

EXECUTIVE SUMMARY

Aquatic Park Improvement Program

In 2006, the City of Berkeley initiated the Aquatic Park Improvement Program (APIP) to prepare concept-level designs for the hydrology and habitat improvement recommendations in the 2003 Natural Resource Management Study.

Existing Conditions

Aquatic Park was created from intertidal and subtidal areas in the 1930s as part of the construction of the Bayside Freeway. Aquatic Park has three lagoons: the Main Lagoon (ML), the Model Yacht Basin (MYB), and the Radio Tower Pond (RTP). The entire park is 102 acres and includes: 68.0 acres of open water in the three lagoons, 0.7 acres of salt/brackish wetlands, 1.1 acres of freshwater wetlands, 11.0 acres of lawn, 7.0 acres of roads and trails, and 14.0 acres of buildings and uplands.

The lagoons are connected to the Bay by small 24 inch culverts or tide tubes, many of which are deteriorating. The five main tide tubes under I-80 are falling apart on the bay side, and failing riprap and parts of the pipes are blocking tidal flows into the Main Lagoon. The Model Yacht Basin tide tube is buried in sand on the bay side. The Radio Tower Pond tide tube has collapsed under the frontage road and appears to have separated on the bay side.

The primary type of habitat in Aquatic Park is shallow subtidal aquatic habitat in the three lagoons. In San Francisco Bay shallow subtidal habitat is a highly productive zone which supports a nursery for many marine crustaceans and fish. Bay fish species require cold water temperatures (58-68°F) and marine salinities (22 to 33 ppt.) These small fish are a major food source to diving ducks which overwinter in San Francisco Bay and Aquatic Park. Wading birds—egrets and herons, as well as pelicans, cormorants, mergansers, and other fish-eating birds—also feed on the small fish.

In 2004 the Regional Water Quality Control Board's Surface Water Ambient Monitoring Program monitored summer and fall water temperatures and dissolved oxygen (DO) levels at three sites in the Main Lagoon. The monitoring found chronic high water temperatures and low dissolved oxygen levels that are fatal to fish.

The three lagoons have small areas of salt/brackish wetland. The lagoons of Aquatic Park have steep slopes and a very small average tidal range of 0.1 ft. in contrast to the 6.2 ft. average tidal range in the Bay. The shoreline areas offer an opportunity to eradicate invasive non-native plants and revegetate with high marsh/transition zone native plants.

Habitat improvement of Bird Island and upland areas on the western side of the Main Lagoon are included in the APIP. These areas have a greater degree of isolation from recreational use and a higher potential for a successful habitat restoration. Bird Island is 0.45 acres and is inundated in storms. The island needs to be filled in order to raise elevations and revegetate for bird roosting habitat.

A large portion of the City of Berkeley drains towards Aquatic Park. The majority of this runoff drains into the Potter Street and Strawberry Stormdrains. During high runoff periods, stormwater can enter the lagoons from these two drains. A portion of the watershed immediately east of the park also drains directly into the Main Lagoon. Many contaminants are carried on clay particles in stormwater. These particles can deposit out when they reach slow-moving water in creeks, the lagoon system or San Francisco Bay. Under the current conditions it takes 48.5 days to remove stormwater from the lagoons after a 100-year event. Under the proposed project it will take only 10.4 days to remove the stormwater following a 100-year event, resulting in greatly improved habitat for fish and other wildlife.

There is a total of 1.1 acres of small freshwater wetlands on the eastern border of the park adjacent to the railroad berm. There are many characteristics of Aquatic Park's freshwater wetlands which greatly reduce their value as wildlife habitat. Most of the wetlands are immediately adjacent to active recreation areas where disc golf, hiking, walking, dog walking, and other sports occur.

SUMMARY OF RECOMMENDATIONS

Hydrology Improvements

- 1. Aquatic habitat improvement is the highest priority action for park enhancement.** Aquatic habitat is the primary habitat in Aquatic Park and suffers from poor water quality conditions in the summer and fall. A major increase in water circulation and tidal exchange is needed to improve habitat for fish and other wildlife.
- 2. Maximize the increase in tidal circulation and tidal volume.** The current five tide tubes that provide tidal water to the Main Lagoon are falling apart. A new and improved tidal connection and water circulation system is needed. Alternative 4B would create larger connections at the Potter Street and Strawberry stormdrains, excavate a new open channel between the Model Yacht Basin and the Main Lagoon, install a structure to protect the bay side of the five tide tubes. This alternative would increase the volume of tidal water entering the Main Lagoon from 22 acre-feet to 115 acre-feet per tidal cycle. Alternative 4B provides the largest tidal range and the greatest water quality improvement. Due to the low elevation of the Radio Transmitter Building, the tidal range at the Radio Tower Pond cannot be changed unless a berm is constructed around the building.
- 3. Block stormwater inflow volumes at new connections.** Slide gates will be installed at the new connections. The gates will also be used to block the maximum amount of stormwater. In addition, increasing tidal circulation will remove stormwater at a much faster rate than under current conditions and will reduce effects on aquatic life.
- 4. Consider installing a bioswale along the road/lawn on the northeastern end of the park to filter stormwater flowing directly from streets into the park.**
- 5. Consider creating a demonstration area for ultra urban stormwater treatment using biofiltration facilities installed on streets, parking lots and other locations in the local Aquatic Park watershed.** These facilities will reduce the concentration of pollutants in stormwater which directly enters the Main Lagoon.
- 6. Consider as an optional action installation of in-line vortex filtration units on stormdrains** at the eastern edge of the railroad/western ends of Dwight, Channing, and Bancroft Streets. For the stormdrains at Parker, Carleton, Grayson, and Heinz Streets, vortex filter units can be installed in the park to replace the oil/water separators. The vortex filters would not remove the small particulates which transport many of the persistent pollutants, but could provide a treatment option while the biofiltration program is implemented.

Habitat Improvements

- 1. Implement a salt/brackish wetland restoration on 1.3 acres north of the Rowing Club.** Excavate the site to the -1.5 ft. (Berkeley Datum) elevation to create salt marsh and high marsh

transition areas. Install a berm along the road edge of the site to serve as a vegetated transition area and barrier to unleashed dogs.

- 2. Reuse excavated soil from wetland creation to restore additional areas.** The Rowing Club site elevations are -1 to +4 ft. and will require excavation of 6,230 cubic yards of soil. If soils tests show the material is acceptable, the soil could be used for improving bird roosting habitat on Bird Island and native plant re-vegetation areas in the three abandoned parking areas on the west side of the park.
- 3. Remove invasive plants in all shoreline areas and all stem and seed-reproducing invasive plants in other areas of the park.** Invasive plants on and near existing wetlands, especially in the Radio Tower Pond and near the wetland restoration site, need to be eradicated to make the wetland restoration a success.
- 4. Replant shoreline areas with native plants.** Replant shoreline areas with a variety of native species and cypress trees.
- 5. Fill Bird Island with soil excavated from the wetland creation to create bird roosting habitat.** The City will need to eliminate recreational use of the island.
- 6. Restore native vegetation on asphalt parking areas on the western side of the Main Lagoon (P1, P2, and P3).** These areas are no longer used. Asphalt would be removed and covered with 2.5 feet of excavated soil and revegetated with native plants.
- 7. Consider an optional action to construct a 1.02 acre pilot freshwater wetland incorporating Freshwater Wetland 1 and removing the adjacent lawn.** Summer water from the stormdrain system would be needed for the wetland and may not be permitted by the Regional Water Board. Eradicate ivy in freshwater wetlands and increase riparian habitat in FW-3 and FW-4 areas.
- 8. Monitor water quality and aquatic life in the lagoons before and after water circulation improvements**
- 9. Post and enforce wildlife protection regulations, including leash laws, throughout the park.**
- 10. Address homeless encampments and evaluate the number and location of trash cans to reduce dumping and littering.**
- 11. Plan a tree replacement program for invasive Eucalyptus and Acacia in the park.**

AQUATIC PARK IMPROVEMENT PROGRAM SUMMARY REPORT



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AQUATIC PARK IMPROVEMENT PROGRAM SUMMARY REPORT

INTRODUCTION

Aquatic Park is located in West Berkeley adjacent to Interstate 80 between Ashby and University Avenues and is the largest city park in Berkeley. The City of Berkeley has completed several planning efforts for Aquatic Park. In 1990 a Master Plan was prepared which identified enhancing natural resources and improving water quality as major goals. The Master Plan also recommended the southern end of the park become a bird sanctuary. In 2003 the City released a Natural Resource Management Study (NRMS). This study provided recommendations to improve water quality by increasing water circulation and increasing wetland habitat areas; however, a limited amount of hydrologic modeling and data collection was completed for the NRMS. In 2006 the City moved forward with the Aquatic Park Improvement Program (APIP) to prepare concept-level designs for the major recommendations in the NRMS. This report summarizes the studies and analyses for the APIP completed by a consulting team of Laurel Marcus & Associates (LMA) and Hydrologic Systems Inc. (HSI). The City will complete CEQA review and permit acquisition for the recommended alternative. The City is currently working with the State Coastal Conservancy on implementation funding.

PROGRAM PURPOSE

The goals of the APIP include:

- Improve water circulation and quality
- Restore and expand natural habitat to the extent feasible
- Balance protection of recreational uses with water quality and habitat restoration
- Improve park appearance
- Provide realistic and clear detailing of improvements to be made, equipment or materials to be used, phasing and monitoring and maintenance requirements
- Encourage increased on-going study and monitoring of conditions at the Park
- Encourage active pursuit of funding for those components of the APIP that can't be funded through the Coastal Conservancy/Proposition 50 funds.

BACKGROUND

Aquatic Park was created from intertidal and subtidal areas in the 1930s as part of the construction of the Bayside Freeway. Aquatic Park now has three lagoons: the Main Lagoon, the Model Yacht Basin, and the Radio Tower Pond. The largest lagoon is the Main Lagoon (ML) at 58.3 acres with the Model Yacht Basin (MYB) to the south at 5.0 acres. The Radio Tower Pond (RTP) of 4.7 acres is the southernmost lagoon and only partially owned by the City. The entire park is 102 acres and includes: 68.0 acres of aquatic habitat in the three lagoons, 0.7 acres of salt/brackish wetland, 1.1 acres of freshwater wetland, 11.0 acres of lawn, 7.0 acres of roads and trails, and 14.0 acres of buildings and uplands.

CONCEPT DESIGN DEVELOPMENT

The Aquatic Park Subcommittee of the Parks & Recreation Commission oversaw the development of the APIP. Four commissioners volunteered to be on the subcommittee. Fourteen publicly noticed meetings were held in 2006-2008. The consulting team of LMA and HSI attended the subcommittee meetings and over 11 meetings with city staff and various stakeholders. At these meetings, the consulting team presented technical information and addressed concerns raised by city staff and the public. On January 17, 2008 the Aquatic Park Subcommittee approved the preferred plan (Alternative 4B). On January 28, 2008 The Parks and Recreation Commission approved the recommended alternative with the amendment that no stormwater be allowed into the lagoons at the new Potter St. and Strawberry connections.

As part of the design development process, the consulting team collected and analyzed data on the existing hydrologic and habitat conditions in the park. The team completed surveys of site topography and elevations, dimensions and structural integrity of the tide tubes and stormdrains; monitored tidal cycles; digitally mapped salt/brackish wetlands, freshwater wetlands, and non-native invasive plants; delineated the watershed area of each stormdrain; and collected and reviewed data on water quality, fisheries, and water bird use of the park and nearby bay shallows. A use area/protection area analysis was then created for the park, and design guidelines were drafted for the APIP. A series of recommendations for hydrologic and habitat improvements were formulated. A detailed hydrologic and hydraulic model was used to analyze existing conditions and evaluate 14 alternatives for improved tidal circulation.

The consulting team identified a recommended alternative (4B) and prepared concept level designs for hydrologic improvements, shoreline revegetation, invasive plant removal, wetland creation and wildlife enhancement measures including improvements to Bird Island, tidal wetland creation at the Rowing Club site, and asphalt removal and revegetation on the western area of the park. Concept level cost estimates were also prepared for the components of the concept design. A detailed project description was prepared for use in CEQA and the permitting process. The team identified potential environmental impacts resulting from implementation of the concept design and recommended areas for further study in order to fully evaluate the environmental effects of the concept design.

Finally, the consulting team analyzed the ability to use the existing freshwater wetlands to serve as biofilters for inflowing stormwater. In addition to these tasks, HSI completed a flushing rate analysis to evaluate residence time of stormwater in the lagoons under existing conditions and under the recommended alternative. LMA completed an analysis of watershed BMPs and biofilter improvements to reduce urban stormwater contaminants from reaching the lagoons during rain storms.

EXISTING CONDITIONS

Aquatic Park has three lagoons and areas of turf and landscaping, roads, native vegetation, and various recreation areas. The park is used for active recreation such as waterskiing, rowing, kayaking, and bicycling as well as hiking and birdwatching. There is an established disc golf course along the east side of the park, and a children's playground. While park rules restrict off-leash dogs, they are frequent in the park and often chase wildlife from the lagoon shoreline. In general the western side of the park has less recreational use than the eastern side.

Hydrology

Aquatic Park receives both stormwater from the City of Berkeley and tidal water from the San Francisco Bay. The flow of water into and out of the lagoon system varies by season. During the summer months, water enters the lagoons from San Francisco Bay through a series of tide tubes that cross under Interstate 80. During the winter months, both tidal water and stormwater can enter the lagoon.

The lagoons receive tidal flushing from water entering the lagoon through a series of culverts or tide tubes. There are a total of nine culvert connections in the lagoon circulation system. The tidal infrastructure of Aquatic Park is deteriorating. The main tide tubes are falling apart on the bay side and failing riprap and parts of the pipes are occluding flows into several of the tide tubes. The Model Yacht Basin tide tube is buried in sand on the bay side. The Radio Tower Pond tide tube has collapsed under the frontage road and appears to have separated on the bay side.

Due to the small size of the tide tubes and their elevation, the average daily tidal range in the lagoons is very small (<0.1 ft.). The lowest tidal elevation acceptable in each lagoon is defined by the elevation of the tide tubes or stormdrain that drains the lagoon and, in the Main Lagoon, navigational hazards that would be exposed at low tide. In addition, each lagoon has shoreline buildings and roadways or other facilities which limit the allowable highest-tide elevation.

A large portion of the City of Berkeley drains towards Aquatic Park. The majority of this runoff drains into the Potter Street Stormdrain and the Strawberry Stormdrain. During high runoff periods, stormwater can enter the lagoons from these two drains. During large storm events most of the watershed immediately east of the park drains directly into the Main Lagoon through a set of seven stormdrains.

Habitat

The primary type of habitat in Aquatic Park is shallow subtidal aquatic habitat in the three lagoons (68 acres total). Aquatic Park is located in central San Francisco Bay which has the most ocean-like conditions of any area of the Bay. There are a number of schooling "bait" fish which are typically very abundant in the central bay and are found in lagoons similar to Aquatic Park, such as Lake Merritt and the tidal lagoon at the Oakland Airport. These small fish are a major food source to diving ducks such as scaups, buffleheads, surfscoters, and grebes which

over-winter in San Francisco Bay and Aquatic Park. Wading birds—egrets and herons, as well as pelicans, cormorants, mergansers, and other fish-eating birds—also feed on the small fish. Aquatic Park supports a variety of wintering water birds. These birds are mostly fish eaters who use the lagoons in winter when water temperatures are cool and small fish are likely to inhabit the lagoons. Data collected in June and September 2004 through the Regional Board's Surface Water Ambient Monitoring Program (SWAMP) show high water temperature and low dissolved oxygen levels, which likely limits fish survival. Large algal blooms and foul odors are also typical conditions in the lagoons in the summer and fall due to very low water circulation and poor water quality.

The three lagoons also have small areas of salt/brackish wetland (0.7 acres total). A natural tidal lagoon would have gently sloping edges and a larger tidal range creating the conditions for tidal wetlands. The lagoons of Aquatic Park have steep slopes and a very small average tidal range. These conditions limit the area for salt/brackish marsh to small pockets along the shoreline of the Main Lagoon and Model Yacht Basin. The Radio Tower Pond has the largest area of salt/brackish marsh along its western edge. At the outlets of the stormdrains on the eastern shoreline of the Main Lagoon, brackish marsh plants grow in pockets. In addition to these pockets, individual high marsh plants grow in the rock riprap of the lagoon shorelines, especially in the Main Lagoon. These wetlands in the Main Lagoon do not provide much wildlife habitat due to their small size and proximity to active recreation uses.

There are intertidal mudflats in several locations where inundation periods are too lengthy for salt marsh plant species to establish. The Main Lagoon has a non-vegetated intertidal flat adjacent to the Rowing Club and the Radio Tower Pond has a large intertidal flat.

Upland areas in Aquatic Park include lawn, pathways, roads, currently used and abandoned parking areas, non-wetland edges of the lagoons and both derelict and currently used buildings. These areas cover 25 acres of the park. The majority of recreation facilities are along the eastern side of the park. The western side of the Main Lagoon has an asphalt access road and a series of asphalt parking areas. The Waterski Club and Rowing Club have facilities on the western side of the Main Lagoon. Another upland area is Bird Island. Bird Island has a building on it which is used by the Waterskiing Club. The elevation of Bird Island is low and the island floods during large storms. The Model Yacht Basin and Radio Tower Pond are bordered by roads including an on-ramp to I-80, parking, and areas of ornamental plantings. At many locations in the upland areas there are homeless encampments. All three lagoons have Monterey cypress planted near the shoreline. These cypresses are used for roosting by various species of herons and egrets.

There are six small freshwater wetlands on the eastern border of the park adjacent to the railroad berm (1.1 acres total). Several have a small creeklet draining into the Main Lagoon. The freshwater wetlands have mostly saturated muddy soils with wetland plants. Most of the wetlands at Aquatic Park have dense cattails or tules due to the soggy soil conditions. Grass areas next to the freshwater wetlands are also often saturated. Many features of Aquatic Park's freshwater wetlands greatly reduce their value as wildlife habitat, such as immediately adjacent active recreation areas, homeless encampments, and significant infestations of invasive non-native plants.

MODELING AND ANALYSIS

Hydrology

A hydraulic model was developed to evaluate the pipe network that connects Aquatic Park with the bay. The United States Environmental Protection Agency Stormwater Management Model (SWMM) was used for the analysis because it is uniquely suited to the evaluation of networks of pipes and impoundments under unsteady tidal conditions. The model was run for the existing condition to determine the volume of water that is presently flowing into and out of the lagoons. Various project components were evaluated in an effort to determine the most effective modifications that could be made to the connections with the bay.

One or all of the following four components of the lagoon system were analyzed:

- 1) Increasing the capacity of the connection at the Strawberry Stormdrain.
- 2) Increasing the capacity of the Potter St. Stormdrain connection.
- 3) Improving the connection between the Model Yacht Basin and the Main Lagoon.
- 4) Opening up the Northern Tide Tube.

Each project component was modeled separately and in combination under three separate scenarios. The first scenario was to allow water only to flow through the lagoon system in a south to north direction. The second scenario allowed water only to flow through the lagoon system in a north to south direction. The third scenario allowed water to enter and exit the lagoon in any direction based on the hydraulics of the connection. The objective of the one-way scenarios was to force a positive circulation through the system. A one-way flow pattern would minimize stagnant areas in the lagoons and force a positive flushing action. However, the scenario allowing water to flow in and out of all connections had the greatest volume of water circulating daily through the system. For each of the three scenarios the four components of the lagoon system described above were analyzed. An additional scenario was added, which was an analysis of several of the components individually to determine their relative importance to circulation in the lagoons.

To determine the volume of stormwater entering the lagoon system, a watershed hydrologic model was developed to compute the flow in the Potter Street and Strawberry stormdrains. The watershed model simulated the rainfall to runoff processes for the 2-year through 100-year storm events over the Aquatic Park watershed. The results of this analysis provided flow rates for the Strawberry Stormdrain and the Potter Street Stormdrain. This flow was used as input to a hydraulic model to determine the volume of stormwater that flows into the lagoons on each storm event.

An evaluation of the results of the circulation model showed that Alternative 4B, which would enlarge the connection between the Potter Street Stormdrain and the Model Yacht Basin, construct a 20 ft. wide channel between the Model Yacht Basin from the Main Lagoon, modify the Strawberry Stormdrain connection to allow tidal flow to enter and exit the Main Lagoon, construct a new connection between the Radio Tower Pond and the Potter Street Stormdrain, and repair the Bay tide tubes, provides for a 420% increase in water exchange per tidal cycle compared to the existing condition. The volume of tidal water entering the Main Lagoon per

tidal cycle would increase from the current 22 acre-feet to 115 acre-feet. Based on the model analysis, Alternative 4B was selected as the preferred alternative.

The model was used to evaluate retention time of stormwater in the Main Lagoon from two different size storms under existing conditions and under the recommended alternative. Under the current conditions it takes 48.5 days to remove stormwater from the lagoons after a 100 year storm event. Under the preferred alternative it will only take 10.4 days to remove the stormwater following a 100 year storm event resulting in greatly improved aquatic habitat conditions.

The hydrologic analysis also determined the volume of discharge that enters the lagoon from the sub-basins immediately east of the park termed the "local" watershed. These sub-basins, made up of storm drains along Bancroft, Channing, Dwight, Parker, Carleton, Grayson and Heinz Streets, can drain directly into the Main Lagoon during large storm events. Watershed modeling showed that 30% of stormwater entering the lagoons originated not from the Potter and Strawberry stormdrains, but from stormdrains and urban runoff along the east side of the park.

The persistent urban stormwater contaminants that pose the greatest biological problems in the tidal lagoons of Aquatic Park as well as San Francisco Bay are transported on clay particles moving as suspended sediment in stormwater. Revising the water circulation in the lagoons to move stormwater out quickly will reduce the deposition of clay particles in the lagoons; however, these particles will still move into the bay. The most effective way to reduce pollutants is to treat stormwater in the watershed of Aquatic Park.

The urban streets, parking lots, and buildings of the local watershed could be retrofitted with stormwater biofiltration facilities. Biofiltration facilities provide treatment of stormwater as it flows along streets and through parking lots and before it enters the stormdrain system. Biofiltration facilities provide a medium which can rapidly and effectively filter out trash and a high percentage of the fine sediment particles, bacteria, and nutrients, and biologically treat these contaminants. Biofiltration facilities have been found to remove 80 percent or greater of the total suspended sediments (TSS) from stormwater and therefore a high percentage of the metals, nutrients, pesticides, coliform bacteria, oil and gas, and other contaminants. For the Aquatic Park local watershed, design of these facilities will need to take into account soil conditions, rainfall amounts, land uses, utility and pipe systems, land ownership, and overall redevelopment planning. Additional stormwater facilities that could be included in the Aquatic Park local watershed are stormwater detention facilities such as cisterns and rain barrels, as well as residential and even commercial use of porous pavement, rain gardens, and grassy swales. All of these measures will need to be retrofit into the Aquatic Park local watershed to effectively filter contaminants out before stormwater reaches the lagoon system. This watershed is ultra-urban: it contains no open land and is almost entirely paved over.

As an optional APIP component vortex filters could be installed on the storm pipes on the upslope/east side of the railroad berm at the Bancroft, Dwight, and Channing Street stormdrains and in the park to replace the oil/water separators on the Heinz, Grayson, Carleton, and Parker Street stormdrains. These filters would remove trash, large particulates, and oil and grease and would consist of a unit placed in the stormdrain as an in-line facility or next to the pipe as an off-

line unit. The vortex filters would not remove the small particulates which transport many of the persistent pollutants; thus, this type of filter would not take the place of the biofilters but could provide treatment while the biofilter improvements are installed.

Habitat

Open water habitat is the major type of wildlife habitat in Aquatic Park. A lack of water circulation and very small daily tidal volume are the main causes of poor aquatic habitat conditions. Revising water circulation and increasing the volume of tidal water entering and exiting the lagoon system daily could dramatically improve water quality and aquatic habitat. To achieve the greatest level of habitat improvement, Alternative 4B is recommended. Under this alternative, both winter and summer conditions for fish would be improved. After tidal improvements are made, monitoring can determine if conditions in the Main Lagoon will support additional enhancements of aquatic habitat, such as eelgrass and native oyster beds.

Salt/brackish wetlands are very limited in the Main Lagoon and Model Yacht Basin. Several shoreline areas were evaluated for excavation for wetland restoration. The Rowing Club site was selected as the salt/brackish wetland restoration site due to its larger size and lack of shoreline trees. There is also an intertidal flat and narrow strip of pickleweed marsh along the lagoon shoreline. Creating a salt/brackish wetland adjacent to an intertidal area will create a larger, more valuable wildlife area. Once the wetland site is excavated, some salt marsh plants would be planted and some would be expected to colonize. An upland berm would be constructed to reduce disturbance from dogs and park users.

The shoreline areas of the rest of the Main Lagoon and the other two lagoons offer an opportunity to eradicate invasive non-native plants and revegetate with high marsh/transition zone native plants. The mapped invasive plants were split into three stages of removal. Following invasives removal along the lagoon shoreline, native species could be planted along the lagoon shorelines.

Improvement of Bird Island and upland areas on the western side of the Main Lagoon are included in the APIP. These areas have a greater degree of isolation from recreational use and a higher potential for successful habitat restoration. The soil at the wetland restoration site would be tested for contaminants and if usable then several projects would be done to re-use the soil. Bird Island would have a ring of rock placed on its shoreline to allow the excavated soil to be placed on the island and build up elevations and allow planting of native trees and shrubs. Approximately two acres of upland areas can be improved using the soil excavated from the wetland restoration and channel between the Model Yacht Basin and the Main Lagoon. The abandoned parking lots and adjacent vegetated bulbout areas on the west side of the park could be enhanced as native upland habitats. The asphalt in the parking areas would be broken up and removed and soil placed in 2.5 foot tall mounds. A variety of native species would be planted and a drip irrigation system would be installed. Finally a small berm would be constructed around the radio transmitter building in the RTP to allow a greater level of tidal water circulation without causing flooding of the building.

Enhancement options for the freshwater wetlands are included as an optional component of the APIP. Change to the vegetation of the freshwater wetlands is unlikely to increase habitat values unless disturbance levels can be reduced. Two different options were evaluated for the freshwater wetlands: a pilot wetland restoration project and riparian revegetation. The proposed pilot project would reconfigure a one-acre area to create an open pond with a vegetated wetland border to isolate some habitat areas and produce a more attractive habitat for wetland birds. However, in order to have an adequate water level in the created pond, surface water from the local watershed will be needed in the summer from one of the stormdrains. The Regional Board has a policy which limits the use of existing wetlands for treatment of stormwater. The pilot wetland would incorporate an existing freshwater wetland but would mostly convert lawn to wetland, so it's not clear how this policy will apply to the project. If, due to Regional Water Quality Control Board concerns, additional water is not available from the stormdrains, then creation of the pilot wetland should not move forward. If the freshwater wetland cannot be adequately improved, then the saturated soils could be used to increase the riparian habitat in the area.

The greatest challenge to creating viable wildlife habitats at Aquatic Park is buffering habitat areas from the high level of human activity and unleashed dogs in the park. The eastern side of the park has the highest amount of human activity, but both the east and west sides of the park suffer from unleashed dogs disturbing birds and wildlife and sometimes chasing them into the lagoons. The west side is the primary focus for habitat improvements to take advantage of the lower level of recreation.

Adaptive management is an approach used in ecological restoration projects and involves changing management strategies as ecosystem monitoring and performance is evaluated. There are several types of management strategies at Aquatic Park that should use this approach. Prior to implementing the water circulation improvements, a water and sediment quality characterization of the Main Lagoon could be done. This study will establish the baseline conditions in the system and allow long-term comparison with post-project conditions. Another component of the baseline and on-going monitoring could be characterization of the benthic invertebrates which inhabit various areas of the lagoons. Once the project is built, monitoring of water levels and water quality is recommended. This detailed pre- and post-project monitoring can be used in evaluating the effects on the aquatic habitat of various settings of the gates on the tide connections.

For the upland habitat areas, adaptive management practices could be used in revising revegetation and replanting practices and/or species. A final level of adaptive management should review the success of first step efforts to control human and unleashed dog disturbance to habitat areas.

TABLE I SUMMARY OF CONSTRAINTS
Tidal Hydrology
The current connections to the San Francisco Bay limit tidal water from entering the lagoons.
The existing tide tubes date from the 1930s and are deteriorating and collapsing.
Installing new tide tubes under I-80 is expensive and infeasible.
Larger connections to the existing stormdrains, if not managed correctly, can allow more stormwater into the lagoon. The additional stormwater will temporarily reduce the salinity and may increase the amount of pollutants entering the lagoon.
Constructing new connections will be complicated because the existing openings should remain operational until the new connections are completed.
The presence of buildings and roads on the lagoon shoreline limits the elevation of high tide and the volume of additional bay water that can be let into the lagoon.
The recreational uses of the lagoon will limit the low-tide elevation and the volume of tidal water which can be exchanged with the bay.
Watershed Hydrology and Urban Stormwater
Stormwater flows into the Main Lagoon from the two major stormdrains under certain conditions: in Strawberry Stormdrain when flows overtop a weir and from the Potter St Stormdrain.
Stormwater flows into the Main Lagoon from localized stormdrains along the eastern edge of the park.
Stormwater flows directly into the lagoon from several adjacent streets.
Summer urban flows provide additional nutrients and likely increase the water quality problems in the Main Lagoon.
Urban stormwater varies in the concentrations of contaminants over the winter season. The first flush of runoff in the fall/winter typically carries the highest concentration of contaminants and is the most important to filter or treat.
There is limited water quality monitoring data for the lagoons and for stormwater in the Berkeley area.
There is limited area in the park to filter stormwater.
Regulations may restrict directing additional stormwater to freshwater wetlands for bio-treatment.
Maintenance is a requirement for stormwater filtration facilities.
Shallow Subtidal Aquatic Habitat and Water Quality
Very limited tidal inflows and water circulation in Main Lagoon and Radio Tower Pond.
Deteriorating tide tubes likely to further reduce inflows.
High water temperatures occur in summer and fall.
Algal and aquatic plant growth from warm stagnant conditions results in low dissolved oxygen in the lagoon. DO levels drop below RWQCB water quality standards in the summer and fall.
Stormwater inflows are retained in the lagoons for several weeks due to limited water circulation possibly allowing for contaminants to deposit out.
Salt/Brackish Wetland and Shoreline Habitats
The Main Lagoon has a very small average tidal range of .2 ft. and the Model Yacht Basin has an average tidal range of about 1.77 ft. This is in comparison to the average 6.16 ft. tidal range in the adjacent San Francisco Bay.
Most of the lagoon shorelines are rock-lined and relatively steep (>10%) or consist of rock terraces and will not support wetlands.
Wind-driven waves erode the eastern shorelines and could limit success of wetland creation.
Human recreational use is high along the Main Lagoon and Model Yacht Basin and includes unleashed dogs which run near the shoreline and into the water to chase birds.. Unleashed dogs also deter any nesting by resident ducks or shorebirds.

TABLE I SUMMARY OF CONSTRAINTS	
Salt/Brackish Wetland and Shoreline Habitats	
Invasive plants, such as ice plant, cover areas of the shoreline on and near existing and potential wetland sites.	
Black-crowned night herons roost in the willows in the northeast corner of Radio Tower Pond and in the cypress along the western shoreline of the Main Lagoon.	
Homeless encampments, trash dumping and other activities disturb and degrade shoreline areas, further limiting habitat values.	
Upland and Bird Roosting Habitat	
The upland areas support active recreation including biking, walking, leashed and unleashed dog walking, disc golf and boat launching.	
There are limited wildlife species using the upland areas.	
There are high levels of disturbance and human uses.	
Homeless encampments, trash dumping and other activities that disturb habitat occur in upland areas.	
There are invasive non-native plants in the upland areas.	
There are a number of derelict and unused buildings in the park.	
The road between the Model Yacht Basin and Radio Tower Pond is used by a large number of cars as a freeway on-ramp.	
Freshwater Wetlands	
The freshwater wetlands have shallow ponding and saturated soil encouraging the growth of dense cattails with little vegetative diversity or open water. Water flows are likely from groundwater seeps and aesthetics of wetlands are low. Water flows saturate lawn areas.	
Water from the marshes flows through narrow channels into the lagoon. Changing the narrow deep channels to wide shallow channels would create more cattails and muddy areas.	
Invasive ivy is killing some of the willow trees and other invasive plants also occur.	
Areas next to freshwater wetlands are used for active recreation which involves people and unleashed dogs walking through the marshes, creating a very high level of disturbance and diminishing value for wildlife habitat.	
There are homeless encampments in the wetlands which reduce habitat values.	
Wetlands are not large enough, even if doubled in area, to adequately filter and treat winter stormwater from the stormdrains in the park. Wetlands could possibly filter and treat summer nuisance flows.	
Regulations may restrict increasing urban runoff into the wetlands and changing their form.	
It may be difficult to find funding for changes and improvements to the freshwater wetlands due to the negative effects of the high disturbance levels on habitat values and the small area of the marshes set in a recreational area.	

TABLE II SUMMARY OF OPPORTUNITIES
Tidal Hydrology
The connections to two large stormdrains adjacent to the park could be modified to increase the amount of cooler and relatively unpolluted water coming into the lagoons from San Francisco Bay.
Putting better controls on the Potter Street Stormdrain connection and Strawberry Stormdrain connection will allow for selectively blocking out stormwater inflow. This is particularly important for blocking the first flush that occurs during fall and early winter.
Larger connections in the Potter Street and Strawberry stormdrains will allow for significantly faster removal of any stormwater that flows into the lagoon.
Repair and stabilization of the five main tide tubes will prevent them from totally collapsing and preventing bay water from entering the lagoon. This is essentially the only existing opening for bay water to enter the Main Lagoon.
Replacing the two 24-inch culverts between the Model Yacht Basin and the Main Lagoon with a larger channel opening will allow tide water from the Potter Street Stormdrain to enter the Main Lagoon. Presently very little of the tidal flow from Potter Street Stormdrain enters the Main Lagoon.
A new channel connection between the Main Lagoon and the Model Yacht Basin will require less maintenance to keep open. The existing culverts require continual maintenance to keep them from getting clogged up with marine growth. Presently they have less than half of their original flow capacity, and they were cleaned out two years ago.
Watershed Hydrology and Urban Stormwater
<i>In the Park:</i>
Control structures can be installed at Potter Street Stormdrain and Strawberry Stormdrain to limit stormwater inflows into the lagoons.
A bioswale could be installed along the road/lawn on the northern end of the park to filter stormwater flowing directly from streets into the park.
Increased water circulation in the lagoon system will remove stormwater at a much faster rate.
<i>Outside the Park:</i>
There are numerous locations in the urban area which could have biofiltration facilities installed on streets, parking lots and other locations.
The eastern edge of the railroad/western ends of streets could accommodate a series of large vortex filters to cleanse stormwater before entering the park.
The Aquatic Park area could be used as a regional demonstration project for integrated ultra urban stormwater treatment, habitat restoration, monitoring and adaptive management.
Shallow Subtidal Aquatic Habitat and Water Quality
There are two locations, Potter Street Stormdrain and Strawberry Stormdrain, which can be used to improve the volume of tidal exchange and water circulation in the lagoons.
Increasing tidal volume and circulation would reduce stagnant warm water conditions and increase cold water and dissolved oxygen, creating aquatic conditions more like the central bay habitats for fish.
Increased tidal circulation would remove stormwater from the lagoons at a much faster rate.
Summer/fall bird use includes mallard ducks, double-crested cormorants, Forster's terns, snowy egrets and shorebirds. According to the 2005 Bird Study these species forage in the Main Lagoon. October through March migratory diving ducks, including scaup and bufflehead, use the Main Lagoon as a foraging area. Year-round residents include great blue herons, black-crowned night herons and great egrets. Improved aquatic habitat would benefit these species.

