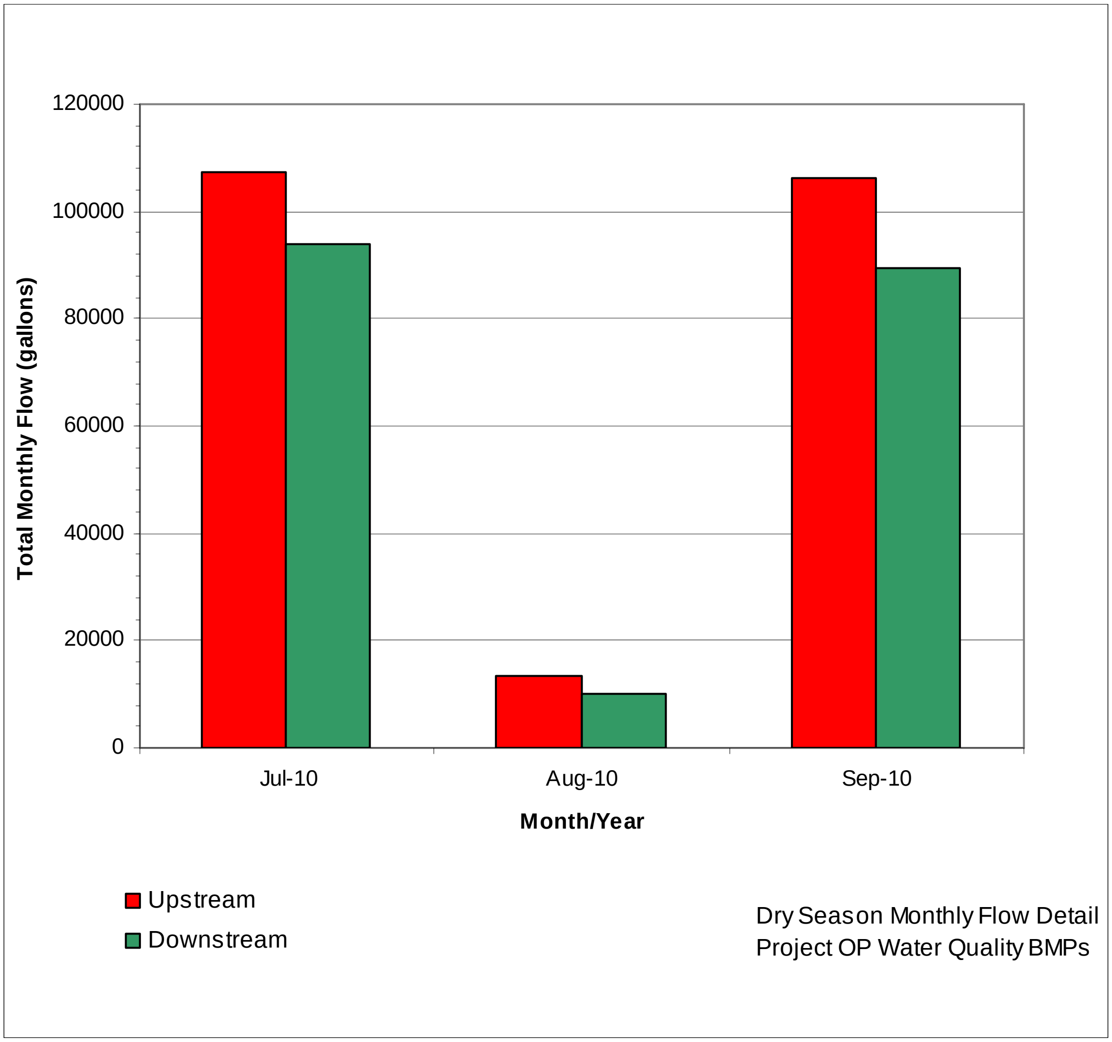


Figure 43. Dry Season Detail of Monthly Flow Comparison Project OP

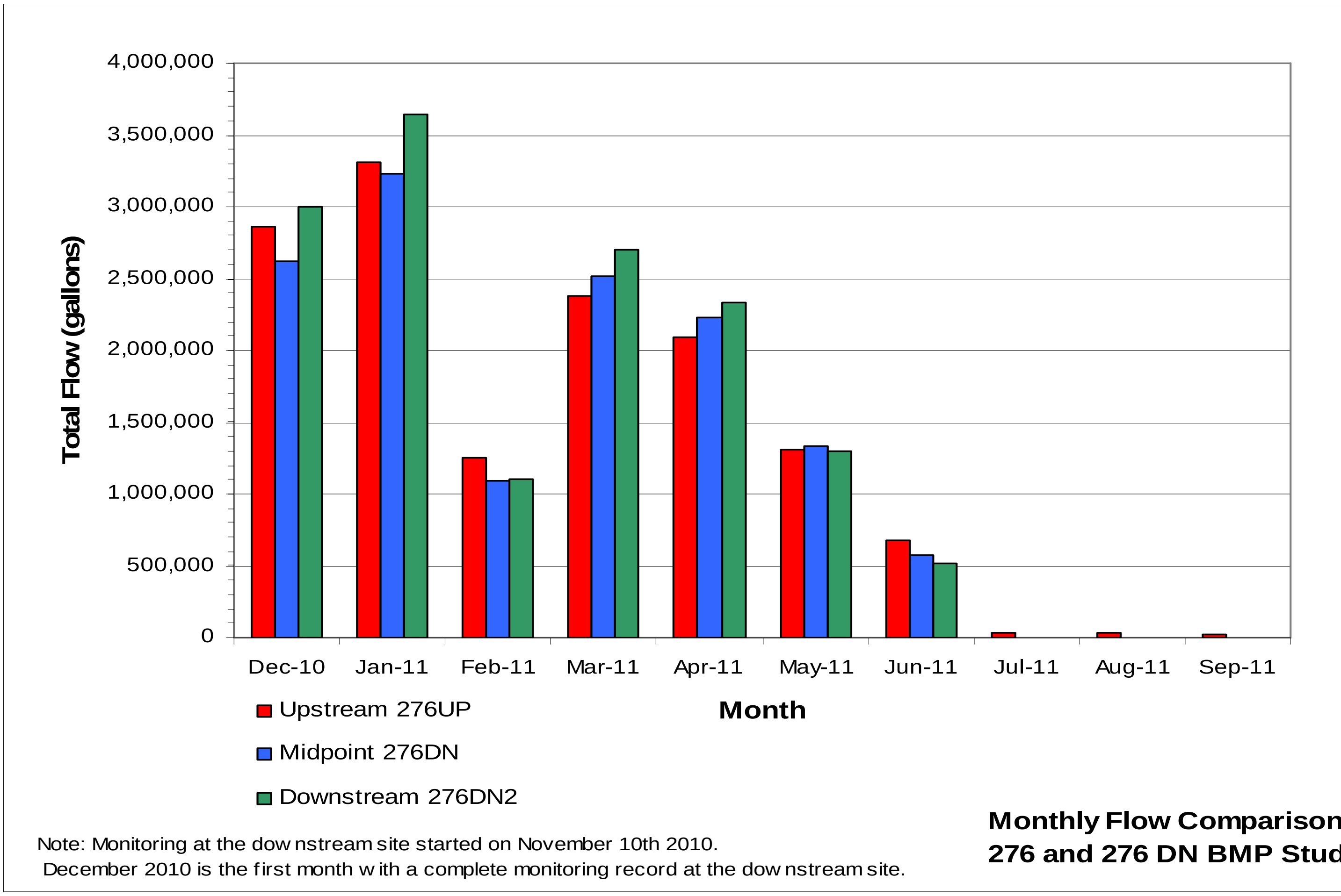


Figure 44. Monthly Flow Comparison Flow Control Projects 276 and 276DN

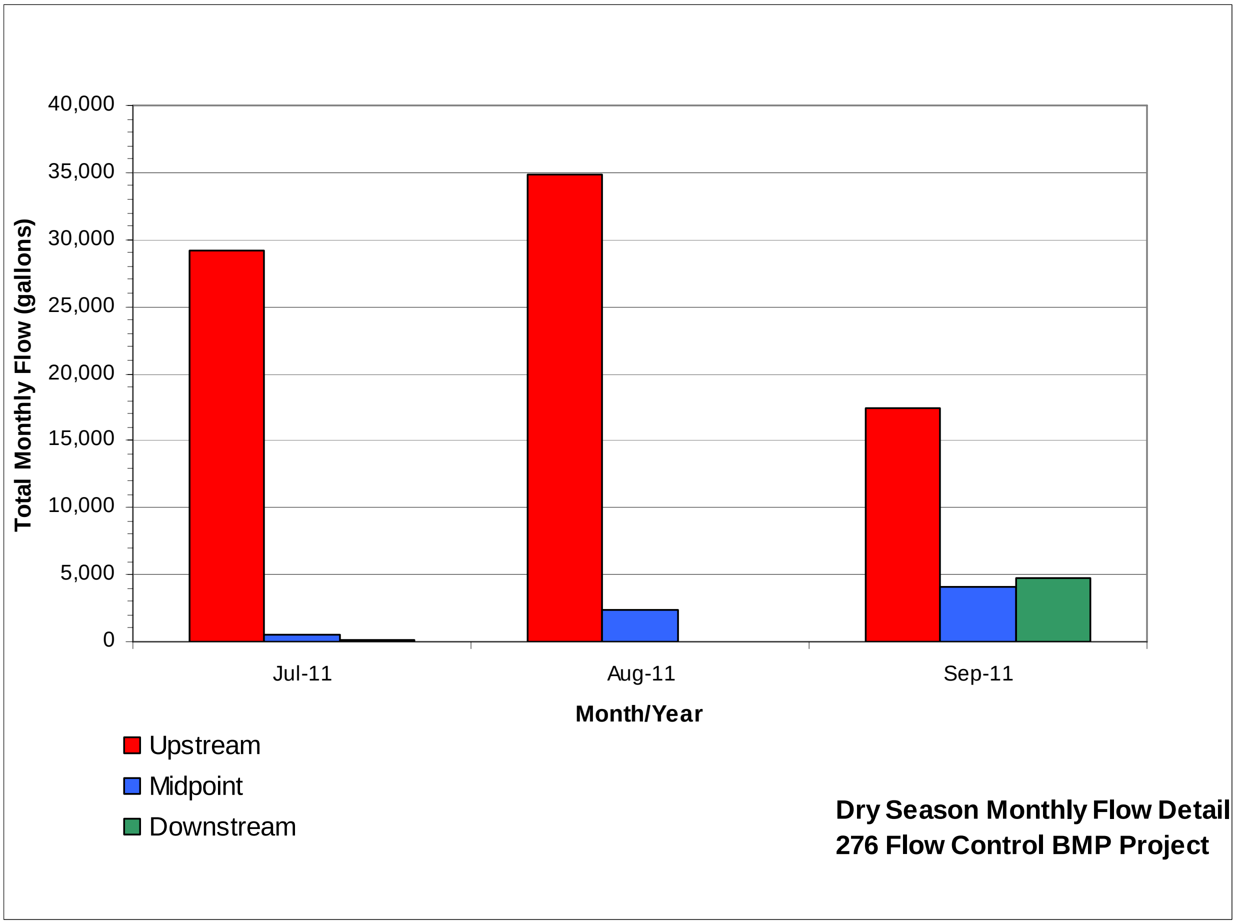


Figure 45. Dry Season Detail of Monthly Flow Comparison Flow Control Projects 276 and 276DN

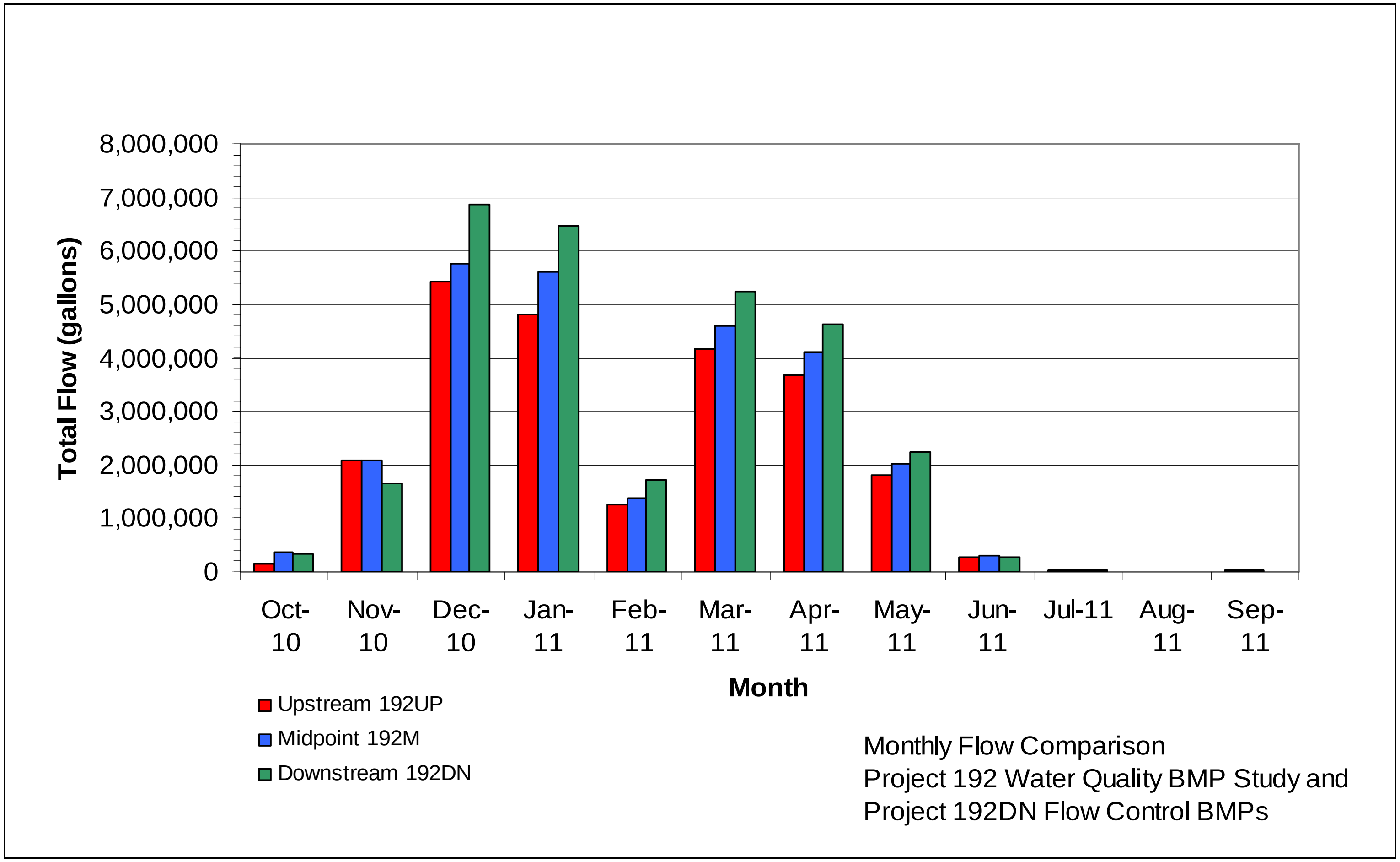


Figure 46. Monthly Flow Comparison Water Quality BMP Project 192 and Flow Control Project 192DN

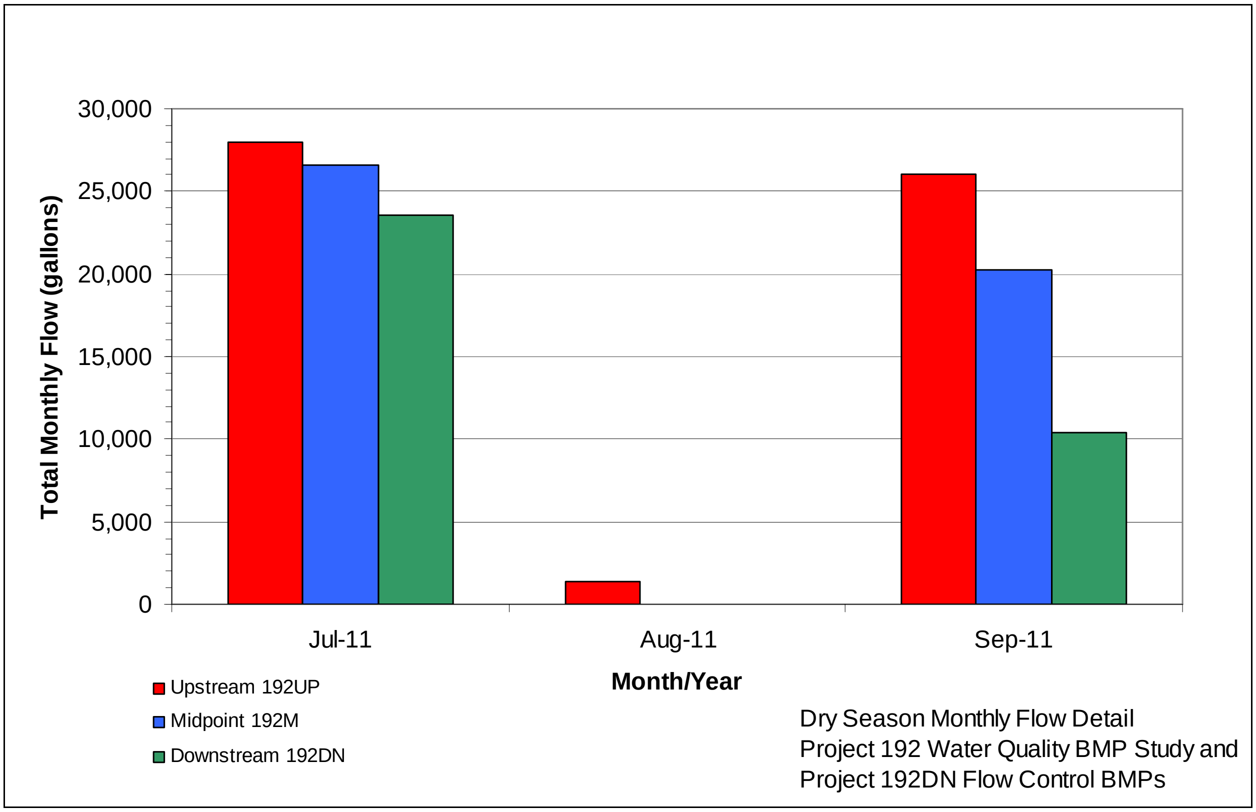


Figure 47. Dry Season Detail of Monthly Flow Comparison Water Quality BMP Project 192 and Flow Control Project 192DN

TABLES

Table 1. Water Quality BMP Project Information

Project ID	Project Location	BMP Installation Date	Monitoring Time Frame		Monitoring Location	Monitoring Station ID	Laboratory ID
148	148th Ave NE above SE 102nd St	May 4th 2009	2010 Water Year	Aug. 2009 – Sept. 2010	Upstream	148UP	RSW1UP
					Downstream	148DN	RSW1DN
136	SE 136th St and 170th Ave NE	June 6th 2009			Upstream	136UP	RSW8UP
					Downstream	136DN	RSW8DN
192	Petrovitsky Rd above SE 192nd Dr	September 27th 2010	2011 Water Year	Oct. 2010 – Sept. 2011	Upstream	192UP	RSW17UP
					Downstream	192M	RSW17DN
OP	Petrovitsky Rd at Old Petrovitsky Rd	August 9th 2010		Oct. 2010 – Sept. 2011	Upstream	OPUP	RSW18UP
					Downstream	OPDN	RSW18DN

Table 2. Flow Control BMP Project Information

Project ID	Project Location	BMP Installation Date	Monitoring Time Frame		Monitoring Location	Monitoring Station ID
PET	Petrovitsky Rd below SE 192nd Dr	June 30th 2009	2010 Water Year	August 2009 – September 2010	Upstream	PETUP
					Downstream	PETDN
276	Hobart Rd below SE 213th St	July 10th 2009	2010 & 2011 Water Year	August 2009 – September 2011	Upstream	276UP
					Downstream	276DN
192DN	Petrovitsky Rd above SE 192nd Dr	September 27th 2010	2011 Water Year	2010 – September 2011	Upstream	192M
					Downstream	192DN
276DN	Petrovitsky Rd at Old Petrovitsky Rd	December 16th 2010		September 2010 – September 2011	Upstream	276DN
					Downstream	276DN2

Project 192DN monitoring was done at the same location as the PET project. The BMPs monitored for the PET project were included in the 192DN project.

