Final Report

Aquatic Park
Water Quality Improvement Study

Prepared for

City of Berkeley

Prepared by

CH2M HILL
Merritt Smith Consulting
Resource Management Associates
Ray B. Krone & Associates

December 1994

SFO100301F2.DOC

Contents

Figures

Tables

Section 1
Summary

This report presents an evaluation of alternatives for management of water quality in Aquatic Park and alternatives for stormwater treatment in Aquatic Park.

The objectives of the Aquatic Park Water Quality Improvement Study are as follows:

- Document water quality in Aquatic Park and identify and evaluate alternatives for water quality improvement consistent with desired uses. Aquatic Park consists of three major water bodies: the Main Lagoon, the Model Yacht Basin, and the Radio Tower Pond. Because the Radio Tower Pond is not currently owned or operated by the City of Berkeley, it is not addressed in this report to the extent of the other two basins.

- Evaluate the feasibility of alternatives for use of Aquatic Park to improve stormwater quality prior to discharge to San Francisco Bay. Consistent with water quality regulations, the City of Berkeley has a program to manage stormwater quality. The City obtained a grant from the Alameda County Urban Runoff Clean Water Program specifically to evaluate the use of Aquatic Park to treat stormwater.

The City has also prepared a master plan for the overall use of the Park. The *Aquatic Park Master Plan* identifies several alternatives for enhancing the Park, including shoreline modification and the creation and enhancement of wildlife habitat. Water quality management and stormwater treatment alternatives were developed within this Water Quality Improvement study with an awareness of *Aquatic Park Master Plan* alternatives. In fact, the hydraulic model was used to evaluate the impact of Master Plan alternatives, as described in this report.

1.1 Conditions in Aquatic Park

Aquatic Park is a facility that offers diverse recreation amenities such as walking trails, exercise facilities, and boat docks located adjacent to the Main Lagoon. Aquatic Park is used and enjoyed by the community as a place for walking, running, frisbee golf, rowing, sailing, water-skiing, fishing, and wildlife viewing. In addition, the Park provides habitat for fish and wildlife, including many birds.

The Park was designed to take advantage of tidal energy to flush Bay water through the Park. Pipes connect the two primary basins in the Park (the 5-acre Model Yacht Basin and the 60-acre Main Lagoon) to each other and the Bay. These pipes, and the associated tide gates and other hydraulic control facilities, are in disrepair and do not function as designed. Figure 1-1 describes the location of hydraulic control facilities and their condition.

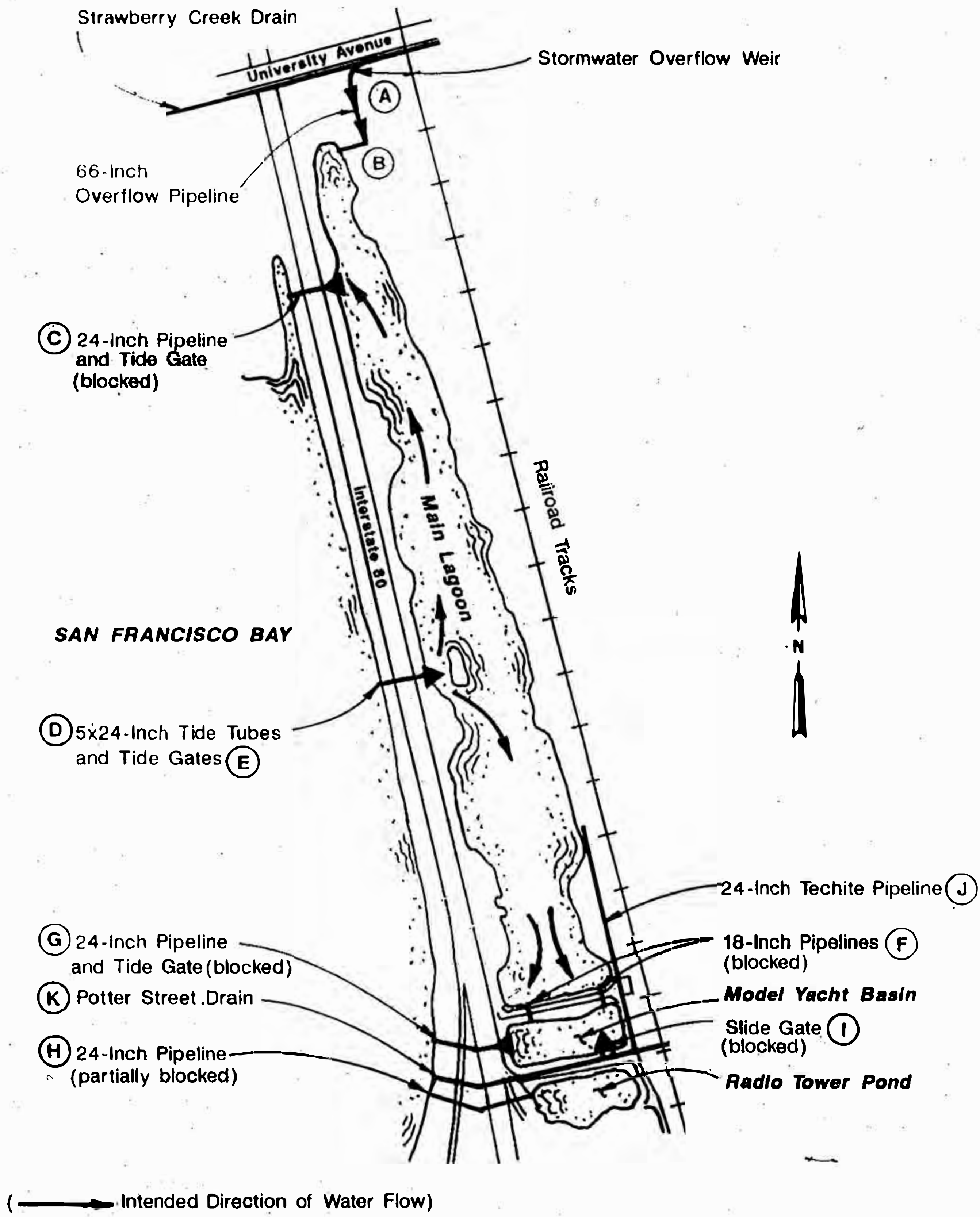


Figure 1-1

EXISTING CONDITIONS

Aquatic Park Water Quality

Improvement Study

The characterization of conditions in the Park undertaken in this analysis indicates that numeric water quality objectives are being attained and water quality is generally adequate for the beneficial uses of the Park. However, aquatic plants grow abundantly. Those plants are occasionally responsible for odors that some consider to be a nuisance, and may impair some beneficial uses such as boating and water-skiing. Although levels of bacteria measured in this study were acceptable (i.e., below the permissible level or water quality standard) for water contact, evidence indicates that stormwater discharges to the Park probably cause the standard to be exceeded for several days after a storm.

Water that flows into the Park from San Francisco Bay contains a large amount of sediment and ample nutrients to supply plant growth. The rooted aquatic plants grow in abundance because sediment from the Bay has accumulated in the Park and created vast shallow areas (less than 5 feet) which allows sufficient light to penetrate to the shallow bottom. The shallow areas and associated rooted plants also create safety hazards for water-skiers. The rooted aquatic plants do provide a benefit, however, in that if those plants were not depleting the nutrients that are supplied with Bay water, suspended algae would proliferate.

1.2 Water Quality Management Alternatives

Two alternatives were developed for management of water quality to control rooted aquatic plants, algae and bacteria. Both alternatives are compatible with the objectives of the *Aquatic Park Master Plan*. The alternatives were developed to manage water quality without the use of herbicides or new pipes connecting the Park directly to the Bay beneath the freeway. A third alternative, the no project alternative, was also included in the alternative analysis. The alternatives are summarized as follows:

1. **No Project Alternative.** This alternative would involve relocation of water skiing activity to water of sufficient depth, if possible, or the prohibition of this activity. Interpretive signs could also be posted to inform Park users that the growth and decay of the rooted aquatic plants (and their production of odor) is a natural process.

2. **Rehabilitate Existing Structures.** The existing pipes would be cleaned of accumulated debris and tide gates would be repaired or replaced. Aquatic plants would be controlled by using a mechanical harvester or by dredging.

3. **Modify Existing Structures.** The direction of flow would be changed and the volume of water being transported through the Park would be increased over that provided by the original design and Alternative 2. Flow and volume would be altered by using the large storm drains at each end of the Park to convey Bay water to and from the Park. New connections to these existing storm drains would be constructed and piping within the Park would be replaced. Aquatic plants would be controlled by using a mechanical harvester or by dredging.

Table 1-1 Estimated Cost of Water Quality Alternatives (1994 dollars)			
Alternative	**Initial Capital (thousands $)**	**Annual O&M**	**30-Year Net Present Value (thousands $)[a]**
2A - Rehab. + Dredge	$ 8,270	$20,200	$ 8,690
2B - Rehab. + Harvest	$ 270	$30,400	$ 960
3A - Modify + Dredge	$ 8,360	$17,360	$ 8,700
3B - Modify + Harvest	$ 365	$27,830	$ 983

[a]Assumes 3% discount rate.

Sediment accumulation that naturally occurs in the Main Lagoon and the Model Yacht Basin encourages rooted plant growth. This growth may be controlled by dredging the sediment or harvesting the aquatic plants. While dredging is considered the most effective means of controlling the rooted aquatic plants, dredging is extremely costly. If rooted aquatic plant control is desired prior to the availability of funds for a dredging project, a mechanical harvester could be used. However, if rooted aquatic plants are controlled with mechanical harvesting prior to or instead of dredging, the potential for high levels of algae will increase because fewer rooted plants are expected to result in more light and nutrients available to algae. Increased flushing can decrease algae concentrations.

Regardless of which alternative is selected, dredging would ultimately be necessary to prevent filling of the Main Lagoon and the Model Yacht Basin with sediment. Based on a preliminary sediment characterization and current regulations, sediment quality appears adequate at this time for dredging spoils disposal at the Alcatraz disposal site.

The effectiveness of the water quality management alternatives is summarized in Table 1-2. The flow rates and detention times identified in this table for each alternative represent the average over a 30-day period with typical tides. The algae concentrations shown are the theoretical maximum concentrations that would be reached if the nutrient supply was unlimited.

Alternative	Average Flow (cfs)	Detention Time (days)	Maximum Algae (µg/L chlorophyll a)	Rooted Aquatic Plants	Sediment Accumulation (inches/ year)	Sediment Accumulation (years to accum. 5 feet sediment)
1. No Project	6	21	20[a], 430[b]	Not controlled	<1	>50
2. Rehabilitate Existing Structures	8	16	390[b]	Not controlled	1	50
2A Rehab & Dredging	8	39	190[b]	Controlled	1	50
2B Rehab & Harvesting	8	16	390[b]	Controlled	1	50
3 Modify Existing Structures	15	9	240[b]	Not controlled	2	26
3A Modify & Dredging	15	21	160[b]	Controlled	2	26
3B New & Harvesting	15	9	240[b]	Controlled	2	26

Table 1-2
Effectiveness of Water Quality Management Alternatives

[a] Denotes maximum Chlorophyll a value identified in '93/'94 sampling.
[b] Denotes maximum Chlorophyll a value estimated with unlimited nutrient supply.

If dredging at the time of hydraulic improvements is determined to be infeasible due to funding or other reasons and the City chooses to control rooted aquatic plants by harvesting, then implementation of Alternative 3B would provide the greatest flushing to control algae until dredging can be implemented.

If dredging can be implemented with hydraulic improvements, Alternative 2A would be the preferred alternative. The analysis presented in Table 1-2 indicates that Alternative 2A addresses each of the water quality issues satisfactorily and would accumulate sediment at a lower rate than would Alternative 3 (due to lower flows). The analysis also indicates that Alternatives 2A and 3A would control algae to a similar extent (190 and 160 µg/L, respectively). However, estimates of the water quality resulting from each alternative are not exact. If insufficient flushing to control algae were to result from implementation of Alternative 2A, then Alternative 3A could be implemented.

1.3 Stormwater Treatment Alternatives

The City of Berkeley is currently implementing a stormwater quality control program. The City obtained a $60,000 grant to study the feasibility of, and, if appropriate, construct a demonstration stormwater treatment facility at Aquatic Park. Two alternatives for using the Model Yacht Basin as a treatment facility were developed. Use of the Main Lagoon was not evaluated because the Model Yacht Basin provides containment of removed contaminants in a smaller area.

The Full Treatment Alternative involves diverting stormwater into the Model Yacht Basin to remove settleable solids. The Treatment/Habitat Alternative involves modifying the basin to provide additional wildlife habitat and a smaller treatment capacity. Both alternatives could be implemented with or without dredging of the basin.

The estimated cost of the Full Treatment Alternative is summarized in Table 1-3. Facilities include a diversion structure to convey flows from the techite line to the Model Yacht Basin, new sliding gates on existing structures to control flow directions and rehabilitation of the pipe connecting the Model Yacht Basin and the Bay. The dredging cost of $664,000 is also included in the cost of Water Quality Management Alternatives 2A and 3A.

The Treatment/Habitat Alternative would need to be defined more precisely to determine the cost. Dredging and disposal costs in the Treatment/Habitat Alternative may be substantially decreased because dredge spoils could potentially be used onsite to create the wildlife habitat.

Table 1-3
Estimated Cost of Full Treatment Alternative (1994 Dollars)

Component	Capital Cost	Annual O&M	30-Year Present Value
Facilities	$77,400	$13,900	$348,900
Dredging	$664,000	$0	$664,000
Total Estimated Cost	**$741,400**	**$13,900**	**$1,012,900**

Note: 30-year present value of Habitat/Treatment Alternative with a 200-foot width and a 10-foot depth would be $790,900.

The effectiveness of the two alternatives at removing pollutants is summarized in Table 1-4. The table shows that dredging improves solids removal (4 to 5 percent) and contaminant removal (9 percent) efficiency. Table 1-4 also shows that the volume of stormwater that can be treated is less for the Treatment/Habitat Alternative than for the Full Treatment Alternative. This is because the volume of the basin is reduced and flow (as measured by treated volume) must be reduced to achieve approximately the same solids removal rate as with the Full Treatment Alternative.

Table 1-4
Stormwater Treatment Volume and Efficiency for 10-Year Storm Event

Alternative (With Initial Dredging Depth)	Treated Volume (AF)	Solids Removed (%)	Sediment Removed (CY)[a]	Contaminant Removal (%)
Full Treatment Alternative				
Entire Basin (no dredging)[b]	36	81	22	49
Entire Basin (10 foot depth)	36	86	23	58
Treatment/Habitat Alternative				
200 foot Width (6 foot depth)	24	79	14	44
200 foot Width (10 foot depth)	24	83	15	53

[a]Assumes a suspended solids concentration of 500 mg/L and a sediment bulk density of 1.67 (40% solids).
[b]Basin depth is currently 3-4 feet.

Implementation of a stormwater treatment alternative would result in the accumulation of sediments that contain pollutants of stormwater origin. Comparison of sediment quality data collected in the Model Yacht Basin to data from a local stormwater treatment system in Alameda County indicates that implementation of a stormwater treatment project in the Model Yacht Basin would not cause a significant degradation of sediment quality.

1.4 Recommendations

Implementation of water quality management alternatives and stormwater treatment alternatives is not currently mandated to comply with environmental regulations. However, the City should implement a plan to manage water quality and treat stormwater based on the goals and objectives of the Aquatic Park Master Plan and this study.

To provide a solid basis for decision-making, the following use prioritization process is recommended:

- Identify the full range of desired uses in the Park.
- Determine which uses are compatible with each other.
- Outline the phasing of decisions based on use priorities.

This process will be facilitated by the cost and water quality impact analysis presented in this report and the perspectives outlined in the Master Plan. With an understanding of highest priority uses, a decision process can be used to select the best water quality and stormwater alternatives to implement. The following 2-step decision process is recommended to determine the appropriate course of action for management of water quality in the Park:

1. The City should determine the need for control of rooted aquatic plants. Based upon current uses (e.g., water skiing), it appears that control is desirable. However, the impacts of that control are significant costs (i.e., dredging) or significant increases in algae concentration and reduced water clarity as a result of harvesting.

    a. If the plants are not considered a nuisance because water skiing is restricted or discontinued, then Alternative 1 (No Project) could be implemented. Maintenance of the existing hydraulic facilities (pipes, valves, and gates) would also be recommended to maintaln the current amount of circulation between the Bay and Park.

    b. If control of the plants is determined to be desirable, a strategy should be specified (harvest, dredge, or harvest until dredging can be implemented).

    - If dredging is used to control rooted aquatic plants, Alternative 2A could adequately maintain water quality. If additional circulation flow is needed in the future to control algae, Alternative 3A could be implemented at a later time.

- If harvesting is used to control rooted aquatic plants, Alternative 3B would likely be necessary to adequately maintain water quality (lower algae concentrations).

With either alternative, the City should consider posting signs to inform Park users when water-contact recreation is inadvisable (e.g., wet-weather season).

2. The City should determine whether to fund an "active" stormwater treatment demonstration project. While some stormwater treatment occurs with the Park's current configuration, both the Full Treatment and the Treatment/Habitat alternatives would increase the volume of stormwater treated each year. Additional treatment is also consistent with the *Aquatic Park Master Plan* objectives.

Based upon the City's desire to improve stormwater treatment while minimizing costs, and the likelihood that dredging will not occur immediately, we recommend that the Full Treatment/no dredging option be implemented. If dredging of the Main Lagoon is done in the future, similar dredging of the Model Yacht Basin should be done. If the City determines that habitat creation in the Model Yacht Basin is an objective of equal importance to stormwater treatment, we would recommend implementing the Treatment/Habitat alternative with 6 foot depth based on the following two reasons.

- Treatment volume is still two-thirds that of the Full Treatment Alternative.

- Dredging to a 10-foot depth is significantly more expensive than dredging to a 6-foot depth with only marginal additional water quality benefit.

Ultimately, based upon the use prioritization process described above, the City will make the final determination of which, if either, stormwater treatment alternative will be implemented in the future.

Section 2
Background and Description of Park

This section describes Aquatic Park, the purpose and objective of the study that is summarized in this report, and the approach that was used in the study.

2.1 Park Overview

Aquatic Park is located in west Berkeley, across Interstate 80 from San Francisco Bay (see Figure 2-1). The aquatic portion of the Park consists of three basins that are connected to San Francisco Bay with a series of pipes. Recreation amenities such as walking trails, exercise facilities, and boat docks are located adjacent to the Main Lagoon. Aquatic Park is used and enjoyed by the community as a place for walking, running, frisbee golf, rowing, sailing, water-skiing, fishing, and wildlife viewing. In addition, the Park provides habitat for wildlife, including fish and birds. Figure 2-2 shows the park environment.

Aquatic Park was constructed in the 1930s when Interstate 80 was built and separated the old shoreline from the bay. In 1932 the park was constructed and in 1935 the lagoon was dredged. Since then the park has been a major feature in Berkeley providing many recreational opportunities.

2.1.1 Related Programs

Several programs that affect Aquatic Park and its future are ongoing. These programs include the Aquatic Park Master Plan and the Alameda County Urban Runoff Clean Water Program. In 1990, a draft Aquatic Park Master Plan was developed to provide a basis for long-term management decisions about the Park. The Aquatic Park Master Plan outlines a plan that will be used to guide future uses of the Park.

In 1991, the City, along with Alameda County and 13 other cities in the county formed the Alameda County Urban Runoff Clean Water Program (Clean Water Program). This program was developed in response to a federal mandate that requires the City to obtain a permit to discharge its stormwater. The purpose of the program is to reduce pollutants in stormwater that enter local creeks and San Francisco Bay. In Berkeley, a significant amount of stormwater runoff from medium and large storms is discharged into Aquatic Park. The Clean Water Program is an important step toward reducing pollutants to U.S. waters. The stormwater treatment study grant obtained by the City was provided by this program.

2.2.1 Existing Hydraulic Facilities

Each of the three basins of Aquatic Park are connected to the Bay with pipes. The 60-acre Main Lagoon and the 5-acre Model Yacht Basin are also connected to each other. The Potter Street storm drain prevents connection of the 5-acre Radio Tower Pond with the Model Yacht

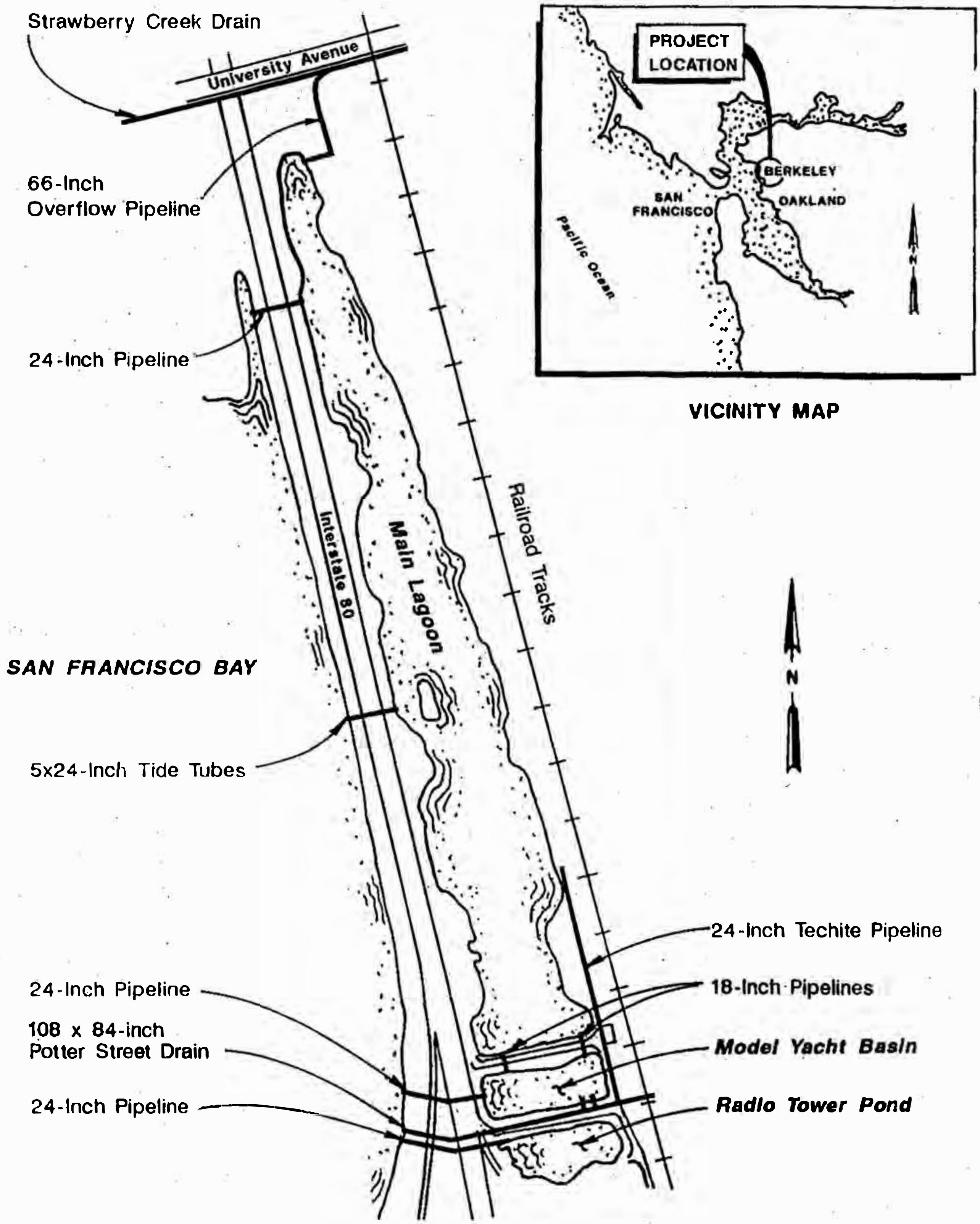


Figure 2-1
SITE MAP
Aquatic Park Water Quality
Improvement Study

CH2M HILL

BAW35974.AI. 6

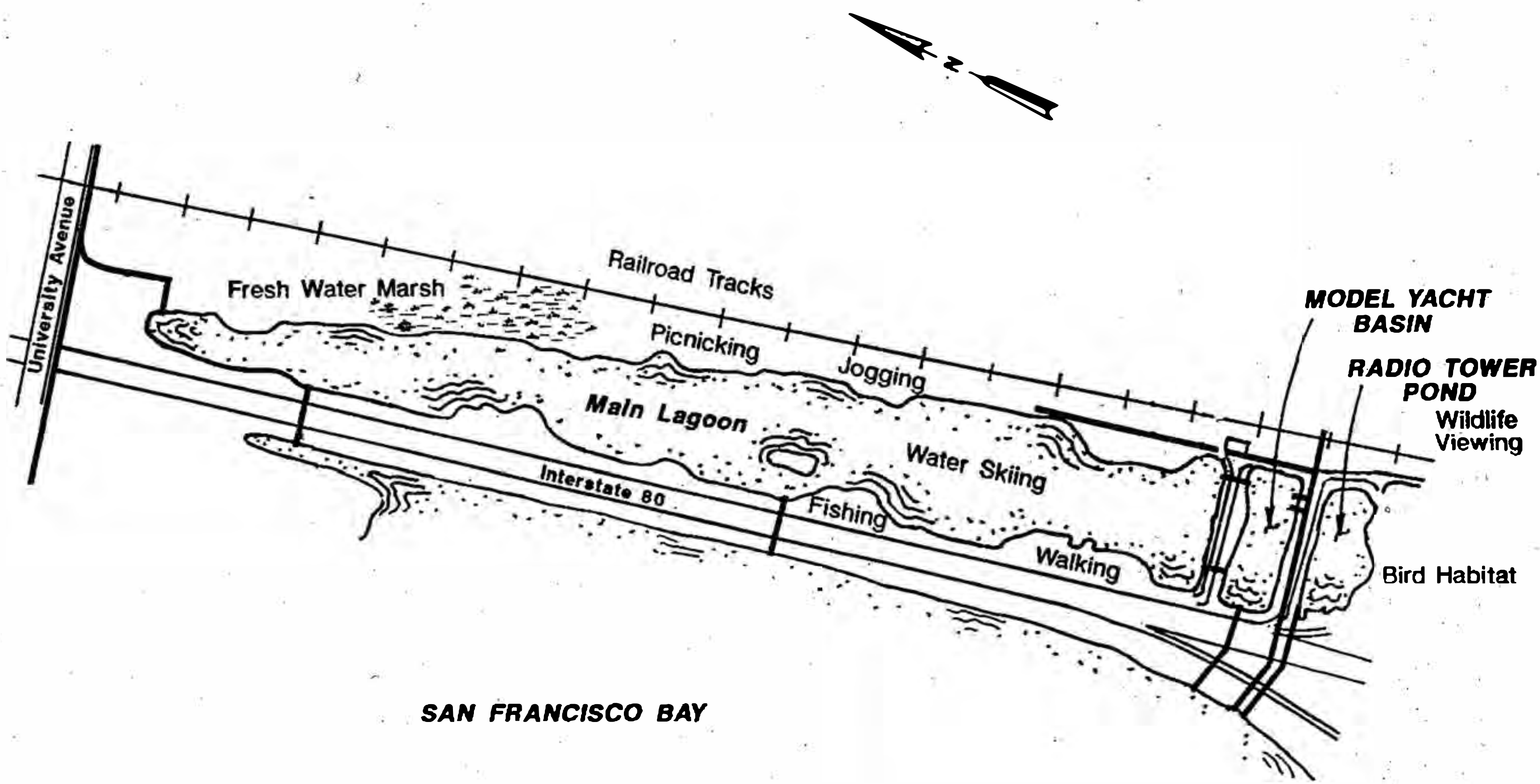


Figure 2-2
AQUATIC PARK USES
Aquatic Park Water Quality
Improvement Study

CH2M HILL

Basin. The Potter Street storm drain and Strawberry Creek are also connected to the Park. Figure 2-1 describes the facilities (as originally constructed) that control the movement of water (hydraulic control facilities), and thus water quality in the Park.

The current condition of the three basins is summarized as follows:

- Hydraulic control facilities are in disrepair and sediment has accumulated in pipes such that flow is severely or completely restricted.
- Aquatic plants grow abundantly in many areas of the Main Lagoon and Model Yacht Basin creating nuisance conditions during portions of the year.
- Bacteria values are usually below the maximum allowable amount for safe water-contact recreation, but may occasionally exceed the standard (discussed further in Section 3.3).
- Five to six feet of sediment has accumulated in the basins, which are now generally only 2 to 8 feet deep (discussed further in Section 3.3).
- Nuisance odors are produced in each of the basins. The odors are caused by rotting aquatic plants in the basins and exposed sediment in the Radio Tower Pond.

These conditions prompted the evaluation that is summarized in this report.

2.2 Project Description

This report summarizes the findings of the Aquatic Park Water Quality Improvement Study. The objectives of the Aquatic Park Water Quality Improvement Study are as follows:

- Document water quality in Aquatic Park, identify and evaluate alternatives for water quality improvement consistent with desired uses. Because the Radio Tower Pond is not owned or operated by the City of Berkeley, it is not addressed in this report to the extent of the other two basins.
- Evaluate the feasibility of alternatives for use of Aquatic Park to improve stormwater quality prior to discharge to San Francisco Bay. Consistent with water quality regulations, the City of Berkeley has a program to manage stormwater quality. The City obtained a grant from the Alameda County Urban Runoff Clean Water Program specifically to evaluate the use of Aquatic Park to treat stormwater.

The Aquatic Park Water Quality Improvement Study consisted of the following steps:

- **Characterization of Existing Conditions.** Water quality, sediment quality, water depth, and hydraulic facilities were evaluated in the field by collecting samples for analysis and by surveying. The purpose of this evaluation was to provide the basis for developing water quality management alternatives. Water quality sampling methods and data are presented in detail in Appendix A.

- **Development of Hydraulic and Water Quality Model.** A computer simulation of water movement, sediment accumulation and plant growth in the Park was developed as a tool to evaluate alternatives. This model is described in Appendix B.

- **Identification and Evaluation of Water Quality Management Alternatives.** Strategies for addressing water quality and sedimentation issues were identified and evaluated for cost, effectiveness, feasibility and consistency with Aquatic Park management objectives.

- **Identification and Evaluation of Stormwater Treatment Alternatives.** Options for stormwater diversion into Aquatic Park were evaluated for cost, treatment effectiveness, feasibility and consistency with Aquatic Park management objectives.

2.3 Relationship to Other Plans and Studies

The Aquatic Park Water Quality Improvement Study was conducted in coordination with several parallel planning and study efforts that relate to Aquatic Park. The relationship between the Aquatic Park Water Quality Improvement Study and the other programs is summarized as follows:

- **Aquatic Park Master Plan.** The Aquatic Park Master Plan identifies several alternatives for enhancing the Park, including shoreline modification and the creation and enhancement of wildlife habitat. Water quality management and stormwater treatment alternatives were developed with an awareness of Aquatic Park Master Plan alternatives. In fact, the hydraulic model was used to evaluate the impact of Master Plan alternatives, as described in this report.

- **Storm Drainage Master Plan.** Concurrent with the development of the water quality improvement alternatives, CH2M HILL was evaluating the City's storm drainage system. The scope of the Storm Drainage Evaluation Study (Storm Drainage Master Plan) was to assess the physical and hydraulic condition of the storm drains in the City. Data from the Evaluation Study were used to help develop the hydraulic model and alternatives for this study. The Storm Drainage Master Plan resulted in recommendations to divert stormwater during high runoff events into Aquatic Park. The additional stormwater should not significantly affect the water quality of Aquatic Park for three reasons.

First, and most importantly, this will be an infrequent event (during high runoff events only). Secondly, the sediment concentration in stormwater is low compared to that of the Bay water entering Aquatic Park and finally bacterial die-off is relatively quick (further described in Section 3.3.3). The hydraulic connections and structures that are recommended in the Storm Drainage Master Plan will need to be coordinated with the final recommendations of this study to preserve the water quality benefits.

- **Saltwater Emergency Fire Protection Program.** Another project that interfaces with the Water Quality Improvement Study is the proposed new Saltwater Emergency Fire Protection System. As a result of the 1992 fire in the Oakland/Berkeley hills, the City has proposed several potential sites, including Aquatic Park, for drawing saltwater for emergency fire fighting use. If Aquatic Park is selected as a site, this project would require the placement of a relatively large pumping station near the Park and would result in the periodic pumping of water from the Park that would temporarily affect circulation patterns. The ultimate recommendations for the Water Quality Improvement Study should be coordinated with the Saltwater Emergency Fire Protection Program recommendation.

Section 3

Water Movement and Quality in Aquatic Park

This section describes how water was intended to move through Aquatic Park, factors that control water quality in the Park, and the existing hydraulic and water quality conditions of the Park.

3.1 Original Design of Aquatic Park

The hydraulic control facilities in the Park consist of pipes that convey water and appurtenant facilities such as slide gates, tide gates, valves and weirs that are intended to control the direction and/or amount of water movement. Water movement is driven by tide-induced changes in the water surface elevation in the Bay. The existing hydraulic control facilities were designed to bring water into the Park from the Bay via the five gated tide tubes when the tide is high in the Bay. When the tide recedes in the Bay, pipes at the north end of the Main Lagoon and in the Model Yacht Basin were designed to convey water from the Park back to the Bay. The Strawberry Creek and Potter Street storm drains were connected to the Park to relieve stormwater capacity limitations in these storm drainage facilities. During peak storm flows, runoff is diverted into the Park to reduce flooding from surcharging of storm drain lines upstream. Figure 3-1 describes the location of hydraulic control facilities associated with the Park.

3.2 Water Movement in Aquatic Park

Movement of water from the Bay through the Park and back to the Bay is a potentially effective means of managing water quality in the Park. The key water quality parameters at Aquatic Park that are affected by water movement are aquatic plants (rooted plants and suspended algae), bacteria, sedimentation and water depth. They are related to each other and are summarized as follows:

- **Rooted Aquatic Plants**. Plants grow from their roots in the bottom of lagoons upward toward the surface. Plants require a sufficient amount of light to grow. Thus, rooted plants are unable to grow in deep or turbid water. Rooted aquatic plants can obtain required growth nutrients from sediment via roots or from water via leaves. Rooted aquatic plants are beneficial for fish and some birds. Abundant rooted aquatic plants are considered to be a nuisance by boaters and swimmers, and can produce objectionable odors when plants die and decay. Annual die-off of plant stems and leaves occurs in late summer and is a normal process for these plants.