TABLE II SUMMARY OF OPPORTUNITIES
Salt/Brackish Wetland and Shoreline Habitats
A wetland could be created by excavating material out of the shoreline in one of several locations. Filling the water area to create wetlands would reduce the tidal prism and reduce the volume of water circulating through the lagoon. The western shoreline of the Main Lagoon is not eroded by waves and could support a new wetland.
The western portion of the Main Lagoon has a lower level of recreational use. Dogs and people could be restricted through design of vegetative barriers, signs and some fencing.
Invasive plants are located on and near existing and potential wetland sites and will need to be eradicated.
Sites P2, P3 or the Rowing Club areas could be graded to create intertidal conditions. Excavated material could be used to create vegetated berms along the edge of a new wetland to restrict unleashed dogs and for other native plant re-vegetation areas (P-1, P-2 and P-3) along the western road, to create a berm around the Radio Transmitter Building in the Radio Tower Pond and to improve Bird Island.
Removal of the black-crowned night heron roosting areas in the northeast corner of the Radio Tower Pond and the cypress along the western shoreline of the Main Lagoon should be avoided.
Senescent and dead trees could be removed and replaced with cypress seedlings and native vegetation.
The northern portion of the eastern shoreline trail could be relocated and the shoreline could be revegetated while retaining the rock walls and riprap to protect against erosion.
Upland and Bird Roosting Habitat
Derelict buildings could be restored or removed.
Un-needed road pavement and parking areas on the western side of the park could be removed and revegetated.
Trails along the shoreline could be relocated to reduce disturbance and the shoreline area could be revegetated.
Some upland areas could be restored to tidal wetlands or freshwater wetlands.
Once the freeway on-ramp is closed much of the pavement could be removed, a trail could be created and revegetation completed.
Turf area on the northern end of the Main Lagoon along the eastside could be used as a bioswale to filter street stormwater runoff from directly entering the lagoon.
Invasive and dead plants could be removed and natives and non-invasive ornamentals planted.
Freshwater Wetlands
Wetlands could be deepened into ponds so that cattails will not dominate marshes allowing for greater water flow, vegetative diversity, aesthetic appeal, creation of water-isolated, less disturbed habitat areas and less maintenance.
Habitat for a wider diversity of bird species could be created if vegetation is changed and disturbance is significantly reduced.
Freshwater wetlands could be altered and expanded to filter summer nuisance flows and improve the quality of water entering the Main Lagoon. Currently summer flows either directly flow into the Main Lagoon or into the transit pipe and into Potter Street Stormdrain.
Several willow groves in the wetland area support songbirds and could be enhanced.
Removal of invasive plants should be an initial step in wetland improvements.
The disc golf course would need to be revised and integrated into any changes in the wetlands to reduce incursions and disturbance.
Signs, low fencing, and potentially some type of enforcement may be needed to keep dogs and people out of the freshwater wetlands.
Changes to the wetlands could reduce saturation of the lawn areas and trails and maintenance needs.

RECOMMENDATIONS

Hydrology Improvements

- 1. Aquatic habitat improvement is the highest priority action for park enhancement.** Aquatic habitat is the primary habitat in Aquatic Park and suffers from poor water quality conditions in the summer and fall. A major increase in water circulation and tidal exchange is needed to improve habitat to support fish and other aquatic life.
- 2. Maximize the increase in tidal circulation and tidal volume.** The current five tide tubes that provide tidal water to the Main Lagoon are falling apart. A new and improved tidal connection and water circulation system is needed. Alternative 4B would create larger connections at the Potter Street and Strawberry stormdrains, and would include excavation to create a new open channel between the Model Yacht Basin and the Main Lagoon, and a structure to protect the bay side of the five tide tubes. This alternative would increase the volume of tidal water entering the Main Lagoon from 22 acre-feet to 115 acre-feet per tidal cycle. Alternative 4B provides the largest tidal range and the greatest water quality improvement. Due to the low elevation of the Radio Transmitter Building, the tidal range at the Radio Tower Pond cannot be changed unless a berm is constructed around the building.
- 3. Block stormwater inflow volumes at new connections.** Enlarging the connections at the Potter Street and Strawberry stormdrains could allow more urban runoff into the lagoon. Slide gates will be installed at the new connections. The gates will be able to block first flush flows which carry the largest concentrations of pollutants. The gates will also be used to block the maximum amount of stormwater. In addition, increasing tidal circulation will remove stormwater at a much faster rate than under current conditions and will reduce effects on aquatic life.
- 4. Consider installing a bioswale along the road/lawn on the northeastern end of the park to filter stormwater flowing directly from streets into the park.**
- 5. Consider creating a demonstration area for ultra urban stormwater treatment using biofiltration facilities installed on streets, parking lots and other locations in the Aquatic Park watershed.** These facilities will reduce the concentration of pollutants in stormwater which directly enters the Main Lagoon.

OPTIONAL ACTION

- 6. Consider as an optional action installation of in-line vortex filtration units on eastside stormdrains** at the eastern edge of the railroad/western ends of Dwight, Channing, and Bancroft Streets. For the stormdrains at Parker, Carleton, Grayson, and Heinz Streets, vortex filter units can be installed in the park to replace the oil/water separators. The vortex filters would not remove the small particulates which transport many of the persistent pollutants, but would provide a treatment option while the biofiltration program is implemented.

Habitat Improvements

1. **Implement a salt/brackish wetland restoration on 1.3 acres at the Rowing Club site.** Excavate the site to the -1.5 ft. (Berkeley Datum) elevation to create salt marsh and high marsh transition areas. Install a berm along the road edge of the site to serve as a vegetated transition area and barrier to unleashed dogs.
2. **Reuse excavated material from wetland creation to restore additional areas, if feasible.** The Rowing Club site elevations are -1 to +4 ft. and will require excavation of 6,230 cubic yards of soil. If soils tests show the material is acceptable, the excavated material could be used for improving bird roosting habitat on Bird Island and native plant re-vegetation areas (P-1, P-2 and P-3).
3. **Remove invasive plants in all shoreline areas and all stem and seed-reproducing invasive plants in other areas of the park.** Invasive plants on and near existing wetlands, especially in the Radio Tower Pond and near the wetland restoration site, need to be eradicated to make the wetland restoration a success.
4. **Replant shoreline areas with native plants.** Remove dead trees on the shoreline and replant with cypress seedlings and native vegetation.
5. **Fill Bird Island with soil excavated from the wetland creation to create areas for tree planting for bird roosting habitat.**
6. **Install additional nearshore roosting structures** for birds made up of anchored floating platforms, rock or large wood
7. **Asphalt parking areas on the western side of the Main Lagoon (P1, P2, and P3) are no longer used and would be removed and covered with 2.5 feet of excavated soil and revegetated with native plants.**
8. **Eradicate ivy in freshwater wetlands and increase riparian habitat in FW-3 and FW-4 areas.**
9. **Monitor water quality and aquatic life.** Increasing the tidal volume and circulation will improve the habitat quality of the lagoons by reducing stagnant warm water conditions and increasing dissolved oxygen. As part of the implementation of tidal improvements, both water quality and aquatic life should be monitored. The results of the monitoring should be used to revise management methods and, if possible, implement additional subtidal habitat improvements such as eelgrass plantings, creation of oyster beds and placement of rocks for herring spawning.
10. **Post and enforce wildlife protection regulations, including leash laws, throughout the park.** Shoreline improvements recommended in the 2005 Bird Study include planting willow or other dense vegetation and fencing the shoreline to reduce disturbance from recreation and dogs. The fencing recommendation will conflict with other recreational uses. Posting and

enforcing rules against off-leash dogs and informing park visitors of how to behave to reduce negative effects on the birds should be tried prior to fencing the shoreline on new habitat areas.

11. Address homeless encampments and evaluate the number and location of trash cans to reduce dumping and littering.

OPTIONAL AND FUTURE ACTIONS

12. Evaluate construction of a 1.0 acre pilot freshwater wetland incorporating FW 1 and the adjacent lawn. Summer water from the stormdrain system would be needed for the wetland.

13. Plan a tree replacement program. Eucalyptus and Acacia make up the largest area of invasive non native plants in the park. As part of future efforts to remove these trees, a tree replacement planting program should be initiated to evaluate the locations and species for replacement trees well in advance of the removal of Acacia and Eucalyptus. As the outer railroad tracks are returned to active use there is high likelihood that the Eucalyptus will be trimmed or cut.

NEXT STEPS: ENVIRONMENTAL REVIEW AND PERMITTING

The next steps in the implementation of the Aquatic Park Improvement Program are to:

- 1) Complete several studies;
- 2) Complete a CEQA (California Environmental Quality Act) document on the project; The City of Berkeley will serve as the lead agency for the CEQA review
- 3) Complete a grant process with the Coastal Conservancy;
- 4) Complete the permit process.

Features of the recommended project that need additional analysis:

1. Soils in the salt/brackish wetland excavation area and Model Yacht Basin to Main Lagoon channel excavation area need to be tested. These tests would determine if there are any contaminant levels which would limit re-use of the soil for restoration projects on Bird Island and the P1, P2, and P3 upland sites.

Once CEQA is completed, the City can work with the California Coastal Conservancy to gain approval of the proposed \$2.0 million in funding. This funding is expected to cover only parts of the APIP including hydrology improvements for aquatic habitat, salt/brackish wetland creation, shoreline invasives removal and revegetation, and enhancement of Bird Island and areas P1, P2, and P3.

Concurrent with the CEQA process, the City will need to apply for permits to implement the APIP from the Regional Water Quality Control Board, the Army Corps of Engineers and the California Department of Fish and Game for most of the project components, and the San Francisco Bay Conservation and Development Commission and the Army Corps of Engineers for the bay side structure to protect the five tide tubes.

AQUATIC PARK IMPROVEMENT PROGRAM TECHNICAL REPORT



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**AQUATIC PARK IMPROVEMENT PROGRAM
TECHNICAL REPORT**

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I. INTRODUCTION

Aquatic Park is located in West Berkeley adjacent to Interstate 80 between Ashby and University Avenues (Figure 1) and is the largest city park in Berkeley. The City has completed several planning efforts for Aquatic Park. In 1990 a Master Plan was prepared which identified enhancing natural resources and improving water quality as major goals. The Master Plan also recommended the southern end of the park become a bird sanctuary. In 2003 the City released a Natural Resource Management Study (NRMS). This study provided recommendations to improve water quality by increasing water circulation and increasing wetland habitat areas. A limited amount of hydrologic modeling and data collection was completed for the study. In 2006 the City moved forward with the Aquatic Park Improvement Program (APIP) to prepare concept-level designs for the major recommendations in the NRMS. This report outlines and discusses the studies and analyses for the APIP completed by a consulting team of Laurel Marcus & Associates (LMA) and Hydrologic Systems Inc. (HSI). The City will complete CEQA review and permit acquisition for the recommended alternative. The City is currently working with the State Coastal Conservancy on implementation funding.

II. SCOPE OF CONCEPT DESIGN

The tasks carried out by the consulting team included:

Meetings

The Consulting team attended over 25 meetings with the Aquatic Park Subcommittee, city staff, and various stakeholders

Collect and Analyze Data

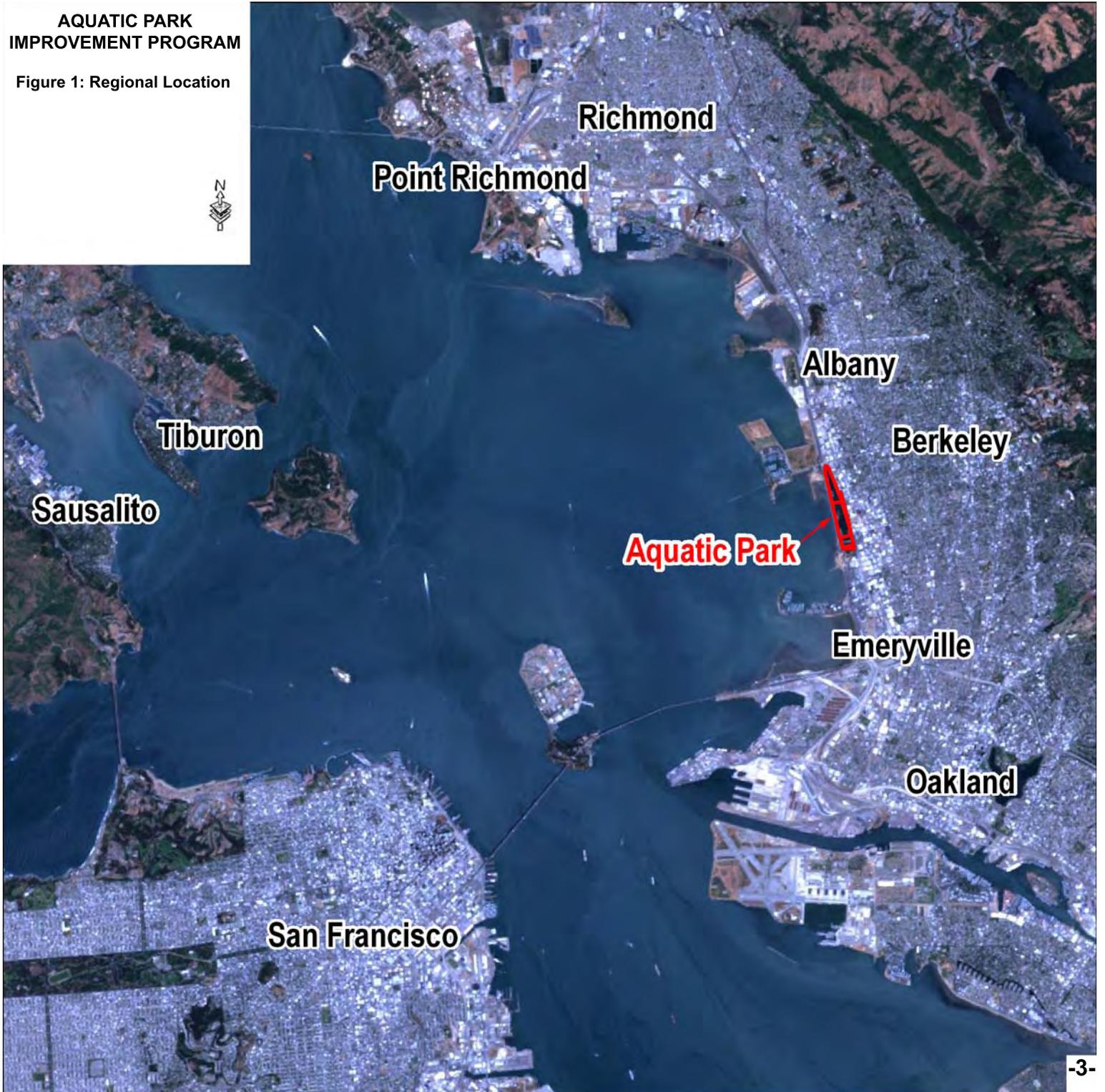
- Site topographic surveys were completed of the shoreline and upland areas. Elevation and dimensions were measured for all stormdrains, tide tubes and other pertinent structures. The structural integrity (condition, wall thickness, rebar location, geometry) of the tide tubes and stormdrains were surveyed.
- Tidal cycles were monitored in the lagoon system.
- The watershed area or drainage basin of each stormdrain was delineated.
- Digital field mapping of salt/brackish wetlands, freshwater wetlands, and non-native invasive plant species was completed.
- Studies of water bird use of the Main Lagoon were reviewed.
- Water quality and fisheries data was collected for both Aquatic Park and the bay shallows nearest to the park.
- A use area/protection area analysis was created for the park.
- Design guidelines were drafted for the APIP.

Concept Design

- A hydrologic model of the watershed feeding into Aquatic Park was created and a series of different storm events were analyzed.

**AQUATIC PARK
IMPROVEMENT PROGRAM**

Figure 1: Regional Location



- A hydraulic model of the lagoon system and its tide tubes/stormdrains was created. Fourteen different alternatives were evaluated for changing lagoon hydrology using the model. These included making major changes to the Strawberry Stormdrain overflow.
- A concept level designs (25%) was prepared for the recommended hydrologic alternative including location sizes, structure types, elevations, materials, and costs for all new connections, gates and other changes.
- Concept-level maps and descriptions of shoreline revegetation areas, invasive plant removal, wetland creation and wildlife protection measures associated with hydrologic improvements to the Lagoon were prepared.
- Concept-level maps and descriptions of invasive non-native plant eradication sites throughout the park and revegetation measures were prepared.
- The ability to use the existing freshwater wetlands to serve as biofilters for inflowing stormwater was analyzed. Also evaluated were deepening, revising inflow and outflow conditions, revegetation and maintenance needs.
- Concept design was prepared for revegetation and improvement of Bird Island to benefit roosting birds.
- The western area of the park was reviewed for opportunities to remove existing asphalt and replant with native species.
- Steps were identified to create a new tidal wetland at the Rowing Club site.
- Concept level cost estimates were prepared for the components of the Concept Design.

Environmental Issue Analysis

- Potential environmental impacts resulting from implementation of the Concept Design were identified. A detailed project description was prepared for use in CEQA and the permitting process.

Recommended Further Study

- Information needs to fully evaluate the environmental effects of the Concept Design were identified.

In addition to these tasks, HSI completed a flushing rate analysis of the Lagoon system to evaluate stormwater residence time in the lagoons under existing conditions and under the recommended alternative. LMA completed an analysis of watershed BMPs and biofilter improvements to reduce urban contaminants reaching the lagoons during rain storms.

III. EXISTING CONDITIONS

General Features of Aquatic Park

Aquatic Park was created in the 1930s as part of the construction of the Bayside Freeway. The alignment of the freeway cut off a portion of the bay. The isolated section of the bay became the three lagoons that we see today. The freeway was later expanded to become the present Interstate 80. The lagoons were used as borrow areas for the freeway construction. The deeper

areas of the lagoon, which follow the western edge, can be seen as a long narrow trench in bathymetric maps.

Early maps and nautical charts of the area show the location of Aquatic Park as sub- and intertidal bay bottom (Figures 2, 3, 4, and 5). The adjacent shoreline appears as a sandy upland with willow groves and a few waterways. Later maps show the old shoreline became the eastern edge of the Main Lagoon. Historic maps also show the park when only one lagoon existed before a separator was constructed between the Main Lagoon and the Model Yacht Basin. Figure 5 shows the Radio Tower Pond and another lagoon to the south which has since been filled.

Aquatic Park now has three lagoons (Figures 6A and 6B) and areas of turf and landscaping, roads, native vegetation, and various recreation areas. The largest lagoon is the Main Lagoon (ML) at 58.3 acres with the Model Yacht Basin (MYB) to the south at 5.0 acres. The Radio Tower Pond (RTP) of 4.7 acres is the southernmost lagoon and only partially owned by the City. The entire park is 102 acres and includes: 68.0 acres of open water in the three lagoons, 0.7 acres of salt/brackish wetland, 1.1 acres of freshwater wetland, 11.0 acres of grass, 7.0 acres of roads and trails, and 14.0 acres of buildings and uplands.

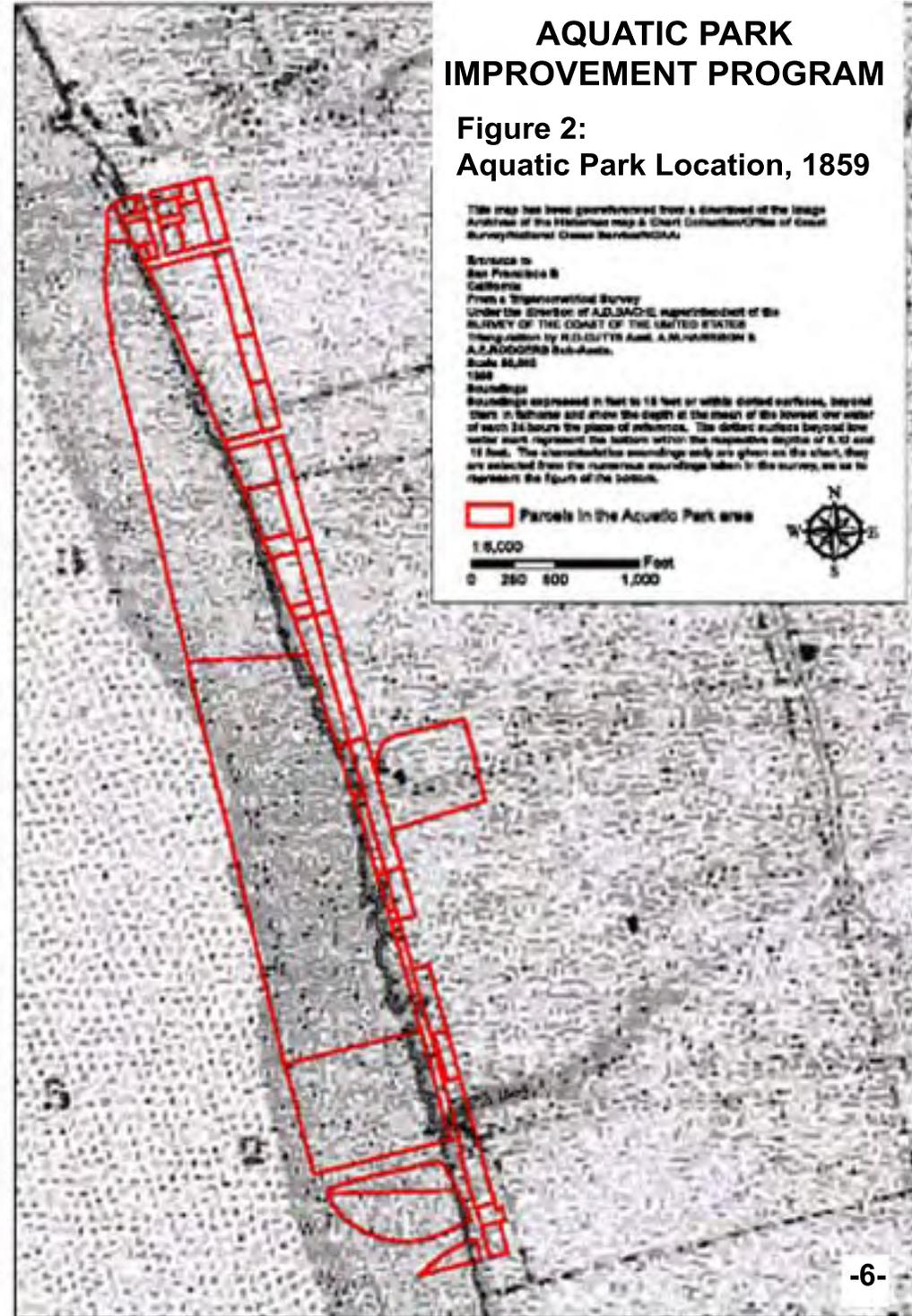
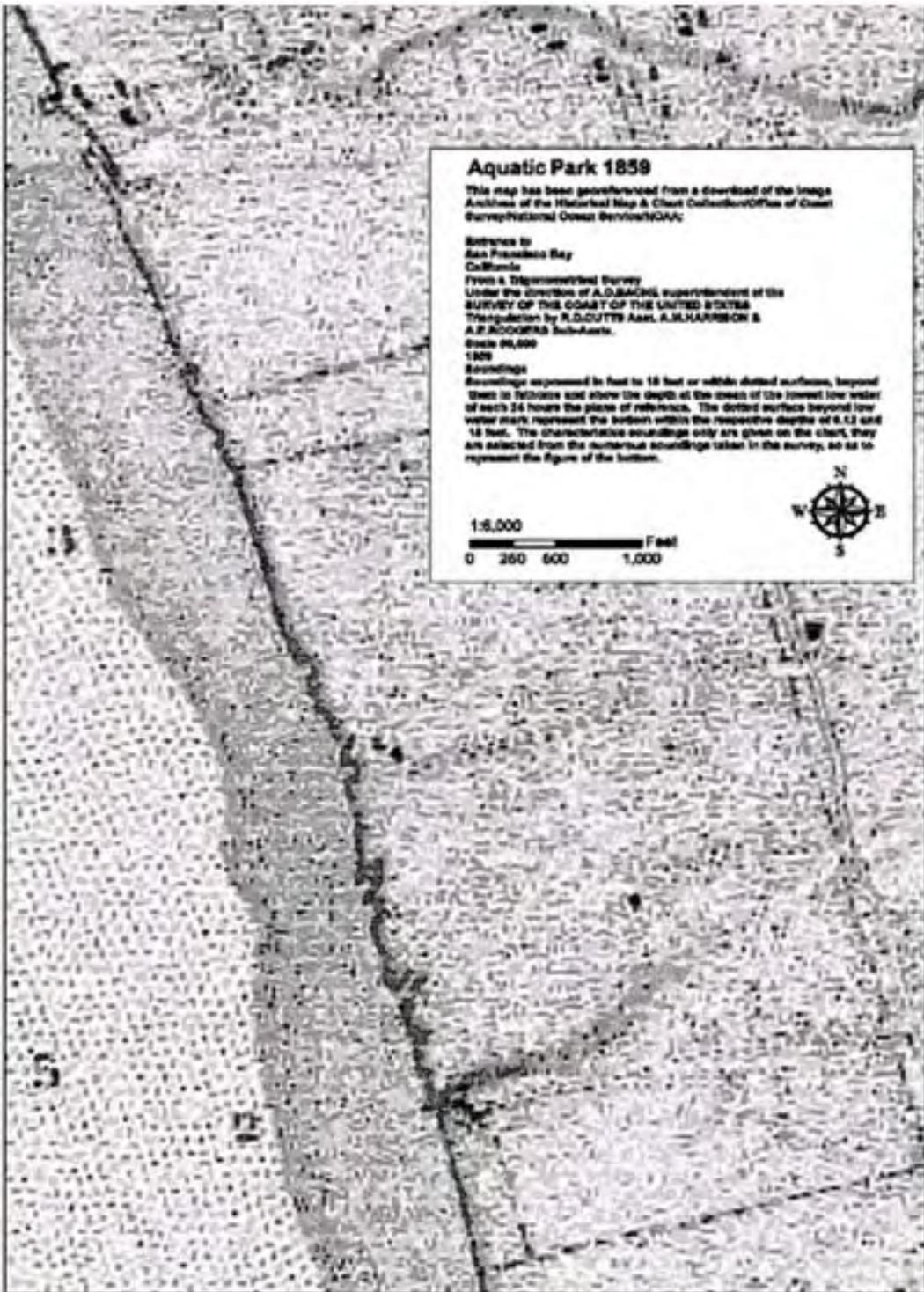
The lagoons are intertidal and each is connected to the Bay by a set of tide tubes and/or stormdrains. Due to the small size of the tide tubes and their elevation, the tidal range in the lagoons is very small.

Bathymetric or underwater measurements of the lagoon bottom and the topography of the park lands are depicted in Figures 7A and 7B. The bathymetric survey was completed in 2002 and a topographic survey was done in 2006. Both the Main Lagoon and Model Yacht Basin have subtidal and intertidal areas. The City of Berkeley uses a unique elevation datum which is roughly similar to 0.0 ft. = Mean Higher High Water (MHHW). There are two other datums more commonly used. Navigational charts use Mean Lower Low Water (MLLW) to define 0.0 ft. All of the measurements used in this report are in the Berkeley Datum. It is not uncommon for a city, county, or even a local agency to use their own datum for the construction of facilities within their jurisdiction. These datums are typically only used locally, and differ from national datums such as the National Geodetic Vertical Datum of 1292 (NGVD) or the North American Vertical Datum of 1988 (NAVD) that are commonly used by federal and state agencies. All public works facilities constructed by the City of Berkeley use the Berkeley Datum. Table 1 is a list of the tide characteristics for the bay. The values are provided in both the 1988 North American Vertical Datum (NAVD) and Berkeley Datum.

From the bathymetric study, the volume and surface area of the lagoon were determined. Figure 8 shows the relationship between lagoon elevation and volume in the lagoon. Figure 9 shows the relationship between elevation and surface area of the lagoon.

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Figure 2:
Aquatic Park Location, 1859



AQUATIC PARK IMPROVEMENT PROGRAM

Figure 3:
Aquatic Park Location, 1949

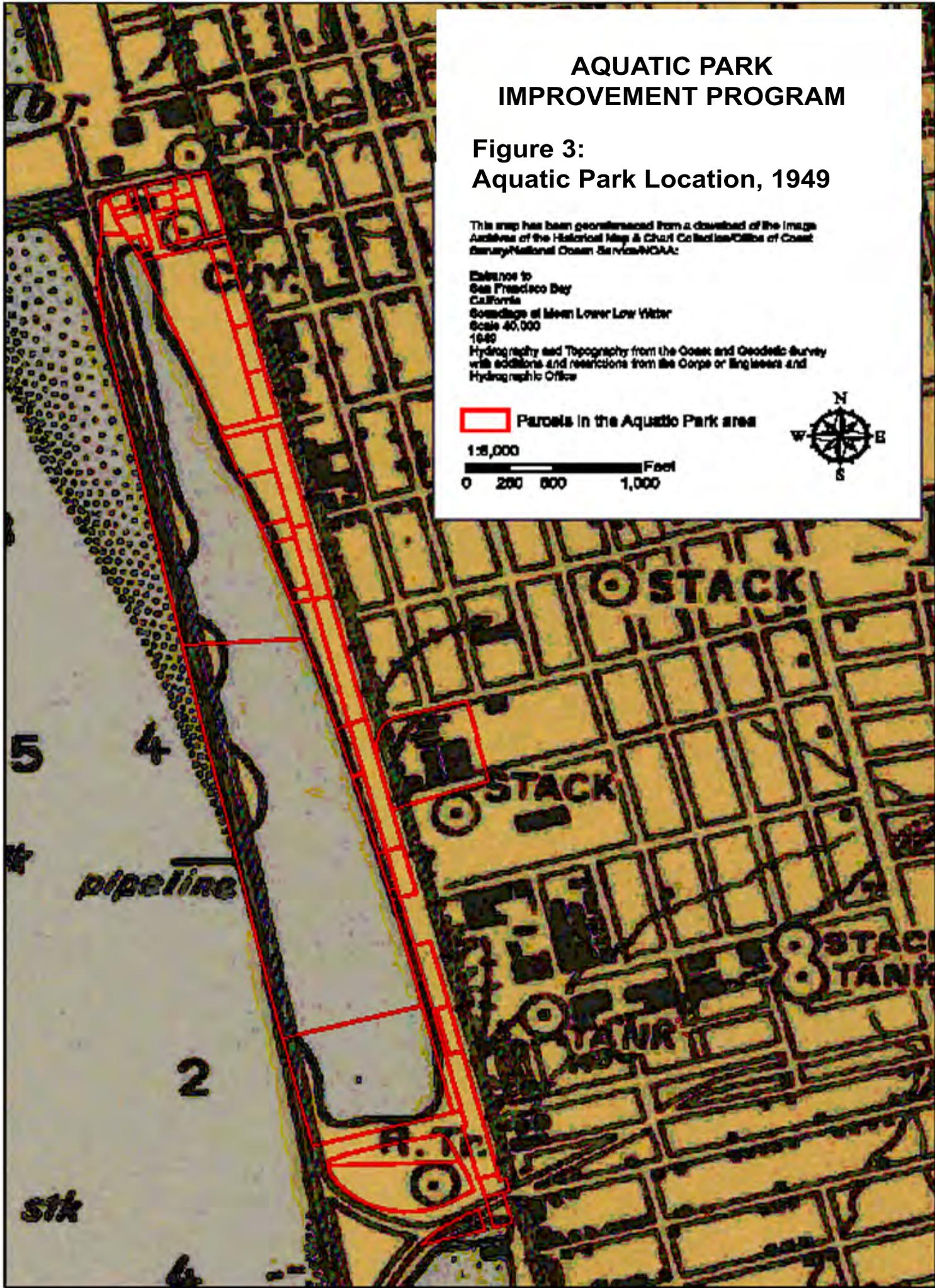
This map has been georeferenced from a download of the Image Archives of the Historical Map & Chart Collection/Office of Coast Survey/National Ocean Service/NOAA:

Distance to
San Francisco Bay
California
Soundings of Mean Lower Low Water
Scale 40,000
1949

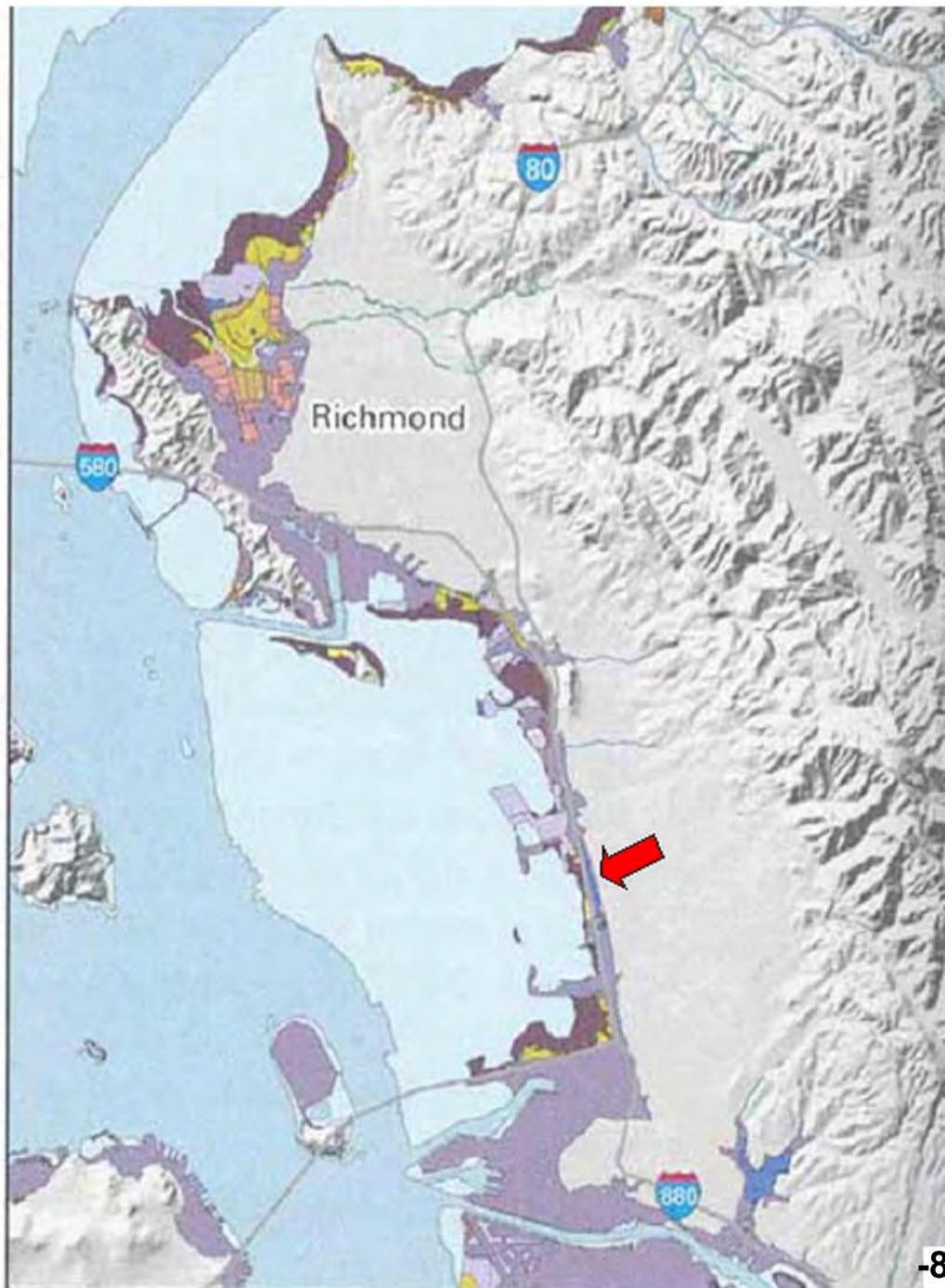
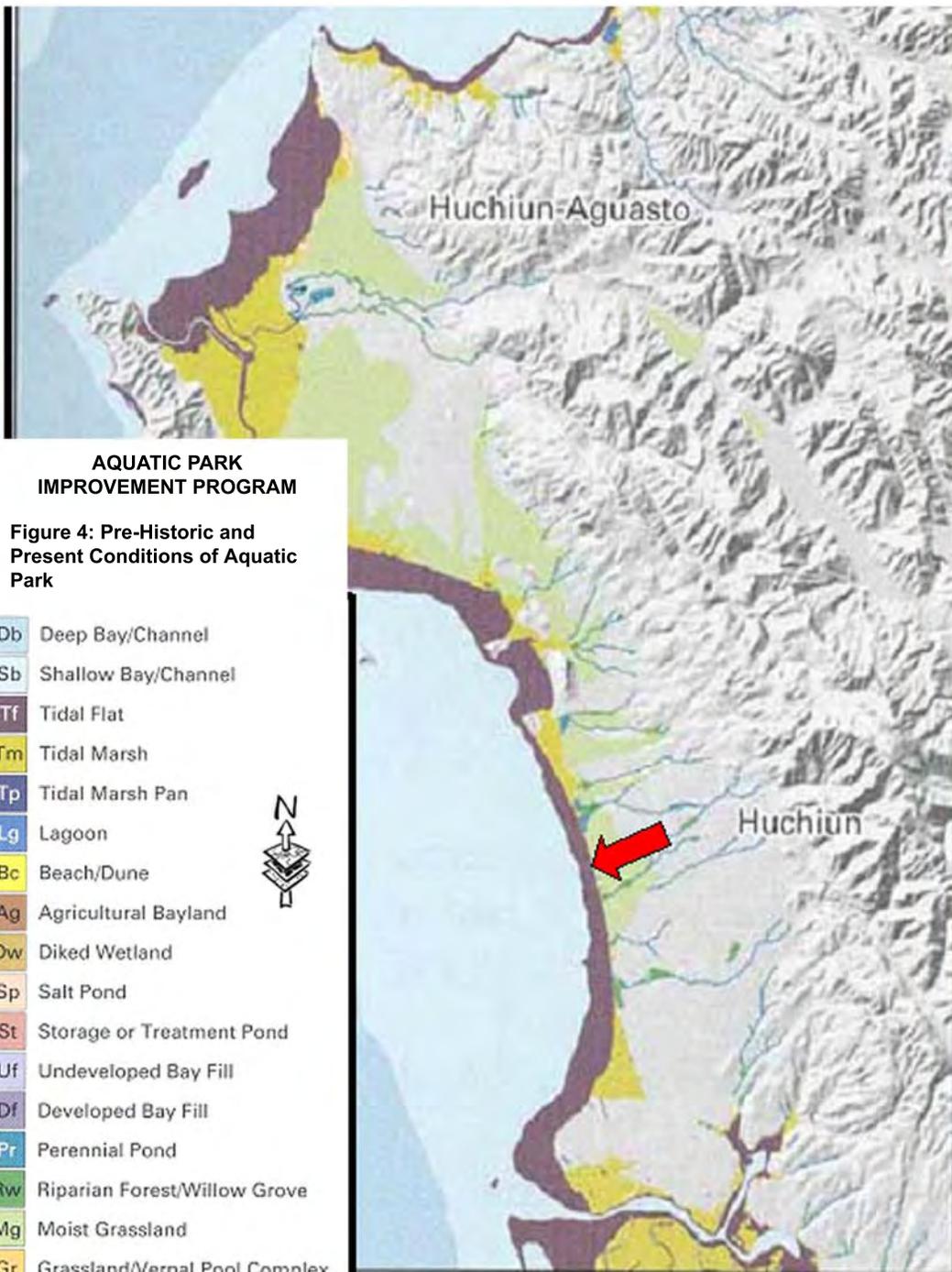
Hydrography and Topography from the Coast and Geodetic Survey
with additions and corrections from the Corps of Engineers and
Hydrographic Office

