AKART FEASIBILITY STUDY

Treatment Alternative Evaluation for WSDOT Bridge Washing Effluent

Prepared for

Washington State Department of Transportation
P.O. Box 47331
Olympia, Washington 98504-7991

Prepared by

Herrera Environmental Consultants, Inc.
2200 Sixth Avenue, Suite 1100
Seattle, Washington 98121
Telephone: 206/441-9080

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Contents

Tables

Introduction

Background

The Washington State Department of Transportation (WSDOT) is responsible for preservation of 274 steel bridges and 29 steel marine transfer spans (ferry terminals). Maintenance of these structures involves routine washing and periodic painting. To prepare for painting, the structures must also be washed though more thoroughly than during routine cleaning. Effluent from bridge and transfer span cleaning activities contains pollutants that are washed off these structures such as suspended solids, metals from paint particles, and bacteria from bird feces. To ensure that state water quality standards are not exceeded in receiving water bodies as a result of these and other WSDOT activities, the Washington Department of Ecology (Ecology) and WSDOT have developed an Implementing Agreement (IA) specifying pollution prevention and reduction measures and procedures.

Current requirements for bridge and transfer span washing in preparation for painting, as defined in the IA and in WSDOT *Standard Specifications* (2002), include the use of screened tarps to control and contain paint particles, upland disposal of collected paint particles and abrasive grit, and collection and upland disposal of accumulated bird feces and nests.

The IA requirements are currently being updated by Ecology and WSDOT for better project management and environmental clarity. To support decision-making processes related to this review, this report evaluates potential measures to protect water quality during bridge and marine span washing activities, and to identify an alternative that meets the definition of AKART (all known, available, and reasonable technology). As defined in WAC 173-201A, AKART shall represent the most current methodology that can be reasonably required for preventing, controlling, or abating the pollutants associated with a discharge. An analysis was conducted to prioritize alternative measures that could be implemented to prevent or reduce the discharge of washwater pollutants to receiving water bodies. Four alternatives were evaluated based on a preliminary assessment of environmental impacts, a technical feasibility evaluation, and a cost analysis. Based on this analysis, a ranking system was applied to identify the relative merits of each alternative. This report presents the methods and results of this analysis and identifies a preferred alternative. A more detailed water quality analysis of "reasonable potential" will be conducted, if necessary, when concurrence is reached with Ecology on the preferred alternative. This subsequent analysis will evaluate the potential for state quality standards to be violated due to bridge washing activities when the preferred alternative is used to manage the associated effluent.

Description of Bridge Washing Activities

WSDOT conducts two types of bridge and transfer span washing activities: 1) routine maintenance washing, and 2) surface preparation for painting. Typically, routine maintenance washing is conducted by WSDOT maintenance crews, while painting and associated washing are conducted by contractors.

Maintenance Washing

Bridges

Routine maintenance washing of bridges typically occurs on a five-year cycle and involves the following steps:

- Establish traffic control
- Establish fall protection systems
- Remove dry debris, such as dust and bird feces, by hand and vacuum (vactor truck)
- Wash steel with clean water using a high-volume, low-pressure system.

To reduce pollutant discharge to receiving waters below, dry material is disposed of at an upland location and in some instances a vacuum is applied during washing to capture some of the loosened material. Maintenance washing activities are typically performed during high river flows (late fall, winter, and early spring), also reducing the potential impact on receiving water quality. Approximately 400 to 600 gallons of water is used to clean a typical bridge structure (625 tons of steel).

Marine Transfer Spans

Routine maintenance washing of marine transfer spans does not use filter tarps and typically occurs on a semi-annual cycle. Routine maintenance washing involves the following steps:

- Dry debris, such as bird feces, is removed by hand or vacuum and subsequently disposed of upland.
- When necessary, a biodegradable degreaser (e.g., Simple Green) is applied to the marine span surfaces. Surfaces are typically not washed after a degreaser is applied, but washing may occur in some instances depending upon the activity.

- Approximately 200-600 gallons of water are used to clean marine transfer spans.
- Steel structures are washed with clean water using a high-volume, low-pressure system.

Paint Preparation Washing

Bridges

Bridge washing in preparation for painting differs from maintenance washing. Paint preparation washing uses a low-volume, high-pressure washing system to more thoroughly remove debris and loose paint material from the steel surfaces.

Bridge painting occurs on a schedule dictated by the rate at which paint systems deteriorate. Most bridges are inspected every one to two years and evaluated according to paint system condition. One of three paint system condition levels is identified at each bridge based on the following criteria:

- Condition level 1: Paint is in like new condition
- Condition level 2: Paint is peeling or deteriorating, but no steel is exposed
- Condition level 3: Paint is peeling or deteriorating exposing the underlying steel.

When a bridge is identified in condition level 3 and has 2 percent or more steel exposed, it is added to the statewide painting list. Due to varied bridge settings and environmental conditions, the frequency of bridge painting varies and is typically greater than 15 years. The following steps are conducted during bridge painting:

- Establish traffic control – traffic control is typically set up and taken down on a daily basis to reduce traffic congestion during peak travel times
- Establish fall protection systems (scaffolding, rigging, ropes and other equipment)
- Construct tarp systems around and beneath the work area
- Remove dry debris by hand and vacuum
- Wash steel surfaces with a low-volume, high pressure (3,200 pounds per square inch) system – effluent passes through a filter tarp to remove particulate material before discharge to the environment below
- After the steel surfaces have dried, spot blast with metal slag (Blastox or Kleenblast) to remove flaking/chipping paint and oxidized steel

- Blow down surfaces to remove residual dust and debris from the steel – all material from spot blasting activity is contained and stored on site
- Apply zinc-based primer coat to spot-blasted areas
- Apply an intermediate coat and top coat of moisture cure urethane to all steel surfaces

In some cases, full containment of washing activities has been conducted at WSDOT bridge painting sites. In these cases, effluent was often disposed of by discharging to land areas near the bridge site or to storm sewer systems. If effluent from the bridge washing activities exceeds disposal limits for local municipal sanitary sewer systems and treatment is not an option, the effluent is designated as a hazardous waste and subsequently disposed of at an appropriate facility.

Marine Transfer Spans

Marine transfer spans are painted at a frequency of 15 or more years. In preparation for painting, the span surfaces are cleaned using the same methodology described above for bridges. Filtration tarps are also used during paint preparation washing of marine transfer spans.

AKART Analysis

State law (Chapter 90.48 RCW, Water Pollution Control) contains the following provision regarding water quality protection:

> "It is declared to be the public policy that the state of Washington to maintain the highest possible standards to insure the purity of all waters of the state consistent with public health and public enjoyment thereof, the propagation and protection of wild life, birds, game, fish and other aquatic life, and the industrial development of the state, and to that end require the use of all know available and reasonable methods by industries and others to prevent and control the pollution of the waters of the state of Washington."

To satisfy the provisions of this law, AKART treatment practices must be used for all wastewater discharges that require certain approvals from Ecology. "AKART" is an acronym of for "all known, available, and reasonable methods of prevention, control, and treatment." When Ecology designates a treatment practice as AKART, it is intended to represent the most current methodology that can be reasonably required for preventing, controlling, or abating the pollutants associated with a discharge (WAC 173-201A). Furthermore, Ecology requires that an engineering report be prepared in order to identify AKART treatment practices for specific wastewater discharges.

