AKART Analysis Report

Marine Industries Northwest, Inc.
Tacoma, Washington

March 18, 1996

Prepared for

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313 F. Street East
Tacoma, Washington

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AKART ANALYSIS REPORT

MARINE INDUSTRIES NORTHWEST, INC.
313 F. STREET EAST
TACOMA, WASHINGTON

MARCH 18, 1996

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EXECUTIVE SUMMARY

Marine Industries Northwest Inc. (MINW) is a commercial ship repair facility located on the southerly shore of the Middle Waterway in Commencement Bay in Tacoma, Washington. The Washington State Department of Ecology (Ecology) has determined that the stormwater quality discharged by MINW does not meet the stormwater quality discharge standards established in the NPDES permit issued by Ecology. Ecology established the discharge standards in accordance with the water quality beneficial use classification for the Middle Waterway, which is Marine Class B. The principal constituents of concern identified by Ecology that are contained in the stormwater discharged by MINW are the heavy metals, namely copper, lead, and zinc. These metals are components of marine paints and corrosion protection systems ubiquitously used in the ship and boat industry. MINW has already implemented many of the recognized best management practices (BMPs) identified for the shipyard industry and is planning to pave the site to facilitate, to the extent practicable, more effective housekeeping measures and to collect and treat its stormwater.

This AKART analysis compares the quality of stormwater generated by several representative shipyards similar to MINW in an effort to characterize the quality of the stormwater likely to result after the site is paved and other source control measures are implemented in accordance with the current plan. Evaluation of the quality of stormwater discharged by other shipyards indicates that copper, lead, and zinc significantly exceed the marine water quality standards. By comparison, shipyard wastewater generated by pressure washing of hulls contains concentrations of copper and zinc, for example, at least an order of magnitude greater than found in the stormwater. Surprisingly, the concentrations of copper, lead and zinc contained in urban stormwater throughout the United States, Washington, and in the City of Tacoma are generally of the same order of magnitude as that characterized for the shipyard industry. The concentrations of copper, lead, and zinc in urban stormwater are often an order of magnitude or greater than the discharge limitations established for MINW.

MINW has three options for discharging stormwater: discharge to the Middle Waterway under an NPDES permit, discharge to groundwater through infiltration, and discharge to the City of Tacoma sewage collection system. Only the first two options are considered in this AKART report. Discharge to the City of Tacoma sewer system would likely require MINW to retain all stormwater onsite during the storm event and discharge the stormwater when hydraulic conditions within the City's collection system and at the City's treatment facility were conducive to receiving the retained stormwater by controlled discharge. The costs, logistics, and spatial constraints associated with this alternative do not appear reasonable as compared to the results and recommendations of this AKART analysis.

The recommended approach for achieving AKART for the shipyard industry focuses on pollution prevention and implementation of rigorous source control procedures that focus on housekeeping. Treatment technology conventionally applied in the metals finishing industry is not capable of reducing the concentration of the metals, particularly copper to the required discharge standards. For example, the California State Department of Health Services, Toxic Substances Control Division (1988) determined the feasible treatment level for copper to be 2.6 mg/L, lead to be 0.5 mg/L, and zinc to be 4.1 mg/L for wastewater containing these metals. These limits are several orders of magnitude greater than the discharge limits specified for MINW. Advanced technologies have been developed and implemented in the metals finishing industry that could likely achieve the required concentrations specified in MINW's permit; however, the cost would be unreasonable and disproportionate with respect to the incremental reduction in metals concentration. The metal industry limits the implementation of such technology to those instances when the recovered metals can be recycled into an existing process to offset use and cost of an otherwise imported process feed material. MINW has no such process to recycle recovered metals that would provide a reasonable economic incentive to offset the cost for an advanced treatment system.

The recommendations for achieving AKART at MINW are to implement appropriate treatment technology in stages. Emphasis should be directed toward completing the paving and stormwater drainage systems at the site so other source control BMPs, such as mechanical and vacuum sweeping of the exposed work surfaces can be cleaned when work is not actively being performed. The collection system should be configured to allow stormwater and housekeeping wastewater from the marine railway work area, which may at times contain significant concentrations of metals, to be diverted to the existing pressure washing wastewater batch treatment system for metals reduction. A stormwater detention/sedimentation basin is recommended to provide treatment of the stormwater through gravity sedimentation. Substantial evidence exists that indicates over 90 percent of the total recoverable metals in urban stormwater, and stormwater derived from shipyards, is associated with the fine particulates suspended in the water. The recommended detention/sedimentation basin will provide a minimum hydraulic detention time of 24 hours, based on a 6-month 24-hr storm event, which should be adequate to remove over 90 percent of the suspended solids load. It is recommended that provisions be made in the design and construction of the conveyance system to the detention/sedimentation basin to allow injection of a liquid cationic coagulant and an anionic flocculent to augment the metals removal process if monitoring data indicate that enhancement is necessary. The recommended method for disposal of the treated groundwater is onsite infiltration, rather than to surface waters of the Middle Waterway. This method of disposal is consistent with the preferred means for disposal of stormwater identified in the *Puget Sound Stormwater Management Manual* (Ecology 1992a). The quality of the treated stormwater after infiltration is estimated to be below the concentration limits established for protection of a groundwater resource; the shallow groundwater that will receive the infiltrated treated stormwater from MINW is not known to have any existing or future beneficial use. Application of treated stormwater is not anticipated to degrade the quality of this groundwater aquifer. The stormwater treatment and infiltration facilities will be constructed on undeveloped property not currently occupied by MINW.

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1.0 INTRODUCTION

This report identifies and evaluates all known, available, and reasonable methods of prevention, control, and treatment (AKART) for stormwater generated at Marine Industries Northwest Inc. (MINW), located in Tacoma, WA.

MINW is a commercial vessel repair yard located at 313 F. Street East, on the Middle Waterway of Commencement Bay. The site covers an area of approximately 2.8 acres (approximately 121,000 ft^2). A general site plan is presented on Figure 1. MINW has leased the property from Foss Maritime Company since 1981. Ship hull pressure washing, grit blasting, metal fabrication and painting are the principal activities accomplished at the site. These activities have been identified by the Washington State Department of Ecology (Ecology) and the U.S. Environmental Protection Agency (EPA) as having significant potential to contaminate stormwater. MINW also operates a marine railway and a dry dock for raising vessels to provide access to vessels requiring repair.

Several buildings and structures are located on the property. The area covered by building and structure roofs is approximately 31,000 ft^2. The remaining 90,000 ft^2 of the site is currently unpaved. Accumulated spent grit mixed with site soil forms the working ground surface in most areas, but there are a few areas that are paved as shown on the site plan (Figure 1). MINW plans to pave the site to provide an impermeable surface that will allow grit to be recovered by a combination of surface cleaning procedures (i.e. shoveling, dry and wet sweeping, and vacuuming).

MINW generates a maximum of approximately 1,000 gallons of wastewater from pressure washing per week. Wastewater resulting from pressure washing of ship hulls is collected on the dry dock and around the marine railway and pumped to an approximate 20,000-gallon holding tank. The water contained in this tank is treated by an existing batch treatment system that provides adequate treatment for the water to be reused. Water that cannot be reused due to the accumulation of minerals (salts) will be discharged in a legal manner either under a discharge permit from the City of Tacoma sewage collection system or to a licensed waste disposal company.

Ecology has provided final approval of the engineering report, and installation and performance of the pressure washing wastewater treatment system. A 700-gallon batch treatment tank outfitted with a mechanical mixer forms the primary component of the treatment system. The treatment system provides for coagulation, flocculation, and gravity sedimentation for removal of particulate material from the wastewater generated by pressure washing. A proprietary dry coagulant is used at the rate of approximately 5 lbs per 1,000 gallons to promote removal of fine suspended particulates. After addition of the coagulant, mixing, and an adequate settling period, the resulting clear water is decanted from the tank and conveyed through a 25 micron bag (fabric) filter. The filtered water is pumped to one of two treated wash water holding tanks, which have a combined capacity of 2,800 gallons.

The National Pollution Discharge Elimination System (NPDES) permit (WA-004044-4) issued by Ecology dated June 30, 1992, establishes specific discharge limitations for discharge of stormwater including: pH, oil and grease, total recoverable copper, total recoverable lead, and total recoverable zinc. The specific limits for these parameters are presented in Table 1. The concentrations for copper, lead, and zinc correspond to the EPA marine water quality standards, which have been adopted by Ecology. Ecology has not provided for a mixing zone, so the water quality criteria and the discharge criteria for copper, lead, and zinc are identical. The Washington Administrative Code (WAC) 173-201A requires dischargers to fully apply AKART prior to Ecology authorizing a mixing zone. WAC 173-201A recommends the Puget Sound Stormwater Management Manual (PSSWMM) (Ecology 1992a) be used as a guidance document in selection of appropriate best management practices (BMPs) for application of AKART.

The PSSWMM emphasizes the importance of source control through prevention: visa vis housekeeping, work practices, spill response, and training. Additionally, the PSSWMM recommends a preference for infiltration over surface water discharge as a means for disposal of stormwater. Where infiltration cannot be achieved directly, the PSSWMM recommends a sequence for selection of BMPs as follows:

- First, a sediment trapping BMP
- Second, an oil and grease BMP for highly impervious cover areas
- Third, a BMP capable of treating soluble pollutants.

The Pollution Prevention Act of 1990 established a national policy that emphasizes pollution prevention over control or treatment. With this policy, Congress defined a pollution prevention hierarchy for all pollution prevention programs:

- Pollution should be prevented or reduced at the source wherever feasible
- Pollution that cannot be prevented should be recycled in an environmentally acceptable manner
- Pollution that cannot be prevented or recycled should be treated in an environmentally safe manner

- Disposal or other releases to the environment should be a last resort and should be conducted in an environmentally safe manner.

The PSSWMM is consistent with the federal policy and is consistent with the decision making hierarchy stated above.

The current NPDES permit for MINW does not address the possibility that stormwater could be disposed of by infiltration. The PSSWMM (Ecology 1992a) requires that infiltration be considered the preferred BMPs for stormwater management. A settling basin or detention facility is required prior to infiltration, to remove the majority of the particulate material so the efficiency of the infiltration system is not impaired by the accumulation of sediment.

The Safe Drinking Water Act (SDWA) was created in 1974 with the primary goal to ensure public health by improving the quality of the nation's drinking water. The Underground Injection Control (UIC) program was created as a subset of SDWA in 1974 to prevent injection of waste underground that could cause groundwater contamination and subsequent violations of the national drinking water standards. WAC 218-030(16) defines a usable source of drinking water as a groundwater containing fewer than 10,000 mg/L total dissolved solids. The shallow groundwater at the MINW site is not known to be of any direct beneficial use because of the likely brackish nature resulting from intrusion of estuarine water into the aquifer as a result of tidal action. The quality of the shallow groundwater aquifer will be confirmed and reported in the engineering report.

2.0 STORMWATER CHARACTERIZATION

Ecology has expressed concern regarding the quality of water entering the Middle Waterway of Commencement Bay from seeps in the intertidal zone at the MINW site and the existing stormwater discharge system. The seeps are thought to be principally influenced by infiltration of stormwater through accumulated spent grit blasting. Stormwater quality sampling and analysis have identified copper, lead, zinc, suspended solids, oil and grease and pH as the constituents of concern. Copper, lead, and zinc in MINW's stormwater have been frequently reported at concentrations several orders of magnitude greater than the water quality standards for the receiving water (i.e. Middle Waterway). Ecology has reported that the stormwater monitoring data collected over the last 3 years indicate the following concentrations: copper in the range of 131 to

2,340 µg/L; lead in the range of 28 to 2,730 µg/L; zinc in the range of 520 to 4,050 µg/L; total suspended solids in the range of 1.7 to 200 mg/L; and oil and grease in the range of 0.1 to 20 mg/L.

The quality of the stormwater discharge through for MINW is not likely representative of the quality of the stormwater that will be generated after implementation of planned source control BMPs (i.e. paving, housekeeping, and upgraded work practices). Other shipyards in western Washington similar to MINW have implemented source control BMPs such as paving and housekeeping to reduce the concentration of toxic substances in their stormwater discharge.

Stormwater quality data from several shipyards were used to estimate the probable quality of stormwater to be generated by MINW after implementation of site paving and drainage source control BMPs. Data reviewed was provided by Ecology on Foss, Marco, MCI, and Todd shipyards. Additional data were obtained from Nichols Brothers Boat Shop. Tables 2, 3, 4, and 5 present statistical parameters calculated from the results of stormwater analyses for copper, lead, zinc, and total suspended solids for each of the shipyards. The concentrations of copper, lead, and zinc in the stormwater from MCI's shipyard is significantly greater as compared to the other shipyards; therefore, it is concluded that MCI is not representative of the stormwater likely to be generated by MINW.