 Parcels in the Aquatic Park area

1:5,000
 Feet
0 200 600 1,000



AQUATIC PARK: HISTORIC CONDNTION



AQUATIC PARK IMPROVEMENT PROGRAM

Figure 4: Pre-Historic and Present Conditions of Aquatic Park

- Db Deep Bay/Channel
- Sb Shallow Bay/Channel
- Tf Tidal Flat
- Tm Tidal Marsh
- Tp Tidal Marsh Pan
- Lg Lagoon
- Bc Beach/Dune
- Ag Agricultural Bayland
- Dw Diked Wetland
- Sp Salt Pond
- St Storage or Treatment Pond
- Uf Undeveloped Bay Fill
- Df Developed Bay Fill
- Pr Perennial Pond
- Rw Riparian Forest/Willow Grove
- Mg Moist Grassland
- Gr Grassland/Vernal Pool Complex



Past

Present

Source: Baylands Ecosystem Habitat Goals, 1999

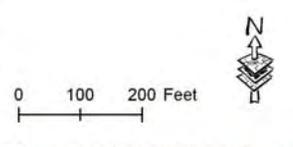


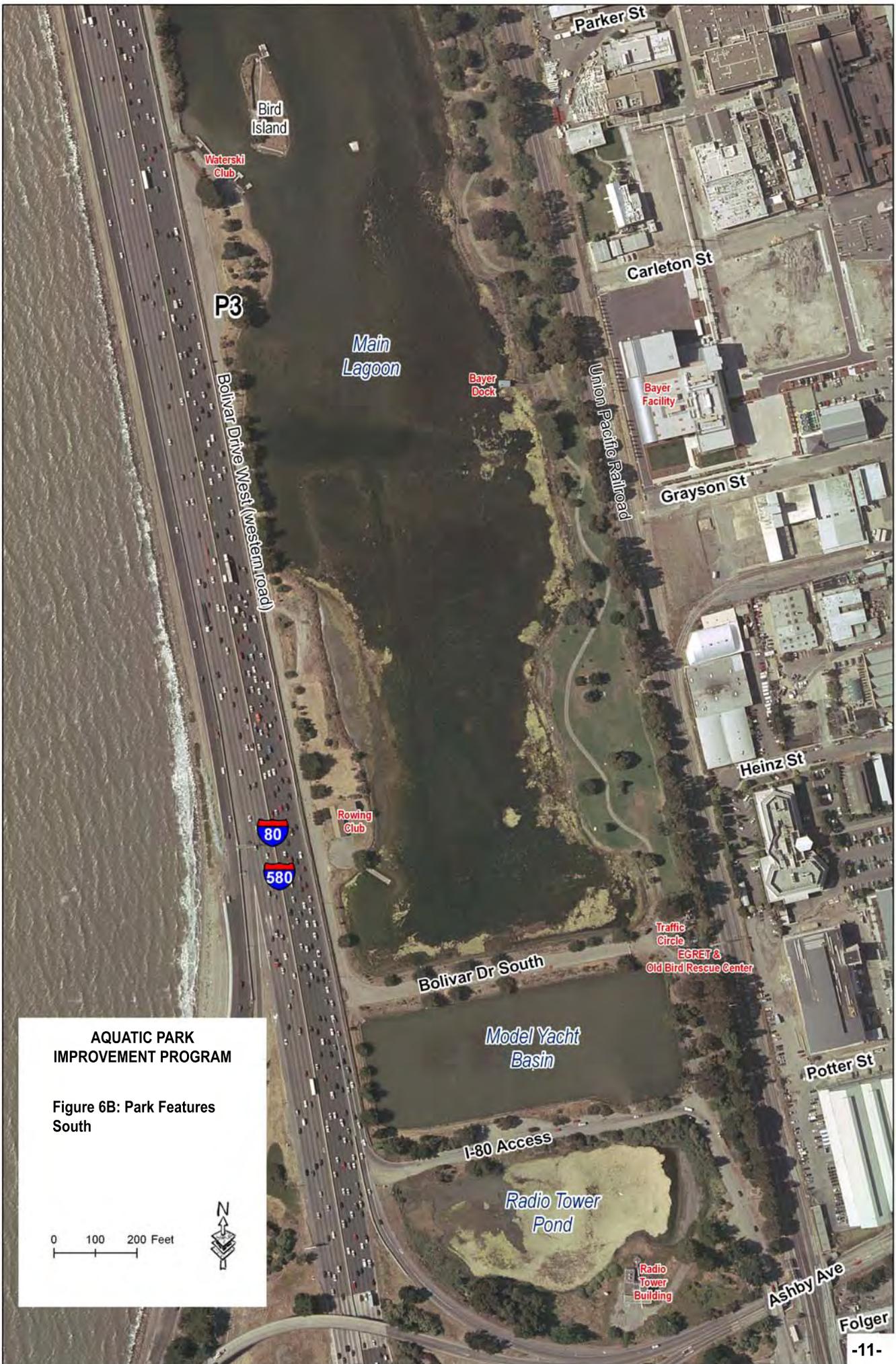
Photo: Western Electric Oscillator, 1947.

Figure 5: Radio Tower Pond (on left) in 1947

**AQUATIC PARK
IMPROVEMENT PROGRAM**

**Figure 6A: Park Features
North**





**AQUATIC PARK
IMPROVEMENT PROGRAM**

**Figure 6B: Park Features
South**

0 100 200 Feet



AQUATIC PARK IMPROVEMENT PROGRAM

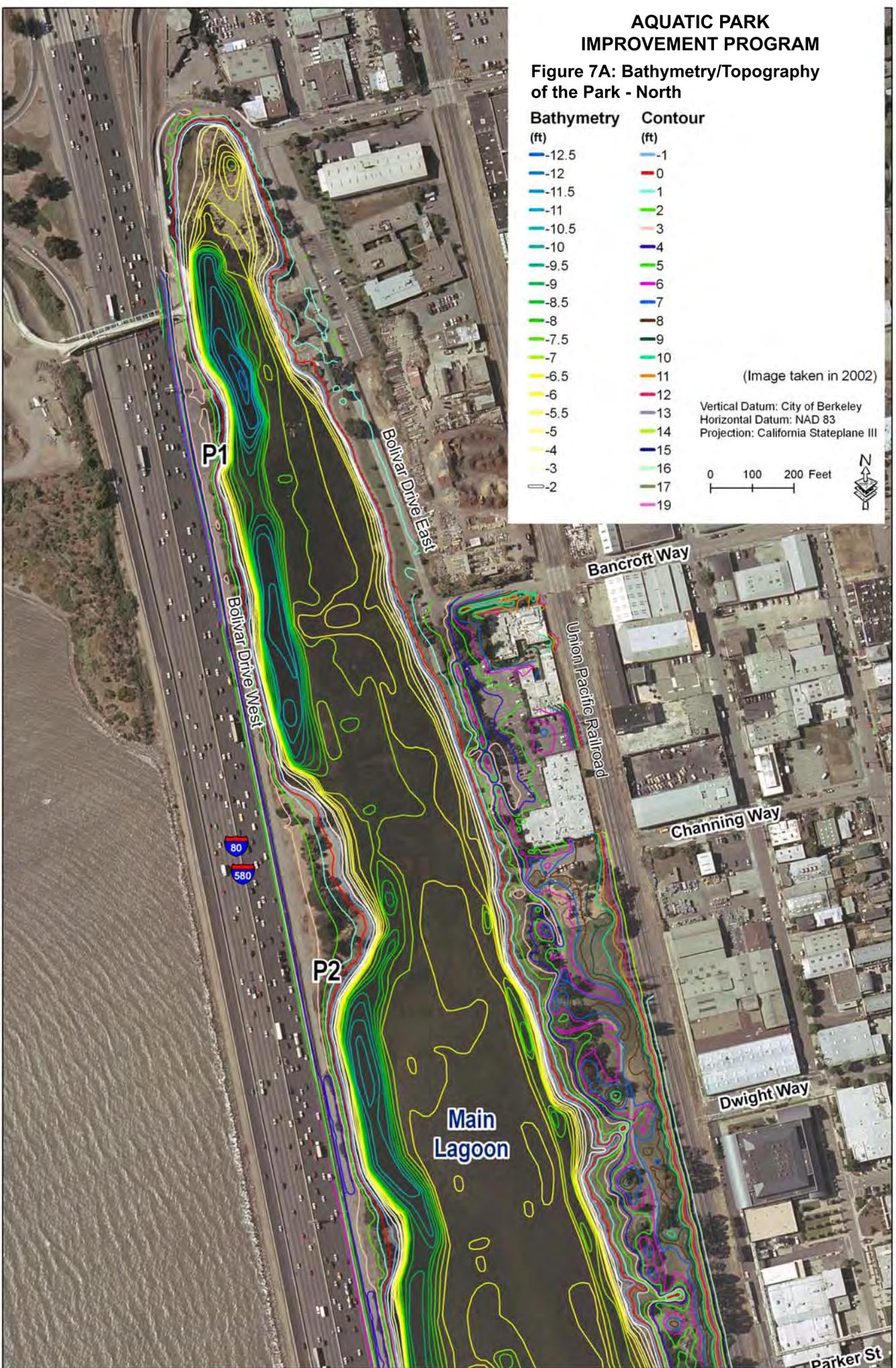
Figure 7A: Bathymetry/Topography of the Park - North

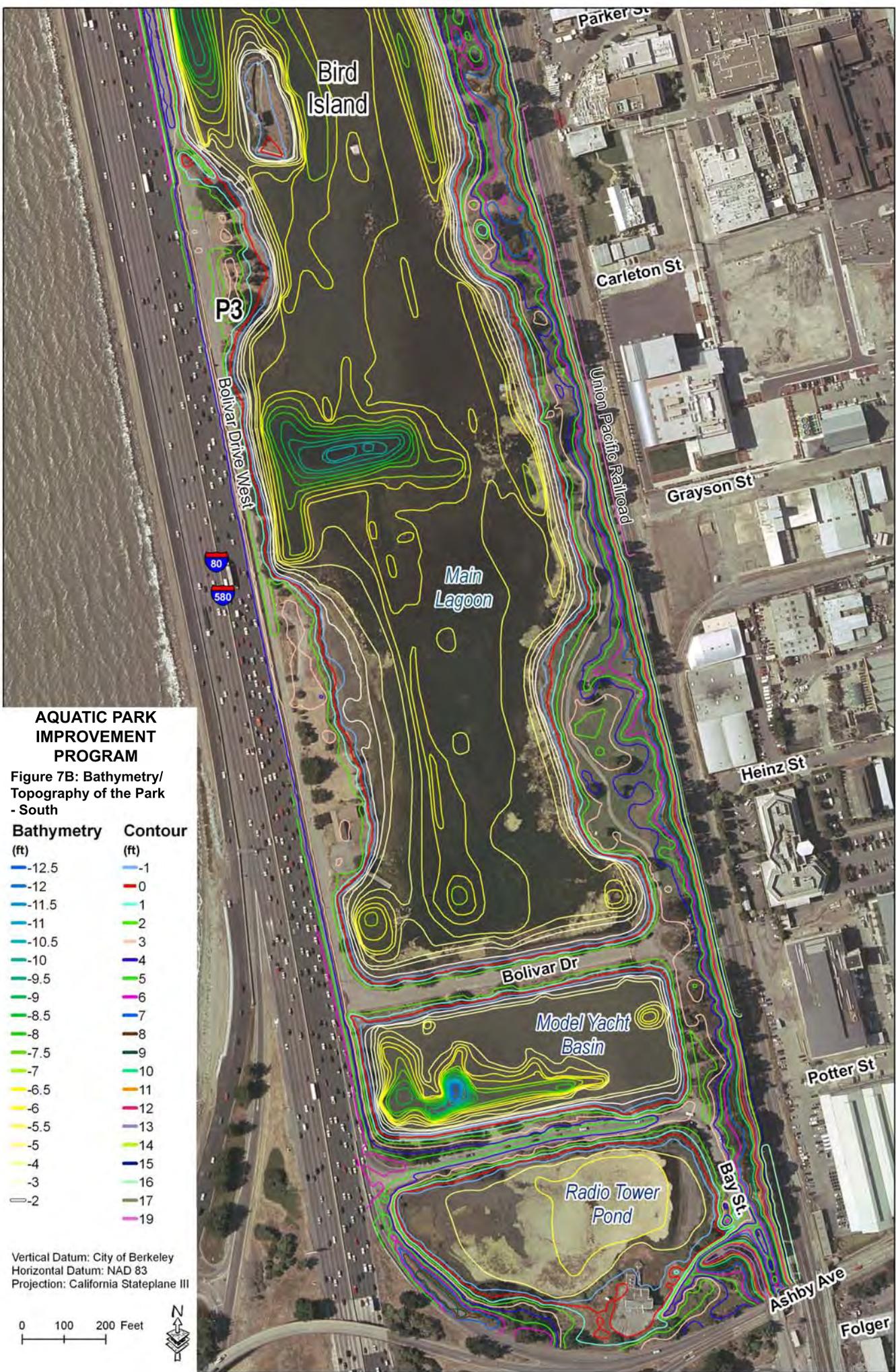
Bathymetry (ft)	Contour (ft)
-12.5	-1
-12	0
-11.5	1
-11	2
-10.5	3
-10	4
-9.5	5
-9	6
-8.5	7
-8	8
-7.5	9
-7	10
-6.5	11
-6	12
-5.5	13
-5	14
-4	15
-3	16
-2	17
	18
	19

(Image taken in 2002)

Vertical Datum: City of Berkeley
Horizontal Datum: NAD 83
Projection: California Stateplane III

0 100 200 Feet



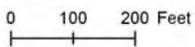


**AQUATIC PARK
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PROGRAM**

Figure 7B: Bathymetry/
Topography of the Park
- South

Bathymetry (ft)	Contour (ft)
-12.5	-1
-12	0
-11.5	1
-11	2
-10.5	3
-10	4
-9.5	5
-9	6
-8.5	7
-8	8
-7.5	9
-7	10
-6.5	11
-6	12
-5.5	13
-5	14
-4	15
-3	16
-2	17
	19

Vertical Datum: City of Berkeley
Horizontal Datum: NAD 83
Projection: California Stateplane III



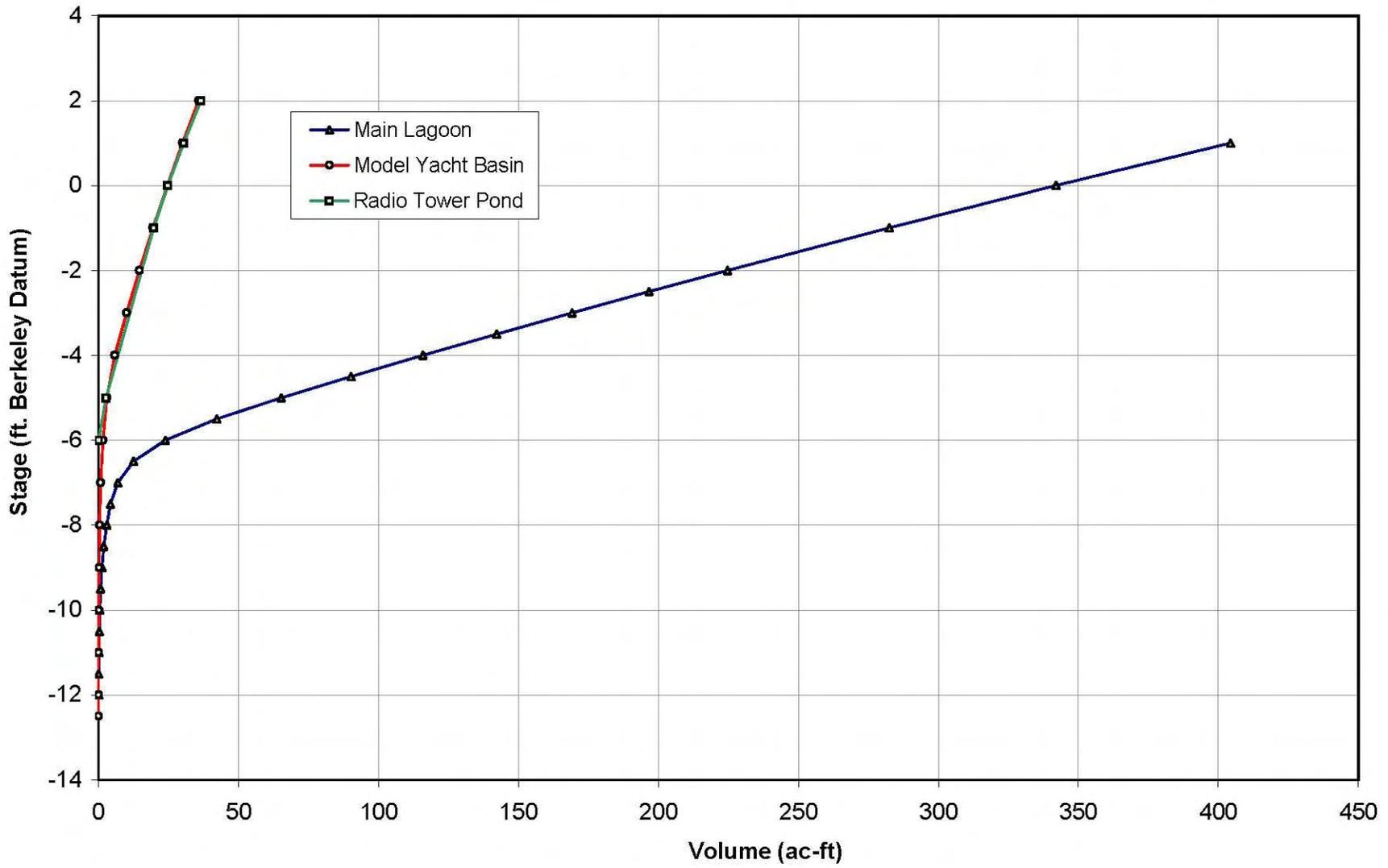


Figure 8: Stage Storage Curve for Aquatic Park Lagoons

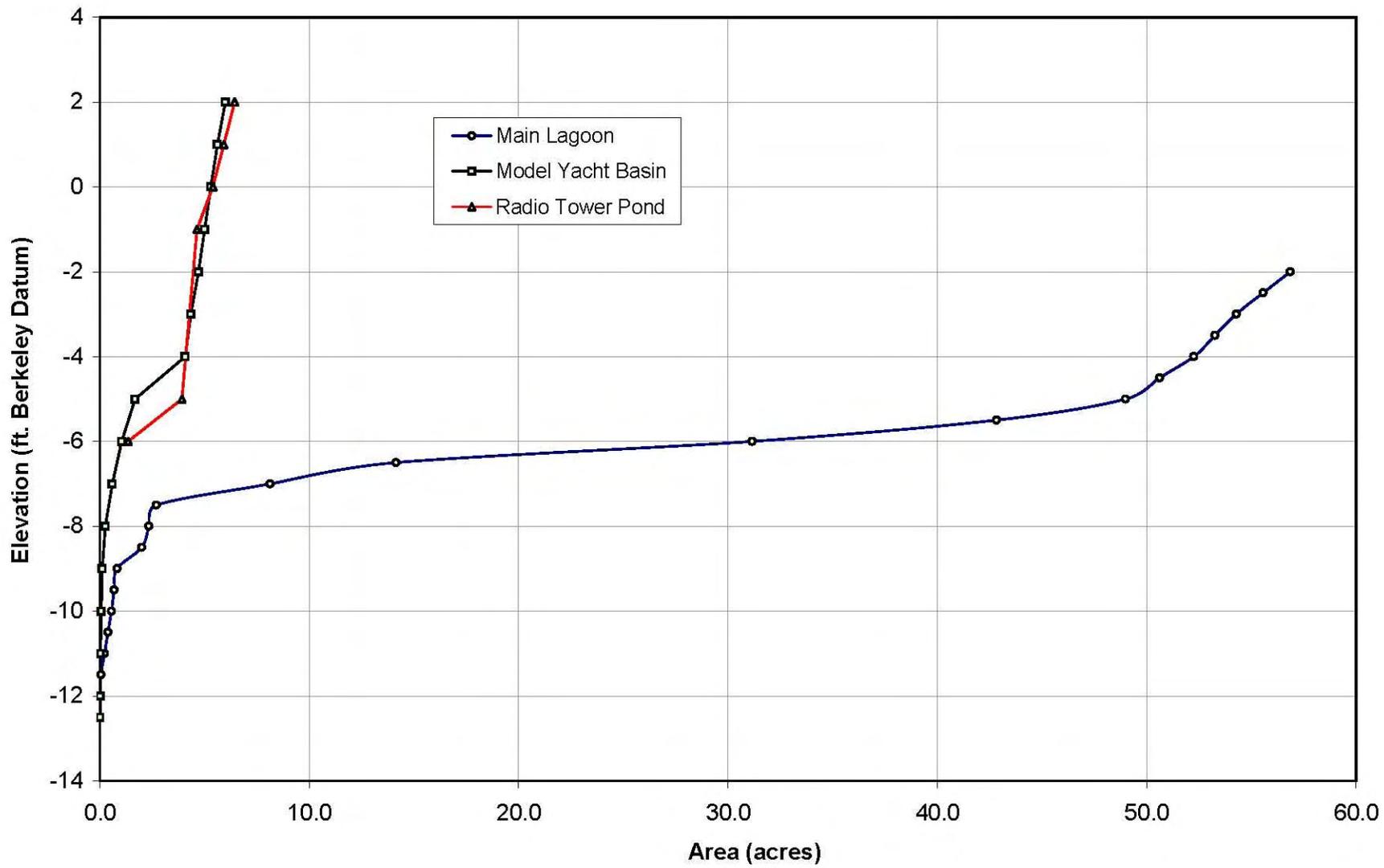


Figure 9: Stage-Area Curves for Aquatic Park Lagoons

Table 1: Berkeley Tidal Gage				
NOAA Station ID: 9414290				
	MLLW	NAVD 88	Berkeley Datum	
	(ft)	(ft)	(ft)	
MEAN HIGHER HIGH WATER (MHHW)	6.170	6.023	0.140	
MEAN HIGH WATER (MHW)	5.580	5.433	-0.450	
MEAN TIDE LEVEL (MTL)	3.350	3.203	-2.680	
MEAN LOW WATER (MLW)	1.130	0.983	-4.900	
MEAN LOWER LOW WATER (MLLW)	0.000	-0.147	-6.030	
Information From NOAA Bench Mark Sheet				
From Corpscom NAVD88 = 2.713 ft above NGVD 1929				

The Main Lagoon was constructed with steep sideslopes limiting the intertidal zone to the mostly rocky shoreline area (Figure 10). The Model Yacht Basin also has steep sideslopes and rock terraces along a portion of its banks (Figure 11). The Radio Tower Pond is very shallow with steep sideslopes.

Aquatic Park is used for active recreation such as waterskiing, rowing, kayaking, and bicycling as well as hiking and birdwatching. There is an established disc golf course along the east side of the park, and a children’s playground. While park rules restrict off-leash dogs, they are frequent in the park and often chase wildlife from the lagoon shoreline. In general the western side of the park has less recreational use than the eastern side.

Tidal Hydrology

Aquatic Park receives both stormwater from the City of Berkeley and tidal water from the San Francisco Bay. The flow of water into and out of the lagoon system varies by season. During the summer months, water enters the lagoons from San Francisco Bay through a series of tide tubes that cross under Interstate 80. During the winter months, both tidal water and stormwater can enter the lagoon.

Tidal Connections

The lagoons receive tidal flushing from water entering the lagoon through a series of culverts or tide tubes. There are a total of nine culvert connections that are involved in the lagoon circulation system (Table 2). The location of those culverts is shown in Figure 12. Five of the connections directly connect the lagoon with the bay. Two culverts connect the Model Yacht

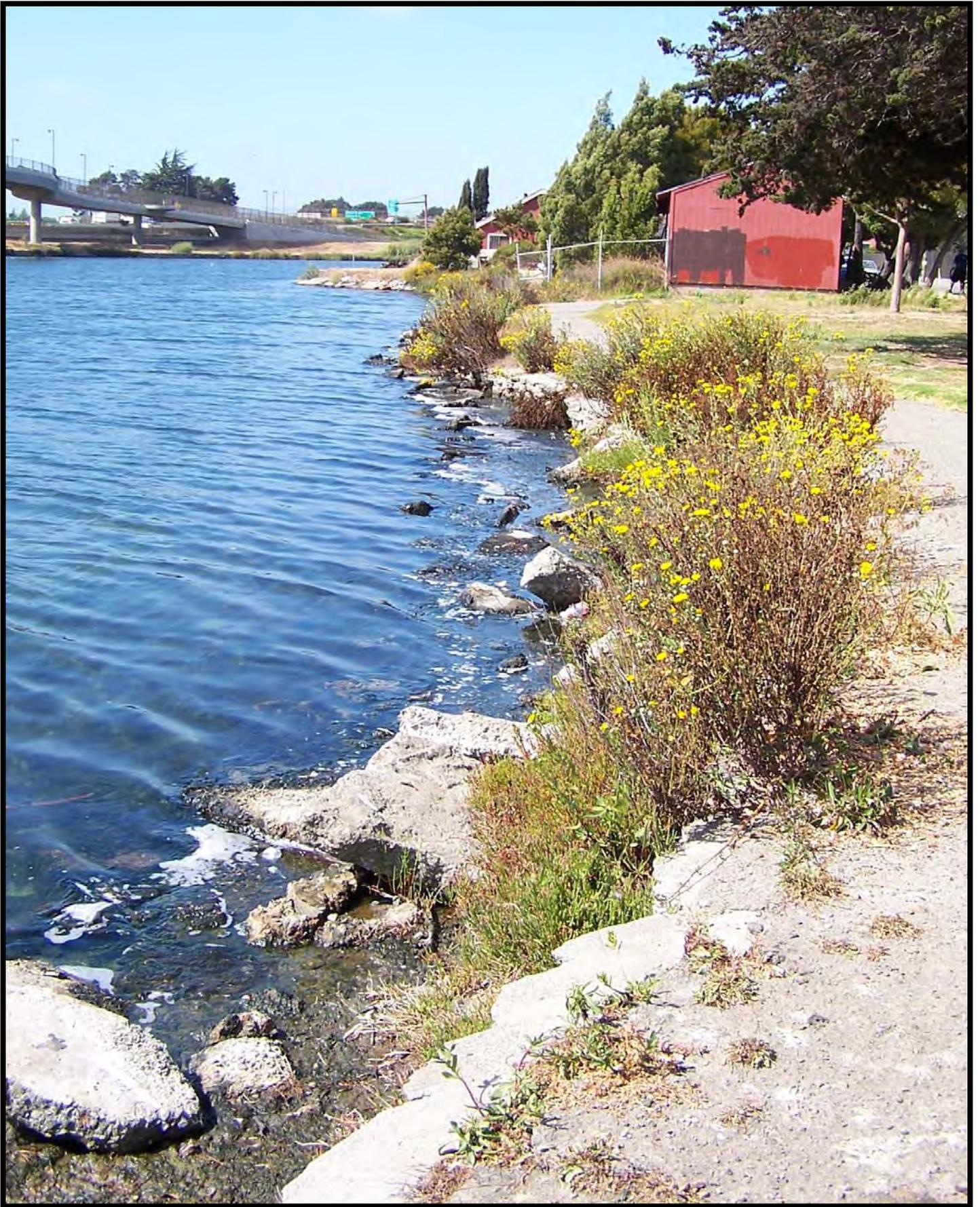


Figure 10: Rocky Shoreline of Main Lagoon

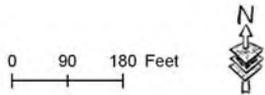


Figure 11: Model Yacht Basin has rock terraces on its shoreline.



**AQUATIC PARK
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Figure 12A: Tidal Connections
- North



AQUATIC PARK
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Figure 12B: Tidal Connections
- South

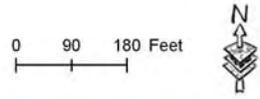


Table 2: Summary of Tidal Connections		
Description	Size	Condition
Connection between the Radio Tower Pond and San Francisco Bay	One 24 inch cement pipe	The Tide Tube has partially collapsed below the I-80 roadbed. Complete blockage may occur.
Potter Street Stormdrain	1-7' tall by 9' wide cement pipe	Condition is ok.
Model Yacht Basin Connection with San Francisco Bay	One 24 inch cement pipe	Lagoon side inlet is ok. Outlet is often buried in bay sands.
Connection between Potter Street Stormdrain and the Model Yacht Basin	Two 24 inch cement pipes	Condition is ok.
Connection between the Model Yacht Basin and the Main Lagoon	Two 24 inch cement pipes	Condition is ok. Requires periodic removal of marine growth.
Tide Tubes Between the Main Lagoon and San Francisco Bay	Five 24 inch cement pipes	Lagoon side inlet ok. Outlet is in bad condition.
Northern Tide Tube Connection Between the Main Lagoon and San Francisco Bay	One 24 inch cement pipe	Lagoon side inlet is in good condition. Outlet cannot be found. It may have been buried in freeway or bay trail construction.
Connection between Strawberry Stormdrain and the Main Lagoon.	One 90 inch cement pipe	Condition is good. Lagoon side outlet is partially buried.
Strawberry Stormdrain	90" dia concrete pipe	Condition is ok.

Basin with the Main Lagoon, and one connection, the Strawberry Stormdrain, is only active during storm flow conditions.

The Main Lagoon is connected to the San Francisco Bay by five 24-inch culverts under Interstate 80 (I-80) and to the Model Yacht Basin by two 24-inch culverts. There is an additional tide tube at the northern end of the Main Lagoon which is no longer functional. The Model Yacht Basin receives tidal flows through two 24-inch connections to the Potter St. Stormdrain which is intertidal through the park. The Model Yacht Basin also receives some tidal inflows through a single 24-inch tide tube under I-80. The Radio Tower Pond receives a small amount of tidal inflow from a single 24-inch tide tube under I-80 (Figure 13).

The tidal infrastructure of Aquatic Park is deteriorating. The main tide tubes are falling apart on the bay side and failing riprap and parts of the pipes are occluding flows into several of the



Figure 13: Tide tube to Radio Tower Pond shows separation of pipe segments.

Below: Potter Street Stormdrain is intertidal under I-80 and into Aquatic Park



tide tubes (Figure 14). The Model Yacht Basin tide tube is buried in sand on the bay side. The Radio Tower Pond tide tube has collapsed under the frontage road and appears to have separated on the bay side (Figure 13). Due to this collapse, the flow into and out of the Radio Tower Pond has been reduced. It is possible this pipe may completely collapse, closing off the tidal connection of the Radio Tower Pond and likely creating stagnant conditions. The Potter Street stormdrain appears to be in far better condition than any of the tide tubes (Figure 13). There is an overflow connection at the Strawberry Stormdrain to the Main Lagoon. A weir in the connecting pipe prevents tidal flows from entering the Main Lagoon. Only large rainfall events generate sufficient storm flows to overtop the weir.

A series of cross-sections through the different culverts draining the lagoon was developed to show the basic elevations of the different culvert features and the lagoon. Figure 15 is a cross-section through the Potter Street Stormdrain pipe. This cross-section shows the elevation of the inlets and outlets relative to the Model Yacht Basin. Figure 16 is a cross-section running east-west through the Main Lagoon and five main tide tubes. Figure 17 is a cross-section through the Strawberry Stormdrain connection. The relative tidal range for the bay and lagoon are indicated on the cross-sections. Figure 18 is a profile of all of the culvert outlets showing their respective elevations.

The inflow of tidal water to the Aquatic Park system is driven by the rising and falling tides in San Francisco Bay. During a rising tide, flow enters the lagoon through the tide tubes shown in Figure 12. During the falling tide, flow leaves the lagoon and flows back out to the bay. Due to the limited flow area of the existing tide tubes, the water level in the lagoon lags behind the tide level in the bay. Before the water level in the lagoon can catch up to the bay tide height, the bay tide begins to recede. The same process occurs for the falling tide. Before the lagoon can fall to a level equal to the low tide in the bay, the bay tide begins to rise. The result is that the tide range in the lagoon is much smaller than it is in San Francisco Bay.

In San Francisco Bay there are basically two high tides and two low tides per day. One high tide will be higher than the other and one low tide will be lower than the other. The time period to complete these two tidal cycles is approximately 25 hours. Figure 19 is a plot of this semi-diurnal tidal cycle. Because this cycle is longer than a standard 24 hour day, the high and low tides occur at different times each day.

The amount of water exchanged during each cycle is a function of two things. The first is the capacity of the culverts that connect the lagoon with the bay. The second element is the difference in water surface elevation between the bay tide and the lagoon water level. The maximum flow rate into the lagoon occurs during the peak of the bay high tide. The tides in San Francisco Bay have approximately a six foot tidal range. The Mean Lower Low Tide is approximately -6.03 ft. Berkeley Datum and the Mean Higher High Tide is approximately +0.14 ft. Berkeley Datum.



Figure 14: Main Lagoon Inlet/Outlet Tide Tubes in 2002 (left); and in 2007 (below) showing major deterioration.