To satisfy the above requirements, this document prioritizes alternative treatments measures for bridge washing effluent based on a preliminary assessment of environmental impacts, a cost analysis, and a technical feasibility evaluation. The results from these assessments are presented in separate subsections to follow. These assessments are then used at the conclusion of this document to identify a preferred treatment alternative. A more detailed technical analysis of "reasonable potential" will then be conducted in a separate report, if necessary, to evaluate the potential for state quality standards to be violated if the preferred alternative is used to manage bridge washing effluent.

Identification of Alternatives

Four pollutant prevention/reduction measures were identified by Ecology and WSDOT in a review of all known and available technology. These alternatives are evaluated in the following section based on a preliminary assessment of water quality impacts, a cost analysis, and an evaluation of their technical feasibility. A description of each of the four treatment alternatives is provided below.

Alternative 1 – Full containment and disposal of process water to a sanitary sewer

This alternative involves containment and collection of all washwater so that none is discharged to the water bodies (or land areas) below the bridge or marine transfer span structure.

Containment structures are constructed around the washing area using an impermeable tarp material and the washwater collected at the base of the containment area is continuously vacuumed into an on-site storage tank.

Collected washwater will contain debris cleaned from the bridge structure and must be disposed of appropriately. Discharge of washwater to a municipal sanitary sewer is permitted if concentrations of water quality parameters do not exceed specific local criteria. Table 1 below displays the discharge limits to the Lacey-Olympia-Tumwater-Thurston (LOTT) and King County wastewater treatment systems for copper, lead, and zinc. If these limits are exceeded in the bridge washing effluent, alternative disposal locations must be used (such as industrial waste disposal facilities) or pretreatment must be conducted to reduce pollutant levels in the water.

Table 1. Industrial pollutant limits for discharge to municipal sewer systems.

Pollutant	LOTT Wastewater Treatment Discharge Limits (Total; mg/L)	KC Wastewater Treatment Discharge Limits (Total; mg/L)
Copper	0.5	3
Lead	0.4	2
Zinc	1.0	5

In practice, painting contractors may hire a subcontractor, such as a portable toilet company, to dispose of the wastewater generated during washing. Appropriate disposal of the spent washwater would then be determined by the subcontractor based on water quality levels and proximity to disposal sites. Land application of washwater may be determined to be the appropriate method of disposal in some cases (see Alternative 3).

Alternative 2 – Recycling of process water to reduce disposal volumes

This alternative involves recycling of effluent to reduce storage and disposal costs. The same full containment activities are conducted under this alternative as under Alternative 1, however there is a smaller volume of effluent for disposal at the end of the project. On-site water quality treatment would be required to recycle effluent because clean water is needed to operate high pressure washing equipment. Filtration is a potential method to remove particulates from washwater before it is reused by washing equipment.

Alternative 3 – Full containment and disposal using land application/ polymer treatment

This alternative is similar to Alternative 1 except with respect to the method of effluent disposal. As was discussed above, appropriate disposal of effluent will be affected by pollutant levels in the water and proximity to disposal sites. In some cases, land application of washwater may be the preferred method of disposal. Land application involves using wastewater to irrigate crops, a practice regulated by Ecology. If pollutant concentrations in the water exceed levels allowed for land application, pretreatment may be required or land application may not be allowed.

Wastewater pretreatment to allow land application may involve removal of dissolved metals. Potential methods of dissolved metals removal could include the addition of organic polymers to act as coagulates for the metals.

Alternative 4 – Current WSDOT practice using alternative mesh sizes for filter tarps

This alternative reflects current WSDOT bridge washing practice for most bridge painting activities. A containment structure is constructed around the washing area using filter mesh material. This filter mesh allows effluent to pass through and discharge to the waterway or land area below, but collects debris and particulate matter that is cleaned from the bridge. (The specific steps used in WSDOT's current bridge washing practice are described in detail on page 4 of this document.)

Filter tarps must currently have a minimum apparent opening size (AOS) of 425 micrometers, equivalent to a #40 sieve. Use of filter tarp material with a reduced AOS (as low as 55 micrometers or #250 sieve) could improve pollutant capture from the washwater as smaller particulate matter will be removed as the water passes through. However, reducing the AOS would not impact dissolved constituents of the washwater. WSDOT is updating its standards to require all filter tarps used in bridge washing to have AOS equivalent to a #70 sieve.

Evaluation of Alternatives

This section evaluates the four proposed treatment alternatives for bridge washing effluent based on a preliminary assessment of environmental impacts, a technical feasibility evaluation, and a cost analysis. Unless noted otherwise, a "bridge structure" in these following sections refers to both steel bridges and marine transfer spans.

Preliminary Water Quality Impact Evaluation

The primary pollutant source associated with WSDOT's bridge and transfer span washing activities is deteriorating paint on steel bridge structures. The primer paint used on these structures may contain high levels of lead, zinc, and other heavy metals, with lesser amounts found in the intermediate, topcoat, and subsequent paint application finishes. Actual concentrations of heavy metals in the paint applied to WSDOT's bridge structures vary with the age of the paint (WSDOT 2003). Paints used prior to the late 1980s contained up to 65 or 75 percent lead and smaller amounts of other heavy metals. Since the late 1980s, paints have contained up to 55 percent zinc, 7 percent chromium, and smaller amounts of other heavy metals.

Pollutants from a variety of secondary sources may also be found in the washwater. These pollutants generally accumulate on bridge structure surfaces during daily bridge use or during scheduled repair or maintenance operations. Table 2 presents a list of these pollutants with the primary pathway for deposition on the bridge structure.

Table 2. Secondary sources for pollutants in WSDOT bridge washing effluent.

Pollutant	Deposition Pathway
Particulates	Pavement wear, vehicles, atmosphere
Nitrogen, Phosphorus	Atmosphere, roadside fertilizer application, nesting birds or other wildlife
Lead	Tire wear, auto exhaust
Zinc	Tire wear, motor oil, grease
Iron	Auto body rust, steel highway structures, moving engine parts
Copper	Metal plating, brake lining wear, moving engine parts, bearing and bushing wear, fungicides and insecticides
Cadmium	Tire wear, insecticides
Chromium	Metal plating, moving engine parts, brake lining wear
Nickel	Diesel fuel and gasoline, lubricating oil, metal plating, brake lining wear, asphalt paving
Manganese	Moving engine parts
Cyanide	Anticake compound used to keep deicing salt granular
Sodium, Calcium, Chloride	Deicing salts
Sulphate	Roadway beds, fuel, deicing salts
Petroleum	Spills, leaks or blow-by of motor lubricants, antifreeze and hydraulic fluids, asphalt surface leachate
Fecal matter	Nesting birds and other wildlife

Source: EPA 1993.

At higher concentrations, many of the chemical contaminants associated with the washwater can be harmful to fish and other aquatic life. For example, heavy metal toxicity to aquatic organisms can include both acute mortality and chronic effects such as impaired growth and reproduction with mortality to offspring (Leland and Kuwabara 1985). In addition, bacterial contamination of surface waters can lead to human health concerns. To protect aquatic life, Ecology has established acute and chronic water quality standards for metals and other pollutants in surface waters of the state (WAC 173-201A). Water quality standards for heavy metals are summarized in Table 3.