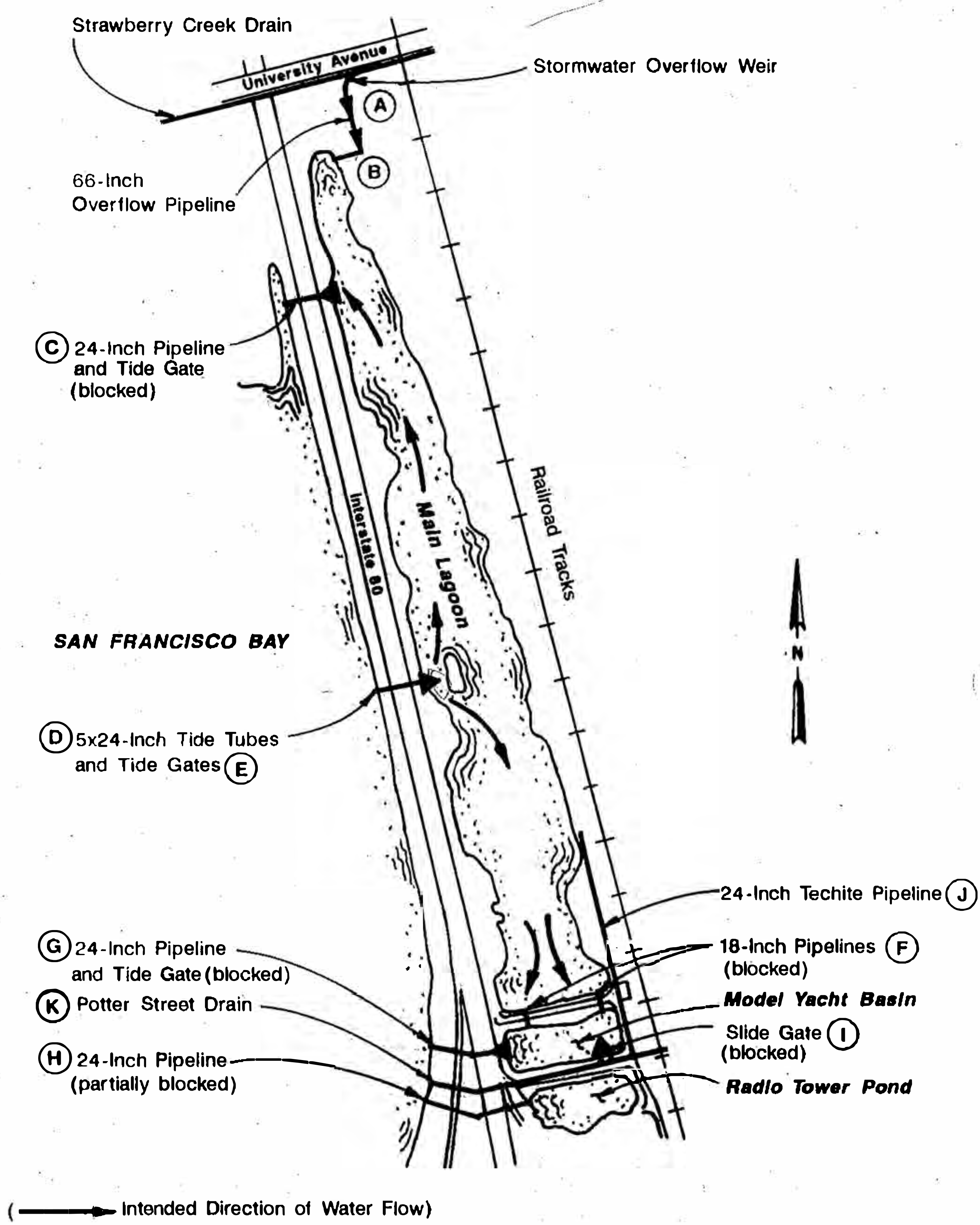


Figure 3-1
EXISTING CONDITIONS
Aquatic Park Water Quality
Improvement Study

- **Algae.** Algae are microscopic unicellular or larger filamentous plants that can grow suspended in water or attached to rocks, wood, or other plants. Suspended algae can accumulate if light and nutrients are present and they are not flushed out of ponds. When algae grow and accumulate, they can cause the water to appear green and turbid. Rooted aquatic plants tend to control algae because they can outcompete algae for light and nutrients.

- **Bacteria.** Coliform bacteria are considered to be an indicator of the presence of pathogens that may threaten human health. Regulatory authorities have established standards for waters that are used for contact recreation. Coliform bacteria enter the Park via urban stormwater and bird feces (deposited primarily in winter when birds are present in relatively great numbers).

- **Sedimentation**. Near-shore shallow Bay waters are turbulent, which causes sediment to become mixed from the Bay bottom and remain in suspension. When turbulence decreases, suspended sediment drops to the bottom. Aquatic Park is a much less turbulent environment than the Bay, so sediment that is transported with Bay water accumulates in the Park. Sediment is also suspended in stormwater; and such sediment can settle in quiesant locations like Aquatic Park.

- **Water Depth**. Shallow water in a lagoon such as Aquatic Park promotes the growth of rooted aquatic plants. Deeper water discourages rooted plant growth. Shallow water depth allows more rapid flushing of water through the Park over a tidal cycle, and therefore allows more rapid flushing of suspended algae and bacteria. Deeper water depth requires greater flow rates to flush similar volumes of water over a tidal cycle. Deeper water depth also tends to reduce the amount of suspended algae growth in a system such as Aquatic Park where algae are mixed vertically throughout the water column. Shallow water interferes with some beneficial uses such as boating and water-skiing.

- **Exchange With Bay**. Bay water contains nutrients and sediments. When the flow rate of Bay water through the Park is increased, more sedimentation occurs and more nutrients are available for rooted plant and algal growth. However, increased flow rates have the benefit of flushing algae from the Park.

3.3 Existing Conditions at Aquatic Park

This section describes the existing condition of the hydraulic control facilities, sediment accumulation, and water quality at Aquatic Park.

3.3.1 Hydraulic Control Facilities

Based on City of Berkeley survey documents and discussions with City staff, the hydraulic control facilities have been affected by the corrosive effects of sea water and sediment accumulation. Many of the pipes are clogged and do not function as designed. The Strawberry Creek and Potter Street drains, however, are adequately flushed by winter stormflows and do not clog with sediment. Table 3-1 summarizes the condition of each facility, and refers to facilities identified in Figure 3-1. Information in Table 3-1 is based on observations of water flow, inspection of the unconfined visible portions of the facility by the consultant, and input from City staff.

3.3.2 Sediment Accumulation

The depth of Aquatic Park varies substantially, which is due in part to accumulation of Bay sediment. Figure 3-2 summarizes depth information that was obtained at Aquatic Park. Depths were obtained from the Aquatic Park Master Plan and from physical measurement. Water depth is as little as two feet in some areas of the Park. Based on historical dredging records and long-term average flow estimates in the Park, the estimated sediment accumulation rate is 0.1 foot per year.

3.3.3 Water Quality

Water quality conditions in the Park have not been previously assessed and reported to the City. The Aquatic Park Master Plan reported that the perception by the public is that water quality in the Park is poor. Water and sediment quality in Aquatic Park and stormwater that flows into Aquatic Park were characterized in this study to provide a basis for evaluating water quality management alternatives. The field sampling program methods and results are summarized in Appendix A. This section of the report summarizes results of the field sampling program. Specifically, lagoon and Bay water, stormwater quality, and sediment quality are described.

Lagoon Water Quality. Results of the water quality data analysis are grouped for solids, bacteria, nutrients, metals and algae in the Park lagoons. Observations about the distribution of rooted aquatic plants were also made and are described below. The water quality objectives for the protection of aquatic life and human health from the State Water Resources Control Board (SWRCB) Enclosed Bays and Estuaries Plan (EBEP) and the San Francisco Bay Basin Plan were used to evaluate Aquatic Park water quality data. Table 3-2 summarizes the water quality data that were collected in this study and water quality objectives are included for comparison.

<u>Solids.</u> Lower levels of solids were found in the lagoons than were found in the Bay. This is expected since suspended solids settle in the Park due to the limited mixing and poor circulation in the lagoons. Settling of solids in the Park has resulted in reduced water depth.

Table 3-1
Description of Existing Hydraulic Control Facilities
Associated with Aquatic Park

Description	Location on Figure 3-1	Original Purpose of Facility	Current Condition of Facility
Weir connecting Strawberry Creek SD to B	A	Divert peak flow to AP, drain high water from AP to SD	Believed to be fully functional
66" RCP	B	Convey water in both directions from A to AP	Capacity to transport water from AP to A limited by invert elevation of +1.2 feet NGVD
24" VCP	C	Convey water from Park to Bay	Almost or completely blocked, pipe condition unknown. Outer flap gate believed to be absent.
5 Tide Gates, "Tide Window"	D	Prevent water from flowing from AP into Bay, except when water level in AP is very high and can escape through the tide window	Sediment accumulates in AP directly in front of flap gates, restricting their motion and limiting inflow from Bay. This sediment is periodically removed.
5-24" RCP	E	Convey Bay water to D and AP, convey water from AP to Bay under high water conditions in AP	Pipes lower at AP end than Bay end. The maximum elevation of the invert is +0.8 feet NGVD.
2-18" RCP	F	Convey water from Main Lagoon to Model Yacht Basin	Almost or completely blocked, pipe condition unknown.
24" VCP	G	Convey water from Model Yacht Basin to Bay	Almost or completely blocked, pipe condition unknown. Outer flap gate believed to be absent.
24" RCP	H	Convey water from Radio Tower Pond to Bay	Partially blocked.
18" and 24" RCP with gates	I	Control flow from Potter St. SD into Model Yacht Basin	Gates absent. Water moves in and out of Basin with tide. SD contains Bay water (or storm runoff after rain)
24" Techite SD	J	Collects storm runoff and conveys to Potter St. SD, designed to overflow to AP when flow exceeds capacity.	Pipe appears to serve intended function, overflow structure condition not known.
108" x 84" Potter Street SD	K	Convey City storm runoff to Bay	Believed to be fully functional.

Abbreviations SD = storm drain, AP = Aquatic Park, RCP = reinforced concrete pipe, NGVD = National Geodetic Datum, a general recognized basis for engineering surveys, VCP = vitreous clay pipe

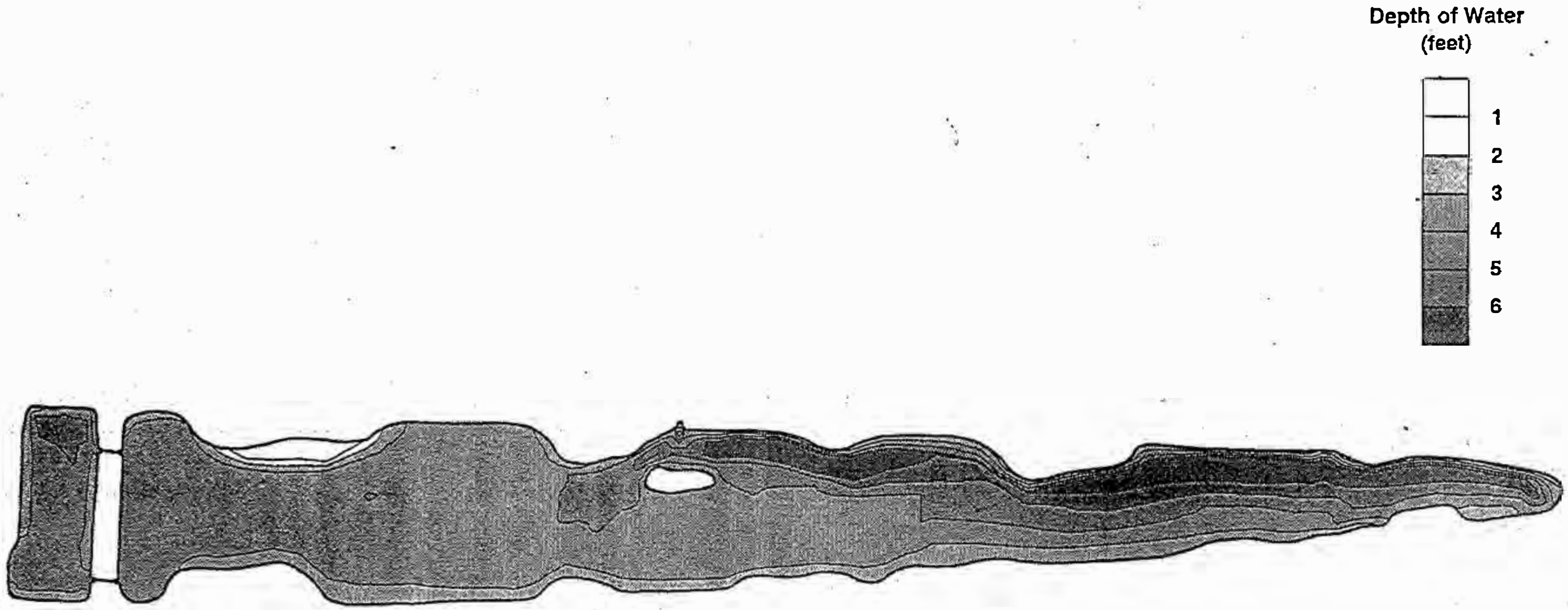


Figure 3-2
BATHYMETRIC MAP OF AQUATIC PARK
Aquatic Park Water Quality
Improvement Study

The shallow water favors the growth of aquatic plants, and algae, and may be a safety issue for some water recreational uses.

Table 3-2
Summary of Aquatic Park Water Quality Data

Constituent	Units	Range in Park[a]	Range in SF Bay	Stormwater	RWQCB Objectives[b]
Total Suspended Solids	mg/L	2 - 47	12 - 130		
Total Coliform	MPN100ml	1 - 49	5 - 140	2,400,000	240
Fecal Coliform	MPN100ml	1 - 49	2 - 22	120,000	200
Nitrate, as N	mg/L	0.015 - 0.1	0.1 - 0.21	0.48	
Nitrite, as N	mg/L	0.015 - 0.03	0.015 - 0.03	0.06	
Ammonia, as N	mg/L	0.025 - 0.1	0.025 - 0.1	0.31	1.0[c]
Total Phosphorus, as P	mg/L	0.08 - 0.57	0.15 - 0.27	0.48	
Chlorophyll a	µg/L	0.005 - 0.02	0.005		
Cadmium	mg/L	0.00013 - 0.0005	0.0001 - 0.0005	0.00025	0.0093
Chromium	mg/L	0.0015 - 0.01	0.005 - 0.008	0.003	0.05
Copper	mg/L	0.001 - 0.007	0.001 - 0.009	0.036	0.0049
Lead	mg/L	0.001 - 0.002	0.001 - 0.005	0.045	0.0056
Mercury	mg/L	[illegible]	[illegible]	0.00025	0.0021
Nickel	mg/L	0.0025	0.0025 - 0.005	0.0084	0.0083
Selenium	mg/L			0.0025	0.071
Silver	mg/L	0.00025 - 0.0005	0.00025 - 0.0005	0.0005	0.0023
Zinc	mg/L	0.0025 - 0.022	0.005 - 0.05	0.23	0.086

Note: non-detectable values are shown as half the detection limit.
[a] The Aquatic Park ranges are given for the Main Lagoon and the Model Yacht Basin.
[b] The lowest of the aquatic life/human health objectives in the San Francisco Bay RWQCB Basin Plan are given.
[c] The ammonia objective is approximate.

Bacteria are often associated with pathogens harmful to human health and are therefore problematic (even in low concentrations) for the contact recreation occurring in the Park . Therefore, water quality and public health authorities have established standards for water contact recreation and other uses. Bacteria levels were low in the lagoons (0-49 MPN/100ml total coliform), and lower than in the Bay (5-140 MPN/100ml total coliform) on all three dry weather sampling dates, and less than Regional Water Quality Control Board SF Bay Basin Plan objectives for bacteria (240 MPN/100ml total coliform), as described in Figure 3-3. The low bacteria values detected in February indicate that the level of bacteria is not elevated continuously as a result of stormwater discharge to the Park. However, the level of bacteria in stormwater is higher than in Aquatic Park.

Figure 3-3 also shows the range of bacteria levels in Lake Merritt and Foster City Lagoon. These water bodies are similar to Aquatic Park, in that they are located in an urban setting, receive storm runoff from the surrounding urban area, and exchange of water with the Bay is tide-driven. The comparison of bacteria data in Figure 3-3 shows that the range of bacteria levels measured in the Park are lower than the range reported for Lake Merritt and Foster City Lagoon.

The low bacteria values detected in the Park in February indicate that the level of bacteria is not elevated continuously as a result of stormwater discharge to the Park . However, the level of bacteria in stormwater is higher than in Aquatic Park. The density of bacteria in stormwater is typically about 10^6 MPN/100 mL, which is consistent with that measured in the Potter Street drain as part of this study. During a rainfall event, bacteria levels could be expected to increase significantly in the Model Yacht Basin due to the stormwater inflows from the Potter Street storm drain. If, in a storm, 10 percent of the water in the Model Yacht Basin is stormwater, the density of coliform bacteria would be about 10^5 MPN/100 mL. Stormwater could also affect water quality in the Main Lagoon under high stormflow conditions when the Strawberry Creek drain and techite line overflow. Bacteria would decline following a storm event due to die off and flushing. The low levels of bacteria in the Park on 28 February (50 MPN/100 mL) following a substantial storm on 20 February indicate that the approximate rate of bacteria die-off and flushing is 0.95/day assuming 10^6 MPN/100 mL in stormwater, 10 percent stormwater in Modal Yacht Basin at the end of the storm (10^5 MPN/100 mL) and decay/dieoff occurred at an exponential described by the standard formula.

$$C_t = C_0 e^{-kt}$$

where C_t = concentration at time = t (50 MPN/100 mL)

C_0 = concentration at time = 0 (10^5 MPN/100 mL)

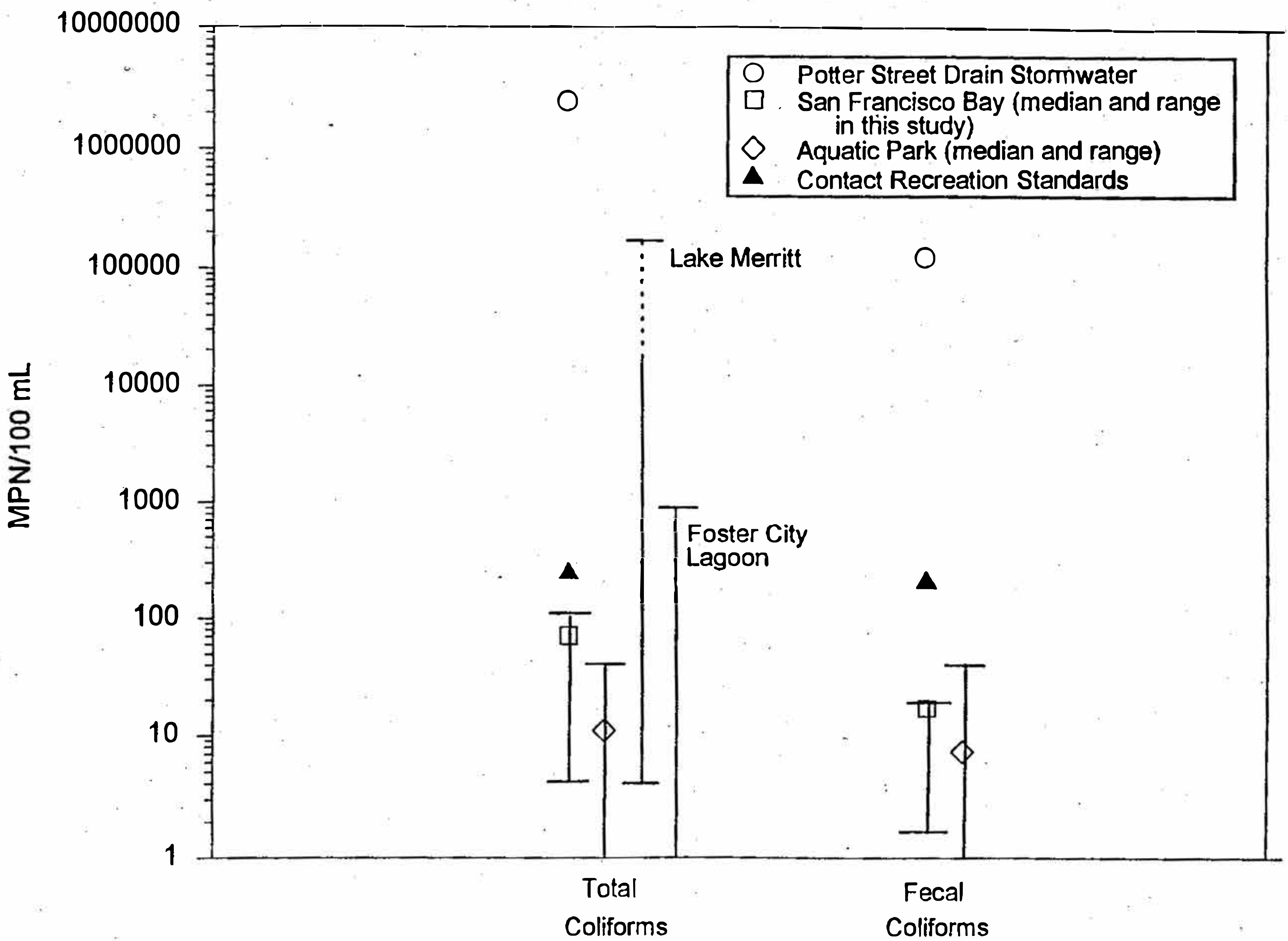
e = inverse natural log function

k = rate constant (estimated to be 0.95)

t = time (8 days)

<u>Nutrient</u> levels (nitrate, ammonia, phosphorus and ammonia) were generally low in the lagoons on all sampling dates. In contrast to phosphorus, the concentration of ammonia, nitrite and nitrate in the Park was generally below the limit of analytic detection, which indicates nitrogen limits the growth of algae. The concentration of nitrogen species was

Figure 3-3 Bacteria in Waters of Aquatic Park and Nearby San Francisco Bay



BAW35974.AI.60

CH2M HILL

generally greater in the Bay, indicating that the Bay supplies nitrogen to the Park. Water quality objectives for nutrients have only been established for ammonia. Ammonia is a toxicant, and the concentration of ammonia in the Park on all dates was much less than the ammonia objective.

Metals have known toxicity to organisms and the SWRCB objectives provide guidance for evaluating metals toxicity risks (see Figure 3-4). Metals data indicate low levels in the lagoons relative to SWRCB objectives for aquatic life and human health. In the Bay, the copper objective was exceeded in July.

Rainfall events that produce an overflow of stormwater from the Potter Street storm drain would contribute significant levels of metals to the lagoons and potentially exceed SWRCB objectives.

Chlorophyll. Chlorophyll indicates the presence of suspended algae. Chlorophyll values were low on all sampling dates. This appears to be due to uptake of nutrients by the rooted aquatic plants and the filamentous algae that grows in close association with the rooted aquatic plants. Objectionable odors may be caused by living plants and algae, but become more pronounced when plants and algae die and decay in the fall season. Removal of the rooted aquatic plants would potentially make the nutrients available for algae growth.

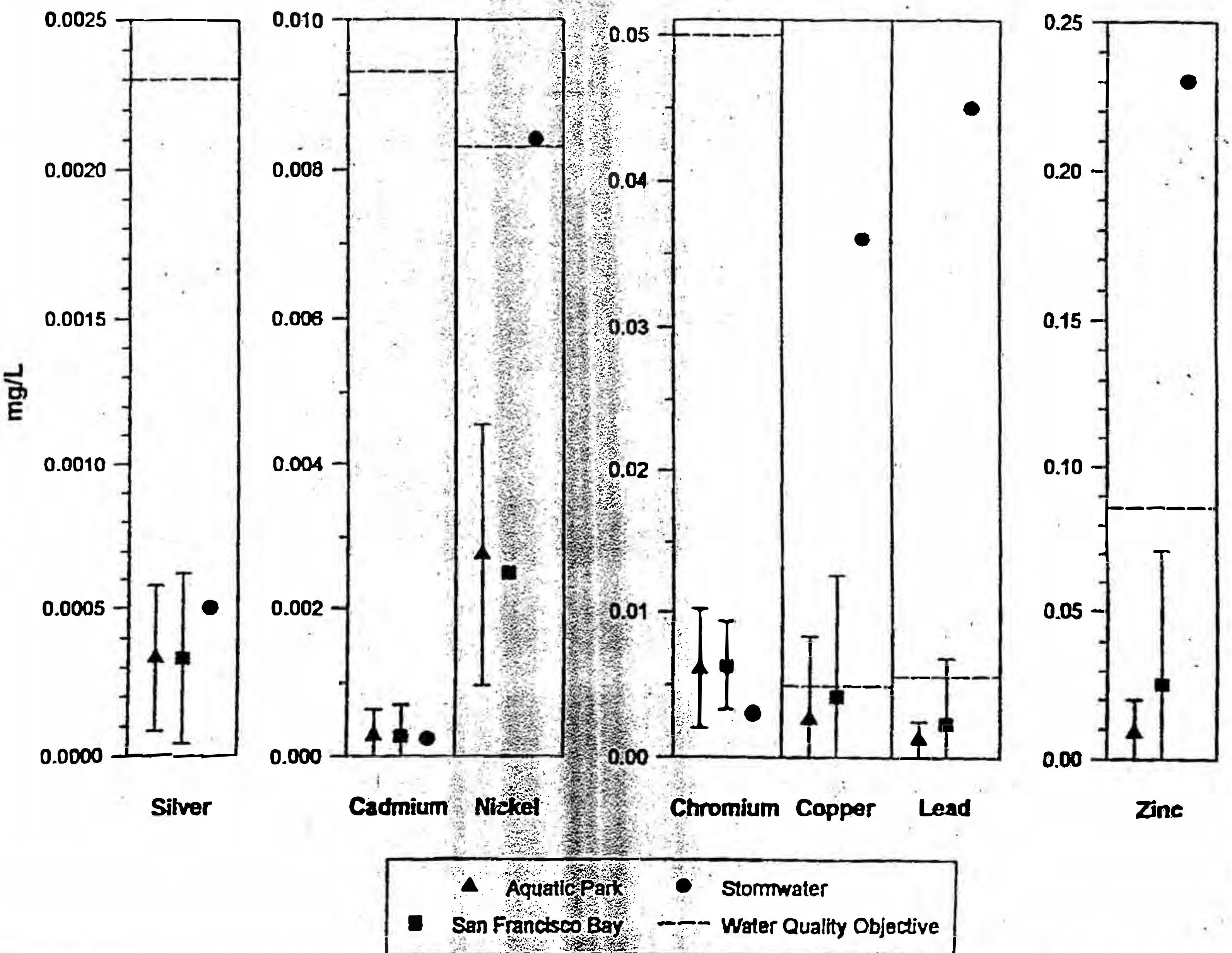
Rooted Aquatic Plants. Rooted Aquatic Plants were qualitatively assessed during the field studies. The plants were found to be widespread in July and October in areas of the Park of depth less than about 4 feet (see Figure 3-2), covering the southern half of the Main Lagoon, and all of the Model Yacht Basin. Water-skier tow boat activity maintains an open swath down the center of the southern half of the Main Lagoon. The rooted aquatic plant is *Ruppia sp.* Filamentous algae (*Enteromorpha* and *Cladophora*) grow in association with the *Ruppia.* The plants were virtually absent in February, which is consistent with their growth pattern. These plants are common in similar water bodies (e.g., Lake Merritt, Foster City Lagoon) and regarded as a nuisance by some managers.

3.3.4 Stormwater Quality

Stormwater quality was characterized during one storm in May, 1993. The data indicate that stormwater quality from the May event was similar to stormwater quality characterized in other studies (Alameda County Urban Runoff Clean Water Program, and EBMUD Local Effects Monitoring Program).

Solids data are characteristically high in the stormwater grab sample taken in the beginning of the rainfall event. As the storm progressed, TSS decreased reflecting the "first flush" nature of the grab samples and was lowest at the end of the storm after most of the solids had been flushed from paved areas. Stormwater overflow from the Potter Street storm drain transports these solids to the Model Yacht Basin in potentially high concentrations.

Figure 3-4. Metals in Waters of Aquatic Park and Nearby San Francisco Bay
(ranges shown are ± 2 standard deviations)



BAW35974.AI.60

CH2M HILL

Bacteria levels were high in the composite sample owing to the urban runoff that transports animal waste and other sources of bacterial contamination (see Figure 3-3). These high concentrations of bacteria indicate the likely presence of pathogens harmful to humans. Stormwater overflows to the Park transport bacteria to the Main Lagoon where water-contact recreation is common. However, water skiing is limited to March 1 through October 31 and recreation during the wet weather season has limited water-contact (e.g., fishing, hiking, wildlife viewing).

Nutrient levels are also high in the stormwater composite sample (much higher than background levels in the lagoons) creating the potential for increased plant and algal growth with stormwater inflows to the Park.

Metals data from the stormwater composite sample exceed four of seven RWQCB objectives (see Figure 3-4). As with solids, nutrients and bacteria, stormwater inflows to the Park transport metals to the lagoons potentially affecting aquatic organisms, birds and humans.

Organic compounds such as oil and pesticides were not analyzed in the stormwater samples from the Potter Street drain, but are found in typical urban runoff.

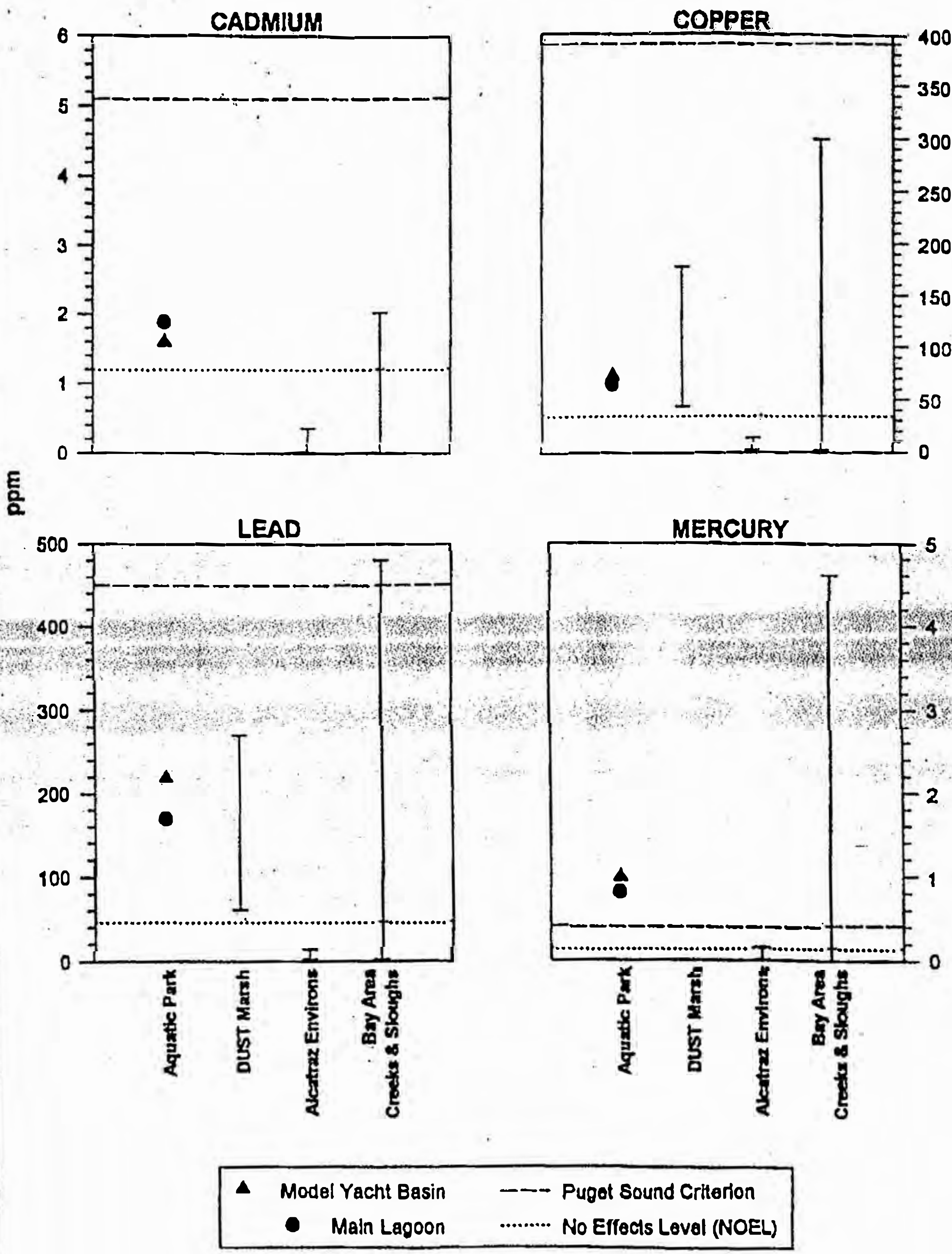
3.3.5 Sediment Quality

Sediment quality data from the Main Lagoon and the Model Yacht Basin are summarized in Table 3-3 and Figure 3-5. The Park sediment quality data are compared to data from US Army Corps of Engineers collected in the vicinity of their Alcatraz disposal site (known as the Alcatraz Environs). The Environs data were collected at locations near the Alcatraz disposal site and were selected as a reference by the Corps for evaluating the suitability of material for disposal at the Alcatraz site. Review of the collected data initially characterizing sediment quality in the Park with Corps staff, indicate that the material in the Park is suitable for disposal at Alcatraz. Additional characterization of sediment quality would be needed as a basis for an application for a discharge permit.

This initial characterization of conditions in the Park indicates that numeric water quality objectives are being attained and water quality is generally adequate for the beneficial uses of the Park. However, aquatic plants grow abundantly and are responsible for nuisance odor conditions and may impair some beneficial uses such as boating and water-skiing. Although levels of bacteria measured in this study were below the standard for water contact, stormwater discharges to the Park probably cause the standard to be exceeded for several days. Sediment quality is adequate for disposal at the Alcatraz site based on preliminary sediment characterization.