Figure 15: Cross Section through Potter Street Drain Pipe

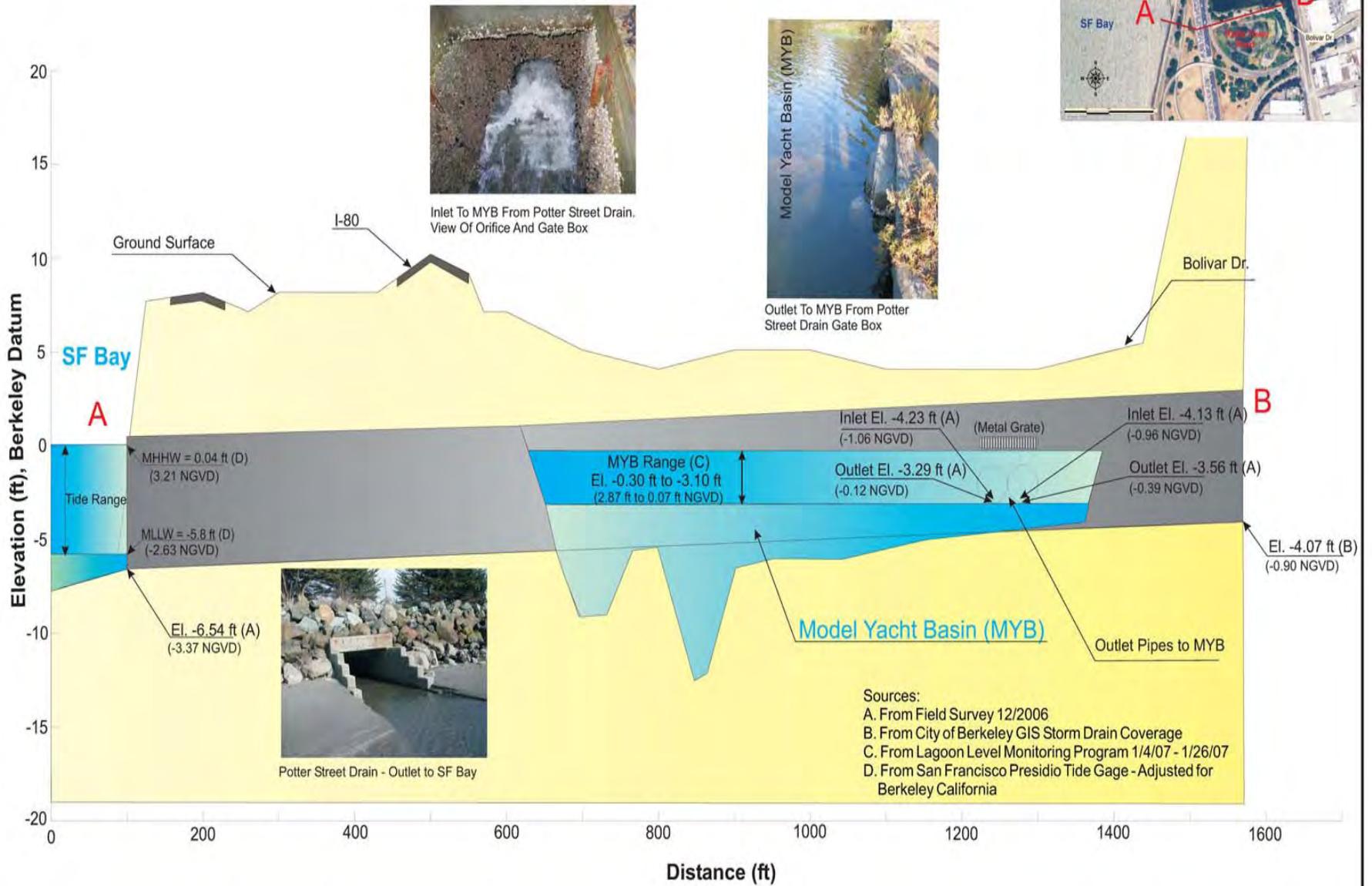


Figure 16: Cross Section Between Main Lagoon and SF Bay

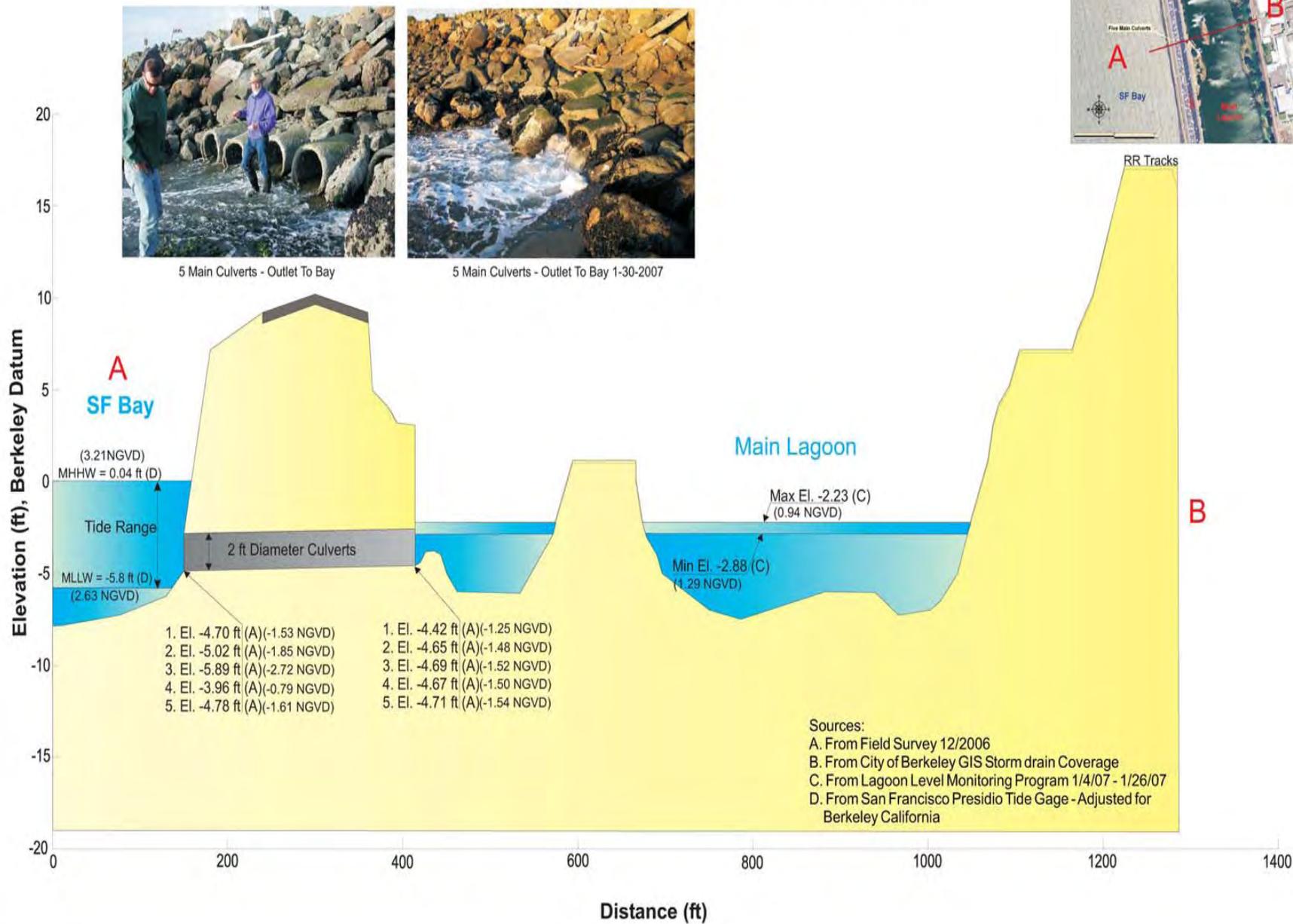


Figure 17: Strawberry Drain Between Main Lagoon and SF Bay

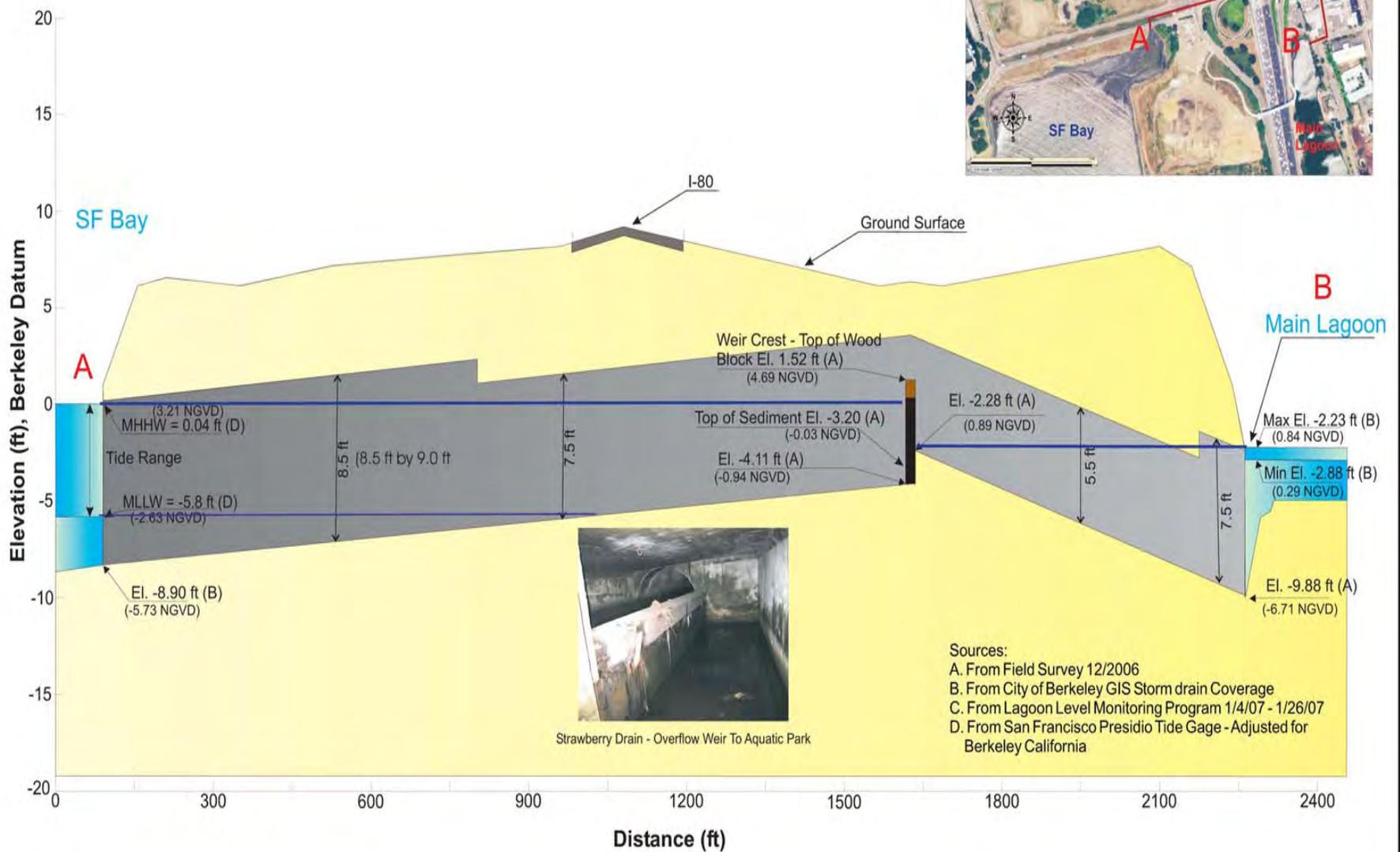
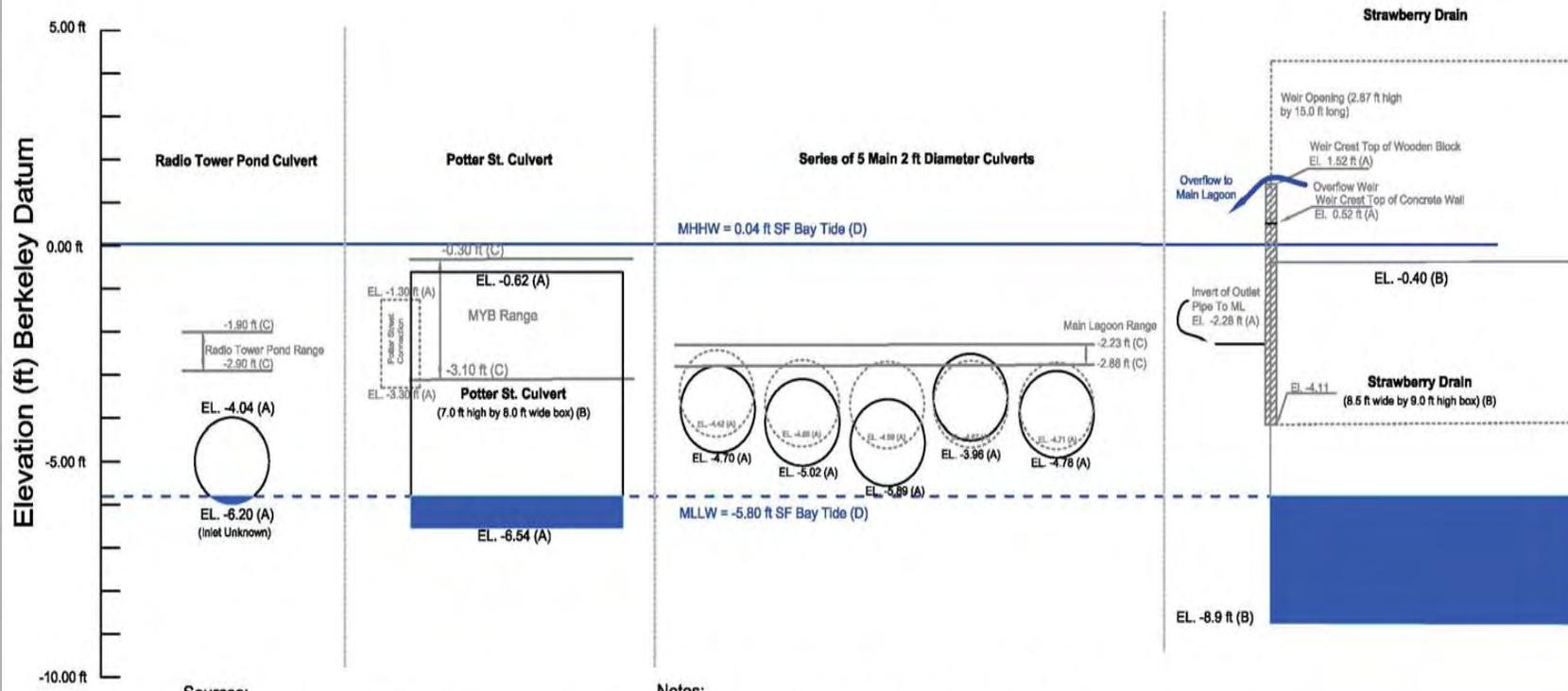


Figure 18: Aquatic Park - Culvert Elevations at Bay Outfall with Tidal Ranges for S.F. Bay and Lagoons



- Sources:
- A. From Field Survey 12/2006
 - B. From City of Berkeley GIS Storm Drain Coverage
 - C. From Lagoon Level Monitoring Program 1/4/07 - 1/26/07
 - D. From San Francisco Presidio Tide Gage - Adjusted for Berkeley California

- Notes:
- 1. Dashed outlines represent the lagoon side culvert inlets
 - 2. Solid outlines represent the bay side culvert outlets.

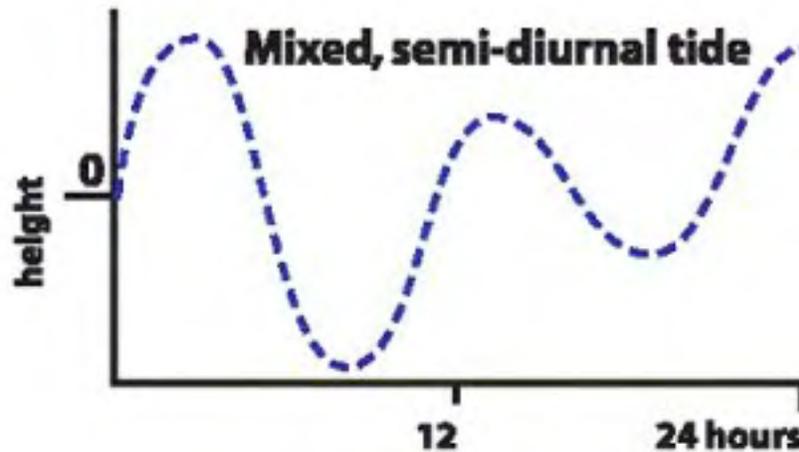


Figure 19: Semi-Diurnal Tidal Cycle

Lagoon Tidal Levels

The greater the tidal range in the lagoon, the greater the amount of water that is flushed out to the bay each day. The maximum tidal range would be to have the lagoon experience the same tidal range as the bay. Unfortunately, the capacity of the existing tidal connections restricts the amount of water that can enter and exit the lagoon. The result is a muted tidal regime within the lagoon.

To determine the actual tidal range in the lagoon, a data collection program was implemented in January 2007. Water level sensors were installed in the Radio Tower Pond, the Model Yacht Basin and the Main Lagoon. Figure 20 is a map showing where the sensors were located within each lagoon. Figure 21 is a plot of the water levels that were recorded within the lagoons during the monitoring period. The plots for each lagoon are placed side by side for ease of comparison. As can be seen in the figures, the tidal range within each lagoon is very small. The range of monitored data is provided in Table 3 (Figure 22). The tide range for San Francisco Bay has also been included for comparison purposes. During this period, extreme high and low tides occurred in the bay.

Table 3: Results of Lagoon Monitoring Program (1/5/2007 – 3/28/2007)					
Gage	Minimum Monitored (ft)	Maximum Monitored (ft)	Maximum Tidal Range (ft)	Average Tidal Range (ft)	Mean Tidal Level (ft)
Main Lagoon	-2.88	-1.86	1.02	0.21	-2.39
Model Yacht Basin	-3.12	-0.07	3.05	1.77	-2.16
Radio Tower Pond	-3.75	-2.01	1.74	0.36	-2.62
San Francisco Bay	-7.30	0.81	8.11	6.16	-2.73
All elevations are in feet, Berkeley Datum					

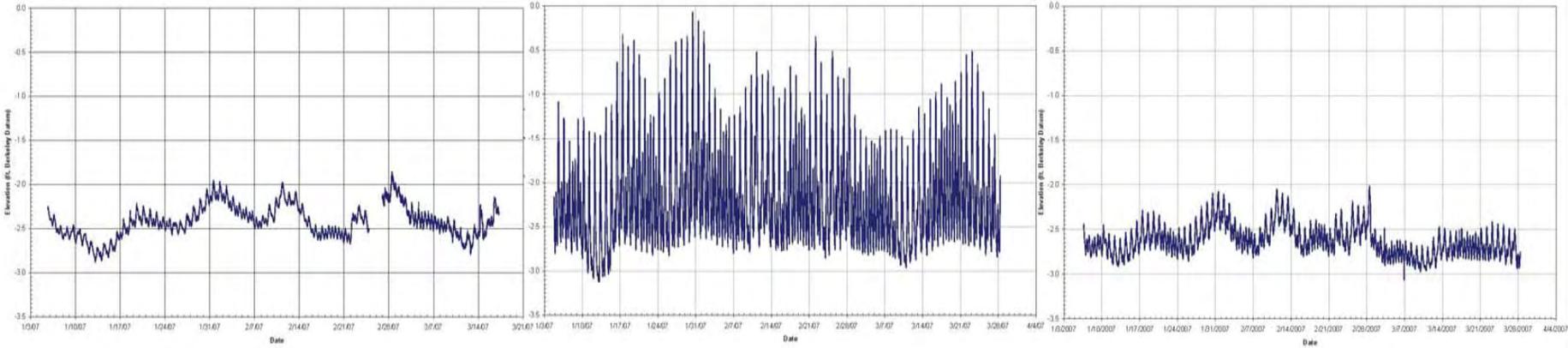
AQUATIC PARK IMPROVEMENT PROGRAM

Figure 20: Tidal Monitoring Gauge Locations

 Tidal Monitoring Gauge Locations



Figure 21: Comparison of Aquatic Park Tide Ranges From January Through March 2007



Main Lagoon

Model Yacht Basin

Radio Tower Pond

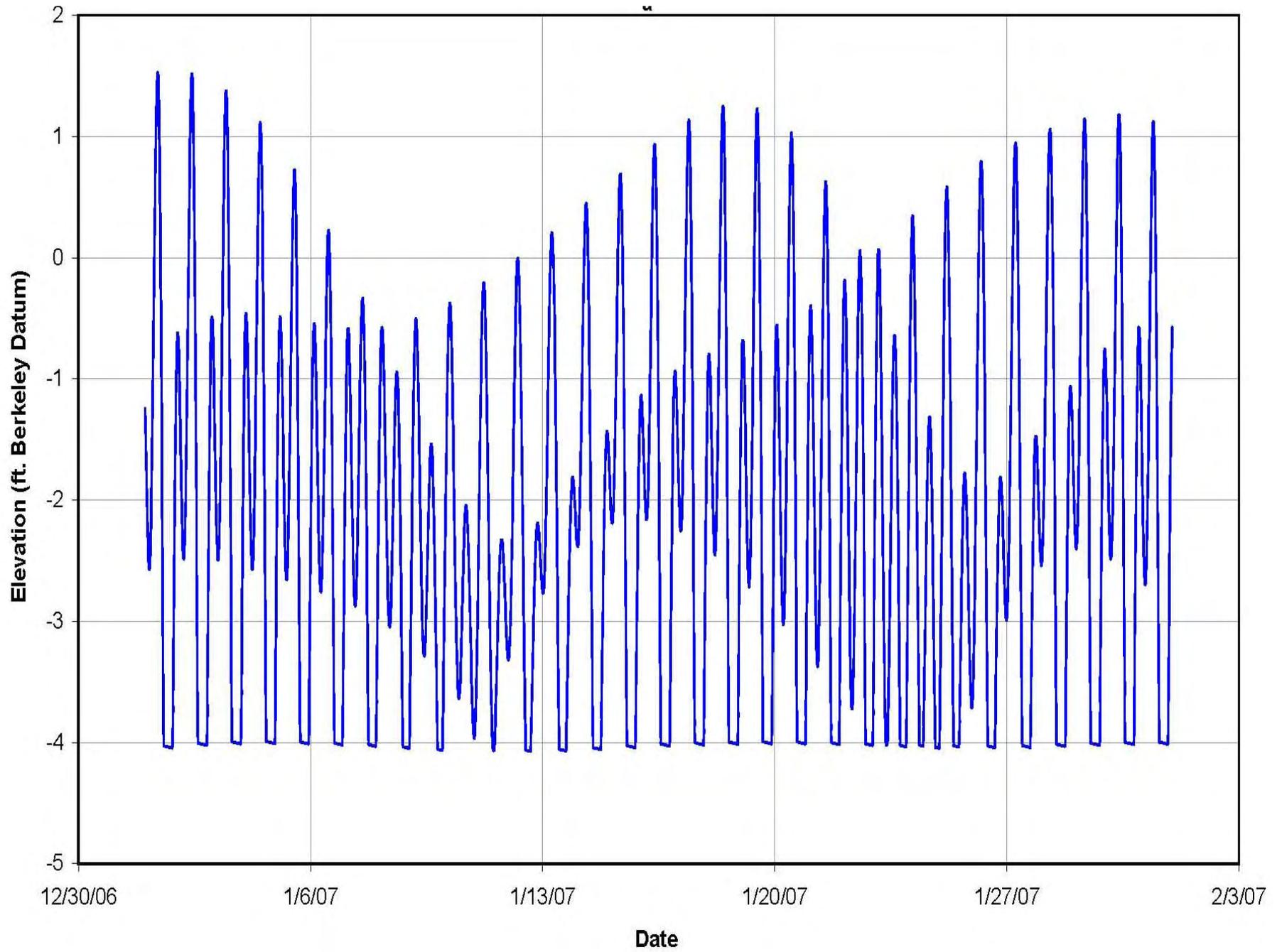


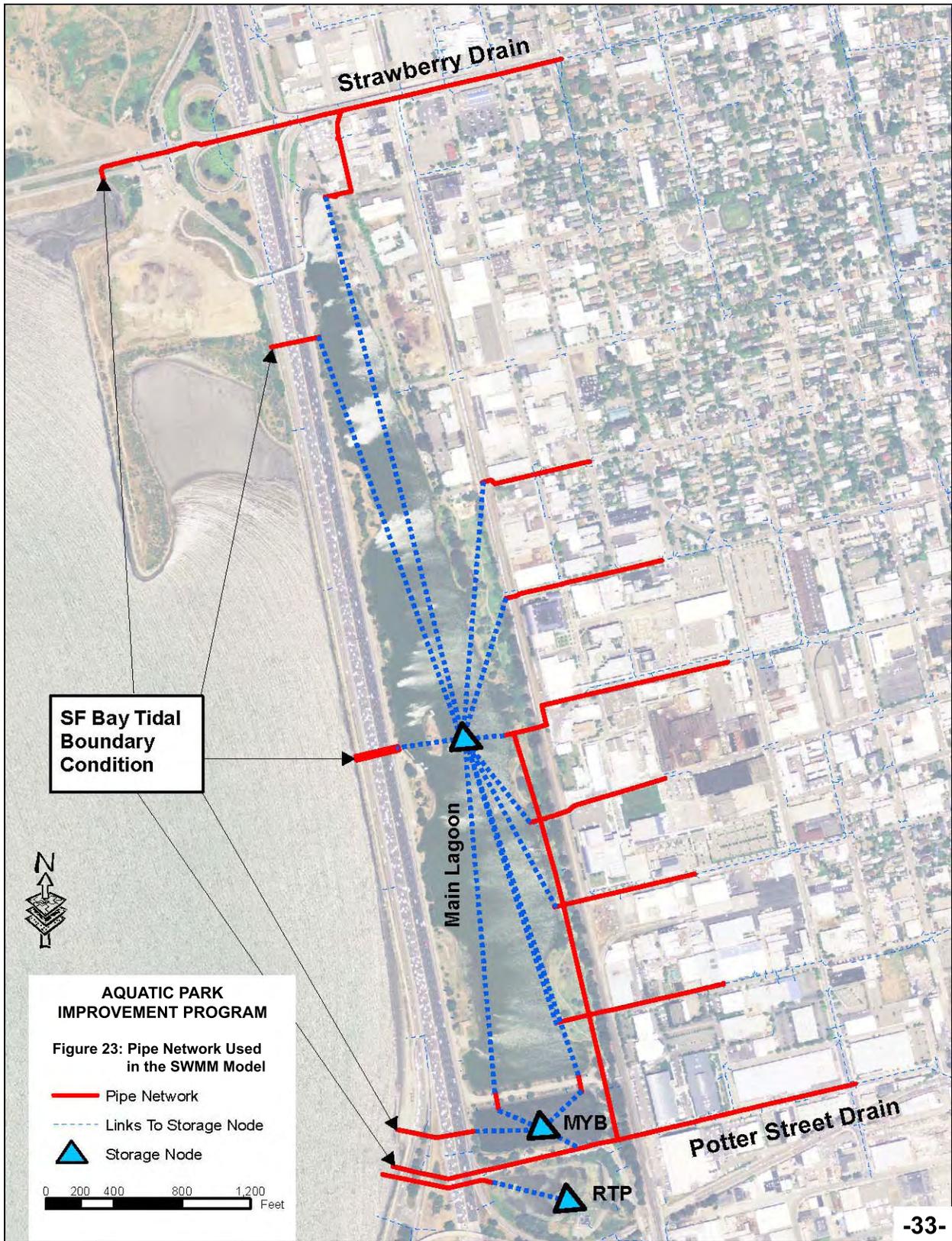
Figure 22: Tidal Range of San Francisco Bay for January 2007

Tidal Flow Modeling

A hydraulic model was developed to evaluate the pipe network that connects Aquatic Park with the bay. The United States Environmental Protection Agency Stormwater Management Model (SWMM) was used for the analysis. This is a hydraulic model that is uniquely suited to the evaluation of networks of pipes and impoundments under unsteady tidal conditions. The existing pipe network information was obtained from the City of Berkeley. This information was also cross-checked through field surveys of the pipes in the immediate vicinity of Aquatic Park. Figure 23 is a map of the pipe network in and around Aquatic Park used in the model.

The model was run for January and February of 2007 to determine the normal tidal fluctuations in the lagoon. This period was selected because of the availability of data for each of the lagoons from the water level monitoring program. The model was calibrated to get the best match to the monitoring data. The calibration factors were the entrance and exit losses, the pipe roughness, and the effective diameter. The diameter was selected due to the observed incrustation of barnacles on the existing pipes. The barnacles can reduce the effective diameter of the pipe. The results from the calibrated model are provided in Tables 4 and 5.

Each lagoon has shoreline buildings and roadways or other facilities which limit the allowable high-tide elevation. In the Main Lagoon the Old Sailing Center is the lowest elevation building at an elevation of +0.5 ft. Berkeley Datum (Figure 24A). On the shoreline of the Model Yacht Basin, the lowest elevation structure is a road at +2.0 ft. Berkeley Datum (Figure 24B). At the Radio Tower Pond the Radio Transmitter Building sits at -1.5 ft. Berkeley Datum (Figure 24C). These elevations represent a constraint to the highest tides that can be allowed into each lagoon. The low tide elevation in each lagoon is defined by several features: the lowest elevation in the tide tubes or stormdrain that drains the lagoon and, in the Main Lagoon, navigational hazards that would be exposed by the low tide. Table 6 summarizes the lagoon elevations and constraints in tidal range.



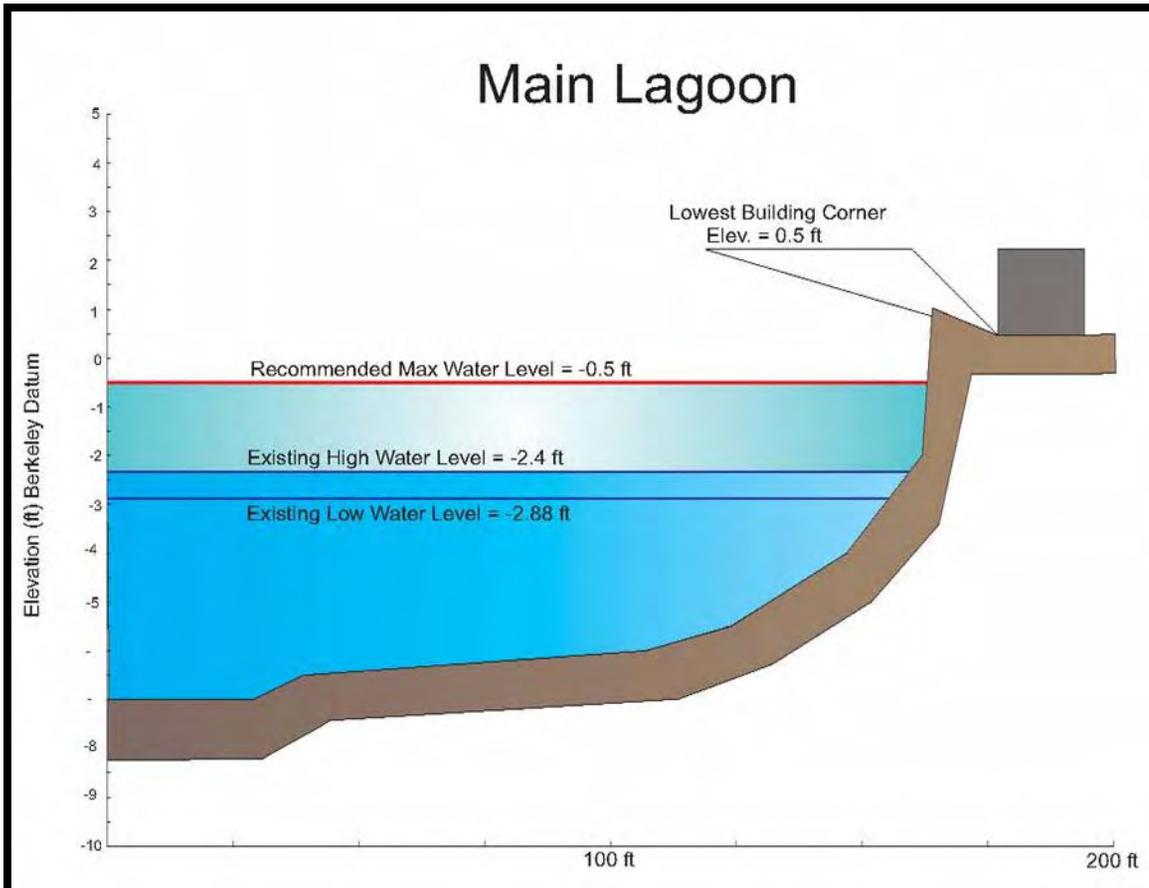


Figure 24A: Water Levels in Main Lagoon and buildings with lowest elevations which limit the high tide range for the Main Lagoon.



Model Yacht Basin

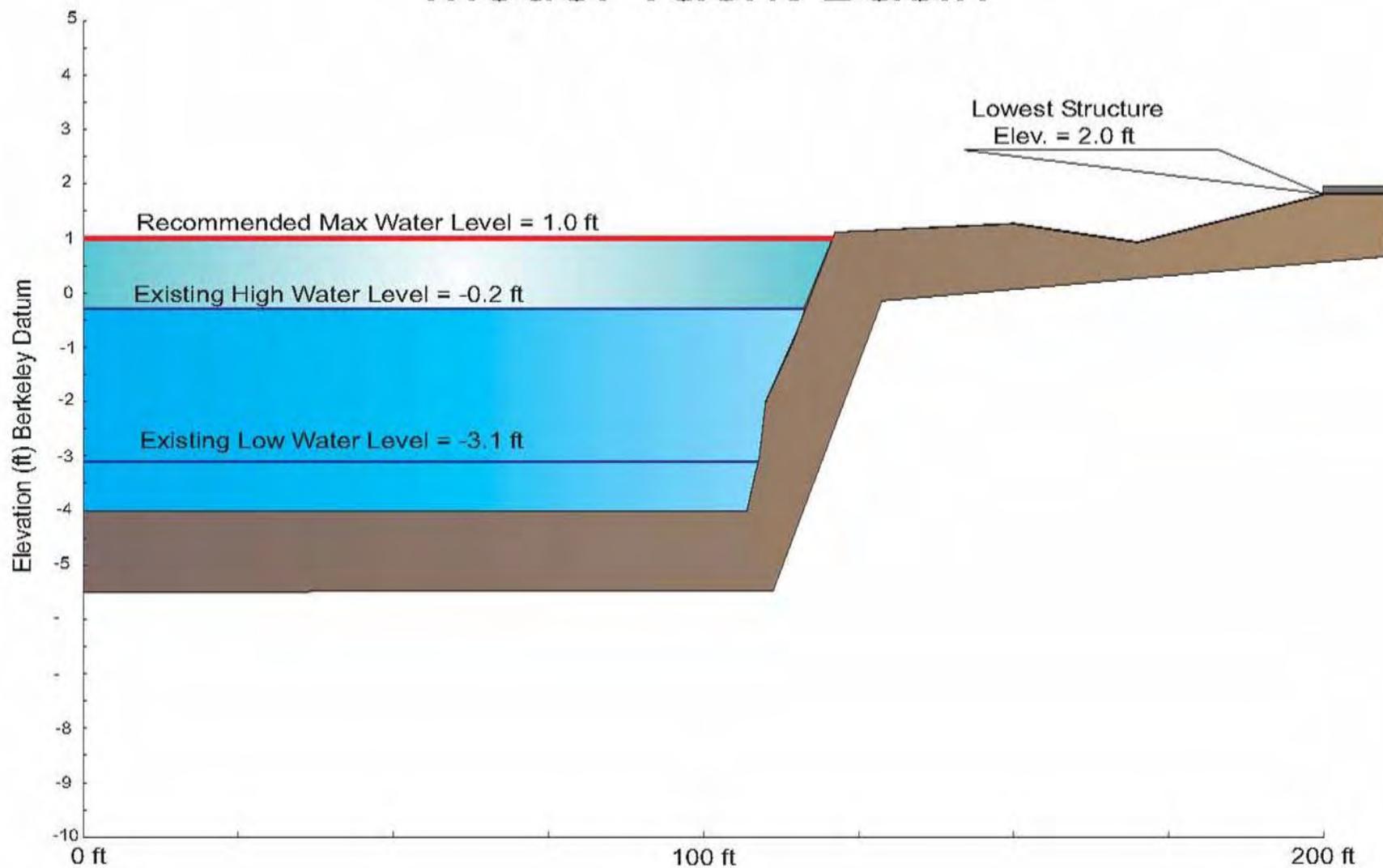


Figure 24B: Water Levels in Model Yacht Basin

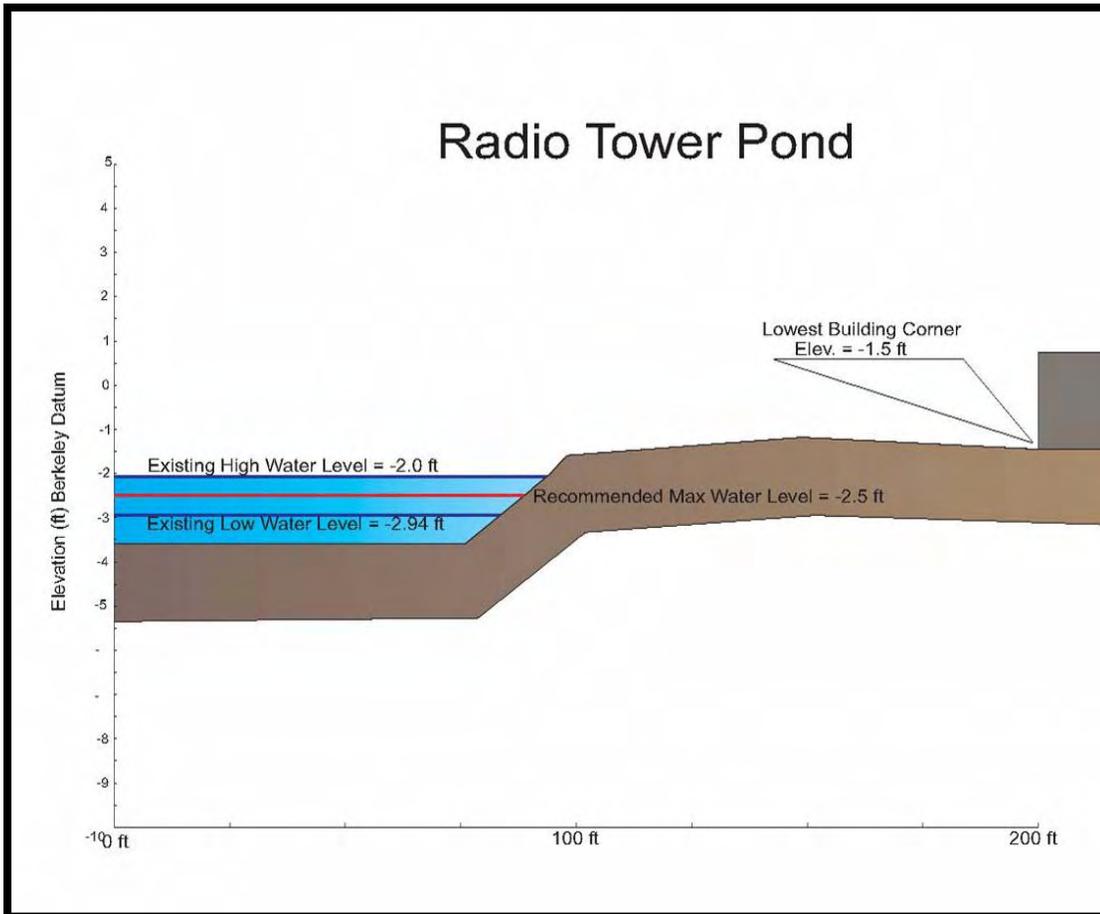


Figure 24C: Water Levels in Radio Tower Pond and Radio Transmitter Building which limits high tide range in the Radio Tower Pond.