Actual concentrations of heavy metals and other contaminants in the washwater will vary depending on the following factors:

> <u>Condition of Bridge Structure</u>. Over time, an increasing percentage of the paint applied to a bridge structure will show signs of deterioration. With complete failure, the paint will begin to peel away completely, leaving the underlying steel exposed. The amount of paint deterioration on a bridge structure can vary tremendously depending on their design, location, and environmental setting (WSDOT 2003). In general, paint that has deteriorated or failed will be much easier to remove during bridge washing activities. Thus, it follows that bridge washing effluent from structures having a higher percentage of deteriorating or failed paint will likely have higher pollutant concentrations.

Wash Equipment Discharge Volume and Pressure. Both the discharge volume and pressure used during washing activities can affect pollutant levels in the resultant effluent stream, though often in opposing ways. Higher discharge volumes dilute pollutants that are liberated from bridge structures, thereby lowering their overall concentrations in the bridge washing effluent. Conversely, increasing the pressure of water that is applied to bridge structures may increase the amount of paint and other debris that is scoured off. Under these conditions, higher pollutant levels would be observed in bridge washing effluent.

Table 3. Washington state surface water quality standards (in mg/L) for heavy metals.

	Freshwater		Marine	
Parameter [a]	Acute [b]	Chronic [c]	Acute [b]	Chronic [c]
Arsenic	0.360	0.190	0.0690	0.0360
Cadmium [d]	0.0037	0.0010	0.042	0.0093
Chromium (Tri) [d,e]	0.5487	0.1780	–	–
Copper [d]	0.0170	0.0114	0.0048	0.0031
Lead [d]	0.0646	0.0025	0.2100	0.0081
Mercury	0.0021	0.000013[f]	0.0018	0.000025[f]
Nickel	1.4154	0.1572	0.0740	0.0082
Selenium	0.0200[f]	0.0050[f]	0.290	0.0710
Silver [d]	0.0034[g]	–	0.0019	–
Zinc [d]	0.1144	0.1045	0.0900	0.0810

Source: WAC 173-201A

[a] Standards are for the dissolved fraction of associated metal unless noted otherwise.
[b] Values represent 1- hour average concentrations not to be exceeded more than once every three years on average unless noted otherwise.
[c] Values represent 4-day average concentrations not to be exceeded more than once every three years on average unless noted otherwise.
[d] Standard is hardness dependant. Values presented reflect standard at a typical hardness value (100 mg/L as $CaCO_3$)
[e] Where methods to measure trivalent chromium are unavailable, standards represent total recoverable chromium.
[f] Standard is for total-recoverable fraction.
[g] Instantaneous concentration not to be exceeded anytime.

Based on the above considerations, washwater pollutant concentrations associated with routine maintenance washing are expected to be relatively low because high discharge volumes and low water pressures are commonly used for this task. Conversely, the washwater associated with paint preparation washing would likely have higher pollutant concentrations because of the lower discharge volumes and high water pressure used for this task.

In an effort to measure actual washwater pollutant concentrations associated with paint preparation washing, WSDOT conducted three separate studies in 2001 and 2002 on steel bridges located within Western Washington. The specific location and dates for these studies are as follows:

- Stillaguamish River bridge near Stanwood, WA – August 2001
- Skykomish River bridge near Gold Bar, WA – May 2002
- Cowlitz River bridge near Kelso, WA – June 2002

For each study, the effluent from bridge washing operations was sampled after it passed through the filter tarp system describe above for Alternative 4. These samples were subsequently submitted to a laboratory for analyses of selected heavy metals and other pollutants. Field measurements of pH, dissolved oxygen, and conductivity were also made at the time of sample collection. A more detailed description of the sampling and analytical procedures used in these studies are provided in the field reports prepared by WSDOT (2001, 2002a, 2002b). Results from the three studies above are summarized in Appendix A. Based on a comparison to the water quality standards presented in Table 3, these data indicate that copper, lead, and zinc concentrations in the raw washwater can potentially exceed state water quality criteria.

In practice, compliance with the state water quality standards would not be assessed based on the pollutant concentrations in raw washwater; rather, compliance would be assessed at the boundary of a mixing zone if the treatment alternative meets Ecology's requirements for AKART. Mixing zones are areas in the receiving water body where the water quality standards may be exceeded but they are small enough so as not to interfere with beneficial uses (Ecology 2002). Mixing zones are established in a manner that limits the duration of exposure for organisms passing through the effluent plume in order to minimize the risk from the discharge. Water quality standards for chronic protection must be met at the boundary of this zone and beyond. A smaller zone in which acute criteria may be exceeded can also be authorized. This zone must be small enough to limit exposure times and therefore not cause acute mortalities or interfere with passage of aquatic organisms in the water body. The mixing zone dimensions for rivers and streams, estuaries, oceanic waters, and lakes are defined separately in WAC 173-201A.

An analysis of washwater pollutant concentrations at the mixing zone boundary is outside the scope of this document. This analysis will be conducted, if necessary, in the water quality analysis of reasonable potential that is referenced in the *Introduction* to this document. General water quality impacts are discussed below for the bridge washing alternatives.

Alternatives 1, 2, and 3

Alternatives 1, 2, and 3 utilize an impermeable tarp system as the primary mechanism for managing effluent from bridge washing activities. Because they are suspended beneath the power washing equipment, the tarp systems effectively capture all the associated washwater and prevent paint chips and other debris from entering the receiving water below. Thus, Alternatives 1–3 provide full containment where both the solids and water generated from the washing process are prevented from reaching the receiving water. Under this scenario, there would be no associated water quality impacts because there is no off-site discharge for Alternatives 1, 2, and 3.

Alternative 4

Alternative 4 uses a permeable tarp to trap solids or particulate matter while allowing the water to pass through. The filter tarp used for Alternative 4 would effectively remove solids from the washwater that are greater than the pore size of the tarp. Under current WSDOT specifications, filter tarps must have a maximum apparent opening size (AOS) of 425 microns, equivalent to a #40 sieve. Use of filter tarp material with a lower AOS (as low as 55 micrometers or #250 sieve) could improve pollutant capture from the washwater because smaller particles would be removed. This would be particularly beneficial for work over lakes or marine waters. Due to the low current velocities in these areas, particulate matter from the washing activities can settle out and concentrate in areas directly below the bridge structure, causing potential sediment quality problems. However, filter tarps would generally not be effective at removing dissolved constituents from the washwater. Because Ecology establishes limits for most heavy metals in water based on their dissolved fractions (Table 3), filter tarps would provide little benefit in relation to the regulatory requirements for these pollutants.

In general, water quality impacts associated with Alternative 4 would largely depend on the dilution capacity of the receiving water and, by extension, the washwater discharge rate and level of contamination. Large to medium sized aquatic systems with relatively high dilution capacities would likely see no adverse water quality impacts. Potential adverse impacts to smaller aquatic systems might be mitigated, if necessary, by only conducting washing activities during periods when flows are at their maximum and by limiting the number of washers that can be operated simultaneously in locations where their respective effluent will potentially commingle in the receiving water.