Table 3. Hydrologic Analysis Summary for Water Quality BMP Project Sites

<table>
<tr><th rowspan="2">Project</th><th rowspan="2">Watershed Area (acres)</th><th rowspan="2">Soil Type</th><th rowspan="2">Soil Group</th><th colspan="2">Impervious Area</th><th colspan="2">Pervious Area (acres)</th><th rowspan="2">Raingage</th><th rowspan="2">25 Year Peak Flow (cfs)</th></tr>
<tr><th>Acres</th><th>%</th><th>Grass</th><th>Forest</th></tr>
<tr><td>148</td><td>35.47</td><td rowspan="3">Ag C</td><td rowspan="4">C</td><td>5.32</td><td>15</td><td>15.07</td><td>15.08</td><td rowspan="4">SeaTac</td><td>8.69</td></tr>
<tr><td>136</td><td>10.4</td><td>2.07</td><td>20</td><td>4.14</td><td>4.14</td><td>2.94</td></tr>
<tr><td>192</td><td>47.8</td><td>7.17</td><td>15</td><td>20.3</td><td>20.3</td><td>11.69</td></tr>
<tr><td>OP</td><td>18.32</td><td>Ag B</td><td>2.75</td><td>15</td><td>15.57</td><td>--</td><td>2.56</td></tr>
<tr><td colspan="10">Soil Types AgC: Alderwood gravely sandy loam 6 to 15 percent slopes. AgB: Alderwood gravely sandy loam 0 to 6 percent slopes. Soil Survey King County Area Wa. 1973
Soil Group C: hydrologic soil group for soils with a moderately high runoff potential when thoroughly wet. Natural Resources Conservation Service 2007
cfs – cubic feet per second
SeaTac Rainfall Soil Survey King County Area Wa. 1973.</td></tr>
</table>

Table 4. Hydrologic Analysis Summary for Flow Control BMP Project Sites

Project	Watershed Area (acres)	Soil Type	Soil Group	Impervious Area		Pervious Area (acres)			Raingage	25 Year Peak Flow (cfs)
				Acres	%	Grass	Pasture	Forest		
276	27.4	Ag C	C	4.1	15	11.6	--	11.6	Landsburg	9.77
276DN	42.7			6.41	15	7.99	17.79	10.53		10.14
PET/192 DN[1]	47.8			7.17	15	20.3	--	20.3	SeaTac	11.69

[1]PET and 192 projects occupied the same reach of ditch.
Soil Types AgC: Alderwood gravely sandy loam 6 to 15 percent slopes. AgB: Alderwood gravely sandy loam 0 to 6 percent slopes. Soil Survey King County Area Wa. 1973.
Soil Group C: hydrologic soil group for soils with a moderately high runoff potential when thoroughly wet. Natural Resources Conservation Service 2007.
cfs – cubic feet per second
SeaTac Rainfall Soil Survey King County Area Wa. 1973.

Table 5. BMP Construction Costs

Water Quality BMP Construction Costs

Item	Project 148	Project 136	Project OP	Project 192 WQ & 192DN Flow Control Project[1]	Average Cost per BMP
No. of BMPs	3	4	13	7	
Length of Ditch Treated (feet)	100	100	260	270	
Crew	$2,500	$1,500	$4,600	$3,650	
Equipment	$1,000	$1,000	$2,000	$1,100	
Materials	$400	$400	$1030	$9,030	
Total	$3,900	$2,900	$7,630	$5,700	
Cost per BMP	$1,300	$725	$587	$814	$856

Flow Control BMP Construction Costs

Item	Project PET	Project 276	Project 276DN	Average Cost per BMP
No. of BMPs	5	10	13	
Length of Ditch Treated (feet)	200	400	320	
Crew	$2,000	$2,500	$3,600	
Equipment	$1,000	$1,000	$1,400	
Materials	$300	$300	$980	
Total	$3,300	$3,800	$6,000	
Cost per BMP	$660	$380	$460	$500

Individual BMP cost averaged across all projects: $700

[1]Installation of the 192 water quality and 192DS flow control BMP studies was completed in a single day. Six BMPs were placed for 192 and one additional BMP was added downstream of the 192 downstream flume to the five flow control BMPs placed the previous year for the PET flow control project. The costs for this installation are the combined costs of placing seven BMPs.

Installation costs at all projects except for Project 136 included a small amount of crew time assisting with preparation of the flumes for monitoring flow. This time was approximately one hour per project.

Table 6. Analytical Parameters and Reporting Limits by Year

Type of Monitoring	Parameter	Reporting Limit Criteria and Units	148 and 136 2010 WY Projects	192 and OP 2011 WY Projects
Storm Samples (Flow-weighted Composite Samples)	Total suspended solids	1.0 mg/L	X	X
	Hardness as $CaCO_3$	0.33 (mg/ $CaCO_3$/L)	X	X
	Total kjeldahl nitrogen	0.2 mg/L	X	X
	Nitrate-nitrite (NO23)	0.04 mg/L	X	X
	Total phosphorus	0.01 mg/L		X
	orthophosphate	0.005 mg/L	X	X
	arsenic, total	0.5 ug/L		X
	arsenic, dissolved	0.5 ug/L	X	X
	cadmium, dissolved	0.25 ug/L	X	
	chromium, total	1.0 ug/L		X
	chromium, dissolved	1.0 ug/L	X	X
	copper , total	2.0 ug/L		X
	copper, dissolved	2.0 ug/L	X	X
	lead, total recoverable	0.1 ug/L		X
	lead, dissolved	0.1 ug/L	X	X
	nickel, total recoverable	0.5 ug/L		X
	nickel, dissolved	0.5 ug/L	X	X
	selenium, dissolved	1.0 ug/L	X	
	tin, dissolved	1.5 ug/L	X	
	Total Recoverable zinc	2.5 ug/L		X
	Dissolved zinc	2.5 ug/L	X	X
	PAH-SIM	1.0 ug/L	X	X
Grab samples	Total Petroleum	0.2 mg/L	X	
	Fecal Coliform	1 cfu	X	

Notes:

mg/L – milligrams per liter

ug/L – micrograms per liter

cfu – colony forming units

WY – water year

Table 7. Seventeen PAHs Analyzed from Flow-weighted Composite Samples

PAH Parameters	
Acenaphthene	Dibenzo(a,h)anthracene
Acenaphthylene	2-Methylnaphthalene
Anthracene	Fluoranthene
Benzo(a)anthracene	Fluorene
Benzo(a)pyrene	Indeno(1,2,3-Cd)Pyrene
Benzo(b)fluoranthene	Naphthalene
Benzo(g,h,i)perylene	Phenanthrene
Benzo(k)fluoranthene	Pyrene
Chrysene	

Table 8. Water Quality Parameters, Instrument Resolution and Accuracy

Type of Monitoring	Parameter	Instrument Resolution	Instrument Accuracy
Single Point Storm Water Quality Parameters[1]	Dissolved Oxygen	0.01 mg/L	0 to 20 mg/L: +/- 2% of reading or 0.2 mg/L whichever is greater.
	pH	0.1 units	+/- 0.2 units
	Conductivity	0.001 to 0.1 mS/cm (range dependant)	+/-0.5 % of reading = 0.001 mS/cm
	Temperature	0.01°C	+/- 0.15°C
	Turbidity	0.1 NTU	+/-2% of reading or 0.3 NTU whichever is greater in YSI AMCO-AEPA Polymer Standards
Continuous Monitoring[2]	Temperature	0.02°C at 25°C	+/- 0.2 °C
	Turbidity[3]	0.1 NTU	+/-2% of reading or 0.3 NTU whichever is greater in YSI AMCO-AEPA Polymer Standards

[1] Single point field parameters were monitored using YSI Inc. 6920 sondes. Resolution and accuracy data from YSI.

[2] Continuous temperature measurements recorded using ONSET® Hobo Water Temp Pro V2 Loggers. Resolution and accuracy data from ONSET®.

[3] Continuous turbidity measurements recorded using YSI 600 OMS sondes. Resolution and accuracy data from YSI.

NTU - Nephelometric Turbidity Units

°C – degrees Celcius

Table 9. Project 148 Monitoring Summary for 2010 Water Year

Project Site ID	Composite Sample ID	Grab Sample ID	Antecedent Dry Period (hrs)	Intra-storm Break (hrs)	Stormflow Start (date/time)	Total Stormflow (gal)	Sampled Stormflow (gal)	Total Rain (in)	Comment
148UP	L49169-1	L49169-5	31	<6	10/16/09 9:00	12,400	11,997	1.50	Sample analyzed through Ditch Grant
148DN	L49169-2	L49169-6	31	<6	10/16/09 10:45	17,203	17,011	1.50	Sample analyzed through Ditch Grant
148UP	L49467-1	L49467-5	41	<6	10/28/09 19:50	5,490	3,592	0.40	Composites successful. Grab samples
148DN	L49467-2	L49467-6	41	<6	10/28/09 19:30	5,475	4,478	0.40	Composites successful. Grab samples
148UP	L49581-1	L49581-5	63	<6	11/5/09 12:10	9,655	7,618	0.84	Composites successful. Grab samples
148DN	L49581-2	L49581-6	63	<6	11/5/09 12:20	11,962	9,497	0.84	Composites successful. Grab samples
148UP	L49923-1	L49923-2	39	<6	1/10/10 22:40	76,960	39,699	0.8	
148DN	L49918-2	L49918-6	39	<6	1/10/10 22:40	82,141	44,133	0.8	
148UP	L50043-1	L50043-2	110	<6	1/29/10 23:50	16,483	9,761	0.4	Sample volume was lower than expected due to sampler intake placed partially out of water only collecting a partial aliquot. Sampled stormflow represents bulk of storm.
148DN	L50044-2	L50044-6	110	<6	1/30/10 0:10	19,610	8,730	0.4	Sample volume was lower than expected due to sampler intake placed partially out of water only collecting a partial aliquot. Sampled stormflow represents bulk of storm.
148UP	L50156-1	L50156-2	25	<6	2/4/10 22:10	6,830	4,320	0.2	
148DN	L50157-2	L50157-6	25	<6	2/4/10 22:10	8,122	7,126	0.2	Sample includes three aliquots collected
148UP	L50181-1	L50181-5	180	<6	2/23/10 17:15	9,839	3,957	0.57	Sampled light rain for almost 18 hours, field crew thought that storm was complete at a few hour break in rain and pulled sample, took to lab. Sample represents first flush portion of storm and was kept.
148DN	L50181-2	L50181-6	180	<6	2/23/10 17:40	10,613	3,491	0.57	Sampled light rain for almost 18 hours, field crew thought that storm was complete at a few hour break in rain and pulled sample, took to lab. Sample represents first flush portion of storm and was kept.
148UP	L50300-1	L50300-2	76	<6	3/25/10 3:50	7,584	5,820	0.58	On-site rain gage malfunction
148DN	L50299-2	L50299-6	76	<6	3/25/10 4:00	10,278	5,747	0.58	On-site rain gage malfunction
148UP	L50574-1	L50574-2	120	<6	4/13/10 2:10	5,877	5,827	0.14	Renton Raingage recorded 0.14 inches, onsite gage recorded 0.27 inches. Flow consistent with higher rainfall amounts
148DN	L50575-2	L50575-6	120	<6	4/13/10 2:20	6,019	4,917	0.14	Renton Raingage recorded 0.14 inches, onsite gage recorded 0.27 inches. Flow consistent with higher rainfall amounts
148UP	L50698-1	L50698-2	72	<6	4/20/10 22:37	32,002	5,336	1.12	Rain significantly more than predicted, paced for smaller storm. Composite captured the first flush well into the main storm peak, sample was kept.
148DN	L50699-2	L50699-6	72	<6	4/20/10 23:00	37,507	5,524	1.12	Rain significantly more than predicted, paced for smaller storm. Composite captured the first flush well into the main storm peak, sample was kept.
148UP		L51050-2	109	<6	6/15/10 20:45	7,842	5,721	0.46	
148DN		L51051-6	109	<6	6/15/10 21:00	8,864	5,831	0.46	Sampler not set up correctly. Sampler triggered but no sample collected.
148UP		L51159-5	271	<6	7/2/10 5:10	58	1	0.34	*Grab samples only. Storm did not produced only 58 gallons of flow. No composites collected.
148DN		L51159-6	271	<6	No Flow	0	--	0.34	Storm resulted in less than 1 gallon of downstream flow. Water pooled just above flume, did not flow through flume. Grab collected in pool.

Table 9. Project 148 Monitoring Summary for 2010 Water Year

Project Site ID	Composite Sample ID	Grab Sample ID	Antecedent Dry Period (hrs)	Intra-storm Break (hrs)	Stormflow Start (date/time)	Total Stormflow (gal)	Sampled Stormflow (gal)	Total Rain (in)	Comment
148UP	L51252-1	L51252-5	552	<6	8/31/10 8:00	1,989	1,631	0.56	Four hour break in rain resulted in 2 flow peaks with no base flow in between. Sampler picked up all of 1st peak and over 1/2 of second peak. Sample kept.
148DN	L51252-2	L51252-6	552	<6	8/31/10 9:20	307	285	0.56	Four hour break in rain resulted in 2 flow peaks with no base flow in between. Sampler picked up all of 1st peak but none of second peak. Sample kept as representative of first flush and due to difficulty in collecting a matching downstream sample during
148UP		L51656-3	24	<6	9/23/10 10:10	238	95	0.25	Grab samples collected and submitted from small amount of stormflow. Only 5 aliquots sampled. No downstream flow. Sample not analyzed.
148DN		L51656-4	24	<6	No Flow	--	0	0.25	Grab samples collected. Stormflow pooling above flume. Insufficient flow for composite samples, no aliquots collected.

Notes:

hrs - hours
gal - gallons
in - inches

Table 10. Project 136 Monitoring Summary for 2010 Water Year

Project Site ID	Composite Sample ID	Grab Sample ID	Antecedent Dry Period (hrs)	Intra-storm Break (hrs)	Stormflow Start (date/time)	Total Stormflow (gal)	Sampled Stormflow (gal)	Total Rain (in)	Comment
136UP	L49169-3	L49169-7	31	<6	10/16/09 11:00	31,569	29,721	1.50	--
136DN	L49169-4	L49169-8	31	<6	10/16/09 11:00	46,401	45,482	1.50	--
136UP	L49467-3	L49467-7	41	<6	10/28/09 20:40	10,200	7,211	0.40	Level readings ok mid storm, but 0.047 low at end of storm. No obvious change in record, no corrections. Sample container filled but many errors listed for aliquot collection. Strainer may need deeper placement in water to sample.
136DN	L49467-4	L49467-8	41	<6	10/28/09 20:30	18,922	11,396	0.40	Need to review sample strainer placement.
136UP	L49581-3	L49581-7	63	<6	11/5/09 12:30	23,517	17,590	0.84	Rainfall less than predicted, samplers paced for a larger stormflow event. Sample volume limited. Composite sample submitted. White foam noted at culvert outlet. No direct weir reading at end of storm. Reading on 11/9/09: weir= 0.12, meter= 0.108. Diff
136DN	L49581-4	L49581-8	63	<6	11/5/09 12:30	31,632	25,358	0.84	Rainfall less than predicted, samplers paced for a larger stormflow event. Sample volume limited. Composite sample submitted. No direct weir reading at end of storm. Reading on 11/9/09: weir= 0.125, meter= 0.136. Diff=0.011. Reset Meter to 0.125
136UP	L49787-3	--	197	<6	12/14/09 18:00	9,750	8,080	0.44	--
136DN	L49787-4	--	197	<6	12/14/09 19:45	12,020	11,978	0.44	--
136UP	L49918-3	--	39	<6	1/10/10 23:00	64,255	41,919	0.88	First 3 aliquots representing 8% of total flow taken before true start of storm.
136DN	L49918-4	--	39	<6	1/10/10 23:00	60,119	70,216	0.88	Last six aliquots representing 13% of the total flow taken after end of storm and start of next rainfall.
136UP	L50182-3	--	180	<6	2/23/10 18:06	20,901	9,621	0.57	Sampled for 17 hours during front end of showery rain event, samples kept although totals <50% of storm.
136DN	L50182-4	--	180	<6	2/23/10 18:14	25,300	9,576	0.57	Sampled for 15 hours during front end of showery rain event, samples kept although totals <50% of storm. Suspect data as noted. No rain during period of suspect data.
136UP	L50299-3	L50299-7	76	<6	3/25/10 4:00	20,241	9,394	0.57	Missed the first 2 hours (about 6%) of storm flow and sampled 46% of total storm. Sampled significant proportion of storm into main storm peak and samples were kept.
136DN	L50299-4	L50299-8	76	<6	3/25/10 5:00	22,401	9,057	0.57	Missed the first 2 hours (about 6%) of storm flow and sampled 46% of total storm. Sampled significant proportion of storm into main storm peak and samples were kept. Adjusted level down during storm on 3/25/10 @ 10:31 by 0.011 ft.
136UP	L50699-3	L50699-7	72	<6	4/20/10 23:12	33,366	5,648	1.12	Rainfall total significantly more than predicted. Sample kept as representative of front or first flush portion of storm.