Table 4: Aquatic Park Existing Condition Circulation Model Volume of Exchange for a Mean Daily Tidal Cycle	
Culvert Location and Flow Direction	Volume (ac-ft)
Inflow through Potter Street	12.1
Outflow to Potter Street	9.4
Inflow from MYB to ML	4.0
Outflow from ML to MYB	0.0
Inflow from Bay through 5 Main Culverts	10.0
Outflow to Bay through 5 Main Culverts	12.8
Inflow through Northern Tide Tube	0.0
Outflow through Northern Tide Tube	0.0
Inflow through Strawberry 12 inch Low Flow Drain Connection	0.0
Inflow through Strawberry 12 inch Low Flow Drain Connection	0.0
Inflow through the Strawberry Drain Weir Connection	0.0
Outflow through the Strawberry Drain Weir Connection	0.0
Summary of Water Exchange	
Total New Water In	22.2
Total Water Out	22.2

Table 5: Aquatic Park Existing Condition Tidal Ranges	
Location	Elevation (ft. Berkeley Datum)
Model Yacht Basin High	-0.48
Model Yacht Basin Low	-2.74
Range	2.26
Main Lagoon High	-2.27
Main Lagoon Low	-2.77
Range	0.50
Mean Water Level	-2.52

Table 6: Aquatic Park - Water Level Limits					
	Lowest Building Elevation	Recommended Minimum Building Buffer	Maximum Water Level	Existing High Water Level	Allowable Rise
	(ft.)	(ft.)	(ft.)	(ft.)	(ft.)
Radio Tower Pond	-1.5	1	-2.5	-2	-0.5
Model Yacht Basin	2	1	1	-0.2	0.8
Main Lagoon	0.5	1	-0.5	-2.4	1.9
All elevations are in feet, Berkeley Datum					

Tidal Hydrology-Constraints

1. The current connections to the San Francisco Bay limit tidal water from entering the lagoons.
2. The existing tide tubes date from the 1930s and are deteriorating and collapsing.
3. Installing new tide tubes under I-80 is expensive and infeasible.
4. Larger connections to the existing stormdrains, if not managed correctly, can allow more stormwater into the lagoon. The additional stormwater will temporarily reduce the salinity and may increase the amount of pollutants entering the lagoon.
5. Constructing new connections will be complicated because the existing openings should remain operational until the new connections are completed.
6. The presence of buildings and roads on the lagoon shoreline limits the elevation of high tide and the volume of additional bay water that can be let into the lagoon.
7. The recreational uses of the lagoon will limit the low-tide elevation and the volume of tidal water which can be exchanged with the bay.

Tidal Hydrology-Opportunities

1. The connections to two large stormdrains adjacent to the park could be modified to increase the amount of cooler and relatively unpolluted water coming into the lagoons from San Francisco Bay.
2. Putting better controls on the Potter Street Stormdrain connection and Strawberry Stormdrain connection will allow for selectively blocking out stormwater inflow. This is particularly important for blocking the first flush that occurs during fall and early winter.
3. Larger connections in the Potter Street and Strawberry stormdrains will allow for significantly faster removal of any stormwater that flows into the lagoon.
4. Repair and stabilization of the five main tide tubes will prevent them from totally collapsing and preventing bay water from entering the lagoon. This is essentially the only existing opening for bay water to enter the Main Lagoon
5. Replacing the two 24-inch culverts between the Model Yacht Basin and the Main Lagoon with a larger channel opening will allow tide water from the Potter Street

Stormdrain to enter the Main Lagoon. Presently very little of the tidal flow from Potter Street Stormdrain enters the Main Lagoon.

6. A new channel connection between the Main Lagoon and the Model Yacht Basin will require less maintenance to keep open. The existing culverts require continual maintenance to keep them from getting clogged up with marine growth. Presently they have less than half of their original flow capacity, and they were cleaned out two years ago.

Shallow Subtidal Aquatic Habitat and Water Quality

The primary type of habitat in Aquatic Park is shallow subtidal aquatic habitat in the three lagoons. There have not been any fish studies done in the lagoons, but there have been long-term studies of fish in San Francisco Bay just offshore from the frontage road west of the park (Figure 25).

Aquatic Park is located in central San Francisco Bay which has the most ocean-like conditions of any area of the bay. The Golden Gate is directly west of Aquatic Park, making this area of the bay the most consistently saline and cold from the direct ocean influence. A tidal lagoon in the central bay could have most of the characteristics of the bay: primarily marine conditions with ocean salinities and year-round cold water temperatures.

Shallow subtidal habitats are typically no more than 18 ft. deeper than Mean Lower Low Water (MLLW) and have a sandy/muddy bottom. The shallow water allows sunlight to penetrate and diatomaceous algae or phytoplankton to bloom. These phytoplankton in turn support zooplankton—free floating copepods and larval forms of crustaceans and fish. This rich soup supports a nursery for many marine crustaceans and fish (Figure 26). For example, California bay shrimp adults (*Crangon franciscorum*) live in the central bay with its higher salinities, but their eggs hatch in winter when stormwater reduces salinities and the juveniles move to the north bay's lower salinity areas. Dungeness crab adults (*Cancer magister*) mate and release eggs in the nearshore ocean area. The free-floating larvae move into the central bay, settle to the bottom and become shelled crabs. Pacific herring (*Clupea harengus*) enter the central bay to spawn in winter, laying eggs on underwater rocks and eelgrass. California halibut (*Paralichthys californicus*) live in the nearshore ocean. As the juveniles move into the central bay, they settle to the bottom where they grow to become adults and leave for the ocean.

Table 7 lists all of the fish species recorded from Station 275 located in the shallow subtidal area offshore from the I-80 frontage road near Aquatic Park (Figure 25). Relative abundance of each species is also listed. Table 8 lists the most abundant fish species sampled at Station 275 over the period of record. The most abundant species would be expected to inhabit the lagoons at Aquatic Park if temperature and salinity conditions were similar to the central bay. Figures 27 and 28 show the temperature and salinity conditions required by bay fish species. Most species require 15-20°C (58-68°F) temperatures and salinities of 22 to 33 ppt. Figure 29 shows the water temperatures measured at Station 275 that range from 15-20°C (58-68°F).

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Figure 25: Beach Seine
Station 275 Location





Northern anchovy



Topsmelt



Bay pipefish

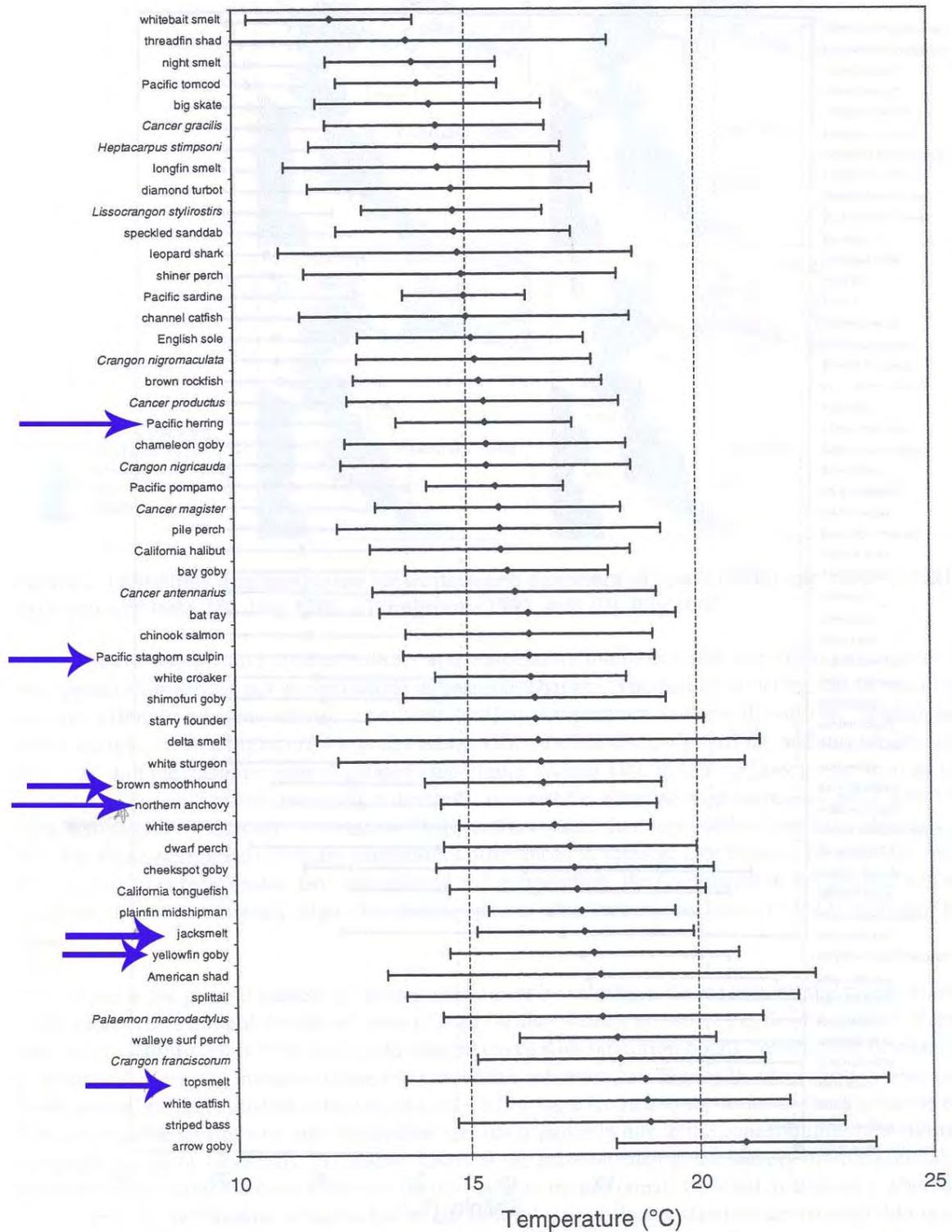


Pacific herring



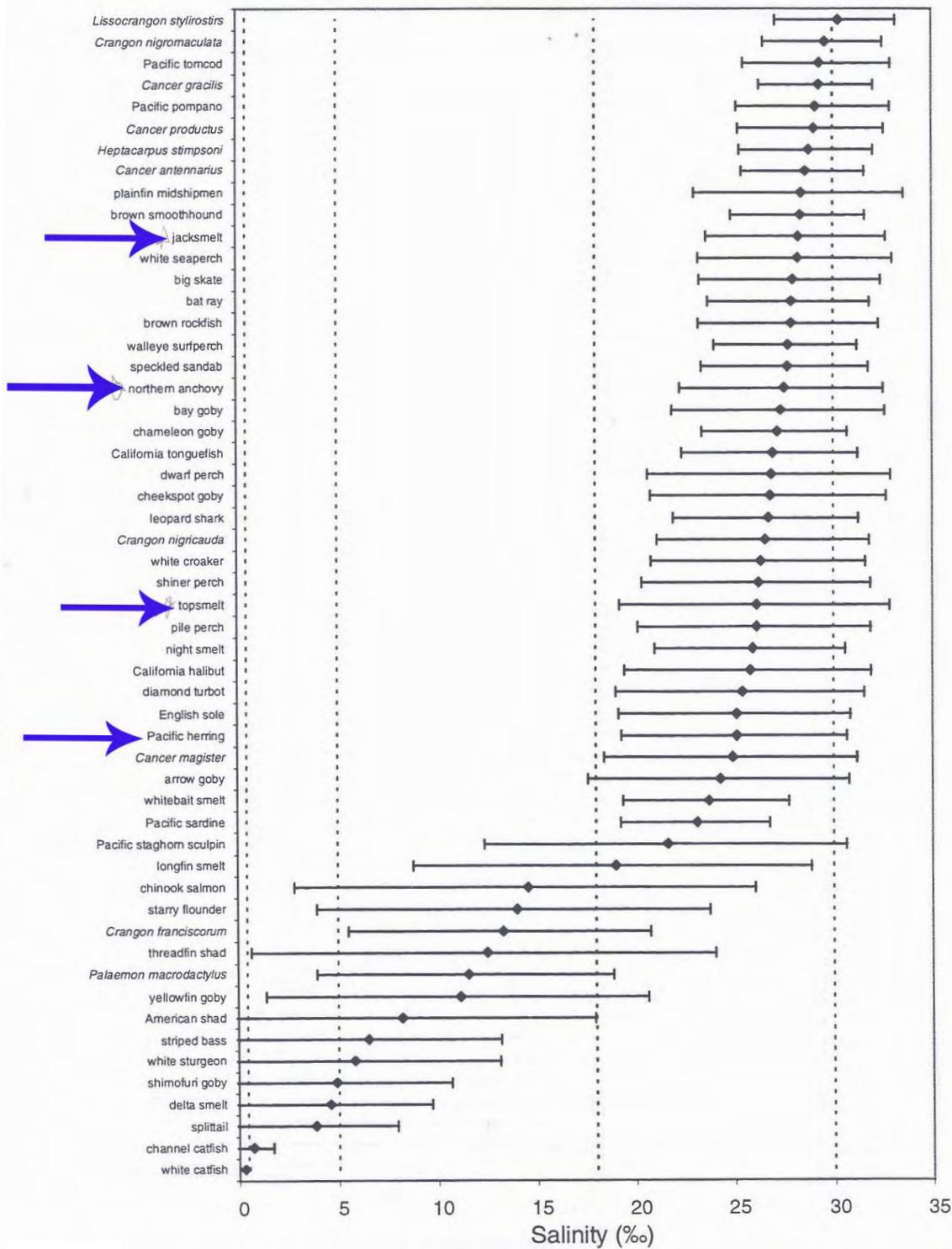
Pacific staghorn sculpin

Figure 26: Fish Species of the Central San Francisco Bay



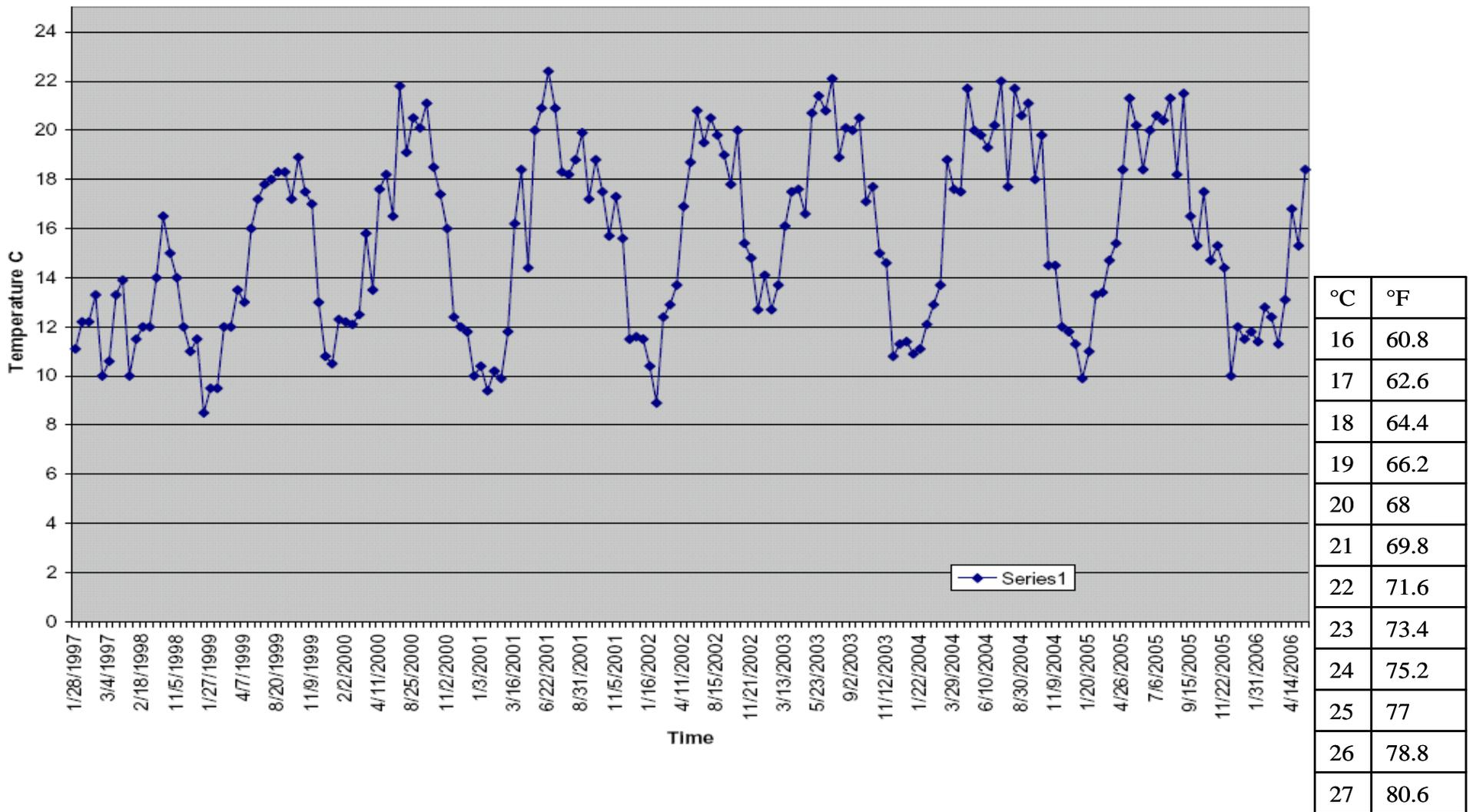
Mean temperature (°C) ± 1 standard deviation for the 54 most commonly collected species of fishes, shrimps, and crabs. Data from beach seine for topsmelt, arrow goby, and dwarf perch, otter trawl for shrimps, crabs, and demersal fishes, and midwater trawl for pelagic fishes. CPUE weighted by surface temperature for beach seine, bottom temperature for otter trawl, and water column average temperature for midwater trawl.

Figure 27: Temperatures tolerated by Central Bay fish species



Mean salinity (‰) ±1 standard deviation for the 54 most commonly collected species of fishes, shrimps, and crabs. Data from beach seine for topsmelt, arrow goby, and dwarf perch, otter trawl for shrimps, crabs, and demersal fishes, and midwater trawl for pelagic fishes. CPUE weighted by surface salinity for beach seine, bottom salinity for otter trawl, and water column average salinity for midwater trawl. The vertical lines are the boundaries for the Venice system of salinity classification.

**Figure 28: Salinity ranges for bay fish species;
Typical Central Bay fish species need salinities of 20-30 ppt**



**Figure 29: Water Temperatures Measured at Station 275
Central San Francisco Bay near Frontage Road, Berkeley 1997-2006**

Table 7
Fish Species Recorded at Berkeley Frontage Rd., Station 275
Beach Seine Sampling San Francisco Bay Delta Tributaries Project
Years of Record: 1976, 1980-1982, 1997-2006

Species	Occurrence
American Shad	Rare
Arrow Goby	Rare
Barred Surfperch	Rare
Bay Pipefish	Common; year-round
Butter Sole	Rare
California Halibut	Rare
Cheekspot Goby	Rare
Chinook Salmon	Uncommon; Feb/March/April only
Delta Smelt	Rare
Dwarf Surfperch	Uncommon
English Sole	Rare
Inland Silverside	Formerly common up to 1999; rare after 1999
Jacksmelt	Formerly common up to 1999; rare after 1999
Longfin Smelt	Rare
Longjaw Mudsucker	Rare
Northern Anchovy	Very abundant; year-round
Pacific Herring	Abundant; winter only
Pacific Staghorn Sculpin	Common; year-round
<i>Pleurobrachia bachei</i>	Rare
Prickly Sculpin	Rare
Rainwater Killifish	Uncommon
Shiner Perch	Uncommon
Silver Perch	Uncommon
Speckled Sanddab	Rare
Starry Flounder	Rare
Striped Bass	Uncommon
Striped Mullet	Rare
Surf Smelt	Rare
Threadfin Shad	Rare
Threespine Stickleback	Common; year-round
Topsmelt	Very abundant; year-round
Walleye Surfperch	Rare
Western Mosquitofish	Rare
Yellowfin Goby	Uncommon
Source: Bay Delta and Tributaries Project, http://bdat.ca.gov/	

Table 8: Station 275 Most Abundant Fish Species 1980-2006		
Species	Salinity Range Tolerated (ppt)	Temperature Range Tolerated (°C)
Pacific Herring	20-30	14-17
Pacific Staghorn Sculpin	17-30	14-18
Bay Pipefish	22-32	14-18
Northern Anchovy	22-32	14-18
Threespine Stickleback	18-32	14-23
Topsmelt	18-32	13-24
Source: Bay Delta and Tributaries Project, http://bdat.ca.gov/		

Table 9: Waterbirds Recorded in Aquatic Park in 2004	
Species	
Canada Goose	American Coot
Gadwall	Black-bellied Plover
Mallard	Semi-palmated Plover
Canvasback	Killdeer
Redhead	Black-necked Stilt
Tufted Duck	American Avocet
Greater Scaup	Greater Yellowlegs
Lesser Scaup	Willet
Surf Scoter	Marbled Godwit
Bufflehead	Western Sandpiper
Common Goldeneye	Least Sandpiper
Hooded Merganser	Dunlin
Red-breasted Merganser	Short-billed Dowitcher
Ruddy Duck	Long-billed Dowitcher
Pied-billed Grebe	Mew Gull
Horned Grebe	Ring-billed Gull
Eared Grebe	California Gull
Brown Pelican	Herring Gull
Double-crested Cormorant	Western Gull
Pelagic Cormorant	Glaucous-winged Gull
Great Blue Heron	Caspian Tern
Great Egret	Common Tern
Snowy Egret	Forster's Tern
Green Heron	Belted Kingfisher
Black-crowned Night Heron	
Source: Avocet Research Associates 2005	

There are a number of schooling “bait” fish which are typically very abundant in the central bay and are found in lagoons similar to Aquatic Park, such as Lake Merritt and the tidal lagoon at the Oakland Airport. These include topsmelt (*Atherinops affinis*), jacksmelt (*Atherinopsis californiensis*), and northern anchovy (*Engraulis mordax*) (Figure 26). These small fish are a major food source to diving ducks such as scaups, buffleheads, surfscoters, and grebes which over-winter in San Francisco Bay. Wading birds—egrets and herons, as well as pelicans, cormorants, mergansers, and other fish-eating birds—also feed on the small fish. Aquatic Park supports a variety of wintering water birds (Figures 30 and 31). These birds are mostly fish eaters who use the lagoons in winter when water temperatures are cool and small fish are likely to inhabit the lagoons.

A recent study of waterbirds in Aquatic Park (Table 9) found that 80% of the waterbirds recorded in the lagoons are present only during the winter months. Numbers of waterbirds increase from October to March as migratory waterfowl species including bufflehead, American coot, and scaup arrive. Waterbird numbers on the lagoon increase when there is a storm and bay waters become rough. The waterbirds primarily feed on small “bait” fish.

Lagoon Water Quality

As part of the Natural Resources Management Study, water quality conditions were monitored in August 2002 using continuous recording dataloggers at 1 ft. and 8 ft. depths in the Main Lagoon (Figures 32 and 33). The deeper water was 20-24°C (68-75.2°F) and the surface water was 20-26°C (68-78.8°F).

In 2004 the Regional Board’s Surface Water Ambient Monitoring Program (SWAMP) monitored summer and fall water temperatures and dissolved oxygen (DO) at three sites in the Main Lagoon using continuous recording YSI sondes. Figures 34-39 depict the results of the SWAMP monitoring. The June 2004 data shows a daily fluctuation in temperature and DO typical of a eutrophic system. The northern lagoon shows DO levels consistently dropping below the 7 mg/l level needed for fish in both June and September (Figures 38 and 39). The central and southern lagoon stations show DO levels below 7 mg/l over most of the nights of the June monitoring period and below 7 mg/l every night over the September monitoring period (Figures 34-37). These low DO levels likely limit fish survival (Figures 40 and 41). The algal blooms which are common in the Main Lagoon occur as water temperatures warm (Figure 42). Fertilizers from urban stormdrains that flow into the Main Lagoon probably also increase algal blooms. During the daylight hours algae produce oxygen. During the nighttime, the oxygen in the water is used up through respiration by bacteria which can break down the algae.

Water quality monitoring has not been done in the Model Yacht Basin or Radio Tower Pond. It is likely that the Model Yacht Basin has better water quality than the Main Lagoon due to the greater level of water circulation. The Radio Tower Pond often has large algal blooms in the summer and has very shallow and likely warm water.



Bufflehead



Lesser scaup



Western grebes



Double-crested cormorant



Double-crested cormorant

Figure 30: Water Birds of Aquatic Park



Black-crowned night heron



Great egret

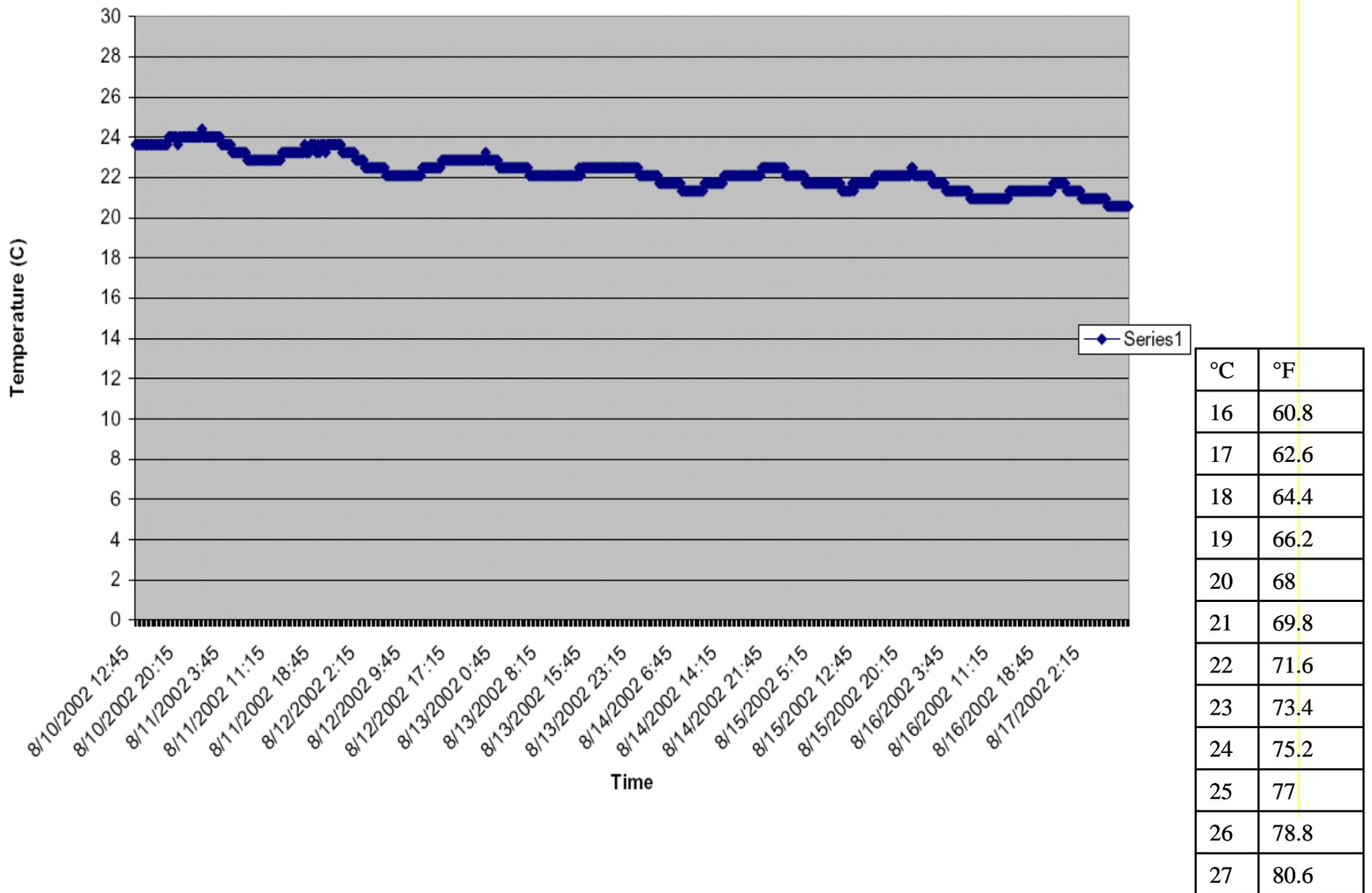


Great blue heron



Snowy egret

Figure 31: Wading Birds of Aquatic Park



**Figure 32: Main Lagoon Water Temperatures at 8 Ft. Below Surface,
 Measured 8/10/2002-8/17/2002
 Typical Central Bay fish species need temperatures of 15-20 degrees C**

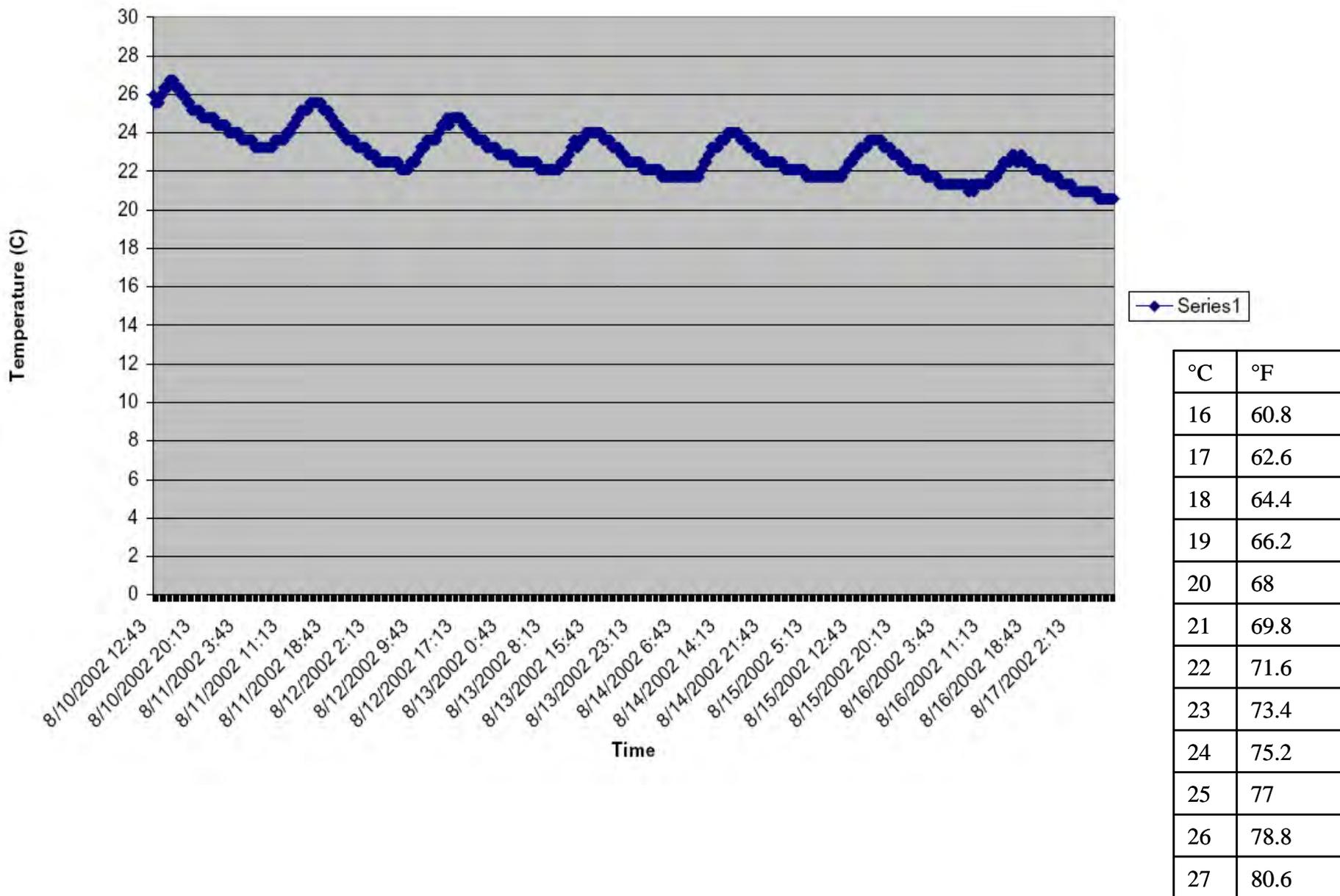
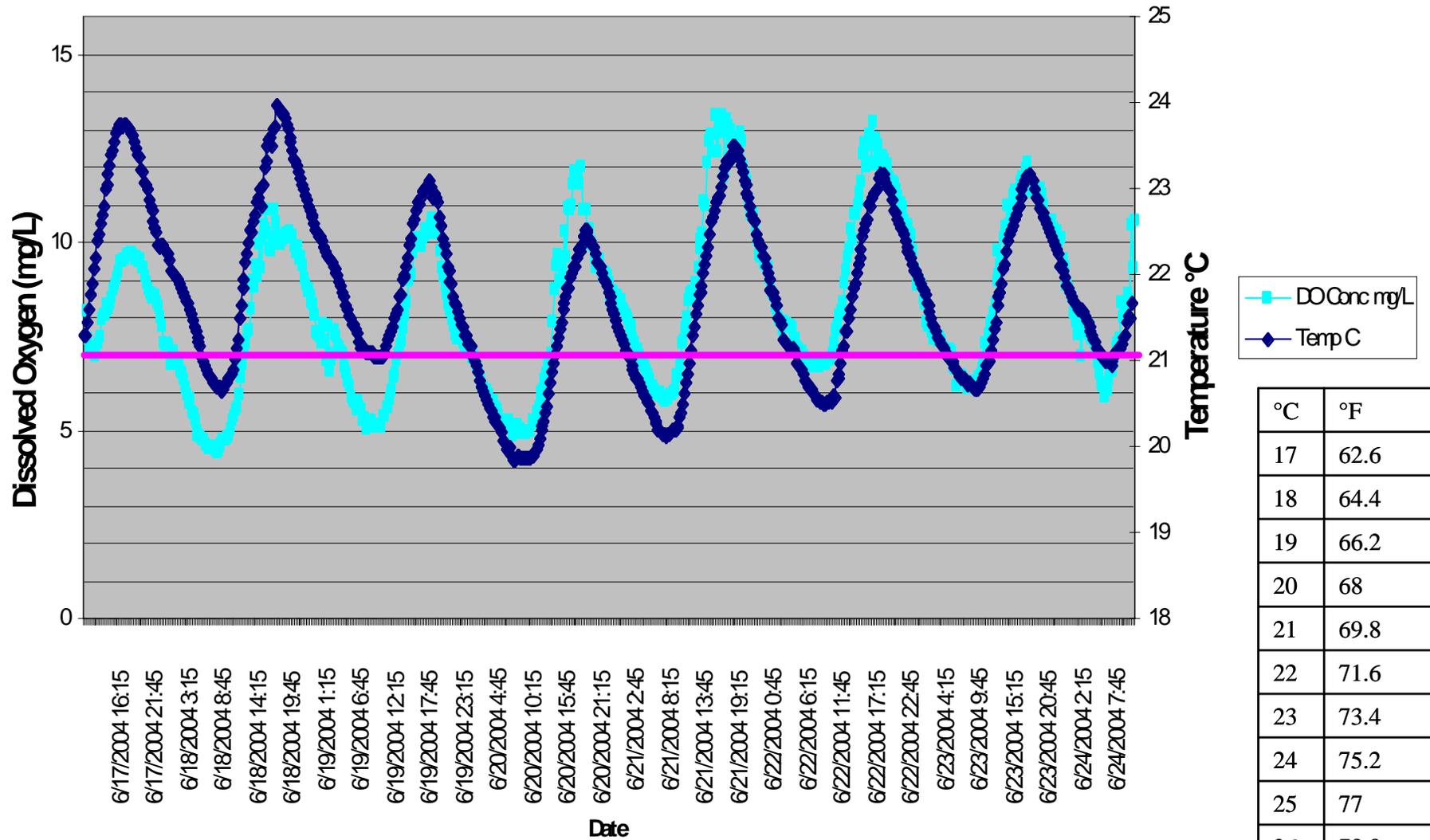