Figure 3-5. Sediment Metals in Aquatic Park and Other Locations

(ranges shown are maximum and minimum values reported)



CH2M HILL

Figure 3-5. Sediment Metals in Aquatic Park and Other Locations

(ranges shown are maximum and minimum values reported)

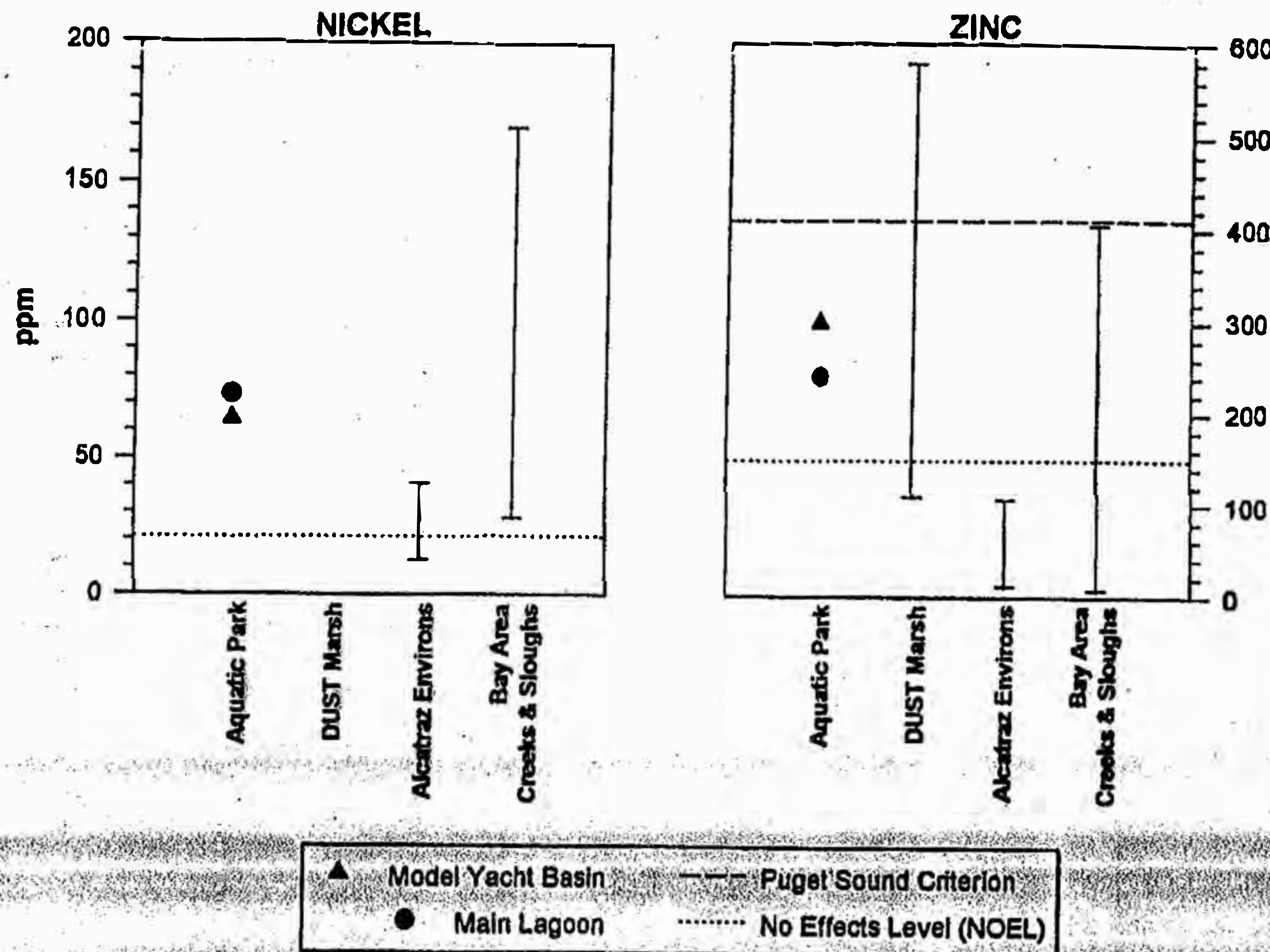


Table 3-3
Berkeley Aquatic Park Study
Sediment Quality Monitoring Results

	Units	Main Lagoon	Model Yacht Basin	Alcatraz Environs Low	Alcatraz Environs High
Conventional					
Grain Size					
gravel (>2000um)	%	0.0	0.0	0.00	17
sand (62.5-2000um)	%	30.0	28.0	91.00	81
silt (3.9-62.54um)	%	41.0	50.0	3.00	1
clay (<3.9um)	%	29.0	22.0	6.00	1
Total Organic Carbon	%	1.8	1.9	0.03	0.19
Oil & Grease	ppm	550.0	460.0	1.22	175.14
Total Volatile Solids	%	5.8	5.3	1.32	2.6
Total Petroleum HCs	ppm	110.0	180.0	<0.6	8
Metal					
Arsenic	ppm	11.0	15.0	1.80	13.2
Cadmium	ppm	1.9	1.6	0.02	0.35
Chromium	ppm	140.0	120.0	19.80	156
Copper	ppm	66.0	73.0	2.70	12.4
Lead	ppm	170.0	220.0	2.30	14.4
Mercury	ppm	0.83	1.0	0.01	0.16
Nickel	ppm	73.0	64.0	12.30	40.7
Selenium	ppm	0.2	0.2	<.1	0.41
Silver	ppm	1.2	2.2	0.02	0.1
Zinc	ppm	240.0	300.0	12.00	106.8
Organics					
Monobutyltins	ppb	<1	<1	ND	<1.3
Dibutyltns	ppb	9.0	6.0	ND	0.6
Tributytins	ppb	9.0	4.0	ND	1.1
PPB	ppb	150.0	140.0	ND	ND
Chlorinated Pesticides* 4,4'-DDE	ppb	8.2	12.0	ND	ND
PAH					
*All Park data non-detectable for pesticides except for 4,4'- DDE, all Environs data non-detectable					

Section 4
Water Quality Management Alternatives

Alternatives have been developed to manage water quality in Aquatic Park. The results of the monitoring program indicate that suspended algae and bacteria are not currently problematic in the Park, but that sediment accumulation and the resulting shallow water conditions have promoted growth of rooted aquatic plants. The rooted aquatic plants create nuisance odors and interfere with some uses of the Park. Study of Aquatic Park has indicated that removing the plants would promote the growth of suspended algae, which could recreate similar nuisance conditions. Management objectives that were the basis of developing alternatives are summarized as follows:

- Control rooted aquatic plant growth.
- Avoid blooms of suspended algae.
- Avoid introducing bacteria-laden stormwater to the Park.

This section describes criteria for identifying alternatives, describes each alternative, and compares the alternatives.

4.1 Identification of Water Quality Management Alternatives

Alternative methods of improving and managing water quality were identified to meet the following criteria:

- **No Chemical Treatment.** Chemical addition to manage water quality was not considered to be a viable management strategy because of the potential adverse impacts. Chemicals that could be used include herbicides that would inhibit growth of rooted aquatic plants and algae, color that would limit light penetration and thus control algae, disinfectants that would kill bacteria, and chemicals that would coagulate and settle algae. Managing water quality without chemical treatment generally involves increased flushing through the Park, or alteration of water depth.

- **No Pumping.** Alternatives that involve pumps that would accelerate the movement of water from the Bay through the Park and back to the Bay were not identified because of the energy requirements and operating cost. Tidal energy can move sufficient water to adequately flush the Park.

- **Avoid Additional Connections to the Bay.** The freeway represents a major obstacle to installation of additional hydraulic connections to the Bay. A cost-prohibitive construction technique known as "jacking and boring" would need to be used to install any additional pipes to avoid impacts on the freeway. A second constriction is a 60-inch wastewater interceptor pipeline that parallels I-80.

Alternatives were developed that emphasize tidal flushing to move water through the Park and rely on dredging or mechanical harvesting to control rooted aquatic plants. Table 4-1 shows management strategies that have been considered in this study and describes how each addresses the water quality problems at Aquatic Park.

Table 4-1
Effect of Management Strategies on Water Quality

	Management Strategies				
Problem	Flushing	Dredging	Flushing and Dredging	Isolate Basins From Stormwater	Harvest Aquatic Plants
Rooted Plants	-	+	+	o	+
Algae	+	-	+	o	-
Bacteria	+	o	+	+	o
Safety	-	+	+	o	o
+ = Positive effect, o= neither positive nor negative effect, - = Negative effect					

Increased flushing removes algae and bacteria from the Park. However, increased flushing also brings more sediment into the Park, which would create more shallow areas for rooted aquatic plant growth and create additional safety concerns. Increased flushing would also supply additional nutrients that stimulate rooted aquatic plant growth. Dredging alone would control rooted plants by rendering the water too deep (owing to light attenuation) but would lengthen detention time which promotes algal growth. Combined dredging and flushing would remove the already accumulated sediment, reduce the light for rooted aquatic plants, and flush algae and bacteria from the Park. Harvesting alone would control rooted aquatic plants, but create conditions that would favor algae growth by removing the shade provided by rooted plants.

Based on the consideration summarized in Table 4-1, three alternatives were identified to meet the criteria described on the previous page as follows:

1. No Project

2. Rehabilitate Existing Structures

3. Modify Existing Structures

Alternatives 2 and 3 are intended to improve flushing in the Park to avoid algae and bacteria accumulation. Sediment accumulation is also addressed in the alternatives. Each of these alternatives and their costs are described below. Further details on the cost estimates are provided in Appendix C.

4.1.1 Alternative 1–No Project

This alternative would involve no change to any of the hydraulic control structures at Aquatic Park and is shown in Figure 4-1. Minor dredging activities to maintain the flap gates at the five 24-inch pipes would continue. This alternative could also involve a program to inform the public that the rooted aquatic plants have ecological value and that their decay and odor production is a natural phenomenon. Water-skiing would need to be limited to areas of sufficient depth to avoid injury and liability. As summarized in Table 4-1, harvesting or dredging alone would not be recommended.

4.1.2 Alternative 2–Rehabilitate Existing Structures

This alternative would involve restoration of the existing facilities so that they would function as originally designed. Water movement would occur as identified in Figure 3-1. Pipes would be cleaned and repaired as needed, and gates and weirs would be replaced. Specifically, facilities identified in Figure 4-1 as C, F, G, H, and I would be rehabilitated to address the problems identified in Table 3-1. This alternative is summarized in Figure 4-2. Rooted aquatic plant growth would be controlled by either dredging or harvesting (identified hereinafter as Alternatives 2A and 2B, respectively). Dredging would eventually be needed to preserve Aquatic Park; without dredging, sediment would eventually fill the basins. Components of Alternative 2 are described below.

Rehabilitation. Existing facilities would be cleaned, repaired or replaced as follows:

- Clean Pipes. The two 24-inch pipes between the Potter Street drain and the Model Yacht Basin, the two 24-inch pipes connecting the Model Yacht Basin with the Main Lagoon, the two 24-inch pipes connecting the Model Yacht Basin and the Main Lagoon to the Bay would be cleaned. The condition of these pipes is not known. Assuming that the pipes have structural integrity and can be cleaned, the estimated cost is $103,200.

- Rehabilitate five tide gates at the Park-side of the five 24-inch tide tubes. Estimated cost: $20,100.

- Replace tide/slide gates in the two 24-inch pipes connecting the Potter Street drain to the Model Yacht Basin. Estimated cost: $38,100.

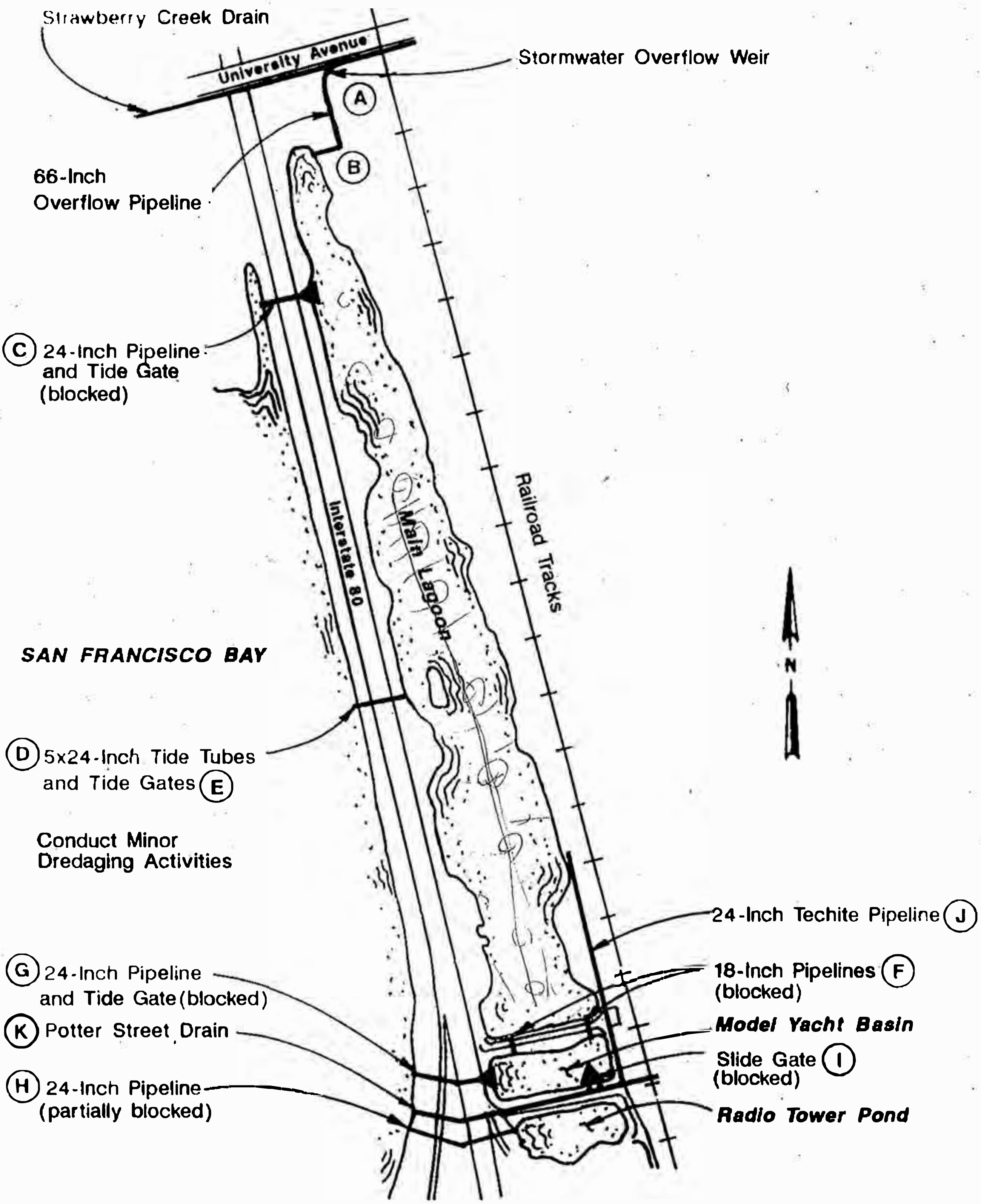


Figure 4-1

ALTERNATIVE 1

Aquatic Park Water Quality
Improvement Study

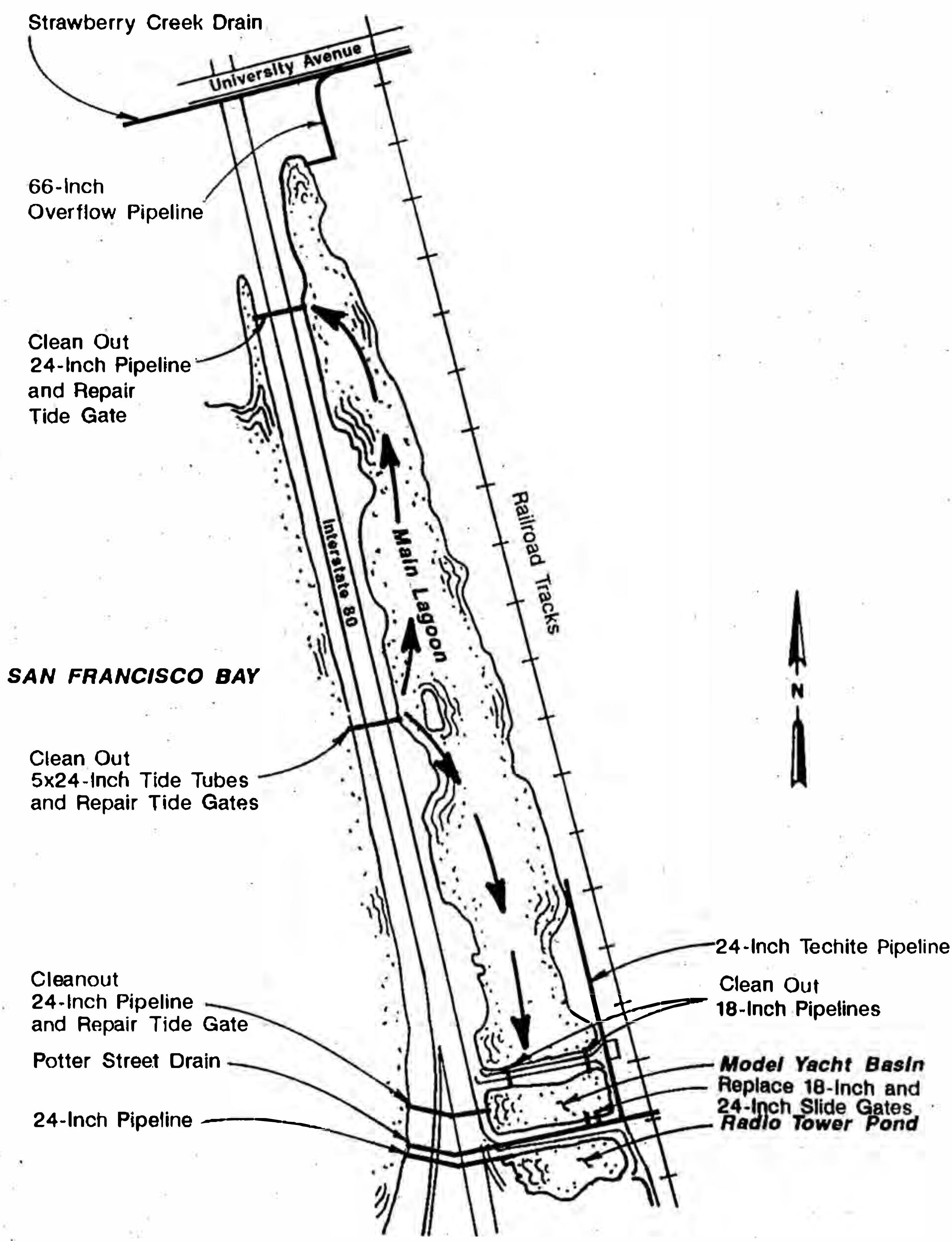


Figure 4-2

ALTERNATIVE 2-REHABILITATE EXISTING STRUCTURES

Aquatic Park Water Quality
Improvement Study

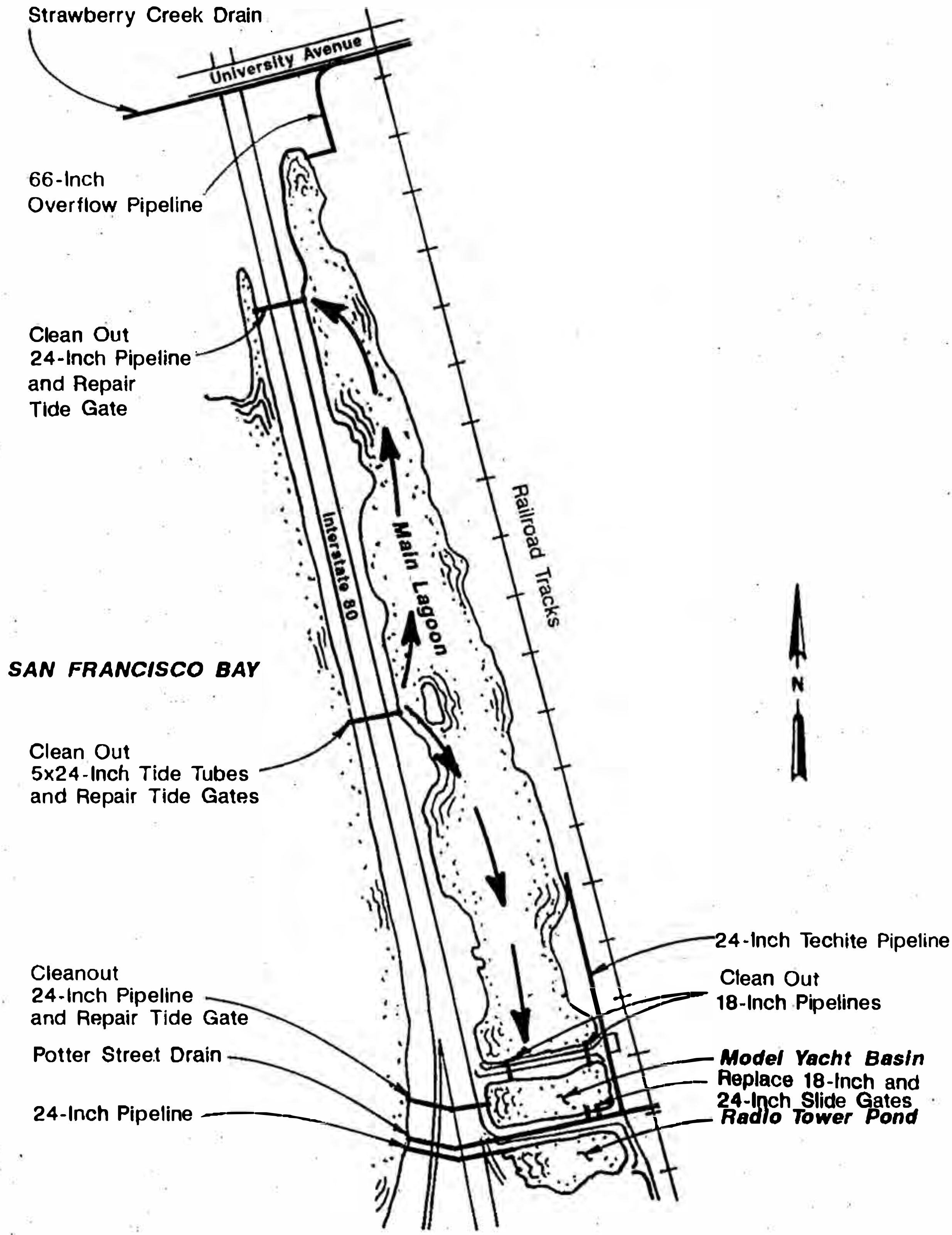


Figure 4-2

ALTERNATIVE 2-REHABILITATE EXISTING STRUCTURES

Aquatic Park Water Quality
Improvement Study

- Replace tide gates on the 24-inch pipe connecting the Model Yacht Basin and the 24-inch pipe connecting the Main Lagoon to the Bay. Estimated cost: $38,100.

Dredging. The estimated volume of sediment that would be removed from the Model Yacht Basin and Main Lagoon is to provide a minimum depth of 10 feet (bottom elevation of -9 NGVD) is 42,000 and 520,000 cubic yards, respectively. A suction dredge would be used and the material would be pumped to a bottom-dump barge located in the Bay. The temporary pipeline to the barge would be located inside one of the existing pipes that pass beneath the freeway. Sediment quality data indicate that the dredged material would be suitable for disposal at the Alcatraz site. The estimated unit dredging and disposal cost is $14.25 per cubic yard, with a $65,000 mobilization cost (assuming Alcatraz disposal). Estimates for the dredging and disposal costs were provided by Marvin Meyer of Dutra Dredging. His costs were based on the type of sediment to be dredged, the equipment necessary to dredge, pump and transport the material, and the depth of the Main Lagoon and Model Yacht Basin. Thus, the total estimated dredging cost would be $8.07 million. Site investigation and permitting would be necessary and add to this cost. In addition, in the event that the Alcatraz disposal site cannot be used, disposal costs may be higher at an alternative site. Closer to the time of dredging, the City may want to consider dewatering options such as drying ponds to decrease the volume of disposal materials.

Harvesting. A mechanical harvester would be used periodically to cut and collect the submerged plants and floating algae in the Main Lagoon and Model Yacht Basin. The harvester is essentially a floating weed cutter with the capability to collect and transport cut weeds and floating algae. It floats on pontoons that allow it to work in shallow water close to shore and the cutting mechanism (much like a hedge trimmer) can reach depths of seven feet. A conveyor belt on the harvester offloads the harvested plants and algae onto the trailer which transports the material for dumping. Three cubic yards of plant matter are collected by the harvester per load. Depending on the density of the plant matter and the depth of the water, one to five acres of surface area can be harvested per day.

Harvesting is an effective method of collecting nearly all of the floating algae and the submerged plants (since they are cut near their base). However, aquatic plants and algae can return quickly (potentially within six weeks) after harvesting, requiring more than one harvest per summer.

Harvesting has been used previously in the Park to control aquatic plants and algae. The City contracted with a local firm to supply and operate the harvester. Based on the contractor's experience and an evaluation of the plant density and spread, approximately 14 days are estimated to be required to harvest the plant material, and that approximately 90 percent of the plant matter would be removed. Approximately 300 cubic yards of plant material would be harvested in 14 days. Harvesting twice during the summer may be necessary in some years to mitigate nuisance concentrations of aquatic plants and algae.

- Replace tide gates on the 24-inch pipe connecting the Model Yacht Basin and the 24-inch pipe connecting the Main Lagoon to the Bay. Estimated cost: $38,100.

Dredging. The estimated volume of sediment that would be removed from the Model Yacht Basin and Main Lagoon is to provide a minimum depth of 10 feet (bottom elevation of -9 NGVD) is 42,000 and 520,000 cubic yards, respectively. A suction dredge would be used and the material would be pumped to a bottom-dump barge located in the Bay. The temporary pipeline to the barge would be located inside one of the existing pipes that pass beneath the freeway. Sediment quality data indicate that the dredged material would be suitable for disposal at the Alcatraz site. The estimated unit dredging and disposal cost is $14.25 per cubic yard, with a $65,000 mobilization cost (assuming Alcatraz disposal). Estimates for the dredging and disposal costs were provided by Marvin Meyer of Dutra Dredging. His costs were based on the type of sediment to be dredged, the equipment necessary to dredge, pump and transport the material, and the depth of the Main Lagoon and Model Yacht Basin. Thus, the total estimated dredging cost would be $8.07 million. Site investigation and permitting would be necessary and add to this cost. In addition, in the event that the Alcatraz disposal site cannot be used, disposal costs may be higher at an alternative site. Closer to the time of dredging, the City may want to consider dewatering options such as drying ponds to decrease the volume of disposal materials.

Harvesting. A mechanical harvester would be used periodically to cut and collect the submerged plants and floating algae in the Main Lagoon and Model Yacht Basin. The harvester is essentially a floating weed cutter with the capability to collect and transport cut weeds and floating algae. It floats on pontoons that allow it to work in shallow water close to shore and the cutting mechanism (much like a hedge trimmer) can reach depths of seven feet. A conveyor belt on the harvester offloads the harvested plants and algae onto the trailer which transports the material for dumping. Three cubic yards of plant matter are collected by the harvester per load. Depending on the density of the plant matter and the depth of the water, one to five acres of surface area can be harvested per day.

Harvesting is an effective method of collecting nearly all of the floating algae and the submerged plants (since they are cut near their base). However, aquatic plants and algae can return quickly (potentially within six weeks) after harvesting, requiring more than one harvest per summer.

Harvesting has been used previously in the Park to control aquatic plants and algae. The City contracted with a local firm to supply and operate the harvester. Based on the contractor's experience and an evaluation of the plant density and spread, approximately 14 days are estimated to be required to harvest the plant material, and that approximately 90 percent of the plant matter would be removed. Approximately 300 cubic yards of plant material would be harvested in 14 days. Harvesting twice during the summer may be necessary in some years to mitigate nuisance concentrations of aquatic plants and algae.

Harvesting Impacts. Fish safely escape the harvester during the cutting process and fish habitat can be easily maintained with this alternative through selective cutting. Different species of fish, and their prey, require different kinds of habitat to survive. Selective harvesting could retain the types of habitat (e.g., certain volumes of rooted plants at a certain depth and location) that are considered desirable for a productive recreational fishery. The harvester has the capability of varying the depth at which it cuts as well as the locations where it cuts.

Harvesting Costs. The City of Berkeley could implement a harvesting alternative to control plants and algae by contracting for harvesting services or by purchasing and operating the harvester. The estimated annual cost of contracting for one harvest per year in 1994 dollars is $20,000, and $40,000 for two harvests per year, including disposal cost that the City would incur directly ($8 per cubic yard disposal cost). An average of 1.5 harvests per year was assumed for cost estimating purposes, two harvests were assumed to be needed in alternating years, with one harvest needed in the other year. The 30-year net present value cost of the contracting option, including plant disposal by the City is $658,000.

Purchasing a harvester is an alternative to contracting those services. The useful life of a harvester operating in a salt water environment is assumed to be 15 years. Thus, the harvestor would need to be purchased initially and then replaced once during the 30 year project life. The estimated cost of purchasing and operating a harvester is summarized in Table 4-2. The operation and maintenance costs are based on an average of 1.5 harvests per year. The average annual operating time of the harvester would be 165 harvesting hours at a rate of $40/engine hour (as estimated by the manufacturer to be their cost when operating as a contractor). It is assumed that City staff would operate and maintain the equipment and dispose of the plants.

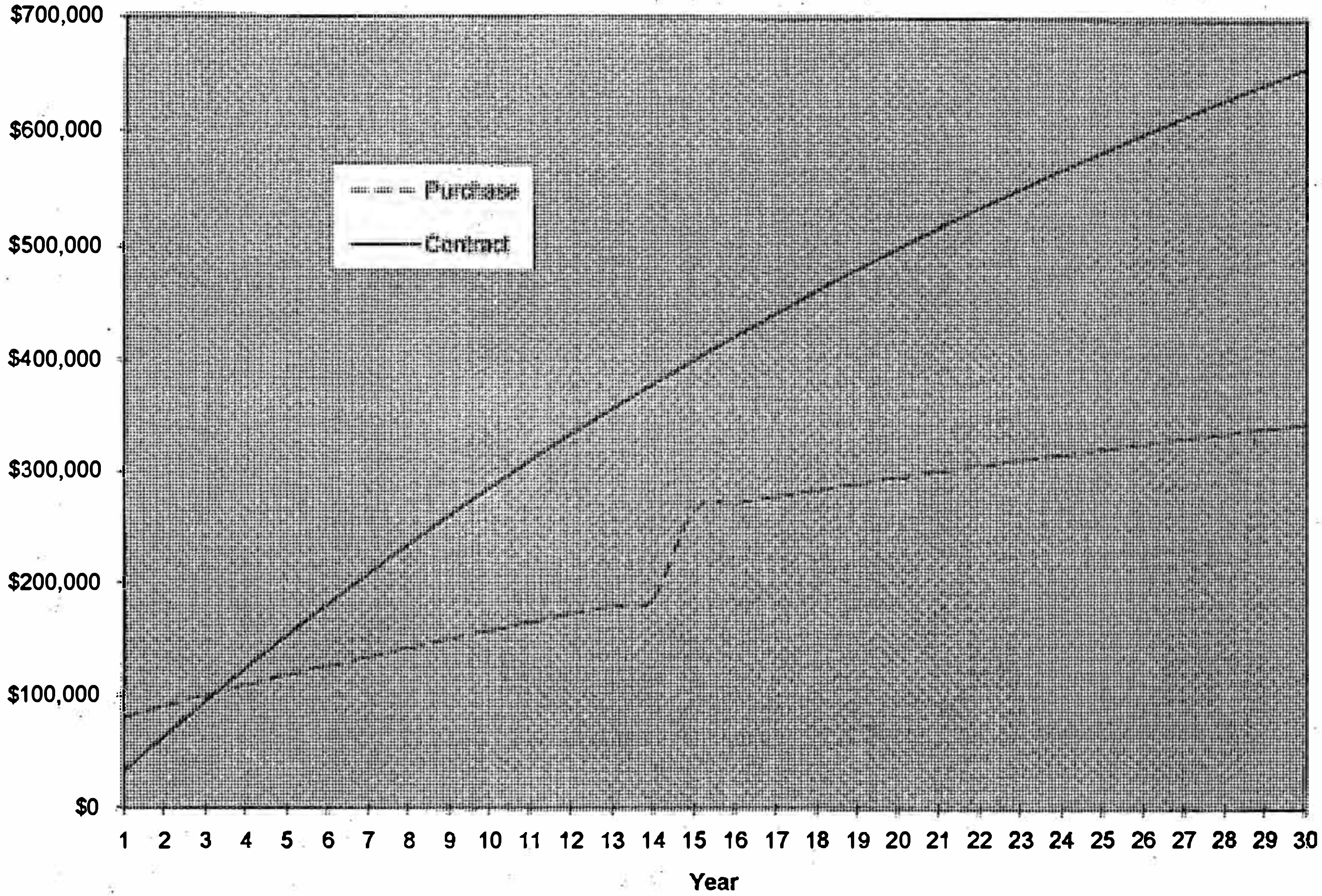
Table 4-2
Harvester Purchase Cost Estimate (1994 dollars)

Item	Initial Capital	Annual
Harvester	$54,500	-
Trailer	$18,200	-
Operation and Maintenance (average annual)	-	$6,600
Plant Disposal	-	$3,600
TOTAL	$72,700	$10,200

Figure 4-3 shows the net present value of the purchase and contract options for periods ranging from 1 to 30 years. This figure shows that the purchase option is less expensive than the contract option if harvesting needs to occur for more than about four years. If routine harvesting is not considered necessary by the City, or the Park is dredged within about three years, then the contract option is the lower cost harvesting option.

Cost estimates for rehabilitation, dredging and harvesting are developed below. Table 4-3 summarizes the cost of each component. The useful life of the rehabilitated structures is

Figure 4-3. Comparison of Net Present Value of Harvester Purchase and Contract Options (1994 dollars)



approximately 30 years. The net present value analysis is based on an assumed 3 percent rate.

Table 4-3
Alternative 2 Cost Summary (1994 dollars)

Component	Capital Cost	Annual O&M	30-yr Present Value[a]
Clean all pipes[b]	$103,200	$16,500	$426,600
Rehabilitate 5 tide gates	20,100	1,900	57,340
Replace tide/slide gates from Model Yacht Basin to Potter Street storm drain	38,100	900	55,740
Replace tide gates on 2-24″ pipes to Bay	38,100	900	55,740
Subtotal -- Rehabilitation	**$199,500**	**$20,200**	**$615,620**
Dredge: year 1	8,070,000		8,070,000
Total Alternative 2A (rehab and dredging)	**$8,269,500**	**$20,200**	**$8,685,620**
Harvest[c]: year 1	72,700	10,200	345,300[d]
Harvest[c]: year 15	72,700		
Total Alternative 2B (rehab and harvest)	**$272,200[e]**	**$30,400**	**$960,920**

[a] 3% inflation rate.

[b] Clean: 2-24″ pipes between Potter St. drain and MYB, 2-18″ pipes between Model Yacht Basin (MYB) and Main Lagoon (ML), 2-24″ pipes out to the Bay (1 from N end and 1 from S end of ML, 5-24″ tide tubes from ML to the Bay).

[c] Purchase option.

[d] Includes 30 years of O&M costs and purchase of a harvester at year 1 and year 15.

[e] Includes only initial capital cost.