3.0 URBAN AND SHIPYARD STORMWATER QUALITY COMPARISON

Concentrations of copper, lead, and zinc in urban stormwater are consistent with concentrations identified for stormwater derived from shipyards. Typical concentrations of copper, lead, and zinc found in urban and shipyard stormwater and pressure washing wastewater are presented in Table 6. A study of urban stormwater at strategic locations throughout the City of Tacoma reported high concentrations of the priority metal contaminants listed Table 6. The majority of the metals in urban stormwater are associated with particulate solids, which is consistent with the findings of the METRO ship hydroblast wastewater study (1992). The majority of the metals associated with urban stormwater can be relatively easily removed through sedimentation practices (Pitt et al. 1994). Pitt also reported that the dissolved fraction of the metals can be effectively removed by either sediment adsorption or organically complexed with other particulates.

Pitt and Amy (1973) provided evidence that particle sizes less that 104 microns contained the greatest concentration of copper, lead, and zinc. Similar results were reported in the METRO

Shipyard Wastewater Treatment Guidelines (1991), which state that 80 to 90 percent of the metals contained in wastewater from hull pressure washing are contained in the solid particles; additionally, the greatest percentage of particles are less than 50 microns.

4.0 BMPs APPLIED TO REDUCING METALS IN URBAN STORMWATER

The effectiveness of strategies applied to reduce metal concentrations in urban stormwater are relevant to evaluating and selecting appropriate and reasonable alternative for reducing metal concentrations in stormwater from shipyards. The concentrations of copper, lead, and zinc contained in stormwater derived from shipyards is of the same order of magnitude as that found in urban stormwater derived from paved streets.

Recharge basins receiving large metal loads remove most of the heavy metals as determined from analysis of sedimentation basin sediment (Pitt et al. 1994). Dissolved metal ions are removed from stormwater during infiltration, mostly by adsorption onto the near-surface particles in the vadose zone, while particulate metals are filtered out at the soil surface. Pitt further reports that studies at recharge basins found that copper, lead, zinc and cadmium accumulated at the soil surface with little downward migration over many years.

Although street sweeping may not be an effective means of reducing heavy metal contaminant loads derived from urban stormwater, some studies (EPA 1974) indicate that vacuum type street cleaning equipment can remove 95 percent or greater of the fine particulate fraction of the street dirt. Studies have proven that street sweeping is most effective in reducing the contaminant concentration in the stormwater when the accumulation of solids is high prior to cleaning. Studies conducted by the American Public Works Association and vacuum sweeper manufacturer performance data indicate that vacuum sweepers, when properly used, typically recover 95 percent of all particulates less 10 microns. The effectiveness of street sweeping in significantly reducing the suspended solids and metals contaminant of urban stormwater is not a function of the process, but where the process is applied. Hence, the majority of stormwater flowing in the urban stormwater system, including street gutters, is very much influenced by the non-point source stormwater runoff from private properties that have not received an equivalent level of source control attention.

5.0 TREATMENT PROCESS ALTERNATIVES

Conventional approaches for treatment of wastewater containing metals are dependent on physical and chemical processes. The intermittent and discontinuous nature of stormwater flows coupled with the low concentration of contaminants, and the generally disproportionate cost for treatment as compared to implementation of source control BMPs, has discouraged the implementation of end of pipe treatment systems for stormwater. For example, the concentration of copper, lead, and zinc in hydroblast water is approximately an order of magnitude greater than the upper 90 percent confidence limit of the average concentration for shipyard affected stormwater when current industry standard source control BMPs are implemented.

The physical state of the metals of concern controls the effectiveness of the available treatment technologies. Treatment technologies conventionally applied to heavy metal affected industrial process wastewater are focused on removal of dissolved metals. On the other hand, the treatment technology conventionally applied to urban stormwater is sedimentation combined with infiltration of the water.

5.1 SEDIMENTATION (WITH/WITHOUT COAGULANT ADDITION)

Sedimentation technology is the simplest of the treatment technologies. Sedimentation technology has been used extensively for both process wastewater treatment and for stormwater treatment. Sedimentation technology is only effective in removing particulate matter that settles under the force of gravity from water. The effectiveness of the sedimentation process can be enhanced with the addition of chemical coagulants to destabilize small particulates that would otherwise settle at a rate too slow to make sedimentation a realistic treatment option. The results of METRO (1991) indicate that alum and lime chemical coagulation can achieve residual concentrations of: copper of 600 µg/L, lead of 60 µg/L, and zinc of 160 µg/L. Compliance monitoring results for MINW's pressure washing batch treatment system, which uses a proprietary dry chemical flocculating product, indicate that this process can achieve concentrations of: copper of approximately 30 µg/L, lead of approximately 40 µg/L, and zinc of approximately 250 µg/L.

5.2 FLOTATION

Flotation technology is applicable for separation of particulate material from water. Flotation technology is most often utilized when the solids have a specific gravity less than water or where it is not significantly greater than water or when the surface area of the solid is high relative to the weight of the solid. Small air bubbles are introduced into the flotation reactor. As the air bubbles rise through the water they come into contact with the suspended solids, whereby the air bubbles can get entrapped in the particle structure or adhere to the particle surface. The buoyant force of the combined particle and air bubble cause the particle to rise to the surface where the particles can be removed by skimming.

METRO (1992) evaluated both induced and dissolved air flotation processes for treatment of wastewater generated from hull pressure washing. When these flotation systems were used in conjunction with alum coagulation these systems were capable of high percent removals, but final effluent was substantially greater than the required NPDES requirements for MINW. Residual concentrations of copper ranged from 150 to 600 µg/L, lead of 30 µg/L, and zinc ranging from 2,000 to 100 µg/L.

5.3 FILTRATION

Filtration technology is a particulate removal system. A variety of filtration systems have been used for removal of particulate material from wastewater. Filters commonly selected for removal of metal particulates include: bag, cartridge, sand, membrane, and diatomaceous earth precoat filters. This section only addresses rapid filtration systems; slow sand type filtration systems are addressed in the section on infiltration systems.

METRO (1992) evaluated several proprietary filtration systems including mixed media, precoat, and ultrafiltration. The study concluded that bag, cartridge, sand and mixed media, and diatomaceous earth pressure filters plug rapidly when treating pressure washing wastewater. The average concentration of suspended solids in pressure washing wastewater is approximately three times greater than shipyard stormwater; therefore, the effective filter run volume would be expected to be three times greater for filtering shipyard stormwater as compared to pressure washing wastewater. Gravity settling prior to filtration is effective in increasing run volume and essential for cartridge, bag, and multi-media filters to prevent excessive plugging. Mixed granular media filtration was demonstrated to reduce copper to approximately 440 µg/L, lead to approximately 60 µg/L, and zinc to 130 µg/L. Additionally, the use of coagulants was reported to enhance and accelerate the settling process, which serves to improve the efficiency of filtration.

Ultrafiltration is a membrane filtration process that consists of forcing the wastewater at a pressure of 50 to 75 psi through a porous membrane that rejects the suspended and colloidal solids at the surface. Water is recirculated over the surface of the membrane to reduce the tendency for blinding the effective surface of the membrane. Ultra filtration is generally effective in removing particles greater than 0.01 microns. Results from METRO (1991) indicate that ultrafiltration can reliably reduce the concentration of copper to 100 µg/L, lead to less than 100 µg/L, and zinc to 100 µg/L. Ultrafiltration produces a brine at the rate of 2.5 to 5 percent of the total volume processed. This brine would require treatment by precipitation or offsite disposal. The process also requires chemical cleaning of the membranes on a regular basis and periodic replacement.

Reverse osmosis (RO) is often considered a filtration technique because the reverse osmosis membrane contains very small pores that block the passage of certain ions, including the metals of concern. RO membranes remove particles smaller than 0.001 microns. RO systems reject ions by overcoming the natural osmotic pressure that is created across the membrane. A concentrated brine is created by all RO systems; the brine contains the ions rejected by the membrane. Brine generation by RO range from 5 to 20 percent of the influent flow rate. The brine generated would need to be treated to remove the metals prior to discharge. RO systems are very susceptible to fouling from chemical and biological scale formation. Preliminary filtration of the influent to the RO is absolutely essential. RO systems are expensive to purchase and are expensive to operate as compared to alternative technologies. RO technology, like ion exchange technology, becomes cost effective when recycling of the metal brine or metal laden regenerate can be reused in the industrial process. Unfortunately, shipyards have no known potential for their reuse.

5.4 PRECIPITATION

Precipitation technology is applied to convert metals that are in the dissolved phase to the particulate. EPA considers the chemical precipitation to be the best practicable control technology for the metal-finishing industry, where it has been frequently implemented for treatment of wastewater derived for these industries. Chemical precipitation technology is particularly suited to a batch processing and is most advantageous when the volume of wastewater is relatively low and the concentration of metals are high. Precipitation technology in a continuous flow reactor has been used successfully for treatment of high-volume, low-concentration wastewater, but with higher chemical dosage rates and when followed by a subsequent sedimentation process. Precipitation technology when accomplished in a continuous flow process often creates up to twice the quantity of chemical sludge as compared to the batch process. Additionally, continuous flow processes often cannot achieve the metal removal efficiency of a batch process because pH cannot be as accurately controlled and continuous flow clarifiers can allow carryover of particulates with the treated water. Therefore, continuous flow metals precipitation technology systems frequently need filtration following sedimentation to achieve the same efficiency of metal removal as a batch treatment process. Conventional metal precipitation technology is very effective in removing simple ionic metal species, but are often ineffective in converting soluble metal complexes and chelates to the particulate phase. Soluble metal complexes and chelates must be destabilized or destroyed prior to application conventional chemical precipitation.

Precipitation is the standard treatment process for removal of soluble phase copper, lead, and zinc. Conventional precipitation technology for these metals is based on formation of insoluble metal hydroxide, through the addition of a strong alkali solution (e.g., sodium hydroxide or lime). Copper oxide, which forms from the hydroxide, has a minimum solubility of approximately 10 μg/L between pH 9 and pH 10.3. Unfortunately, theoretical concentrations are seldom attained in actual practice due to the presence and influence of other ions or completing agents in solution, carryover of colloids precipitates in clarification stage, slow reaction rates, and pH fluctuations (Patterson 1985).

5.5 ION EXCHANGE

Ion exchange technology is intended to removed soluble ionic metals from a dilute solution. High volume, low metal concentration waste waters are the best candidates for application of ion exchange technology. Copper, lead, and zinc ions can be removed from water using a strong cationic exchange resin. Most cationic exchange resins are more selective for common divalent ions such as calcium, magnesium, and iron than for copper, lead, and zinc. Ion exchange is capable of reducing soluble copper concentration to below 30 μg/L, soluble lead concentration below 10 μg/L, and soluble zinc concentration below 50 μg/L. In wastewater treatment applications, primary problems that cause ion exchange systems to perform below expectations include: organic fouling, iron fouling, mud fouling, and polyelectrolyte fouling. Ion exchange systems are not generally effective in removing soluble metal complexes, although selective ion exchange resins can remove some complexed metals. When ion exchange resins reach their exchange capacity it is necessary to regenerate the resin. Regeneration of the resin can be accomplished onsite or offsite, but the residual regenerate solution would need to be treated as a dangerous waste since there is no known opportunity to recycle or reuse the spent regenerant on site. In essence, ion exchange is a metal concentration process that reduces the volume of the wastewater and enhances the opportunities for subsequent metal recovery.

Ion exchange systems typically require minimal space and operator attention. The principal disadvantages associated with application of ion exchange technology are cost for the resin and the potential for resin fouling.

5.6 INFILTRATION SYSTEMS

Detention/sedimentation basins and infiltration trenches are considered the most common management practice for the control of stormwater runoff. Pitt et al. (1994) reports effectiveness of suspended solids at up to 90 percent and heavy metal removal rates in the range of 60 to 95 percent. Veenhuis et al. (1989) reported that detention/sedimentation basins that were constructed with a sand bottom to serve as a filter removed 60 to 80 percent of the suspended solids, 10 to 80 percent of the zinc, and 60 to 80 percent of the lead contained in stormwater based on field data from Austin, Texas. The mechanism for removal of metals by detention/sedimentation basins includes physical and chemical processes. The fine to medium texture soil removes essentially all the suspended solids from the stormwater by straining. Adsorption processes between the heavy metals and organics, clay minerals, iron and manganese oxides, and carbonates provide for effective natural removal mechanisms for reducing the dissolved metal phases. Nussbaum (1991) reported that the poor performance of a detention basin is usually attributable to inadequate inlet and outlet structure designs that allow stirring up and resuspension of sediments and the development of currents within the basin and inadequate maintenance.