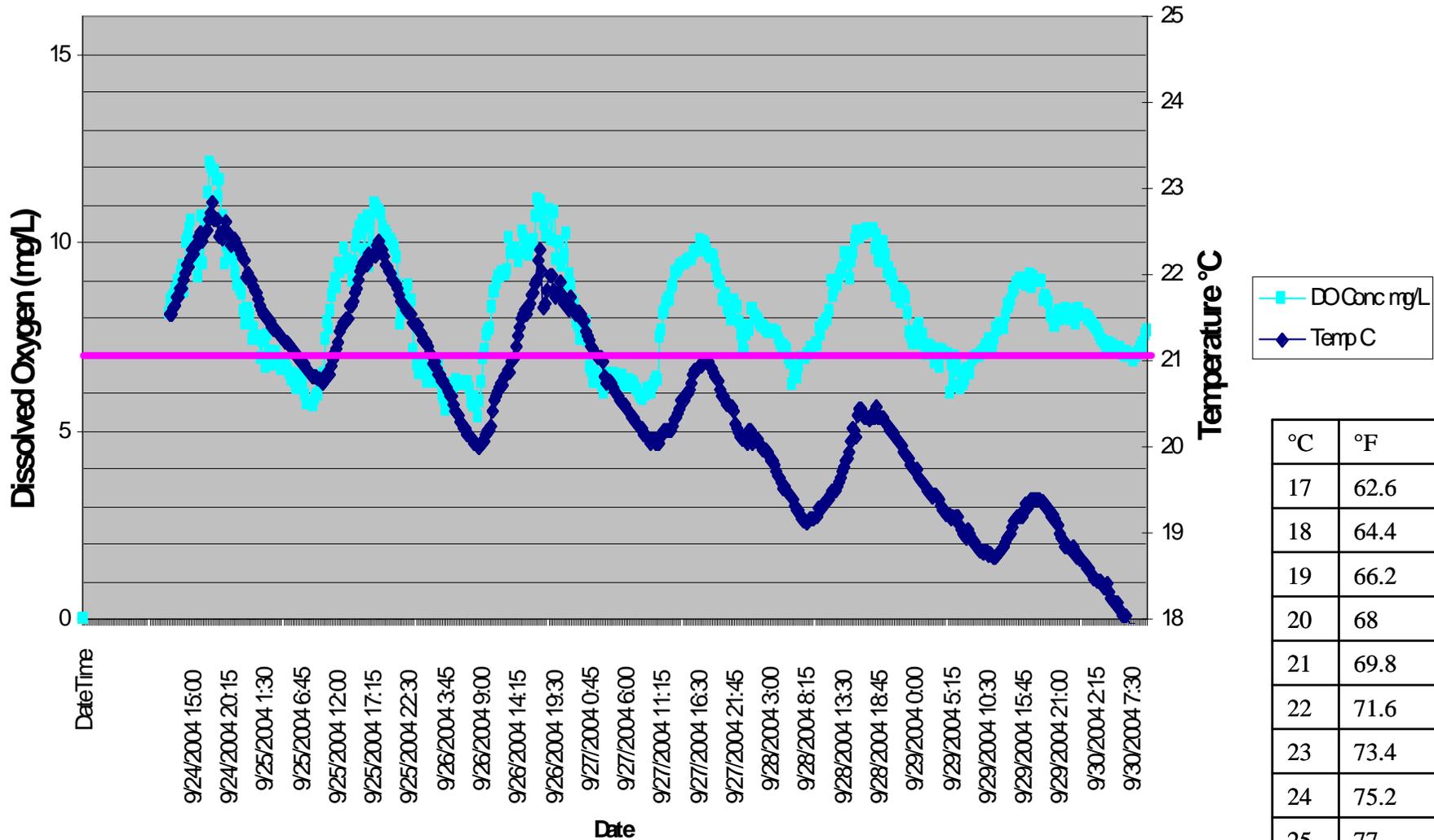
Figure 33: Main Lagoon Water Temperatures at 1 Ft. Below Surface, Measured 8/10/2002-8/17/2002; Typical Central Bay fish species need temperatures of 15-20 degrees C

**Temperature and Dissolved Oxygen for the week of 6/17/04
BAP010 Southern end of Main Lagoon**



**Figure 34: Main Lagoon Water Temperature and
Dissolved Oxygen Monitoring 2004;
Typical bay fish species need temperatures of 15-20 degrees C
and DO levels of 7 mg/l**

**Temperature and Dissolved Oxygen for the week of 9/24/04
BAP010 Southern end of Main Lagoon**



**Figure 35: Main Lagoon Water Temperature and
Dissolved Oxygen Monitoring 2004;
Typical bay fish species need temperatures of 15-20 degrees C
and DO levels of 7 mg/l**

Temperature and Dissolved Oxygen for the week of 6/17/04
 BAP020 Ski Jump Mid-Lagoon

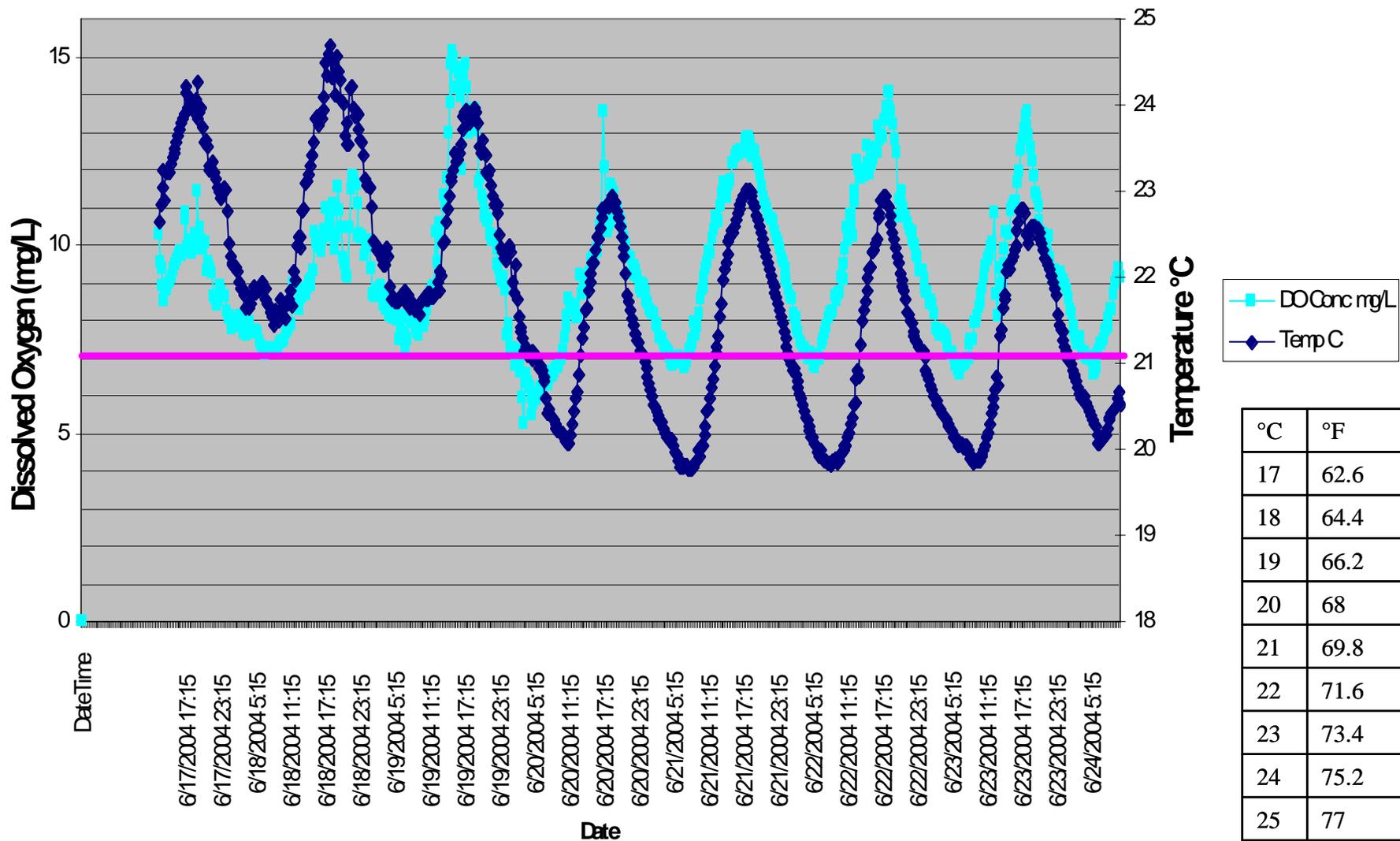
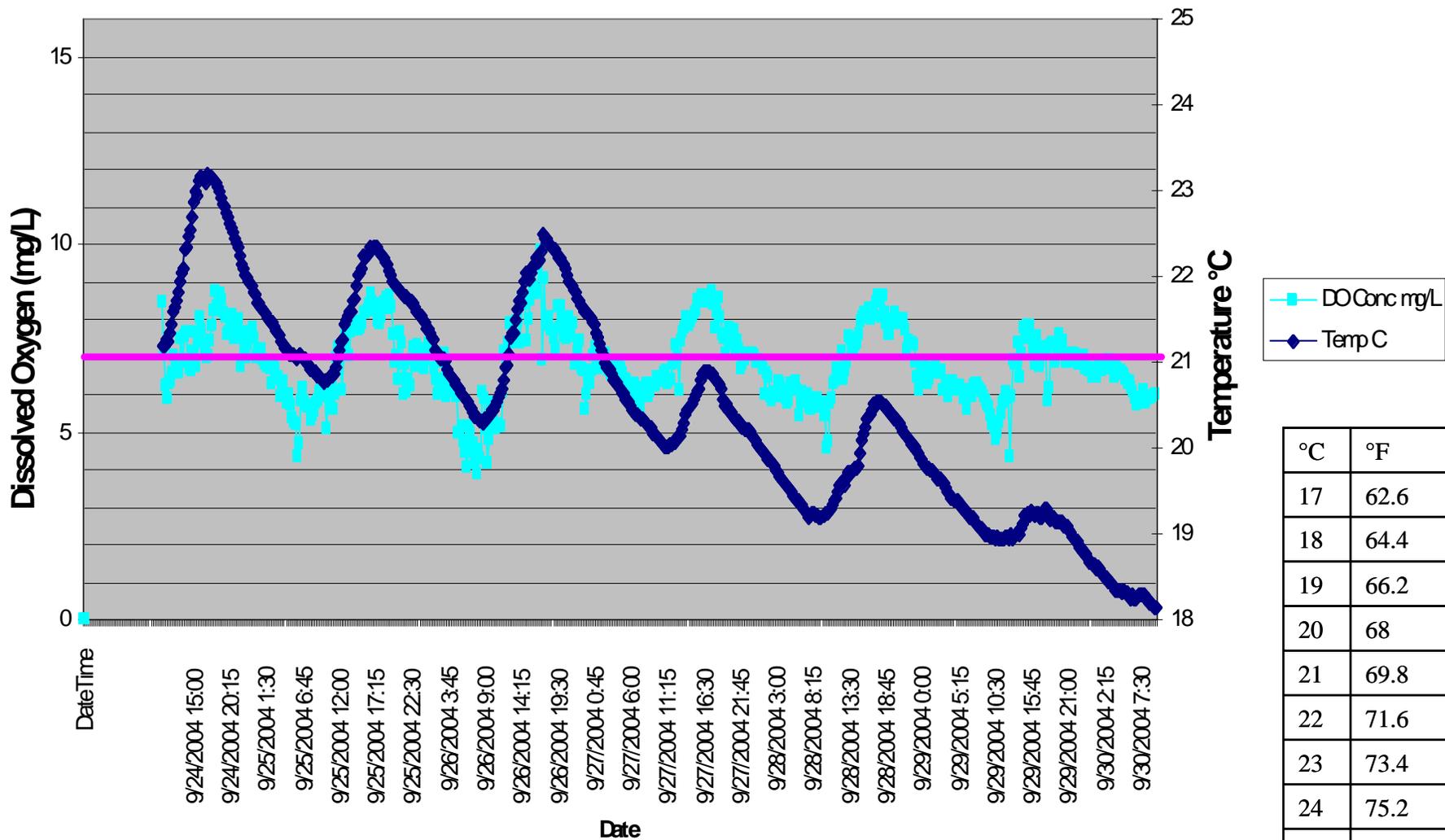


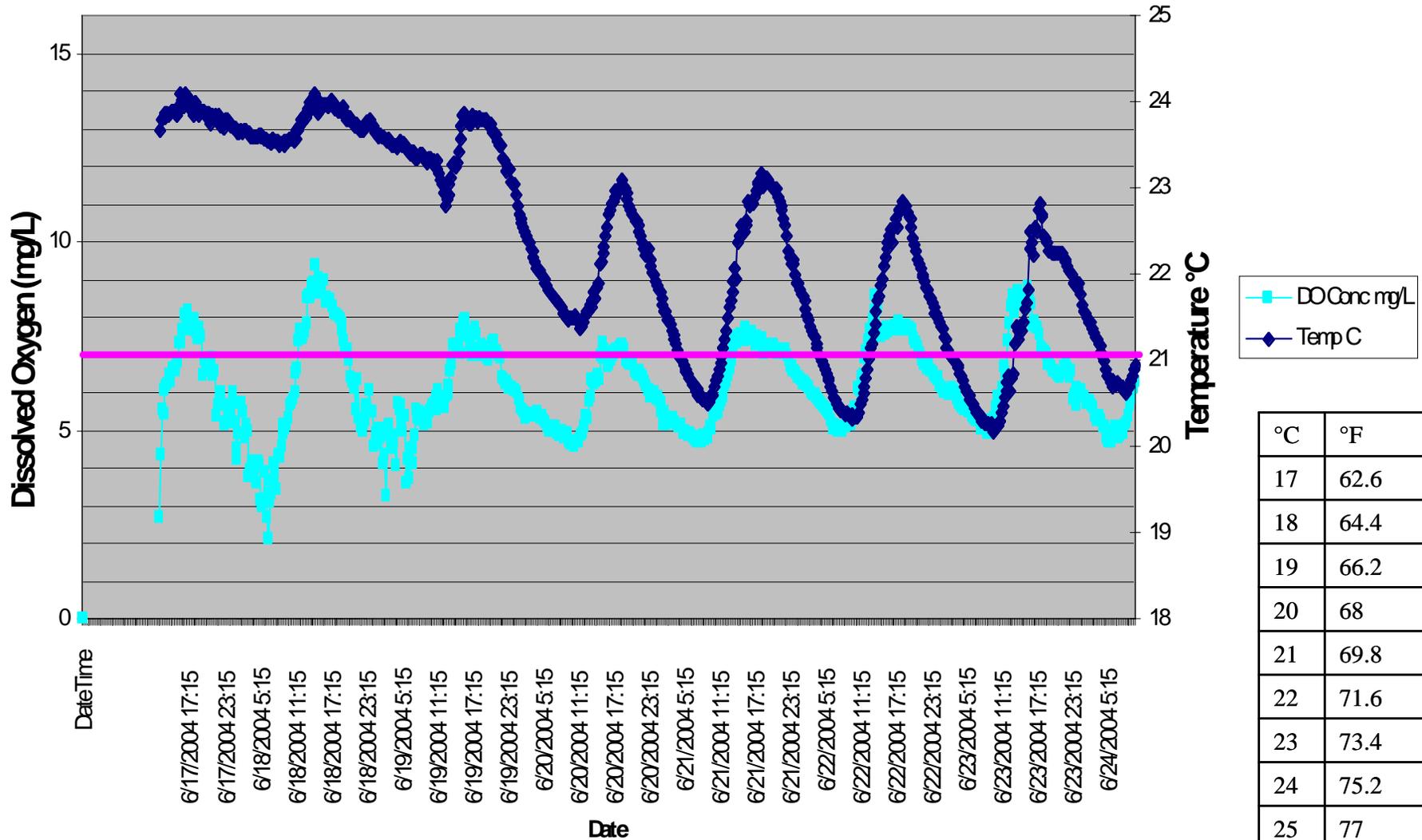
Figure 36: Main Lagoon Water Temperature and Dissolved Oxygen Monitoring 2004;
 Typical bay fish species need temperatures of 15-20 degrees C and DO levels of 7 mg/l

**Temperature and Dissolved Oxygen for the week of 9/24/04
BAP020 Ski Jump Mid-Lagoon**



**Figure 37: Main Lagoon Water Temperature and
Dissolved Oxygen Monitoring 2004;
Typical bay fish species need temperatures of 15-20 degrees C
and DO levels of 7 mg/l**

**Temperature and Dissolved Oxygen for the week of 6/17/04
BAP030 Northern Lagoon**



**Figure 38: Main Lagoon Water Temperature and
Dissolved Oxygen Monitoring 2004;
Typical bay fish species need temperatures of 15-20 degrees C
and DO levels of 7 mg/l**

Temperature and Dissolved Oxygen for the week of 9/24/04
BAP030 Northern Lagoon

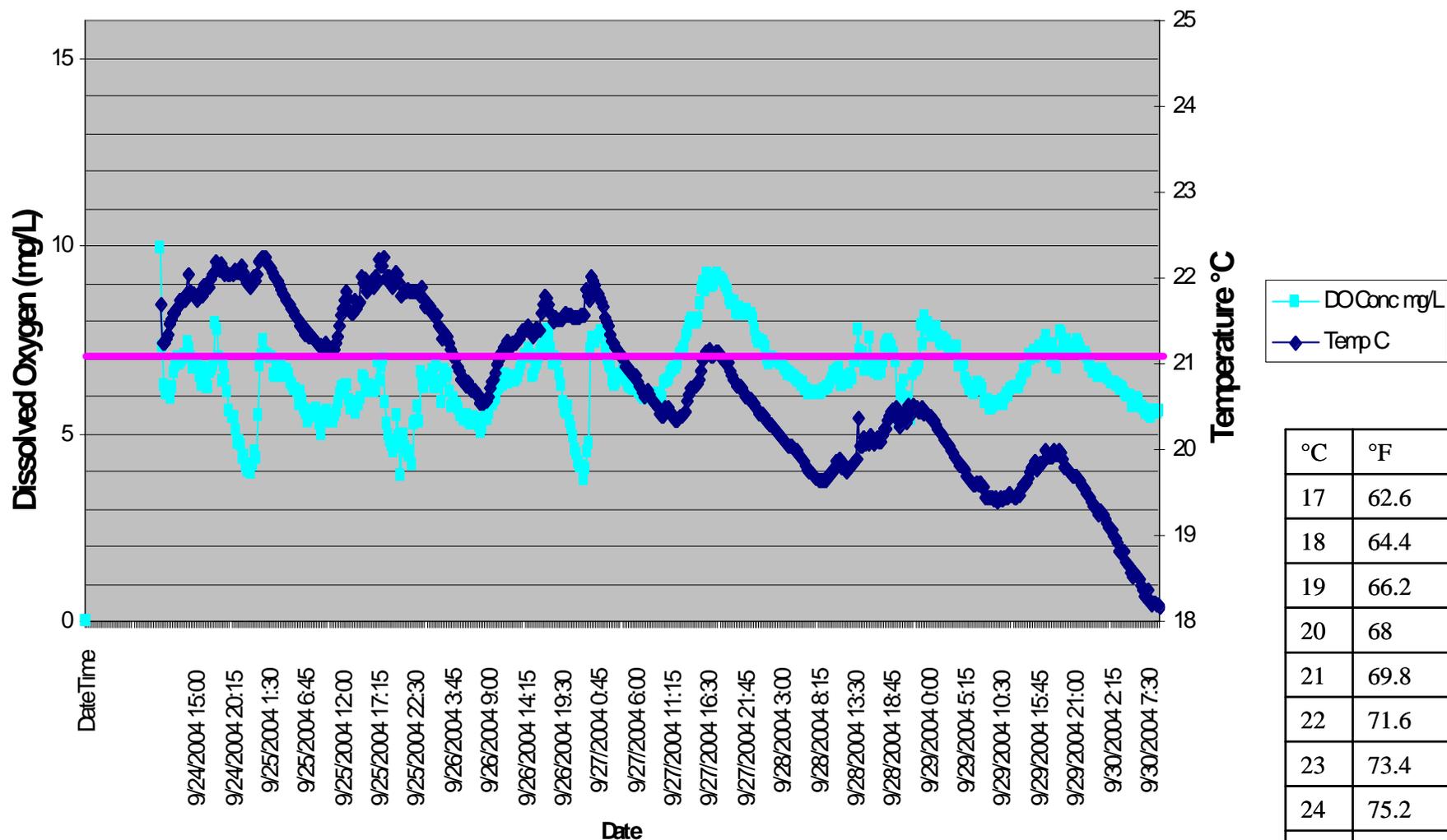


Figure 39: Main Lagoon Water Temperature and Dissolved Oxygen Monitoring 2004;
Typical bay fish species need temperatures of 15-20 degrees C and DO levels of 7 mg/l

**Dissolved Oxygen for
Three Stations in the Main Lagoon of Aquatic Park
Week of 6/17/04**

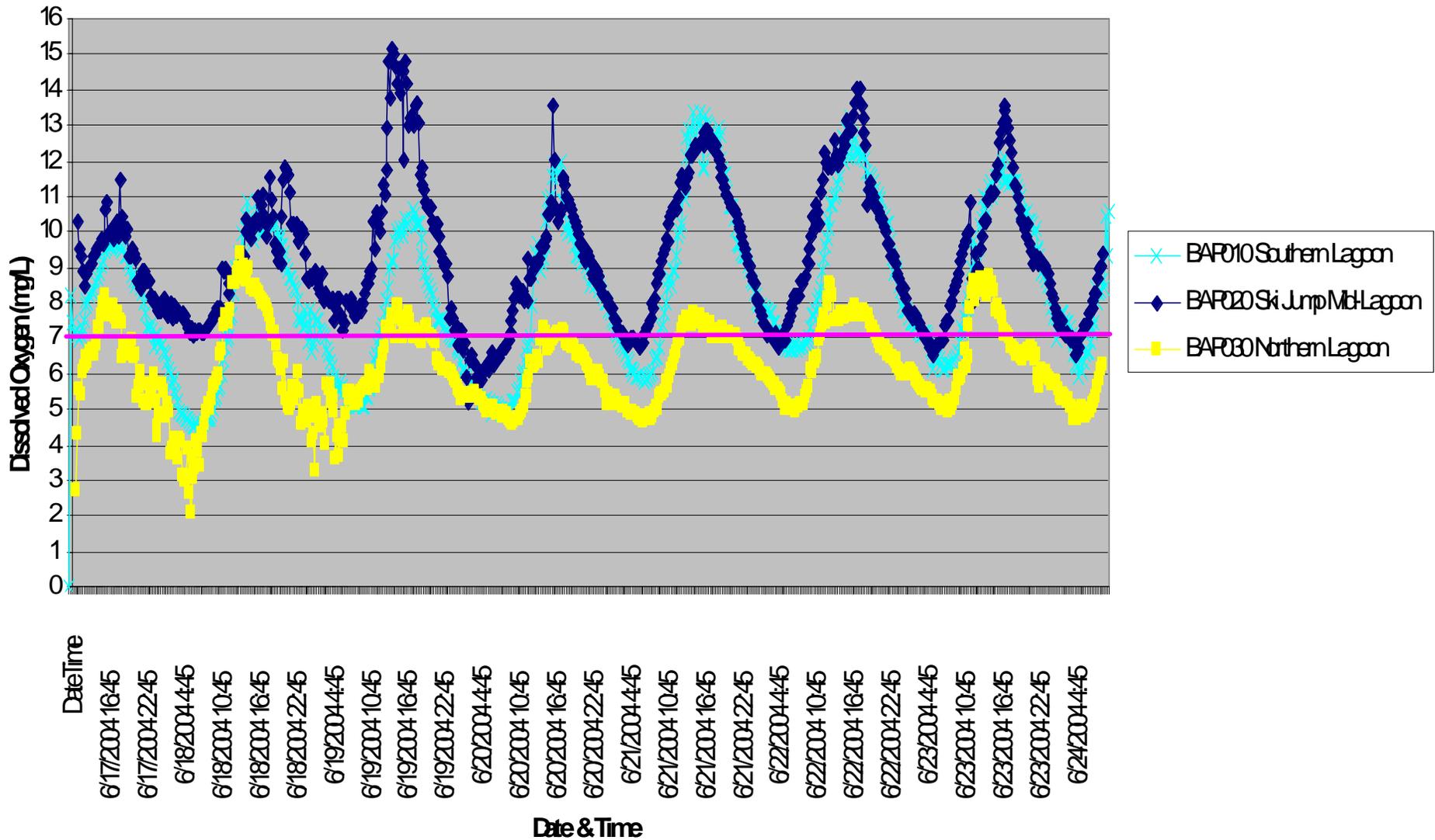
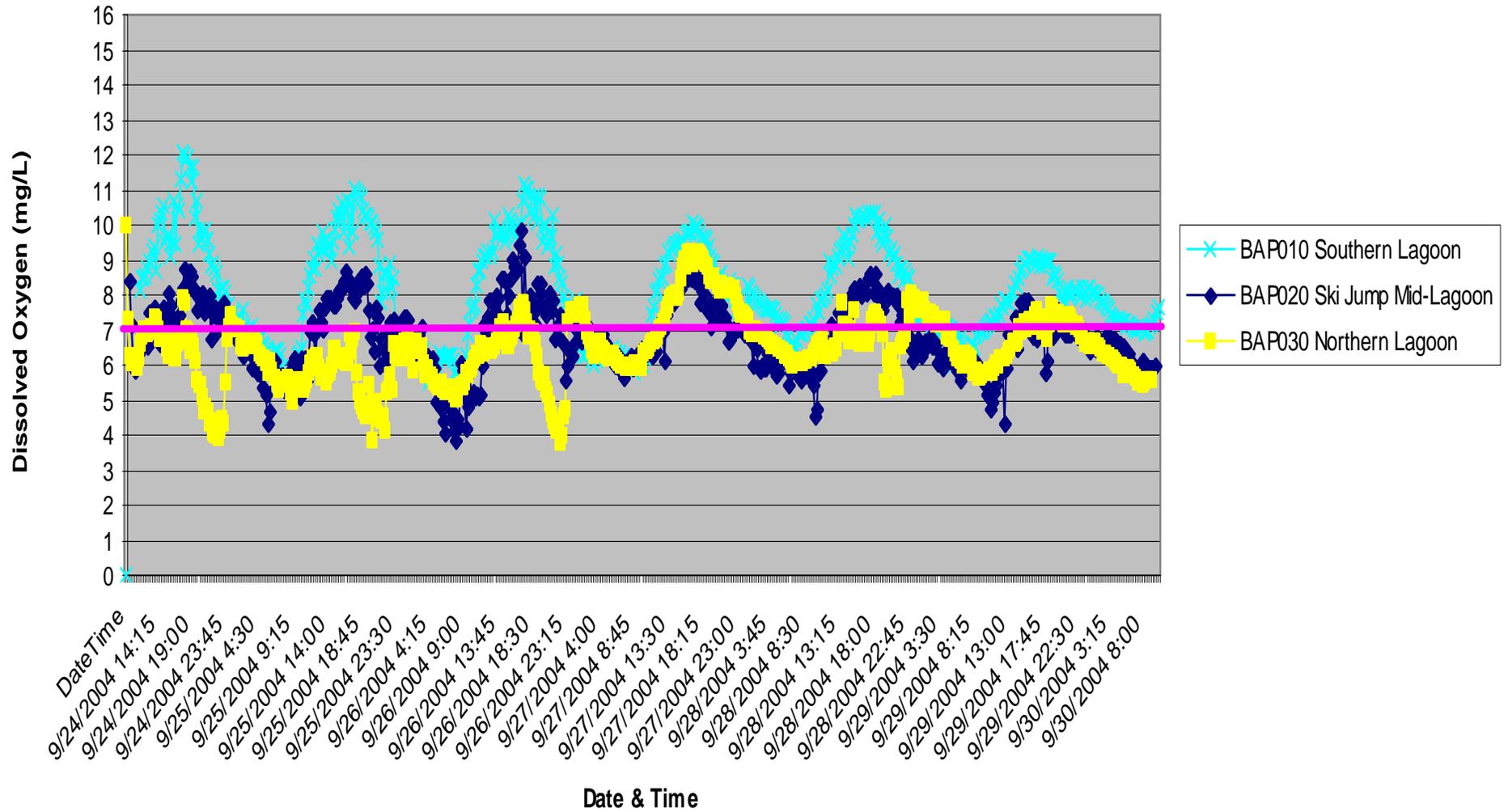


Figure 40: Comparison of Dissolved Oxygen Levels between Three Stations in Main Lagoon for June 17-24, 2004

**Dissolved Oxygen for
Three Stations in the Main Lagoon of Aquatic Park
Week of 9/24/04**



**Figure 41: Comparison of Dissolved Oxygen Levels between
Three Stations in Main Lagoon for September 24-30, 2004**



Figure 42: Algae Blooms in Main Lagoon

Shallow Subtidal Aquatic Habitat and Water Quality-Constraints

1. Very limited tidal inflows and water circulation in Main Lagoon and Radio Tower Pond.
2. Deteriorating tide tubes likely to further reduce inflows.
3. High water temperatures occur in summer and fall.
4. Algal and aquatic plant growth from warm stagnant conditions results in low dissolved oxygen in the lagoon. DO levels drop below RWQCB water quality standards in the summer and fall.
5. Stormwater inflows are retained in the lagoons for several weeks due to limited water circulation possibly allowing for contaminants to deposit out.

Shallow Subtidal Aquatic Habitat and Water Quality-Opportunities

1. There are two locations, Potter Street Stormdrain and Strawberry Stormdrain, which can be used to improve the volume of tidal exchange and water circulation in the lagoons.
2. Increasing tidal volume and circulation would reduce stagnant warm water conditions and increase cold water and dissolved oxygen, creating aquatic conditions more like the central bay habitats for fish.
3. Increased tidal circulation would remove stormwater from the lagoons at a much faster rate.
4. Summer/fall bird use includes mallard ducks, double-crested cormorants, Forster's terns, snowy egrets and shorebirds. According to the 2005 Bird Study these species forage in the Main Lagoon. October through March migratory diving ducks, including scaup and bufflehead, use the Main Lagoon as a foraging area. Year-round residents include great blue herons, black-crowned night herons and great egrets. Improved aquatic habitat would benefit these species.

Salt/Brackish Wetland and Shoreline Habitats

The three lagoons have small areas of salt/brackish wetland (Figure 43). These wetlands were digitized in the field by a wetland specialist. Salt/brackish wetland extent was determined using vegetation type, hydrology, and hydric soils. This method is also termed the "three parameter approach" used for determining jurisdictional wetlands under the federal Clean Water Act.

Along the rock riprap edge of the Main Lagoon, plants such as salt marsh gumplant (*Grindelia stricta*), Jaumea (*Jaumea carnosa*), and pickleweed (*Salicornia pacifica*) grow in between the



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**Figure 43: Salt/Brackish Wetlands
in Aquatic Park, 2007**

- Salt/Brackish Marsh
- Mudflat



rocks. These plants do not form a continuous band of marsh but are simply growing in the only available tidal areas amongst the rocks. This sparsely vegetated, discontinuous band of wetland plants was not included in the mapping.

Intertidal mudflats were also digitized. These are shallow shoreline areas where inundation periods are too lengthy for salt marsh plant species to establish.

A natural tidal lagoon would have gently sloping edges and a larger tidal range creating the conditions for tidal wetlands. Salt/brackish wetland plants have specific adaptations to daily inundation by high tides and to saline and saturated soils. These plants grow in zones defined by these two conditions. In San Francisco Bay, low salt marsh occurs at Mean Sea Level to Mean High Water and is dominated by cordgrass (*Spartina foliosa*), see Appendix A. Cordgrass has aerenchyma, or airspaces, in its stems and can withstand relatively long periods of inundation. High salt marsh occurs from Mean High Water to Mean Higher High Water. The high salt marsh in San Francisco Bay is typically dominated by pickleweed (*Salicornia pacifica*) with a variety of other plant species including sea arrow grass (*Triglochin maritima*), salt grass (*Distichlis spicata*), alkali heath (*Frankenia grandifolia*), jaumea (*Jaumea carnosa*), sea milkwort (*Glaux maritima*), alkali weed (*Cressa truxillensis*), and others (Appendix A). These high marsh species can tolerate high soil salinities but not long periods of inundation. Above Mean Higher High Water is a transition zone where soil salinities are high due to extreme high tides inundating the area several times a year. This transition zone may have plant species from the high marsh as well as salt marsh rosemary (*Limonium californicum*), salt marsh gumplant (*Grindelia stricta*), rabbit's foot grass (*Polypogon monspeliensis*), California buckwheat (*Eriogonum sp.*), and others.

In areas where a freshwater source enters a tidal system, soil salinities will be lower and brackish plants will grow. Alkali bulrush (*Schoenoplectus robustus*, formerly *Scirpus robustus*), brass buttons (*Cotula coronopifolia*), and narrow leaf cattail (*Typha angustifolia*) are commonly found in such areas.

The lagoons of Aquatic Park have steep slopes and a very small average tidal range of 0.2 ft. These conditions limit the area for salt/brackish marsh to small pockets along the shoreline of the Main Lagoon and Model Yacht Basin. The Radio Tower Pond has the largest area of salt/brackish marsh along its western edge (Figure 44). These pockets of salt/brackish wetland total 0.76 acres in all three lagoons. At the outlets of the stormdrains on the eastern shoreline of the Main Lagoon, brackish marsh plants grow in pockets (Figures 45 and 46). In addition to these pockets, high marsh plants grow in the rocky riprap of the lagoon shorelines, especially in the Main Lagoon (Figure 47). These wetlands in the Main Lagoon do not provide much wildlife habitat due to their small size and proximity to active recreation uses.

The Main Lagoon also has a non-vegetated intertidal flat adjacent to the Rowing Club (Figure 48). This area is covered by water for too lengthy a period to support plants; however, the area is also exposed for long periods, making this a harsh environment for worms, invertebrates, and crustaceans. These creatures typically inhabit intertidal mudflats in San Francisco Bay in great profusion, providing the major source of food for migratory shorebirds.



**Figure 44: Salt/brackish
Wetland and Intertidal
Mudflat at Radio Tower Pond**



Figure 45: Small Brackish Wetland at outlet of Stormdrain in Main Lagoon



Figure 46: Small Pocket of Salt/Brackish Wetland on Shoreline of Main Lagoon



Figure 47: *Jaumea carnosa* in Rock Riprap of Main Lagoon Shoreline



Figure 48: Mudflat Adjacent to Rowing Club Site

In the Main Lagoon, shorebirds roost adjacent to this intertidal flat (Figure 49). In 2007 the high tide elevation was low and the intertidal flat was dry except during rain events when the lagoon water level was temporarily higher. In previous years (2002/2003) the flat was intertidal (Figures 50 and 51) and shorebirds were observed feeding. The deterioration of the bay side of the main tide tubes (Figure 14) may have resulted in the change in high tide elevation. The habitat areas adjacent to the shoreline are often disturbed by unleashed dogs (Figure 52).

The shoreline of the Main Lagoon is lined with rocks in most areas. In many locations on the western shoreline, rock walls constructed in the 1930s are crumbling or separating from the lagoon edge. Along the eastern shoreline the wall is nearly completely gone, broken up by wind-driven waves (Figure 53). On the northeastern shoreline the walking trail is adjacent to the lagoon. The Model Yacht Basin has rock terraces along its shoreline as well as deteriorating wooden retaining walls and piers (Figure 11).

Invasive Plants

Invasive non-native plants were identified to species level and mapped throughout the park in 2007 (Figures 54A and 54B). Single or small groupings of invasive plants were digitized as points and larger coverages were mapped in the field as polygons. Where more than one invasive species was present, the coverage of each was digitized. Table 10 lists the acreages and species of invasive plants recorded in the park.