4.1.3 Alternative 3–Modify Existing Structures

Existing hydraulic control facilities at the Park would be modified (see Figure 4-4) to increase flow capacity. The facilities would be modified to bring Bay water into the Park via the Strawberry Creek storm drain and remove the water via the Potter Street storm drain. Specifically, this alternative would involve the following changes to the hydraulic control facilities at the Park (see also Figure 3-3).

- Install approximately 130 feet of 36-inch pipe to connect the Strawberry Creek drain to the 66-inch pipe between the Park and Strawberry Creek. The invert of the pipe (inside bottom) would be 0.0 feet NGVD over the entire 130 foot length. Since the summer time average high tide is approximately 2.3 feet NGVD, this modification would greatly increase the volume of water that can flow into the Park. Both the length of time when the tidal stage exceeds the invert elevation and the hydraulic capacity would be increased. This alternative may also necessitate modifications to the 15-inch and 27-inch sanitary sewers located below the 66-inch pipe. The City's Storm Drain Master Plan recommends replacement of the existing 66" pipe with a 78" pipe. The cost of the 78" pipe is included in the master plan cost estimate.

- Replace one of the 18-inch pipes connecting Main Lagoon and Model Yacht Basin with a 36-inch pipe and clean and rehabilitate the remaining 18-inch pipe. Estimated cost: $75,000.

- Replace 18-inch and 24-inch pipes connecting the Model Yacht Basin and Potter Street storm drain with one 36-inch (invert elevation -2.5 feet NGVD) pipe fitted with a tide gate that prevents flow from the Potter Street drain. The location of the 36-inch pipe connection should be compatible with the stormwater treatment programs. Estimated cost: $37,000.

- Clean five 24-inch pipes and repair tide gate. Estimated cost: $73,000.

- Other connections between the Model Yacht Basin and the Bay, and the Main Lagoon and the Bay would be sealed and abandoned in place. These pipes are currently blocked by sediment and abandonment is optional. The benefit of sealing and abandonment is avoidance of future structural integrity problems and related erosion along the pipe alignments. Estimated cost: $6,000.

Alternatives 3A and 3B involve dredging and harvesting, respectively, to control rooted aquatic plants. The cost of this alternative, based on a 3 percent discount rate, is summarized in Table 4-4.

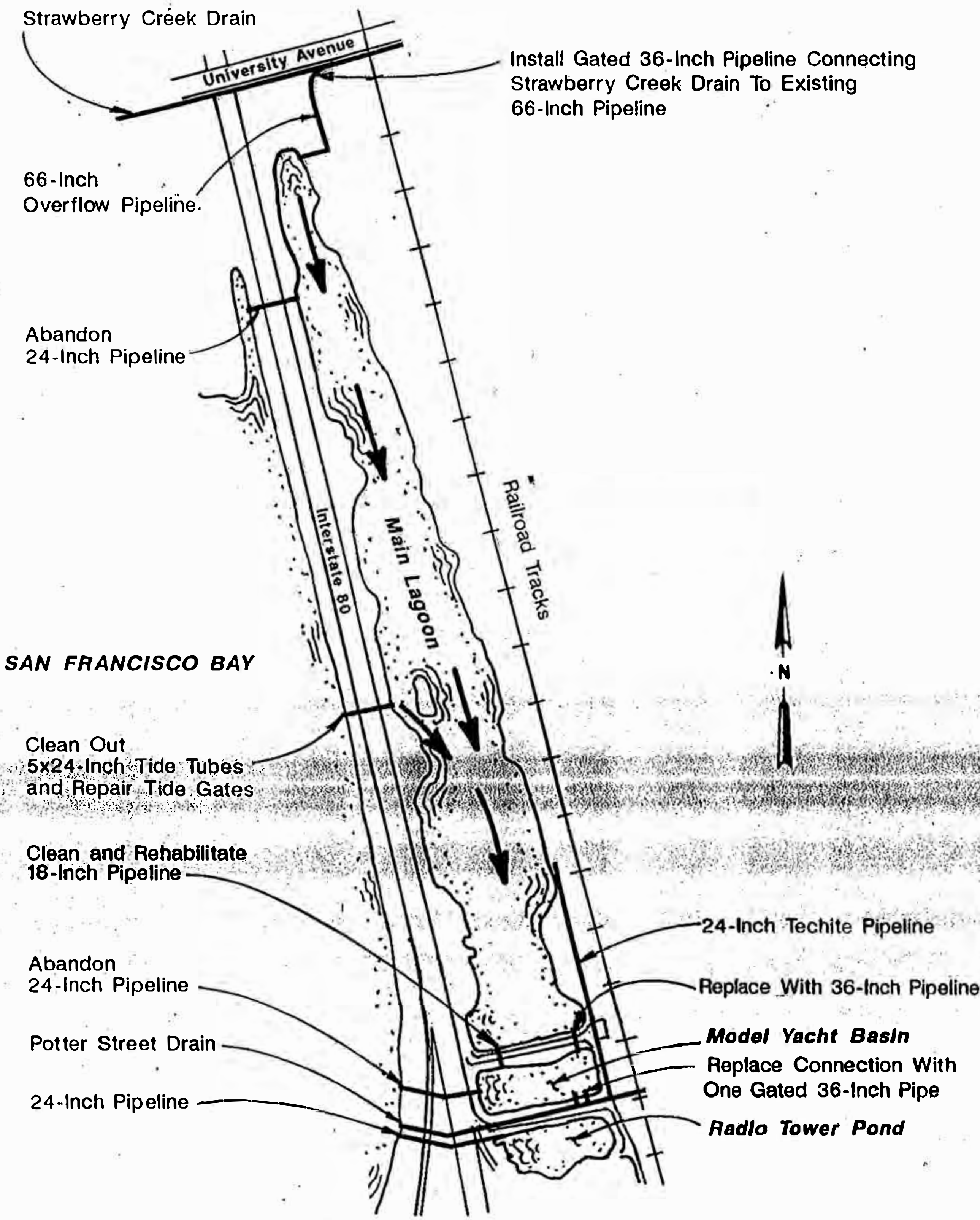


Figure 4-4

ALTERNATIVE 3-MODIFY EXISTING STRUCTURES

Aquatic Park Water Quality
Improvement Study

BAW35974.AI.60

CH2M HILL

Table 4-4 Alternative 3 Cost Summary (1994 dollars)			
Component	**Capital Cost**	**Annual O&M**	**30-yr Present Value[a]**
Lower 130 feet of 66″ pipe between Strawberry Drain and Park	$70,000	$5,400	$175,840
Modify weir at Strawberry Creek drain	31,000	900	48,640
Replace one 18″ pipe with a 36″ gated pipe between Model Yacht Basin and Main Lagoon and clean and rehabilitate the remaining 18″ pipe.	75,000	3,300	139,680
Replace 18″ and 24″ pipes with a 36″ gated pipes between Model Yacht Basin and Potter Street Drain	37,000	1,650	69,340
Clean and repair 24″ tide tubes and gates	73,000	6,380	198,050
Abandon 24″ pipe between the Main Lagoon and Bay and 24″ pipe between the Model Yacht Basin and Bay	6,000		6,000
Subtotal -- New Structures	**$292,000**	**$17,630**	**$637,550**
Dredge[b]: year 1	8,070,000		8,070,000
Total Alternative 3A (modify and dredging)	**$8,360,000[c]**	**$17,630**	**$8,707,600**
Harvest[c]: year 1	72,700	10,200	345,300[d]
Harvest[c]: year 15	72,700 (113,000 at year 15)		
Total Alternative 3B (modify and harvest)	**$364,700[e]**	**$27,830**	**$982,850**

[a] 3% inflation rate.

[b] In this alternative, higher flow rates will lead to sediment accumulation at a rate that may necessitate dredging within 30 years (as identified in Table 4-5). This cost estimate does not include the cost of a second dredging within the 30-year project life.

[c] Purchase option.

[d] Includes 30 years of O&M costs and purchase of harvester at year 1 and year 15.

[e] Includes only initial capital cost.

4.2 Evaluation Of Water Quality Management Alternatives

This section provides information on the effectiveness of the alternatives, a description of permitting issues associated with each alternative, and a description of the consistency of each alternative with the Aquatic Park Master Plan.

4.2.1 Effectiveness of Alternatives

The effectiveness of each alternative was evaluated using the hydraulic and water quality model that is described in the Hydraulic Modeling Plan in Appendix B. Each alternative was characterized in terms of the following factors:

- **Average Flows and Water Levels.** Flows through the Model Yacht Basin and Main Lagoon were computed assuming average tide conditions. The model was run using the repetitive tide until the water surface elevations and intertidal flow rates became repetitive. The intertidal flows were then averaged over the tidal cycle to obtain daily average flows. The number of tidal cycles required to reach a repetitive solution ranged between five and ten days depending on the alternative. The time required to reach equilibrium is a function of the flow capacity of the hydraulic structures. Lower flow capacity required a larger number of tidal cycles. Summertime spring and neap tide conditions were also simulated using the same procedure. These simulations provided an estimate of the range in flows and water surface levels which would be anticipated during a typical summertime lunar cycle and confirmed that the average tidal condition provided a reasonable estimate of long term average flows.

- **Average Detention Time.** Average flow was translated into average hydraulic detention time based on the combined volume of the Model Yacht Basin and Main Lagoon. For Alternative 3, the average detention time is an adequate representation of the age of the water leaving the park. For the other alternatives, however, the age of the water in the northern portion of the Main Lagoon would be somewhat older than predicted by the model since in the other alternatives the main flow path is from the five 24-inch freeway crossing to the Potter Street drain.

- **Suspended Plants.** The hydraulic and water quality model estimates the growth potential of phytoplankton (algae) based on light limitation in a vertically mixed water column. Typical summertime water temperature and turbidity and unlimited nutrients are assumed based on San Francisco Bay data. The model assumes all plant growth potential is realized by algae; the model does not estimate growth of rooted aquatic plants which would be in competition for nutrients. The computed chlorophyll *a* concentrations are intended to serve as an indication of the maximum probable algal concentration. Acceptable levels of algae is quite subjective. Floating algae mats, unusual coloration and odors are undesirable traits. The potential for one or more of these conditions to occur increases with increased predicted chlorophyll *a* concentrations. Nuisance algae levels would most likely occur during warm periods when prevailing onshore winds are weak. The lack of wind will reduce the rate at which the algae are mixed vertically and out of the surface zone with sufficient light for algal growth.

- **Rooted Plants.** The effectiveness of alternatives for the control of rooted aquatic plants is estimated based on an understanding of the effectiveness of dredging and harvesting that has been observed elsewhere. These observations of dredging and harvesting effectiveness are generally not quantitative and represent the best professional judgment of the project team.

- **Sediment Accumulation.** Sediment accumulation estimates are based on the historical rate of accumulation, which is 0.1 foot per year resulting from the estimated long-term average flow rate of 8 cubic feet per second (cfs). As flow increases, the sediment accumulation rate is expected to increase in proportion to flow increases associated with alternatives to the no project alternative. The rate of accumulation can be reduced by limiting the periods during which the conveyance facilities are allowed to operate.

- **Erosion.** Erosion is currently occurring along the east edge of the lagoon. Increased circulation would increase erosion potential.

The effectiveness of the water quality management alternatives is summarized in Table 4-5. The estimated maximum algae concentration given in Table 4-5 is related to water clarity and dissolved oxygen. All of the predicted maximum chlorophyll values are sufficiently high to give the water a green tint. Higher chlorophyll values (390-430 ug/L) would appear very green and turbid, whereas the low values (160-240 ug/L) would appear much less green. The higher chlorophyll values also could create dissolved oxygen conditions that are adverse for fish.

If the Park is not dredged and rooted aquatic plants are not harvested, then suspended algae levels will likely remain low. If plants are harvested (and the Park is not dredged), then the high flushing flows provided by implementation of Alternative 3 would be needed to avoid the very high algae levels associated with Alternatives 1 and 2.

Table 4-5
Effectiveness of Water Quality Management Alternatives

Alternative	Average Flow (cfs)	Detention Time (days)	Maximum Algae (µg/L chlorophyll a)	Rooted Aquatic Plants	Sediment Accumulation (inches/ year)	(years to accum. 5 feet sediment)
1. No Project	6	21	20[a], 430[b]	Not controlled	<1	>50
2. Rehabilitate Existing Structures	8	16	390[b]	Not controlled	1	50
2A Rehab & Dredging	8	39	190[b]	Controlled	1	50
2B Rehab & Harvesting	8	16	390[b]	Controlled	1	50
3 Modify Existing Structures	15	9	240[b]	Not controlled	2	26
3A Modify & Dredging	15	21	160[b]	Controlled	2	26
3B Modify & Harvesting	15	9	240[b]	Controlled	2	26

[a] Denotes maximum Chlorophyll a value identified in 1993/1994 sampling.

[b] Denotes maximum Chlorophyll a value estimated with removal of rooted aquatic plants and unlimited nutrients.

The flow rate and detention time identified in Table 4-5 for each alternative represents the average over a 30-day period with typical tides. The average detention time is a function of average flow and average volume. The average volumes reflected an average water surface elevation for Alternatives 2 and 3 of 0.4 and 0.7 feet NGVD respectively. There is considerable variation in daily average flow and water surface elevation during the lunar tidal cycle. During spring tides, the higher Bay water surface elevations force considerably more water into the Park through the five 24-inch pipes and the lowered 66-inch pipe. The average flow for spring tides is approximately 2.5 times the flow for neap tides. The flow ratio is accentuated by the relative high invert elevation which severely limit the flow capacity during periods when the Bay water surface is below one foot or so.

Increased inflow rates associated with Alternatives 2 and 3 raise the water surface within the Park to the point where the added head can force sufficient water into the Potter Street drain to stabilize the water surface elevation. The corresponding low tide associated with spring tides does not increase the outflow rate since the invert of the Potter Street outfall limits the water surface elevation within the drain to slightly less than 0 feet NGVD. This range in water surface elevations cannot be avoided without gates which control the flow rate based on water surface elevation. Table 4-6 describes water surface elevations and flows under various tidal conditions in dry weather. Hydraulic characteristics of the existing conditions (Alternative 1) were not evaluated and are not shown in Table 4-6.

Table 4-6
Computed Water Surface Elevations and Mean Daily Flows Under Various Tide Conditions

Tide Condition (Diurnal/Mean Range)	Water Surface (NGVD)			Daily Average Flow (cfs)
	Minimum	Maximum	Average	
Alternative 2				
Mean (5.7/4.2)	0.25*	0.55	0.40	8.0
Neap (4.6/3.5)	0.10*	0.25	0.20	5.0
Spring (7.8/5.2)	1.50*	1.80	1.60	12.0
Alternative 3				
Mean (5.7/4.2)	0.50	0.90	0.70	15.0
Neap (4.6/3.5)	0.15	0.35	0.25	9.50
Spring (7.8/5.2)	1.40	2.10	1.70	23.50

* The minimum water surface elevation within the Model Yacht Basin is 0.30 to 0.90 feet lower due to the hydraulic losses through the two existing 18-inch culverts.

4.2.2 Permitting Issues

The main permitting and documentation requirements that apply to the Aquatic Park alternatives are those specified under the California Environmental Quality Act (CEQA), the National Environmental Protection Act (NEPA) and the federal Clean Water Act (CWA). Regulations under these Acts require some level of permitting. The specific permits are discussed below. Of note are the U.S. Army Corps of Engineers (COE) nationwide permits which do not require U.S. Fish and Wildlife Service and U.S. Environmental Protection Agency review and, therefore, require much less time in the permitting process. An individual permit from COE would be required if the COE determined that a significant amount of wetlands would be negatively impacted as a result of the project. An individual permit could require from six to twelve months to obtain. An individual permit would also be needed for disposal of dredge spoils.

An evaluation of the potential permitting issues associated with each of the water quality management alternatives follows:

Alternative 1- No Project. This alternative would not require any California Environmental Quality Act (CEQA) documentation. Any dredging that would be needed to maintain the flap gates would either require continuation under existing Clean Water Act (CWA) permits from the U.S. Army Corps of Engineers (COE), or a Section 10 nationwide permit would need to be obtained through COE.

Alternative 2- Rehabilitate Existing Structures. The components under this alternative potentially would involve rehabilitation construction, dredging, or harvesting of seasonal aquatic plants. Under CEQA it would be likely that the preparation of a Negative

Declaration/Finding of No Significant Impact and Initial Study Environmental Assessment document would need to be prepared. A full Environmental Impact Statement probably would not be necessary.

Dredging undertaken to deepen the Park would require a Section 10 permit and dredge spoil disposal would require a Section 404 permit. COE would need to comply with NEPA and may require development of an EIS.

Any fill or dredging that might be needed to rehabilitate the existing structures would probably need a Section 10 nationwide permit from the COE. Currently, the Park contains Waters of the United States but probably no areas of wetlands (as defined in CWA Section 404). A jurisdictional wetlands and waters delineation would need to be done to ensure that no wetlands would be involved. If wetlands are determined to be present and a significant amount of those wetlands would be impacted, then a Section 10 individual permit would be required.

Alternative 3- Modify Existing Structures. The components under this alternative potentially would involve rehabilitation construction, new construction, dredging, or harvesting of seasonal aquatic plants. Under CEQA, it would be likely that the preparation of a Negative Declaration/Finding of No Significant Impact and Initial Study Environmental Assessment document would need to be prepared. A full Environmental Impact Statement would probably not be necessary.

Any fill or dredging that might be needed to rehabilitate the existing structures and construct new structures would likely need a Section 10 nationwide permit from the COE. Currently, the Park contains Waters of the United States but probably no areas of wetlands. A jurisdictional wetlands and waters delineation would need to be done to ensure that no wetlands would be involved. If wetlands are determined to be present and a significant amount of those wetlands would be impacted then a Section 10 individual permit would be required.

4.2.3 Consistency With Aquatic Park Master Plan

The Aquatic Park Master Plan identifies a recommended alternative for Park improvement that involves the elimination of existing berms that separate the three basins and the termination of the Potter Street drain at Aquatic Park. This Master Plan alternative was evaluated using the hydraulic and water quality model developed for the Aquatic Park Water Quality Improvement Study. A 10-year runoff volume of 280 acre-feet from the 4.3 square mile Potter watershed was assumed for the analysis.

The hydraulic evaluation indicates that flow in the Potter Street Drain for the 10-year storm would cause water levels within the Aquatic Park to raise to 6.5 feet NGVD if the existing berms were eliminated and the Potter Street drain terminated at Aquatic Park. This analysis assumed a maximum tidal stage of 4 feet NGVD in the Bay which is well below the City's estimate of 5.4 feet. More extreme tides would result in higher water surface elevation within the Park.

The analysis does not include flows from the Strawberry Creek overflow weir which would further increase the water surface elevation within the Park. The higher Park water surface would likely compromise the present flood control benefit that the Strawberry Creek diversion provides the Strawberry Creek drainage. A water surface of 6.5 feet NGVD in the Aquatic Park would exceed the current bank height and result in flooding. Therefore, for purposes of evaluating the Aquatic Park Water Quality Improvement Study alternatives for consistency with the Aquatic Park Master Plan, it was assumed that the recommended draft Aquatic Park Master Plan alternative involves all of the proposed elements except for removal of the Potter Street drain and the earthen embankment covering it. Thus, the berm between the Model Yacht Basin and the Main Lagoon could be removed to create one large lagoon, but the Radio Tower Pond would remain as a separate basin.

The recommended draft Aquatic Park Master Plan alternative identifies several changes to the configuration of the Park that are potentially relevant to water movement and water quality management, including berm removal, creation of wetland along the perimeter of the basin. The Aquatic Park Water Quality Improvement Study alternatives are compatible with these possible changes as described below.

- **Berm Removal.** Removal of the berm between the Model Yacht Basin and the Main Lagoon would eliminate the need for replacement of the pipes in this berm that connect the two basins, proposed as part of Aquatic Park Water Quality Improvement Study Alternative 2. Removal of the berm would likely enhance circulation and would thus contribute to improved water quality.

- **Habitat Creation.** Enhancement of a variety of habitats is included as part of the recommended Aquatic Park Master Plan alternative including tidal salt marsh, freshwater marsh, and upland habitat. Although the water quality management alternatives differ from the preferred Aquatic Park Master Plan alternative by not eliminating the Potter Street berm (due to resulting flooding), all three types of habitats could be enhanced with the alternatives developed in this study. Tidal salt marsh could be created by providing habitat at the proper slope and elevation in conjunction with the proper tidal regime. The operation of the Park to provide the appropriate tidal regime for the wetland would need to be considered. The intertidal nature of the salt marsh would preclude the rooted aquatic plants that are currently a nuisance in the Park.

  Creation of a marsh habitat in areas presently covered by water would provide a disposal site for some of the material dredged from the Park and realize potentially significant cost savings. The marsh area could be filled with materials excavated from the deep water portion of the Park from the shoreline using a crane and clam shell. The per yard cost would be much less and the total excavation volume would be decreased. Thus, the habitat creation element of the recommended Aquatic Park Master Plan alternative and water quality management alternatives developed in this Aquatic Park Water Quality Improvement Study report are compatible.

4.3 Comparison of Water Quality Management Alternatives

The alternatives were developed to control water quality issues at the Park that relate to rooted aquatic plant abundance, suspended algae abundance, bacteria density, and sediment accumulation. The anticipated effectiveness of the alternatives is described above in this section and summarized in Table 4-7. Cost information is also summarized in Table 4-7.

Dredging is ultimately necessary to prevent the Main Lagoon and the Model Yacht Basin from becoming filled with sediment. Dredging also is considered the most effective means of controlling the rooted aquatic plants. However, dredging is extremely costly. If rooted aquatic plant control is desired prior to the availability of funds for a dredging project, a mechanical harvester could be used.

If rooted aquatic plants are controlled with mechanical harvesting prior to or instead of dredging, the potential for high levels of algae will increase. Fewer rooted plants are expected to result in more light and nutrients available to algae. Thus, if dredging can be implemented with hydraulic improvements, Alternative 2A would be the preferred alternative because this analysis indicates that it addresses each of the water quality issues satisfactorily and would accumulate sediment at a lower rate than would Alternative 3.

If insufficient flushing to control algae results from implementation of Alternative 2A, then Alternative 3A could be implemented. If dredging at the time of hydraulic improvements is infeasible and the City chooses to control rooted aquatic plants by harvesting, then implementation of Alternative 3 would provide the greatest flushing to control algae until dredging can be implemented.

Table 4-7
Comparison of Water Quality Management Alternatives

Alternative	Rooted Plants	Algae (µg/L)	Bacteria	Existing Sediment	Future Sediment Accumulation	Initial Capital	Present Value
1. No Project	Not controlled	430* (potential)	Not controlled	Not addressed	<1 inch per year		
2. Rehabilitate Existing Structures	Not controlled	390	Partial control	Not addressed	1 inch per year	$199,500	$615,620
2A Rehab & Dredging	Controlled	190	Partial control	Addressed	1 inch per year	$8,269,500	$8,685,620
2B Rehab & Harvesting	Controlled	390	Partial control	Not addressed	1 inch per year	$272,200	$960,920
3 New Structures	Not controlled	240	Greatest control	Not addressed	2 inches per year	$292,000	$637,550
3A New & Dredging	Controlled	160	Greatest control	Addressed	2 inches per year	$8,360,000	$8,707,600
3B New & Harvesting	Controlled	240	Greatest control	Not addressed	2 inches per year	$364,700	$982,850

Section 5
Stormwater Treatment Alternatives

Consistent with water quality regulations, the City of Berkeley has developed and is implementing a City-wide program to manage stormwater quality. The objective of the City's stormwater program is to control pollutants that accumulate throughout the City and are transported via the storm drain system to San Francisco Bay. The stormwater program emphasizes pollution source control, but includes the provision for treatment of stormwater where treatment is cost-effective. To more fully implement the City's stormwater program, the City of Berkeley obtained a $60,000 grant from the Alameda County Urban Runoff Clean Water Program specifically to evaluate the use of, and, if appropriate, construct facilities in Aquatic Park to treat stormwater. This section identifies and describes stormwater treatment alternatives that were considered in the Aquatic Park Water Quality Improvement Study.

5.1 Identification of Stormwater Treatment Alternatives

The treatment of stormwater involves the removal of pollutants to protect, in this case, the Bay from adverse water quality impacts. Diversion of stormwater from a storm drain to Aquatic Park could result in water quality effects and pollutant accumulation in the Park. The Main Lagoon currently receives stormwater from the Strawberry Creek drain during high rainfall runoff conditions, and the techite storm drain line also overflows periodically (see Figure 3-1 for locations of these facilities). With these exceptions, the Main Lagoon is protected from the potential adverse impacts of stormwater. The Model Yacht Basin is routinely affected by storm runoff from the Potter Street storm drain. Based on these considerations and the desire to keep stormwater bacteria out of the Main Lagoon, the stormwater treatment alternative focused on the Model Yacht Basin. The Radio Tower Pond was not considered because it currently provides wetland habitat, is amenable to habitat enhancement as part of an Aquatic Park Master Plan project, is not wholly owned by the City, and is not currently connected to any significant storm drainage facilities.

The techite line was determined to be the most suitable source of stormwater in the vicinity of the Model Yacht Basin. Stormwater from the techite line could include the "first flush" of pollutants whereas the first flush in the Potter Street drain would be diluted with Bay water. The well defined 225-acre watershed will facilitate correlation between watershed usage (primarily industrial) and the quality characteristics of the runoff and sediments trapped by the Model Yacht Basin.

Treatment of stormwater could consist of a range of facilities from a basin that is used to settle sediment to a complex multi-stage facility like a sewage treatment plant. Construction of complex stormwater treatment plants is clearly not consistent with the intent of the water quality regulations upon which the City's stormwater program is founded and therefore no such alternatives were developed. Settling of suspended particulate material from stormwater could potentially remove a substantial quantity of pollutants because many pollutants are attached to suspended particulate material in stormwater.

Alternatives were developed to divert stormwater into, and then out of the Model Yacht Basin as it flows from Berkeley to the Bay so that settling of suspended matter can occur. The effectiveness of a settling basin depends on the size of the particles and the detention time of the basin. The size of particles is important because it determines settling velocity (the rate at which particles drop out of the water column). Detention time is important because it affects the amount of sediment that can be removed before the water discharges from the settling basin. If particle size is small, long detention time is required to remove pollutants. The presence of salt water in a basin enhances settling because salt causes particles to adhere to one another and become larger, thereby increasing settling velocity.

Two alternatives were developed to use the Model Yacht Basin as a stormwater treatment facility in winter that would be consistent with the recommended draft Aquatic Park Master Plan alternative and the water quality management alternatives identified in Section 4 of this report. The two alternatives (Full Treatment and the Treatment/Habitat alternatives) are described below.

5.1.1 Full Treatment Alternative

Two alternatives were reviewed for the Model Yacht Basin, the first with no initial dredging and the second with dredging to a 10-foot depth. Dredging is a desirable, but not essential, element of a treatment project because dredging increases detention time and sediment removal. If the basin is not dredged, rate of stormwater flow would need to be reduced to maintain a detention time that is long enough to allow settling of particles in stormwater. Ultimately, dredging is needed to avoid complete filling of the basins with sediment.

The Model Yacht Basin would retain its existing rectangular shape. Stormwater would be diverted from the techite storm drain located on the east shore of the basin, and discharged to the Bay via the existing but clogged 24-inch pipeline connecting the basin to the Bay (Figure 5-1). Diversion of stormwater from the techite is preferred to the Potter Street drain for two reasons as follows:

- Bay water can comprise a majority of the water present at the Potter Street diversion location. This would displace stormwater that could otherwise be treated. Sufficient salt water would be present in the basin to enhance treatment, regardless of diversion location.

- The diversion from the Potter Street drain is located near the top of the wall of the pipe, rather than at the invert elevation of the pipe. Heavier sediment would not be present in stormwater that is located near the top of the pipe.

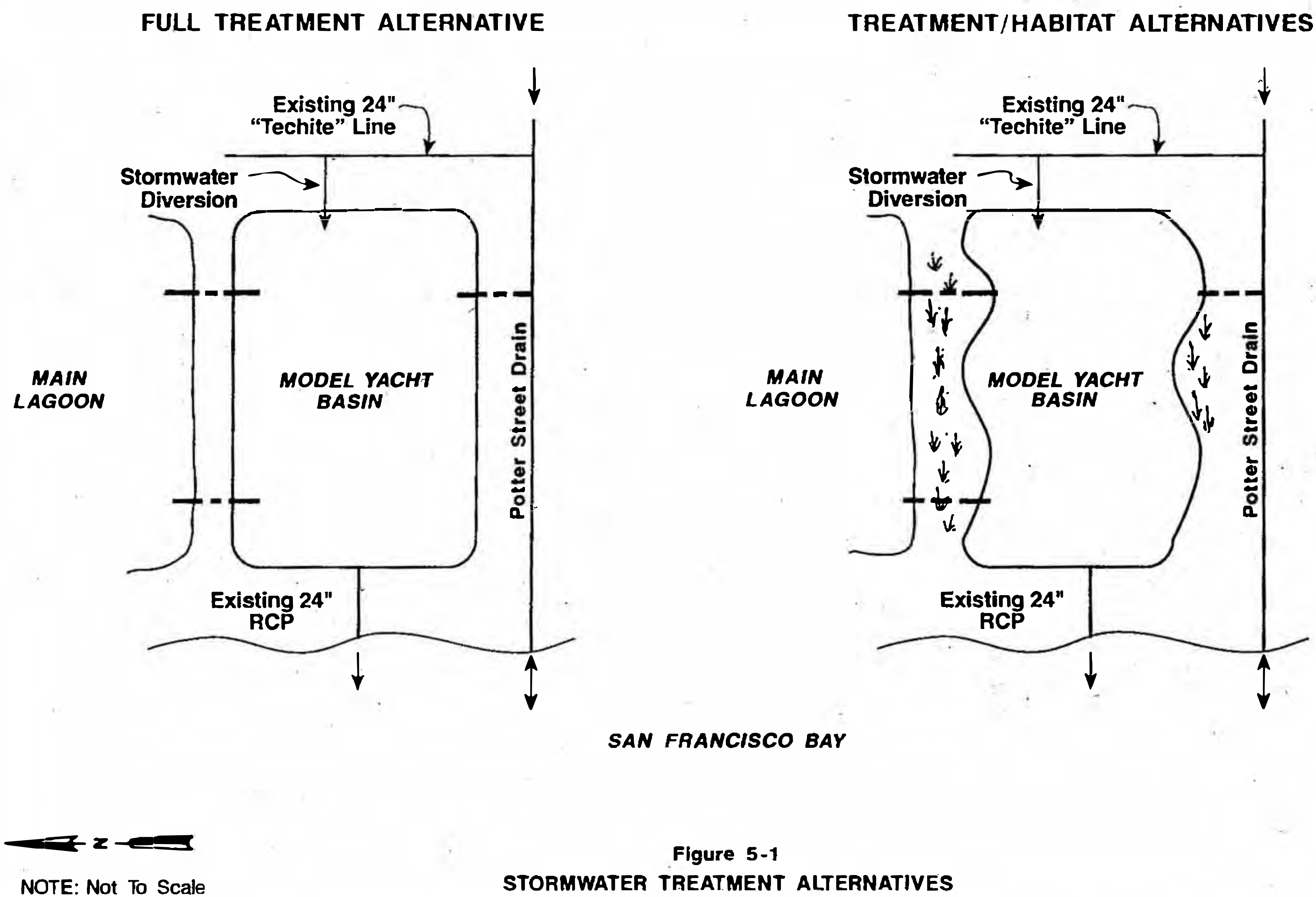


Figure 5-1
STORMWATER TREATMENT ALTERNATIVES
Aquatic Park Water Quality
Improvement Study

BAW35974.AI.60

CH2M HILL

Specific changes that would need to be made to existing facilities to implement this alternative include the following:

- A structure to divert stormwater from the techite storm drain to the basin and a 24-inch pipe to connect the diversion to the basin. Estimated cost: $27,800
- A sliding gate to prevent stormwater or tidal water in the Potter Street drain from entering the Model Yacht Basin during the rainy season. Estimated cost: $6,900.
- Gates on the pipes that connect the Model Yacht Basin to the Main Lagoon. Estimated cost: $12,200.
- Rehabilitation of the 24-inch VCP connecting basin to Bay. A gate would need to be added to prevent back flow of Bay water into basin. If this pipe cannot be rehabilitated then stormwater could be diverted from the basin into the Potter Street drain at the west end of the basin. Estimated rehabilitation cost: $30,500. Estimated cost of constructing Potter Street connection: $34,800.
- Dredge Model Yacht Basin to a depth of 10 feet. Estimated cost: $664,000 (This cost is also included in the $8 million estimate to dredge the Main Lagoon and Model Yacht Basin identified in Table 4-3.)

Cost estimates for the Full Treatment Alternative are shown in Table 5-1. Back-up information on costs are provided in Appendix C.

Table 5-1
Estimated Cost of the Treatment Alternative (1994 dollars)

Component	Capital Cost	Annual O&M	30-yr Present Value[a]
Techite Line Connection	$27,800	$5,400	$133,500
Potter Street Drain Gate	6,900	900	24,600
Gates to Isolate MYB From Main Lagoon	12,200	1,800	47,300
Rehab. 24" Pipe to Bay, Gate	30,500	5,800	143,500
Facilities Subtotal	**$77,400**	**$13,900**	**$348,900**
Dredging	$664,000	$0	$664,000
Total Estimated Cost	**$741,400**	**$13,900**	**$1,012,900**

[a] Assumes 3% discount rate.

5.1.2 Treatment/Habitat Alternatives

These alternatives are similar to the Full Treatment Alternative described above except that the shape of the basin would be modified to increase the shoreline length and provide for esthetic and habitat improvement. Figure 5-1 describes one potential plan for the basin and Figure 5-2 describes habitat that could be created in association with the basin. Additional evaluation of appropriate vegetation and habitat creation should be made at the implementation stage. The creation of the habitat reduces the volume of the basin, which reduces the quantity of stormwater that can be treated, as described in the Evaluation of Stormwater Treatment Alternatives section below.

The habitat would be created using sediments dredged from the basin using a clam shell and crane located on adjacent access roads. A balanced cut and fill configuration would result in a basin with an average width of 200 feet and a water depth of 6 feet with an elevation of approximately 4 feet NGVD. A balanced cut and fill approach would be preferable since it eliminates the need for off site disposal. A second Treatment/Habitat Alternative with a 10-foot water depth was evaluated to provide a clear comparison with the Full Treatment Alternative.

The weight of fill placed adjacent to the area proposed for excavation may create slope stability problems with slumping of the side slopes. A geotechnical evaluation of the sediments may be required to determine if the excavation/fill should be performed in stages to accommodate dewatering and consolidation. The stability uncertainty makes it difficult to provide a cost for this alternative but the cost would be much lower than the $800,000 full treatment alternative.

Additional depth could be gained by raising the berm separating the basin from the Main Lagoon or creating additional habitat within the Main Lagoon itself. However, the concept of raising the berm was rejected because backwater associated with higher water levels in the Model Yacht Basin would cause flooding of the City's storm drain system.