Table 10. Project 136 Monitoring Summary for 2010 Water Year

Project Site ID	Composite Sample ID	Grab Sample ID	Antecedent Dry Period (hrs)	Intra-storm Break (hrs)	Stormflow Start (date/time)	Total Stormflow (gal)	Sampled Stormflow (gal)	Total Rain (in)	Comment
136DN	L50699-4	L50699-8	72	<6	4/20/10 23:19	37,419	5,314	1.12	Rainfall total significantly more than predicted. Sample kept as representative of front or first flush portion of storm.
136UP	L50724-3	--	51	<6	4/26/10 16:40	12,346	8,128	0.35	Sampled more than 50% of storm flow, but missed first 2 hours (12%) of storm flow due to trigger level above this early flow. Samples were kept for analysis.
136DN	L50724-4	--	51	<6	4/26/10 16:40	14,629	9,680	0.35	--
136UP	L51051-3	L51051-7	109	<6	6/15/10 20:15	16,546	5,560	0.46	Sampled percentage low due to long slow lag time in post-storm flow. Sample is representative of main storm event, samples were kept.
136DN	L51051-4	L51051-8	109	<6	6/15/10 21:00	22,027	4,977	0.46	Percentage of storm flow sampled is low due to long slow lag time in post-storm flow. Sample is representative of main storm event, samples were kept.
136UP	L51159-3	L51159-7	271	<6	7/2/10 1:00	5,219	3,794	0.34	Weir and meter levels not documented at end of storm.
136DN	L51159-4	L51159-8	271	<6	7/2/10 1:00	2,493	1,955	0.34	Weir and meter levels not documented at end of storm. Equipment Blank Collected on 7/6/10
136UP	L51252-3	L51252-7	552	<6	8/31/10 8:26	792	703	0.56	*Visited site at 8/31/10 at 08:39 - no flow yet, water in CB is still below culvert. At 10:25 meter reading 0.073 high flow is only 1 gpm. Adjusted meter to 0.05 and adjusted record in Flowlink. Took grabs.
136DN	L51252-4	L51252-8	552	<6	8/31/10 7:45	3,862	1,831	0.56	8/31/10 at 08:38 Is raining. Weir level is 0.04, Meter Level is -0.07, reset to 0.04. Flow over weir is <1 gpm, no visible flow in ditch. Reset pacing to 50 gallons. Sampler trigger is 0.05 - not triggered yet. Level and meter readings not documented during post-storm check.

Notes:

hrs - hours
gal - gallons
in - inches

Table 11. Project 192 Monitoring Summary for 2011 Water Year

Project Site ID	Sample ID	Antecedent Dry Period (hrs)	Intra-storm Break (hrs)	Stormflow Start (date/time)	Total Stormflow (gal)	Sampled Stormflow (gal)	Total Rain (in)	Comment
192UP	L51943-3	32	<6	10/23/10 19:43	88,694	70,008	1.67	Storm criteria met, samples analyzed
192M	L51943-4	32	<6	10/23/10 21:37	93,694	72,640	1.67	Storm criteria met, samples analyzed
192UP	L52160-1	35	<6	11/17/10 6:20	132,347	96,618	0.39	Storm criteria met, samples analyzed
192M	L52160-2	35	<6	11/17/10 6:20	139,058	94,403	0.39	Storm criteria met, samples analyzed
192UP	L52267-1	110	<6	12/7/10 16:23	108,457	77,911	0.82	Flow is turbid.
192M	L52267-2	110	<6	12/7/10 16:41	117,952	78,402	0.82	4 Aliquots (#35 - 39) listed with NM flag. Last aliquot did not have a flag. Flow is turbid.
192UP	L52330-1	63	<6	1/12/2011 2:28	179,299	121,354	1.00	Post storm level measurements not recorded. Reviewed with field staff; meter was working accurately.
192M	L52330-2	63	<6	1/12/2011 2:00	198,048	122,517	1.00	
192UP	L52491-1	39	8*	3/12/11 10:00	203,214	142,639	0.55	Storm targeted during a brief (>24 hr) dry period during an extended period of daily storm events. Base (or interflow) conditions were very high; field team set the trigger level high and the first 2 hours of the storm was missed. A dry period of 8 hours occurred mid-sample. Influent/effluent samples were comparable and the sample was kept.
192M	L52491-2	39	8*	3/12/11 10:10	227,395	157,216	0.55	Storm targeted during a brief (>24 hr) dry period during an extended period of daily storm events. Base (or interflow) conditions were very high; field team set the trigger level high and the first 2 hours of the storm was missed. A dry period of 8 hours occurred mid-sample. Influent/effluent samples were comparable and the sample was kept.
192UP	L52798-1	141	<6	3/24/11 19:36	49,078	30,136	0.40	
192M	L52798-2	141	<6	3/24/11 19:49	52,979	31,950	0.40	
192UP	L52877-1	52	<6	4/13/11 11:20	40,248	33,766	0.23	Storm criteria met, samples analyzed
192M	L52877-2	52	<6	4/13/11 12:14	45,929	37,674	0.23	Storm criteria met, samples analyzed
192UP	L53057-1	28	<6	4/26/11 16:46	32,221	27,796	0.17	Rainfall less than 0.2 inches. Sample aliquots representative of stormflow, samples analyzed.
192M	L53057-2	28	<6	4/26/11 16:58	38,911	33,835	0.17	Rainfall less than 0.2 inches. Sample aliquots representative of stormflow, samples analyzed.
192UP	L53138-1	66	6	5/11/11 3:10	101,422	69,927	0.45	Antecedent dry period of 66 hrs is less than criteria of 72 hours. The stormflow was well covered by the sampling and was kept for analysis as a good representation of upstream/downstream water quality conditions. This along with a concern over the ability to collect criteria storms lead to the decision to submit this sample for analysis.

Table 11. Project 192 Monitoring Summary for 2011 Water Year

Project Site ID	Sample ID	Antecedent Dry Period (hrs)	Intra-storm Break (hrs)	Stormflow Start (date/time)	Total Stormflow (gal)	Sampled Stormflow (gal)	Total Rain (in)	Comment
192M	L53138-2	66	6	5/11/11 3:10	122,632	83,793	0.45	Antecedent dry period of 66 hrs is less than criteria of 72 hours. The stormflow was well covered by the sampling and was kept for analysis as a good representation of upstream/downstream water quality conditions. This along with a concern over the ability to collect criteria storms lead to the decision to submit this sample for analysis.
192UP	L53280-1	84	<6	5/25/11 10:20	23,741	21,982	0.43	Storm criteria met, samples analyzed.
192M	L53280-2	84	<6	5/25/11 10:20	25,512	23,993	0.43	Storm criteria met, samples analyzed.
192UP	L53348-1	41	<6	6/15/11 1:00	4,895	4,895	0.18	Antecedent dry period of 41 hrs is less than criteria of 72 hours, total rainfall was 0.18 inches; less than the 0.2 inch rainfall criteria. The stormflow was well covered by the sampling and was kept for analysis as a good representation of upstream/downstream water quality conditions.
192M	L53348-2	41	<6	6/15/11 1:30	3,893	3,893	0.18	Antecedent dry period of 41 hrs is less than criteria of 72 hours, total rainfall was 0.18 inches; less than the 0.2 inch rainfall criteria. The stormflow was well covered by the sampling and was kept for analysis as a good representation of upstream/downstream water quality conditions.
192UP	L53471-1	131	<6	7/12/11 19:40	26,230	9,523	0.58	High intensity storm came in two cells that resulted two very distinct hydrograph peaks. The sampler captured 87% of the first peak 10,986 gallons from 0.4 inches of rain in one hour. Matched sampling at downstream station - sample was analyzed.
192M	L53471-2	131	<6	7/12/11 19:52	25,920	8,434	0.58	High intensity storm came in two cells that resulted two very distinct hydrograph peaks. The sampler captured 87% of the first peak 10,986 gallons from 0.4 inches of rain in one hour. Matched sampling at downstream station - sample was analyzed.

Notes:

hrs - hours
gal - gallons
in - inches

Table 12. Project OP Monitoring Summary for 2011 Water Year

Project Site ID	Sample ID	Antecedent Dry Period (hrs)	Intra-storm Break (hrs)	Stormflow Start (date/time)	Total Stormflow (gal)	Sampled Stormflow (gal)	Total Rain (in)	Comment
OPUP	L51658-1	251	6	10/8/10 23:20	266,703	107,920	1.87	Sampled stormflow = 266,703 gallons. On-site rain gage recorded 1.61 in. Inter-storm break > 6 hrs on project rain gage, on-site rain gage showed < 6 hr inter-storm break. Sampled <50 percent of storm, but captured storm first flush portion of storm, sampling was comparable at both influent and effluent stations.
OPDN	L51658-2	251	6	10/9/10 0:20	249,543	101,610	1.87	Sampled stormflow = 249,543 gallons. On-site rain gage recorded 1.61 in. Inter-storm break > 6 hrs on project rain gage, on-site rain gage showed < 6 hr inter-storm break. Sampled <50 percent of storm, but captured storm first flush portion of storm, sampling was comparable at both influent and effluent stations.
OPUP	L51943-1	32	<6	10/23/10 15:18	305,989	195,069	1.64	Sampled for 37 hrs with no break in rain. Rain continued 10 hrs after sampling stopped.
OPDN	L51943-2	32	<6	10/23/10 17:50	274,505	195,418	1.64	Sampled for 37 hrs with no break in rain. Rain continued 10 hrs after sampling stopped.
OPUP	L52041-3	84	<6	11/5/10 16:30	82,056	69,873	0.63	
OPDN	L52041-4	84	<6	11/5/10 17:10	82,133	67,760	0.63	
OPUP	L52160-3	35	<6	11/17/10 6:15	87,104	71,635	0.47	
OPDN	L52160-4	35	<6	11/17/10 6:15	92,308	74,278	0.47	
OPUP	L52206-3	39	<6	11/29/10 19:09	147,952	98,320	0.61	
OPDN	L52206-4	39	<6	11/29/10 20:21	156,974	97,375	0.61	
OPUP	L52267-3	110	<6	12/7/10 16:40	93,227	78,568	0.57	Sampling completed before 5 hour break in rainfall. High intensity storm spike after dry period not included in sample.
OPDN	L52267-4	110	<6	12/7/10 17:18	96,677	77,922	0.57	Sampling completed before 5 hour break in rainfall. High intensity storm spike after dry period not included in sample.
OPUP	L52330-3	63	<6	1/12/11 2:00	211,024	117,681	1.00	Snow melt runoff triggered sampler before start of
OPDN	L52330-4	63	<6	1/12/11 2:00	206,700	121,980	1.00	Snow melt runoff triggered sampler before start of
OPUP	L52491-3	39	8	3/12/11 10:16	119,064	87,819	0.55	Inter-storm dry period exceeded by 2 hours; on-site Raingage shows intra-storm dry period <6 hours and sample was kept. Level at upstream station off by 0.07 - possible blockage in bubble line. Flows are recorded low but vary consistently with downstream record. Sampling is consistent with downstream samples and almost all of storm was sampled at both stations. Pacing was low for actual flow. Flow record at upstream station was corrected based on comparison with downstream flow and previous storm response. Samples were kept as representative of upstream/downstream water quality conditions.

Table 12. Project OP Monitoring Summary for 2011 Water Year

Project Site ID	Sample ID	Antecedent Dry Period (hrs)	Intra-storm Break (hrs)	Stormflow Start (date/time)	Total Stormflow (gal)	Sampled Stormflow (gal)	Total Rain (in)	Comment
OPDN	L52491-4	39	8	3/12/11 9:50	130,124	104,035	0.55	Inter-storm dry period exceeded by 2 hours; on-site Raingage shows intra-storm dry period just <6 hours and sample was kept. Level off at upstream station by 0.07 - possible blockage in bubble line. Flows are recorded low but vary consistently with downstream record. Sampling is consistent with downstream samples and almost all of storm was sampled at both stations. Pacing was low for actual flow and sampling includes a >6 hr dry period and continues in to the following storm event. Flow record at upstream station was corrected based on comparison with downstream flow and previous storm response. Samples were kept as representative of upstream/downstream water quality conditions.
OPUP	L52877-3	52	<6	4/13/11 12:10	24,486	23,267	0.23	Storm criteria met, samples analyzed
OPDN	L52877-4	52	<6	4/14/11 0:59	21,530	21,530	0.23	Storm criteria met, samples analyzed
OPUP	L53138-3	66	6	5/11/11 3:20	75,515	61,093	0.45	Antecedent dry period of 66 hrs is less than criteria of 72 hours. Sampling provided good representation of the storm and matched well with the downstream sample. This along with a concern over the ability to collect criteria storms lead to the decision to submit this sample for analysis.
OPDN	L53138-4	66	6	5/11/11 4:00	73,821	60,838	0.45	Antecedent dry period of 66 hrs is less than criteria of 72 hours. Sampling provided good representation of the storm and matched well with the downstream sample. This along with a concern over the ability to collect criteria storms lead to the decision to submit this sample for analysis.
OPUP	L53280-3	84	<6	5/25/11 11:25	44,297	43,999	0.43	prior to storm by 0.055 ft - bubble tube appears to have been moved; noted fresh mowing in area. Mid-storm
OPDN	L53280-4	84	<6	5/25/11 11:25	41,867	41,969	0.43	Storm criteria met, samples analyzed. Mid-storm check is just prior to start of storm.
OPUP	L53696-3	670	<6	8/22/11 19:30	13,266	12,816	0.29	Storm criteria met. Samples analyzed.
OPDN	L53696-4	670	<6	8/22/11 20:10	9,903	8,849	0.29	Storm criteria met. Fewer than 12 aliquots collected, but nine out of 10 attempted aliquots were successful. Sampling is representative of stormflow and comparable to upstream sampling; sample was analyzed.

Notes:

hrs - hours
gal - gallons
in - inches

Table 13. Hypothesis Test Results for Data Sets with All Values Above the MDL

Parameters and units	Project Site ID	Number of Tests (N)	Number of Tests showing Reductions	p Value[2]	Estimated Median	Achieved CI[3]	CI Lower[3, 5]	CI Upper[3, 5]	Mean	Lower CI[4, 5]	Upper CI[4, 5]	Was the Water Quality Improved below the BMP treatment?
Hypothesis Test Results and BMP Efficiency Evaluation (Data Sets with all Values above MDL) [1]				Wilcoxon Signed Rank Test of Upstream vs. Downstream Values — Paired sample test for non-parametric data					Efficiency Evaluation — Bootstrapping Distribution			
TSS (mg/L)	148	11	10	0.009	12.470	95.5	4.200	28.400	44.6	23.7	61.6	Yes. TSS values were significantly lower downstream.
	136	12	2	0.255	-2.500	94.5	-9.600	2.600	-117.8	-315.3	1.3	No. TSS values were higher downstream.
	192	12	9	0.025	15.850	94.5	2.500	34.600	13.1	-21.3	40.4	Yes. TSS values were lower downstream.
	OP	12	9	0.009	7.410	94.5	2.900	40.700	37.7	11.3	60.4	Yes. TSS values were significantly lower downstream.
Nitrate + Nitrite Nitrogen (mg/L)	148	9	2	0.286	-0.079	95.6	-0.655	0.187	-25.7	-60.5	1.5	No. Nitrate Nitrite values were higher downstream.
	136	10	5	0.646	0.020	94.7	-0.415	0.156	-2.4	-21.7	12.1	No. Nitrate Nitrite values were higher downstream.
	192	12	0	0.003	-0.025	94.5	-0.320	-0.018	-12.9	-16.9	-9.0	No. Nitrate Nitrite values were higher downstream.
	OP	12	1	0.038	-0.055	94.5	-0.091	-0.026	-38.0	-67.1	-11.4	No. Nitrate Nitrite values were higher downstream.
TKN (mg/L)	148	11	5	0.689	0.012	95.5	-0.111	0.145	4.4	-9.3	17.9	No. TKN values were higher downstream.
	136	12	2	0.505	-0.031	94.5	-0.182	0.500	-10.0	-28.7	5.7	No. TKN values were not significantly different.
	192	12	11	0.017	0.098	94.5	0.053	0.159	12.9	4.0	20.6	Yes. TKN values were lower downstream.
	OP	12	10	0.021	0.075	94.5	0.018	0.154	14.2	-4.9	28.8	Yes. TKN values were lower downstream.
Ortho-phosphate phosphorus[6] (mg/L)	148	11	11	0.004	-0.014	95.5	-0.048	-0.004	-78.2	-127.1	-41.0	No. All orthophosphate values were higher downstream.
	136	12	3	0.170	-0.019	94.5	-0.059	0.005	-133.6	-269.5	-26.2	No. The orthophosphate values were higher downstream.
	OP	12	4	0.224	-0.005	94.5	-0.014	0.003	-103.2	-183.2	-31.3	No. The orthophosphate was higher downstream.
Phosphorous, Total (mg/L)	192	12	5	0.666	0.002	94.5	-0.012	0.024	0.1	-23.8	21.2	No. The phosphorous values were not significantly different.
	OP	12	4	0.092	0.005	94.5	-0.004	0.027	12.4	-1.5	27.8	No. The phosphorous values are not significantly different.
Arsenic, total (ug/L)	192	12	10	0.025	0.242	94.5	0.073	0.476	17.1	2.3	28.5	Yes. The total arsenic values were lower downstream.
	OP	12	12	0.003	0.197	94.5	0.120	0.988	23.9	13.0	37.9	Yes. The total arsenic values were significantly lower downstream.
Arsenic, dissolved (ug/L)	148	11	0	0.006	-0.173	95.5	-0.552	-0.090	-83.5	-121.7	-51.2	No. The dissolved arsenic values significantly higher downstream.
	136	12	3	0.142	-0.040	94.5	-0.081	0.010	-3.9	-12.5	7.5	No. The dissolved arsenic values were not significantly different.
	192	12	8	0.100	0.033	94.5	-0.010	0.067	-9.7	-52.2	13.8	No. The dissolved arsenic values were not significantly different.
	OP	12	5	0.894	0.004	94.5	-0.100	0.085	-2.3	-12.5	7.1	No. The dissolved arsenic values were not significantly different.