There are also site-specific characteristics of the receiving water that could influence whether there are any water quality impacts associated with Alternative 4. For example, receiving waters with high background concentrations of the pollutant associated with bridge washing would potential be at greater risk for adverse impacts. Similarly, receiving waters with a low pH (acidic) or low water hardness (soft) would also be at greater risk for adverse impacts. Some metals may be more soluble in acidic waters while soft waters can increase the toxicity of metals. Again, the number of washers operating at any one time may need to be restricted in order to mitigate adverse impacts in these types of waters.

Indirect Water Quality Benefits

There may also be indirect water quality benefits associated with bridge washing that relate to the environmental impacts from deteriorating paint systems on bridge structures. As noted above, paint will naturally fail and disassociate from bridge structures over time. WSDOT (2003) estimates that bridge structures have a deterioration threshold such that the first 2 percent of its original paint is lost very slowly. After the first 2 percent is lost, however, a bridge structure may rapidly lose substantial percentages of its remaining paint covering. Thus, if WSDOT's bridge painting schedule allows large numbers of bridge structures to deteriorate past this threshold, the potential for water quality impacts would increase because more failed paint would fall into receiving waters. The associated metals would likely accumulate in sediments where they would have negative impacts on benthic organisms. With time, some these metals would likely be converted to a more soluble forms that would be directly toxic to fish and other aquatic organisms.

Though paint discharges from bridge deterioration are not likely to cause any violations of state water quality standards, these discharges could constitute a violation of the state's water quality antidegradation policy (WAC 173-201A). This policy states that water quality necessary to protect existing and designated uses of the state's water must be maintained and protected. In general, the number of bridges that WSDOT can wash is constrained by available budget. Because Alternative 4 has significantly lower costs relative to the other alternatives (see discussion below), a greater number of bridges could be painted if this alterative was implemented. Thus, Alternative 4 could result in lower loading of heavy metals to aquatic systems from ongoing deterioration of bridge paint.

Technical Feasibility

In general, there are physical characteristics unique to bridge structures that impose constraints on the treatment systems that may be utilized in the management of bridge washing effluent. One of the most significant limiting characteristics is the constricted work zones that are often found both on the bridge structures themselves and in the approach routes leading up to them. Bridges structures typically offer little room beyond that used for traffic conveyance for the storage and operation of equipment associated with bridge washing activities. Equipment must therefore be located in the road right of way adjacent to the bridge, where possible. Washwater management systems that have substantial space requirements would likely require vehicle use restrictions to be imposed while the cleaning work is being performed. The resultant increases in congestion can force additional burdens on the public due to lost time and financial resources.

Additional equipment in the bridge work zones are also a safety issue for workers who may be in proximity to moving traffic during bridge cleaning activities. Washwater management systems that have substantial space requirements only serve to increase safety risks to workers by reducing the available workspace that is sheltered from traffic. Workers would also be required to establish additional traffic controls for these systems, which can be extremely hazardous work in and of itself. Finally, the public is put at increased risk from traffic accidents if they must negotiate work zones that are made confusing by the clutter of treatment equipment.

Operational features of bridges may also impose constraints on the range of treatment alternatives that may be utilized. For example, moveable bridges (e.g., swing, lift, bascule bridges, and marine transfer spans) that must maintain operation during washing can pose additional difficulties in construction and operation of containment systems.

As noted previously, the primary differentiating aspect of the treatment alternatives is that Alternatives 1, 2, and 3 all provide for full containment of washwater whereas Alternative 4 uses a filter tarp to remove most solids down to a minimum size while allowing the washwater to pass through. In order to fully contain, store and treat the washwater, Alternatives 1, 2, and 3 all have substantially larger equipment requirements relative to Alternative 4, leading to greater safety and operational difficulties. Feasibility issues specific to each alternative are discussed in the sections below.

Alternative 1

The primary feasibility issue related to Alternative 1 is whether the collected washwater can meet the disposal limits for discharge to municipal sewer systems. Based on the available data for pollutant concentrations in washwater (Appendix A), metals concentrations would not meet the disposal limits (Table 1) for municipal sanitary sewer systems. In order to meet these discharge limits, it would be necessary to pretreat the washwater prior to its disposal. In many cases, simple filtration could be used to reduce metals concentrations to acceptable levels by removing particulates from the washwater. In some instances, however, dissolved metals concentrations may be in excess of the disposal limits for a particular municipal sewer system (e,g., the LOTT system). In these cases, simple filtration may not be a viable option in and of itself for washwater treatment; rather, chemical precipitation would likely be needed to remove the dissolved metal fraction. Other treatment options for dissolved metals (e.g., reverse osmosis) are likely too costly and complicated to implement for this application.

In the chemical precipitation process, dissolved metals are converted to an insoluble form (particle) by the chemical reaction between the soluble metal compounds and the precipitating reagent. The particles formed by this reaction are removed from solution by settling and/or filtration. The specific operational steps that are typically required for this process include neutralization, precipitation, coagulation/flocculation, solids/liquid separation and dewatering. The effectiveness of a chemical precipitation process is dependent on a number of factors, including the type and concentration of dissolved metals present in solution, the precipitant used, the reaction conditions (especially the pH of the solution), and the presence of other constituents that may inhibit the precipitation reaction.

The most widely used chemical precipitation process is hydroxide precipitation in which metal hydroxides are formed by using calcium hydroxide (lime) or sodium hydroxide (caustic) as the precipitant. (Organic polymers can also be used for this process but are more expensive.) Each dissolved metal has a distinct pH value at which the optimum hydroxide precipitation occurs. For example, the pH values for copper and zinc are 8.1 and 10.1. Metal hydroxides are amphoteric, which means they are increasingly soluble at both low and high pH values. Therefore, the optimum pH for precipitation of one metal may cause another metal to solubilize, or start to go back into solution.

There are a number of feasibility issues associated with using chemical precipitation to treat the washwater. Because the washwater contains a mix of different heavy metals, the precipitation process would necessarily be complicated in order to maintain the proper pH for keeping all the targeted metals in a soluble form. In some cases, a compromise pH might be required that would keep selected metals insoluble while other metals are left still in solution. Additional drawbacks of this treatment process include the need to periodically back flush the filtration system when it becomes clogged. To facilitate this process, a pond or other vessel such as a Baker tank would be required to capture the water used to back flush the filters. Multiple tanks and equipment may be required to conduct this type of treatment, leading to additional work space requirements. This water would have extremely high metals concentrations and would create additional disposal issues. Finally, the chemical precipitation process would require the use of caustic chemicals. The storage and use of these chemicals would create both environmental and human health risks in and of themselves. One of the limitations of chemical precipitation is the relatively high cost of required process chemical, coupled with the associated sludge-hauling and disposal fees.

A portable filtration system incorporating bag, cartridge, or sand filter units could be used at the project site. If dissolved metals removal is necessary for sanitary sewer disposal a portable chemical precipitation system could be used to treat washwater on site, but the cost of such a system would be significant (see *Cost Analysis* section below). These treatment systems would require additional space in the project staging area, which could cause additional feasibility and safety concerns.