5.2 Evaluation of Stormwater Treatment Alternatives

The alternatives were developed to describe the efficiency of pollutant removal (e.g., percent of total pollutants removed), cost, permitting issues, operational considerations of such a treatment facility, and potential environmental impacts of the accumulated pollutants in the Model Yacht Basin. This section describes the evaluation of the alternatives for treatment effectiveness, permitting issues, operational considerations and environmental impacts and consistency with the Master Plan.

5.2.1 Treatment Effectiveness

The evaluation of stormwater treatment efficiency was limited to the removal of inorganic particles associated with stormwater and contaminants (organics, heavy metals, etc.) sorbed or attached to the particles. Oil and other floatable substances were not addressed by the model.

A total of four treatment alternatives were evaluated using two dimensional hydrodynamic and sediment transport model, SEDH (described in Appendix B), to determine the fate of the stormwater borne sediments. These alternatives included:

Full Treatment Alternatives

- The entire Model Yacht Basin without dredging.
- The entire Model Yacht Basin dredged to a depth of 10 feet

Treatment/Habitat Alternatives

- Partial Model Yacht Basin with an average water surface width of 200 feet and 6-foot depth.
- Partial Model Yacht Basin with an average water surface width of 200 feet and 10-foot depth.

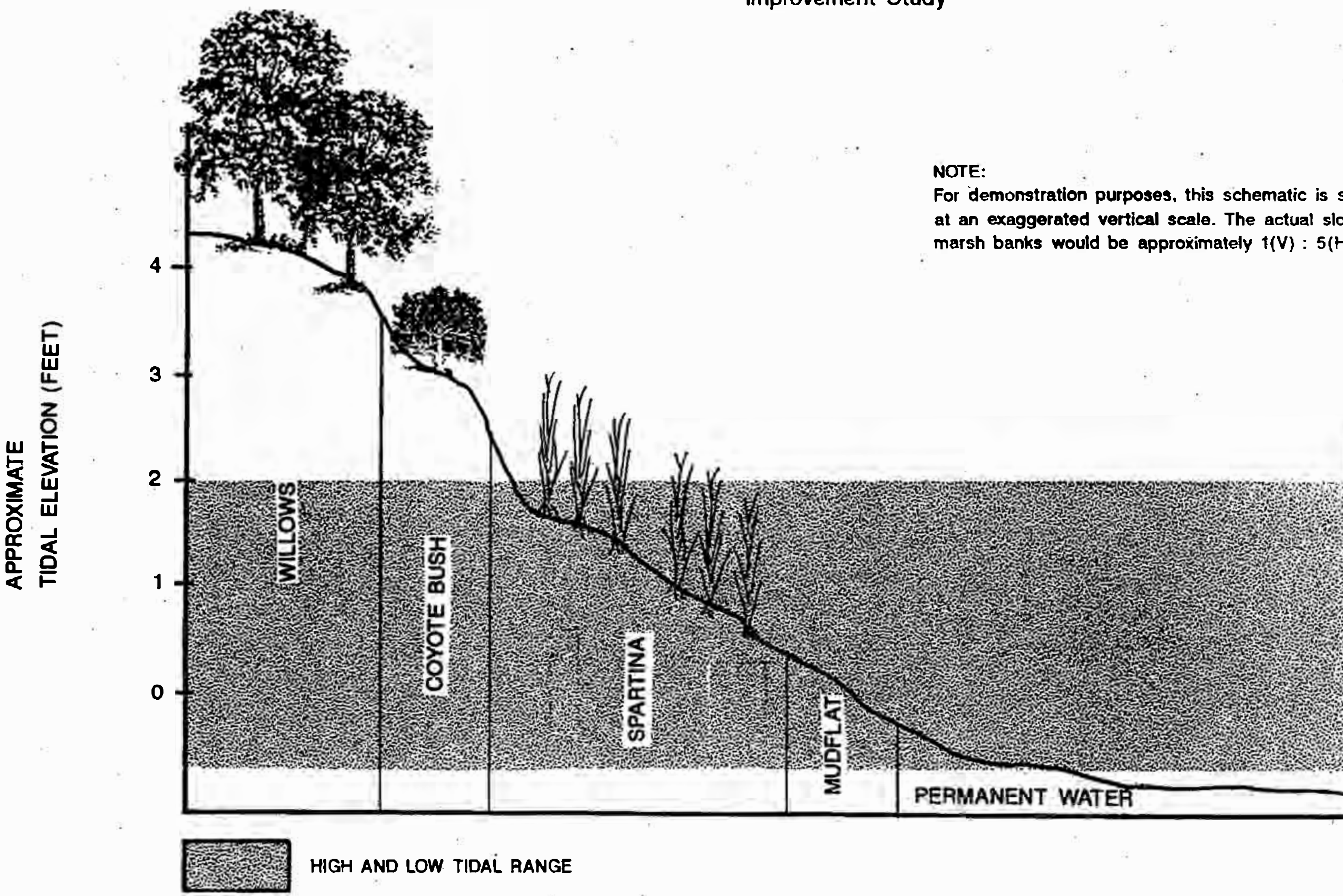
The evaluation was performed for an annual average storm and a ten year storm. Five sediment sizes were simulated, each representing 20 percent of typical urban sediment runoff. The models were run assuming a series of average tides. The simulation began with the basin water surface elevation and flow at dynamic equilibrium (i.e., the same water surface elevation and flow at the beginning of successive tides). The average non-stormwater surface elevation was approximately 0.5 feet NGVD. The storm hydrograph was then routed into the northeast corner of the basin with its associated suspended sediment load.

The rainfall hydrographs for these storms are centrally distributed 6-hour storms and were developed as part of the Storm Drainage Master Plan (CH2M HILL, 1994).

For all alternatives, the piping was conceptually designed such that the maximum water surface elevations would be 4.0 and 4.9 feet NGVD for the annual average and 10-year event respectively. The post storm period was simulated until the bulk of the finest particles either settled to the bottom or flowed from the basin through the outlet pipe. In the simulation, the water surface elevation returned to non-storm levels within three days but several additional days were required to determine the fate of the suspended sediment.

The volume of stormwater treated, the percentage solids removed and percentage of contaminants (typically metals) removed for the 10-year storm event is shown in Table 5-2.

Figure 5-2
STORMWATER TREATMENT MARSH
Aquatic Park Water Quality
Improvement Study



NOTE:
For demonstration purposes, this schematic is shown at an exaggerated vertical scale. The actual slope of the marsh banks would be approximately 1(V) : 5(H).

The contaminant removal percentage assumes that contaminant sorption is proportional to particle surface area.

The volume of sediment removed for a given stormwater volume and trap efficiency is a function of suspended sediment concentration which can be highly variable. An estimate of sediment volume in cubic yards is included in the Table 5-2. The sediment volume assumes a sediment concentration of 500 mg/L (which is twice that measured in the Potter Street drain, but appropriate for a 10-year event) and a bottom sediment bulk density of 1670 Kg/m^3 (40 percent solids). The computed sediment volumes of storm origin are small in comparison to the annual accumulation of sediments of Bay origin. An accumulation of one inch over the 5-acre pond bottom would yield a sediment volume of approximately 670 cubic yards, which is 29 times the accumulated volume of 23 cubic yards from the full treatment with dredging for the 10-year storm.

The volume of stormwater treated for the one-year storm event was 25 and 17 acre-feet for the Full Treatment and Treatment/Habitat alternatives respectively. A slight increase in trap efficiency was computed for the one-year event over the 10-year event.

Table 5-2
Stormwater Treatment Volume and Efficiency for 10-Year Storm Event

Alternative	Treated Volume (AF)	Solids Removed (%)	Sediment Removed (CY)[a]	Contaminant Removal (%)
Full Treatment Alternative Entire Basin (no dredging)	36	81	22	49
Entire Basin (10 foot depth)	36	86	23	58
Treatment/Habitat Alternative 200 foot Width (6 foot depth)	24	79	14	44
200 foot Width (10 foot depth)	24	83	15	53

a Assumes a suspended solids concentration of 500 mg/L and a sediment bulk density of 1.67 (40% solids).

Table 5-2 shows that dredging improves solids and contaminant removal efficiency. Table 5-2 also shows that the volume of stormwater that can be treated is less for the Treatment/Habitat Alternative than for the Full Treatment Alternative. This is because the volume of the basin is reduced and flow (treated volume) must be reduced to achieve the same solids removal rate as with the Full Treatment Alternative.

5.2.2 Permitting Issues

An evaluation of the potential permitting issues associated with both of the stormwater treatment alternatives follows:

Under CEQA it would be likely that the preparation of a Negative Declaration/Finding of No Significant Impact and Initial Study Environmental Assessment document would need to be prepared. A full Environmental Impact Statement probably would not be necessary.

Any fill or dredging would need a Section 10 nationwide permit from the COE. Currently, the Park contains Waters of the United States but probably no areas of wetlands. A jurisdictional wetlands and waters delineation would need to be done to ensure that no wetlands would be affected. If jurisdictional wetlands are determined to be present and a significant amount of those wetlands would be impacted then a Section 10 individual permit would be required. Dredge spoil disposal would require a Section 404 permit as described in Section 4.0.

The proposed enhancement of wetlands and wildlife habitat in the Treatment/Habitat Alternative would probably be viewed in a positive light by COE and the California Department of Fish and Game; the Department that would be involved in any CEQA review.

5.2.3 Environmental Impacts

The purpose of diverting and treating stormwater runoff is to improve the quality of stormwater runoff that is eventually discharged to the Bay from this urbanized area of Berkeley. However, introducing stormwater to the Model Yacht Basin for treatment will affect water and sediment quality in the basin. The purpose of this section is to identify impacts on water and sediment quality to provide an additional basis for determination by the City of the appropriateness of implementing a stormwater treatment project.

Water Quality. Stormwater quality in the Potter Street drain was characterized as part of this project and the information is summarized in Section 3 of this report. The data are consistent with characterizations of stormwater samples in other locations and indicate that water in the Model Yacht Basin following a storm will exceed water quality objectives for bacteria and metals. Water-contact recreation in the basin would be inadvisable until bacteria levels decline following a storm (several days). Posting of the basin with signs that inform people that the basin is treating stormwater to protect the Bay and is periodically unsuitable for water contact may be appropriate. The metals in stormwater are typically associated with particulate substances and the effect of metals in stormwater will be manifest primarily in sediment, as discussed below.

Sediment Quality. The quality of stormwater runoff improves by allowing settling of suspended matter. By diverting storm water runoff to a basin such as the Model Yacht Basin, rather than discharging the runoff directly to the Bay, sedimentation will occur.

The purpose of this section of the report is to estimate the quality of sediments anticipated in the Model Yacht Basin based on sediment quality information from other local urban stormwater runoff and Bay sediment quality studies, and evaluate the potential impacts to aquatic life associated with the predicted sediment quality.

Impact of Stormwater on Sediment Quality. Figure 3-5 summarizes the sediment quality data from other Bay Area studies for comparison with Aquatic Park sediment quality data. The studies from which they were obtained are described below, which is followed by a discussion about how stormwater treatment in the Model Yacht Basin may affect sediment quality.

- The Crandall Creek-Demonstration Urban Storm Treatment Marsh Study (DUST Marsh Study) was prepared by Woodward-Clyde in 1991. The objectives of the study were to assess concentrations of copper, lead, and zinc in the sediment and stormwater runoff, and evaluate the mechanisms of pollutant removal in the marsh. The conclusions of the study indicate that trace metals enter the marsh at the upstream location, with subsequent removal of the metals from the water to the sediment. The metals are removed rapidly upon entry to the marsh. The concentration of trace metals in the sediments near the outlet stations within the marsh are similar to the background control stations. The range of copper, lead, and zinc concentrations at the inlet and outlet of the DUST Marsh are presented in Figure 3-5, with the higher value being indicative of the upper end of the marsh (closest to the stormwater discharge location). Crandall Creek/DUST Marsh data provide an indication of what sediment quality might be in the Model Yacht Basin with implementation of a stormwater treatment facility.

- Alcatraz Environs Sediment Characterization, Summary of Available Sediment Testing (November, 1992). The U.S. Army Corps of Engineers has compiled a summary of available testing data on sediments sampled from a series of stations outside but contiguous to the direct deposition zone of the Alcatraz disposal site for dredged materials. These stations are known as the Alcatraz Environs, and are used as the reference for determining suitability for disposal at the Alcatraz site.

- The Loads Assessment Summary Report was prepared by Woodward-Clyde in 1991 for the Alameda County Urban Runoff Clean Water Program. This report presents the characteristics of nonpoint source discharges and stormwater runoff in Alameda County over a 2-year period 1989 to 1991. The report includes estimates of pollutant loads from nonpoint sources and also presents some conclusions about pollutant loads associated with various land use categories. A significant conclusion of the report is that pollutant loads from urban land uses are much greater than loads from open space land use. The source of nonpoint loads is predominantly from urbanized areas. Open space land use constitute about 55 percent of the study area but are estimated to contribute less than one percent of the metals loadings to the Bay.

  Sediment quality data are also presented for streams in urban areas of the county. The report contains the conclusion that the Alameda County streams contain significant levels of heavy metals, but the concentration levels are generally more than an order of magnitude lower than levels for solids that are considered hazardous wastes. No conclusions regarding the potential toxicity of the sediments is provided. The data from this study are reflected in Figure 3 -5 in the range in Bay Creeks and Sloughs category.

- The Loads Assessment Report Volume I for the Santa Clara County Nonpoint Source Control Program, 1991 also prepared by Woodward-Clyde includes sediment quality data for streams in Santa Clara County.

- The Preliminary Environmental Assessment of Sediments Calabazas Creek Flood Control Project; Bayshore Freeway to Holding Basin Santa Clara, California, was prepared by Terrasearch, Inc. in 1992 for the Santa Clara Valley Water District. It includes sediment quality data for Calabazas Creek Sediments and Calabazas Creek Bay Mud. The data from this study are reflected in Figure 3-5 in the range in Bay Creeks and Sloughs category.

- City of Palo Alto NPDES Special Study Requirements Two-Year Report, 1989-1991, prepared by Woodward-Clyde includes the results of monitoring of San Francisco Bay. The City operates a wastewater treatment plant which discharges treated wastewater to a channel connected to South San Francisco Bay. The City has conducted monitoring of metals in water, sediment, and bivalve tissues to evaluate spatial and seasonal trends at background stations and stations near the Palo Alto effluent discharge. This monitoring is in response to an order from the San Francisco Bay Regional Water Quality Control Board.

  Based upon 2 years of monitoring there appears to be no statistically significant difference between stations for the majority of metals monitored. There does appear to be some enrichment of silver and zinc in the near-field sediments relative to background stations. Additionally, significant seasonal differences were observed for most metals in the sediments suggesting that urban runoff may be contributing to metals in the sediments. The data from this study are reflected in Figure 3-5 in the range in Bay Creeks and Sloughs category.

- South Bay Dischargers Authority Water Quality Monitoring Program, prepared by Larry Walker Associates and Kinnetic Laboratories, Inc. 1984. These data are reflected in Figure 3-5 in the range in Bay Creeks and Sloughs category.

- Water Resources Data for California, Volume 3, U.S. Geologic Survey, 1988 as summarized in the Santa Clara Valley Nonpoint Source Control Program Loads Assessment Report. These data are reflected in Figure 3-5 in the range in Bay Creeks and Sloughs category.

The Model Yacht Basin is currently influenced by Bay sediments (which are affected by urban runoff) and directly by stormwater that enters the basin from the Potter Street drain. Thus, it is not surprising that the quality of sediment currently present in Aquatic Park is intermediate between the values reported for the Crandall Creek/DUST Marsh, and within the range seen in Bay creeks and sloughs that are currently influenced by urban stormwater runoff. Should a stormwater treatment facility be constructed, sediment quality in the Model Yacht Basin would likely be similar to current sediment quality and remain within the range of Crandall Creek/DUST Marsh sediment quality.

Potential Impacts to Aquatic Life. In recent years the regulatory, environmental, and scientific communities have become increasingly concerned about potential deleterious effects that pollutants from nonpoint sources in urban areas can have on water quality and aquatic life. Monitoring conducted nationwide as well as in the San Francisco Bay area indicate that heavy metals, complex organic compounds, oil and grease, nutrients, and oxygen-demanding substances are contributed by urban stormwater runoff. These pollutants may present a threat to valuable aquatic ecosystems and restrict beneficial uses. There is however great uncertainty regarding the relationship between sediment quality and wildlife impacts; no standards exist by which to evaluate sediment quality to establish if they are "clean" or will adversely affect aquatic life.

Despite the absence of standards, evaluation of sediment quality in Figure 3-5 is possible based on information from the Crandall Creek/DUST Marsh and other studies summarized below.

- The potential bioavailability of trace metals within the sediment of the Crandall Creek/DUST Marsh was estimated based on a sequential metals extraction scheme. Metals in the sediment were separated into five fractions according to the degree that the metals are bound to the sediment. The three most available fractions are considered to be bioavailable, that is, available for uptake by organisms. The results indicate that the bioavailability in sediments decrease between the inlet and outlet of the marsh. Deeper sediments contain less bioavailable metals than more shallow sediments. Conclusions in the report indicate that the sediment concentrations of copper, lead, and zinc are low within the marsh and have low bioavailability.

- The Washington State Department of Ecology adopted Sediment Management Standards, Chapter 173-204 WAC, April, 1991 in response to these concerns for the purpose of reducing and ultimately eliminating adverse effects on biological resources and significant health threats to humans from surface sediment contamination. The Sediment Management Standards are intended to:

  a. Establish standards for the quality of surface sediments.

  b. Provide a basis for management and reduction of pollutant discharges.

  c. Provide a management and decision process for the cleanup of contaminated sediments.

  These Standards are included as a reference in Figure 3-5 and are referred to as the Puget Sound Standards. The Puget Sound Standards cannot be used as criteria or objectives in San Francisco Bay. However, the San Francisco Bay Regional Board has indicated they can be used as guidelines to evaluate whether sediment at a site would probably not have toxic effects, would possibly have toxic effects or would probably have toxic effects. If guidelines indicate that chemicals in sediment possibly or probably would have toxic effects, additional studies should be conducted. These studies should include sediment toxicity tests and bioaccumulation tests if the chemical is know to bioaccumulate.

- The Development of an Integrated Approach to the Assessment of Sediment Quality in Florida was prepared for the Florida Department of Environmental Regulation by MacDonald Environmental Services, Ltd. in 1992. The no observable effect level (NOEL) presented in Figure 3-5.

Figure 3-5 shows that the Florida NOEL is exceeded currently in Aquatic Park sediments for cadmium, copper, lead, mercury nickel and zinc, and the higher Puget Sound Standards are exceeded for just one metal (zinc). Since the quality of sediment in the Model Yacht Basin is not expected to be degraded substantially by using the basin to treat stormwater, no adverse effects are expected to occur that are not already occurring (if any). Thus, stormwater treatment in the Model Yacht Basin would probably not significantly increase the risk of adverse environmental impacts.

5.2.4 Consistency With Master Plan

The Aquatic Park Master Plan calls for removal of the berm between the Model Yacht Basin and the Radio Tower Pond. Retaining this berm and the Model Yacht Basin for stormwater treatment would thus be inconsistent with the Master Plan. However, the hydraulic analysis described in Section 4.2.3 of this report indicates that removing the berm would result in flooding; and so the berm was assumed to remain with implementation of the Master Plan. The analysis of environmental impacts of stormwater treatment in Section 5.2.3 indicates that stormwater treatment is expected to be compatible with habitat objectives of the Master Plan.

Section 6

Balancing Aquatic Park Water Quality

The purpose of this section is to describe how a water quality management alternative and a stormwater treatment alternative could be implemented simultaneously. However, a water quality management alternative could be selected and implemented without implementing a stormwater treatment alternative, and vice versa.

Improvement of water quality in Aquatic Park and operation of the stormwater treatment facility would require seasonal operational changes. Operational modes are shown for the dry season and wet season in Figures 6-1, 6-2, and 6-3 for water quality management alternatives 1, 2, and 3, respectively.

In the summer, suspended algae growth will be reduced through increased circulation. This increased circulation is beneficial to the Model Yacht Basin as well as the Main Lagoon. Therefore, since very little stormwater is to be treated in the summer, the Model Yacht Basin will be hydraulically connected to the Main Lagoon and circulation through the Park will be achieved primarily through an exchange of water from the Bay through the Main Lagoon into the Model Yacht Basin and out to the Bay through the Potter Street drain.

The winter operation modes will limit stormwater from entering the Main Lagoon from Potter Street drain thereby reducing the introduction of bacteria from the stormwater. This will reduce circulation in the Main Lagoon in winter, however, during this time, suspended algae growth is limited due to reduced sunlight.

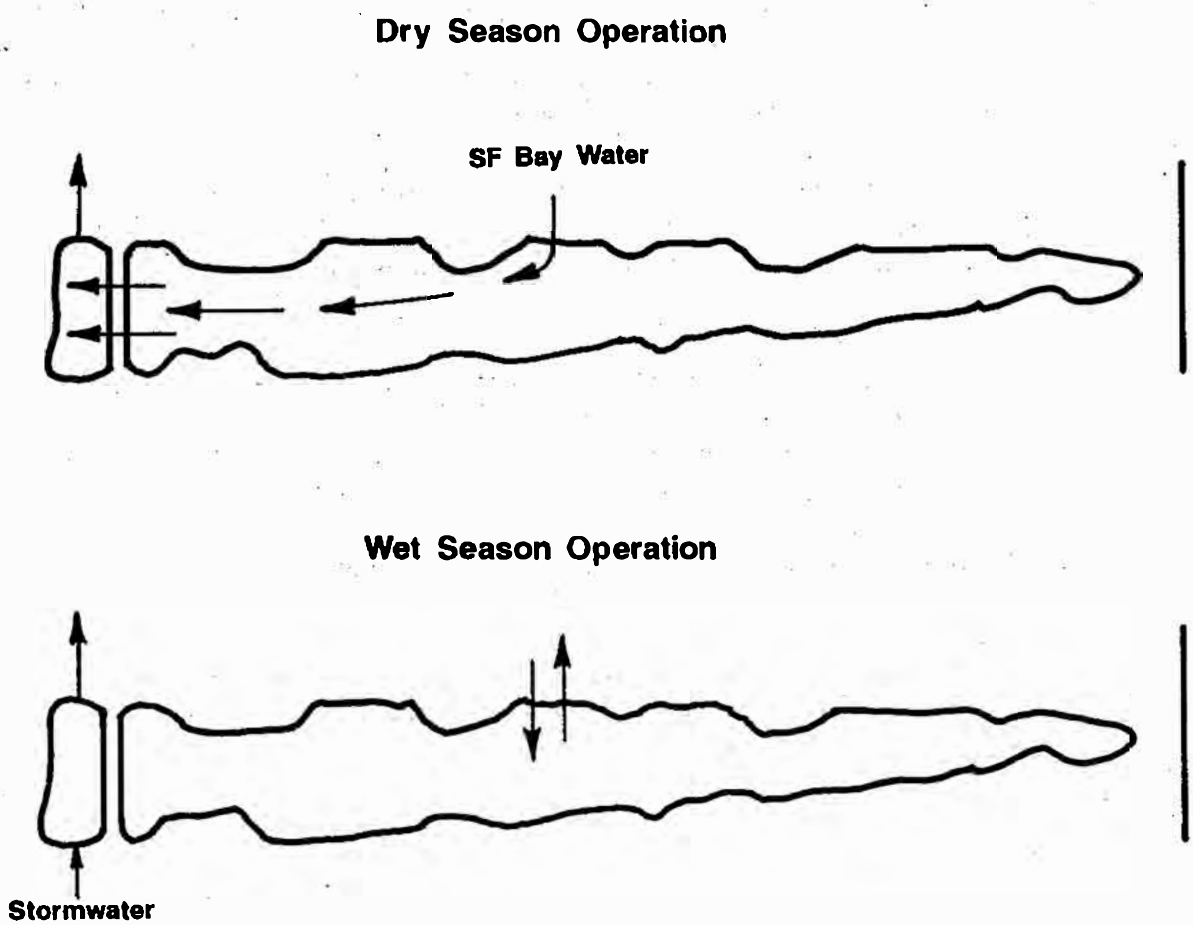


Figure 6-1
OPERATION MODES OF WATER QUALITY ALTERNATIVE 1 WITH STORMWATER TREATMENT
Aquatic Park Water Quality Improvement Study

CH2M HILL

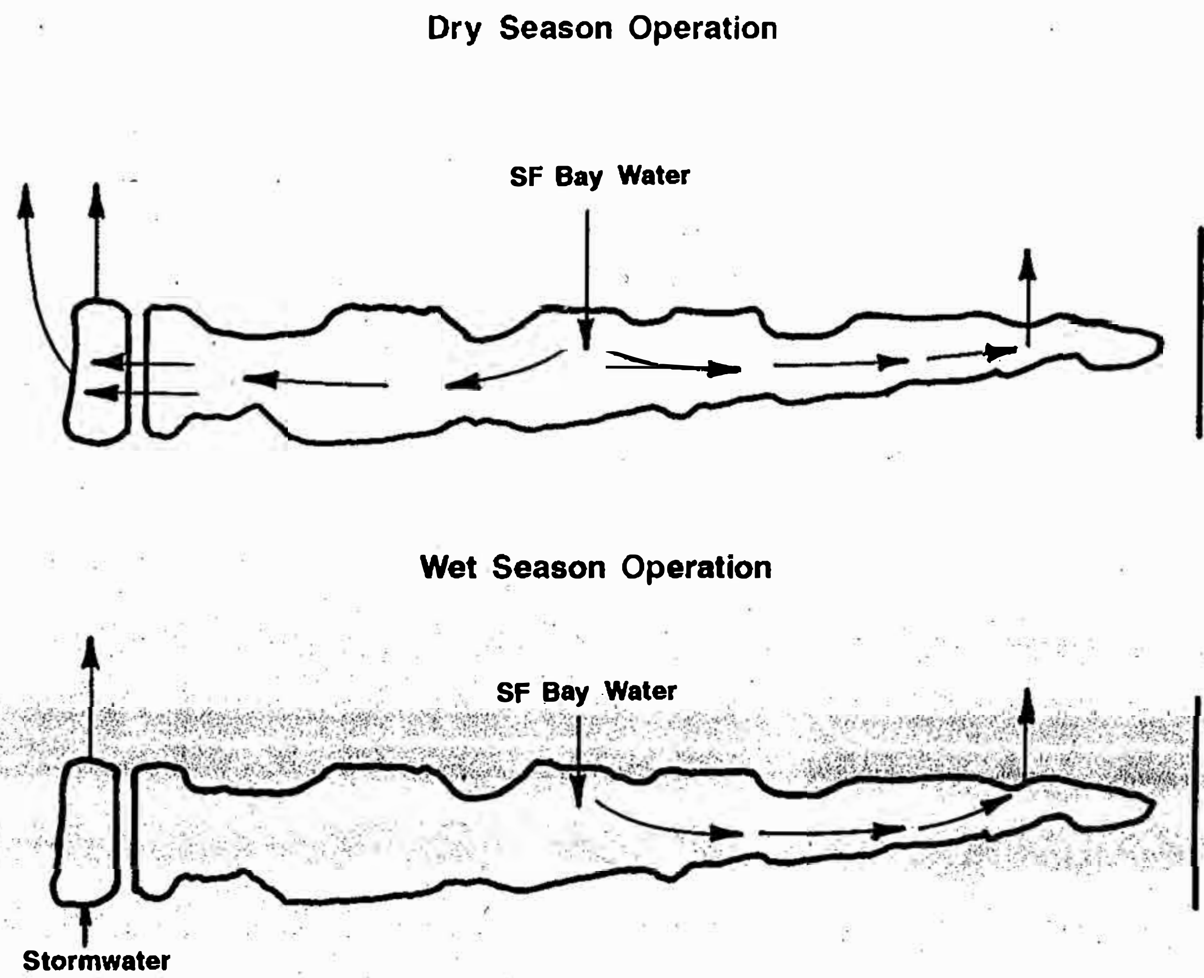


Figure 6-2
OPERATION MODES OF WATER QUALITY ALTERNATIVE 2 WITH STORMWATER TREATMENT
Aquatic Park Water Quality Improvement Study

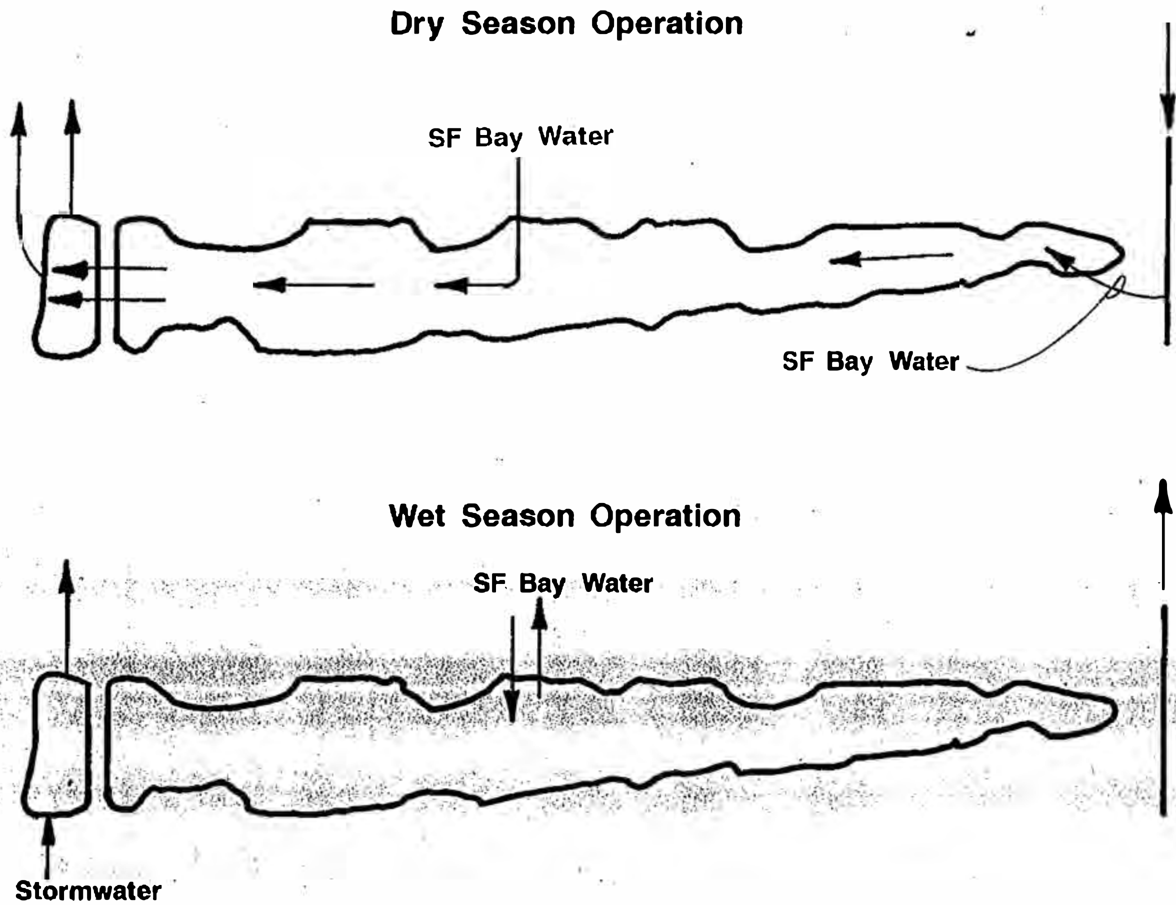


Figure 6-3
OPERATION MODES OF WATER QUALITY ALTERNATIVE 3 WITH STORMWATER TREATMENT
Aquatic Park Water Quality Improvement Study

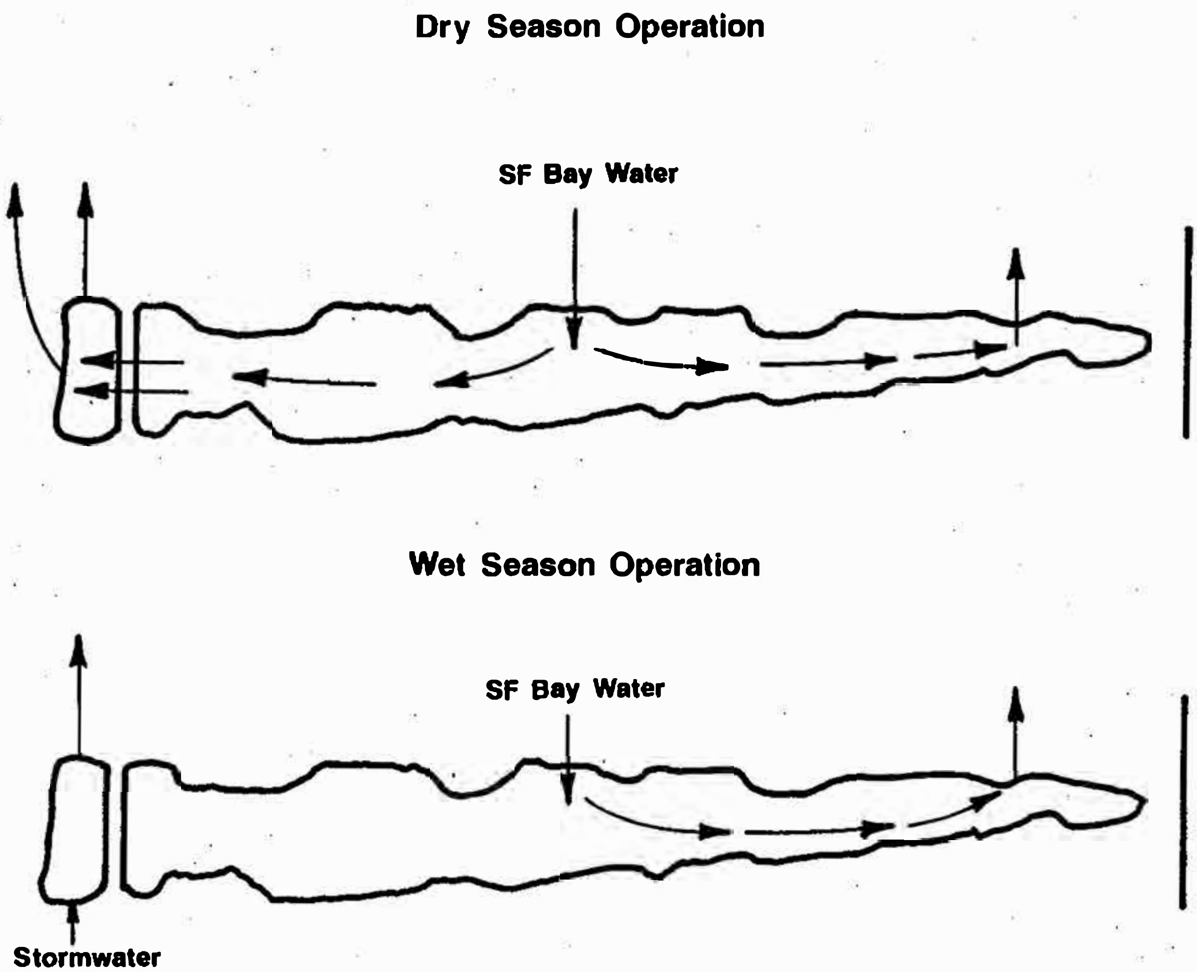
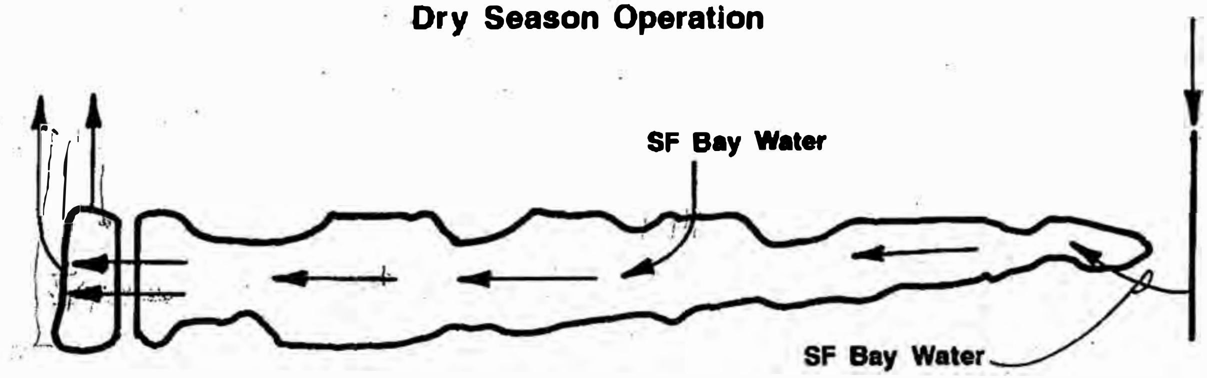


Figure 6-2
OPERATION MODES OF WATER QUALITY ALTERNATIVE 2 WITH STORMWATER TREATMENT
Aquatic Park Water Quality Improvement Study

Dry Season Operation



Wet Season Operation

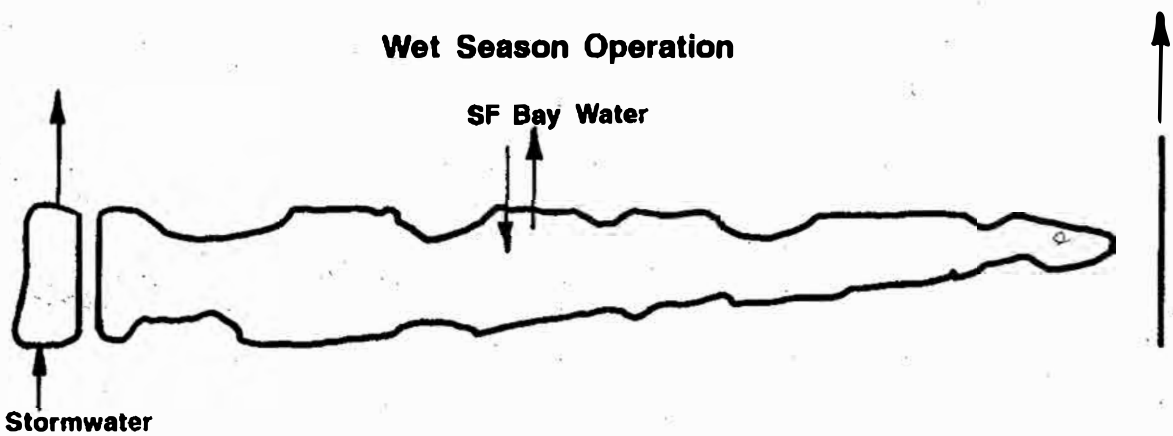


Figure 6-3
OPERATION MODES OF WATER QUALITY ALTERNATIVE 3 WITH STORMWATER TREATMENT
Aquatic Park Water Quality Improvement Study

Section 7
Recommendations

Implementation of water quality management alternatives and stormwater treatment alternatives is not currently mandated to comply with environmental regulations. The City should implement a plan to manage water quality and to treat stormwater based on the goals and objectives in the Aquatic Park Master Plan and fiscal considerations.