5.7 ARTIFICIAL WETLAND

Ecology (1992b) reported that bioswales could provide significant reductions in total metal concentrations contained in stormwater. As with detention/sedimentation basins, bioswales are significantly more effective in removing metals associated with the particulate fraction rather than the dissolved fraction (Urbonas (1993). Data reported indicated that bioswales can achieve an average copper concentration of 10 µg/L, average lead concentration less than 10 µg/L, and average zinc concentration of 60 µg/L. The study concluded that approximately six-fold dilution would be required to achieved the state water quality standards for fresh water as defined in WAC 172-201. The concentrations of copper, lead, and zinc contained in the untreated stormwater were lower than that reported for typical urban stormwater and stormwater derived from shipyards.

Bioswales and artificial wetlands are most effective in reducing concentrations of algal growth stimulating nutrients containing nitrogen and phosphorus, which are not the constituents of concern for stormwater derived from shipyards. Additionally, artificial wetlands attract avian species that would be exposed to potential contamination that would likely be concentrated in the wetland. Therefore, an artificial wetland is not considered appropriate technology for treatment of shipyard stormwater.

6.0 DEVELOPMENT AND EVALUATION OF ALTERNATIVES

6.1 ALTERNATIVE 1

This alternative consist of installing pavement and source control BMPs to provide for collection of contaminated stormwater. Stormwater from building roofs will be discharged to the Middle Waterway of Commencement Bay without treatment. Stormwater collected in paved areas will be collected in catch basins outfitted with pumps and a common discharge pipeline, which shall discharge into a lined stormwater detention basin. The sedimentation basin will have a capacity equal to 100 percent of the water quality storm estimated runoff of 72,000 gallons. The gravity sedimentation basin will be lined so that accumulated sediment can be removed from the basin every 2 to 3 years depending on the rate of accumulation. The bottom will be a concrete slab to provide a smooth, hard surface to facilitate periodic desludging of the basin. A floating weir with a scum baffle will provide for automatic discharge control from the basin. Stormwater will be treated using a batch coagulation/flocculation/sedimentation treatment system. The treatment system would be a scaled up version of the existing pressure wastewater treatment system. Assuming that the stormwater would be processed in 48 hours, and each batch treatment process takes approximately 3 hours, then the estimated batch reactor size is 5,000 gallons. An onsite infiltration basin will be constructed of adequate size to infiltrate the treated stormwater into the shallow groundwater aquifer. Eighteen inches of clean sand will be imported to provide a suitable infiltration media complying with the recommendations of the PSSWMM. Estimated costs for design, construction, operation, and maintenance of the treatment system are presented in Table A-1. Operation and maintenance costs are based on an annual rainfall of 40 inches. A conceptual process flow diagram for this alternative is shown on Figure 2. The estimated costs associated with implementation of this alternative are presented in Table A-1. Life cycle costs for 10 years of operation and the anticipated performance of the systems associated with this alternative are presented in Table 7.

6.2 ALTERNATIVE 2

This alternative consists of installing pavement and source control BMPs as described under Alternative 1. Stormwater from building roofs will be discharged to the Middle Waterway of Commencement Bay without treatment. Stormwater collected in paved areas, except in a 2,000 ft^2 area around the marine railway will be collected in catch basins outfitted with pumps and a common discharge pipeline, which shall discharge into a lined stormwater detention basin. Stormwater from within the marine railway drainage area will be collected and pumped to a 20,000-gallon holding tank. This water has the greatest potential for metals contamination and, therefore, will be treated using the existing batch treatment system. Treated water will be reused to the extent practicable by the hull pressure washing system. Excess treated water will over flow from the treated water storage tanks to a sump, which shall be outfitted with a pump to convey the lined stormwater detention basin. The impoundment will be as described in Alternative 1, except a fixed weir with scum baffle will serve as the outlet structure. A conceptual process flow diagram for this alternative is shown on Figure 3. Estimated costs associated with implementation of this alternative are presented in Table A-2. Life cycle costs for 10 years of operation and the anticipated performance of the systems associated with this alternative are presented in Table 7.

6.3 ALTERNATIVE 3

This alternative is identical to Alternative 1 with respect to the stormwater collection system. Initial settling and flow equalization will be accomplished in a 20,000-gallon epoxy-coated steel tank. Settled stormwater will be pumped from the equalization tank to a package treatment unit featuring chemical coagulation, flocculation, sedimentation, and filtration. Filtration will be accomplished using a multimedia pressure filter. Treated filter water will flow to a treated water retention sump having sufficient retained water capacity to satisfy the filter backwash requirements. The dirty backwash water will be returned to the equalization tank. Filter effluent overflowing the backwash water retention tank would be conveyed to the infiltration basin described in Alternative 1. Settled sludge from the package treatment system and from the equalization tank will be dewatered to approximately 40 percent solids in a plate and frame filter press. Dewatered solids would be disposed of offsite in a legal manner. A conceptual process flow diagram for this alternative is shown on Figure 4. The estimated costs associated with implementation of this alternative are presented in Table A-3. Life cycle costs for 10 years of operation and the anticipated performance requirements are presented in Table 7.

6.4 ALTERNATIVE 4

This alternative provides a stormwater collection system identical to Alternative 1 and a 72,000-gallon stormwater detention basin constructed as described in Alternative 1. A polyelectrolyte coagulant injection system will be provided to enhance the removal efficiency of fine particulates in the detention basin. Settled stormwater will be pumped from the detention/ sedimentation basin through a 5- to 10-micron bag filter assembly prior to discharge to the infiltration basin. Adequate filtration surface area will be provided so that the filtration rate does not exceed 6 gpm per square foot. A backwash water holding tank and backwash pump could be provided, although replacement of the filter media is generally more cost effective. The filter treated water would be discharged to the infiltration system. A dilution ratio of approximately 108 would be required to achieve the water quality standards if the settled stormwater were discharged to the Middle Waterway. A conceptual process flow diagram for this alternative is shown on Figure 5. Estimated costs associated with implementing this alternative are presented in Table A-4. Life cycle costs for 10 years of operation and anticipated system performance are presented in Table 7.

6.5 ALTERNATIVE 5

Alternative 5 is similar to Alternative 4 plus the addition of ion exchange reactors to reduce the concentration of residual dissolved metals; however, the discharge of the treated water would be to the Middle Waterway. The use of ion exchange resins to reduce the residual dissolved metal concentrations would likely be very cost intensive with respect to operations and maintenance due to fouling. Even with ion exchange, there will be a need for a dilution zone when the treated stormwater is discharged to the Middle Waterway. A dilution ratio of approximately 10 would be required to meet the water quality requirements established. A conceptual process flow diagram for this alternative is shown on Figure 6. Estimated costs associated with implementation of this alternative are presented in Table A-5. Life cycle costs for 10 years of operation and anticipated system performance associated with this alternative are presented in Table 7.

7.0 RECOMMENDED APPROACH

The recommended plan for implementation of AKART at MINW follows a phased approach concentrating on:

- Capital improvement source controls
- Provisions for segregation of stormwater sources based on potential for contamination
- Treatment of stormwater by sedimentation and infiltration similar to Alternative 2 as shown on Figure 7.

The capital improvement for source controls includes paving the site to provide a smooth surface that can be effectively cleaned by mechanical means. Existing source controls, such as the curtain assembly around the marine railway, will be potentially more effective with a smooth surface to clean. The curtain provides a physical barrier to inhibit the aerial migration of spent blasting materials and dusts from being spread over the site. Provisions for segregating the drainage system for the marine railway will be constructed to allow collected stormwater and housekeeping water associated with water-sweeping to be diverted to the existing pressure washing batch treatment system. All wastewater generated from pressure washing ship hulls will continue to be collected, treated by the existing chemical batch treatment system, and reused to the extent practicable. This cross connection in the stormwater collection system will provide the capability of diverting stormwater from the marine railway during those periods when activities have a greater potential to generate stormwater with significant concentrations of the metals of concern. After the area has been confirmed clean and no longer likely to present a significant potential for contamination of stormwater, then the responsible operator shall complete a permanent record inspection form prior to opening the valve to allow stormwater to be conveyed to the detention/sedimentation basin. Stormwater generated from other areas of the site will be collected by strategically located catch basins. Each catch basin will be outfitted with a submersible sump pump adequately sized to convey the peak flow rate of stormwater. A common trunk pipeline will convey the pumped stormwater to a stormwater detention/sedimentation basin. Collection system components including inlet and outlet structures, pumps, piping, and emergency overflow will be designed for a peak flow generated by a 100-yr storm event. A magnetic flow meter with totalizer will be installed to monitor the rate and accumulated flow of stormwater to the detention/sedimentation basin. Provisions will be included in the design to allow for future injection of a coagulant into the influent stormwater prior to discharge to the detention/sedimentation basin. The detention/

sedimentation basin will provide for sedimentation and a minimum of 24 hours of detention storage for the 6-month 24-hr storm, based on a stormwater catchment area of 90,000 ft^2. An inlet energy dissipation box will be provided at the inlet to the detention/sedimentation basin to reduce the tendency for hydraulic short circuiting. The detention/sedimentation basin will feature a concrete bottom to inhibit infiltration and to facilitate manual desludging of the detention/sedimentation basin. The side slopes of the detention/sedimentation basin will be lined with HDPE sheeting to preclude embankment erosion and infiltration of stormwater. A fixed weir outlet control structure will be provided to minimize the development of currents in the detention/sedimentation basin that would interfere with the sedimentation process. A minimum weir length of 10 ft will be provided that is consistent with accepted engineering design criteria of 10,000 gpd per ft of weir typically applied to plain sedimentation tanks (WPCF 1981).

The treated stormwater will be conveyed from the detention/sedimentation basin to an infiltration basin. The specific design details of the infiltration basin are dependent on the hydraulic characteristics of the existing site soil and shallow aquifer, which will be characterized by field investigation and reported in the engineering report. The bottom of the infiltration basin will be constructed with 18 inches of fine clean sand. An onsite in filtration test should be conducted to establish the appropriate design parameters. An emergency overflow weir will be provided on the infiltration basin to allow discharge of treated water to the Middle Waterway in the unlikely event that stormwater flow rates exceed the infiltration capacity of the infiltration basin. A schematic process flow diagram and layout of the stormwater collection, detention/sedimentation basin and infiltration basin are shown on Figures 7 and 8, respectively.

The stormwater detention/sedimentation treatment and infiltration system will be constructed on an undeveloped parcel of land adjacent to MINW. Areas not occupied by the treatment and infiltration facilities will not be paved since no industrial use of the site is anticipated. Consequently, there will be no increase in the industrial stormwater drainage area.

A recommended schedule for implementation is presented on Figure 9.

8.0 REFERENCES

California State Department of Health Services. 1988. *Staff Report on Proposed Treatment Standards for Metal-Containing Aqueous Wastes.* Toxic Substances Control Division. September 8.

EPA. 1974. Urban Stormwater Management and Technology, An Assessment. EPA-670/2-74-040. December.

EPA. 1991. Technical Support Document for Water Quality-based Toxics Control. EPA/505/2-90-001, PB91-127415. March.

Ecology. 1992a. Stormwater Management Manual for the Puget Sound Basin.

Ecology. 1992b. Biofiltration Swale Performance, Recommendations, and Design Considerations. Publication 657. October.

METRO. 1991. Shipyard Wastewater Treatment Guidelines, Municipality of Metropolitan Seattle, Water Pollution Control Department, Industrial Waste Section. December.

METRO. 1992. Maritime Industrial Waste Project Reduction of Toxicant Pollution from the Maritime Industry in Puget Sound. Industrial Waste Program Water Pollution Control Department. March.

Nussbaum, J.C. 1990. Urban Storm Water Runoff and Ground-water Quality. EPA 101/F-90-046. January.

Patterson, J.W. 1985. Industrial Wastewater Treatment Technology. Second Edition. Butterworth-Heinemann, Stoneham, MA, 467pp.