Invasive non-native plants are typically introduced as ornamental plants and then escape and invade other lands. A species is only considered “invasive” if it is able to spread and take over native habitat areas. There are non-native species that are used as street or garden plants that are not invasive. Only plants listed as invasive by the California Invasive Plant Council (www.cal-ipc.org) were mapped. Appendix A includes additional information about invasive species.

The first step in restoring or improving salt/brackish wetland habitats in Aquatic Park is to eradicate invasive plants on the shoreline. If this step is not completed, the new native plants can be overwhelmed by the quick-growing, aggressive invasive species.



**Figure 49: Mixed Flock of Shorebirds at Mudfat
Area in Main Lagoon**



Figure 50: Mudflat Area in 2002



Figure 51: Mudflat Area in Main Lagoon, 2007
Change in measured high tide level in
Main Lagoon: 2002: -1.57 ft and 2007: -1.95 ft, Berkeley Datum



Figure 52: Dog tracks. Unleashed dogs are frequently observed chasing the shorebirds and ducks from shoreline areas. While the dogs are rarely quick enough to catch a bird several studies have shown that the constant harassment by dogs causes the birds to spend less time eating and resting and therefore they may not gain enough weight to successfully over-winter and complete a long migration. Unleashed dogs also deter any nesting by resident ducks or shorebirds.



Figure 53: Rock Wall Falling off Shoreline Trail on East Shore of Main Lagoon

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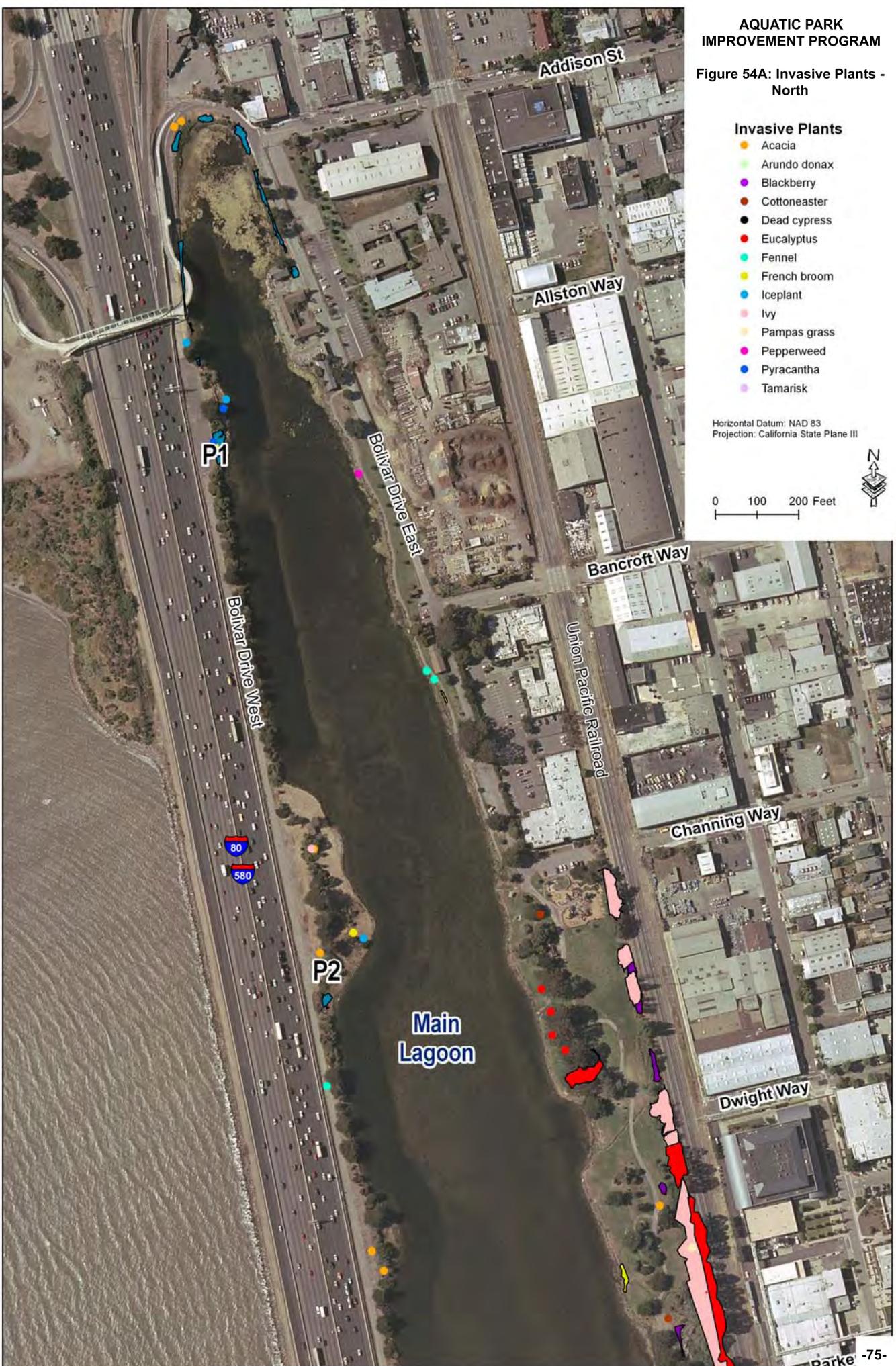
Figure 54A: Invasive Plants - North

Invasive Plants

- Acacia
- Arundo donax
- Blackberry
- Cottoneaster
- Dead cypress
- Eucalyptus
- Fennel
- French broom
- Iceplant
- Ivy
- Pampas grass
- Pepperweed
- Pyracantha
- Tamarisk

Horizontal Datum: NAD 83
Projection: California State Plane III

0 100 200 Feet



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Figure 54B: Invasive Plants - South

Invasive Plants

- Acacia
- Arundo donax
- Blackberry
- Cottoneaster
- Dead cypress
- Eucalyptus
- Fennel
- French broom
- Iceplant
- Ivy
- Pampas grass
- Pepperweed
- Pyracantha
- Tamarisk

Horizontal Datum: NAD 83
Projection: California State Plane III

0 100 200 Feet



Table 10: Invasive Non-Native Plant Species on Lagoon Shorelines in Aquatic Park		
Species	Total Acres in Aquatic Park	Shoreline Location
Wattle (<i>Acacia sp.</i>)	1.75 acres	Main Lagoon
Giant reed (<i>Arundo donax</i>)	<0.01 acres	None
Himalayan blackberry (<i>Rubus discolor</i>)	0.46 acres	None
Cotoneaster (<i>Cotoneaster sp.</i>)	0.02 acres	Main Lagoon
Blue gum (<i>Eucalyptus globulus</i>)	3.79 acres	Main Lagoon
Fennel (<i>Foeniculum vulgare</i>)	0.02 acres	Main Lagoon
Broom (<i>Cytisus scoparius, Genista monspessulana, Genista juncea</i>)	0.03 acres	Main Lagoon
Ice plant (<i>Carpobrotus edulis</i>)	0.26 acres	Main Lagoon, Radio Tower Pond,
English ivy (<i>Hedera helix</i>)	1.28 acres	In Radio Tower Pond shoreline area
Pampas grass (<i>Cortaderia selloana</i>)	<0.01 acres	None
Pepperweed (<i>Lepidium latifolium</i>)	<0.01 acres	Main Lagoon
Firethorn (<i>Pyracantha sp.</i>)	0.02 acres	Main Lagoon
Salt cedar (<i>Tamarix sp.</i>)	0.01 acres	Main Lagoon

Salt/Brackish Wetland and Shoreline Habitats-Constraints

1. The Main Lagoon has a very small average tidal range of .2 ft. and the Model Yacht Basin has an average tidal range of about 1.77 ft. This is in comparison to the average 6.16 ft. tidal range in the adjacent San Francisco Bay.
2. Most of the lagoon shorelines are rock-lined and relatively steep (>10%) or consist of rock terraces and will not support wetlands.
3. Wind-driven waves erode the eastern shorelines and could limit success of wetland creation.
4. Human recreational use is high along the Main Lagoon and Model Yacht Basin and includes unleashed dogs which run near the shoreline and into the water to chase birds. While the dogs are rarely quick enough to catch a bird, several studies have shown that the constant harassment by dogs and resulting stress causes the birds to spend less time eating and resting and therefore they may not gain enough weight to successfully over-winter and complete a long migration. Unleashed dogs also deter any nesting by resident ducks or shorebirds.

5. Invasive plants, such as ice plant, cover areas of the shoreline on and near existing and potential wetland sites.
6. Black-crowned night herons roost in the willows in the northeast corner of Radio Tower Pond and in the cypress along the western shoreline of the Main Lagoon.
7. Homeless encampments, trash dumping and other activities disturb and degrade shoreline areas, further limiting habitat values.

Salt/Brackish Wetland and Shoreline Habitats-Opportunities

1. A wetland could be created by excavating material out of the shoreline in one of several locations. Filling the water area to create wetlands would reduce the tidal prism and reduce the volume of water circulating through the lagoon. The western shoreline of the Main Lagoon is not eroded by waves and could support a new wetland.
2. The western portion of the Main Lagoon has a lower level of recreational use. Dogs and people could be restricted through design of vegetative barriers, signs and some fencing.
3. Invasive plants are located on and near existing and potential wetland sites and will need to be eradicated.
4. Sites P2, P3 or the Rowing Club areas could be graded to create intertidal conditions. Excavated material could be used to create vegetated berms along the edge of a new wetland to restrict unleashed dogs and for other native plant re-vegetation areas (P-1, P-2 and P-3) along the western road, to create a berm around the Radio Transmitter Building in the Radio Tower Pond and to improve Bird Island.
5. Removal of the black-crowned night heron roosting areas in the northeast corner of the Radio Tower Pond and the cypress along the western shoreline of the Main Lagoon should be avoided.
6. Senescent and dead trees could be removed and replaced with cypress seedlings and native vegetation.
7. The northern portion of the eastern shoreline trail could be relocated and the shoreline could be revegetated while retaining the rock walls and riprap to protect against erosion.

Upland and Bird Roosting Habitat

Upland areas in Aquatic Park include grass, pathways, roads, used and abandoned parking areas, non-wetland edges of the lagoons and both derelict and currently used buildings. These

areas cover 25 acres of the park. The majority of recreation facilities are along the eastern side of the park. Starting at the northern side of the Main Lagoon is the Addison Street entrance to the park. Turning south along the east shore, there is a waterside trail and a road for cars with parking. There is a workshop building, lawn areas, some ornamental trees, and two derelict buildings (the Old Rod & Gun Club and a storage building). A children's playground is located where Channing Street reaches the lagoon.

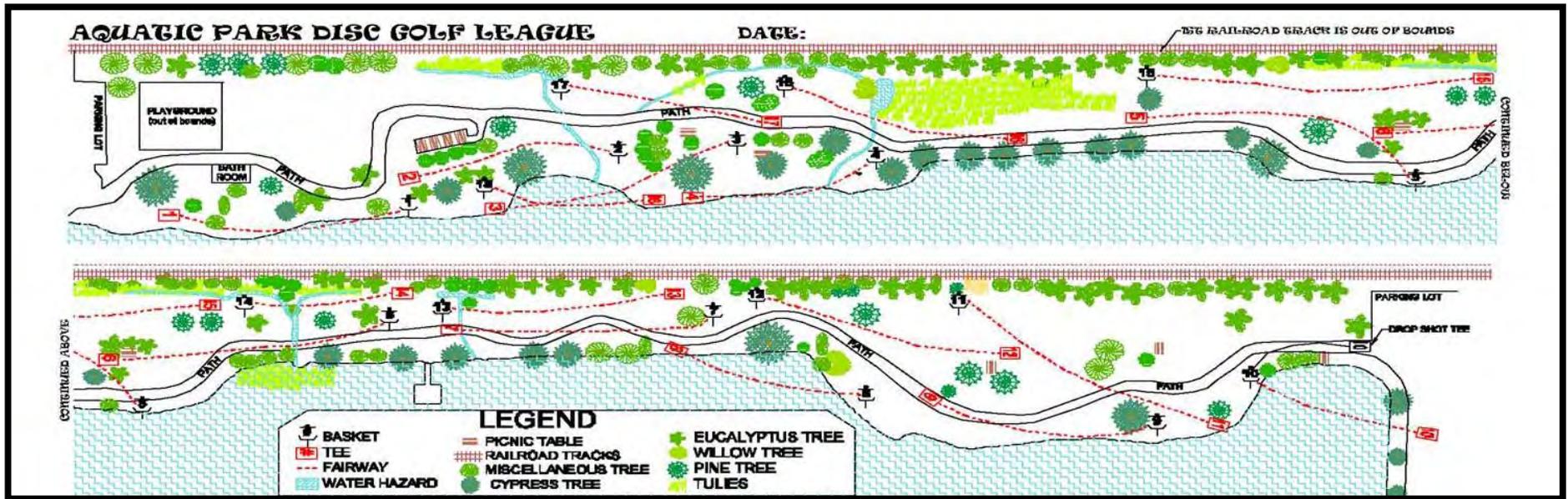
South of the playground is an area covered with turf and various ornamental trees including acacias. There is a disc golf course that extends from south of the playground to the end of the Main Lagoon (Figure 55). This portion of the park was re-landscaped in the 1970s with the addition of hummocks and small mounds to create areas protected from the afternoon wind. There are picnic tables in various locations along the eastern side of the Main Lagoon. The majority of recreational uses are on the eastern side of the Main Lagoon.

The western side of the Main Lagoon has an asphalt access road and a series of asphalt parking areas (Figure 56). The Waterski Club and Rowing Club have facilities on the western side of the Main Lagoon; however, the access road is only needed for emergency vehicles. This access road is also used by bicyclists who cross over the highway on the overpass. The parking areas are not used. The western side of the Main Lagoon is very noisy due to the adjacent highway. There is a derelict bathroom building on the western side of the Main Lagoon.

The Model Yacht Basin and Radio Tower Pond are bordered by roads, parking, and areas of ornamental plantings. The road between the Model Yacht Basin and Radio Tower Pond is an on-ramp to I-80. There is a Radio Transmitter Building which is used as a radio museum at the Radio Tower Pond. At many locations in the upland areas there are homeless encampments. All three lagoons have Monterey cypress planted near the shoreline. The cypresses are used for roosting by various species of herons and egrets.

Another upland area is the island in the Main Lagoon called Bird Island. The island has a building on it which is used by the Waterskiing Club (Figures 57A and 57B). The island is accessed by a floating walkway from the Main Lagoon shoreline. The elevation of Bird Island is low (0 to +2.0 ft. Berkeley Datum) and the island floods during large storms.

Figure 55: Disc Golf on East Shore of Main Lagoon





Site P1



Site P2

Figure 56: The access road and parking areas on the western side of Main Lagoon are largely unused.

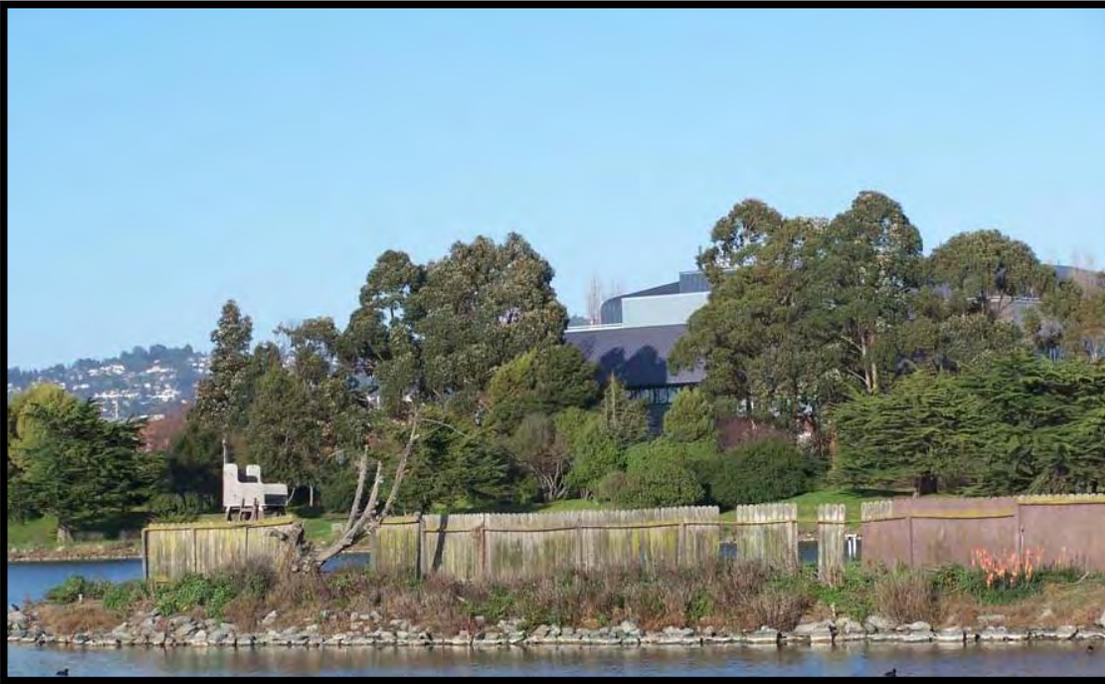


Figure 57A: Bird Island with Waterski Club Building





Figure 57B: Bird Island

Upland and Bird Roosting Habitat-Constraints

1. The upland areas support active recreation including biking, walking, leashed and unleashed dog walking, disc golf and boat launching.
2. There are limited wildlife species using the upland areas.
3. There are high levels of disturbance and human uses.
4. Homeless encampments, trash dumping and other activities that disturb habitat occur in upland areas.
5. There are invasive non-native plants in the upland areas.
6. There are a number of derelict and unused buildings in the park.
7. The road between the Model Yacht Basin and Radio Tower Pond is used by a large number of cars as a freeway on-ramp.

Upland and Bird Roosting Habitat-Opportunities

1. Derelict buildings could be restored or removed.
2. Un-needed road pavement and parking areas on the western side of the park could be removed and revegetated.
3. Trails along the shoreline could be relocated to reduce disturbance and the shoreline area could be revegetated.
4. Some upland areas could be restored to tidal wetlands or freshwater wetlands.
5. Once the freeway on-ramp is closed much of the pavement could be removed, a trail could be created and revegetation completed.
6. Turf area on the northern end of the Main Lagoon along the eastside could be used as a bioswale to filter street stormwater runoff from directly entering the lagoon.
7. Invasive and dead plants could be removed and natives and non-invasive ornamentals planted.

Watershed Hydrology and Urban Stormwater

Introduction

A large portion of the City of Berkeley drains towards Aquatic Park (Figure 58A). The majority of this runoff drains into the Potter Street Stormdrain and the Strawberry Stormdrain. During high runoff periods, stormwater can enter the lagoons from these two drains. A portion of the watershed immediately east of the park drains directly into the Main Lagoon.

The goal of the hydrologic analysis was twofold. The first goal was to develop a watershed model that would simulate the rainfall-runoff processes for the 2-year through 100-year storm events over the watershed. The results of this analysis provided flow rates for the Strawberry Stormdrain and the Potter Street Stormdrain. This flow was used as input to a hydraulic model to determine the volume of stormwater that flows into the lagoons on each storm event. The model routed the flow through the city stormdrain system to determine the discharge and duration of flow through the pipe network.

The second goal of the hydrologic analysis was to determine the volume of discharge that enters the lagoon from the sub-basins immediately east of the park. These sub-basins drain directly into the Main Lagoon and do not flow into the Strawberry or Potter Street stormdrains.

To determine the volume of stormwater entering the lagoon system, a watershed model was developed to compute the flow in the Potter Street and Strawberry stormdrains. The watershed draining to these stormdrains was delineated using a 5-foot Digital Elevation Map (DEM) and information from the City of Berkeley. Figure 58B shows the areas that drain to the Strawberry Stormdrain, Potter Street Stormdrain, and directly into the Main Lagoon.

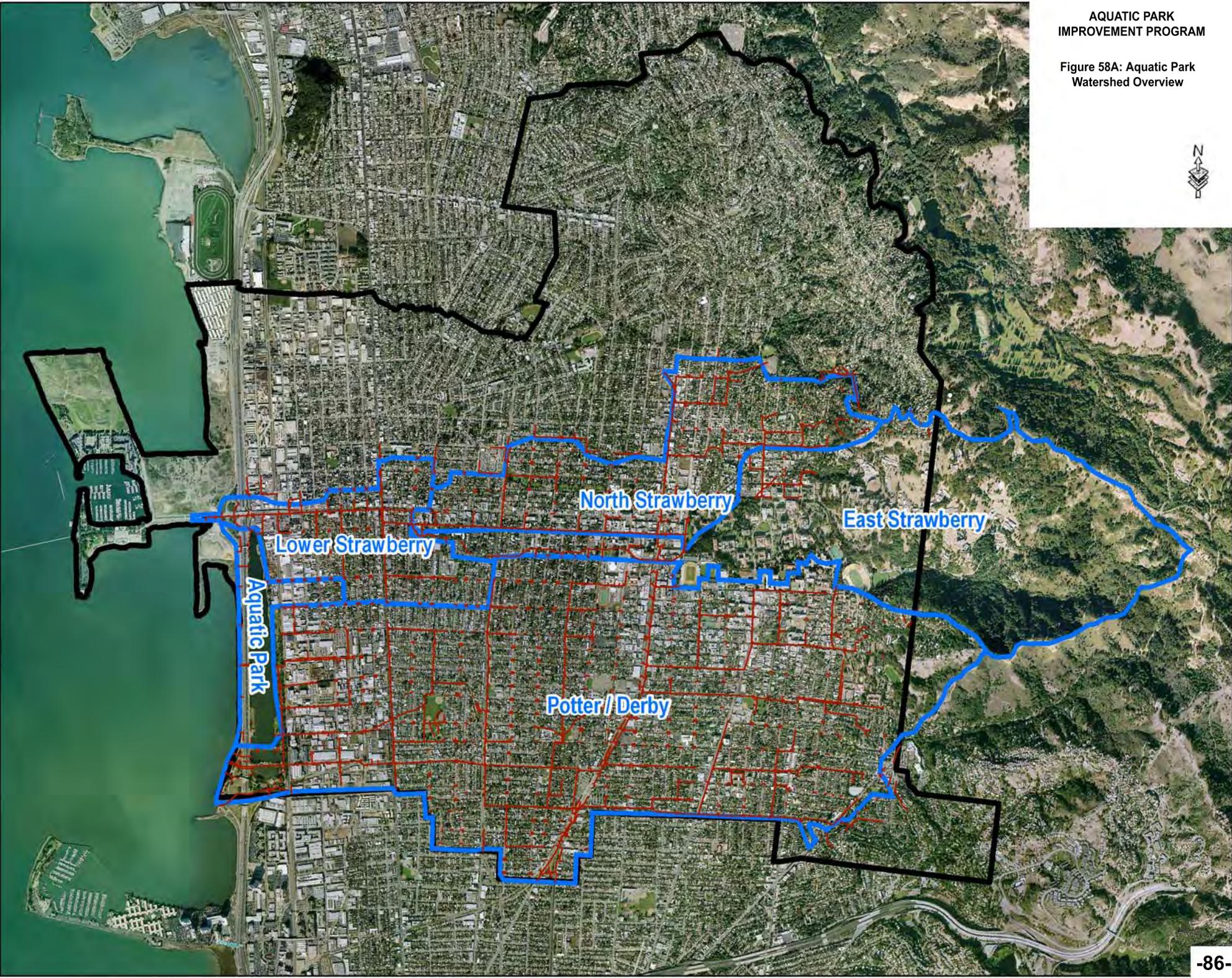
Watershed Delineation

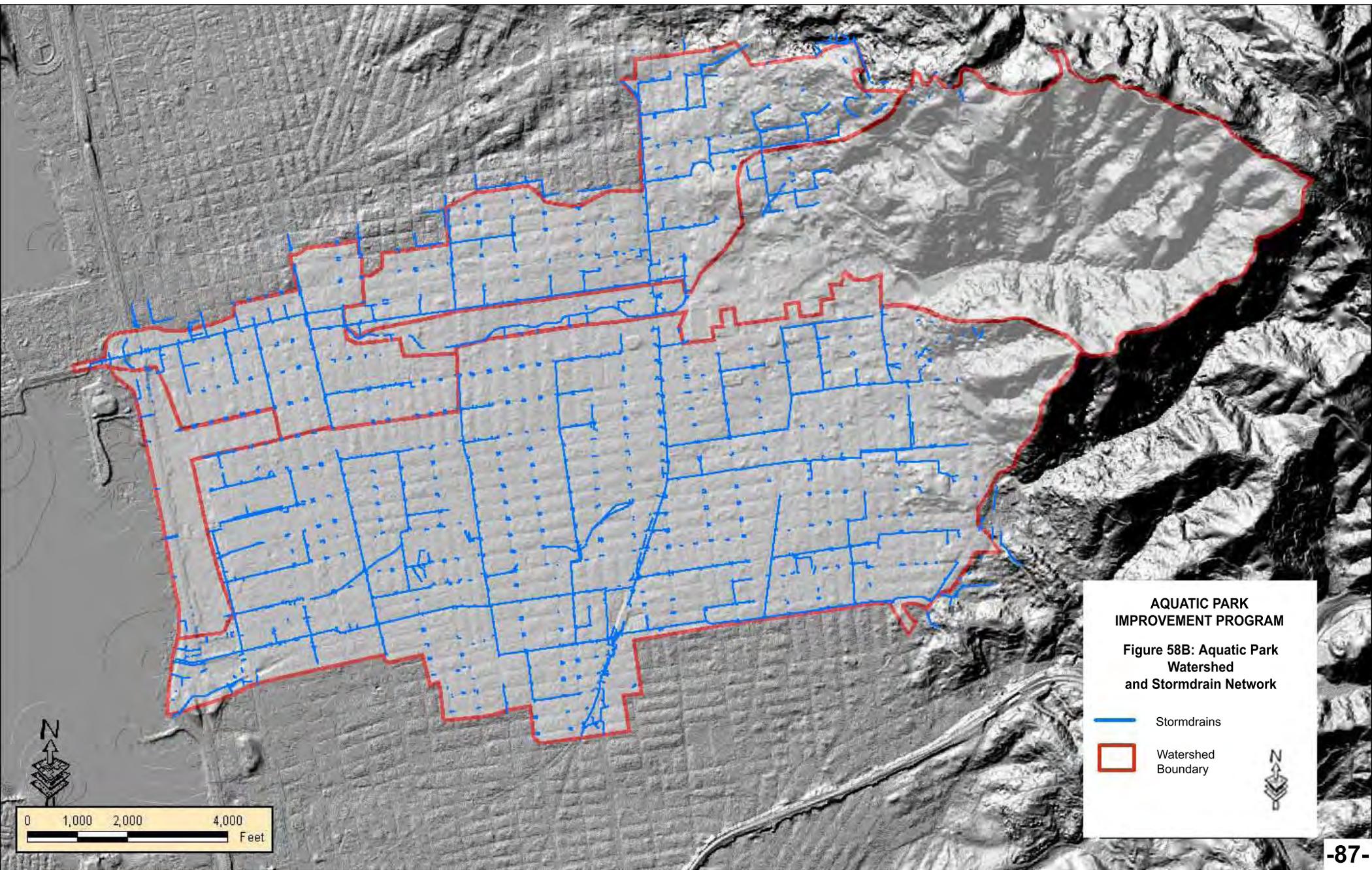
The watershed area above Aquatic Park consists of approximately 6.8 square miles. The upper elevation of the watershed is approximately 1,916 ft. NAVD. The lower elevation of the basin is essentially 0 ft. NAVD.

To accurately define the runoff characteristics, the watershed was divided into 24 separate sub-basins. The sub-basins were defined through common runoff characteristics and stormdrain system connectivity that were distinct from adjacent basins. Figure 59 is a plan view of the watershed showing the location and extent of the 24 sub-basins. Figure 60 is a blow-up of the watershed in the area surrounding Aquatic Park. The sub-basin areas are provided in Table 11.

Sub-basins 1 through 7 drain to the Strawberry Stormdrain. Sub-basins 8 through 13 drain to the Potter Street Stormdrain. Sub-basin 14 drains directly to the Radio Tower Pond. Sub-basins 15 through 21 drain directly to the Main Lagoon and the Model Yacht Basin. Sub-basins 22 and 23 represent precipitation on the Main Lagoon and Model Yacht Basin directly.

Figure 58A: Aquatic Park
Watershed Overview



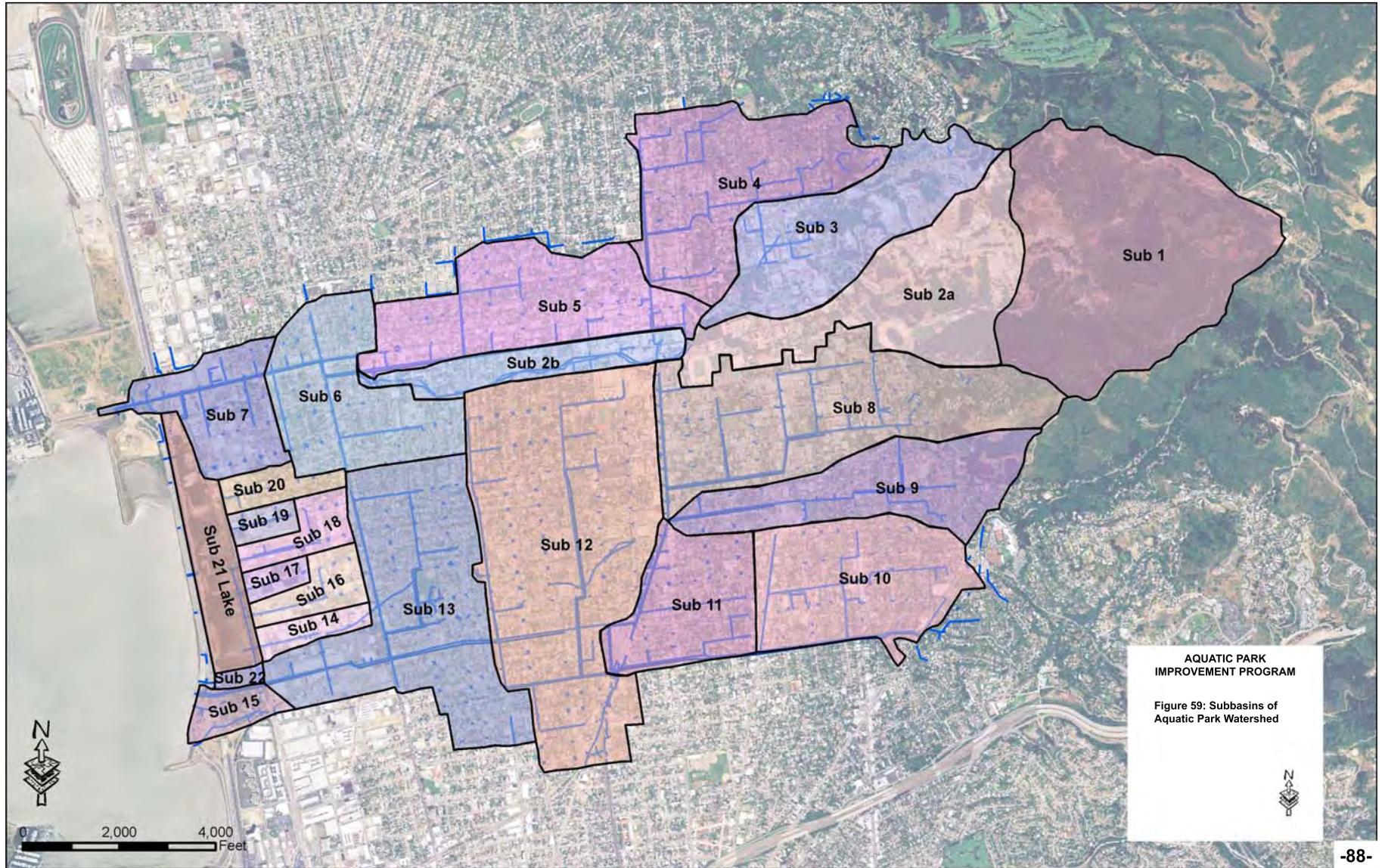


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**Figure 58B: Aquatic Park
Watershed
and Stormdrain Network**

-  Stormdrains
-  Watershed Boundary







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Figure 60: Aquatic Park
Stormdrain Pipe Network

— Stormdrain



Based on City of Berkeley GIS

Sub-basin Number	Description	Area (acres)
1	Strawberry	494.5
2	Strawberry	299.8
2B	Strawberry	96.4
3	Strawberry	240.7
4	Strawberry	288
5	Strawberry	260.4
6	Strawberry	220.4
7	Strawberry	130.7
8	Potter St.	393.6
9	Potter St.	215.3
10	Potter St.	244
11	Potter St.	164.4
12	Potter St.	629.8
13	Potter St.	346.4
14	Radio Tower Pond	30.8
15	Heinz St.	37.8
16	Grayson St.	50
17	Carlton St.	18.7
18	Parker St.	46.6
19	Dwight St.	22.5
20	Channing St.	35.9
21	Bancroft St.	20.7
22	Main Lagoon	112.6
23	Model Yacht Basin	8.6
Total		4,380.5

Precipitation

Methodology

There are a variety of precipitation gages in the vicinity of the project site. Our goal was to develop hourly precipitation data sets for the 2-, 5-, 10-, 25-, and 100-year, 24-hour storm events. A long term hourly precipitation gage is required to develop this type of data set. Precipitation varies across the Berkeley hills, both in the east to west direction as well as north to south. Precipitation also typically varies with elevation, with precipitation increasing as elevation increases.

Winter storms that produce the greatest amount of precipitation typically come out of the northwest, moving across the Bay area. As they move to the southeast, the orography or the physical geography of the ranges of the Berkeley hills have a pronounced effect on the

precipitation intensity (Figure 61). To account for this effect, the precipitation gage must be representative of the location, elevation, and orientation of the sloping watershed. Often, the precipitation data from a gage can be adjusted to reflect the conditions of a specific study area.

A review of the available precipitation gages in the vicinity of the project site revealed three gages that had hourly precipitation data: Richmond City Hall, Oakland North, and Tilden Park. Alameda County has developed an isohyetal map from these and other gages in the vicinity. This map provides the intensity, duration, and frequency information on precipitation in the project area. The information in the county analysis compared favorably to the gage data that was reviewed. Therefore, the Alameda County data was used for this analysis.

A tabulation of the annual data has been provided in Appendix B. Table 12 provides a tabulation of the total precipitation for each storm.

Table 12: December 2005 Precipitation Event	
Frequency	Precipitation (in)
2-Yr	2.64
5-Yr	3.36
10-Yr	3.86
15-Yr	4.15
25-Yr	4.67
100-Yr	5.79

Balanced Hydrograph Development

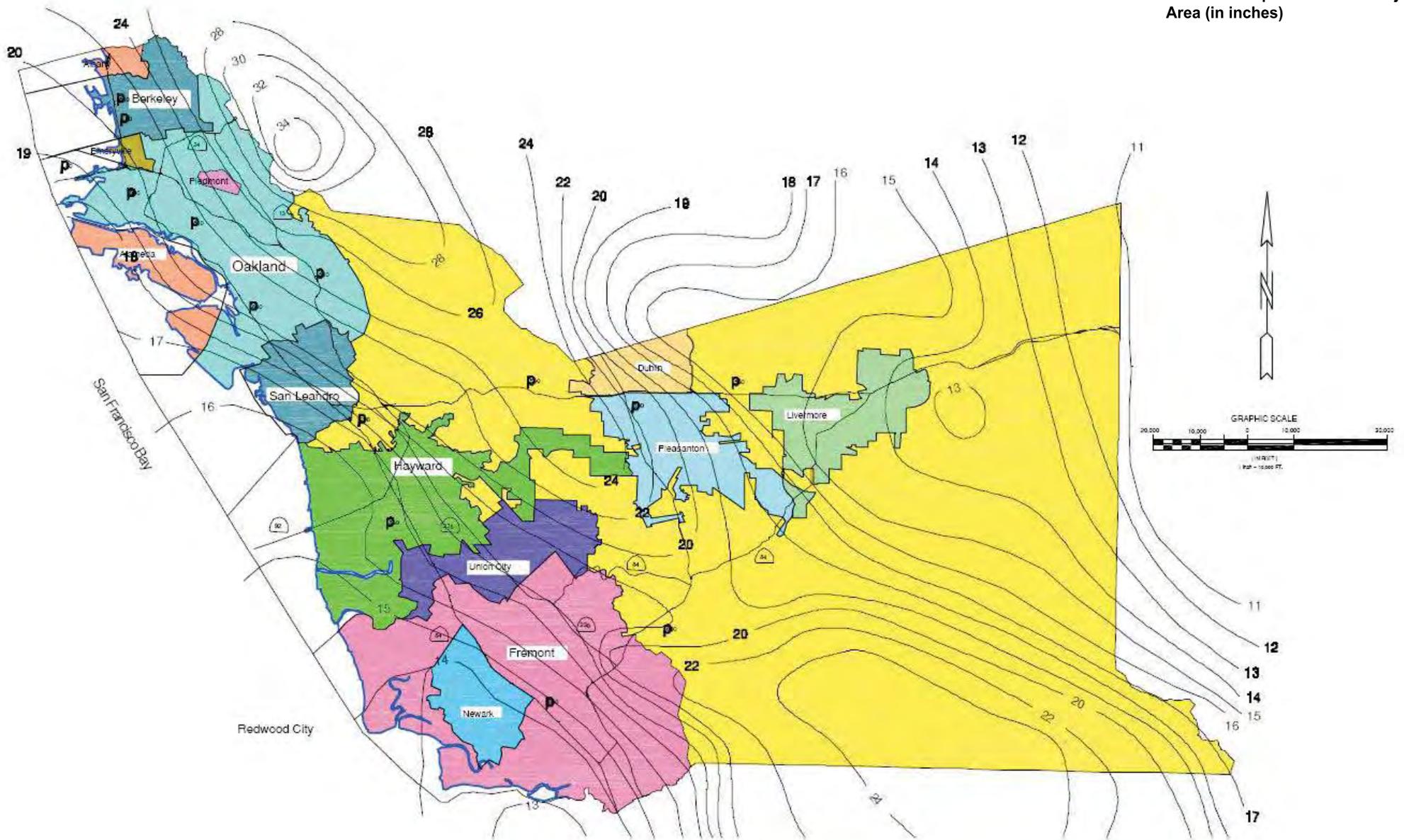
The hourly precipitation data from the Alameda County precipitation analysis was arranged to produce a balanced hyetograph for the 2-, 5-, 10-, 15-, 25-, and 100-year storm events. A balanced hyetograph is constructed in a way to ensure that the 24-hour hyetograph contains the 1-hour peak rainfall as well as the 2-hour and 3-hour through the 24-hour duration event for the specified return frequency. This allows the 24-hour storm event to be applied to basins that peak within different duration periods. Table 13 lists the hourly precipitation data for the different storm events. These hyetographs were applied to the sub-basins throughout the watershed. Figures 62 through 66 are time series plots of each of the hyetographs.