7.1 Water Quality Management Alternatives

The alternatives under consideration are briefly summarized below:

Alternative 1	No alteration/rehabilitation of existing hydraulic control structures Minor dredging on Bay side to maintain tidal tube gates Potential sign posting program about natural processes in lagoon No harvesting or dredging in Park
Alternative 2A	Rehabilitation of existing facilities to allow original function Dredging of Main Lagoon to provide a minimum depth of 10 feet
Alternative 2B	Rehabilitation of existing facilities to allow original function Harvesting of rooted aquatic plants and algae periodically
Alternative 3A	Modify existing structures to allow increased flow Dredging of Main Lagoon to provide a minimum depth of 10 feet
Alternative 3B	Modify existing structures to allow increased flow Harvesting of rooted aquatic plants and algae periodically

Alternative 3A is the preferred alternative for improved water quality because of the additional flow through the Park during the dry season and the decreased number of rooted aquatic plants. However, it is also the most costly alternative. Until the City is able to designate fiscal resources for implementation of Alternative 3A, Alternative 1 should be implemented.

The following decision process is recommended for the City to determine the appropriate course of action for management of water quality in the Park.

- Implement Alternative 1. Maintain the tide tubes to keep prevent clogging.
- Identify the full range of desired usage of Aquatic Park and determine which usages are compatible with each other. From this decision, determine if rooted aquatic plants should be controlled.

- If control of the plants is desirable, a strategy should be selected (harvest, dredge, or harvest until dredging can be implemented).

- If dredging is used to control rooted aquatic plants, Alternative 2A could adequately maintain water quality. If additional flow is needed in the future to control algae, Alternative 3A could be implemented at a later time.

- If harvesting is used to control rooted aquatic plants, Alternative 3B would likely be necessary to adequately maintain water quality.

7.2 Stormwater Treatment Alternatives

While some stormwater occurs with the Park's current configuration, both the Full Treatment Alternative and the Treatment/Habitat Alternative would increase the volume of stormwater treated. Both alternatives are also consistent with the objectives and goals of the Aquatic Park Master Plan and this study found no significant water quality barriers to implementing either of these alternatives.

The difference between the two alternatives is essentially stormwater volume versus increased wildlife habitat. The City should prioritize potential benefits of a modified Model Yacht Basin and consider implementing one of these alternatives.

Section 8
References

Engineering-Science, Inc. 1991. 1991 Annual Report, Lake Management Report for the Lake Merritt Estuary, Oakland, California. Alameda County Flood Control and Water Conservation District.

Katznelson, R., W.T. Jewell and S.L. Anderson. June, 1993. Spatial and Temporal Variations in Toxicity in a Marsh Receiving Urban Runoff. University of California, Lawrence Berkeley Laboratory, Energy and Environment Division.

Larry Walker Associates, Inc. and Kinnetic Laboratories, Inc. 1984. South Bay Dischargers Authority Water Quality Monitoring Program. South Bay Dischargers Authority.

MacDonald Environmental Services, Ltd. 1992. Development of an Integrated Approach to the Assessment of Sediment Quality in Florida. Florida Department of Environmental Regulation.

MPA Design. June, 1990. City of Berkeley Aquatic Park Master Plan.

Terrasearch, Inc. 1992. Preliminary Environmental Assessment of Sediments in Calabazas Creek Flood Control Project; Bayshore Freeway to Holding Basin Santa Clara, California. Santa Clara Valley Water District.

US Army Corps of Engineers. November, 1992. Alcatraz Environs Sediment Characterization, Summary of Available Sediment Testing.

US Geologic Survey. 1988. Water Resources Data for California. Volume 3.

Washington State Department of Ecology. April, 1991. Sediment Management Standards. Chapter 173-204 WAC. "Puget Sound Standards".

Woodward-Clyde Consultants. 1991. Crandall Creek-Demonstration Urban Storm Treatment Marsh Study (DUST Marsh Study).

Woodward-Clyde Consultants. 1991. Loads Assessment Report Volume I. Santa Clara County Nonpoint Source Control Program.

Woodward-Clyde Consultants. 1991. Loads Assessment Summary Report. Alameda County Urban Runoff Clean Water Program.

Woodward-Clyde Consultants. 1991. NPDES Special Study Requirements Two-Year Report, 1989- 1991. City of Palo Alto.

Section 8
References

Engineering-Science, Inc. 1991. 1991 Annual Report, Lake Management Report for the Lake Merritt Estuary, Oakland, California. Alameda County Flood Control and Water Conservation District.

Katznelson, R., W.T. Jewell and S.L. Anderson. June, 1993. Spatial and Temporal Variations in Toxicity in a Marsh Receiving Urban Runoff. University of California, Lawrence Berkeley Laboratory, Energy and Environment Division.

Larry Walker Associates, Inc. and Kinnetic Laboratories, Inc. 1984. South Bay Dischargers Authority Water Quality Monitoring Program. South Bay Dischargers Authority.

MacDonald Environmental Services, Ltd. 1992. Development of an Integrated Approach to the Assessment of Sediment Quality in Florida. Florida Department of Environmental Regulation.

MPA Design. June, 1990. City of Berkeley Aquatic Park Master Plan.

Terrasearch, Inc. 1992. Preliminary Environmental Assessment of Sediments in Calabazas Creek Flood Control Project; Bayshore Freeway to Holding Basin Santa Clara, California. Santa Clara Valley Water District.

US Army Corps of Engineers. November, 1992. Alcatraz Environs Sediment Characterization, Summary of Available Sediment Testing.

US Geologic Survey. 1988. Water Resources Data for California. Volume 3.

Washington State Department of Ecology. April, 1991. Sediment Management Standards. Chapter 173-204 WAC. "Puget Sound Standards".

Woodward-Clyde Consultants. 1991. Crandall Creek-Demonstration Urban Storm Treatment Marsh Study (DUST Marsh Study).

Woodward-Clyde Consultants. 1991. Loads Assessment Report Volume I. Santa Clara County Nonpoint Source Control Program.

Woodward-Clyde Consultants. 1991. Loads Assessment Summary Report. Alameda County Urban Runoff Clean Water Program.

Woodward-Clyde Consultants. 1991. NPDES Special Study Requirements Two-Year Report, 1989- 1991. City of Palo Alto.

Contents for Appendices

Appendix A
Water Quality
Technical Memorandum

Appendix A
Water Quality Technical Memorandum

Subject: Water Quality Investigation At Berkeley Aquatic Park
Project: Aquatic Park Water Quality Improvement Study
Date: 1 April 1994
Prepared By: Richard W. Maddox
Reviewed By: Meleah S. Ashford, CH2M HILL
David W. Smith, Merritt Smith Consulting

Summary

Water and sediment quality in Aquatic Park and stormwater that flows into Aquatic Park were characterized to provide a basis for evaluating water quality management alternatives.

The limited characterization of conditions in the Park indicates that numeric water quality objectives are being attained and water quality is generally adequate for the beneficial uses of the Park. However, aquatic plants grow abundantly and are responsible for nuisance odor conditions and may impair some beneficial uses such as boating and water-skiing. Although levels of bacteria measured in this study were below the standard for water contact, stormwater discharges to the Park probably cause the standard to be exceeded for several days. Sediment quality is adequate for disposal at the Alcatraz site based on preliminary sediment characterization.

Introduction

The purpose of this technical memorandum is to describe and explain the current water quality conditions of Berkeley Aquatic Park (Park). This document was prepared as part of the Aquatic Park Water Quality Improvement Study.

Aquatic Park Setting

Aquatic Park is located in west Berkeley and is described in Figure 1. The Park is comprised of two interconnected, tidally influenced lagoons (Main Lagoon and Model Yacht Basin), and one basin that is connected only to the Bay (Radio Tower). Recreational uses of the Park include bird-watching, water-skiing, rowing, fishing, frisbee golf, walking and jogging.

The existing system of pipes and gates was designed to flush bay water through all three basins. However, accumulated sediments have restricted circulation. The perception that water quality in the Park is widespread (as reflected in the draft Aquatic Park Master Plan). Odors produced at the Park and the dense populations of rooted aquatic plants appear to contribute to the perception of water quality that is held by the public.

Project Overview

The Aquatic Park Water Quality Improvement Study was conducted to meet two objectives as follows:

1. Describe current water quality conditions in the Park and develop alternatives for improving water quality conditions.

2. Develop and evaluate alternatives for treating stormwater in the Park before discharging to San Francisco Bay.

The Aquatic Park Water Quality Improvement Study consisted of the following components:

- **Characterization of Existing Conditions.** Water and sediment samples were collected for analysis, and an evaluation of hydraulic structures was conducted to provide the basis for developing water quality management alternatives.

- **Development of Hydraulic and Water Quality Model.** A computer simulation of water movement, sediment accumulation and plant growth in the Park was developed as a tool for evaluating alternatives.

- **Identification and Evaluation of Water Quality Management Alternatives.** Strategies for addressing water quality and sedimentation issues were identified and evaluated for effectiveness, cost, feasibility and consistency with Park management objectives.

- **Identification and Evaluation of Stormwater Treatment** reidentified and evaluated for effectiveness, cost, feasibility and consistency with Park management objectives.

The water quality data and evaluation described in this technical memorandum meet the initial objectives of the project by providing water quality information as a basis for development of alternatives for water quality improvement and stormwater treatment.

A water quality monitoring plan was developed at the inception of the project to provide a methodology for conducting sample collection in the Park. A summary of the monitoring plan follows.

Aquatic Park Water Quality Monitoring Plan

The purpose of the monitoring program was to collect data for determining the suitability of water quality to the current and potential uses of the Park, and to provide the information necessary for recommending improvements to water quality. The uses of the Park (contact and non-contact recreation, wildlife habitat, stormwater treatment) are potentially affected by the following water quality issues:

- Bacteria
- Odor
- Aquatic plant growth
- Sedimentation

Bacteria in the Park derive from bird use and stormwater inflows, and excessive levels, if present, would pose a health risk to water contact recreation such as water-skiing. Odor appears to originate from aquatic plant growth which is influenced by the availability of nutrients and light. Excessive plant growth is an aesthetic nuisance and impacts fishing access and water-skiing safety. Sedimentation is due to a combination of using tidal waters for flushing and poor water circulation in the lagoons and affects water-skiing safety and overall water quality. As sedimentation increases, circulation decreases limiting flushing of solids, nutrients and bacteria. Table 1 lists the water quality constituents monitored in the Park and the water quality issues to which each relate.

Table 1
Aquatic Park Water Quality Constituents

Constituent	Related Issue
Solids Total Suspended Solids (TSS)*	Indicates sediment suspension.
Bacteria Total and Fecal Coliform*	Bacteria, affects water contact recreation.
Nutrients Nitrate + Nitrite*	Nutrient source for plant growth.
Ammonia*	Nutrient, can be derived from anoxic sediments.
Total Phosphorus*	Nutrient source for plant growth.
Chlorophyll a	Planktonic algae, indicates plant biomass.
Metals Total Metals (Cd, Cr, Cu, Pb, Ni, Ag, Zn)*	Allows evaluation of attainment of water quality objectives.
Physical Temperature	Affects plant growth.
Salinity	Indicates influence of fresh and salt water sources.
Dissolved Oxygen	Indicates oxygen depletion due to organic decomposition such as aquatic plants.
Secchi Depth	Indicates light availability for plant growth and may indicate sediment accumulation.

* Constituents analyzed in Potter Street sample (including Total Organic Carbon)

Figure 1 identifies the five monitoring locations where water samples were collected. The monitoring locations follow:

- San Francisco Bay near main tide gate system
- North end of Main Lagoon
- South end of Main Lagoon
- Center of Model Yacht Basin
- Center of Radio Tower Pond
- Potter Street drain

Samples were collected to characterize summer conditions when aquatic plants have begun their growth cycle, and late summer/early fall when aquatic plant abundance is highest in the Park. Samples were collected at each monitoring location on 14 July and 5 October 1993.

In high flow conditions (when rainfall is heavy and runoff is high) stormwater runoff from the Potter Street drain is diverted into the Model Yacht Basin. Stormwater runoff quality was characterized to provide baseline data for understanding runoff inputs to the Park and for evaluating the potential effectiveness of stormwater treatment. One rain event was sampled in the late spring (30 May 1993) from the Potter Street drain near Seventh Street.

The monitoring plan described above was modified in early 1994 to include water sample collections intended to characterize winter Park conditions. The samples were collected on 28 February 1994 at each monitoring location.

In addition, sediment samples were collected from the Main Lagoon and the Model Yacht Basin on 28 February 1994. This preliminary assessment of sediments in the Park provides information useful for the investigation of sediment disposal options, and for potential impacts from stormwater treatment. Sediment disposal options (of dredging spoils) are dependent on the quality of sediments relative to the US Army Corps of Engineers testing results at the Corps disposal sites. The sediment samples were analyzed for the following constituents as required in the Corps testing guidelines:

Conventional

- Grain size
- Total Organic Carbon
- Total Recoverable Petroleum Hydrocarbons (TRPH)
- Total Volatile Solids
- Total and Water Soluble Sulfides
- Total Solids/Water Content

Metals

- Metals (Ag, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn)

Organics

- Phthalate esters
- PAHs
- PCBs
- Pesticides
- Butyltins

Data results for water quality and sediment sampling are reported in the section that follows.

Current Water Quality Conditions

Water and sediment samples were collected to ascertain current Aquatic Park water quality conditions. Methodologies for sample collection are described below along with data results and their evaluation.

Methodology

Water quality samples were collected in the Main Lagoon (ML), Model Yacht Basin (MYB), the Radio Tower Pond (RTP) and San Francisco Bay near the ML tide tubes (SFB). Sediment samples were collected in the Main Lagoon and the Model Yacht Basin, and stormwater samples were collected from Potter Street just east of the Park. Table 2 describes the sampling program including dates, locations, and types of samples collected for the project.

Table 2
Aquatic Park Sampling Program

Sampling Date	Sampling Location	Sample Type
30 May 1993	Potter Street storm drain	Stormwater runoff
14 July 1993	ML, MYB, RTP, SFB	Park water quality
5 October 1993	ML, MYB, RTP, SFB	Park water quality
28 February 1994	ML, MYB, RTP, SFB	Park water quality; sediment quality (ML, MYB)

All water quality samples were analyzed by National Environmental Testing, Inc. (NET) in Santa Rosa, CA. Sediment samples were analyzed by ToxScan Inc. in Watsonville, CA. The ToxScan laboratory provided sediment analyses with the low detection limits required by the US Army Corps of Engineers for disposal consideration of dredged material.

Lagoon Water Sampling

Water samples were collected to provide data on water quality conditions over three seasons in the Park. Sampling was conducted on 14 July and 5 October, 1993, and 28 February 1994. Sampling methodology was identical for all three collections, and required two field personnel to conduct as described below. The 28 February data were collected approximately eight days after a rainfall event.

Due to the shallow depth of the Radio Tower Pond and the Model Yacht Basin, an inflatable boat was used to collect water quality samples. The muddy bottom of the lagoons precluded wading. The inflatable was rowed to the center of each lagoon to conduct sampling on the morning of all three sampling dates. Physical parameters (temperature, salinity, and dissolved oxygen) were collected using YSI (brand name) meters calibrated prior to collecting. The probes of the meters were suspended over the side of the boat and just below the surface to collect data. Secchi depths (measure of water clarity) were recorded using a white 12-inch disc attached to the end of a pole (with the exception of the 28 February reading when a piece of paper was used in place of the disc). Results were recorded in a field notebook. Chemical parameters were collected using sample containers supplied by NET that contained the appropriate preservatives when required. Containers were labeled with the location, date and time of the collection. Samples were taken in a consistent manner by submerging the containers approximately one foot below the surface for filling. Containers (with appropriate preservation) were stored in coolers.

A 14-foot aluminum boat with outboard was used to collect samples in the Main Lagoon. The boat was launched from the ramp next to the water-ski area in the early afternoon on each of the three sampling days. Samples were collected in the center of the north and the center of the south ends of the lagoon. Physical and chemical parameters were measured as described above.

Stormwater Sampling

Stormwater samples were collected to provide data on a rainfall event that would represent a characteristic runoff input to the Park. These samples were collected during a moderate rainfall event throughout the night on 30 May 1993. The sampling location on Potter Street was chosen for its close proximity to the Park (making it representative of the type of runoff that would enter the Park) and for reasons of safety and access.

Grab samples were taken to analyze for Total Suspended Solids (TSS) and a composite was made to analyze for the remainder of constituents. Three grab samples were collected at intervals relative to the stormwater flow through the storm drain pipe. A sample was collected at low flow just after the rain began, at the peak flow, and after the rain had stopped when flow was again minimal. Flow was estimated using a Marsh-McBirney velocity meter and water depth measurements. Grab samples were collected using a bucket lowered through a manhole opening. The composite was created by mixing equal volumes of each of the three grab samples. All samples were labeled and stored for transport in containers supplied by NET.

Sediment Sampling

Sediment samples were collected in the Main Lagoon and the Model Yacht Basin on 28 February 1994. These samples were collected concurrently with the water quality sample collection. A sediment coring device made of aged PVC pipe was used to collect the samples. Samples were collected at three locations in the Main Lagoon (north end, middle and south end) and two locations in the Model Yacht Basin (center to the west end, and center to the east end).

The coring device (approximately five inches in diameter) was pushed into the sediment as deeply as possible, the surface end was then capped, and the pipe was pulled to the surface along with a core of sediment. Cores ranged in length from about eight to twelve inches. A plunger was used to push the core onto a clean PVC surface where it was halved longitudinally. One half of each of two cores collected in the Model Yacht Basin was placed in a new zip-loc bag to be submitted as a composite sample. The collection and compositing procedure was repeated at the three Main Lagoon locations. Sediment samples were initially submitted to NET for analysis, but after learning that NET detection limits did not meet the US Army Corps of Engineers requirements, the samples were shipped to ToxScan for analysis.

A chain-of-custody form was completed for all samples collected, and an NET courier picked up the samples each afternoon for processing at their lab in Santa Rosa. Sediment samples were subsequently shipped overnight to ToxScan for analysis. Preliminary results were faxed to Merritt Smith Consulting within four weeks of sample submittal with final results mailed the following week. Results and their analysis are described in the section that follows.

Data Results and Analyses

Data results for water quality sampling (in the three lagoons and Potter Street stormwater), and sediment sampling are summarized in the appendix (Table 3-7) of this technical memorandum. Water quality objectives as defined by the State Water Resources Control Board (SWRCB), were used to evaluate Aquatic Park water quality data.

Water quality issues of concern in the Park have been identified as excessive aquatic plant growth, sedimentation, and bacteria. Plant growth is strongly influenced by the level of nutrients in the water. Nutrients are contributed to the Park primarily via the nutrient-rich waters of the Bay. The presence of solids influences plant growth and sedimentation. Turbid water prevents light penetration and inhibits algal growth. Bacteria sources to the Park include waters from the Bay and stormwater inflows.

Details of the data results follow. Results of the water quality data analysis are grouped for solids, bacteria, nutrients and metals in the Park lagoons and in stormwater. Sediment results follow and are grouped for conventional constituents, metals and organics.

Lagoon Water Sampling

Solids. Lower levels of solids were found in the lagoons than were found in the Bay. Suspended solids settle in the Park due to the limited mixing and poor circulation in the lagoons. Settling of solids from in the Park has resulted in reduced water depth. The shallow water favors the growth of aquatic plants, and algae, and may be a safety issue for water-skiers.

Bacteria are often associated with pathogens harmful to human health and are therefore problematic (even in low concentrations) for the contact recreation occurring in the Park. Therefore, water quality and public health authorities have established standards for water contact recreation and other uses. Bacteria levels were low in the lagoons (0-49 MPN/100ml total coliform), and lower than in the Bay (5-140 MPN/100ml total coliform) on all three dry weather sampling dates, and less than Regional Water Quality Control Board SF Bay Basin Plan objectives for bacteria (240 MPN/100ml total coliform). The low bacteria values detected in February indicate that the level of bacteria is not elevated continuously as a result of stormwater discharge to the Park. However, the level of bacteria in stormwater is higher than in Aquatic Park (see Tables 3, 4, and 5).

During a rainfall event, bacteria levels could be expected to increase significantly in the Model Yacht Basin due to the stormwater inflows from the Potter Street storm drain. This could also occur in the Main Lagoon under high stormflow conditions that would cause the Strawberry Creek drain and techite line to overflow. Bacteria would decline following a storm event due to die off and flushing. The low levels of bacteria in the Park on 28 February following a substantial storm on 20 February indicate the approximate rate of bacteria die-off and flushing.

Nutrient levels (nitrate, ammonia, phosphorus and ammonia) were generally low in the lagoons on all sampling dates. In contrast to phosphorus, the concentration of ammonia, nitrite and nitrate in the Park was generally below the limit of analytic detection, which indicates nitrogen limits the growth of algae. The concentration of nitrogen species was generally greater in the Bay, indicating that the Bay supplies nitrogen to the Park. Water quality objectives for nutrients have only been established for ammonia. Ammonia is a toxicant, and the concentration of ammonia in the Park on all dates was much less than the ammonia objective.

Chlorophyll. Chlorophyll indicates the presence of suspended algae. Chlorophyll values were low on all sampling dates. This appears to be due to uptake of nutrients by the rooted aquatic plants and the filamentous algae that grows in close association with the rooted aquatic plants. Objectionable odors may be caused by living plants and algae, but become more pronounced when plants and algae die and decay in the fall. Removal of the rooted aquatic plants would potentially make the nutrients available for algae growth.

Metals have known toxicity to organisms and the SWRCB objectives provide guidance for evaluating metals toxicity risks. Metals data indicate low levels in the lagoons relative to SWRCB objectives for aquatic life and human health. In the Bay, the copper objective was exceeded in July (see Table 1). Rainfall events that produce an overflow of stormwater from the Potter Street storm drain would contribute significant levels of metals to the lagoons and potentially exceed SWRCB objectives.

Stormwater Sampling

Solids data are characteristically high in the stormwater grab sample taken in the beginning of the rainfall event (see Table 6). As the storm progressed, TSS decreased reflecting the "first flush" nature of the grab samples and was lowest at the end of the storm after most of the solids had been flushed from paved areas. Stormwater overflow from the Potter Street storm drain transports these solids to the Model Yacht Basin in potentially high concentrations.

Bacteria concentrations are high in the composite sample owing to the urban runoff that transports animal waste and other sources of bacterial contamination. These high concentrations of bacteria indicate the likely presence of pathogens harmful to humans. Stormwater overflows to the Park transport bacteria to the Main Lagoon where water contact recreation is common.

Nutrient levels are also high in the stormwater composite sample (much higher than background levels in the lagoons) creating the potential for increased plant and algal growth with stormwater inflows to the Park.

Metals data from the stormwater composite sample exceed four of nine SWRCB objectives. As with solids, nutrients and bacteria, stormwater inflows to the Park transport metals to the lagoons potentially affecting aquatic organisms, birds and humans.

Sediment Sampling

Sediment quality data from the Main Lagoon and the Model Yacht Basin are summarized in Table 7. The Park sediment quality data are compared to data from US Army Corps of Engineers collected in the vicinity of their Alcatraz disposal site (known as the Alcatraz Environs). The Environs data were collected at locations near the Alcatraz disposal site and were selected as a reference by the Corps for evaluating the suitability of material for disposal at the Alcatraz site. In the event that dredging is the selected alternative for improving water quality, preliminary sediment characterizations indicate that the sediment quality is suitable for disposal at the Alcatraz site. Additional characterization of sediment quality would be needed as a basis for an application for a discharge permit.

Conclusions

This initial characterization of conditions in the Park indicates that numeric water quality objectives are being attained and water quality is generally adequate for the beneficial uses of the Park. However, aquatic plants grow abundantly and are responsible for nuisance odor conditions and may impair some beneficial uses such as boating and water-skiing. Although levels of bacteria measured in this study were below the standard for water contact, stormwater discharges to the Park probably cause the standard to be exceeded for several days. Sediment quality is adequate for disposal at the Alcatraz site based on preliminary sediment characterization.

Table 3

Berkeley Aquatic Park Study
Dry Weather Water Quality Monitoring Results

	Units	Main Lagoon North 14-Jul-93 1330 hrs	Main Lagoon South 14-Jul-93 1350 hrs	Model Yacht Basin 14-Jul-93 1455 hrs	Radio Tower Pond 14-Jul-93 1535 hrs	SF Bay 14-Jul-93 1620 hrs	SWRCB Water Quality Objectives*
Total Suspended Solids (TSS)	mg/L	<4	18	16	32	130	
Total Coliform	MPN100ml	2	8	49	<2	5	240
Fecal Coliform	MPN100ml	2	8	49	<2	2	200
Nitrate, as N	mg/L	0.03	0.03	0.03	<0.03	0.18	
Nitrite, as N	mg/L	<0.03	<0.03	<0.03	<0.03	<0.03	
Ammonia, as N	mg/L	0.09	0.1	0.08	0.06	0.07	1
Total Phosphorus, as P	mg/L	0.47	0.57	0.15	0.08	0.27	
Chlorophyll a	ug/L	<0.01	<0.01	0.02	0.02	<0.01	
Cadmium	mg/L	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.0093
Chromium	mg/L	<0.003	0.007	0.007	0.006	0.008	0.05
Copper	mg/L	<0.002	0.007	<0.002	<0.002	0.009	0.0049
Lead	mg/L	<0.002	<0.002	<0.002	<0.002	0.005	0.0056
Nickel	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	0.0083
Silver	mg/L	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.0023
Zinc	mg/L	0.011	0.014	0.022	0.012	0.021	0.086
Temperature	degrees C	23.1	22.5	25	28	17	
Salinity	ppt	25.9	26.1	25.1	28.8	24.2	
Dissolved Oxygen (DO)	ppm	7.2	7.1	11.9	13.2	7.4	
Secchi Depth	centimeters	155 (bottom)	108 (bottom)	60	30 (bottom)	35	

* State Water Resources Control Board objectives for Enclosed Bays and Estuaries. Toxicity objectives for metals identified are the lower of the three methods used in SWRCB analyses (4-day average, daily average, and 1-hour), and the lower of Aquatic Life and Human Health objectives. Toxicity objective for ammonia is approximate since the objective is based on pH. Objectives for bacteria appear in the SF Bay Basin Plan of the Enclosed Bays and Estuaries Plan.

Table 4

Berkeley Aquatic Park Study
Dry Weather Water Quality Monitoring Results

	Units	Main Lagoon North 5-Oct-93 1330 hrs	Main Lagoon South 5-Oct-93 1350 hrs	Model Yacht Basin 5-Oct-93 1455 hrs	Radio Tower Pond 5-Oct-93 1535 hrs	SF Bay 5-Oct-93 1620 hrs	SWRCB Water Quality Objectives*
Total Suspended Solids (TSS)	mg/L	<4	4.8	<4	5.6	12	
Total Coliform	MPN100ml	13	<2	49	11	70	240
Fecal Coliform	MPN100ml	13	<2	11	11	17	200
Nitrate, as N	mg/L	0.06	0.06	0.1	<0.03	0.1	
Nitrite, as N	mg/L	<0.03	<0.03	0.03	<0.03	0.03	
Ammonia, as N	mg/L	<0.05	<0.05	0.08	<0.05	0.1	1
Total Phosphorus, as P	mg/L	0.1	0.11	0.12	0.17	0.16	
Chlorophyll a	ug/L	<0.01	<0.01	<0.01	0.02	<0.01	
Cadmium	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	0.0093
Chromium	mg/L	0.01	0.008	0.005	0.005	0.005	0.05
Copper	mg/L	<0.002	<0.002	<0.002	<0.002	<0.002	0.0049
Lead	mg/L	<0.002	<0.002	<0.002	<0.002	<0.002	0.0056
Nickel	mg/L	<0.005	<0.005	<0.005	0.0056	<0.005	0.0083
Silver	mg/L	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.0023
Zinc	mg/L	<0.005	<0.005	0.01	0.01	0.05	0.086
Temperature	degrees C	17.9	17.2	17.6	17	17.2	
Salinity	ppt	29.2	29.2	27.9	29.5	27.8	
Dissolved Oxygen (DO)	ppm	5.9	6.6	6.2	6.6	6.8	
Secchi Depth	centimeters	140	115	83 (bottom)	28 (bottom)	70	

* State Water Resources Control Board objectives for Enclosed Bays and Estuaries. Toxicity objectives for metals identified are the lower of the three methods used in SWRCB analyses (4-day average, daily average, and 1-hour), and the lower of Aquatic Life and Human Health objectives. Toxicity objective for ammonia is approximate since the objective is based on pH. Objectives for bacteria appear in the SF Bay Basin Plan of the Enclosed Bays and Estuaries Plan.

Table 5

Berkeley Aquatic Park Study
Dry Weather Water Quality Monitoring Results

	Units	Main Lagoon North 28-Feb-94 1250 hrs	Main Lagoon South 28-Feb-94 1333 hrs	Model Yacht Basin 28-Feb-94 0930 hrs	Radio Tower Pond 28-Feb-94 1030 hrs	SF Bay 28-Feb-94 1432 hrs	SWRCB Water Quality Objectives*
Total Suspended Solids (TSS)	mg/L	36	36	47	12	56	
Total Coliform	MPN100ml	33	2	49	11	140	240
Fecal Coliform	MPN100ml	11	<2	<2	7	22	200
Nitrate, as N	mg/L	<0.03	<0.03	<0.03	<0.03	0.21	
Nitrite, as N	mg/L	<0.03	<0.03	<0.03	<0.03	<0.03	
Ammonia, as N	mg/L	<0.05	<0.05	<0.05	0.05	<0.05	1
Total Phosphorus, as P	mg/L	0.08	0.12	0.12	0.12	0.15	
Dissolved Phosphorus	mg/L	0.04	0.06	0.17	0.05	0.11	
Chlorophyll a	ug/L	<0.01	<0.01	0.02	0.01	<0.01	
Cadmium	mg/L	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.0093
Chromium	mg/L	0.006	0.007	0.005	0.006	0.006	0.05
Copper	mg/L	<0.005	<0.005	<0.005	0.01	<0.005	0.0049
Lead	mg/L	<0.002	<0.002	0.002	0.003	<0.002	0.0056
Nickel	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	0.0083
Silver	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	0.0023
Zinc	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	0.086
Temperature	degrees C	15.1	15.2	13.8	13.1	15.1	
Salinity	ppt	20.5	20.4	21.2	19.5	23.5	
Dissolved Oxygen (DO)	ppm	9.5	8.9	12	9.1	9.5	
Secchi Depth	centimeters	(bottom)	60 (bottom)				

* State Water Resources Control Board objectives for Enclosed Bays and Estuaries. Toxicity objectives for metals identified are the lower of the three methods used in SWRCB analyses (4-day average, daily average, and 1-hour), and the lower of Aquatic Life and Human Health objectives. Toxicity objective for ammonia is approximate since the objective is based on pH. Objectives for bacteria appear in the SF Bay Basin Plan of the Enclosed Bays and Estuaries Plan.