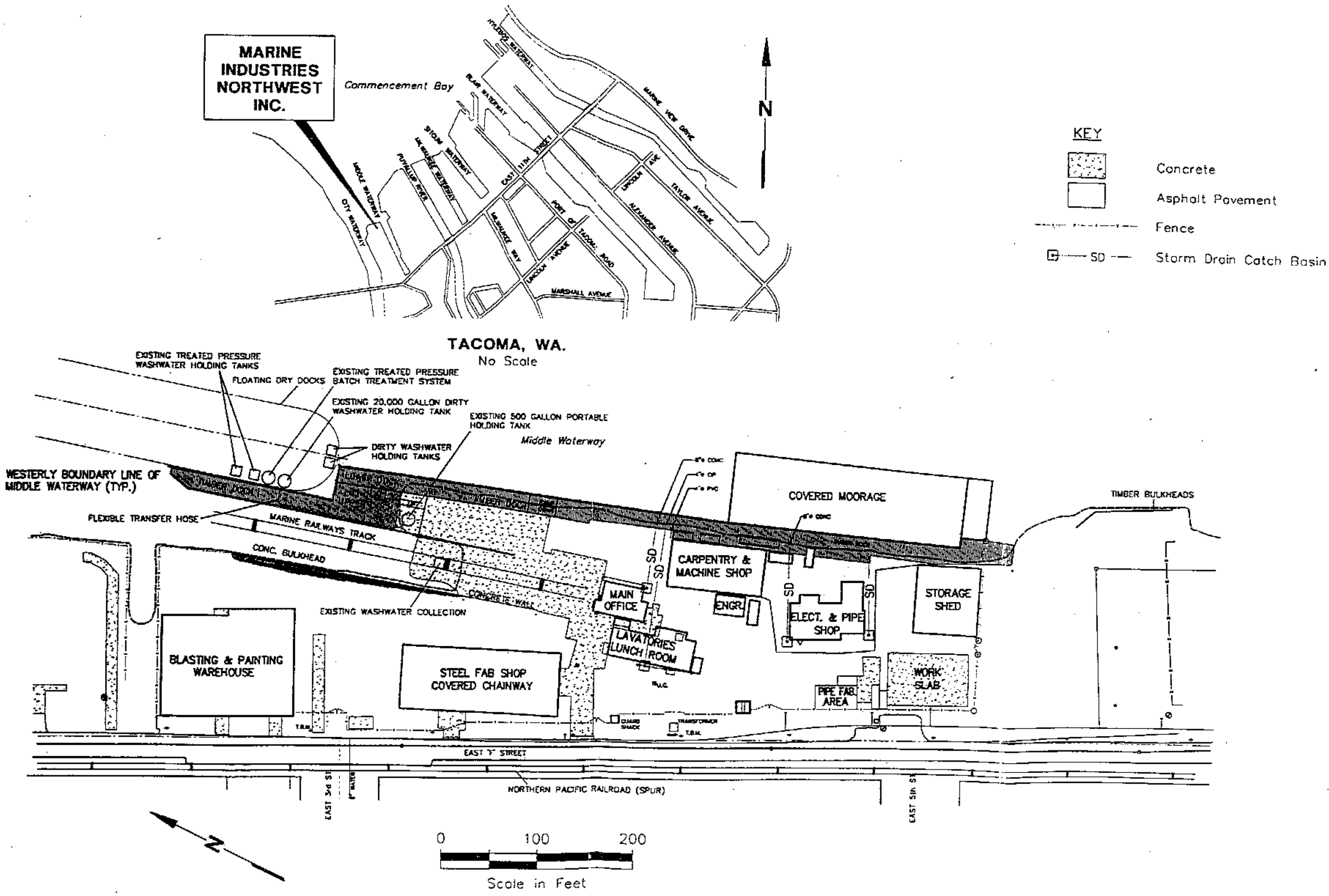
Pitt, R., S. Clark, and K. Parmer. 1994. Potential Groundwater Contamination from Intentional and Unintentional Stormwater Infiltration. EPA/600/8-94/051, PB94-165354. May.

Pitt, R. and G. Amy. 1973. Toxic Materials Analysis of Street Surface Contaminants. EPA-R2-73-283. Environmental Protection Technology Series. August.

Urbonas, B. and P. Stahre. 1993. Stormwater: best management practices and detention for water quality, drainage, and CSO management. ISBN 0-13-847492-3, Prentice-Hall, Inc, Englewood Cliffs, New Jersey.

Veenhuis, J.E., J.H. Parish, and M.E. Jennings. 1989. Monitoring and Design of Stormwater Control Basin, Design of Urban Runoff Controls. American Society of Civil Engineers, New York.

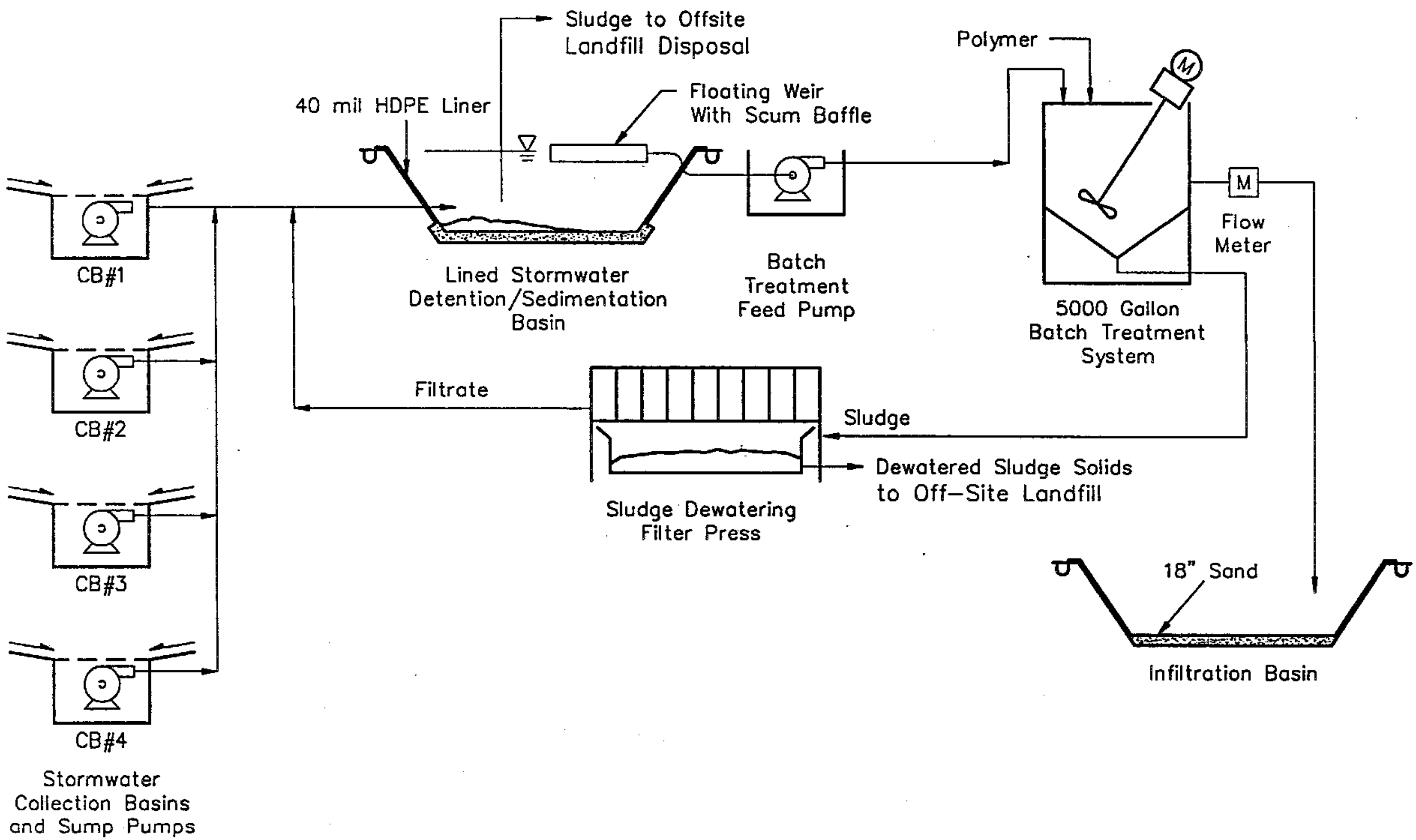
WPCF. 1981. Pretreatment of Industrial Wastes. Manual of Practice No. FP-3, Facilities Development. Water Pollution Control Federal. Washington, D.C. 20037.