Alternative 1 would require a tarped collection system to be constructed that has a higher load bearing capacity than current practice (Alternative 4) in order to support the weight of the captured washwater. This alternative would also require vacuum collection of water from the containment structure, and a large water storage tank to be placed near the work area in order to store the washwater that has been captured. If there is insufficient space adjacent to the bridge for this storage tank, the washwater would have to be collected in tanker trucks and transported to a storage tank at a location further from the project site. Additional equipment would need to be located on the bridge to allow captured washwater to be vacuumed or pumped from the tarp systems. The added equipment requirements for washwater, containment, storage, and treatment could greatly increase traffic congestion during bridge washing activities and create additional safety risks for both workers and drives. In some cases, operational features of the bridge structure may so severely limit available space that it would be extremely difficult to implement Alternative 1.

Alternative 2

The primary feasibility issue for Alternative 2 relates to the cleanliness of the recycled washwater. More specifically, paint chips, sediment, and other materials would need to be removed from the recycled washwater prior to its use in the high-pressure wash equipment. If these materials are not removed, the wash equipment would likely clog and be rendered inoperable. Furthermore, continued recycling of the washwater would likely cause dissolved metals to concentrate in the recycled washwater. The resulting high concentrations of metals in the recycled washwater would likely exceed disposal limits for municipal sewer systems.

Based on the above considerations, it is likely that some type of treatment would be required for the recycled washwater. While a filtration system may be sufficient to prevent paint and other materials from clogging the wash equipment, it may not be adequate for reducing dissolved metals concentrations in the washwater to levels that are consistent with the disposal limits for municipal sewer systems. In order to remove dissolved metals from the washwater, an alternative treatment method such as chemical precipitation would be required. Because the treatment system would need to be operated during washing activities rather than after all of the washwater is captured, washing activities would require additional effort and could take a longer time to complete. Washwater storage requirements would be less under this alternative than under Alternative 1; however, the same feasibility issues related to full containment, storage, and treatment of washwater, as described above, apply to this alternative.

Alternative 3

The primary feasibility issues associated with Alternative 3 are the treatment process that would be used on the washwater and the applicability of land application as a disposal method. Under this alternative, metals would be removed from the washwater using polymers. These polymers act as flocculants by forming bridges between particles that subsequently bind them into large agglomerates or clumps. Once suspended particles are flocculated into larger particles, they can be removed from the liquid by sedimentation, provided that a sufficient density difference exists between the suspended matter and the liquid. The particles may also be removed or separated by media filtration, straining, or floatation.

The process for using polymers to remove metal from wastewater typically involves three-steps (McDonald 2003). During the first step, organics precipitants (e.g., thiocarbamate and polythiocarbonate) are used to form a dense stable floc with the metals that is neither dependent on pH nor affected by chelated or other complexed metals. In the second step, specialty polymers are used as coagulants to enhance floc formation and settling. Lastly, the precipitated flocs are removed from the discharge stream using a separation device. In general, the effectiveness of this treatment process is dependant on how rapidly the flocs are able to settle and how efficiently the fines are removed from the effluent.

Feasibility issues associated with process include the necessity to carefully control the treatment process including the reaction time, temperature, pH, and feed rate for the process chemicals. It is also critical that the appropriate polymer product is used to remove the pollutants of interest in the washwater. Storage of process chemicals at the project site poses a worker safety and spill risk. Multiple tanks and equipment may be required to conduct this type of treatment, leading to additional work space requirements.

A portable polymer precipitation system could be used to treat washwater, but the cost of such a system would be significant (see *Cost Analysis* section below). The same feasibility issues associated with containment, storage and treatment under Alternative 1, as described above, apply to this alternative as well.

Land application of washwater for non-food crop irrigation could be conducted under the current Implementing Agreement between WSDOT and Ecology. WSDOT may seek an NPDES permit to cover this disposal method at their discretion at a later date. One feasibility issue involved in land application is the availability of appropriate land near bridge painting/washing sites.

Alternative 4

Alternative 4 represents current practice and is subject to the general feasibility issues discussed above. This alternative has the least equipment requirements as no water collection, storage, or treatment would be conducted. The use of alternate filter tarps with smaller opening sizes could pose operational problems due to the reduced rate at which water can pass through the material. If substantial ponding of water occurred on the tarp due to the smaller opening sizes and clogging from collected debris, the structural stability of the tarp system could be compromised.

Cost Analysis

Based on an evaluation of six recent completed bridge painting projects (two using full containment of washwater and four using tarp filtration), the cost of painting bridges under different washing conditions was analyzed. The total cost of bridge painting per square foot of steel surface was generally greater for the projects that were washed using full containment than those washed using tarp filtration. The average cost under full containment ($7.23 per square foot) was five percent greater than under tarp filtration ($6.90 per square foot); however, an unusually high unit cost was incurred at one of the tarp filtration sites. It is likely that this higher unit cost was a result of additional painting, access, and safety considerations and not the washing and surface preparation work. If it is disregarded, the average cost difference between full containment ($7.23 per square foot) and tarp filtration ($5.16 per square foot) was 40 percent.

Difference in total costs between bridge painting projects could be due to a number of site-specific conditions. Implementation of full washing containment is likely responsible for a portion of these higher costs. To more closely identify the likely costs involved with just the washing portion of bridge painting projects, an analysis of costs under the four treatment alternatives is described below.

Cost estimates were prepared for bridge washing activities at an example bridge painting project site for comparative purposes. Costs related to overall washing/painting activities that would not be significantly affected by the alternatives analyzed are not included in the estimates. Low and high estimates were developed to reflect some of the variation and uncertainty associated with the cost items. Many variables in site conditions will lead to variations in washing costs that could not be captured in this analysis. These estimates are summarized in Table 4 and described below. A more detailed cost estimate table is provided in Appendix B.

These estimates suggest that implementation of full containment (Alternatives 1 – 3) could lead to washing cost increases in the range of 53 to 146 percent over current practices (Alternative 4). The primary differences in cost between the alternatives are the potential washwater treatment costs and additional labor required when full containment of washwater is implemented. Treatment for dissolved metals removal, if necessary, would lead to very high increases in overall project costs. Costs associated with storage, recycling, and disposal of washwater under Alternatives 1, 2, and 3 are less substantial in comparison, but add to the overall cost difference.

Table 4. Estimated cost of bridge washing activities under water quality protection alternatives 1 – 4.

Cost Item	Alternative 1 – Full Containment/ Disposal to Sanitary Sewer		Alternative 2 – Recycling of Process Water		Alternative 3 – Full Containment/ Land Application		Alternative 4 – Current WSDOT Practice	
	Low	High	Low	High	Low	High	Low	High
Total	**$93,200**	**$144,900**	**$89,400**	**$146,300**	**$140,300**	**$154,800**	**$58,400**	**$63,200**
Labor	$59,500	$73,500	$59,500	$80,900	$59,500	$73,500	$39,700	$44,100
Equipment and Material	$14,000	$14,500	$13,700	$14,200	$14,000	$14,500	$9,100	$9,100
Washwater Storage	$2,800	$2,800	$1,700	$1,700	$2,800	$2,800	$0	$0
On-site Washwater Treatment	$1,600	$40,000	$4,300	$40,000	$50,000	$50,000	$0	$0
Washwater Disposal	$7,300	$6,100	$2,200	$1,500	$6,000	$6,000	$0	$0
Solid Waste Disposal	$8,000	$8,000	$8,000	$8,000	$8,000	$8,000	$9,600	$9,600

Differences between the costs estimated under Alternatives 1 and 2 are generally small, suggesting that under the assumptions made, no clear cost benefit is evident between them. Under Alternative 3, higher costs are estimated at the low end of the range because polymer treatment of washwater is specified and no alternative treatment techniques were considered. At bridge locations throughout the state, site-specific conditions will likely lead to different disposal options and more variation in associated costs. Therefore, on an individual basis, cost differences between Alternatives 1, 2, and 3 will differ and may be significant.