Table 13. Hypothesis Test Results for Data Sets with All Values Above the MDL

Hypothesis Test Results and BMP Efficiency Evaluation (Data Sets with all Values above MDL) [1]												
				Wilcoxon Signed Rank Test of Upstream vs. Downstream Values Paired sample test for non-parametric data					Efficiency Evaluation Bootstrapping Distribution			
Parameters and units	**Project Site ID**	**Number of Tests (N)**	**Number of Tests showing Reductions**	**p Value[2]**	**Estimated Median**	**Achieved CI[3]**	**CI Lower[3, 5]**	**CI Upper[3, 5]**	**Mean**	**Lower CI[4, 5]**	**Upper CI[4, 5]**	**Was the Water Quality Improved below the BMP treatment?**
Chromium, total (ug/L)	192	12	11	0.005	0.628	94.5	0.190	2.510	23.2	14.1	31.8	Yes. The total chromium values were lower downstream.
	OP	12	11	0.065	0.493	94.5	-0.020	2.090	-5.1	-85.4	44.9	The downstream chromium values were usually lower; however, the data set is skewed by an outlier value.
Chromium, dissolved	OP	12	2	0.515	-0.013	94.5	-0.145	0.030	-238.0	-710.0	0.968	No. the dissolved chromium values were not significantly different.
Copper, total (ug/L)	192	12	10	0.004	1.350	94.5	0.340	3.850	7.9	3.2	14.6	Yes. The total copper values were significantly lower downstream.
	OP	12	10	0.007	1.232	94.5	0.450	5.750	28.6	14.4	44.1	Yes. The total copper values were significantly lower downstream.
Copper, dissolved (ug/L)	148	11	2	0.307	-0.190	95.5	-0.580	0.550	-2.0	-20.3	19.8	No. The dissolved copper values were not significantly different.
	136	12	3	0.209	-0.313	94.5	-1.050	0.190	-25.7	-70.1	3.3	No. The dissolved copper values were not significantly different.
	192	12	9	0.053	0.173	94.5	0.050	0.310	15.1	3.3	29.7	rejecting the null hypothesis. The mean, upper and lower CI's are positive. Nine results show reductions and include one upstream outlier.
	OP	12	6	0.859	-0.005	94.5	-0.210	0.195	-2.8	-10.1	4.2	No. The dissolved copper values were not significantly different.
Lead, total (ug/L)	192	12	11	0.009	0.941	94.5	0.290	2.140	27.2	14.9	39.2	Yes. The total lead values were significantly lower downstream.
	OP	12	10	0.007	2.070	94.5	0.750	9.090	33.7	2.4	59.2	Yes. The total lead values were significantly lower downstream.
Nickel, total (ug/L)	192	12	11	0.008	0.657	94.5	0.210	2.650	18.9	9.2	27.7	Yes. The total nickel values were significantly reduced.
	OP	12	11	0.078	0.3578	94.5	-0.06	1.62	10.5	-36.8	41.3	The downstream nickel values were usually lower; however, the data set is skewed by an outlier value.
Nickel, dissolved (ug/L)	148	11	2	0.230	-0.093	95.5	-0.520	0.366	-47.6	-113.1	4.4	No. The dissolved nickel values were not significantly different.
	136	12	5	0.583	-0.039	94.5	-0.345	0.060	-9.2	-32.1	7.9	No. The dissolved nickel values were not significantly different.
	192	12	9	0.028	0.059	94.5	0.008	0.156	7.8	0.9	15.0	The dissolved nickel values were reduced in nine out of 12 samples with a p value just above 0.02.
	OP	12	7	0.845	-295.000	945.0	0.232	0.091	-63.0	-197.6	9.6	No. The dissolved nickel values were not significantly different.
Zinc, total (ug/L)	192	12	9	0.017	2.535	94.5	0.240	6.150	17.6	4.0	34.7	Yes. The total zinc values were significantly reduced.
	OP	12	10	0.031	12.300	94.5	5.000	38.600	22.7	-25.5	55.2	Yes. The total zinc values were significantly reduced.

Table 13. Hypothesis Test Results for Data Sets with All Values Above the MDL

Hypothesis Test Results and BMP Efficiency Evaluation (Data Sets with all Values above MDL) [1]													
				Wilcoxon Signed Rank Test of Upstream vs. Downstream Values Paired sample test for non-parametric data						Efficiency Evaluation Bootstrapping Distribution			
Parameters and units	**Project Site ID**	**Number of Tests (N)**	**Number of Tests showing Reductions**	**p Value[2]**	**Estimated Median**	**Achieved CI[3]**	**CI Lower[3, 5]**	**CI Upper[3, 5]**	**Mean**	**Lower CI[4, 5]**	**Upper CI[4, 5]**	**Was the Water Quality Improved below the BMP treatment?**
Zinc, dissolved (ug/L)	148	11	9	0.023	1.310	95.5	0.180	5.800	20.5	2.2	38.9	Yes. The dissolved zinc values were reduced downstream.
	136	12	8	0.410	0.793	94.5	-2.850	2.080	0.8	-24.8	20.1	No. The dissolved zinc values were not reduced.
	192	12	5	0.610	-0.133	94.5	-0.830	0.300	-17.6	-53.9	4.2	No. The dissolved zinc values were not reduced.
	OP	12	11	0.038	4.980	94.5	2.680	6.600	16.1	-27.0	41.9	Yes. The dissolved zinc values were reduced.
Hardness[7] (ug/L)	148	11	11	0.004	-7.750	95.5	-15.6	-4.100	-57.0	-92.2	-29.2	Yes. Hardness values were higher downstream.
	136	12	10	0.060	-1.650	94.5	-4.300	0.000	-8.6	-17.8	1.3	Yes. Hardness values were higher downstream.
	192	12	3	0.038	1.300	94.5	0.200	2.500	3.2	1.2	5.1	No. Hardness values were not significantly increased downstream.
	OP	12	7	0.906	0.200	94.5	-1.500	2.900	1.2	-6.6	9.4	No. Hardness values were not significantly increased downstream.
Total PAH (ug/L)	148	11	11	0.004	0.735	95.5	0.300	1.298	63.1	50.6	75.7	Yes. Total PAH values were reduced downstream.
	136	12	6	0.724	0.011	94.5	-0.118	0.060	-82.1	-313.6	48.8	No. Total PAH values were not significantly reduced downstream.
	192	12	7	0.029	0.015	94.5	0.001	0.055	21.3	6.5	38.4	Yes. Total PAH values were reduced downstream.
	OP	12	12	0.003	0.021	94.5	0.007	0.042	43.5	28.0	58.1	Yes. Total PAH values were reduced downstream.
Fecal Coliform (cfu)	136	8	2	0.353	-573	94.1	-2715	1710	-510	-1351	0.776	No. The fecal coliform values were higher downstream.

Notes:

[1] This table summarizes statistics and hypothosis tests for data sets with all results above MDL.

[2] p Value: the null hypothesis that there is no significant difference between the means of upstream and downstream data sets at the 95% confidence interval can be rejected if the p value is less than 0.05.

[3] CI - confidence interval achieved using the Wilcoxon Signed Rank test for pair samples.

[4] CI - achieved using Bootstrapping at 1,000 interations.

[5] CIs with negative values result from downstream results that are higher or increased below the BMPs

[6] Orthophosphate was expected to be higher downstream due to leaching from the compost in the BMPs.

[7] Hardness was expected to increase downstream due to increased stormwater contact time with minerals in the ditch. Increased hardness downstream from the BMPs would be considered a water quality benefit.

Table 14. Hypothesis Test Results for Data Sets with Non-Detected Values

Hypothesis Test Results and BMP Efficiency Evaluation (Data Sets with Non-detected Values)[1]														
						Wilcoxon Signed Rank Test[2] of Upstream vs. Downstream Values					Percent Efficiency Confidence Intervals			
						Paired sample test for non-parametric data					Bootstrapping Distribution*			
Parameters and units	Project Site ID	# of Tests (N)	Number of Tests showing Reductions	MDL	Number of Values Below MDL	p Value[3]	Mean	Achieved CI[4]	CI Lower[4, 6]	CI Upper[4, 5]	Mean	CI Lower[5, 6]	CI Upper[5, 6]	Was the Water Quality Improved below the BMP treatment?
Fecal Coliform	148 Up	8	3	1 cfu	2	353.0	-79.3	94.8	-100.0	589.0	-667	-1891	13.4	No. Fecal coliform was not reduced downstream
	148 Dn	8		1 cfu	2									
Lead, dissolved (ug/L)	148 Up	11	2	0.1	7	0.024	-0.070	95.5	-0.130	-0.015	0.102	0.055	0.168	No. Lead, dissolved was not reduced downstream
	148 Dn				2									
	136 Up	12	6		2	0.445	0.010	94.5	-0.015	0.045	13.4	-4.30	32.1	No. Lead, dissolved was not reduced downstream
	136 Dn				5									
	192 Up		8		4	0.014	0.033	94.5	0.010	0.055	24.8	10.4	40.2	Yes. Lead, dissolved values were lower downstream
	192 Dn				8									
	OP Up		8		2	0.114	0.025	94.5	-0.005	0.050	11.0	-4.0	24.9	Lead, dissolved was lower in 8 out of 12 effluent results, but the null hypothesis
	Op Dn				3									
Chromium, dissolved (ug/L)	148 Up	11	3	0.2	5	0.726	0.000	95.5	-0.070	0.068	-8.9	-40.9	22.2	No clear trend was observed in downstream vlaues
	148 Dn				4									
	136 Up	12	0		6	0.142	-0.025	94.5	-0.6	0.000	-53.9	-113.3	-2.0	No. Dowstream chromium, dissolved values were higher
	136 Dn				6									
	192 Up		1		11	--	--	--	--	--	--	--	--	Insufficient data above MDL to compute statistics. Based on this data set this parameter is not considered a water quality treatment issue at this site.
	192 Dn				10	--	--	--	--	--	--	--	--	
Ortho-phosphate	192 Up	12	2	0.002	9	0.281	0.000	94.5	-0.001	0.0001	-120.6	-322.7	1.5	No. Orthophosphate Phosphorus values were not reduced downstream.
	192 Dn				7									
Cadmium, dissolved (ug/L)	148 Up	11	0	0.05	10	--	--	--	--	--	--	--	--	Insufficient data above MDL to compute statistics. Based on this data set this parameter is not considered a water quality treatment issue at this site
	148 Dn					--	--	--	--	--	--	--	--	
	136 Up	12	0		11	--	--	--	--	--	--	--	--	
	136 Dn					--	--	--	--	--	--	--	--	
Selenium, dissolved (ug/L)	148 Up	11	--	0.5	11	--	--	--	--	--	--	--	--	
	148 Dn					--	--	--	--	--	--	--	--	
	136 Up	12	--		12	--	--	--	--	--	--	--	--	
	136 Dn					--	--	--	--	--	--	--	--	
Tin, dissolved (ug/L)	148 Up	11	--	0.3	11	--	--	--	--	--	--	--	--	
	148 Dn					--	--	--	--	--	--	--	--	
	136 Up	12	--		12	--	--	--	--	--	--	--	--	
	136 Dn					--	--	--	--	--	--	--	--	
TPH (mg/L)	148 Up	11	--	0.19	7	--	--	--	--	--	--	--	--	
	148 Dn					--	--	--	--	--	--	--	--	
	136 Up	12	--		8	--	--	--	--	--	--	--	--	
	136 Dn					--	--	--	--	--	--	--	--	

[1] This table summarizes statistics and hypothesis tests for data sets with results that include <MDL (Left Censored) data.

[2] Hypothesis testing using a Wilcoxon Signed Rank Test for evaluating non-parametric sample pairs. 1/2 MDL values were substituted for non-detected data

[3] p value: reject the null hypothesis that there is no significant difference between the means of upstream and downstream data sets at the 95% confidence interval if the p value is less than 0.05.

[4] CI - confidence interval achieved using the Wilcoxon Signed Rank test for pair samples.

[5] CI - achieved using Bootstrapping at 1000 interations.

[6] CIs with negative values result from downstream results that are higher or increased below the BMPs.

-- - No values due to results <MDL

ug/L - micrograms per liter

mg/L - milligrams per liter

cfu - colony forming units

Table 15. Descriptive Statistics for Data Sets with All Values Above the MDL

Descriptive Statistics (Data Sets with Values Above MDL)													
Parameter	**Project Site ID**	**# of Tests (N)**	**Mean**	**Standard Error of the Mean**	**Standard Deviation**	**Variance**	**Minimum**	**25th Percentile**	**Median**	**75th Percentile**	**Maximum**	**IQR**	**Skewness**
TSS	148 Up	11	28.43	8.44	27.98	782.88	5	10.2	14	66	74.1	55.8	1.08
	148 Dn		13.82	4.39	14.57	212.43	2.53	3.8	6.6	19.2	48	15.4	1.61
	136 Up	12	12.9	2.81	9.73	94.76	2.31	4.98	11.2	19.28	34.6	14.29	1.17
	136 Dn		15.79	3.38	11.7	136.91	5	6.4	11.4	22.13	44.2	15.73	1.44
	192 Up		91.6	50.5	175.1	30652.8	2.1	15.4	33.7	56.2	624	40.8	3.02
	192 Dn		64	35.5	122.9	15095.4	5.2	10.4	17.1	39.7	432	29.3	2.91
	OP Up		28.1	10.5	36.3	1320.4	4	9.3	13.9	24.7	123	15.4	2.17
	OP Dn		7.99	1.08	3.73	13.89	3.74	5.53	6.87	10.2	17.1	4.67	1.42
Nitrite + Nitrate Nitrogen	148 Up	11	0.946	0.138	0.415	0.172	0.468	0.632	0.865	1.182	1.8	0.55	1.2
	148 Dn		1.118	0.169	0.508	0.258	0.492	0.833	0.993	1.385	2.16	0.552	1.26
	136 Up	12	1.164	0.107	0.339	0.115	0.677	0.911	1.14	1.385	1.8	0.474	0.36
	136 Dn		1.204	0.156	0.495	0.245	0.595	0.697	1.16	1.578	2.17	0.88	0.61
	192 Up		0.2619	0.0625	0.2166	0.0469	0.0983	0.1303	0.195	0.303	0.894	0.1727	2.6
	192 Dn		0.2876	0.0629	0.2178	0.0474	0.106	0.159	0.222	0.3223	0.921	0.1633	2.54
	OP Up		0.2397	0.0879	0.3047	0.0928	0.09	0.1032	0.148	0.235	1.19	0.1317	3.25
	OP Dn		0.2398	0.031	0.1075	0.0116	0.12	0.1415	0.213	0.348	0.419	0.2065	0.56
TKN	148 Up	11	0.564	0.111	0.37	0.137	0.203	0.341	0.421	0.77	1.52	0.429	1.96
	148 Dn		0.558	0.156	0.518	0.269	0.219	0.301	0.422	0.462	2.05	0.161	2.83
	136 Up	12	0.808	0.201	0.698	0.487	0.223	0.415	0.601	0.966	2.81	0.55	2.44
	136 Dn		0.876	0.246	0.852	0.726	0.27	0.425	0.591	0.987	3.42	0.562	2.81
	192 Up		0.81	0.192	0.666	0.444	0.361	0.466	0.587	0.942	2.81	0.475	2.85
	192 Dn		0.687	0.152	0.526	0.276	0.328	0.378	0.494	0.856	2.23	0.478	2.65
	OP Up		0.5315	0.0914	0.3167	0.1003	0.16	0.3388	0.446	0.7203	1.31	0.3815	1.53
	OP Dn		0.4379	0.0832	0.288	0.083	0.17	0.257	0.357	0.474	1.18	0.217	1.88
Orthophosphate phosphorus	148 Up	11	0.0345	0.0143	0.0473	0.0022	0.0069	0.0112	0.0216	0.0394	0.173	0.0282	2.99
	148 Dn		0.0605	0.0226	0.0751	0.0056	0.0113	0.0152	0.0278	0.0791	0.264	0.0639	2.34
	136 Up	12	0.0576	0.0273	0.0944	0.0089	0.0039	0.0147	0.0317	0.0522	0.352	0.0376	3.25
	136 Dn		0.0821	0.0223	0.0773	0.006	0.0125	0.0166	0.0553	0.1243	0.258	0.1077	1.11
	OP Up		0.01595	0.00598	0.02073	0.00043	0.0034	0.00529	0.00767	0.01295	0.0686	0.0077	2.15
	OP Dn		0.02011	0.00441	0.01528	0.00023	0.00595	0.00692	0.01625	0.02615	0.0517	0.0192	1.16
Phosphorus, total	192 Up	12	0.1134	0.0578	0.2001	0.0401	0.0078	0.0273	0.0552	0.0813	0.733	0.054	3.18
	192 Dn		0.0986	0.0429	0.1487	0.0221	0.0109	0.0199	0.0408	0.1027	0.542	0.0828	2.82
	OP Up		0.0573	0.0106	0.0366	0.0013	0.0207	0.0312	0.0445	0.0926	0.123	0.0614	1.14
	OP Dn		0.04497	0.00597	0.02069	0.00043	0.022	0.03145	0.03825	0.05702	0.0944	0.0256	1.43
Arsenic, dissolved	148 Up	11	0.2961	0.0398	0.1321	0.0174	0.17	0.2	0.23	0.42	0.567	0.22	1.06
	148 Dn		0.56	0.12	0.399	0.159	0.28	0.29	0.42	0.641	1.59	0.351	2.06
	136 Up	12	0.5065	0.0648	0.2245	0.0504	0.27	0.3425	0.42	0.635	1.04	0.2925	1.37
	136 Dn		0.536	0.0812	0.2814	0.0792	0.22	0.3325	0.45	0.6987	1.21	0.3662	1.34
	192 Up		0.3287	0.036	0.1246	0.0155	0.15	0.2075	0.355	0.4125	0.554	0.205	0.07
	192 Dn		0.3193	0.03	0.1039	0.0108	0.15	0.2275	0.315	0.3825	0.532	0.155	2
	OP Up		0.7362	0.0913	0.3164	0.1001	0.36	0.4858	0.6165	1.13	1.19	0.6442	0.59
	OP Dn		0.7327	0.0816	0.2825	0.0798	0.38	0.5028	0.6305	1.0063	1.24	0.5035	0.6
Arsenic, total	192 Up	12	1.437	0.399	1.384	1.915	0.56	0.705	0.914	1.453	5.39	0.748	2.53
	192 Dn		1.173	0.339	1.174	1.377	0.37	0.53	0.832	1.212	4.61	0.681	2.68
	OP Up		1.51	0.346	1.198	1.436	0.748	0.853	1.01	1.567	4.8	0.714	2.33
	OP Dn		0.9448	0.0813	0.2816	0.0793	0.641	0.71	0.8015	1.2075	1.43	0.4975	0.57
Chromium, dissolved	OP Up	12	0.38	0.0484	0.1677	0.0281	0.23	0.24	0.35	0.47	0.78	0.23	1.44
	OP Dn		0.927	0.518	1.794	3.217	0.25	0.323	0.395	0.505	6.61	0.183	3.44
Chromium, total	192 Up	12	4.7	2.26	7.81	61.07	0.38	1.13	2.04	2.76	27.2	1.63	2.64
	192 Dn		3.57	1.85	6.4	40.9	0.26	0.86	1.54	1.73	22.9	0.87	2.98
	OP Up		2.323	0.563	1.95	3.804	0.84	1.013	1.5	3.208	7.27	2.195	1.82
	OP Dn		1.755	0.65	2.253	5.076	0.58	0.883	0.99	1.27	8.73	0.387	3.19
Copper, dissolved	148 Up	11	2.368	0.514	1.705	2.908	1.1	1.2	2	2.63	6.89	1.43	2.14
	148 Dn		2.486	0.661	2.191	4.802	0.14	1.5	2.18	2.33	8.64	0.83	2
	136 Up	12	3.353	0.91	3.153	9.943	1.4	1.675	2.355	3.817	12.9	2.142	2.94
	136 Dn		3.807	0.887	3.074	9.448	1.4	1.55	2.86	4.83	12.5	3.28	2.29
	192 Up		3.12	1.17	4.06	16.48	0.99	1.33	1.8	2.13	15.3	0.8	1.9
	192 Dn		1.872	0.392	1.357	1.84	0.77	1.2	1.55	1.975	5.94	0.775	2.82
	OP Up		2.55	0.446	1.546	2.39	1.4	1.625	2.125	2.845	7.12	1.22	2.69
	OP Dn		2.55	0.4	1.387	1.925	1.4	1.85	2.03	2.877	6.66	1.027	2.71