Marine Industries Northwest, Inc.
Site Plan and Vicinity Map

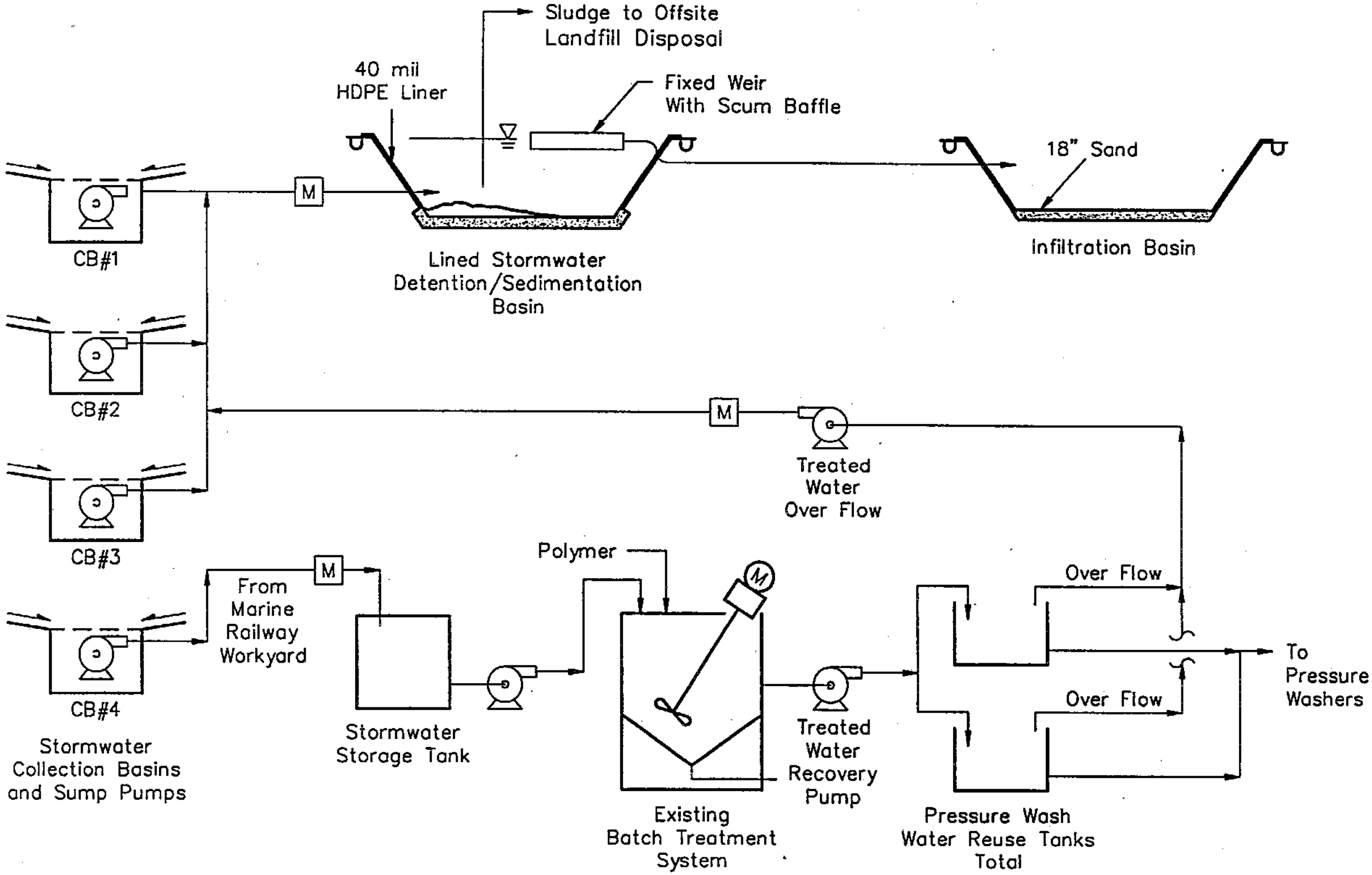
Figure 1

347001.25 Marine Industries Northwest/Report (A) 2/96



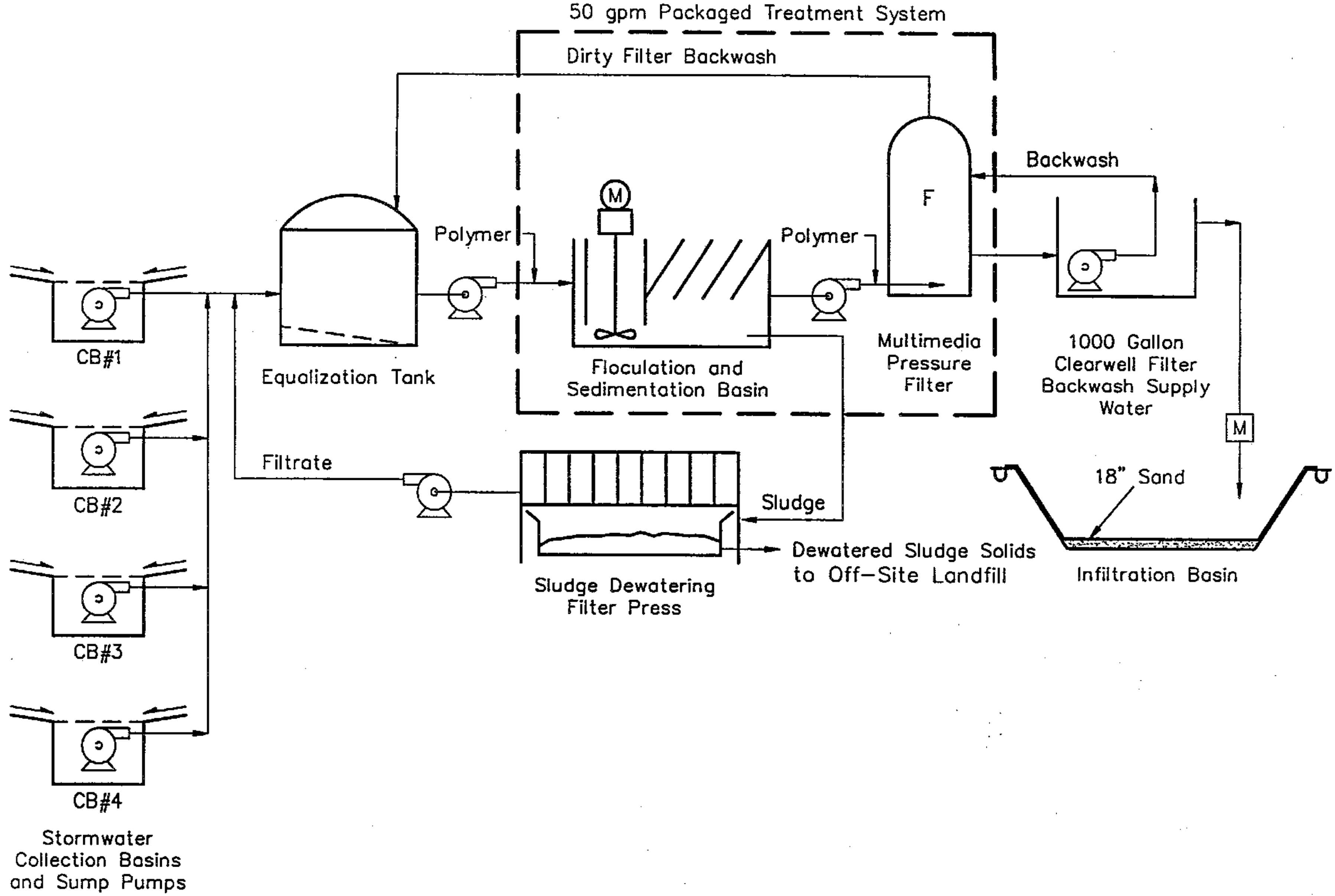
Alternative 1

Figure 2



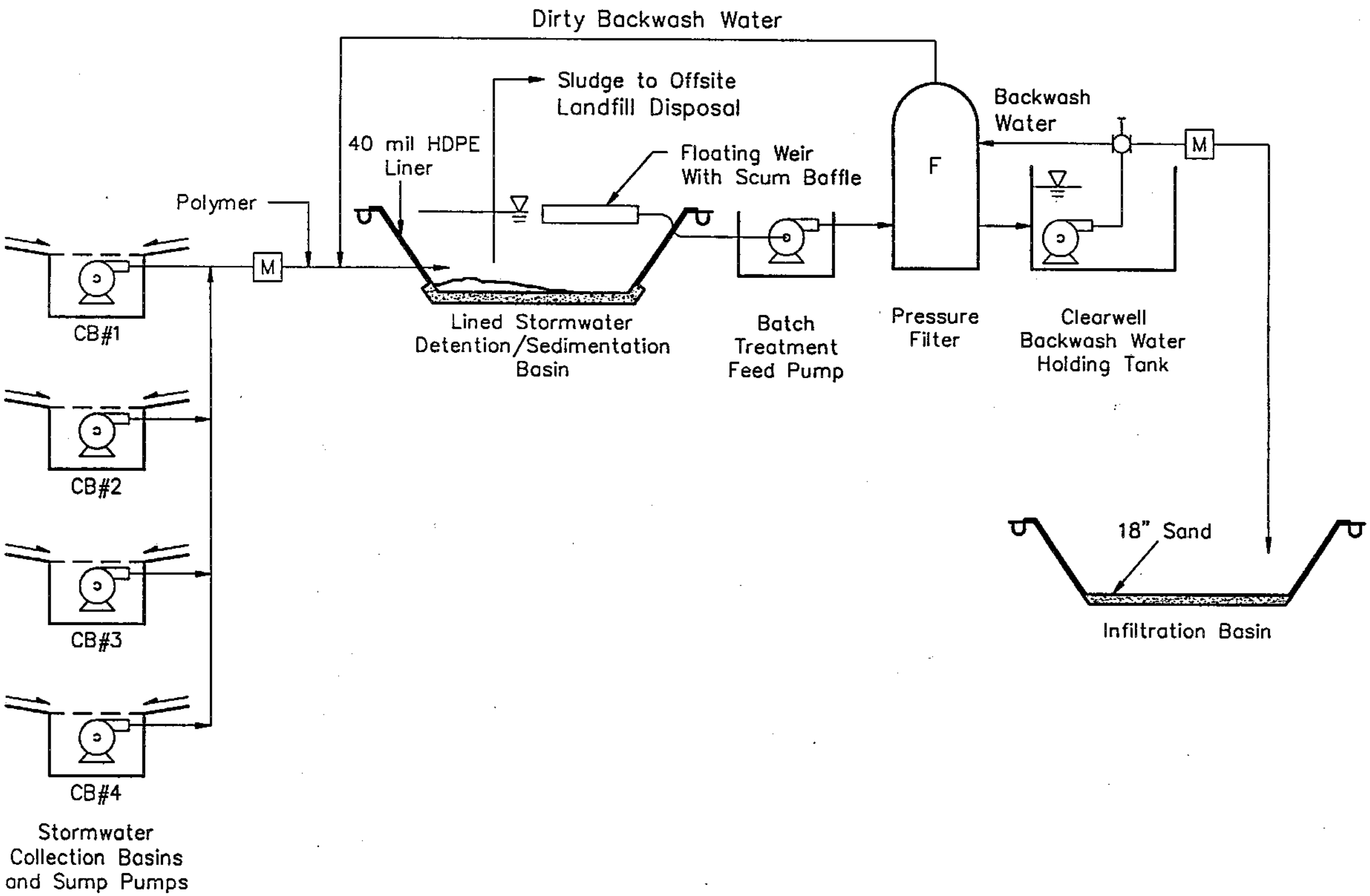
Alternative 2

Figure 3



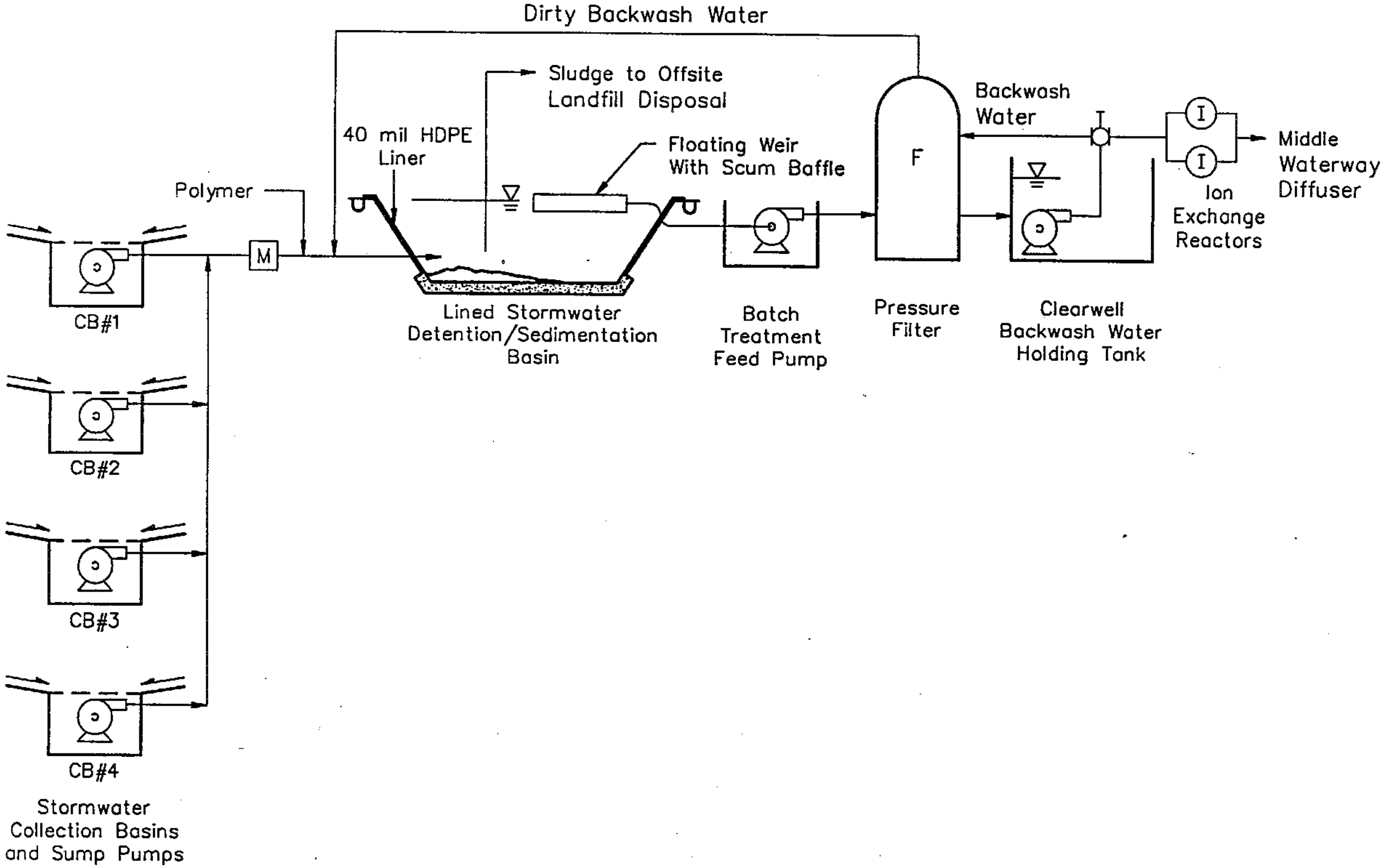
Alternative 3

Figure 4



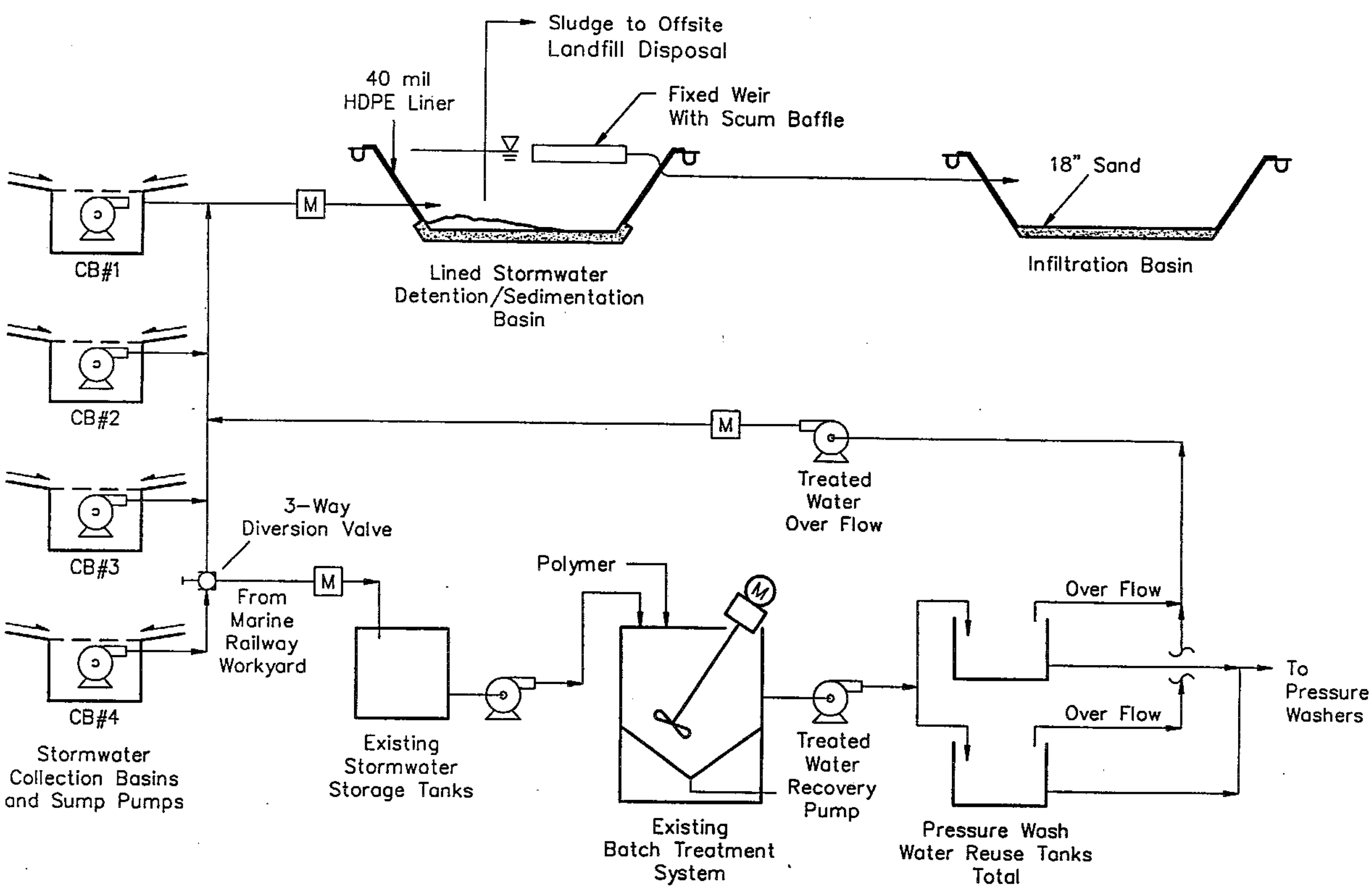
Alternative 4

Figure 5



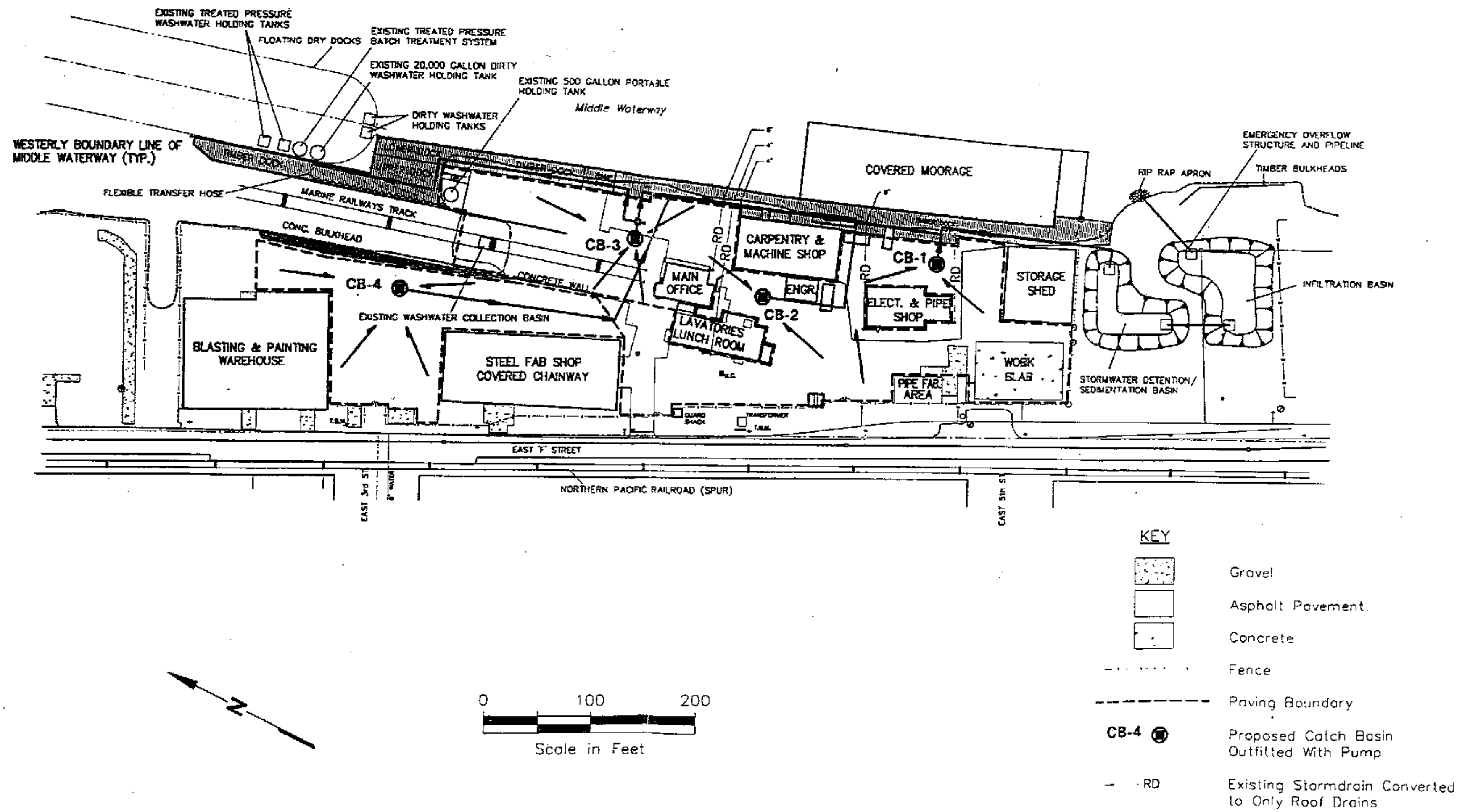
Alternative 5

Figure 6



Recommended Stormwater Management System

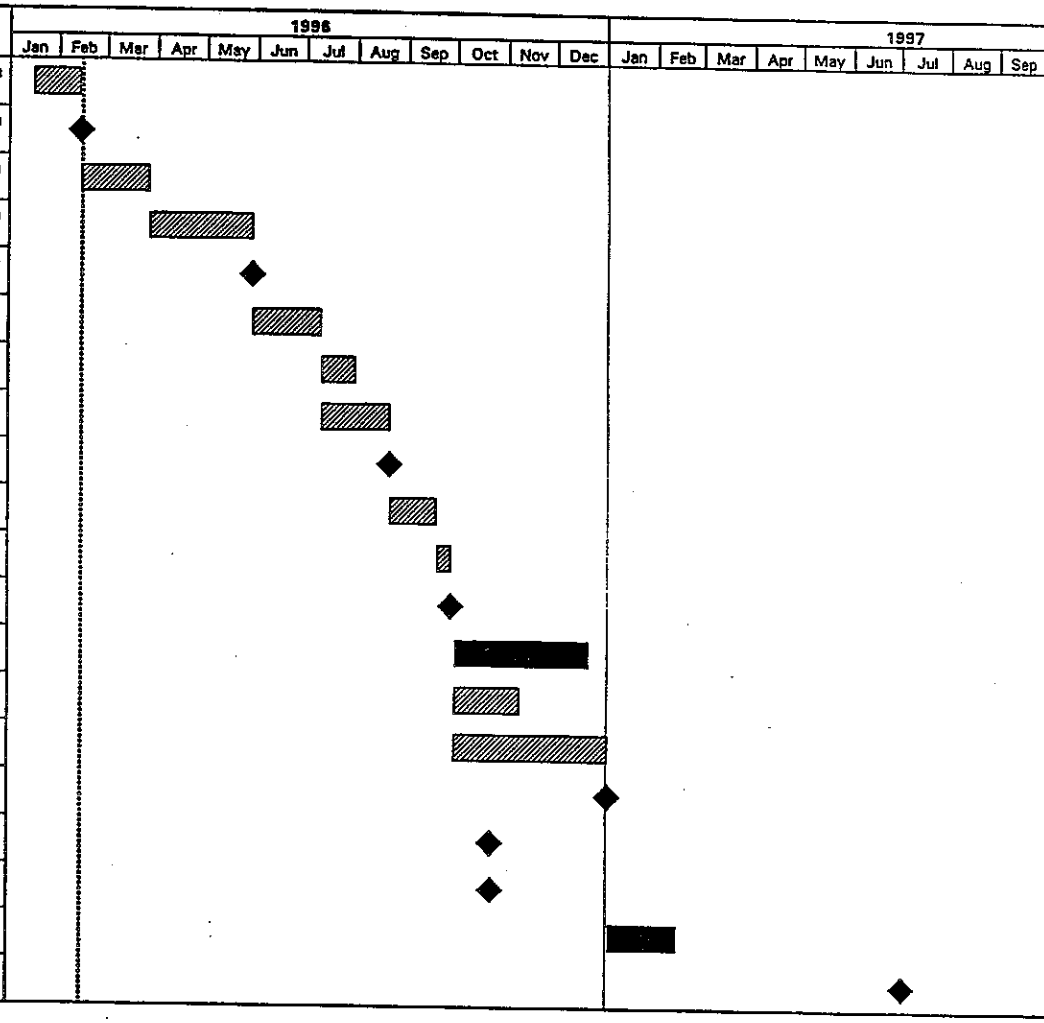
Figure 7



Stormwater Treatment BMP Plan

Figure 8

ID	Name	Scheduled Start	Scheduled Finish
1	Prepare AKART Report	1/16/96 8:00am	2/13/96 5:00pm
2	Submit AKART to Ecology for review	2/14/96 8:00am	2/14/96 8:00am
3	Ecology Review and AKART determination	2/14/96 8:00am	3/26/96 5:00pm
4	Prepare Engineering Report (Drawings and Specs)	3/27/96 8:00am	5/28/96 5:00pm
5	Submit Engineering to Ecology	5/28/96 5:00pm	5/28/96 5:00pm
6	Ecology Review Period	5/29/96 8:00am	7/9/96 5:00pm
7	Incorporate Ecology and Agency Review comments	7/10/96 8:00am	7/30/96 5:00pm
8	Prepare Construction Bid Documents	7/10/96 8:00am	8/20/96 5:00pm
9	Issue Construction Bid Docs	8/20/96 5:00pm	8/20/96 5:00pm
10	Solicit Bids from Contractors	8/21/96 8:00am	9/18/96 5:00pm
11	Evaluate Bids	9/19/96 8:00am	9/27/96 5:00pm