To develop the cost estimates, assumptions were made where necessary regarding the size and location of the bridge to be washed and regarding the characteristics of the washwater. Reflecting available information, the estimate presented is loosely based on the I-5 Cowlitz River Bridge, which was painted during the summer of 2002. Each of the two portions of this bridge have a width of 31.9 feet, a steel length of 483 feet, a steel surface area of 88,200 square feet, and a weight of 588 tons. This bridge was washed during four separate events over 2.5 months, using a total of approximately 20,000 gallons of water.

Assumptions of pollutant levels in bridge washing effluent are based on water quality samples collected and analyzed by WSDOT during the bridge washing studies described previously (WSDOT 2001, 2002a, 2002b). These samples were collected after tarp filtration, and therefore represent the pollutant levels that would potentially reach the receiving water under Alternative 4. It is further assumed that effluent collected under alternatives 1 – 3 would be screened before storage using a similar filter material, leading to similar effluent pollutant levels. Pollutant concentrations found in the effluent samples are summarized in Appendix A.

Cost values and assumptions for individual cost estimate items are described the sections to follow with a discussion of the differences between alternatives.

Labor

An hourly rate for laborers was estimated at $45 to $50 per hour. It is assumed that two laborers can clean 400 square feet of steel per hour. Under the full containment alternatives (1, 2, and 3), a third laborer is included in the estimate to account for vacuuming of collected water during washing. The cell rates and washing rate assumptions are based on discussions with a painting contractor familiar with both filter tarp and full containment cleaning methods (Long Painting).

Because the filter tarps systems for Alternatives 1, 2, and 3 may require more structural integrity to support the weight of the captured washwater, it is possible that mobilization, set up, construction, break-down and demobilization for these alternatives would take more time relative to that required for the filter tarp systems used associated with Alternative 4. To account for this effect, the cleaning rate was varied in the cost estimate between 360 and 400 square feet per hour, reflecting an increase in project timing of up to 10 percent.

To account for additional work potentially required to operate and maintain a washwater treatment system for recycling under Alternative 2, the labor rate was increased by up to 10 percent.

Equipment and Material

High pressure washers and vacuum equipment was estimated to cost $3 per hour of operation. Filter tarp material and full containment tarp material was estimated to cost $0.25 and $0.40 per square foot, respectively. Filter tarp material costs may be greater if smaller mesh sizes are used. The total amount of tarp material was estimated to be equal to the length of bridge span by 50 feet wide. The cost rate assumptions are based on discussions with a painting contractor (Long Painting, Seattle, Washington). The cost of water was assumed to be $20 per thousand gallons, based on a review of recent WSDOT bid tabulations from the Northwest and Olympic Regions (Unit Bid Analysis).

Washwater Storage

Under Alternatives 1 and 3, it is assumed that collected effluent would be stored in 21,000-gallon storage tanks at a rental rate of $35 per day. Under Alternative 2, it is assumed that 5,000 gallons of water would be used and recycled, and therefore less storage would be necessary. A 6,900-gallon storage tank would be used in this case, costing $20 per day. Delivery of the storage tanks to the site is assumed to cost $77 per hour for 2 hours. These assumptions represent values provided by an equipment vendor (Rain for Rent, Arlington, Washington).

On-site Washwater Treatment

Under Alternative 1, treatment of washwater is assumed to be required to reduce metals concentrations in the water to levels adequate for disposal. The appropriate treatment method will vary based on metals concentrations in the washwater and on the discharge criteria of the sanitary sewer system. A filtration system that removes particulate matter from the washwater may be adequate in some cases. However, based on water quality samples collected from three recent bridge washing projects (see Appendix A), dissolved metals (e.g., zinc) may exceed the discharge criteria for some of the more restrictive municipal sanitary sewer systems. Thus, a greater degree of treatment would be required in some instances. In cases where dissolved metals must be removed from the washwater before discharge, it was determined that chemical precipitation would be the appropriate treatment method. For the purposes of this cost estimate, low and high treatment costs reflect the cost of a portable, two-stage filtration system and an on-site chemical precipitation system. It is assumed that a two-stage filtration system is comprised a sand media filter followed by a combination bag/cartridge filter. The estimated cost of operating this system includes rental costs of $700 per month (sand filter) and $650 per month (bag/cartridge filter) for 1 month, and 4 sets of cartridges at $70 each. These cost assumptions are based on values provided by an equipment vendor (Rain for Rent, Arlington, Washington). The cost of an on-site chemical precipitation system is assumed to be $40,000, based on a range of reasonable values provided by a water treatment contractor (The Clearwater Group, Black Diamond, Washington). Based on these estimates, removal of dissolved metals from the washwater will result in a very large increase (between 8 and 24 times greater) in cost.

Under Alternative 2, recycling of washwater would require an on-site treatment system to be operated throughout the project duration, as high-pressure washers will not function properly using water that contains particulate matter. The same treatment assumptions were made as under Alternative 1, except that the rental duration of the filtration system is assumed to be three months.

Under Alternative 3, treatment of washwater would be conducted using polymer precipitation to accommodate land application permit requirements. The cost of such a system is difficult to estimate, however it would likely be greater than a chemical precipitation system used for the same purpose. A value of $50,000 was assumed based on a range of values provided for chemical precipitation systems by a water treatment contractor (The Clearwater Group, Black Diamond, Washington).

Washwater Disposal

Under Alternatives 1, 2, and 3, washwater must be transported to an appropriate disposal site. Transportation costs of the effluent in 5,000-gallon tankers is assumed to cost $0.30 per gallon, based on discussions with a waste management contractor (Northwest Cascade, Puyallup, Washington). This assumes that the material is being transported to a location up to 2 hours away. Travel times for washwater effluent will likely exceed 2 hours for many bridge washing projects.

The cost of washwater disposal can vary depending upon the location of the bridge in relation to available disposal sites. Under Alternatives 1 and 2, effluent would be discharged to a sanitary sewer. It is likely that treatment of the washwater would be required, as described in the *On-site Washwater Treatment* section above, before it could be discharged to a municipal sanitary sewer system.

Disposal fees will vary depending upon the sanitary sewer system that the water is discharged to. For the purposes of this cost estimate, it is assumed that the washwater that was treated by filtration (the low estimate) was disposed of at the King County wastewater treatment system, and the washwater treated by chemical precipitation (high estimate) was disposed in the LOTT system, which has more stringent discharge criteria than the King County. Disposal fees are estimated at $1335 for large discharges (Alternative 1) and $695 for smaller discharges (Alternative 2) based on fees charged by the King County Industrial Waste Program. Disposal fees for washwater at the LOTT system was estimated at a rate of $2.72 per 100 gallons based on their current rates.

Under Alternative 3, it is assumed that the primary cost for land application disposal is transportation, based on discussions with a waste management contractor (Northwest Cascade, Puyallup, Washington). For the purposes of this cost estimate, only transportation costs were included in the disposal cost estimate.