Table 15. Descriptive Statistics for Data Sets with All Values Above the MDL

Descriptive Statistics (Data Sets with Values Above MDL)													
Parameter	Project Site ID	# of Tests (N)	Mean	Standard Error of the Mean	Standard Deviation	Variance	Minimum	25th Percentile	Median	75th Percentile	Maximum	IQR	Skewness
Copper, total	192 Up	12	10.02	3.95	13.67	187	1.8	3.35	5.19	7.99	48.6	4.63	2.52
	192 Dn		8.06	3.31	11.46	131.25	1.4	2.24	4.27	5.57	41.1	3.33	2.64
	OP Up		6.54	1.12	3.88	15.08	2.93	4	4.69	9.22	15.2	5.22	1.38
	OP Dn		3.887	0.403	1.394	1.944	2.94	3.175	3.585	3.952	8.14	0.777	3
Lead, total	192 Up	12	5.98	2.73	9.47	89.63	0.48	1.41	2.61	3.62	31.9	2.21	2.39
	192 Dn		4.76	2.37	8.23	67.67	0.27	0.73	1.83	2.61	27.9	1.88	2.53
	OP Up		6.29	1.98	6.86	47.12	0.63	1.93	3.54	8.4	22.8	6.47	1.73
	OP Dn		2.004	0.391	1.354	1.832	0.616	1.192	1.75	2.473	5.69	1.28	1.99
Nickel, dissolved	148 Up	11	0.748	0.176	0.583	0.34	0.24	0.33	0.38	1.44	1.77	1.11	0.92
	148 Dn		0.87	0.191	0.635	0.403	0.32	0.38	0.677	1.33	2.02	0.95	1.06
	136 Up	12	0.72	0.149	0.517	0.267	0.34	0.41	0.46	0.962	2.08	0.552	2
	136 Dn		0.857	0.239	0.829	0.687	0.28	0.36	0.485	0.877	2.7	0.517	1.84
	192 Up		0.7972	0.0905	0.3134	0.0982	0.33	0.5315	0.7325	1.1075	1.29	0.576	0.31
	192 Dn		0.7123	0.0735	0.2545	0.0648	0.38	0.54	0.6645	0.8797	1.24	0.3397	0.81
	OP Up		0.5841	0.0568	0.1966	0.0387	0.34	0.46	0.5175	0.7422	0.92	0.2822	0.72
	OP Dn		0.916	0.334	1.155	1.335	0.32	0.4	0.534	0.843	4.5	0.443	3.2
Nickel, total	192 Up	12	5.29	2.3	7.96	63.4	0.88	1.64	2.27	3.36	28.1	1.72	2.62
	192 Dn		4.09	1.87	6.48	41.98	0.8	1.29	2.02	2.17	23.7	0.89	2.99
	OP Up		2.118	0.563	1.951	3.805	0.99	1.18	1.3	1.933	7.76	0.753	2.65
	OP Dn		1.412	0.361	1.251	1.566	0.858	0.898	1	1.313	5.33	0.414	3.3
Zinc, dissolved	148 Up	11	7.3	1.1	3.66	13.39	3.58	4.35	5.69	9.86	15.7	5.51	1.3
	148 Dn		5.212	0.74	2.456	6.031	2.5	2.64	5.17	7.62	9.55	4.98	0.44
	136 Up	12	10.13	1.47	5.09	25.95	4.83	6.81	8.75	12.31	20.8	5.49	1.37
	136 Dn		11.29	3.14	10.88	118.47	4.45	5.3	6.88	15.36	41.2	10.05	2.26
	192 Up		4.441	0.286	0.99	0.981	2.85	3.505	4.63	5.235	5.97	1.73	-0.11
	192 Dn		4.99	0.506	1.752	3.068	3.33	3.685	4.53	5.735	9.49	2.05	1.74
	OP Up		14.624	0.835	2.893	8.371	9.49	13.2	13.65	17.65	19.6	4.45	2
	OP Dn		12.05	3	10.39	107.94	6.15	7.71	9.07	10.85	44.4	3.14	3.23
Zinc, total	192 Up	12	23.18	8.77	30.39	923.51	4.45	7.35	12.2	21.3	111	13.95	2.63
	192 Dn		12.97	3.06	10.58	112.03	4.47	6.76	10.95	13.28	44.4	6.52	2.73
	OP Up		36.51	9.64	33.41	1115.93	0.95	21.33	24.8	38.13	125	16.8	2.04
	OP Dn		16.96	3.48	12.05	145.08	1.32	13.05	14.35	15.78	51.7	2.72	2.38
Total PAHs	148 Up	11	1.128	0.291	0.964	0.93	0.167	0.188	0.892	2.121	2.783	1.933	0.71
	148 Dn		0.354	0.113	0.375	0.141	0.045	0.1	0.154	0.568	1.256	0.468	1.67
	136 Up	12	0.1864	0.0593	0.2055	0.0422	0.028	0.0566	0.095	0.3277	0.6514	0.2712	1.54
	136 Dn		0.311	0.156	0.541	0.292	0.009	0.029	0.051	0.574	1.808	0.545	2.3
	192 Up		0.0954	0.0411	0.1424	0.0203	0.011	0.0165	0.0223	0.1296	0.4881	0.113	2.28
	192 Dn		0.0629	0.0259	0.0897	0.008	0.011	0.0152	0.0174	0.0867	0.2641	0.0715	1.8
	OP Up		0.0543	0.015	0.0521	0.0027	0.0063	0.0167	0.028	0.1014	0.166	0.0846	1.14
	OP Dn		0.0286	0.0111	0.0386	0.0015	0.0052	0.0075	0.0164	0.036	0.1448	0.0285	2.88
Hardness	148 Up	11	17.673	0.849	2.816	7.93	13.4	14.4	18.5	20.2	21.3	5.8	-0.46
	148 Dn		26.81	2.09	6.94	48.16	17.1	23.6	26	27	40.4	3.4	0.96
	136 Up	12	23.47	1.46	5.06	25.58	15	19.85	22.75	28.32	31.7	8.47	0.07
	136 Dn		25.3	1.95	6.75	45.5	17.1	21.42	23.15	29.4	42.1	7.98	1.45
	192 Up		40.3	2.15	7.45	55.56	24.4	35.43	40.45	45.77	51.7	10.35	-0.54
	192 Dn		38.95	1.98	6.84	46.85	23.3	35.27	39.55	42.97	49.4	7.7	-0.75
	OP Up		21.51	1.87	6.47	41.87	14.1	15.65	20.35	26.2	35.5	10.55	0.83
	OP Dn		20.96	1.79	6.2	38.47	13.4	16.48	20.85	21.65	38.2	5.17	2
Fecal coliform	136 Up	8	1,291	553	1,564	2,446,298	70	168	855	1,875	4,700	1,708	1.71
	136 Dn		1,879	707	2,000	4,000,927	160	183	1,350	3,425	5,500	3,243	0.86

Notes:

Statistics calculated using Minitab 16 software (licensed to King County) on data sets with no <MDL data.

IQR - interquartile range

Table 16. Descriptive Statistics for Data Sets with Non-Detected Values

Descriptive Statistics for Data Sets with Non-detected Values[1]											
					Descriptive Statistics for Left Censored Data[2]						
Parameter and units	**Project Site ID**	**# of Tests (N)**	**MDL***	**Number of Values Below MDL**	**Mean**	**Standard Error**	**Standard Deviation**	**90th Percentile**	**75th Percentile**	**Median**	**25th Percentile**
Fecal Coliform (cfu)	148 Up	8	1 cfu	2	1956	1079	2644	6500	3700	1400	50
	148 Dn	8	1 cfu	2	2125	1172	2871	7500	2500	2400	130
Lead, dissolved (ug/L)	148 Up	11	0.1	7	0.190	0.067	0.135	0.390	0.390	0.150	0.110
	148 Dn			2	0.199	0.030	0.091	0.360	0.270	0.150	0.130
	136 Up	12		2	0.187	0.021	0.065	0.350	0.200	0.180	0.160
	136 Dn			5	0.224	0.039	0.126	0.450	0.230	0.190	0.170
	192 Up			4	0.165	0.024	0.068	0.300	0.230	0.150	0.120
	192 Dn			8	0.175	0.040	0.062	0.260	0.260	0.180	0.140
	OP Up			2	0.220	0.026	0.082	0.340	0.300	0.200	0.140
	Op Dn			3	0.207	0.026	0.078	0.370	0.250	0.190	0.150
Chromium, dissolved (ug/L)	148 Up	11	0.2	5	0.983	0.365	0.893	2.170	2.070	0.670	0.300
	148 Dn			4	0.656	0.264	0.698	2.190	0.700	0.460	0.210
	136 Up	12		6	0.370	0.074	0.181	0.700	0.420	0.380	0.230
	136 Dn			6	0.875	0.334	0.818	2.190	1.590	0.600	0.300
	192 Up			11	--	--	--	--	--	--	--
	192 Dn			10	--	--	--	--	--	--	--
Ortho-phosphate Phosphorus (mg/L)	192 Up	12	0.002	9	0.0027	0.0026	0.0005	0.0031	0.0030	0.0027	0.0022
	192 Dn			7	0.0098	0.0075	0.0165	0.0398	0.0031	0.0220	0.0021
Cadmium, dissolved (ug/L)	148 Up	11		10	--	--	--	--	--	--	--
	148 Dn				--	--	--	--	--	--	--
	136 Up	12		11	--	--	--	--	--	--	--
	136 Dn				--	--	--	--	--	--	--
Selenium, dissolved (ug/L)	148 Up	11		11	--	--	--	--	--	--	--
	148 Dn				--	--	--	--	--	--	--
	136 Up	12		12	--	--	--	--	--	--	--
	136 Dn				--	--	--	--	--	--	--
Tin, dissolved (ug/L)	148 Up	11		11	--	--	--	--	--	--	--
	148 Dn				--	--	--	--	--	--	--
	136 Up	12		12	--	--	--	--	--	--	--
	136 Dn				--	--	--	--	--	--	--
TPH (mg/L)	148 Up	11		7	--	--	--	--	--	--	--
	148 Dn				--	--	--	--	--	--	--
	136 Up	12		8	--	--	--	--	--	--	--
	136 Dn				--	--	--	--	--	--	--

Notes:

[1] This table summaries statistics and hypothosis tests for data sets with results reported as <MDL (Left Censored) data

[2] Descriptive statisitics were calculated using KMStats v. 1.8 Copyright (c) 2004-2009 by Dennis R. Helsel for the Kaplan-Meier method

[3] Hypothesis testing using Wilcoxon - Substituted 1/2 MDL for non-detected data

<MDL - less than method detection limit
ug/L - micrograms per liter
mg/L - milligrams per liter
cfu - colony forming units

Table 17. Project 148 Analytical Results for 2010 Water Year

Storm No.:		1		2		3		4		5		6		7		8		9		10		11		12	
Project Site:		Project 148		Project 148		Project 148		Project 148		Project 148		Project 148		Project 148		Project 148		Project 148		Project 148		Project 148		Project 148	
Storm Date:		October 16-18, 2009		October 28-29, 2009		November 6, 2009		January 10-11, 2010		January 30-31, 2010		February 4-5, 2010		February 23-24, 2010		March 25-26, 2010		April 13, 2010		April 20-21, 2010		August 31, 2010		September 23, 2010	
Parameter	Units	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream
Nitrite + Nitrate Nitrogen	mg/L	--	--	--	--	1.39	0.929	1.8	1.71	0.974	1.06	0.851	1.05	0.865	0.915	0.585	0.993	0.679	0.75	0.468	0.492	0.901	2.16	--	--
Orthophosphate Phosphorus	mg/L	0.0394	0.116	0.0215	0.0791	0.0399	0.0593	0.0216	0.0255	0.0114	0.0152	0.0112	0.0161	0.00692	0.0113	0.0231	0.0278	0.008	0.012	0.0232	0.0388	0.173	0.264	--	--
Total Kjeldahl Nitrogen	mg/L	0.571	0.462	0.421	0.422	0.77	0.462	0.473	0.29	0.203	0.219	0.416	0.312	0.298	0.301	0.363	0.459	0.341	0.359	0.823	0.806	1.52	2.05	--	--
Total Suspended Solids	mg/L	16.8	9	11.6	3.8	66	32.2	73.3	17.7	5	3.6	24	6.6	10.2	2.53	14	19.2	12.4	5	74.1	48	5.33	4.4	--	--
Dissolved Arsenic	ug/L	0.36	0.963	0.23	0.641	0.45	0.581	0.25	0.35	0.2	0.28	0.19	0.28	0.17	0.29	0.42	0.42	0.2	0.33	0.22	0.44	0.567	1.59	--	--
Dissolved Cadmium	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	0.052	0.07	--	--
Dissolved Chromium	ug/L	0.67	0.46	2.07	2.19	2.17	0.7	0.3	0.35	<MDL	<MDL	<MDL	0.21	<MDL	0.2	0.24	<MDL	<MDL	<MDL	<MDL	<MDL	0.45	0.48	--	--
Dissolved Copper	ug/L	2.63	3.38	2.27	2.3	2.47	2.33	1.3	1.5	1.1	1.5	1.1	0.14	1.4	1.8	2	2.18	1.2	1.4	3.69	2.18	6.89	8.64	--	--
Dissolved Lead	ug/L	0.15	0.13	0.11	0.29	<MDL	0.13	<MDL	0.12	<MDL	<MDL	<MDL	0.27	<MDL	0.15	0.11	0.23	<MDL	<MDL	<MDL	0.11	0.39	0.36	--	--
Dissolved Nickel	ug/L	1.44	0.677	1.77	1.94	1.57	0.678	0.503	2.02	0.36	1.06	0.33	0.36	0.38	0.4	0.33	0.4	0.31	0.32	0.24	0.38	0.99	1.33	--	--
Dissolved Selenium	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	--	--
Dissolved Tin	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	--	--
Dissolved Zinc	ug/L	10.4	9.55	15.7	2.5	9.29	7.93	6.61	6.43	4.96	2.64	5.54	3.62	4.29	3.53	3.58	5.17	4.35	2.54	5.69	5.8	9.86	7.62	--	--
Calcium, Total, ICP	ug/L	3,990	7,970	5,130	11,500	4,240	8,130	4,940	5,420	5,450	7,880	4,930	6,920	5,420	7,080	6,370	7,570	5,550	7,720	3,650	4,930	3,820	12,800	--	--
Hardness	ug/L	14.4	26	18.5	38.2	15.7	26.9	18.7	19.5	20.3	27	18.5	24.1	19.5	23.6	21.3	26	20.2	26.1	13.9	17.1	13.4	40.4	--	--
Magnesium, Total, ICP	ug/L	1,070	1,470	1,390	2,310	1,250	1,600	1,530	1,450	1,630	1,780	1,510	1,660	1,450	1,450	1,300	1,720	1,550	1,660	1,150	1,150	939	2,030	--	--
2-Methylnaphthalene	ug/L	0.0065	0.0099	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	0.0053	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	0.0054	<MDL	<MDL	0.0076	0.0087	--	--
Acenapthene	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	0.0052	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	--	--
Acenaphthylene	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	0.015	0.019	--	--
Anthracene	ug/L	0.011	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	0.014	<MDL	--	--
Benzo(a)anthracene	ug/L	0.0782	0.022	0.119	0.0762	0.169	0.0952	0.219	0.033	0.019	0.024	0.0493	0.011	<MDL	<MDL	<MDL	0.031	0.0402	0.023	0.111	0.043	<MDL	<MDL	--	--
Benzo(a)pyrene	ug/L	0.099	0.013	0.182	0.134	0.264	0.168	0.312	0.028	0.0212	0.02	0.057	<MDL	<MDL	<MDL	<MDL	<MDL	0.0478	<MDL	0.177	0.0501	<MDL	<MDL	--	--
Benzo(b)fluoranthene	ug/L	0.112	0.016	0.175	0.117	0.293	0.173	0.291	0.037	0.0423	0.026	0.0881	0.012	<MDL	<MDL	<MDL	<MDL	0.0654	<MDL	0.252	0.0794	<MDL	<MDL	--	--
Benzo(g,h,i)perylene	ug/L	0.0694	0.01	0.0755	0.015	0.201	0.0793	<MDL	0.027	0.0234	0.017	0.0658	<MDL	<MDL	<MDL	<MDL	0.016	0.0488	0.011	0.139	0.0516	<MDL	<MDL	--	--
Benzo(k)fluoranthene	ug/L	0.105	0.015	0.209	0.153	0.308	0.194	0.243	0.032	0.02	0.022	0.0818	0.0099	<MDL	<MDL	<MDL	<MDL	0.0568	<MDL	0.197	0.0659	<MDL	<MDL	--	--
Chrysene	ug/L	0.129	0.023	0.105	0.031	0.252	0.0994	0.308	0.046	0.0382	0.029	0.0984	0.012	<MDL	0.011	<MDL	0.03	0.0616	0.028	0.215	0.0889	<MDL	<MDL	--	--
Dibenzo(a,h)anthracene	ug/L	0.029	<MDL	0.037	0.016	0.0484	0.023	<MDL	<MDL	<MDL	0.011	0.019	<MDL	<MDL	<MDL	<MDL	0.011	0.016	<MDL	<MDL	0.012	<MDL	<MDL	--	--
Fluoranthene	ug/L	0.235	0.02	0.119	<MDL	0.485	0.144	0.422	0.0565	0.0803	0.026	0.178	0.024	<MDL	0.013	0.067	0.016	0.136	0.024	0.41	0.155	0.0534	<MDL	--	--
Fluorene	ug/L	0.014	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	0.014	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	--	--
Indeno(1,2,3-Cd)Pyrene	ug/L	0.0688	<MDL	0.0639	0.017	0.165	0.0667	<MDL	0.025	0.019	0.017	0.054	0.011	<MDL	<MDL	<MDL	0.015	0.0416	<MDL	0.111	0.041	<MDL	<MDL	--	--
Naphthalene	ug/L	0.011	0.0087	0.0092	0.0084	0.0068	0.008	0.02	0.02	0.016	0.017	<MDL	<MDL	0.167	0.0394	<MDL	0.009	0.0383	0.0255	0.019	0.023	0.011	0.017	--	--
Phenanthrene	ug/L	0.0658	<MDL	0.036	<MDL	0.13	0.0545	0.119	0.02	0.0231	<MDL	0.0494	<MDL	<MDL	<MDL	0.0228	<MDL	0.0372	0.01	0.105	0.042	0.034	<MDL	--	--
Pyrene	ug/L	0.188	0.016	0.128	<MDL	0.461	0.151	0.609	0.0574	0.0557	0.02	0.151	0.02	<MDL	0.011	0.0978	0.02	0.116	0.019	0.385	0.115	0.037	<MDL	--	--
Diesel Range (>C12-C24)	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	--	--	--	--	--	--	--	--	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Lube Oil Range (>C24)	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	--	--	--	--	--	--	--	--	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Fecal Coliform	cfu/100 ml	1,400	2,400	50	200	80	130	--	--	--	--	--	--	--	--	5	<MDL	<MDL	22	3,700	2,500	6,500	7,500	410	100
Sum of PAHs	ug/L	1.2217	0.1536	1.2586	0.5676	2.7832	1.2561	2.543	0.3819	0.3582	0.2535	0.8918	0.0999	0.167	0.0744	0.1876	0.148	0.7057	0.1459	2.121	0.7669	0.172	0.0447	0	0
Total Flow	gallons	12,400	17,203	5,490	5,475	9,655	11,962	76,960	82,141	16,483	19,610	6,830	8,122	9,839	10,613	7,584	10,278	5,877	6,019	32,002	37,507	1,989	307	238	0
Base Flow	gallons	0	0	0	0	0	0	11,661	14,465	3,554	2,942	1,755	4,340	1,797	1,797	183	154	2,854	2,868	0	0	0	0	0	0

Notes:

-- - No sample collected.
mg/L - milligrams per liter.
ug/L - micrograms per liter.
cfu/100 ml - colony forming units per 100 milliliters.
<MDL - less than method detection limit.
ICP - inductively coupled plasma.
PAHs - polycyclic aromatic hydrocarbons.
Calcium and magnesium analyzed to calculate hardness.