12	Award Construction Contract	9/27/96 5:00pm	9/27/96 5:00pm
13	Construct Treatment System	9/30/96 8:00am	12/20/96 5:00pm
14	Install catch basins, pumps and piping	9/30/96 8:00am	11/8/96 5:00pm
15	Install paving	9/30/96 8:00am	1/1/97 5:00pm
16	Implement Source Control Measures fully implemented	1/1/97 5:00pm	1/1/97 5:00pm
17	Complete Acute Toxicity Tests	10/22/96 8:00am	10/22/96 8:00am
18	Apply to Ecology for NPDES renewal	10/22/96 5:00pm	10/22/96 5:00pm
19	Initiate Discharge Monitoring Program	1/2/97 8:00am	2/12/97 5:00pm
20	Existing NPDES permit expires	6/30/97 5:00pm	6/30/97 5:00pm



Project: Marine Industries Northwest, Inc
Stormwater AKART Report
Date: 2/14/96

Critical ▨ Progress ▬ Summary ▬
Noncritical ■ Milestone ◆ Rolled Up ◇

Preliminary Project Schedule

Figure 9

TABLE 1

STORMWATER DISCHARGE LIMITATIONS

Constituent	NPDES Discharge[(a)]	Underground Injection Control[(b)]	City of Tacoma Sewer System[(c)]
pH	5.5 to 11.0	6.5 to 8.5	6 to 9
Oil and grease (mg/L)	15	NS	50
Suspended solids (mg/L)	45	NS	225
Copper (µg/L)	2.9	1,000	1,000
Lead (µg/L)	140	50	400
Zinc (µg/L)	95	5,000	2,000

NS = Not specified.

(a) MINW NPDES Permit No. WA-004044-4 (Ecology June 30, 1992).

(b) Underground Injection Control Program WAC 173-218 and 173-200.

(c) City of Tacoma Chapter 12.08. Sewage Disposal and Drainage Regulations and Rates; as amended by Ordinance No. 25659, February. 1995.