Table 6

Berkeley Aquatic Park Study
Wet Weather Water Quality Monitoring Results

	Units	Potter Street 30-May-93 1915 hrs	Potter Street 30-May-93 2200 hrs	Potter Street 31-May-93 0030 hrs	Potter Street 30-31-May-93 Composite	SWRCB Water Quality Objectives*
Total Suspended Solids (TSS)	mg/L	250	70	15		
Total Coliform	MPN100ml				2,400,000	240
Fecal Coliform	MPN100ml				120,000	200
Nitrate, as N	mg/L				0.48	
Nitrite, as N	mg/L				0.06	
Ammonia, as N	mg/L				0.31	1
Total Phosphorus, as P	mg/L				0.48	
Total Organic Carbon (TOC)	mg/L				20	
Cadmium	mg/L				<0.0005	0.0093
Chromium	mg/L				0.003	0.05
Copper	mg/L				0.036	0.0049
Lead	mg/L				0.045	0.0056
Mercury	mg/L				<0.0005	0.0021
Nickel	mg/L				0.0084	0.0083
Selenium	mg/L				<0.005	0.071
Silver	mg/L				<0.001	0.0023
Zinc	mg/L				0.23	0.086

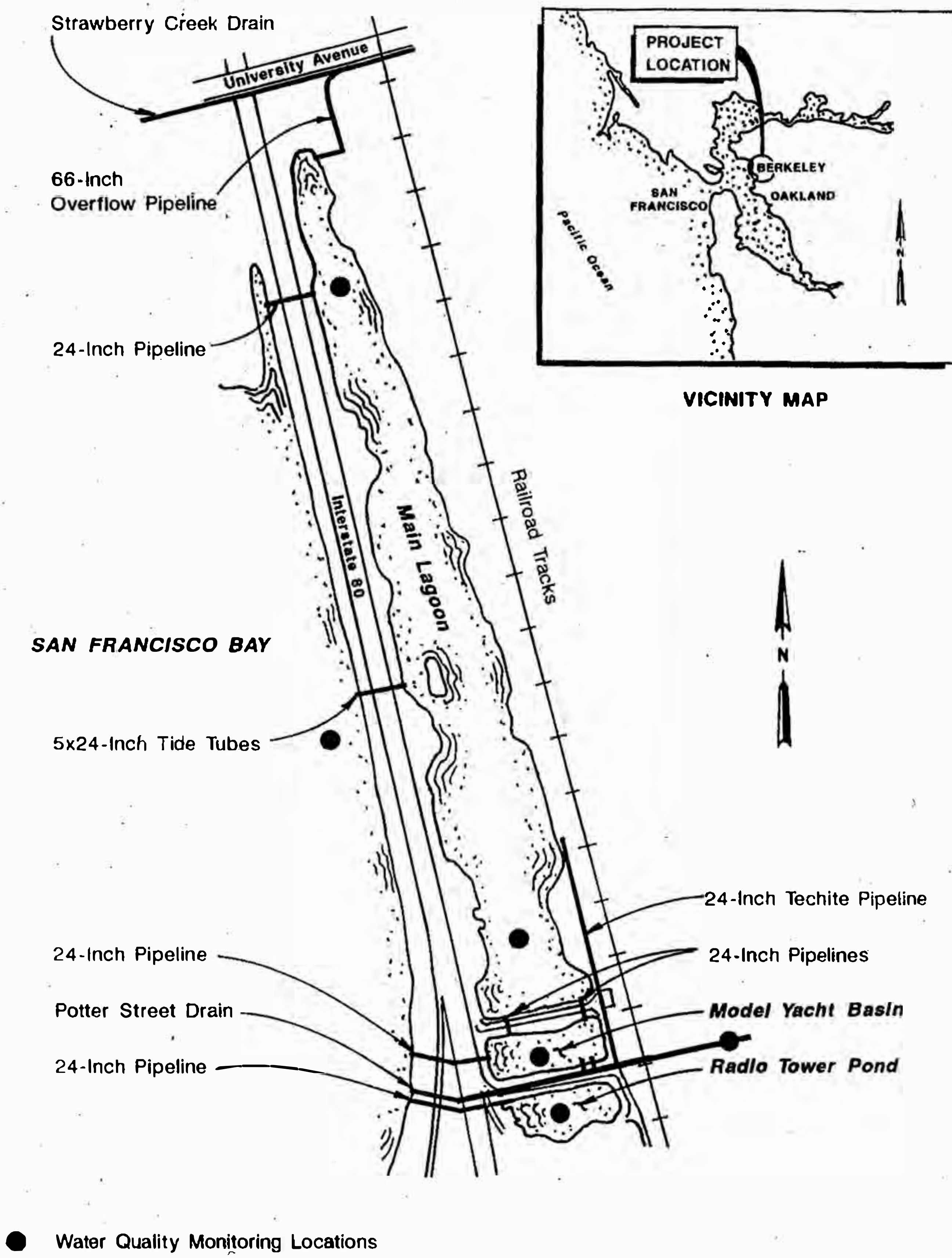
* State Water Resources Control Board objectives for Enclosed Bays and Estuaries. Toxicity objectives for metals identified are the lower of the three methods used in SWRCB analyses (4-day average, daily average, and 1-hour), and the lower of Aquatic Life and Human Health objectives. Toxicity objective for ammonia is approximate since the objective is based on pH. Objectives for bacteria appear in the SF Bay Basin Plan of the Enclosed Bays and Estuaries Plan.

Table 7

Berkeley Aquatic Park Study
Sediment Quality Monitoring Results

	Units	Main Lagoon	Model Yacht Basin	Alcatraz Environs Low	Alcatraz Environs High
Conventionals:					
Grain Size					
gravel (>2000um)	%	0.0	0.0	0.00	17
sand (62.5-2000um)	%	30.0	28.0	91.00	81
silt (3.9-62.5um)	%	41.0	50.0	3.00	1
clay (<3.9um)	%	29.0	22.0	6.00	1
Total Organic Carbon	%	1.8	1.9	0.03	0.19
Oil & Grease	ppm	550.0	460.0	1.22	175.14
Total Volatile Solids	%	5.8	5.3	1.32	2.6
Total Petroleum HCs	ppm	110.0	180.0	<0.6	8
Metals:					
Arsenic	ppm	11.0	15.0	1.80	13.2
Cadmium	ppm	1.9	1.6	0.02	0.35
Chromium	ppm	140.0	120.0	19.80	156
Copper	ppm	66.0	73.0	2.70	12.4
Lead	ppm	170.0	220.0	2.30	14.4
Mercury	ppm	0.83	1.0	0.01	0.16
Nickel	ppm	73.0	64.0	12.30	40.7
Selenium	ppm	0.2	0.2	<.1	0.41
Silver	ppm	1.2	2.2	0.02	0.1
Zinc	ppm	240.0	300.0	12.00	106.8
Organics:					
Monobutyltins	ppb	<1	<1	ND	<1.3
Dibutyltins	ppb	9.0	6.0	ND	0.6
Tributyltins	ppb	9.0	4.0	ND	1.1
PCBs	ppb	150.0	140.0	ND	ND
Chlorinated Pesticides*					
4,4'-DDE	ppb	8.2	12.0	ND	ND
PAHs					

* All Park data non-detectable for pesticides except for 4,4'-DDE, all Environs data non-detectable.



Appendix A - Figure 1
SITE MAP
Aquatic Park Water Quality
Improvement Study

CH2M HILL

BAW35974.AI.60

Appendix B
Hydraulic and Water Quality Model Development Technical Memorandum

APPENDIX B

DEVELOPMENT OF HYDRODYNAMIC AND WATER QUALITY MODELS OF BERKELEY AQUATIC PARK

Introduction

This appendix describes the computer models and methodology used in the numerical model evaluation of the water quality management and storm water treatment alternatives and documents the assumptions used in the analysis. It is designed to augment the information contained in the body of the report and is not intended as a "stand alone" document. Therefore, it will be necessary to refer to specific tables and figures contained in the body of the report. The following sections describe the models used in the analysis along with the assumptions made during their application.

Model Descriptions

Two basic types of numerical models were used for the study; a one-dimensional link-node hydrodynamic model, and a set of two-dimensional depth-averaged finite element models for flow, water quality and sediment transport analysis.

The "link-node" hydrodynamic module is a branched one-dimensional formulation, which simulates average velocity and flow in the cross-section of each channel (model link) and average stage at each volume element (model node). A node generally represents half the volume of the channels connecting to the node. Nodes are interconnected by channels, each characterized by length, cross-sectional area, hydraulic radius (depth), and a bottom friction factor (Mannings's "n" value). In addition to representing flow channels, the model links can be assigned to represent hydraulic structures such as pipes, culverts and weirs where flow through the link element is some function of differential hydraulic head. Tide gates may simulated by restricting flow in the link to a single direction. External flows may be added or subtracted to any node. In estuary modeling, tidal elevations can be specified at designated nodes.

RMA-2 is a generalized free surface hydrodynamic model which is used to compute a continuous temporal and spatial description of fluid velocities and depth throughout a river or estuary system. RMA-4 is a generalized water quality model which computes a temporal and spatial description of conservative and non-conservative water quality parameters. SEDH is a generalized sediment transport model which computes a temporal and spatial description suspended sediment within the water column and bed sediment mass while accounting for deposition to and scour from the bottom sediments. RMA-4 and SEDH use the results from RMA-2 for its description of the flow field. Each model utilizes the same 2-D finite element models representation which subdivides the modeled area into a series of triangular and quadrilateral elements each interconnected at nodal points located at the corners and the mid-side points of the elements.

RMA-2 solves a matrix of differential equations which represent the hydrodynamic response of shallow water waves throughout a river or estuary. They are essentially a hydrodynamic quantification of Newton's second law (force = mass x acceleration) and include the effects of momentum transfer, wind and bottom friction, the Coriolis force and turbulent diffusion. The complex effects of turbulent diffusion are approximated by a simplified turbulent diffusion analogy (eddy diffusion). The equations are solved by the finite element method. The prototype system is represented by a network of line, triangle and quadrilateral elements. Typical applications have included: San Francisco Bay, CA; Cape Fear, NC; Atchafalaya Delta and Bay, LA; Columbia River Estuary, OR; and Pearl River, MS. RMA-2 is used as the hydrodynamics module of the U.S. Army Corps of Engineers TABS-2 modeling package.

RMA-4 solves a matrix of differential equations representing the conveyance of dissolved or suspended materials by advection and turbulent mixing and are derived from a statement of conservation of mass. The simplified approach of eddy diffusion is used to approximate the complex process of time dependent mixing by turbulent mixing. The model was originally developed under contract to the Corps of Engineers, and has been established as an integral part of the Corps' TABS-2. RMA-4 permits simulation of several water quality variables including temperature, dissolved oxygen, BOD, coliform bacteria, the nitrogen and phosphorous species, phytoplankton and up to 6 linked, non-conservative constituents may be defined by the user. For this application, analysis was limited to computation of hydraulic residence time (i.e., length of time the water has resided in the Park). The equations are solved by the finite element method as in RMA-2. The model has been used for simulating water quality constituents in lakes, rivers, estuaries and groundwater systems using steady-state and dynamic flow regimes. Typical applications have included: Water Quality modeling in San Francisco Bay, CA, Temperature distribution for Johnsonville Power Station, and Oil slick transport in Suisun Bay - Sacramento Delta, CA.

SEDH solves a matrix of differential equations representing the transport of suspended sediment particles by advection and turbulent mixing. Velocities and depths computed by the RMA-2 flow model are used to define transport of the suspended material and to develop bed shear stresses. Cohesive sediments (clay) remain in suspension as long as the bed shear stress exceeds the critical shear stress for deposition. Once on the bottom, the structure of the cohesive sediment beds change with time and overburden, such that a greater critical shear stress is required for erosion and resuspension. The distribution of non-cohesive sediments (sands and coarse silts) in suspension varies with depth. The rate of change of the non-cohesive sediment bed is based on the near bottom concentration and the ratio of bed shear stress to critical shear stress. The model was originally developed under contract to the Corps of Engineers, and has been established as an integral part of the Corps' TABS-2. The model has been used for simulation of sediment transport and shoaling in lakes, rivers and estuaries. Typical applications include prediction of shoaling and scour rates at the mouth of the Columbia River, within Harry S. Truman Reservoir, in Fisherman's Wharf Harbor in San Francisco Bay, and within the proposed Lighthouse and Miller Park Marinas in the Sacramento-San Joaquin River Delta.

Model Evaluation of Water Quality Management Alternatives

Evaluation of water quality management alternatives involved a three step process. Preliminary screening of alternatives was performed using the link-node hydrodynamic model. A typical link-node model representation of the Berkeley Aquatic Park is presented in Figure B-1. Intertidal flows through, and stages within the Aquatic Park for mean, spring and neap tide conditions were computed to determine appropriate structure sizes. The maximum hydraulic residence time was estimated as the average Park volume divided by the mean flow through rate. Based on the maximum hydraulic residence time and average depth, the potential for excessive algae concentrations was computed based on light limitation in a vertically mixed water column. Typical summertime water temperatures and turbidities and unlimited nutrients were assumed. As an independent check on the maximum hydraulic residence time estimation, the identical conditions were simulated using 2-D hydrodynamic (RMA-2) and water quality model (RMA-4).

Modeling Approach

Flow velocities within the Aquatic Park are very low due to the constraints of the system of pipes and gates connecting the Park to the Bay. The low velocities result in essentially no head losses except in the various pipes. Therefore, accurate model predictions are predicated on an accurate representation of each of the existing and proposed pipe connections. The following assumptions were made in determining the hydraulic capacity of each structure.

- Minor losses at pipe exits were set at one velocity head based on the differential flow velocity
- Minor losses at pipe entrances were set at one half of the velocity head based on differential velocity
- Flow through a pipe could be limited by either inlet or outlet control at various times during the tidal cycle and model accommodations were provided for both conditions when appropriate (e.g., 5-24" freeway crossing)
- For pipes flowing partially full, step backwater computations were performed to compute flows (e.g., 66" connection to Strawberry Creek)
- Elevation of inverts were based on survey data and as built drawings and uniform slopes between the two ends were assumed except when available indicated grate changes.

The 2-D hydrodynamic (RMA-2) and water quality (RMA-4) models were used to examine flow and residence time within the Aquatic Park in detail. The 2-D network used in these simulations is presented in Figure B-2. The hydrodynamic model was run to establish the flow regime over the tidal cycle for an average tide condition. The flows and depths of water were then input into the water quality model and a residence time simulation performed for a 30 day period. Plots of flow and residence time were used to identify areas of poor circulation for various alternatives,

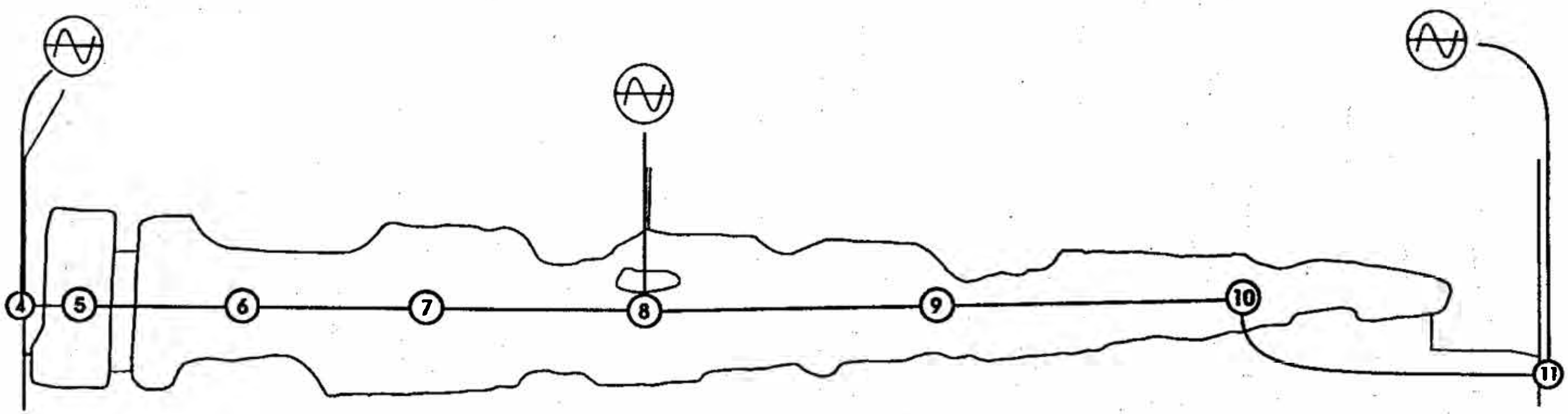


Figure B-1. Typical Link-Node Network for Hydrodynamic Analysis of the Main Lagoon

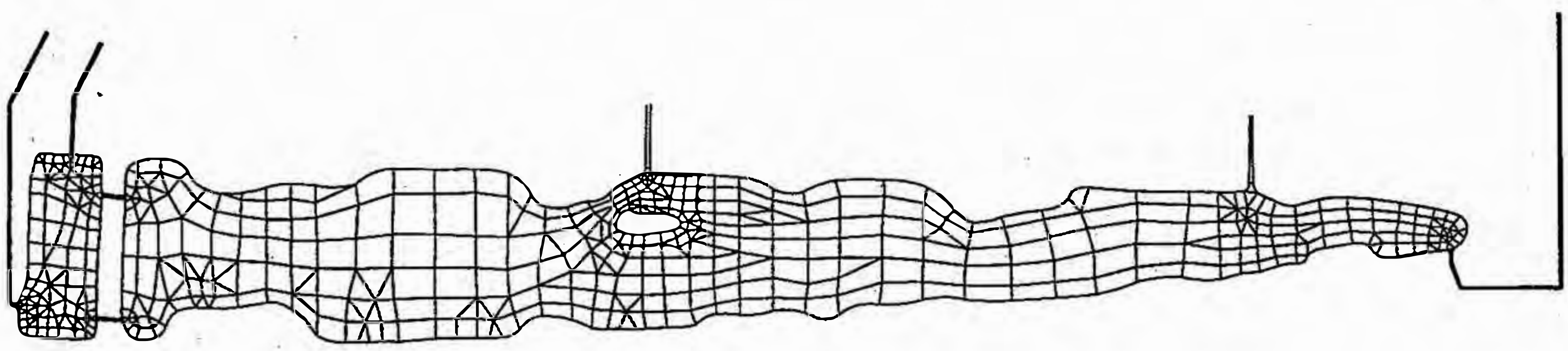


Figure B-2. Finite Element Network for Berkeley Aquatic Park Water Quality Analysis

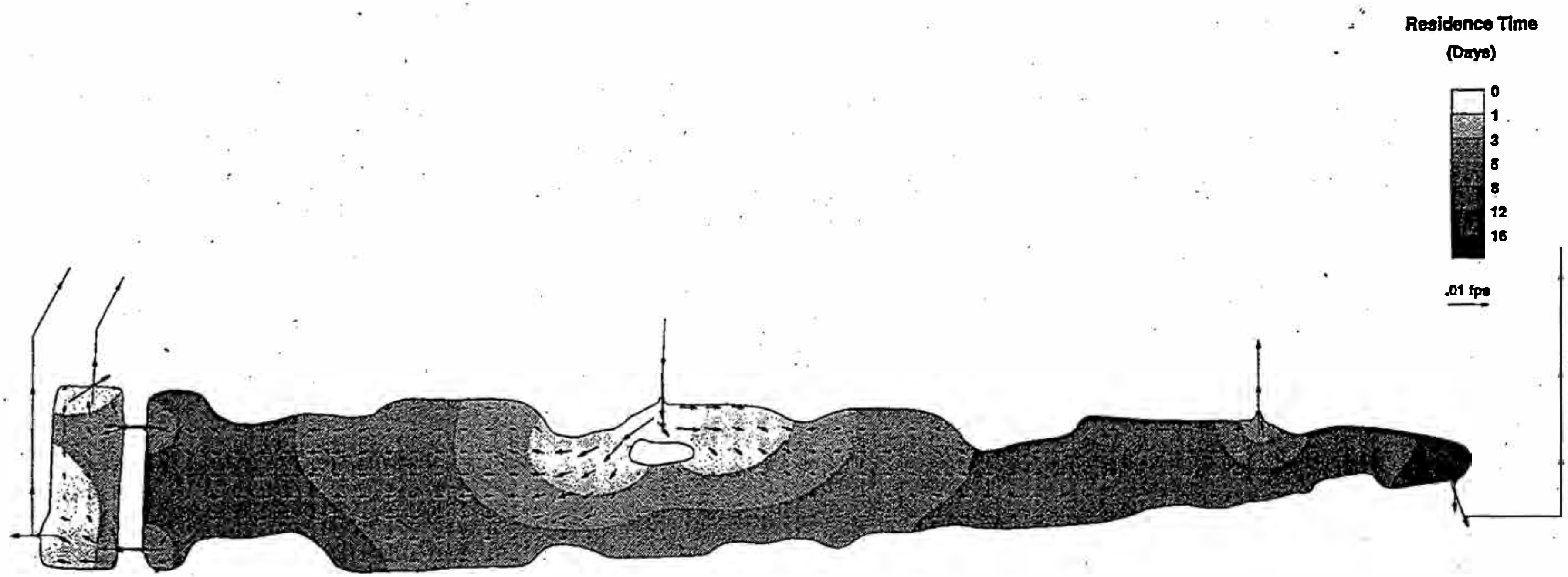


Figure B-3. Residence Time Plot of Aquatic Park for Case with Existing Hydraulic Structures in Full Working Condition and to evaluate how the additon of certain hydraulic structures (such as tide gates) may be used to reduce the overall residence time within the Aquatic Park. Figure B-3 shows a typical residence time plot of the Aquatic Park.

Model Results

The model results are presented in main body of the report in section 4.2.1. This section includes a description of several candidate alternative and the corresponding predictions for mean circulation rate, water surface elevation ranges, algae growth potential and sediment deposition. It should be stressed that the elevation and condition of any pipe is critical in determining its capacity. Prior to adoption of any enhanced circulation scheme, additional survey and water surface data would be required. As a minimum, tide stage recorders should be installed in both the Strawberry Creek and Potter Street storm drains to confirm the hydraulic model results since the water surface elevations at these locations are critical design factors.

Model Evaluation of Storm Water Treatment Alternatives

The proposed storm water treatment alternatives divert storm water, principally from the techite storm drain (Figure 5-1) to the Model Yacht Basin where settling of suspended particles would occur, then back out to the Bay through the existing 24-inch VCP, or out to the Potter Street drain through a new hydraulic structure. In contrast to the process for estimating sedimentation rates in the Main Lagoon for the various proposed water quality management alternatives, there is no historical basis for estimating sedimentation or retention rates in using the Model Yacht Basin as a storm water treatment facility. To fully evaluate the effectiveness of the storm water treatment alternatives, the two-dimensional finite element hydrodynamic (RMA-2) and sediment transport (SEDH) models were used to track the transport and settling of suspended particles in the Model Yacht Basin.

Modeling Approach

During storm events, the pipes connecting the Model Yacht Basin to the Main Lagoon would be closed to flow, isolating the Model Yacht Basin from the rest of the Aquatic Park. Storm water would enter the east end of the Model Yacht Basin by a newly constructed connection to the nearby techite storm drain. Presently, the techite storm drain continues southward and intersects the Potter Street drain. To determine the amount of storm water flow into the Model Yacht Basin, a link-node model of the techite drain, Potter Street drain and Model Yacht Basin system was developed and run for average and 10-year storm flows and mean tide conditions.

The link-node model results provided the inflow, outflow and initial water surface elevation for the two-dimensional hydrodynamic simulation of the Model Yacht Basin. The finite element network representation of the Model Yacht Basin storm water treatment facility is presented in Figure B-4. Dynamic equilibrium was establish by running the simulation for an initial 25-hour tidal cycle prior to the storm event. The simulation was continued for the storm event and for 3 following days until dynamic equilibrium was again attained.

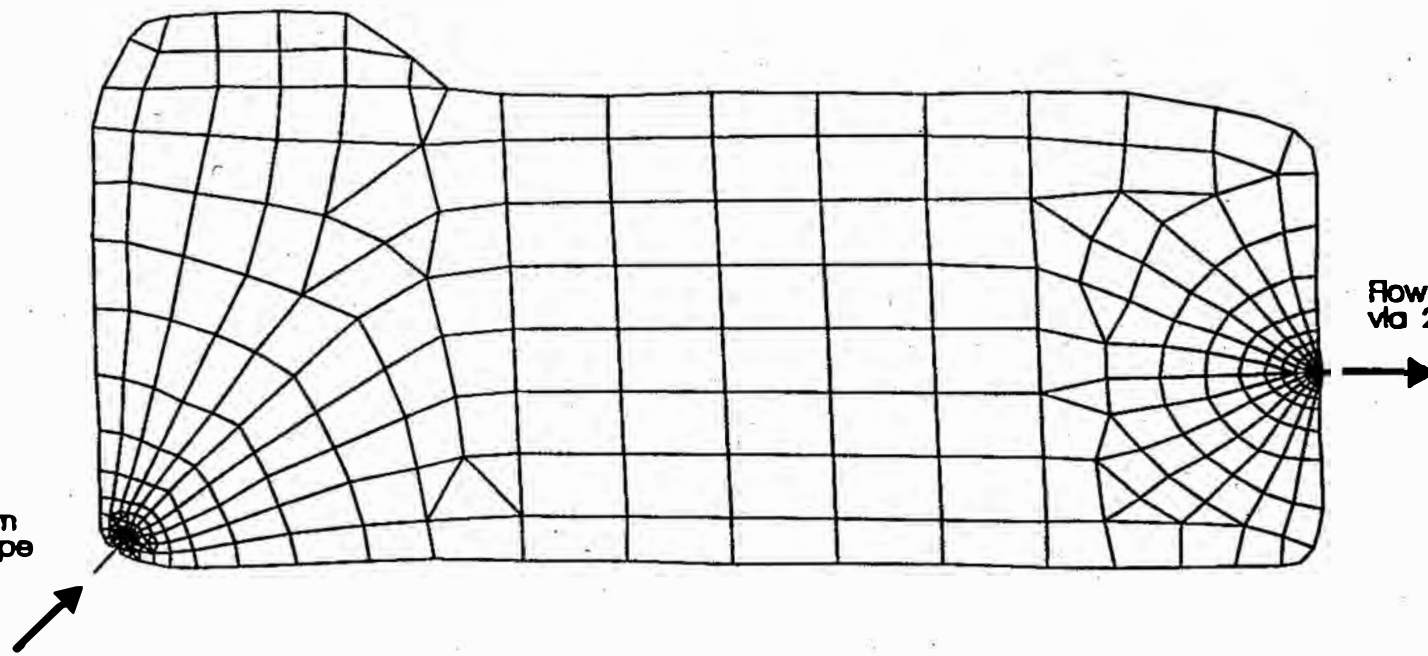


Figure B-4. Finite Element Network for Storm Water Treatment Analysis, Full Treatment Alternative

The flow velocities and depth of water results from the 2-D hydrodynamic model were then used in the 2-D sediment model (SEDH) to compute the transport and deposition of the suspended particles in the Model Yacht Basin. The two main input parameters for the sediment model are the particle settling velocity and the suspended sediment concentration of the incoming storm water. The EPA (1983) in the "Nationwide Urban Runoff Program" (NURP) developed a distribution of particle settling velocities characteristic of the suspended particles found in urban runoff. The settling velocities of particles in urban runoff were divided by NURP into five equal fractions, and are presented in Table B-1. The suspended sediment concentration for the storm water inflow was taken to be 500 mg/l. This is at the high end of the suspended sediment concentration measured from urban storm water runoff from the Dust Marsh Creek area of Alameda County (1991).

Table B-1. Settling Velocities of Particles in Urban Runoff

Size Fraction	% of Particle Mass in Urban Runoff	Average Settling Velocity (ft/hr)
1	0 - 20%	0.03
2	20 - 40%	0.3
3	40 - 60%	1.5
4	60 - 80%	7.0
5	80 - 100%	65.0

Model Results

Each of the storm water treatment alternatives listed in section 5 were simulated: the entire Model Yacht Basin (MYB) without dredging; the entire MYB dredged to ten feet; the partial MYB at 6 foot depth; and the partial MYB at 10 foot depth. The sediment model can simulate the transport and deposition of only one particle size fraction at a time. Thus the model evaluation of a storm water treatment alternative would consist of five individual computer runs. Each run was proceeded until the specific particle fraction had either completely settled out or was flushed out of the Model Yacht Basin.

Figure B-5 shows the sediment deposition pattern for the case with the entire MYB without dredging. The figure shows most of the sediment deposition occurs near the outlet from the techite drain connection, and primarily results from the quick settling of the coarser particle fractions. The modeling results show in general almost complete settling for all but the smallest particle size fraction. Comparative model results of the four treatment alternatives is presented in Section 5 and Table 5.

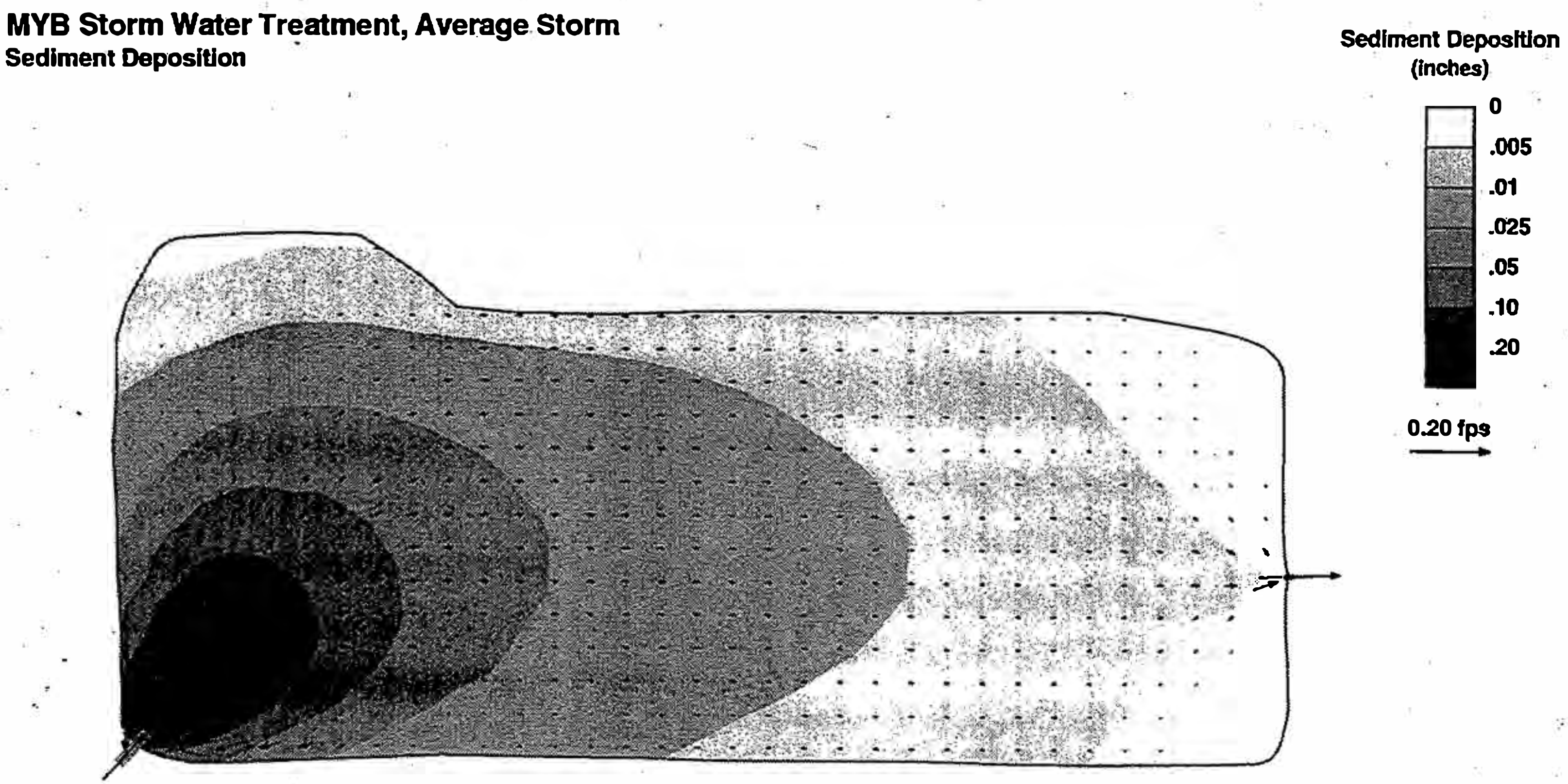


Figure B-5. Sediment Deposition and Flow Velocities for Model Yacht Basin Storm Water Treatment

Model Evaluation of Removal of Potter Street Drain and Embankment

The draft Aquatic Park Master Plan identifies a recommend alternative for Park improvement which includes the removal of the existing berms that separate the Main Lagoon, the Model Yacht Basin and the Radio Tower Pond. This includes the removal of the existing Potter Street drain between the Model Yacht Basin and the Radio Tower Pond. A model analysis was performed to assess the potential for high water levels developing within the Aquatic Park during storm events if this alternative is actualized.

Modeling Approach

A link-node representation was constructed of the combined Main Lagoon - Model Yacht Basin - Radio Tower Pond system. The link-node representation included the remaining Potter Street storm drain connecting the Bay to the combined basins. Inflow for the Potter Street drain were for the 10-year storm event. The Bay tide was a typical winter time maximum tide, timed so that high tide coincided with the peak storm flow. The storm flow and tide are shown in Figure B-6.