Table 18. Project 136 Analytical Results for 2010 Water Year

	Storm No.:	1		2		3		4		5		6		7		8		9		10		11		12	
	Project Site:	Project 136		Project 136		Project 136		Project 136		Project 136		Project 136		Project 136		Project 136		Project 136		Project 136		Project 136		Project 136	
	Storm Date:	October 16-18, 2009		October 28-29, 2009		November 6, 2009		December 14-15, 2009		January 10-11, 2010		February 23-24, 2010		March 25-26, 2010		April 20-21, 2010		April 26-27, 2010		June 15, 2010		July 2, 2010		August 31, 2010	
Parameter	**Units**	**Upstream**	**Downstream**	**Upstream**	**Downstream**	**Upstream**	**Downstream**	**Upstream**	**Downstream**	**Upstream**	**Downstream**	**Upstream**	**Downstream**	**Upstream**	**Downstream**	**Upstream**	**Downstream**	**Upstream**	**Downstream**	**Upstream**	**Downstream**	**Upstream**	**Downstream**	**Upstream**	**Downstream**
Nitrite + Nitrate Nitrogen	mg/L	--	--	--	--	1.05	1.06	1.28	1.2	1.8	1.66	1.49	1.55	0.968	0.595	0.677	0.671	1.35	1.31	0.74	0.706	1.08	1.12	1.2	2.17
Orthophosphate Phosphorus	mg/L	0.0486	0.164	0.0137	0.119	0.0279	0.126	0.0634	0.119	0.0117	0.0146	0.0347	0.0255	0.0287	0.0154	0.0175	0.02	0.0039	0.0125	0.0351	0.0327	0.0534	0.078	0.352	0.258
Total Kjeldahl Nitrogen	mg/L	0.556	0.594	0.27	0.518	0.407	0.589	0.803	0.828	0.223	0.27	0.646	0.518	0.525	0.394	1.02	1.04	0.441	0.366	0.739	0.679	1.26	1.29	2.81	3.42
Total Suspended Solids	mg/L	6.73	10.9	2.31	28.3	7.35	21.9	3.95	5.78	10	16.6	12.6	8.7	21.1	22.2	34.6	44.2	4.4	5	12.4	11.9	25.6	5.8	13.8	8.2
Arsenic, Dissolved, ICP-MS	ug/L	0.77	0.84	0.39	0.46	0.508	0.583	0.35	0.44	0.32	0.33	0.27	0.28	0.41	0.22	0.43	0.4	0.34	0.34	0.605	0.596	0.645	0.733	1.04	1.21
Cadmium, Dissolved, ICP-MS	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	0.06	0.081
Chromium, Dissolved, ICP-MS	ug/L	0.38	0.3	0.22	0.27	0.23	0.6	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	0.27	0.3	0.7	2.19	0.42	1.59
Copper, Dissolved, ICP-MS	ug/L	4.08	5.09	2.47	2.56	2.76	4.28	1.9	2.47	1.4	4.62	1.5	1.4	2.01	1.5	2.24	1.5	1.6	1.7	3.03	3.16	4.35	4.9	12.9	12.5
Lead, Dissolved, ICP-MS	ug/L	0.21	0.19	0.18	0.15	0.19	0.18	0.16	0.17	<MDL	<MDL	0.11	<MDL	0.16	<MDL	0.13	<MDL	<MDL	<MDL	0.18	0.2	0.2	0.23	0.35	0.45
Nickel, Dissolved, ICP-MS	ug/L	0.989	0.694	0.46	0.49	0.528	0.772	0.41	0.47	0.4	0.35	0.46	0.39	0.42	0.28	0.34	0.29	0.41	0.48	0.88	0.912	1.26	2.46	2.08	2.7
Selenium, Dissolved, ICP-MS	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Tin, Dissolved, ICP-MS	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Zinc, Dissolved, ICP-MS	ug/L	9.17	7.42	7.06	4.45	9.63	6.98	9.38	6.77	8.33	7.25	7.47	5.64	6.73	5.19	4.83	6.02	5.8	4.87	20.8	21.7	13.2	18	19.2	41.2
Calcium, Total, ICP	ug/L	4,580	5,600	5,740	7,080	5,370	6,430	5,990	6,290	6,790	7,110	8,530	8,670	7,430	4,720	6,230	6,290	8,820	9,110	8,140	8,590	6,590	6,290	9,740	12,100
Hardness, Calc	ug/L	15	19.3	19.6	24.9	17.9	22.2	20.6	21.5	22.9	24.1	28.7	29.5	25.2	17.1	20.8	21.4	29.4	30.7	27.2	29.1	22.6	21.7	31.7	42.1
Magnesium, Total, ICP	ug/L	856	1,300	1,280	1,770	1,090	1,490	1,370	1,410	1,440	1,540	1,800	1,900	1,600	1,280	1,280	1,380	1,790	1,930	1,660	1,870	1,480	1,450	1,800	2,910
2-Methylnaphthalene	ug/L	0.0055	0.0071	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	0.0049	<MDL	<MDL	<MDL	0.01	0.012	<MDL	<MDL	0.0082	0.01
Acenaphthene	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Acenaphthylene	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	0.01	0.0602	<MDL	0.0054	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	0.011	<MDL	<MDL	<MDL	0.016	0.014
Anthracene	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	0.014	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	0.0095	<MDL
Benzo(a)anthracene	ug/L	0.015	0.01	0.0803	0.0816	0.0648	0.0729	0.063	0.0593	0.016	<MDL	<MDL	<MDL	0.023	0.119	0.011	0.014	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Benzo(a)pyrene	ug/L	<MDL	<MDL	0.142	0.146	0.122	0.136	<MDL	<MDL	0.011	<MDL	<MDL	<MDL	<MDL	0.129	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Benzo(b)fluoranthene	ug/L	<MDL	<MDL	0.124	0.135	0.106	0.125	0.103	<MDL	0.013	0.01	<MDL	<MDL	<MDL	0.181	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Benzo(g,h,i)perylene	ug/L	<MDL	<MDL	0.011	0.034	<MDL	0.03	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	0.014	0.121	<MDL	0.01	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Benzo(k)fluoranthene	ug/L	<MDL	<MDL	0.164	0.168	0.142	0.156	0.141	<MDL	0.013	<MDL	<MDL	<MDL	<MDL	0.134	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Chrysene	ug/L	0.011	0.012	0.028	0.043	0.019	0.037	0.018	0.015	0.013	<MDL	<MDL	<MDL	0.023	0.196	0.014	0.014	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Dibenzo(a,h)anthracene	ug/L	<MDL	<MDL	<MDL	0.02	<MDL	0.015	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	0.035	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Fluoranthene	ug/L	<MDL	0.011	0.013	0.028	<MDL	0.039	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	0.013	0.371	0.014	0.012	<MDL	<MDL	<MDL	<MDL	0.014	<MDL	<MDL	<MDL
Fluorene	ug/L	<MDL	<MDL	0.014	<MDL	0.0099	<MDL	0.016	<MDL	0.016	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	0.019	<MDL	<MDL	0.018	<MDL	<MDL	<MDL
Indeno(1,2,3-Cd)Pyrene	ug/L	<MDL	<MDL	0.013	0.032	<MDL	0.028	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	0.012	0.102	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Naphthalene	ug/L	0.0073	0.0062	0.0091	0.0076	0.0064	0.0059	0.016	0.018	0.015	0.011	0.015	0.0088	0.013	0.014	0.023	0.015	0.016	0.018	0.034	0.034	0.01	0.0092	0.011	0.016
Phenanthrene	ug/L	0.011	<MDL	0.042	0.018	0.018	0.026	0.012	<MDL	<MDL	<MDL	0.021	<MDL	0.022	0.0964	0.022	0.013	0.012	<MDL	0.022	<MDL	0.041	<MDL	0.045	<MDL
Pyrene	ug/L	<MDL	0.01	0.011	0.032	<MDL	0.044	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	0.012	0.31	0.013	0.011	<MDL	<MDL	<MDL	<MDL	0.01	<MDL	<MDL	<MDL
Diesel Range (>C12-C24)	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	--	--	--	--	--	--	<MDL	<MDL	<MDL	<MDL	--	--	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Lube Oil Range (>C24)	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	--	--	--	--	--	--	<MDL	<MDL	<MDL	<MDL	--	--	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Fecal Coliform	cfu/100 ml	1,400	400	160	5,500	310	2,300	--	--	--	--	--	--	190	190	1,500	2,600	--	--	70	160	2,000	3,700	4,700	180
Sum of PAHs		0.0498	0.0563	0.6514	0.7452	0.4881	0.7148	0.393	0.1525	0.097	0.0264	0.036	0.0088	0.132	1.8084	0.1019	0.089	0.028	0.037	0.077	0.046	0.093	0.0092	0.0897	0.04
Flow	gallons	31,450	46,080	9,058	15,776	21,205	27,822	9,695	12,058	70,030	65,656	11,331	14,206	18,048	19,819	28,129	31,120	10,470	12,683	16,546	22,027	5,219	2,493	787	3,862
Baseflow	gallons	0	0	0	0	2022	2384	1460	0	18992	13936	2026	1766	2744	1364	0	0	2520	3320	462	396	0	0	0	0

Notes:

-- - No sample collected.
mg/L - milligrams per liter.
ug/L - micrograms per liter.
cfu/100 ml - colony forming units per 100 milliliters.
<MDL - less than method detection limit.
ICP - inductively coupled plasma.
PAHs - polycyclic aromatic hydrocarbons.
Calcium and magnesium analyzed to calculate hardness.

Table 19. Project 192 Analytical Results for 2011 Water Year

	Storm No.:	1		2		3		4		5		6	
	Project Site:	Project 192		Project 192		Project 192		Project 192		Project 192		Project 192	
	Storm Date:	October 23, 2010		November 17, 2010		December 7, 2010		January 12, 2011		March 13, 2011		March 24, 2011	
Parameter	**Units**	**Upstream**	**Downstream**	**Upstream**	**Downstream**	**Upstream**	**Downstream**	**Upstream**	**Downstream**	**Upstream**	**Downstream**	**Upstream**	**Downstream**
Nitrite + Nitrate Nitrogen	mg/L	0.224	0.281	0.264	0.296	0.195	0.223	0.316	0.331	0.387	0.406	0.195	0.216
Orthophosphate Phosphorus	mg/L	0.0031	0.0398	<MDL	0.0021	<MDL	<MDL	0.0027	0.0022	<MDL	<MDL	<MDL	<MDL
Total Kjeldahl Nitrogen	mg/L	0.361	0.47	0.568	0.419	0.99	0.887	0.379	0.328	0.537	0.357	0.607	0.518
Total Phosphorous	mg/L	0.0577	0.102	0.0759	0.0411	0.179	0.188	0.0526	0.0405	0.026	0.0131	0.058	0.0362
Total Suspended Solids	mg/L	19.6	16.6	42.1	17.6	193	155	50.7	42.2	15	6.2	43.7	10.4
Dissolved Arsenic	ug/L	0.16	0.532	0.2	0.21	0.15	0.15	0.23	0.21	0.46	0.39	0.42	0.36
Dissolved Chromium	ug/L	<MDL	0.21	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Dissolved Copper	ug/L	2	2.35	1.7	1.6	1.9	1.9	1.3	1.3	0.99	0.77	15.3	1.7
Dissolved Lead	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	0.12	<MDL	0.11	<MDL	0.3	0.26
Dissolved Nickel	ug/L	0.33	0.38	0.569	0.552	0.5	0.44	0.519	0.552	0.644	0.536	0.819	0.744
Dissolved Zinc	ug/L	4.06	3.5	5.39	4.9	4.62	4.39	4.69	5.03	3.17	3.28	5.72	5.97
Total Arsenic	ug/L	0.606	0.861	0.829	0.509	2.78	2.06	1	0.911	0.796	0.5	1.13	0.802
Total Calcium	ug/L	6,390	5,900	8,730	9,040	9,750	9,960	8,940	9,060	9,060	8,760	11,300	10,900
Total Chromium	ug/L	2.1	1.68	2.81	1.59	12.8	7.82	1.98	1.75	1.12	0.79	2.41	1.59
Total Copper	ug/L	5.36	5.31	8.61	5.66	25.5	19.6	5.02	4.68	3.63	1.8	5.86	3.76
Hardness	mg/L	24.4	23.3	36.1	36.4	46	43.4	35.1	34.9	35.2	33.7	42.5	40.9
Total Lead	ug/L	2.07	1.79	3.65	1.87	18.4	14.5	3.38	2.82	1.59	0.601	3.15	1.86
Total Magnesium	ug/L	2,050	2,080	3,460	3,350	5,260	4,500	3,100	2,980	3,070	2,880	3,490	3,310
Total Nickel	ug/L	2.36	1.91	3.34	2.13	13.8	8.33	2.19	1.98	1.57	1.06	2.96	2.07
Total Zinc	ug/L	11.5	10	16.5	11.2	51.8	44.4	12.9	12.6	7.51	5.7	14.3	10.9
2-Methylnaphthalene	ug/L	0.0092	0.008	0.0311	0.0083	0.0903	0.0578	0.0402	0.0328	0.0053	0.0048	0.0081	0.0054
Acenapthene	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Acenaphthylene	ug/L	<MDL	<MDL	<MDL	0.015	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Anthracene	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Benzo(a)anthracene	ug/L	<MDL	<MDL	<MDL	<MDL	0.018	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Benzo(a)pyrene	ug/L	<MDL	<MDL	<MDL	<MDL	0.016	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Benzo(b)fluoranthene	ug/L	<MDL	<MDL	<MDL	<MDL	0.029	0.019	<MDL	<MDL	<MDL	<MDL	--	--
Benzo(b,j,k)fluoranthene	ug/L	--	--	--	--	--	--	--	--	--	--	0.013	<MDL
Benzo(g,h,i)perylene	ug/L	<MDL	<MDL	<MDL	<MDL	0.03	0.021	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Benzo(k)fluoranthene	ug/L	<MDL	<MDL	<MDL	<MDL	0.015	0.01	<MDL	<MDL	<MDL	<MDL	--	--
Chrysene	ug/L	<MDL	<MDL	<MDL	<MDL	0.041	0.028	0.011	0.0098	<MDL	<MDL	<MDL	<MDL
Dibenzo(a,h)anthracene	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Fluoranthene	ug/L	<MDL	<MDL	<MDL	<MDL	0.041	0.021	0.016	<MDL	<MDL	<MDL	<MDL	<MDL
Fluorene	ug/L	<MDL	<MDL	0.012	<MDL	0.023	0.01	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Indeno(1,2,3-Cd)Pyrene	ug/L	<MDL	<MDL	<MDL	<MDL	0.015	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Naphthalene	ug/L	0.0095	0.012	0.0261	<MDL	0.0459	0.0323	0.0318	0.0309	0.011	0.011	0.0099	0.0067
Phenanthrene	ug/L	<MDL	<MDL	0.025	<MDL	0.0542	0.021	0.021	0.017	<MDL	<MDL	<MDL	<MDL
Pyrene	ug/L	<MDL	<MDL	0.019	0.01	0.0697	0.044	0.015	0.014	<MDL	<MDL	0.012	<MDL
Sum of PAHs		0.0187	0.02	0.1132	0.0333	0.4881	0.2641	0.135	0.1045	0.0163	0.0158	0.043	0.0121
Flow	gallons	70,008	74,305	105,344	111,230	79,850	87,815	162,448	179,389	161,569	179,389	30,523	33,406
Baseflow	gallons	0	0	38	39	10	10	15	15	85	97	17	17

	Storm No.:	7		8		9		10		11		12	
	Project Site:	Project 192		Project 192		Project 192		Project 192		Project 192		Project 192	
	Storm Date:	April 13, 2011		April 26, 2011		May 11, 2011		May 25, 2011		June 15, 2011		July 13, 2011	
Parameter	**Units**	**Upstream**	**Downstream**	**Upstream**	**Downstream**	**Upstream**	**Downstream**	**Upstream**	**Downstream**	**Upstream**	**Downstream**	**Upstream**	**Downstream**
Nitrite + Nitrate Nitrogen	mg/L	0.146	0.171	0.11	0.124	0.0983	0.106	0.125	0.155	0.188	0.221	0.894	0.921
Orthophosphate Phosphorus	mg/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	0.0031	0.0022	0.002
Total Kjeldahl Nitrogen	mg/L	0.687	0.59	0.458	0.364	0.491	0.419	0.797	0.763	1.03	0.893	2.81	2.23
Total Phosphorous	mg/L	0.0191	0.0165	0.0078	0.0109	0.031	0.0302	0.0379	0.0594	0.0831	0.103	0.733	0.542
Total Suspended Solids	mg/L	9.2	10.4	2.1	5.2	16.4	13.9	25.3	32	58	26.7	624	432
Dissolved Arsenic	ug/L	0.554	0.42	0.36	0.29	0.39	0.32	0.37	0.31	0.35	0.36	0.3	0.28
Dissolved Chromium	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	0.26	0.24
Dissolved Copper	ug/L	1.4	1.2	1.3	1	1.4	1.2	1.9	1.5	2.17	2	6.07	5.94
Dissolved Lead	ug/L	0.23	0.18	0.11	<MDL	0.15	<MDL	<MDL	<MDL	0.15	0.14	0.15	0.12
Dissolved Nickel	ug/L	1.1	1.05	0.708	0.671	0.757	0.658	1.29	0.828	1.11	0.897	1.22	1.24
Dissolved Zinc	ug/L	4.77	4.51	2.85	3.68	3.32	3.33	4.64	3.7	5.97	6.83	4.09	4.55
Total Arsenic	ug/L	0.761	0.633	0.56	0.37	0.686	0.595	1.16	1.31	1.55	0.918	5.39	4.61
Total Calcium	ug/L	11,100	10,700	10,100	10,200	9,410	9,620	13,400	13,700	12,000	11,100	10,600	10,100
Total Chromium	ug/L	0.55	0.51	0.38	0.26	1.33	1.09	1.16	1.35	2.61	1.48	27.2	22.9
Total Copper	ug/L	2.32	2.04	1.8	1.4	3.26	2.85	4.16	4.22	6.12	4.32	48.6	41.1
Hardness	mg/L	44.1	41.7	38.4	38.2	36.6	37.1	48.4	49.4	45.1	41	51.7	47.4
Total Lead	ug/L	0.744	0.61	0.48	0.27	1.39	1.09	1.47	1.78	3.54	1.99	31.9	27.9
Total Magnesium	ug/L	3,960	3,630	3,210	3,130	3,180	3,170	3,630	3,680	3,670	3,240	6,130	5,350
Total Nickel	ug/L	1.19	1.18	0.88	0.804	1.88	1.61	1.85	2.12	3.37	2.19	28.1	23.7
Total Zinc	ug/L	6.84	6.6	4.45	4.47	7.3	7.23	11.1	13.5	22.9	18	111	100
2-Methylnaphthalene	ug/L	<MDL	<MDL	<MDL	<MDL	0.0051	<MDL	0.0073	0.0067	0.0085	0.0062	0.0288	0.0469
Acenapthene	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Acenaphthylene	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Anthracene	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Benzo(a)anthracene	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Benzo(a)pyrene	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Benzo(b)fluoranthene	ug/L	--	--	--	--	--	--	--	--	--	--	--	--
Benzo(b,j,k)fluoranthene	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	0.027	0.021
Benzo(g,h,i)perylene	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	0.017	0.011
Benzo(k)fluoranthene	ug/L	--	--	--	--	--	--	--	--	--	--	--	--
Chrysene	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	0.036	0.024
Dibenzo(a,h)anthracene	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Fluoranthene	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	0.024	0.022
Fluorene	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Indeno(1,2,3-Cd)Pyrene	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Naphthalene	ug/L	0.015	0.017	0.011	0.011	0.015	0.015	0.01	0.011	0.016	0.0095	0.0351	0.0413
Phenanthrene	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	0.042	0.036
Pyrene	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	0.033	0.026
Sum of PAHs		0.015	0.017	0.011	0.011	0.0201	0.015	0.0173	0.0177	0.0245	0.0157	0.2429	0.2282
Flow	gallons	34,848	39,598	28,906	34,154	73,961	89,962	22,412	23,993	4,554	3,674	26,230	25,920
Baseflow	gallons	27	33	21	25	19	24	5	4	0	1	0	0

Notes:

-- - No sample collected.
mg/L - milligrams per liter.
ug/L - micrograms per liter.
cfu/100 ml - colony forming units per 100 milliliters.
<MDL - less than method detection limit.
ICP - inductively coupled plasma.
PAHs - polycyclic aromatic hydrocarbons.
Calcium and magnesium analyzed to calculate hardness.
Benzo(b,j,k)fluoranthene analyte replaced Benzo(b)fluoranthene and Benzo(k)fluoranthene effective March 2011.