Solid Waste Disposal

Disposal of debris and paint residue collected by filter tarps or full containment structures is assumed to cost approximately $8,000, based on estimated values provided by painting contractors (Dunkin and Bush Painting, Redmond, Washington). In addition, it is assumed that the filter tarps under Alternative 4 would be disposed of after use due to the clogging of pore spaces, increasing the cost by approximately 20 percent ($9,600).

Preferred Alternative

This section identifies a preferred alternative for washwater treatment based on a synthesis of the information presented above in the preliminary assessment of environmental impacts, technical feasibility evaluation, and cost analysis. In order facilitate this process, a numerical ranking system was developed to compare the relative merits of each alternative. Each of the three categories in the AKART analysis above were assigned three potential ranking categories as defined below:

- Potential for environmental impact: high – 1; medium – 2; low – 3
- Level of technical feasibility: low – 1; medium – 2; high – 3
- Estimated cost: high – 1; medium – 2; low – 3

For these ranking categories, a low number for a particular alternative would indicate it is less preferred. The individual ranks from each of these assessment criteria were then combined to produce an overall ranking for each alternative in order to identify a preferred alternative. The results from this analysis are presented in Table 5.

Table 5. Ranking of proposed alternatives based on potential for environment impacts, technical feasibility, and cost.

	Potential for Environmental Impact [a]	Level of Technical Feasibility [a]	Estimated Cost [a]	Overall Ranking [a]
Alternative 1	3	2	1	6
Alternative 2	3	1	1	5
Alternative 3	3	1	1	5
Alternative 4	2	3	3	8

[a] Higher values are preferred

For environmental impacts, only high ranks (3) were assigned to the three full containment alternatives to reflect the fact that there would be no discharge to any receiving water and, therefore, no potential for environmental impacts. A medium (2) rank was assigned to Alternative 4 for environmental impacts to give credit for the treatment that is afforded by the filter tarps and the potential reduction in the heavy metal loads that might be realized through the more aggressive bridge washing schedule that would likely be possible under this alternative.

Alternatives 2 and 3 were given a low rank (1) for level of technical feasibility. Alternative 2 was given a low rank because some kind of treatment process would be required during washing activities to maintain the proper functioning of the wash equipment and treatment may also be required to meet disposal limits for municipal sewer systems. Alternative 3 was given a low rank because a complex treatment process, polymer precipitation, would be used to facilitate land application of washwater. Both of these alternatives are also subject to the feasibility concerns related to using full containment. Alternative 1 was given a medium rank (2) because some kind of treatment method would likely be required after washing is completed to meet disposal limits for municipal sewer systems. Alternative 1 would also be subject to the feasibility concerns related to using full containment. Finally, Alternative 4 was given a high rank (3) because it is the current practice and has the least complexity as no water collection, storage, or treatment would be conducted.

For cost, Alternatives 1, 2, and 3 were given low ranks (1) because the estimated upper range for each was generally similar. Alternative 4 was given a high rank (3) because its associated costs were considerably less than those of the other alternatives.

Based on the overall rankings for the alternatives (Table 5), Alternative 4 was identified as the preferred alternative for treating washwater. This conclusion is subject to review and approval by both WSDOT and Ecology. If both WSDOT and Ecology concur with this conclusion, an additional analysis of "reasonable potential" will be conducted to evaluate whether state quality standards will be violated if Alternative 4 is used to manage effluent associated with WSDOT's bridge washing activities. This analysis will follow guidelines and procedures outlined in Ecology's Water Quality Program Permit Writer's Manual (2002), and will include a mixing zone analysis consistent with Ecology's *Guidance for Conducting Mixing Zone Analyses.*

Because the analysis of reasonable potential must apply to a large number of bridge and marine transfer spans crossing a variety of water body types, water quality impacts will be evaluated at six locations representative of different structure types and water body conditions. Three representative locations will be selected for bridges over small, medium, and large rivers, corresponding approximately to the 10^{th}, 50^{th}, and 90^{th} percentile bridge lengths. Representative freshwater lake, oceanic water, and marine transfer span locations will also be identified for this analysis. In general, representative locations will be selected based on the availability of flow and background water quality data. Analyses of water quality impacts at these representative locations will subsequently be applied to all similar structures.

The associated analyses will compare acute water quality standards for chromium, copper, lead, zinc, and fecal coliform bacteria to estimated receiving water concentrations at the applicable mixing zone boundaries. For small and medium rivers, the following simple dilution equation will be used to evaluate receiving water pollutant concentrations:

$$C_a = (Q_e * C_e + 0.025 * Q_r * C_b) / (Q_e + Q_r)$$

where:

C_a = acute water quality concentration (mg/L)
Q_e = effluent flow rate (cfs)
Q_r = river flow rate (cfs)
C_b = background (river) water quality concentration (mg/L).

Receiving water pollutant concentrations associated with medium and large rivers, lakes and oceanic waters, and marine transfer spans will be evaluated using a specialize software for performing mixing zone analyses (i.e., CORMIX).

Results from the analysis of reasonable potential will be summarized in a technical addendum to this document. This addendum will include a description of the methods and results of the analysis, and will discuss any resulting conclusions. Engineering drawings and calculations will also be included in this addendum.

References

90.48 RCW. February 19, 2003. Water Pollution Control. Revised Code of Washington.

Ecology. July 2002. Water Quality Program Permit Writer's Manual. Publication 92-109. Washington State Department of Ecology (Ecology), Olympia, WA.

Leland, H.V. and J.S. Kuwabara. 1985. Trace metals. pp. 374 – 415 in: Fundamentals of Aquatic Toxicology. Edited by G. M. Rand and S. R. Petrocelli. Hemisphere Publishing Corporation, New York, NY.

McDonald, J. 2003. Organic Polymer Precipitation. Retrieved March 10, 2003 from Water Specialist Technologies web site at URL <http://www.waterspecialists.biz/html/organic_polymer_precipitation.html>.

U.S. EPA. Guidance specifying management measures for sources of nonpoint pollution in coastal waters. U.S. Environmental Protection Agency, Office of Water, Washington, D.C.

WAC 173-201A. November 18, 1997. Water quality standards for surface waters of the state of Washington. Washington Administrative Code.

WSDOT. October 2001. Monitoring Report of the Stillaguamish River Bridge Painting Project. Washington State Department of Ecology (WSDOT), Olympia, WA.

WSDOT. May 2002a. Skykomish River Bridge Painting Project. (Field Report). Washington State Department of Ecology (WSDOT), Olympia, WA.

WSDOT. June 2002b. Cowlitz River Bridge Painting Project. (Field Report). Washington State Department of Ecology (WSDOT), Olympia, WA.

WSDOT. January 2003. Potential draft feasibility study and engineering report for bridge washing and maintenance. Prepared by Washington State Department of Ecology (WSDOT) for Washington State Department of Ecology.

Table A1. Effluent pollutant concentrations from WSDOT bridge washing studies.