TABLE 2

TOTAL RECOVERABLE COPPER CONCENTRATION IN STORMWATER FROM SHIPYARDS[h]

Parameter	Foss [a]	Marco [b]	MCI [c]	Todd [d]	Nichols [e]	All [f]	All - MCI [g]
n	30	16	11	2	3	62	51
average	254	145	2737	340	93	662	214
stdev	235	142	3210	14	111	1634	209
min	10	17.9	160	330	17	10	10
max	1000	506	10190	350	220	10190	1000
upper 90% confidence	651	394	8515	381	353	3390	565

Notes:

(a) Data are from sampling location WA0031054 beginning 10/1/92 through 9/1/95

(b) Data are from sampling location SW1 to SW6 beginning 9/1/95 through 11/1/95

(c) Data are from sampling location WA0031348 beginning 4/1/93 through 4/1/94

(d) Data are from sampling location WA0002615B on 3/8/95

(e) Data are from 8/1/94 through 12/1/94

(f) Data from all shipyards are included in the analysis

(g) Data from all shipyards except MCI are included in the analysis

(h) All concentrations are in micrograms per liter

TABLE 3

TOTAL RECOVERABLE ZINC CONCENTRATION IN STORMWATER FROM SHIPYARDS[h]

Parameter	Foss [a]	Marco [b]	MCI [c]	Todd [d]	Nichols [e]	All [f]	All - MCI [g]
n	30	16	11	2	3	62	51
average	1275	615	5125	55	257	1699	960
stdev	1564	520	5673	64	129	3035	1316
min	80	10	19	9	110	9	9
max	6500	1880	17500	100	351	17500	6500
upper 90% confidence	3856	1474	14486	161	560	6767	3172

Notes:

(a) Data are from sampling location WA0031054 beginning 10/1/92 through 9/1/95

(b) Data are from sampling location SW1 to SW6 beginning 9/1/95 through 11/1/95

(c) Data are from sampling location WA0031348 beginning 4/1/93 through 4/1/94

(d) Data are from sampling location WA0002615B on 3/8/95

(e) Data are from 8/1/94 through 12/1/94

(f) Data from all shipyards are included in the analysis

(g) Data from all shipyards except MCI are included in the analysis

(h) All concentrations are in micrograms per liter

TABLE 4

TOTAL RECOVERABLE LEAD CONCENTRATION IN STORMWATER FROM SHIPYARDS[h]

Parameter	Foss [a]	Marco [b]	MCI [c]	Todd [d]	Nichols [e]	All [f]	All - MCI [g]
n	30	16	11	2	0	59	48
average	236	243	204	1450		273	289
stdev	394	412	220	71		424	458
min	25	5.9	2	1400		2	5.9
max	2100	1200	720	1500		2100	2100
upper 90% confidence	885	924	568	1567		972	1045

Notes:

(a) Data are from sampling location WA0031054 beginning 10/1/92 through 9/1/95
(b) Data are from sampling location SW1 to SW6 beginning 9/1/95 through 11/1/95
(c) Data are from sampling location WA0031348 beginning 4/1/93 through 4/1/94
(d) Data are from sampling location WA0002615B on 3/8/95
(e) Data are from 8/1/94 through 12/1/94
(f) Data from all shipyards are included in the analysis
(g) Data from all shipyards except MCI are included in the analysis
(h) All concentrations are in micrograms per liter

TABLE 5

TOTAL SUSPENDED SOLIDS CONCENTRATIONS IN STORMWATER FROM SHIPYARDS[h]

Parameter	Foss [a]	Marco [b]	MCI [c]	Todd [d]	Nichols [e]	All [f]	All - MCI [g]
n	29	12	8	2	2	53	45
average	101	68	615	7	51	166	86
stdev	123	112	599	4	32	310	118
min	5	5	10	4	28	4	4
max	633	360	1594	9	73	1594	633
upper 90% confidence	304	253	1604	12	125	684	284

Notes:

(a) Data are from sampling location WA0031054 beginning 10/1/92 through 9/1/95

(b) Data are from sampling location SW1 to SW6 beginning 9/1/95 through 11/1/95

(c) Data are from sampling location WA0031348 beginning 4/1/93 through 4/1/94

(d) Data are from sampling location WA0002615B on 3/8/95

(e) Data are from 8/1/94 through 12/1/94

(f) Data from all shipyards are included in the analysis

(g) Data from all shipyards except MCI are included in the analysis

(h) All concentrations are in micrograms per liter

TABLE 6

COMPARISON OF WATER QUALITY DATA FOR STORMWATER FROM SHIPYARDS, URBAN, AND CITY OF TACOMA, AND SHIPYARD PRESSURE WASHING WASTEWATER

Constituent	Shipyard Pressure Washing Wastewater[a]		Shipyard Stormwater[b]			City of Tacoma[c]			PSSWMM Industrial[d]	PSSWMM Highway[d]	Typical NURP Site Urban Runoff[e]
pH	7.2	[39][f]		–			–		–	–	–
Suspended solids (mg/L)	261	[33]	86	(117)[f]	[45]	96	(94)	[31]	–	–	100
Oil and grease	20	[5]		–		15	(26)	[26]	–	–	–
Copper (µg/L)	12,500	[40]	213	(209)	[51]	137	(138)	[36]	245	100	34
Lead (µg/L)	340	[40]	288	(458)	[48]	83	(79)	[35]	380	1,780	144
Zinc (µg/L)	6,600	[40]	960	(1,316)	[51]	313	(214)	[28]	275	400	160

(a) METRO. 1992. *Maritime Industrial Waste Project, Reduction of Toxicant Pollution from the Maritime Industry in Puget Sound*. March.
(b) Values represent average of reported values for Marc, Todd, Foss, and Nichols Brothers shipyard stormwater quality data of the dates and at the locations specified in Tables 2 through 4.
(c) Values represent averages of the data reported in the City of Tacoma (1990) surface water quality report during wet weather for the stormwater outfalls: East 96", West 96", Johnny's, Wheeler-Osgood, and Sitcum.
(d) Values are taken from Ecology. 1992. *Comparison of Typical Stormwater Pollutant Concentrations to Water Quality Criteria*. Table IV-1.1.
(e) EPA. 1993. Water quality characteristics of urban runoff from EPA's National Urban Runoff Program. (EPA 1993).
(f) Values contained in parentheses represent the standard deviation; Values in brackets represent the number of samples.

TABLE 7
SUMMARY OF CAPITAL AND O&M COSTS FOR ALTERNATIVE TREATMENT SYSTEMS ESTIMATED PERFORMANCE AND DISCHARGE CONSIDERATIONS

ALTERNATIVE	CAPITAL COSTS FOR TREATMENT SYSTEM	10 YR PRESENT WORTH FOR O&M	ESTIMATED 10-YR LIFE CYCLE COST[a]	ESTIMATED AVERAGE EFFLUENT QUALITY[b] Cu, ug/L	Pb, ug/L	Zn, ug/L	TSS, mg/L	ACCEPTABLE FOR ONSITE INFILTRATION	ACCEPTABLE FOR DISCHARGE TO MIDDLE WATERWAY[c]
1	$ 196,000	$ 615,000	$ 811,000	50 (50)	50 (50)	80 (250)	<10 (<40)	Yes	52
2	$ 195,000	$ 301,000	$ 496,000	50 (150)	50 (80)	80 (350)	<10 (<40)	Yes	109
3	$ 315,000	$ 458,000	$ 773,000	50 (90)	50 (60)	80 (160)	<10 (<40)	Yes	93
4	$ 116,000	$ 339,000	$ 455,000	50 (100)	50 (70)	100 (200)	<20	Yes	108
5	$ 165,000	$ 444,000	$ 609,000	30	10	50	<10	Yes	30
Recommended	$ 136,000	$ 235,000	$ 371,000	50 (150)	50 (80)	80 (350)	<10 (<40)	Yes	109

Notes:

(a) Life cycle costs are the sum of the capital cost and present value of O&M for the treatment system for the defined period.

(b) Values in parentheses represent the estimated water quality prior to the application of water to infiltration system.

(c) Dilution factor values are based on the quality of water prior to infiltration; a factor of 3 was used to establish the 95 percent upper confidence limit on the estimated average concentration of the controlling contaminant of concern.

APPENDIX A

ESTIMATED COSTS FOR IMPLEMENTATION OF ALTERNATIVES

The cost estimates presented are based on experience on similar projects and supplemented by specific equipment pricing where appropriate. The costs are based on a design concept with knowledge of the major items of equipment and facilities. The probable accuracy of the cost estimate is plus or minus 30 percent. It is noted that permitting, regulatory, and taxes are not included in the cost estimates.

TABLE A-1
ESTIMATED COSTS FOR IMPLEMENTATION OF ALTERNATIVE 1

Description	Quantity	Unit	Unit Cost	Extended Cost
1.0 COLLECTION SYSTEM				
Install catch basins	4	ea	$ 2,000	$ 8,000
Sump pumps and controls	4	ea	$ 2,000	$ 8,000
Drainage Piping	1100	ft	$ 20	$ 22,000
Flow meter and totalizer	1	ea	$ 2,500	$ 2,500
Asphalt paving	90,000	sf	$ 2	$ 180,000
Marine Railway Work curtain	1,200	sf	$ 2	$ 2,400
			subtotal	$ 222,900
2.0 TREATMENT				
Excavate sedimentation basin	363	cf	$ 15	$ 5,444
Pond Liner 40 mil HDPE slopes	4000	sf	$ 1.33	$ 5,320
Pond Bottom concrete 6 inches reinforced	82	cy	$ 150	$ 12,250
Inlet and outlet structures	4	ea	$ 1,500	$ 6,000
Batch treatment feed pump and controls	1	ls	$ 2,500	$ 2,500
Batch treatment tank (5000 gal)	1	ls	$15,000	$ 15,000
Batch treatment mixer and controls, 2 hp	1	ls	$ 3,000	$ 3,000
Piping to batch treatment system	100	ft	$ 20	$ 2,000
Effluent flow meter, magnetic indicating/totalizing	1	ls	$ 2,000	$ 2,000
Infiltration pond	651	cy	$ 15	$ 9,764
Infiltration pond sand media - 18" thickness	288	cy	$ 10	$ 2,880
Overflow weir	1	ea	$ 1,500	$ 1,500
Sludge press, feed pump and controls	1	ls	$50,000	$ 50,000
			subtotal	$ 117,659
Total construction cost (collection and treatment)				$ 340,559
Engineering	15	% of capital cost		$ 85,140
Construction management	10	% of capital cost		$ 56,760
Contingency	15	% of capital cost		$ 85,140
		total capital cost		$ 567,598
3.0 OPERATION AND MAINTENANCE				
Polymer cost	10660	lbs	$ 3.00	$ 31,980
Power (collection system)	1000	kw-hr	$ 0.06	$ 60
Power (treatment system)	800	kw-hr	$ 0.06	$ 48
Pond desludging (once per 3 year annualized)	1100	lbs	$ 6.60	$ 7,260
Treatment sludge disposal	26650	lbs	$ 0.15	$ 3,998
Treatment system consumables and spare parts	5	% of T.S. cost		$ 9,805
O&M personnel collection system	728	hr	$ 25	$ 18,200
O&M personnel treatment system	728	hr	$ 25	$ 18,200
			subtotal	$ 89,550
Present Value of Capital cost				$ 567,598
Present Value of O&M for 10 years i=3% effective				$ 772,833
Total Present Value - 10 year life cycle				$ 1,340,431
Total Present Value - 10 year life cycle per 1000 gal				$ 63
Total PV - 10 yr life cycle per 1000 gal (treatment only)				$ 30

TABLE A-2
ESTIMATED COSTS FOR IMPLEMENTATION OF ALTERNATIVE 2

	Description	Quantity	Unit	Unit Cost		Extended Cost
1.0	COLLECTION SYSTEM					
	Install catch basins	4	ea	$ 2,000	$	8,000
	Sump pumps and controls	4	ea	$ 2,000	$	8,000
	Drainage Piping	1100	ft	$ 20	$	22,000
	Flow meter and totalizer	1	ea	$ 2,500	$	2,500
	Asphalt paving	90,000	sf	$ 2	$	180,000
	Marine Railway Work curtain	1,200	sf	$ 2	$	2,400
				subtotal	$	222,900
2.0	TREATMENT					
	Excavate sedimentation basin	363	cf	$ 15	$	5,444
	Pond Liner 40 mil HDPE slopes	4000	sf	$ 1.33	$	5,320
	Pond Bottom concrete 6 inches reinforced	82	cy	$ 150	$	12,250
	Inlet and outlet structures	4	ea	$ 1,500	$	6,000
	Flow meters (from batch treatment and to sed basin)	2	ea	$ 2,500	$	5,000
	Batch treatment feed pump and controls	1	ls	$ 2,500	$	2,500
	Marine Railway stormwater storage tank (20000 gal)	1	ls	$25,000	$	25,000
	Treated water overflow pump system and flow meter	1	ls	$ 4,000	$	4,000
	Piping to batch treatment system	860	ft	$ 20	$	17,200
	Infiltration pond	651	cy	$ 15	$	9,764
	Infiltration pond sand media - 18" thickness	288	cy	$ 10	$	2,880
	Overflow weir	1	ea	$ 1,500	$	1,500
	Sludge press, feed pump and controls	1	ls	$20,000	$	20,000
				subtotal	$	116,859
	Total construction cost				$	339,759
	Engineering	15	% of capital cost		$	84,940
	Construction management	10	% of capital cost		$	56,626
	Contingency	15	% of capital cost		$	84,940
			total capital cost		$	566,265
3.0	OPERATION AND MAINTENANCE					
	Polymer cost	2400	lbs	$ 3.00	$	7,200
	Power (collection system)	1000	kw-hr	$ 0.06	$	60
	Power (treatment system)	400	kw-hr	$ 0.06	$	24
	Pond desludging (once per 3 year annualized)	1100	lbs	$ 6.60	$	7,260
	Treatment sludge disposal	6000	lbs	$ 0.15	$	900
	Treatment system consumables and spare parts	3	% of T.S. cost		$	5,843
	O&M personnel collection system	728	hr	$ 25	$	18,200
	O&M personnel treatment system	546	hr	$ 25	$	13,650
				subtotal	$	53,137
	Present Value of Capital cost				$	566,265
	Present Value of O&M for 10 years i=3% effective				$	458,580
	Total Present Value - 10 year life cycle				$	1,024,844
	Total Present Value - 10 year life cycle per 1000 gal				$	48
	Total PV - 10 yr life cycle per 1000 gal (treatment only)				$	28