Table 20. Project OP Analytical Results for 2011 Water Year

	Storm No.:	1		2		3		4		5		6		7		8		9		10		11		12	
	Project Site:	Project OP		Project OP		Project OP		Project OP		Project OP		Project OP		Project OP		Project OP		Project OP		Project OP		Project OP		Project OP	
	Storm Date:	October 8, 2010		October 23, 2010		November 5, 2010		November 17, 2010		November 29, 2010		December 7, 2010		January 12, 2011		March 13, 2011		April 13, 2011		May 11, 2011		May 25, 2011		August 23, 2011	
Parameter	Units	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream
Nitrite + Nitrate Nitrogen	mg/L	0.155	0.39	0.14	0.236	0.248	0.339	0.143	0.204	0.102	0.146	0.0892	0.14	0.0921	0.123	0.153	0.182	0.263	0.351	0.107	0.129	0.196	0.222	1.19	0.419
Orthophosphate Phosphorus	mg/L	0.00979	0.0517	0.00729	0.0265	0.00845	0.0225	0.00805	0.0168	0.00502	0.0103	0.0061	0.0157	0.0034	0.00611	0.00708	0.00595	0.014	0.00862	0.0041	0.00636	0.00592	0.0106	0.0686	0.0251
Total Kjeldahl Nitrogen	mg/L	0.781	0.808	0.538	0.479	0.88	0.459	0.458	0.323	0.374	0.17	0.434	0.391	0.282	0.21	0.16	0.272	0.333	0.252	0.356	0.292	0.472	0.419	1.31	1.18
Total Phosphorous	mg/L	0.107	0.0944	0.049	0.0608	0.123	0.0442	0.0312	0.0352	0.0314	0.0266	0.0408	0.0372	0.0444	0.0334	0.0207	0.022	0.0283	0.0308	0.0446	0.0393	0.0495	0.0457	0.118	0.07
Total Suspended Solids	mg/L	81.4	11.8	18.3	6.6	123	4.6	9.4	3.74	11.2	5.4	23.2	10.5	25.2	17.1	4.2	5.9	9.3	9.3	12.7	7.8	15	7.13	4	6.02
Dissolved Arsenic	ug/L	0.583	0.856	1.04	1.24	1.19	1.05	1.16	1.1	0.696	0.611	0.45	0.49	0.36	0.38	0.532	0.502	0.503	0.534	0.65	0.65	0.48	0.505	1.19	0.875
Dissolved Chromium	ug/L	0.23	0.49	0.23	6.61	0.35	0.32	0.41	0.41	0.49	0.49	0.35	0.35	0.59	0.51	0.27	0.33	0.35	0.38	0.28	0.29	0.23	0.25	0.78	0.7
Dissolved Copper	ug/L	1.7	2	2.37	2.92	2.95	2.75	3.17	3.06	2.53	2.02	1.6	1.8	1.4	1.4	1.4	1.7	2.12	2.04	2.11	2	2.13	2.25	7.12	6.66
Dissolved Lead	ug/L	<MDL	<MDL	0.13	0.19	0.2	0.14	0.26	0.21	0.34	0.26	0.18	0.15	0.14	<MDL	<MDL	<MDL	0.3	0.25	0.19	0.17	0.13	0.12	0.33	0.37
Dissolved Nickel	ug/L	0.34	0.569	0.533	4.5	0.756	0.616	0.916	0.716	0.571	0.5	0.36	0.32	0.46	0.39	0.46	0.48	0.701	0.886	0.49	0.43	0.502	0.39	0.92	1.2
Dissolved Zinc	ug/L	13.2	7.52	17.8	10.4	19.6	11	17.2	8.97	13.6	9.3	13.7	9.18	17.8	14	9.49	8.43	13.5	6.15	13.2	8.27	12	7.03	14.4	44.1
Total Arsenic	ug/L	2.94	1.23	1.64	1.43	4.8	1.32	1.35	1.11	0.841	0.684	0.999	0.702	0.89	0.741	0.748	0.641	0.782	0.74	0.94	0.848	1.02	0.755	1.17	1.14
Total Calcium	ug/L	3,810	3,550	3,580	4,030	6,080	5,430	5,290	5,720	4,460	5,340	3,540	4,070	5,400	5,670	6,130	6,130	8,800	9,720	4,120	4,560	6,530	5,760	7,490	5,750
Total Chromium	ug/L	4.74	1.27	1.7	8.73	7.27	0.58	0.95	0.67	1.91	1.2	2.36	1.27	3.49	2.56	1	0.99	1.05	0.99	1.3	0.99	1.27	0.86	0.84	0.95
Total Copper	ug/L	9.74	3.58	4.95	4.05	15.2	3.59	4.42	3.66	4.43	3.05	5.08	3.22	12.2	4.25	2.93	2.94	3.58	3.16	3.9	3.36	4.32	3.65	7.67	8.14
Hardness	mg/L	15.3	13.4	14.1	15.5	26.6	20.8	20.9	21.7	18.4	21.5	14.4	15.9	19.8	20.9	23.3	23.1	35.5	38.2	16.7	18.2	25	21.5	28.1	20.8
Total Lead	ug/L	16.9	2.05	4.08	1.19	22.8	0.616	1.68	0.793	4.22	2.15	6.52	2.96	9.03	5.69	0.951	1.32	3.01	2.58	2.68	1.77	2.99	1.73	0.629	1.2
Total Magnesium	ug/L	1,400	1,090	1,270	1,310	2,770	1,750	1,860	1,810	1,750	1,980	1,340	1,390	1,530	1,620	1,940	1,890	3,290	3,370	1,560	1,650	2,110	1,730	2,280	1,560
Total Nickel	ug/L	3.99	1.23	1.73	5.33	7.76	0.898	1.32	0.921	1.18	0.858	1.58	0.899	2	1.53	1.16	0.999	1.18	1.06	1.24	1	1.28	0.88	0.99	1.34
Total Zinc	ug/L	78.3	16	34.3	14.9	125	14.8	21.7	11.4	22.3	13.5	30	15.1	39.4	24.2	14.2	11.6	21.4	12.9	21.3	13.9	27.3	13.8	16.2	51.7
2-Methylnaphthalene	ug/L	<MDL	<MDL	<MDL	<MDL	0.013	0.011	<MDL	<MDL	0.0055	<MDL	<MDL	<MDL	0.013	0.01	0.0052	<MDL	<MDL	<MDL	<MDL	<MDL	0.0073	0.0059	<MDL	<MDL
Acenapthene	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Acenaphthylene	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Anthracene	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Benzo(a)anthracene	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	0.011	0.011	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Benzo(a)pyrene	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	0.013	0.011	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Benzo(b)fluoranthene	ug/L	<MDL	<MDL	<MDL	<MDL	0.013	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	0.012	0.011	<MDL	<MDL	--	--	--	--	--	--	--	--
Benzo(b,j,k)fluoranthene	ug/L	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Benzo(g,h,i)perylene	ug/L	0.0097	<MDL	<MDL	<MDL	0.013	<MDL	<MDL	<MDL	0.013	<MDL	0.016	<MDL	0.021	0.016	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Benzo(k)fluoranthene	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	--	--	--	--	--	--	--	--
Chrysene	ug/L	<MDL	<MDL	<MDL	<MDL	0.013	<MDL	<MDL	<MDL	0.012	<MDL	0.013	<MDL	0.021	0.015	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Dibenzo(a,h)anthracene	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Fluoranthene	ug/L	0.01	<MDL	<MDL	<MDL	0.014	<MDL	<MDL	<MDL	0.014	<MDL	0.016	<MDL	0.023	0.018	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Fluorene	ug/L	<MDL	<MDL	0.018	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Indeno(1,2,3-Cd)Pyrene	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Naphthalene	ug/L	0.009	0.0071	0.0071	0.015	0.016	0.0283	0.0063	0.0052	0.015	0.0097	0.0094	0.014	0.023	0.0348	0.011	0.012	0.0098	0.0088	0.015	0.006	0.011	0.012	0.021	0.019
Phenanthrene	ug/L	<MDL	<MDL	<MDL	<MDL	0.0097	<MDL	<MDL	<MDL	0.013	<MDL	0.013	<MDL	0.02	0.015	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Pyrene	ug/L	0.011	<MDL	0.01	<MDL	0.014	<MDL	<MDL	<MDL	0.022	0.011	0.021	0.012	0.033	0.025	<MDL	<MDL	0.011	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Sum of PAHs		0.0397	0.0071	0.0351	0.015	0.1057	0.0393	0.0063	0.0052	0.1185	0.0427	0.0884	0.026	0.166	0.1448	0.0162	0.012	0.0208	0.0088	0.015	0.006	0.0183	0.0179	0.021	0.019
Flow	gallons	279,127	261,396	220,766	197,607	84,639	84,765	74,178	74,278	147,952	156,974	79,736	79,419	196,482	189,510	87,783	104,035	24,486	21,530	75,515	73,821	44,297	41,867	13,266	9,903
Baseflow	gallons	0	0	0	0	0	3	5	9	5	5	1	2	6	6	7	17	5	5	3	3	0	0	0	0

Notes:

-- - No sample collected.
mg/L - milligrams per liter.
ug/L - micrograms per liter.
cfu/100 ml - colony forming units per 100 milliliters.
<MDL - less than method detection limit.
ICP - inductively coupled plasma.
PAHs - polycyclic aromatic hydrocarbons.
Calcium and magnesium analyzed to calculate hardness.
Benzo(b,j,k)fluoranthene analyte replaced Benzo(b)fluoranthene and Benzo(k)fluoranthene effective March 2011.

Table 21. Discrete Field Parameters Collected During 2010 Water Year Monitoring

Project	Monitoring Location	Date	Time	DO (mg/L)	pH	Temperature (°C)	Turbidity (NTU)	Conductivity (uS/cm)
148	148UP	10/16/2009	12:31:30	9.24	6.52	13.15	9.8	0.085
	148UP	10/29/2009	9:17:57	11.8	7.02	9.08	5.2	0.051
	148UP	11/5/2009	16:32:45	7.27	6.17	11.2	18.3	0.054
	148UP	3/25/2010	9:03:37	11.12	7.18	9.1	4.6	0.05
	148UP	4/13/2010	9:42:16	11.64	6.9	8.99	3.4	0.066
	148UP	4/21/2010	7:30:10	10.3	6.42	9.48	12	0.066
	148UP	6/16/2010	15:30:17	8.87	6.86	12.68	6	0.088
	148UP	8/31/2010	12:05:26	8.69	7.16	15.19	5.1	0.045
	148DN	10/16/2009	13:12:32	9.05	7.82	13.51	13.9	0.08
	148DN	10/29/2009	9:29:19	11.43	7.33	9.29	7.2	0.085
	148DN	11/5/2009	16:24:26	7.97	6.37	10.99	7.8	0.089
	148DN	3/25/2010	8:53:25	10.78	7.32	8.97	3.4	0.072
	148DN	4/13/2010	9:31:58	11.05	7.11	8.96	4.5	0.069
	148DN	4/21/2010	7:10:32	10.35	6.56	9.58	16.1	0.081
	148DN	6/16/2010	15:15:05	8.83	6.99	12.53	6.4	0.072
	148DN	8/31/2010	12:00:26	8.47	7.3	14.93	5.4	0.101
136	136DN	10/16/2009	12:56:00	8.05	6.13	13.33	2.2	0.047
	136DN	10/29/2009	8:59:18	11.31	6.95	9.26	8.2	0.071
	136DN	11/5/2009	15:56:53	8.22	6.32	10.68	5.4	0.099
	136DN	3/25/2010	9:37:20	10.62	6.95	9.33	8.2	0.09
	136DN	4/21/2010	6:48:08	9.74	6.64	10.47	9.9	0.074
	136DN	6/16/2010	16:04:05	8.47	6.9	13.06	3.4	0.097
	136DN	8/31/2010	12:23:32	7.97	6.72	15.12	8.5	0.285
	136UP	10/16/2009	12:40:00	12.16	6.51	13.15	16.1	0.085
	136UP	10/29/2009	8:47:46	10.92	7.07	9.39	11	0.072
	136UP	11/5/2009	16:06:02	7.73	5.95	11.04	3.8	0.081
	136UP	3/25/2010	9:25:50	10.2	6.89	9.49	11.4	0.087
	136UP	4/21/2010	6:42:19	10.14	6.48	10.5	8.9	0.075
	136UP	6/16/2010	16:31:09	7.98	6.73	13	2.8	0.104
	136UP	8/31/2010	12:35:52	7.51	6.5	15.3	9	0.103
Discrete measurements collected with YSI Inc. 6900 series sonde.								

Notes:

DO - dissolved oxygen
mg/L - milligrams per liter
°C - degrees Celsius
NTU - Nephelometric turbidity units
uS/cm - microsiemens per centimeter

Table 22. Project 192 Continuous Turbidity Monitoring Summary

Project 192 - PETROVITSKYat SE 192 Dr
BMPs Installed 9/27/2010
192UP UPSTREAM - (RSW17UP)
192M DOWNSTREAM - (RSW17DN)
192DN Downstream Flow Control Station
Project Raingage: King County 31Y2 Fairwood Gage. Backup gage located at 192UP Monitoring Station

%Eff = (192UP-192M)/192UP*100
%Eff = (192UP-192DN)/192UP*100

Project Site ID	Sonde Deployment Start (date/time)	Sonde Deployment End (date/time)	Maximum Turbidity Value for Deployment [1]	Average Turbidity for Deployment [1]	192M Maximum Turbidity % Efficiency [1]	192DN Average Turbidity % Efficiency	192M Average Turbidity % Efficiency	192DN Average Turbidity % Efficiency	Total # of Turbidity Samples	# of Suspect ("S") Data Flagged	# of Edited ("E") Data Flagged	# of Deleted ("D" or "S, D") Data Flagged[2]	# of Missing Data ("M") Data Flagged [3]
192UP	10/9/10 21:50	10/10/10 12:00	110.2	30.0	35	62	10	29	86	0	0	0	0
192M	10/9/10 21:50	10/10/10 12:00	71.7	27.1					86	0	0	0	0
192DN	10/9/10 21:50	10/10/10 12:00	41.5	21.3					86	0	0	0	0
192UP	10/23/10 20:00	10/25/10 15:00	136.2	36.8	49	70	22	46	259	0	**3**	0	0
192M	10/23/10 20:00	10/25/10 15:00	69.8	28.9					259	0	0	0	0
192DN	10/23/10 20:00	10/25/10 15:00	40.7	19.7					259	0	0	0	0
192UP	11/17/10 6:00	11/18/10 8:30	367.8	40.1	38	62	30	40	160	**2**	**1**	0	0
192M	11/17/10 6:00	11/18/10 8:30	226.6	27.9					160	0	0	0	0
192DN	11/17/10 6:00	11/18/10 8:30	140.3	23.9					160	0	0	0	0
192UP	12/7/10 16:20	12/8/10 13:00	1,038.7	129.6	46	60	21	41	125	0	**2**	0	0
192M	12/7/10 16:20	12/8/10 13:00	558.7	103.0					125	0	0	0	0
192DN	12/7/10 16:20	12/8/10 13:00	413.0	77.1					125	0	0	0	0
192UP	12/8/10 20:00	12/10/10 17:30	544.7	42.6	-11	26	14	26	274	0	**1**	0	0
192M	12/8/10 20:00	12/10/10 17:30	604.2	36.8					274	0	0	0	0
192DN	12/8/10 20:00	12/10/10 17:30	401.9	31.4					274	0	0	0	0
192UP	12/10/10 17:40	12/12/10 2:00	518.9	61.4	21	19	12	21	195	0	0	0	0
192M	12/10/10 17:40	12/12/10 2:00	409.7	54.1					195	0	0	0	0
192DN	12/10/10 17:40	12/12/10 2:00	421.9	48.5					195	0	0	0	0
192UP	12/13/10 15:10	12/14/10 10:00	298.1	24.1	31	49	23	30	114	0	0	0	0
192M	12/13/10 15:10	12/14/10 10:00	205.0	18.6					114	0	0	0	0
192DN	12/13/10 15:10	12/14/10 10:00	152.5	16.7					114	0	0	0	0