Parameter	Stillaguamish River Bridge near Stanwood, WA		Skykomish River Bridge near Gold Bar, WA	Cowlitz River Bridge near Kelso, WA
Sampling Date	August 17, 2001[c]	August 31, 2001	May 17, 2002	June 3, 2002
Conventional/Biological Parameters				
Temperature (C°)[a]	NM	NM	8.2/8.8	13.8/14.4
PH	7.88/7.94	7.79/7.88	7.99/8.30	7.49/7.75
Dissolved Oxygen (mg/L)[a]	NM	NM	11.65/12.22	10.17/10.78
Conductivity (mS/cm)[a]	NM	NM	0.23/0.37	0.18/0.39
Total Coliform (MPN/100 ml)[a]	NM	NM	95/400	NM
Biochemical Oxygen Demand (mg/L)	100	170	33	67
Total Suspended Solids (mg/L)	300	520	403	930
Hardness (mg/L)	NM	NM	120	130
Heavy Metals				
Antimony – dissolved (mg/L)	0.07 U	0.07 U	0.003 U	0.0025 U
Antimony – total (mg/L)	NM	NM	NM	0.0067
Arsenic – dissolved (mg/L)	0.007	0.005 U	0.0011	0.0025 U
Arsenic – total (mg/L)	NM	NM	0.12	0.0061
Beryllium – dissolved (mg/L)	0.003 U	0.003 U	0.002 U	0.002 U
Beryllium – total (mg/L)	NM	NM	NM	0.002 U
Cadmium – dissolved (mg/L)	0.005 U	0.005 U	0.0005 U	0.0025 U
Cadmium – total (mg/L)	NM	NM	NM	0.0011
Chromium – dissolved (mg/L)	0.01 U	0.01 U	0.01 U	0.01 U
Chromium – total (mg/L)	NM	NM	NM	0.368
Copper – dissolved (mg/L)	**0.022**	**0.041**	**0.178**	**0.0263**
Copper – total (mg/L)	NM	NM	2.05	0.128
Lead – dissolved (mg/L)	**0.070**	**0.076**	**0.13**	0.0645
Lead – total (mg/L)	NM	NM	6.48	10.5
Mercury – dissolved (mg/L)	0.0002 U	0.002 U	0.002 U	0.0002 U
Mercury – total (mg/L)	NM	NM	NM	0.0002 U
Nickel – dissolved (mg/L)	0.02 U	0.02 U	0.01 U	0.01 U
Nickel – total (mg/L)	NM	NM	NM	0.0227
Selenium – dissolved (mg/L)	0.05 U	0.05 U	0.003 U	0.0025 U
Selenium – total (mg/L)	NM	NM	NM	0.003 U
Silver – dissolved (mg/L)	0.007 U	0.007 U	0.01 U	0.0025 U
Silver – total (mg/L)	NM	NM	NM	0.01 U
Thallium – dissolved (mg/L)	0.005 U	0.2 U	0.0005 U	0.0025 U
Thallium – total (mg/L)	NM	NM	NM	0.005 U
Zinc – dissolved (mg/L)	**2.1**	**1.7**	**1.06**	**1.34**
Zinc – total (mg/L)	NM	NM	3.63	4.47
Volatile Organics[b]				
Ethylbenzene (mg/L)	NM	NM	0.0024	NM
m, p-Xylene (mg/L)	NM	NM	0.0079	NM
o-Xylene (mg/L)	NM	NM	0.0036	NM
1, 3, 5-Trimethylbenzene	NM	NM	0.0014	NM
4-Chlorotoulene	NM	NM	0.00053	NM
1, 2, 4-Trimethylbenzene	NM	NM	0.0043	NM

Data source: WSDOT 2001, 2002a, 2002b
[a] Values presented are the median and maximum, respectively, from replicate field measurements.
[b] Parameters listed are present in the paints used by WSDOT on bridge structures.
[c] A two tarp system was used on this date to filter bridge washing effluent.
NM: Not measured.
U: Analyte not detected at the specified detection limit.
Values in **bold** exceed state water quality standards for acute freshwater toxicity (see Table 3).

Table B1. WSDOT Bridge Washing Cost Estimate

	unit	Alt 1-low	Alt 1-high	Alt 2-low	Alt 2-high	Alt 3-low	Alt 3-high	Alt 4-low	Alt 4-high
Labor									
cell rate	$/hr	$45	$50	$45	$50	$45	$50	$45	$50
# of laborers	ea	3	3	3	3.3	3	3	2	2
surface area	sf	176,400	176,400	176,400	176,400	176,400	176,400	176,400	176,400
wash rate	sf/hr	400	360	400	360	400	360	400	400
Total Labor		**$59,500**	**$73,500**	**$59,500**	**$80,900**	**$59,500**	**$73,500**	**$39,700**	**$44,100**
Equipment/Material									
pressure washer rate	$/hr	$6	$6	$6	$6	$6	$6	$6	$6
vacuum rate	$/hr	$3	$3	$3	$3	$3	$3	$0	$0
tarp rate	$/sf	$0.4	$0.4	$0.4	$0.4	$0.4	$0.4	$0	$0
tarp size	sf	24,150	24,150	24,150	24,150	24,150	24,150	24,150	24,150
water rate	$/mgal	$20	$20	$20	$20	$20	$20	$20	$20
water volume	mgal	20	20	5	5	20	20	20	20
Total Equipment/Material		**$14,000**	**$14,500**	**$13,700**	**$14,200**	**$14,000**	**$14,500**	**$9,100**	**$9,100**
Wash Water Storage									
wash water storage rate	$/day	$35	$35	$20	$20	$35	$35	$0	$0
duration	days	75	75	75	75	75	75	75	75
delivery rate	$/hr	$77	$77	$77	$77	$77	$77	$77	$77
delivery time	hr	2	2	2	2	2	2	0	0
Total Wash Water Storage		**$2,800**	**$2,800**	**$1,700**	**$1,700**	**$2,800**	**$2,800**	**$0**	**$0**
Wash Water Treatment (on-site)									
sand filter rate	$/mo	$700		$700					
cartridge filter rate	$/mo	$650		$650					
duration	mo	1		3					
cartridge filters, set	$/ea	$70		$70					
# of cartridge replacements	ea	4		4					
chem treatment system	ls		$40,000		$40,000	$50,000	$50,000		
Total Wash Water Treatment		**$1,600**	**$40,000**	**$4,300**	**$40,000**	**$50,000**	**$50,000**	**$0**	**$0**
Wash Water Disposal									
volume	gal	20000	20000	5000	5000	20000	20000		
disposal rate	$/gal		$0.00272		$0.00272				
disposal rate	$	$1,335		$690					
trucking rate	$/gal	$0.3	$0.3	$0.3	$0.3	$0.3	$0.3		
Total Wash Water Disposal		**$7,300**	**$6,100**	**$2,200**	**$1,500**	**$6,000**	**$6,000**	**$0**	**$0**
Solid Waste Disposal									
rate	$/lf	$8.3	$8.3	$8.3	$8.3	$8.3	$8.3	$8.3	$8.3
bridge length	ft	966	966	966	966	966	966	966	966
increase for tarp disposal	%							20	20
Total Solid Waste Disposal		**$8,000**	**$8,000**	**$8,000**	**$8,000**	**$8,000**	**$8,000**	**$9,600**	**$9,600**
Total Cost Estimate	$	**$93,200**	**$144,900**	**$89,400**	**$146,300**	**$140,300**	**$154,800**	**$58,400**	**$62,800**