TABLE A-3
ESTIMATED COSTS FOR IMPLEMENTATION OF ALTERNATIVE 3

	Description	Quantity	Unit	Unit Cost	Extended Cost
1.0	COLLECTION SYSTEM				
	Install catch basins	4	ea	$ 2,000	$ 8,000
	Sump pumps and controls	4	ea	$ 2,000	$ 8,000
	Drainage Piping	1100	ft	$ 20	$ 22,000
	Flow meter and totalizer	1	ea	$ 2,500	$ 2,500
	Asphalt paving	90,000	sf	$ 2	$ 180,000
	Marine Railway Work curtain	1,200	sf	$ 2	$ 2,400
				subtotal	$ 222,900
2.0	TREATMENT				
	75000 Epoxy coated steel equalization tank	1	ls	$75,000	$ 75,000
	50 gpm packaged treatment system	1	ls	$80,000	$ 80,000
	Inlet structures	1	ea	$ 1,500	$ 1,500
	Outlet Structures	1	ea	$ 1,500	$ 1,500
	Effluent flow meter, magnetic indicating/totalizing	1	ls	$ 2,000	$ 2,000
	Infiltration pond	651	cy	$ 15	$ 9,764
	Infiltration pond sand media - 18" thickness	288	cy	$ 10	$ 2,880
	Overflow weir	1	ea	$ 1,500	$ 1,500
	Sludge press, feed pump and controls	1	ls	$15,000	$ 15,000
				subtotal	$ 189,144
	Total construction cost				$ 412,044
	Engineering	15	% of capital cost		$ 103,011
	Construction management	10	% of capital cost		$ 68,674
	Contingency	15	% of capital cost		$ 103,011
			total capital cost		$ 686,741
3.0	OPERATION AND MAINTENANCE				
	Polymer cost	175	lbs	$ 3.00	$ 525
	Power (collection system)	1000	kw-hr	$ 0.06	$ 60
	Power (treatment system)	800	kw-hr	$ 0.06	$ 48
	Treatment sludge disposal	2925	lbs	$ 0.15	$ 439
	Treatment system consumables and spare parts	5	% of T.S. cost		$ 15,762
	O&M personnel collection system	728	hr	$ 25	$ 18,200
	O&M personnel treatment system	1456	hr	$ 25	$ 36,400
				subtotal	$ 71,434
	Present Value of Capital cost				$ 686,741
	Present Value of O&M for 10 years i=3% effective				$ 616,488
	Total Present Value - 10 year life cycle				$ 1,303,229
	Total Present Value - 10 year life cycle per 1000 gal				$ 61
	Total PV - 10 yr life cycle per 1000 gal (treatment only)				$ 35

TABLE A-4
ESTIMATED COSTS FOR IMPLEMENTATION OF ALTERNATIVE 4

	Description	Quantity	Unit	Unit Cost	Extended Cost
1.0	COLLECTION SYSTEM				
	Install catch basins	4	ea	$ 2,000	$ 8,000
	Sump pumps and controls	4	ea	$ 2,000	$ 8,000
	Drainage Piping	1100	ft	$ 20	$ 22,000
	Flow meter and totalizer	1	ea	$ 2,500	$ 2,500
	Asphalt paving	90,000	sf	$ 2	$ 180,000
	Marine Railway Work curtain	1,200	sf	$ 2	$ 2,400
				subtotal	$ 222,900
2.0	TREATMENT				
	Excavate sedimentation basin	363	cf	$ 15	$ 5,444
	Pond Liner 40 mil HDPE slopes	4000	sf	$ 1.33	$ 5,320
	Pond Bottom concrete 6 inches reinforced	82	cy	$ 150	$ 12,250
	Inlet and outlet structures	2	ls	$ 1,500	$ 3,000
	Polymer feed systems	2	ea	$ 500	$ 1,000
	Flow meters to detention basin	1	ea	$ 2,500	$ 2,500
	Treated water overflow pump system and flow meter	1	ls	$ 4,000	$ 4,000
	Piping to batch treatment system	860	ft	$ 20	$ 17,200
	Pressure filtration system	1	ea	$ 3,000	$ 3,000
	Pressure filter feed pump	1	ls	$ 2,000	$ 2,000
	Overflow weir	1	ls	$ 1,500	$ 1,500
	Infiltration pond	651	cy	$ 15	$ 9,764
	Infiltration pond sand media - 18" thickness	288	cy	$ 10	$ 2,880
				subtotal	$ 69,859
	Total construction cost				$ 292,759
	Engineering	15	% of capital cost		$ 73,190
	Construction management	10	% of capital cost		$ 48,793
	Contingency	15	% of capital cost		$ 73,190
			total capital cost		$ 487,931
3.0	OPERATION AND MAINTENANCE				
	Polymer cost	175	lbs	$ 3.00	$ 525
	Power (collection system)	1000	kw-hr	$ 0.06	$ 60
	Power (treatment system)	400	kw-hr	$ 0.06	$ 24
	Pond desludging (once per 3 year annualized)	1538	lbs	$ 6.60	$ 10,150
	Treatment system consumables and spare parts	5	% of T.S. cost		$ 5,822
	O&M personnel collection system	728	hr	$ 25	$ 18,200
	O&M personnel treatment system	910	hr	$ 25	$ 22,750
				subtotal	$ 57,531
	Present Value of Capital cost				$ 487,931
	Present Value of O&M for 10 years i=3% effective				$ 496,499
	Total Present Value - 10 year life cycle				$ 984,431
	Total Present Value - 10 year life cycle per 1000 gal				$ 46
	Total PV - 10 yr life cycle per 1000 gal (treatment only)				$ 25

TABLE A-5
ESTIMATED COSTS FOR IMPLEMENTATION OF ALTERNATIVE 5

	Description	Quantity	Unit	Unit Cost	Extended Cost
1.0	COLLECTION SYSTEM				
	Install catch basins	4	ea	$ 2,000	$ 8,000
	Sump pumps and controls	4	ea	$ 2,000	$ 8,000
	Drainage Piping	1100	ft	$ 20	$ 22,000
	Flow meter and totalizer	1	ea	$ 2,500	$ 2,500
	Asphalt paving	90,000	sf	$ 2	$ 180,000
	Marine Railway Work curtain	1,200	sf	$ 2	$ 2,400
				subtotal	$ 222,900
2.0	TREATMENT				
	Excavate sedimentation basin	363	cf	$ 15	$ 5,444
	Pond Liner 40 mil HDPE slopes	4000	sf	$ 1.33	$ 5,320
	Pond Bottom concrete 6 inches reinforced	82	cy	$ 150	$ 12,250
	Inlet and outlet structures	2	ls.	$ 1,500	$ 3,000
	Polymer feed systems	2	ea	$ 500	$ 1,000
	Flow meters to detention basin	1	ea	$ 2,500	$ 2,500
	Treated water overflow pump system and flow meter	1	ls	$ 4,000	$ 4,000
	Piping to batch treatment system	860	ft	$ 20	$ 17,200
	Pressure filtration system	1	ea	$ 3,000	$ 3,000
	Pressure filter feed pump	1	ls.	$ 2,000	$ 2,000
	50 gpm ion exchange system with feed pumps	1	ls.	$30,000	$ 30,000
	Discharge pumping system, clear well, and overflow weir	1	ls.	$ 5,000	$ 5,000
	Discharge piping and multiport diffuser outfall	1000	ft	$ 15	$ 15,000
				subtotal	$ 105,714
	Total construction cost				$ 328,614
	Engineering	15	% of capital cost		$ 69,009
	Construction management	10	% of capital cost		$ 46,006
	Contingency	15	% of capital cost		$ 69,009
			total capital cost		$ 512,639
3.0	OPERATION AND MAINTENANCE				
	Polymer cost	175	lbs	$ 3.00	$ 525
	Power (collection system)	1000	kw-hr	$ 0.06	$ 60
	Power (treatment system)	4000	kw-hr	$ 0.06	$ 240
	Pond desludging (once per 3 year annualized)	1538	lbs	$ 6.60	$ 10,150
	Treatment system consumables and spare parts	8	% of T.S. cost		$ 13,193
	O&M personnel collection system	728	hr	$ 25	$ 18,200
	O&M personnel treatment system	1092	hr	$ 25	$ 27,300
				subtotal	$ 69,668
	Present Value of Capital cost				$ 512,639
	Present Value of O&M for 10 years i=3% effective				$ 601,248
	Total Present Value - 10 year life cycle				$ 1,113,887
	Total Present Value - 10 year life cycle per 1000 gal				$ 52
	Total PV - 10 yr life cycle per 1000 gal (treatment only)				$ 26

TABLE A-6
ESTIMATED COSTS FOR IMPLEMENTATION OF RECOMMENDED ALTERNATIVE

Description	Quantity	Unit	Unit Cost	Extended Cost
1.0 COLLECTION SYSTEM				
Install catch basins	4	ea	$ 2,000	$ 8,000
Sump pumps and controls	4	ea	$ 2,000	$ 8,000
Drainage Piping	1100	ft	$ 20	$ 22,000
Flow meter and totalizer	1	ea	$ 2,500	$ 2,500
Asphalt paving	90,000	sf	$ 2	$ 180,000
Marine Railway Work curtain	1,200	sf	$ 2	$ 2,400
			subtotal	$ 222,900
2.0 TREATMENT				
Excavate sedimentation basin	363	cf	$ 15	$ 5,444
Pond Liner 40 mil HDPE slopes	4000	sf	$ 1.33	$ 5,320
Pond Bottom concrete 6 inches reinforced	82	cy	$ 150	$ 12,250
Inlet and outlet structures	4	ea	$ 1,500	$ 6,000
Flow meters (from batch treatment and to sed basin)	2	ea	$ 2,500	$ 5,000
Batch treatment feed pump and controls	1	ls	$ 2,500	$ 2,500
Marine Railway stormwater storage tank (10000 gal)	1	ls	$10,000	$ 10,000
Treated water overflow pump system and flow meter	1	ls	$ 4,000	$ 4,000
Piping to batch treatment system	860	ft	$ 20	$ 17,200
Infiltration pond	651	cy	$ 15	$ 9,764
Infiltration pond sand media - 18" thickness	288	cy	$ 10	$ 2,880
Overflow weir	1	ea	$ 1,500	$ 1,500
			subtotal	$ 81,859
Total construction cost				$ 304,759
Engineering	15	% of capital cost		$ 76,190
Construction management	10	% of capital cost		$ 50,793
Contingency	15	% of capital cost		$ 76,190
		total capital cost		$ 507,931
3.0 OPERATION AND MAINTENANCE				
Polymer cost (25% of Marine Railway stormwater)	660	lbs	$ 3.00	$ 1,980
Power (collection system)	1000	kw-hr	$ 0.06	$ 60
Power (treatment system)	400	kw-hr	$ 0.06	$ 24
Pond desludging (once per 3 year annualized)	1100	lbs	$ 6.60	$ 7,260
Treatment sludge disposal	1650	lbs	$ 0.15	$ 248
Treatment system consumables and spare parts	3	% of T.S. cost		$ 4,093
O&M personnel collection system	728	hr	$ 25	$ 18,200
O&M personnel treatment system	546	hr	$ 25	$ 13,650
			subtotal	$ 45,514
Present Value of Capital cost				$ 507,931
Present Value of O&M for 10 years i=3% effective				$ 392,796
Total Present Value - 10 year life cycle				$ 900,728
Total Present Value - 10 year life cycle per 1000 gal				$ 42
Total PV - 10 yr life cycle per 1000 gal (treatment only)				$ 25