Table 22. Project 192 Continuous Turbidity Monitoring Summary

Project 192 - PETROVITSKYat SE 192 Dr
BMPs Installed 9/27/2010
192UP UPSTREAM - (RSW17UP)
192M DOWNSTREAM - (RSW17DN)
192DN Downstream Flow Control Station
Project Raingage: King County 31Y2 Fairwood Gage. Backup gage located at 192UP Monitoring Station

%Eff = (192UP-192M)/192UP*100
%Eff = (192UP-192DN)/192UP*100

Project Site ID	Sonde Deployment Start (date/time)	Sonde Deployment End (date/time)	Maximum Turbidity Value for Deployment [1]	Average Turbidity for Deployment [1]	192M Maximum Turbidity % Efficiency [1]	192DN Average Turbidity % Efficiency	192M Average Turbidity % Efficiency	192DN Average Turbidity % Efficiency	Total # of Turbidity Samples	# of Suspect ("S") Data Flagged	# of Edited ("E") Data Flagged	# of Deleted ("D" or "S, D") Data Flagged[2]	# of Missing Data ("M") Data Flagged [3]
192UP	1/12/11 2:00	1/12/11 19:00	216.7	31.9	43	52	10	23	409	0	0	0	0
192M	1/12/11 2:00	1/12/11 19:00	123.6	28.7					409	0	2	0	0
192DN	1/12/11 2:00	1/12/11 19:00	103.8	24.6					409	0	1	0	0
192UP	1/12/11 19:10	1/14/11 13:00	142.8	14.0	44	59	5	27	252	0	0	0	0
192M	1/12/11 19:10	1/14/11 13:00	79.3	13.4					252	0	2	0	0
192DN	1/12/11 19:10	1/14/11 13:00	58.4	10.2					252	0	0	0	0
192UP	2/3/11 14:00	2/4/11 9:20	1,096.4	106.4	29	67	16	45	117	0	0	0	0
192M	2/3/11 14:00	2/4/11 9:20	778.0	89.5					117	0	0	0	0
192DN	2/3/11 14:00	2/4/11 9:20	358.1	58.1					117	0	0	0	0
192UP	2/6/11 3:20	2/7/11 7:00	337.0	47.9	26	52	12	35	167	0	0	0	0
192M	2/6/11 3:20	2/7/11 7:00	250.1	42.0					167	0	0	0	0
192DN	2/6/11 3:20	2/7/11 7:00	161.7	31.2					167	0	1	0	0
192UP	2/12/11 12:00	2/16/11 9:50	2,638.3	62.4	57	50	19	23	564	0	0	0	0
192M	2/12/11 12:00	2/16/11 9:50	1,143.8	50.5					564	0	0	0	0
192DN	2/12/11 12:00	2/16/11 9:50	1,326.6	48.2					564	0	0	0	0
192UP	3/8/11 18:00	3/9/11 20:00	1,316.0	66.8	33	32	13	17	157	0	0	0	0
192M	3/8/11 18:00	3/9/11 20:00	887.8	58.0					157	0	0	0	0
192DN	3/8/11 18:00	3/9/11 20:00	899.9	55.6					157	0	0	0	0
192UP	3/12/11 10:10	3/13/11 9:40	92.4	22.7	43	65	48	60	142	0	0	0	0
192M	3/12/11 10:10	3/13/11 9:40	52.8	11.8					142	0	0	0	0
192DN	3/12/11 10:10	3/13/11 9:40	32.2	9.1					142	0	0	0	0

Table 22. Project 192 Continuous Turbidity Monitoring Summary

Project 192 - PETROVITSKYat SE 192 Dr

BMPs Installed 9/27/2010

192UP UPSTREAM - (RSW17UP)

192M DOWNSTREAM - (RSW17DN)

192DN Downstream Flow Control Station

Project Raingage: King County 31Y2 Fairwood Gage. Backup gage located at 192UP Monitoring Station

%Eff = (192UP-192M)/192UP*100

%Eff = (192UP-192DN)/192UP*100

Project Site ID	Sonde Deployment Start (date/time)	Sonde Deployment End (date/time)	Maximum Turbidity Value for Deployment [1]	Average Turbidity for Deployment [1]	192M Maximum Turbidity % Efficiency [1]	192DN Average Turbidity % Efficiency	192M Average Turbidity % Efficiency	192DN Average Turbidity % Efficiency	Total # of Turbidity Samples	# of Suspect ("S") Data Flagged	# of Edited ("E") Data Flagged	# of Deleted ("D" or "S, D") Data Flagged[2]	# of Missing Data ("M") Data Flagged [3]
192UP	4/10/11 12:00	4/11/11 16:00	180.6	9.8	50	74	15	17	169	0	0	0	0
192M	4/10/11 12:00	4/11/11 16:00	90.0	8.4					169	0	0	0	0
192DN	4/10/11 12:00	4/11/11 16:00	47.8	8.2					169	0	0	0	0
192UP	4/13/11 11:20	4/14/11 8:10	130.1	11.7	15	73	**-148**	-17	113	0	0	0	0
192M	4/13/11 11:20	4/14/11 8:10	110.9	29.0					113	**25**	0	0	0
192DN	4/13/11 11:20	4/14/11 8:10	34.9	13.6					113	0	0	0	**13**
192UP	5/25/11 10:50	5/26/11 6:10	274.5	25.5	7	75	1	46	112	0	0	**4**	0
192M	5/25/11 10:50	5/26/11 6:10	254.0	25.3					112	0	**1**	**4**	0
192DN	5/25/11 10:50	5/26/11 6:10	67.5	13.8					112	0	0	**4**	0
192UP	7/12/11 19:40	7/13/11 9:20	1,257.6	87.6	46	73	**-6.4**	40	83	0	**1**	0	0
192M	7/12/11 19:40	7/13/11 9:20	676.6	93.2					83	0	0	0	0
192DN	7/12/11 19:40	7/13/11 9:20	337.7	53.0					83	0	**1**	0	0

[1] All turbidity data and associated calculations based on edited data tables. See data tables for raw data and descriptive flags.

[2] Flagged "D" and "S, D" data values applied consistently across all stations and all associated values were deleted for that range for datacomparison/analysis purposes.

[3] Flagged "M" data values indicate missing data due to equipment malfunction. Data gaps (or Missing data) applied consistently across all stations and all associated values were deleted for that time range for data comparison/analysis purposes.

Table 23. Project OP Continuous Turbidity Monitoring Summary

Project OP - Petrovitsky Rd. at Old Petrovitsky Rd. %Eff = (OPUP-OPDN)/OPUP*100
BMPs Installed: 8/9/2010
OPUP UPSTREAM - (RSW18UP)
OPDN DOWNSTREAM - (RSW18DN)
Project Raingage: King County 31Y2 Fairwood Gage. Backup gage located at 192UP Monitoring Station.

Project Site ID	Sonde Deployment Start (date/time)	Sonde Deployment End (date/time)	Maximum Turbidity Value for Deployment[1]	Average Turbidity for Deployment[1]	Maximum Turbidity % Efficiency	Average Turbidity % Efficiency	Total # of Turbidity Samples	# of Suspect ("S") Data Flagged	# of Edited ("E") Data Flagged	# of Deleted ("D" or "S, D") Data Flagged[2]	# of Missing Data ("M") Data Flagged[3]
OPUP	10/8/10 23:30	10/11/10 6:10	83.4	7.6	62	36	329	0	6	0	0
OPDN	10/8/10 23:30	10/11/10 6:10	31.8	4.9			329	0	0	0	0
OPUP	10/23/10 18:00	10/25/10 4:20	815.3	83.3	97	93	207	108	0	0	0
OPDN	10/23/10 18:00	10/25/10 4:20	21.1	5.8			207	0	0	0	0
OPUP	11/17/10 6:10	11/18/10 10:20	53.0	7.7	56	46	170	0	0	0	0
OPDN	11/17/10 6:10	11/18/10 10:20	23.4	4.2			170	0	0	0	0
OPUP	12/7/10 16:40	12/8/10 8:20	82.8	15.1	57	49	1,057	5	1	0	0
OPDN	12/7/10 16:40	12/8/10 8:20	35.2	7.7			1,057	0	0	0	0
OPUP	12/8/10 8:30	12/10/10 14:40	278.6	12.5	67	34	326	0	6	0	0
OPDN	12/8/10 8:30	12/10/10 14:40	92.4	8.2			326	0	0	0	0
OPUP	12/13/10 14:00	12/14/10 6:00	73.2	10.4	57	34	97	0	0	0	0
OPDN	12/13/10 14:00	12/14/10 6:00	31.6	6.8			97	0	0	0	0
OPUP	1/12/11 2:00	1/12/11 14:50	399.1	42.9	89	55	78	0	3	0	0
OPDN	1/12/11 2:00	1/12/11 14:50	44.9	19.2			78	0	0	0	0
OPUP	1/12/11 15:00	1/14/11 14:20	67.9	24.4	48	32	285	0	2	0	0
OPDN	1/12/11 15:00	1/14/11 14:20	35.5	16.7			285	0	0	0	0
OPUP	2/3/11 20:30	2/4/11 6:00	53.2	6.9	50	52	58	0	0	0	0
OPDN	2/3/11 20:30	2/4/11 6:00	26.6	3.3			58	0	0	0	0
OPUP	2/5/11 23:00	2/6/11 11:00	17.3	5.8	61	52	73	0	0	0	0
OPDN	2/5/11 23:00	2/6/11 11:00	6.8	2.8			73	0	0	0	0
OPUP	2/6/11 18:00	2/6/11 23:00	21.6	10.1	32	38	31	0	0	0	0
OPDN	2/6/11 18:00	2/6/11 23:00	14.6	6.3			31	0	0	0	0
OPUP	2/12/11 12:00	2/15/11 23:50	207.5	13.2	25	42	504	0	1	0	0
OPDN	2/12/11 12:00	2/15/11 23:50	156.3	7.7			504	0	0	0	0
OPUP	3/8/11 12:00	3/12/11 9:40	268.8	17.9	47	45	563	0	9	0	0
OPDN	3/8/11 12:00	3/12/11 9:40	141.9	9.8			563	0	0	0	0
OPUP	3/12/11 9:50	3/13/11 15:20	23.3	11.1	48	34	178	0	0	0	0
OPDN	3/12/11 9:50	3/13/11 15:20	12.0	7.3			178	0	0	0	0
OPUP	4/9/11 23:00	4/11/11 18:00	39.9	2.8	68	51	259	0	4	0	0
OPDN	4/9/11 23:00	4/11/11 18:00	12.8	1.3			259	0	1	0	0

[1] All turbidity data and associated calculations based on edited data tables. See data tables for raw data and descriptive flags.

[2] Flagged "D" and "S, D" data values applied consistently across all stations and all associated values were deleted for that range for datacomparison/analysis purposes.

[3] Flagged "M" data values indicate missing data due to equipment malfunction. Data gaps (or Missing data) applied consistently across all stations and all associated values were deleted for that time range for data comparison/analysis purposes.

Table 24. Project PET Continuous Turbidity Monitoring Summary

Project PET - Petrovitsky Rd. at SE 192 Dr. %Eff = (PETUP-PETDN)/PETUP*100

BMPs Installed 9/27/2010

PETUP UPSTREAM

PETDN DOWNSTREAM

Project Raingage: King County 31Y2 Fairwood Gage. Backup gage located at 192UP Monitoring Station

Project Site ID	Sonde Deployment Start (date/time)	Sonde Deployment End (date/time)	Maximum Turbidity Value for Deployment[1]	Average Turbidity for Deployment[1]	Maximum Turbidity % Efficiency	Average Turbidity % Efficiency	Total # of Turbidity Samples	# of Suspect ("S") Data Flagged	# of Edited ("E") Data Flagged	# of Deleted ("D" or "S, D") Data Flagged[2]	# of Missing Data ("M") Data Flagged [3]
PETUP	5/18/10 10:00	5/21/10 0:00	1,567.4	33.4	37	44	249	0	0	0	0
PETDN	5/18/10 10:00	5/21/10 0:00	981.5	18.6			249	0	1	0	0
PETUP	5/26/10 10:00	6/2/10 4:45	1,200.6	18.5	66	36	652	0	0	0	0
PETDN	5/26/10 10:00	6/2/10 4:45	408.5	11.9			652	0	0	0	0
PETUP	6/8/10 20:00	6/9/10 11:15	718.6	42.2	17	-3	62	0	0	0	0
PETDN	6/8/10 20:00	6/9/10 11:15	596.3	43.5			62	0	0	0	0
PETUP	6/15/10 10:00	6/16/10 13:30	511.2	23.1	72	32	111	1	1	0	0
PETDN	6/15/10 10:00	6/16/10 13:30	144.7	15.8			111	0	0	0	0

[1] All turbidity data and associated calculations based on edited data tables. See data tables for raw data and descriptive flags.

[2] Flagged "D" and "S, D" data values applied consistently across all stations and all associated values were deleted for that range for datacomparison/analysis purposes.

[3] Flagged "M" data values indicate missing data due to equipment malfunction. Data gaps (or Missing data) applied consistently across all stations and all associated values were deleted for that time range for data comparison/analysis purposes

Table 25. Project OP Monthly Flow Comparisons

Monthly Flow Results: Project OP					
		Flow (gallons)		Upstream to Downstream (3 BMPs)	
Month/ Year	Rainfall (inches)	Upstream	Downstream	Change In Flow	Percent Change In Flow
Oct-09	5.02	832312	767881	64,431	7.7
Nov-09	6.23	1373940	1480510	-106,570	-7.8
Dec-09	8.48	2635900	2789830	-153,930	-5.8
Jan-10	7.03	2433140	2461180	-28,040	-1.2
Feb-10	3.5	1168870	1102120	66,750	5.7
Mar-10	7.25	2800400	2756140	44,260	1.6
Apr-10	6.28	1146870	1121230	25,640	2.2
May-10	4.62	1195990	1183990	12,000	1.0
Jun-10	2.49	173030	152905	20,125	11.6
Jul-10	1.12	107188	93772	13,416	12.5
Aug-10	0.33	13266	9903	3,363	25.4
Sep-10	1.88	106199	89361	16,838	15.9

Notes:

Shaded values show a reduction in downstream flow. Negative values show an increase in downstream flow.

Table 26. Projects 192 and 192DN Monthly Flow Comparisons

Monthly Flow Control Results: Projects 192 and 192DN										
		Flow (gallons)			Project 192: 192Up to 192M (6 BMPs)		Project 192DN: 192M to 192DN (6 BMPs)		192UP to 192DN (12 BMPs)	
Month/Year	Rainfall	Upstream 192UP	Midpoint 192M	Downstream 192DN	Change In Flow	Percent Change In Flow	Change In Flow	Percent Change In Flow	Change In Flow	Percent Change In Flow
Oct-10	5.02	150,810	368,562	348,287	-217,752	-144.4	20,275	5.5	-197,477	-130.9
Nov-10	6.23	2,081,300	2,077,000	1,668,470	4,300	0.2	408,530	19.7	412,830	19.8
Dec-10	8.48	5,414,560	5,756,860	6,852,540	-342,300	-6.3	-1,095,680	-19.0	-1,437,980	-26.6
Jan-11	7.03	4,826,020	5,605,824	6,472,610	-779,804	-16.2	-866,786	-15.5	-1,646,590	-34.1
Feb-11	3.5	1,251,840	1,385,410	1,706,440	-133,570	-10.7	-321,030	-23.2	-454,600	-36.3
Mar-11	7.25	4,163,230	4,607,930	5,244,670	-444,700	-10.7	-636,740	-13.8	-1,081,440	-26.0
Apr-11	6.28	3,669,630	4,092,590	4,634,860	-422,960	-11.5	-542,270	-13.3	-965,230	-26.3
May-11	4.62	1,823,200	2,024,250	2,235,040	-201,050	-11.0	-210,790	-10.4	-411,840	-22.6
Jun-11	2.49	288,856	297,717	287,792	-8,861	-3.1	9,925	3.3	1,064	0.4
Jul-11	1.12	27,959	26,551	23,592	1,408	5.0	2,959	11.1	4,367	15.6
Aug-11	0.33	1,370	0	0	1,370	100.0	0	0.0	1,370	100.0
Sep-11	1.88	26,004	20,260	10,432	5,744	22.1	9,828	48.5	15,572	59.9
Wet Season	43.79	21,557,390	23,894,176	26,927,877	-2,336,786	-10.8	-3,033,701	108.7	-5,370,487	-24.9
Dry Season	10.44	2,167,389	2,368,778	2,556,856	-201,389	-9.3	-188,078	107.9	-389,467	-18.0
July - Sept	3.33	55,333	46,811	34,024	8,522	15.4	12,787	75.0	21,309	38.5

Notes:

Shaded values show a reduction in downstream flow. Negative values show an increase in downstream flow.

* Flow data includes periods when the flumes were overtopped; total flow is an estimate for those periods.

Table 27. Project 276 and 276DN Monthly Flow Comparisons

Monthly Flow Control Results: Project 276 and 276DN											
		Flow (gallons)			Upstream to Mid Point (10 BMPs)		Mid Point To Downstream[1] (6 BMPs)		Upstream to Downstream[1] (12 BMPs)		
Month/ Year	Rainfall (inches)	Upstream 276UP	Midpoint 276DN	Downstream 276DN2	Change In Flow	Percent Change In Flow	Change In Flow	Percent Change In Flow	Change In Flow	Percent Change In Flow	
Oct-10	6.24	570,007	532,199	--	37,808	6.6	--	--	--	--	
Nov-10	6.35	1,782,420	1,552,840	1,025,950	229,580	12.9	526,890	33.9	756,470	42.4	
Dec-10	9	2,864,750	2,623,600	2,994,720	241,150	8.4	-371,120	-14.1	-129,970	-4.5	
Jan-11	11.47	3,312,330	3,235,120	3,644,590	77,210	2.3	-409,470	-12.7	-332,260	-10.0	
Feb-11	4.92	1,250,300	1,095,030	1,105,970	155,270	12.4	-10,940	-1.0	144,330	11.5	
Mar-11	9.68	2,375,210	2,516,790	2,695,860	-141,580	-6.0	-179,070	-7.1	-320,650	-13.5	
Apr-11	8.26	2,094,000	2,225,160	2,331,660	-131,160	-6.3	-106,500	-4.8	-237,660	-11.3	
May-11	6.3	1,312,890	1,337,490	1,300,540	-24,600	-1.9	36,950	2.8	12,350	0.9	
Jun-11	4.91	674,657	570,418	519,832	104,239	15.5	50,586	8.9	154,825	22.9	
Jul-11	1.69	29,169	549	144	28,620	98.1	405	73.8	29,025	99.5	
Aug-11	0.63	34,843	2,340	0	32,503	93.3	2,340	100.0	34,843	100.0	
Sep-11	2.7	17,420	4,113	4,738	13,307	76.4	-625	-15.2	12,682	72.8	

Notes:

Shaded values show a reduction in downstream flow. Negative values show an increase in downstream flow.

Flow data for Jan. and Feb. includes periods when the flumes were overtopped; total flow is estimated.

* Flow data includes periods when the flumes were overtopped; total flow is an estimate for those periods.

[1]Downstream BMP monitoring started 11/10/2010 just after installation.