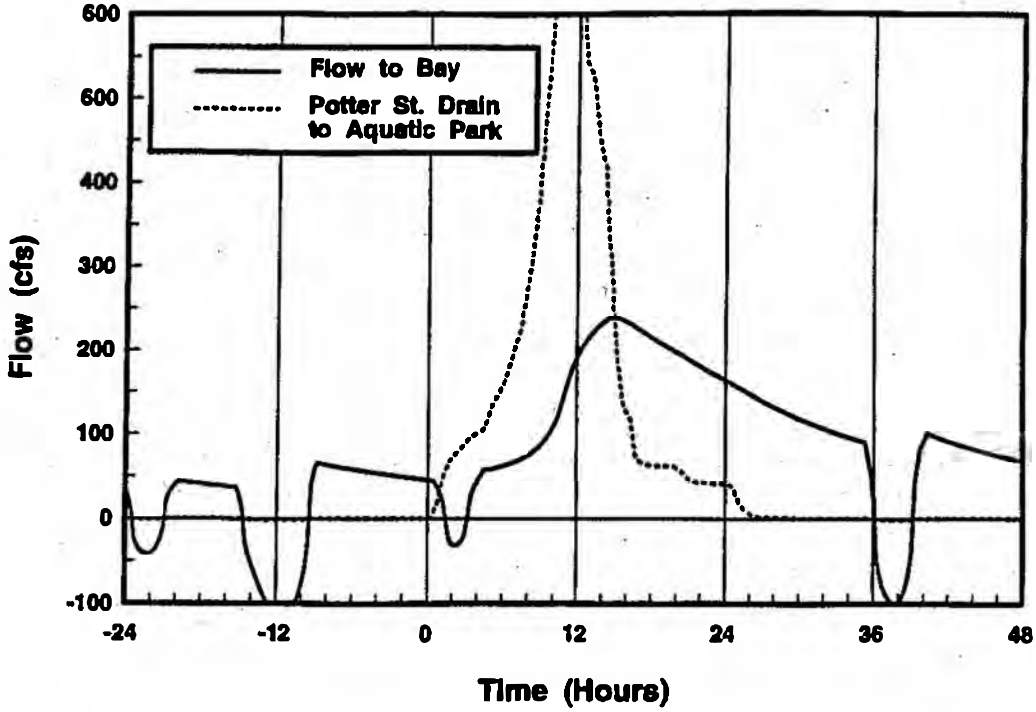
Model Results

The water level in the Aquatic Park during the storm event is plotted in Figure B-6b. The peak water surface level in the Park is over 6 feet NGVD. Often wind and lower barometric pressure can raise the Bay tide to higher than predicted levels, and potentially higher water levels in the Aquatic Park. Figure B-6a shows the flow to the Bay from the Aquatic Park is much less than the flow coming in from the Potter Street drain. This loss in flow capacity in the culvert to the Bay is due to a water lever lower in the Park than a closed Potter Street drain, and to the loss in hydraulic head needed to re-accelerate the water flowing back into the culvert to the Bay. The analysis does not include flows from the Strawberry Creek overflow weir which would further increase the water surface elevation within the Park. The higher Park water surface would likely compromise the present flood control benefit the Park diversion provides the Strawberry Creek drainage.

References

U.S. Evironmental Protection Agency, Water Planning Division. 1983. **Results of the Nationwide Urban Runoff Program, Vol. I, Final Report**, NTIS Accession Number: PB84-185552.

Woodward-Clyde Consultants. 1991. **Sediment and Storm Runoff Concentration of Copper, Zinc and Lead in the Crandall Creek - Dust Marsh System**, Submitted to the County of Alameda Public Works Agency, Haward, Calif.



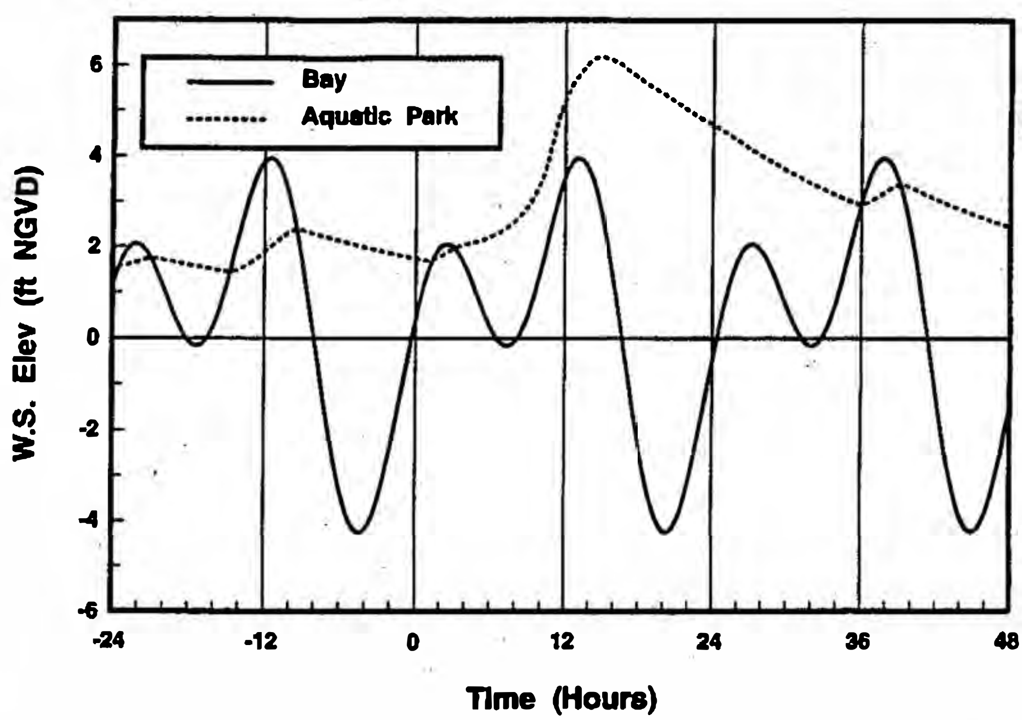


Figure B-6. (a) Flow and (b) water surface elevation for 10-year storm event with removal of embankments and storm drain between Main Lagoon, Model Yacht Basin and Radio Tower Pond.

Appendix C
Basis for Cost Estimate

Appendix C
Basis of Cost Estimate

The following paragraphs describe the method used to develop cost estimates for the water quality management and stormwater treatment alternatives.

Basis of Initial Capital and Present-Worth Cost Estimates

The cost estimates presented in this report represent order-of-magnitude costs for evaluating alternatives. Order-of-magnitude estimates are prepared without detailed engineering analysis of the various system components or site data. This type of estimate is expected to be accurate from 30 percent above to 15 percent below the actual cost. The final costs of alternative implementation will depend on a number of variable factors including actual labor and material costs, final design implementation schedule, and engineering. As a result, the final costs may vary from the estimates presented in this report.

Specific assumptions used to determine initial capital and present worth costs include the following:

- All costs are based upon the November 1993 Engineering News Record Construction Cost Index (ENR Index) of 6484 for the San Francisco Bay Area.
- Capital costs include a 40 percent markup for overhead, profit, mobilization, bonding insurance and contingency.
- A 30-year project life was assumed and a 3 percent interest rate was assumed to determine present worth.

Basis of Operations and Maintenance Costs

The cost estimates presented in this report for operations and maintenance costs apply to upkeep of the hydraulic facilities. The final costs of operation and maintenance will depend on variable factors, such as the need for pipe cleaning which is based on amount of sediment accumulation. Additional City resources will be required for monitoring and public education, if implemented. These activities are discussed further in the Operational Management Plan in Appendix D.

Specific assumptions used to determine operation and maintenance cost estimates include the following:

- Pipes will be inspected twice a year and cleaned once a year.
- Slide gates will be maintained twice a year.

Appendix D
Operational Management Plan

Appendix D
Operational Management Plan

Introduction

This Operational Management Plan (OMP) is a stand-alone appendix to the Aquatic Park Water Quality Study (CH2M HILL, 1994). It describes the operation and maintenance practices for Aquatic Park (Park) associated with Alternative 3B in the study. Aquatic Park consists of three major water bodies: the Main Lagoon, the Model Yacht Basin, and the Radio Tower Pond. Because the Radio Tower Pond is not currently owned or operated by the City of Berkeley, it is not addressed in this OMP.

There are two parts to the recommended alternative:

- A water quality management plan which would increase circulation in the Main Lagoon and Model Yacht Basin
- Stormwater treatment project which would provide treatment in the Model Yacht Basin.

This OMP includes management practices for both a water quality management plan and a stormwater treatment project. If only one part of the alternative is implemented, this plan should be revised accordingly.

The recommended water quality management alternative is Alternative 3B, "Modify Existing Structures with Harvesting." In this alternative, the current direction of flow would be changed and the volume of water being transported through the Park would be increased. Flow and volume would be altered by using the large storm drains at each end of the Park to convey Bay water to and from the Park. New connections to these existing storm drains would be constructed along with replacement of pipes within the Park. Aquatic plants would be controlled by using a mechanical harvester.

A preferred alternative for stormwater treatment has not been selected at this time, because the City needs to prioritize Aquatic Park uses before selecting an alternative. The difference between the alternatives (Full Treatment versus Treatment/Habitat) is essentially higher stormwater volume versus increased wildlife habitat; and operations would be essentially the same for the two alternatives.

Operations and Maintenance

This section describes the circulation patterns proposed for the Park and the associated operations for the dry and wet seasons, inspection and maintenance of the hydraulic facilities, and harvesting.

Conceptual Description of Park Operations

Improvement of water quality in Aquatic Park and operation of the stormwater treatment facility will require seasonal operational changes. There will be two circulation patterns for the basins:

- Dry season (May 1 - September 30)
- Wet season (October 1 through April 30).

In the dry season, suspended algae growth will be reduced through increased circulation. This increased circulation is beneficial to the Model Yacht Basin as well as the Main Lagoon. Therefore, since very little stormwater is to be treated in the dry season, the Model Yacht Basin will be hydraulically connected to the Main Lagoon and circulation through the Park will be achieved primarily through an exchange of water from the Bay through the Main Lagoon into the Model Yacht Basin and out to the Bay through the Potter Street Drain (Figure 1).

The wet season operation modes will limit stormwater into the Main Lagoon from the Potter Street drain thereby reducing the introduction of bacteria from stormwater. This will reduce circulation in the Main Lagoon in the wet season; however, during this time, suspended algae growth is limited due to reduced sunlight.

Specific operations for the dry and wet season scenarios with and without implementation of a stormwater treatment basin are described in the next two sections.

Operations if a Stormwater Treatment Alternative is Implemented

If a stormwater treatment alternative is implemented with Water Quality Management Alternative 3B, seasonal operational changes will be required. Figure 2 shows the flow directions and status of the gates (i.e., open/closed) for dry season operations. All gates between the Main Lagoon and the Model Yacht Basin should be opened during the dry season to allow maximum circulation through the basins. Figure 2 shows the flow directions and status of the gates (i.e., open/closed) for wet season operations. All gates between the Main Lagoon and the Model Yacht Basin should be closed during the wet season operations to prevent mixing between the basins.

Operations if a Stormwater Treatment Alternative is Not Implemented

No seasonal operational changes are required if a stormwater treatment alternative is not implemented.

Hydraulic Facilities

Inspection of the hydraulic structures is recommended twice a year. These inspections should focus on: amount of sediment in pipes, condition and upkeep of slide gates, bank erosion around structures, etc. Maintenance of the slide gates is recommended twice a year. Due to differences in gate operations, this schedule should be updated according to the manufacturer's specifications after the hydraulic structures have been installed. For efficiency, these inspection and maintenance activities can take place when operators go to the Park to change the flow directions for the dry and wet seasons.

Harvesting

Harvesting should occur on an as-needed basis to avoid conditions that the City determines are unacceptable. City staff should conduct periodic inspection of conditions at the Park to assess the need for harvesting. Algae growth has historically been high in the late summer and early fall (July - October). It is recommended that the City implement regular maintenance on the harvester on an annual basis in the early spring. Records of harvest dates and quantity of plant material harvested should be kept as a basis for management.

Monitoring Plan

The purpose of this section is to describe a plan for monitoring water quality to produce information about the suitability of Aquatic Park for its intended recreation and wildlife habitat uses, to provide the basis for evaluating the effectiveness of stormwater treatment and to provide a basis for management decisions. The monitoring plan includes the following sections:

- Measurement Parameters and Methods
- Monitoring Stations
- Monitoring Frequency

Measurement Parameters and Methods

Parameters for evaluating sediment quality and accumulation, water quality, and aquatic plant density at Aquatic Park are described in this section.

Sediment

The quality of sediment should be evaluated as described in Table 1. Sediment accumulation should also be evaluated by using permanently installed staff gauges or by some other means to assure a consistent local datum. Sediment samples should be collected to characterize the appropriate sediment layers, and samples should be collected at three to six locations.

Table 1 Sediment Parameters to be Monitored at Aquatic Park	
Parameter	**Purpose**
Sediment accumulation	Adjust flushing rate in Main Lagoon to balance sediment accumulation rate and algae concentration in water column (as indicated by chlorophyll)
Particle size	Relate this information to suspended solids data in Model Yacht Basin
Metals	Indicates pollutant removal effectiveness
Total petroleum hydrocarbons	Indicates pollutant removal effectiveness
Polynuclear aromatic hydrocarbons	Indicates pollutant removal effectiveness

Water Quality

Water quality should be evaluated as described in Table 2. Samples should be collected to be representative of the conditions that are being characterized. For example, water quality samples collected in the Model Yacht Basin to characterize stormwater treatment effectiveness should be spatially integrated as appropriate. Samples may also be time-integrated under conditions of changing water quality to reflect average conditions over the desired period of time.

Table 2 Water Quality Parameters to be Monitored at Aquatic Park	
Parameter	**Purpose**
Dissolved oxygen	Indicates depletion due to decomposition of organic matter such as aquatic plants
Salinity	Indicates relative influence of fresh and salt water sources
Turbidity	Indicates light availability and, when related to chlorophyll and total suspended solids data, indicates whether turbidity is organic or inorganic
Total suspended solids	Indicates sediment suspension
Total and fecal bacteria (6 dilutions)	Indicates suitability for water-contact recreation
Chlorophyll	Indicates amount of planktonic algae
Metals[a]	Total and dissolved metals data will indicate treatment effectiveness in Model Yacht Basin
Polynuclear aromatic hydrocarbons	Indicates pollutant removal effectiveness
a. Test water samples for a broad suite of metals initially; decrease number of metals tested based on monitoring results.	

Aquatic Plants

The density of aquatic plants should be assessed in quadrats that are representative of conditions in the Park. Quadrats are square plots used in ecological population studies. Plant density can be evaluated semi-quantitatively by estimating the fraction of the water surface that is covered by plants, or by the approximate density of plants within the water column defined by the quadrate.

Monitoring Stations

The location of stations for sediment, water quality, and aquatic plant monitoring are described in this section. Sediment and water quality monitoring station locations are shown approximately in Figure 3. If a stormwater treatment alternative is not implemented, sampling will only be conducted at Stations 1, 2, and 4. Station 3 is located in the stormwater inlet to the Model Yacht Basin and is intended to reflect influent quality prior to stormwater treatment. Likewise, Station 5 is located near the basin outlet to reflect effluent quality. Station locations should be adjusted to meet field constraints.

Composite samples should be created from grab samples collected in the general vicinity of the station. The composite samples can be spatially and/or time-integrated depending on the specific information City staff seeks to determine. Approximately five stations for monitoring plant density should be established to be representative of the Park.

Monitoring Frequency

Table 3 describes the monitoring schedule for sediment and water quality if a stormwater treatment alternative is implemented. In the case that a stormwater treatment alternative is not implemented, sampling would not be conducted at Stations 3 and 5. The schedule should be adjusted as appropriate in response to monitoring results and management needs.

Main Lagoon

Characterization of water quality in the Main Lagoon should occur at Stations 1 and 2 four times a year except for bacteria sampling which should be conducted weekly.

Model Yacht Basin

Characterization of the stormwater treatment effectiveness of the Model Yacht Basin should occur during two storms each year, as indicated in Table 3 for Stations 3 and 5. Samples from Station 4 should be evaluated during the same two winter storms as samples from Station 3 and 5, and once each during spring, summer and fall simultaneously with collections at Stations 1 and 2. Proper characterization of treatment effectiveness should include intensive sampling over the course of several storms.

Table 3 Sample Collection Frequency for Sediment and Water Quality					
Parameters	Stations				
	1	2	3[a]	4[b]	5[a]
Sediment					
Sediment Accumulation	Y	Y		Y	
Particle size	5Y	5Y		5Y	
Metals	5Y	5Y		5Y	
Total petroleum hydrocarbons	5Y	5Y		5Y	
Polynuclear aromatic hydrocarbons	5Y	5Y		5Y	
Water					
Dissolved oxygen	4/Y	4/Y	2/Y	5/Y	2/Y
Salinity	4/Y	4/Y	2/Y	5/Y	2/Y
Turbidity	4/Y	4/Y	2/Y	5/Y	2/Y
Total suspended solids	4/Y	4/Y	2/Y	5/Y	2/Y
Particle size			2/Y	2/Y	2/Y
Total and fecal bacteria (6 dilutions)	W	W	2/Y	2/Y	2/Y
Chlorophyll	4/Y	4/Y		4/Y	
Metals			2/Y	2/Y	2/Y
Polynuclear aromatic hydrocarbons			2/Y	2/Y	2/Y

Y=yearly, x/Y=x times per year, xY=every x years, W=weekly
a. Monitoring at this station will only be conducted if a stormwater treatment alternative is implemented.
b. If a stormwater treatment alternative is not implemented, the Station 4 sampling schedule should be changed to the schedule of Stations 1 and 2.

Plant density should be monitored approximately monthly during the growth season from about May through late September.

Impact of Monitoring Results on Operations

A monitoring plan is identified above to provide the basis for evaluating the effect of operations on water quality throughout the Park and stormwater in the Model Yacht Basin. The purpose of this section is to provide general guidance on how the information from the monitoring program could be used to manage the Park. General guidance on the interpretation of data in monitoring parameters is described below.

- **Sediment Accumulation.** The accumulation of sediment in the Main Lagoon is undesirable because it promotes the growth of rooted aquatic plants. The Bay is the primary source of sediment in the Park, and the flow of Bay water through the Park could be adjusted to decrease importation of sediment. The transport of sediment from the Bay to the Park is likely to be greatest in late spring through mid-summer when wind-induced turbulence in the Bay is greatest, and flow could be adjusted in this period. Reduced flow, however, could lead to increased algae, as indicated by chlorophyll data.

Sediment accumulation in the Model Yacht Basin reflects directly the treatment effectiveness of the basin. Sedimentation is enhanced by the presence of salt in the basin. Operation could be adjusted to provide adequate antecedent salinity to enhance sedimentation.

- **Sediment Particle Size.** Particle size distribution in sediment is proposed for analysis to provide an indication of sediment characteristics. This information should be related to suspended sediment particle size as needed to determine sedimentation patterns in the Park.

- **Metals.** Metals are associated with suspended particulate material in storm and Bay water. Metals monitoring is proposed to provide a basis to evaluate treatment effectiveness and to evaluate the potential for ecologically problematic accumulation of metals.

- **TPHs and PAHs.** These are classes of organic compounds that should measured to evaluate the potential for ecologically problematic accumulation. The combination of these tests provides a comprehensive characterization of the pollutants associated with petroleum. The TPH test provides an overall measure of gasoline, diesel fuel and oil and grease. The PAH test provides information on specific combusted petroleum products and has a lower detection limit than the TPH test (0.5 ppm compared to 10 ppm). However, the PAH test does not measure noncombusted products such as grease.

- **Dissolved Oxygen.** The concentration of dissolved oxygen is important to survival of fish. Values below about 5 mg/L should be considered unacceptable from the perspective of maintaining habitat for a wide range of aquatic life. Odors can develop when dissolved oxygen values are less than about 2 mg/L. Decay of algae and plants would be likely causes of dissolved oxygen depletion in Aquatic Park. Short-term solutions to address dissolved oxygen depletion include removal of the decaying plant material and increased flushing. Long-term solutions include management of plant and algae biomass.

- **Salinity.** Salinity is an indicator of the influence of Bay water on the Park. Interpretation of salinity collected in the Park may necessitate measurement of salinity in the Bay or Strawberry Creek storm drain. Antecedent salinity conditions in the Model Yacht Basin are expected to influence sedimentation efficiency in stormwater.

- **Turbidity.** Turbidity should be monitored to provide an indication of water clarity and how water clarity responds to Park management.

- **Total Suspended Solids and Particle Size Distribution.** The amount and sizes of suspended material should be evaluated across the Model Yacht Basin so that treatment effectiveness can be evaluated and stormwater inflow rates adjusted as appropriate to optimize treatment. These constituents will also provide information about the fate of solids of Bay origin in the Main Lagoon.

- **Bacteria.** Standards for water contact recreation, non-contact recreation, and other uses have been established to protect public health as described in Table-4.

Table 4
Water Quality Objectives for Coliform Bacteria[a]

Beneficial Use	Fecal Coliform MPN/100 ml	Total Coliform MPN/100 ml
Water Contact Recreation	log mean <200 90 percentile <400	median <240 no sample >10,000
Shellfish Harvesting[c]	median <14 90 percentile <43	median <70 90 percentile <230[b]
Non-Contact Water Recreation[d]	mean <2000 90 percentile <4000	- -
Municipal Supply surface water[e] groundwater	log mean <20 -	log mean <100 median <2.2[f]

Notes:
a. Based on a minimum of five consecutive samples equally spaced over a 30 day period.
b. Based on a five-tube decimal dilution test or 300 MPN/100 ml when a three tube decimal dilution test is used.
c. Source: Natural Shellfish Sanitation Program.
d. Source: Report of the Committee on Water Quality Criteria, National Technical Advisory Committee.
e. Source: DOHS recommendation.
f. Based on a seven day median.

Coliform bacteria should be monitored to determine attainment of these standards. The Park should be posted consistent with health regulations when Park water quality is out of attainment.

- **Chlorophyll.** Chlorophyll is an indicator of the amount of algae suspended in the water column. If chlorophyll levels become too high (as indicated by dissolved oxygen, turbidity and aesthetic considerations), flows should be managed to flush algae. Collection of chlorophyll data may not be needed to manage for dissolved oxygen, turbidity and aesthetic considerations, but data collection will provide the basis to relate objective data about water quality to other observations and management.

- **Metals.** Measurement of total and dissolved metals is recommended to evaluate stormwater treatment performance. Stormwater inflow rates could be adjusted to optimize treatment.

- **PAHs.** PAHs are found in stormwater, and are believed to adversely affect fish and wildlife in the Bay. Evaluating the Model Yacht Basin for PAH removal will provide an indication of the overall benefits of stormwater treatment.

Public Education and Awareness

The purpose of this section is to describe public education activities planned at the Park in correlation with implementation of the water quality management plan and a stormwater treatment project. Aquatic Park is used and enjoyed by the community as a place for walking, running, frisbee golf, rowing, sailing, water-skiing, fishing, and wildlife viewing. In addition, the Park provides habitat for fish and wildlife, including many birds. Many Berkeley residents are interested in the natural processes at the Park and the City plans to install educational and interpretive signs around the Park to increase public awareness.

Two types of signs could be located around the Park:

- Water quality notices advising people to not engage in water-contact recreation in the Main Lagoon during the wet season

- Interpretative signs to inform Park users about the multiple uses of the Park and the natural processes that occur in the basins.

The water quality notices would only be posted during wet season operations and could be posted and removed by City crews when they change the operation of the Park from dry to wet season and vice-versa. As data is generated from the monitoring program, the signs could be changed more frequently. However, this would require more City resources.

Information incorporated into the interpretative signs would include:

- Habitat for wildlife

- Seasonal operation of Park, including flood control in the winter and increased circulation in the summer

- Recreational benefits

If a stormwater treatment alternative is implemented, a sign near the Model Yacht Basin could explain the seasonal processes in the Model Yacht Basin.

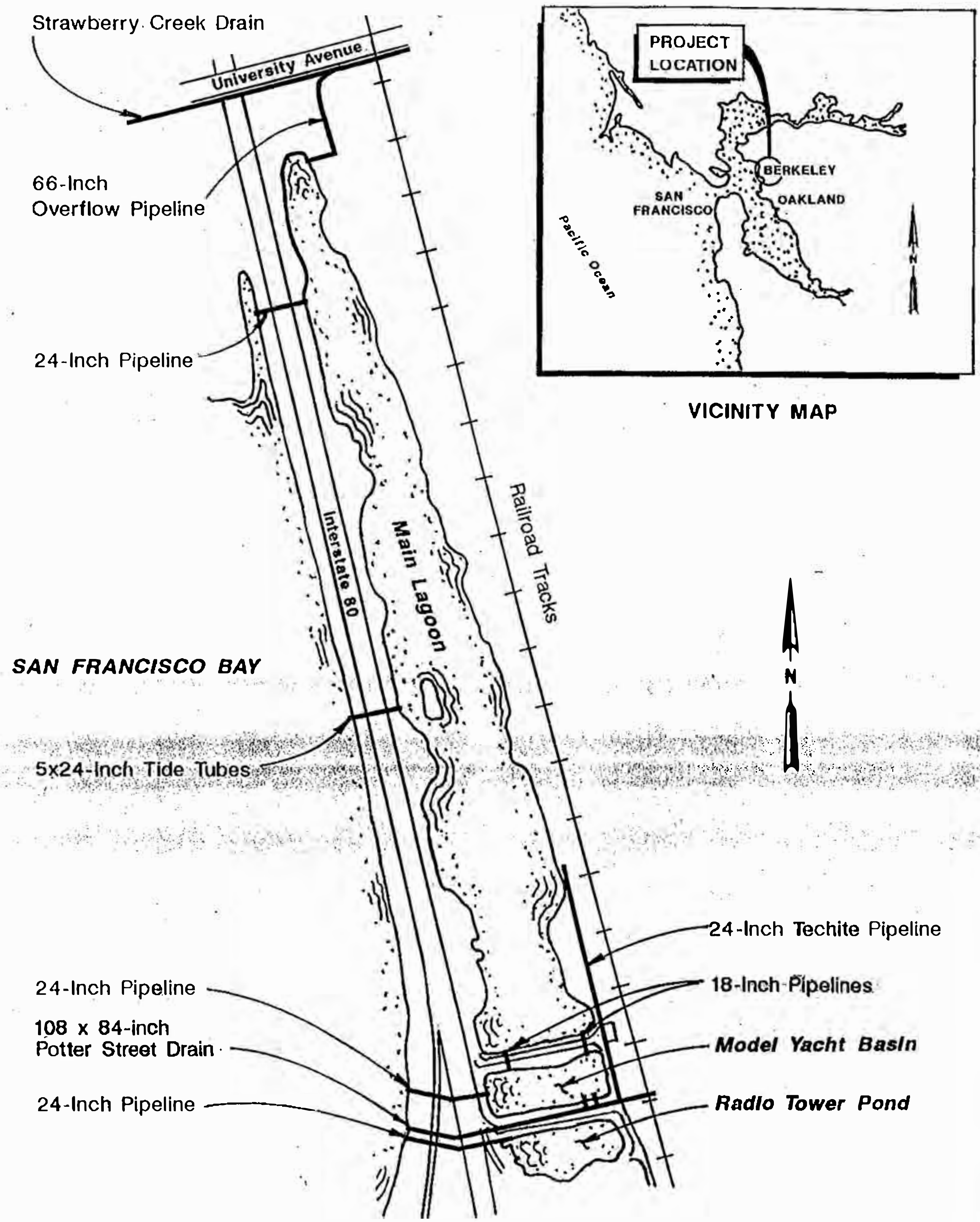


Figure 1
SITE MAP
Aquatic Park Water Quality
Improvement Study

CH2M HILL

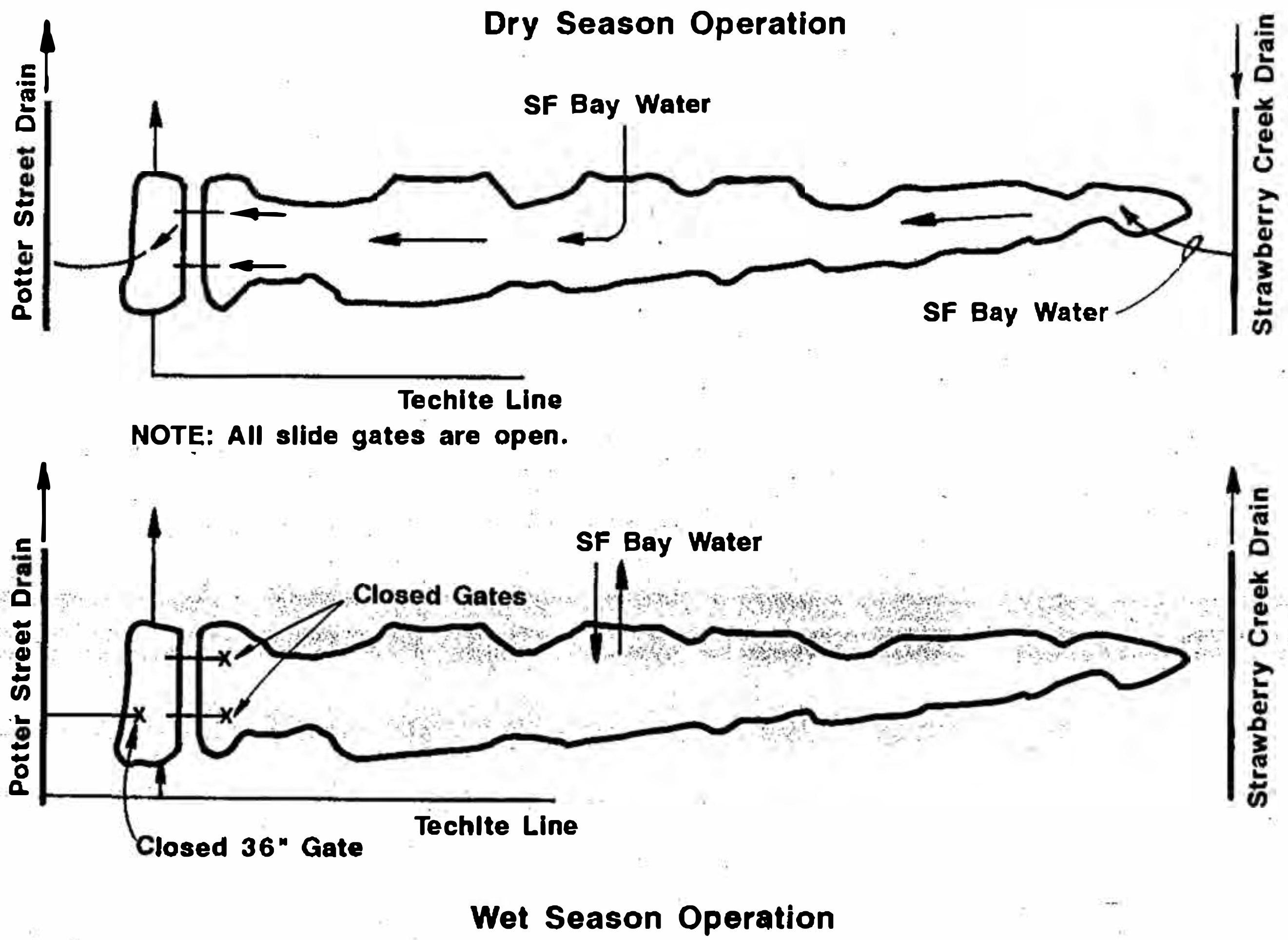
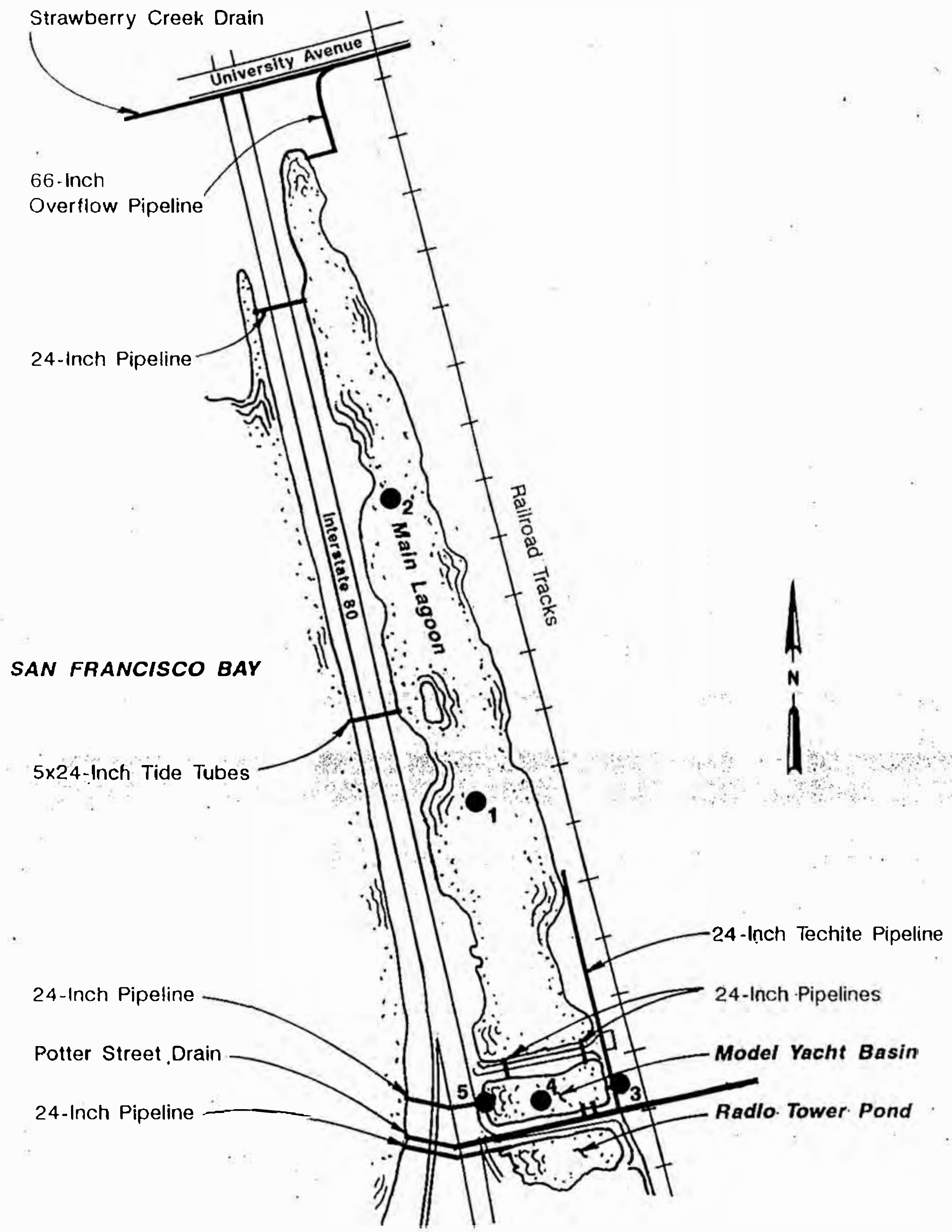


Figure 2
OPERATION MODES OF WATER QUALITY ALTERNATIVE 3 WITH STORMWATER TREATMENT
Aquatic Park Water Quality Improvement Study



● Water Quality Monitoring Locations

Figure 3
MONITORING STATION LOCATIONS
Aquatic Park Water Quality
Improvement Study

CH2M HILL