Precipitation Evaluation

The results of the precipitation analysis show that the peak 3-hour duration for the December 2005 storm event had a 75-year return frequency. Based on observations from local residents, a flood event of this magnitude has not occurred in recorded memory. That observation record only extends back forty to fifty years, so it is not necessarily out of line with the computed frequency.

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Figure 61: Isohyetal Map of Mean Annual Precipitation in the Project Area (in inches)



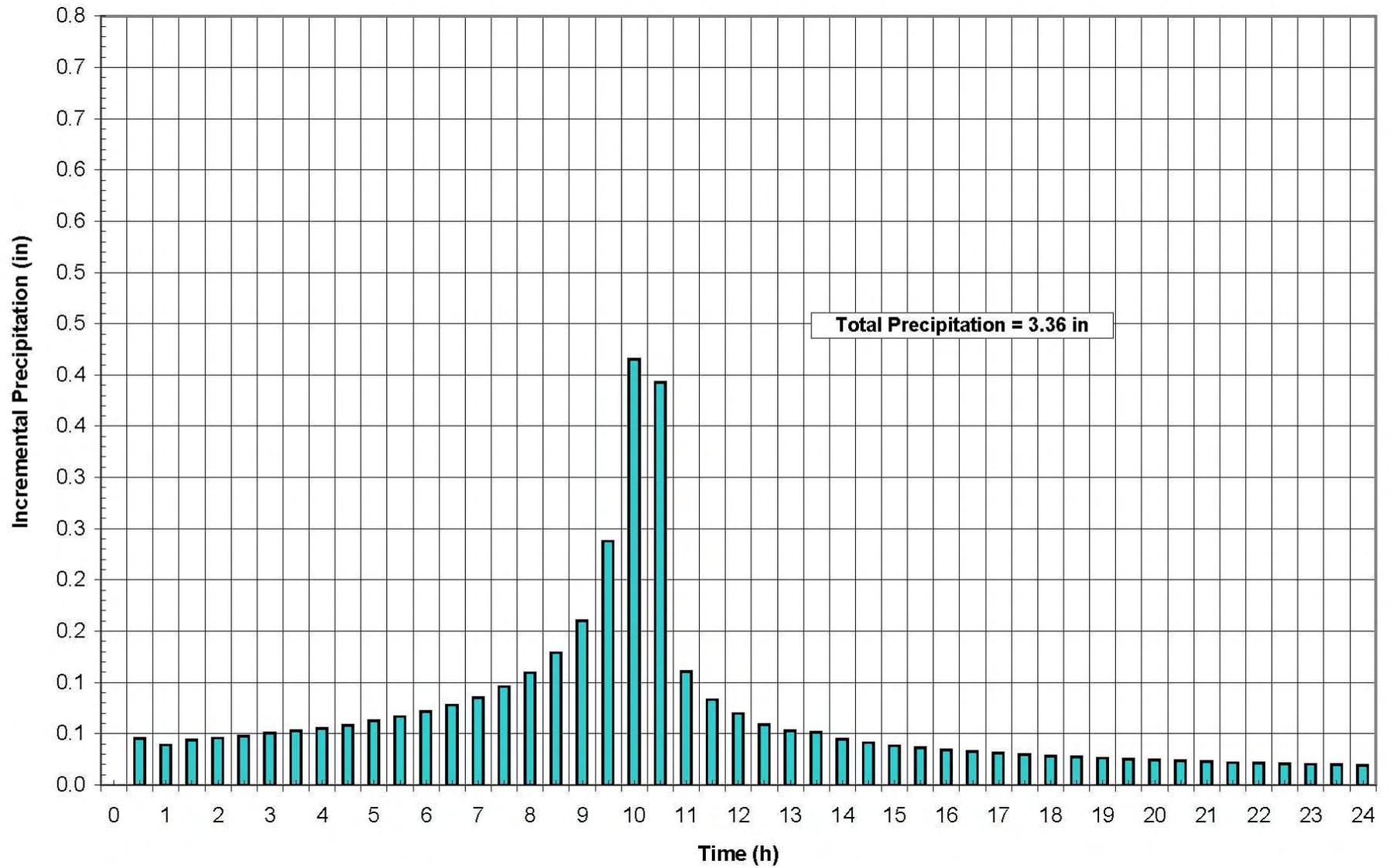


Figure 62: Hyetograph for 5-Year, 24-Hour Storm Event in Aquatic Park watershed

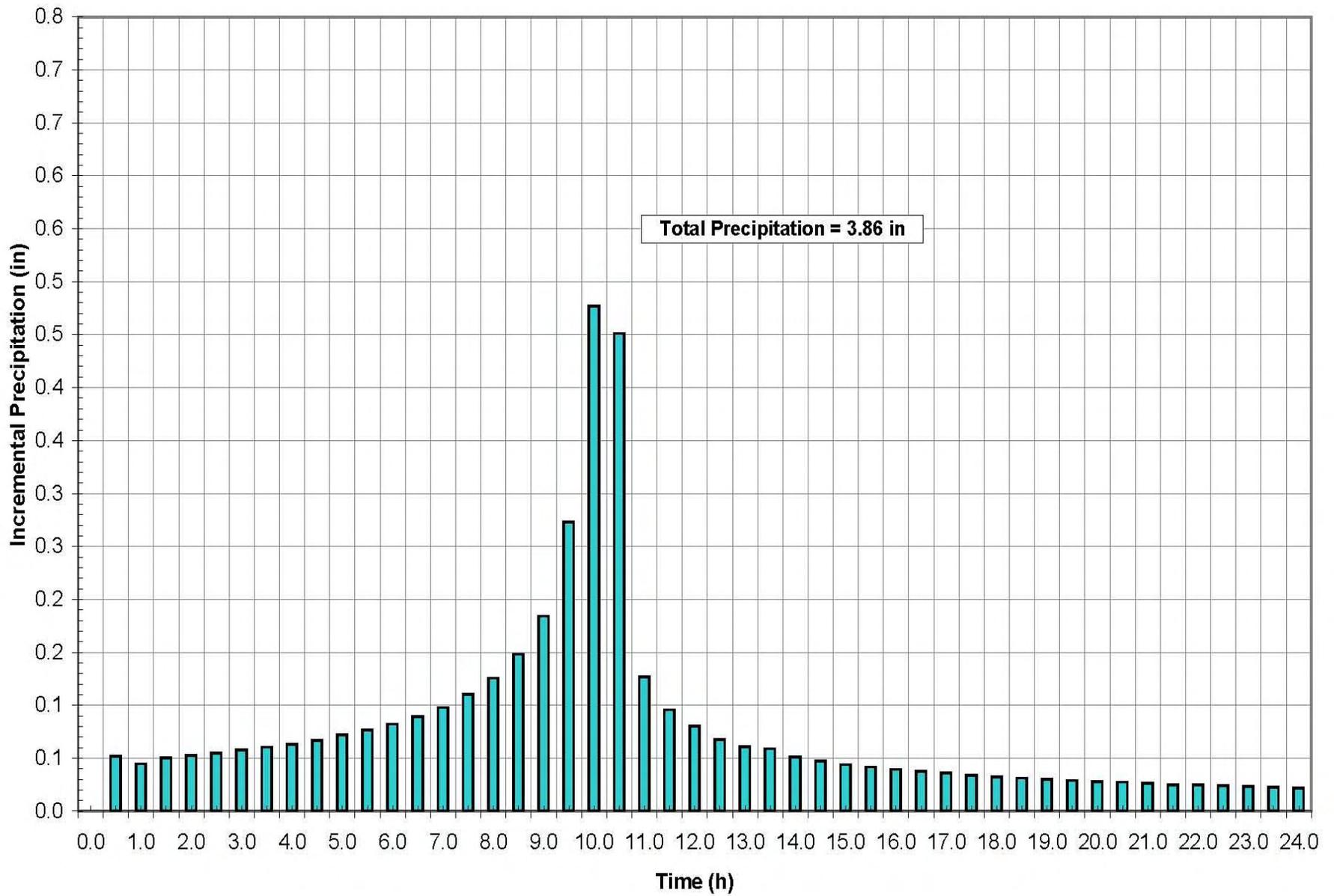


Figure 63: Hyetograph for 10-Year, 24-Hour Storm Event in Aquatic Park watershed

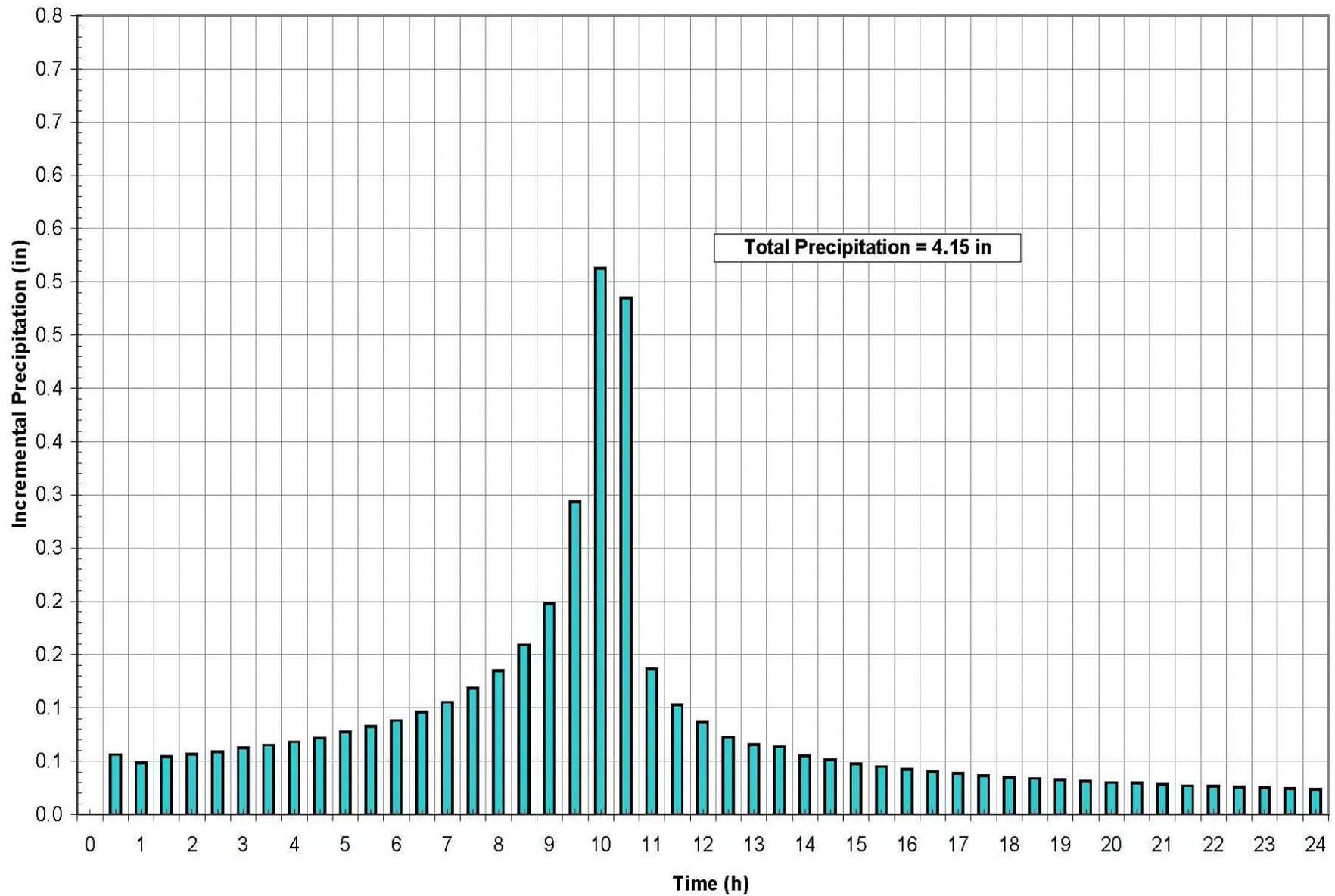


Figure 64: Hyetograph for 15-Year, 24-Hour Storm Event in Aquatic Park watershed

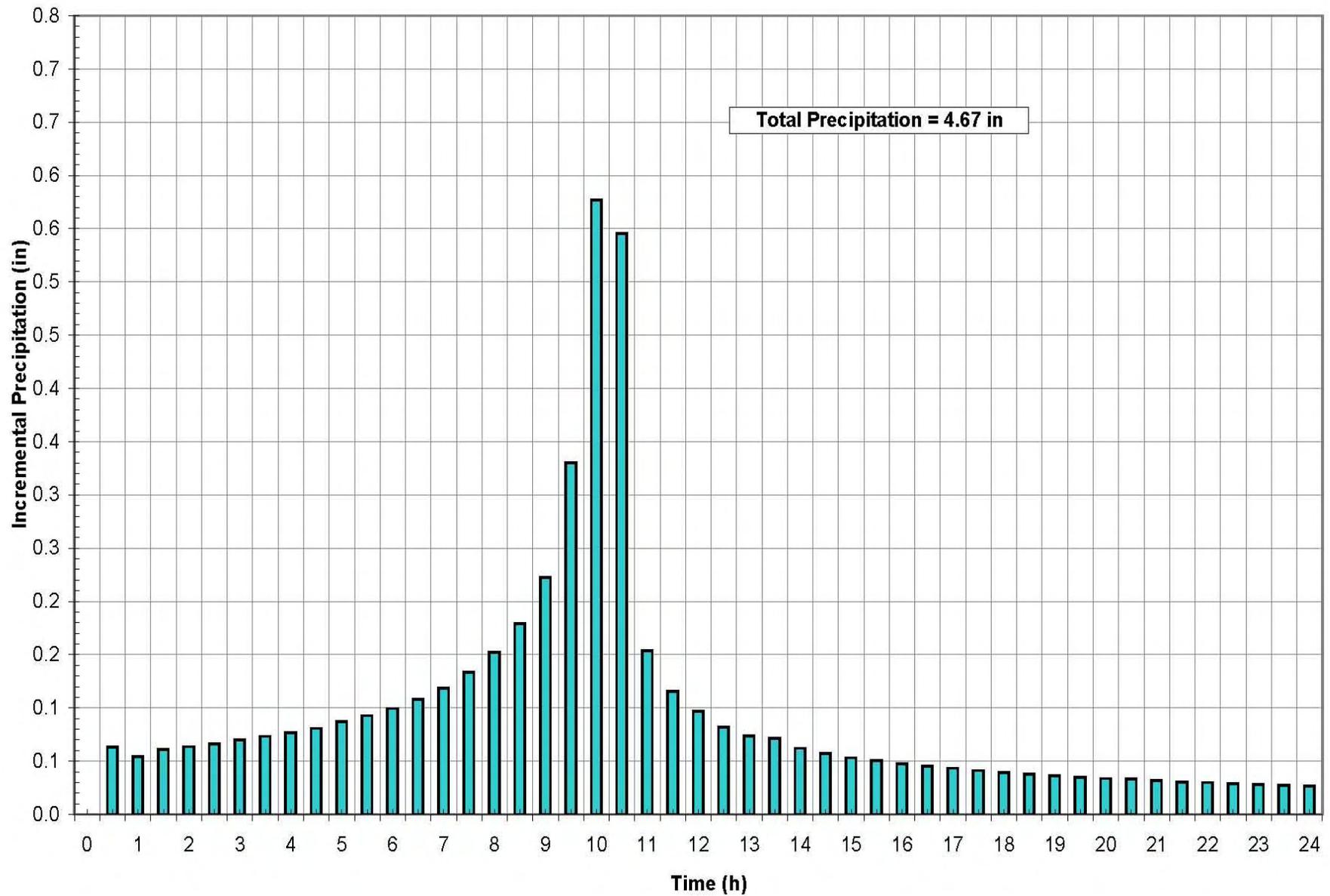


Figure 65: Hyetograph for 25-Year, 24-Hour Storm Event in Aquatic Park watershed

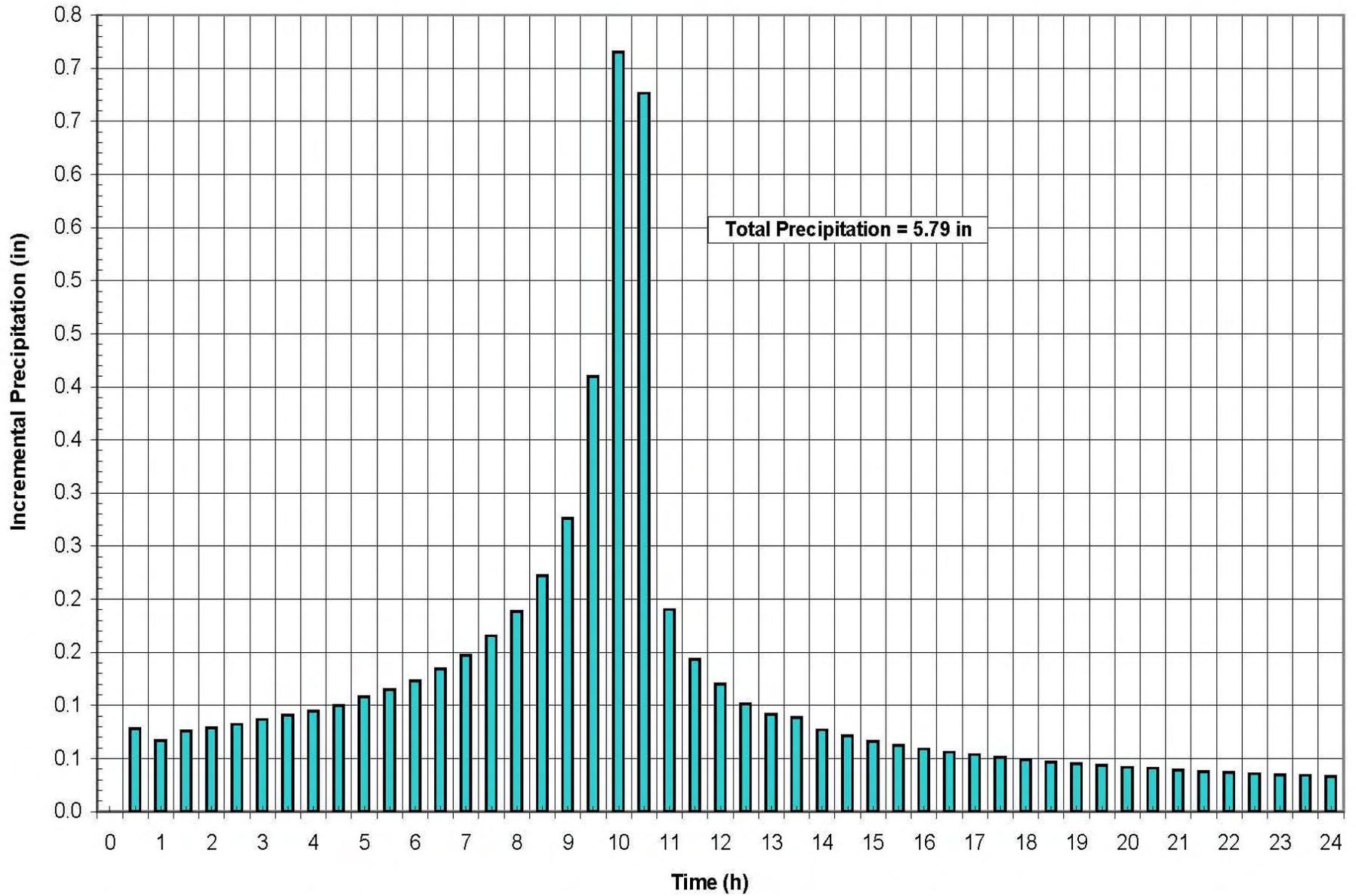


Figure 66: Hyetograph for 100-Year, 24-Hour Storm Event in Aquatic Park watershed

Table 13: Aquatic Park Watershed 24-Hour Storm Hyetographs (in)						
Hour	2-Year Event	5-Year Event	10-Year Event	15-Year Event	25-Year Event	100-Year Event
0	0.00	0.00	0.00	0.00	0.00	0.00
1	0.07	0.04	0.04	0.05	0.05	0.07
2	0.07	0.05	0.05	0.06	0.06	0.08
3	0.08	0.05	0.06	0.06	0.07	0.09
4	0.08	0.06	0.06	0.07	0.08	0.09
5	0.10	0.06	0.07	0.08	0.09	0.11
6	0.11	0.07	0.08	0.09	0.10	0.12
7	0.13	0.09	0.10	0.11	0.12	0.15
8	0.16	0.11	0.13	0.14	0.15	0.19
9	0.23	0.16	0.18	0.20	0.22	0.28
10	0.51	0.42	0.48	0.51	0.58	0.72
11	0.40	0.11	0.13	0.14	0.15	0.19
12	0.12	0.07	0.08	0.09	0.10	0.12
13	0.09	0.05	0.06	0.07	0.07	0.09
14	0.08	0.04	0.05	0.06	0.06	0.08
15	0.06	0.04	0.04	0.05	0.05	0.07
16	0.06	0.03	0.04	0.04	0.05	0.06
17	0.05	0.03	0.04	0.04	0.04	0.05
18	0.05	0.03	0.03	0.03	0.04	0.05
19	0.04	0.03	0.03	0.03	0.04	0.05
20	0.04	0.02	0.03	0.03	0.03	0.04
21	0.04	0.02	0.03	0.03	0.03	0.04
22	0.03	0.02	0.02	0.03	0.03	0.04
23	0.03	0.02	0.02	0.02	0.03	0.03
24	0.03	0.02	0.02	0.02	0.03	0.03
Peak Hour Intensity	0.33	0.42	0.48	0.51	0.58	0.72
Total Volume	2.64	3.36	3.86	4.15	4.67	5.79

Soils Analysis

One of the key components in evaluating runoff in the watershed is the soil type and texture. The data developed in the Soil Conservation Service Soil Survey for Alameda County Western Part were used to characterize the soils within the watershed (SCS 1981). Soil characteristics can have a strong impact on the volume and timing of runoff. The two factors that have the greatest influence on runoff are soil permeability and hydrologic soil group. These factors have been determined by the Natural Resource Conservation Service (NRCS, formerly the SCS) in their analysis of Alameda County soils.

Hydrologic Soil Group

Soils are classified by the NRCS into four hydrologic soil groups based on the soil's runoff potential. The four hydrologic soil groups are A, B, C and D. Soils classified as an A generally have the smallest runoff potential, whereas Group D has the greatest runoff potential. Details of this classification can be found in 'Urban Hydrology for Small Watersheds' published by the Engineering Division of the Natural Resource Conservation Service, United States Department of Agriculture, Technical Release-55. The four different soil groups are described below.

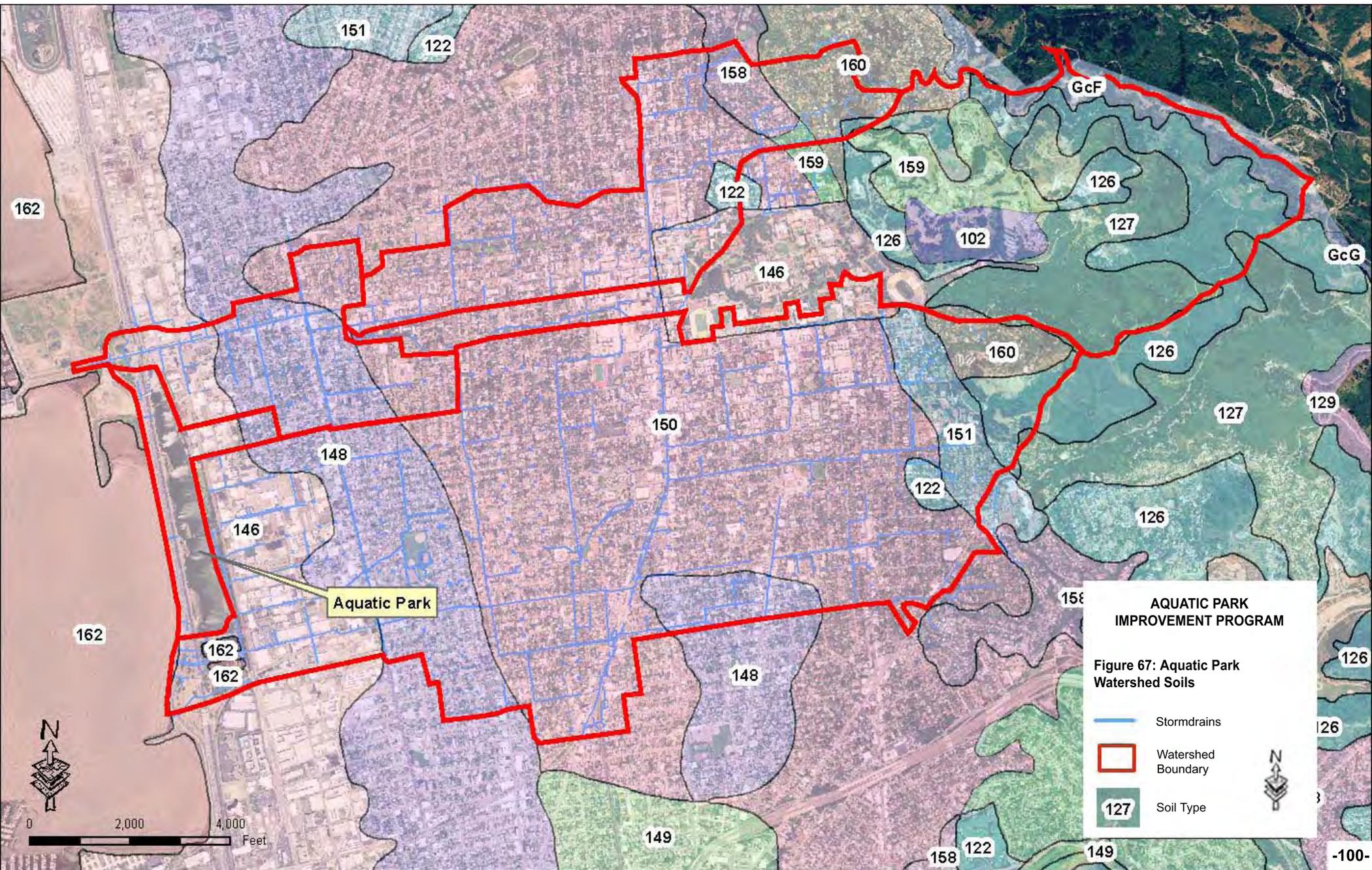
Group A: Soils consist of sand, loamy sand or sandy loam types of soils. This group has low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sands or gravels and have a high rate of water transmission.

Group B: Soils consist of silt loam or loam. This group has a moderate infiltration rate when thoroughly wetted and consists chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures.

Group C: Soils consist of sandy clay loam. This group has low infiltration rates when thoroughly wetted and consists chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine structure.

Group D: Soils consist of clay loam, silty clay loam, sandy clay, silty clay or clay. This group has the highest runoff potential. This group has very low infiltration rates when thoroughly wetted and consists chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface and shallow soils over nearly impervious material.

The type and extent of the different soils were input into an ArcView/GIS database and mapped over the study area. From the GIS database, the relative influence that the various soil types have on runoff was analyzed. Figure 67 is a plan view of the watershed showing the alignment and distribution of the different soil types. In the figure, the soil types are identified by color as well as a MUSYM Number. We identified each soil type with the infiltration rate and the hydrologic soil group. A description of the soil types and the MUSYM numbers identified on the map are provided in Table 14.



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Figure 67: Aquatic Park Watershed Soils

-  Stormdrains
-  Watershed Boundary
-  Soil Type



Table 14: Soils Characteristics			
MUSYM No	Name	Permeability (In/hr)	Hydrologic Soil Groups (A-D)
102	Altamont clay, 30 to 50 percent slopes	0.2 - 0.6	D
122	Los Osos-Millsholm complex, 9 to 30 percent slopes	0.2 - 0.6	C
126	Maymen loam, 30 to 75 percent slopes	0.6 - 2.0	D
127	Maymen-Los Gatos complex, 30 to 75 percent slopes	0.6 - 2.0	C
146	Urban land		D
148	Urban land-Clear Lake complex	0.06 - 0.2	D
150	Urban land-Tierra complex, 2 to 5 percent slopes	0.6 - 2.0	D
151	Urban land-Tierra complex, 5 to 15 percent slopes	0.6 - 2.0	D
158	Xerorthents-Los Osos complex, 30 to 50 percent slopes	0.2 - 0.6	C
159	Xerorthents-Millsholm complex, 30 to 50 percent slopes	0.6 - 2.0	D
160	Xerorthents-Millsholm complex, 50 to 75 percent slopes	0.6 - 2.0	D
162	Water	NA	W
GcF	Gilroy Clay Loam, 30 to 50 percent slopes	0.2 - 0.6	C

Sub-Basin Runoff Characteristics

The runoff characteristics of each sub-basin were computed to determine the rate and timing of stormwater runoff for any particular storm event.

Curve Number Determination

The runoff curve number (CN) is a land cover/use index that represents the effect of soils, land use, and antecedent moisture conditions on rainfall runoff. Curve numbers for this project were taken from *Hydrologic Analysis and Design* by Richard McCuen (McCuen 1989). For any particular land use, the CN can change depending on the hydrologic soil group underlying the basin.

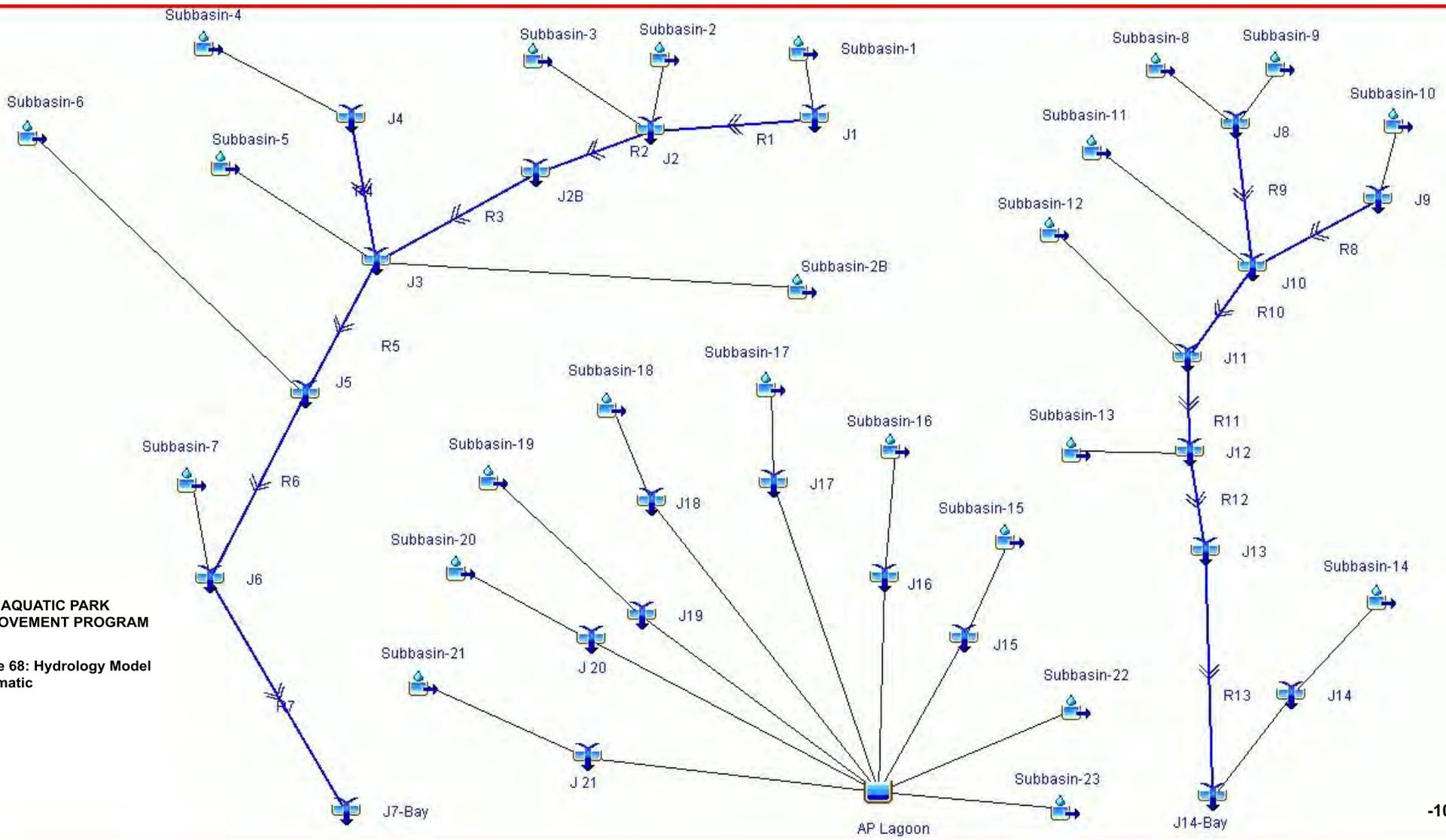
The area of each soil type within each of the sub-basins was calculated to come up with a composite hydrologic soil group for each of the sub-basins. This information together with the land use within each of the sub-basins was used to compute a composite runoff curve number for each sub-basin. A composite curve number was computed for each sub-basin based on the land use and soil types represented in the basin.

Flow Path and Lag Time

Runoff, as computed by the model, is a function of precipitation, basin topography, land use, and soil type. The basin topography dictates the slope and path that runoff will follow through the basin. The topography of the watershed was obtained from a LIDAR study provided by the City of Berkeley. The topographic information was entered into the project GIS to determine the slope and path lengths that overland flow will follow. The runoff from each of the sub-basins drains into the urban stormdrain network. The culvert sizes and invert elevations for the network were provided as a GIS layer from the City of Berkeley GIS department. Through an analysis of the flow path, slope, and stormdrain characteristics, the timing of the runoff from each watershed was determined. The runoff timing is converted into a lag time parameter which is used within the watershed model. Table 15 is a summary of the sub-basin runoff characteristics.

Stormwater Runoff Analysis

The Army Corps of Engineers Hydrologic Modeling System (HMS) was used to determine the runoff characteristics that results from precipitation over the Aquatic Park Watershed. This computer model allows for the analysis of stormwater runoff from multiple linked basins with various runoff characteristics. The basins can be connected by common channels, overland flow or stormdrain pipes. The basin network map showing the linkage and connections between the different sub-basins is shown in Figure 68.



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**Figure 68: Hydrology Model
Schematic**

Basin No.	Area (acres)	Total length (ft.)	Max Elev. (ft.)	Min Elev. (ft.)	Basin Slope	% Impervious	Curve No.	Lag Time (hr.)
1	494.5	6,797	1,719.5	560	0.1706	0	74	2.01
2	299.8	20,707	1350	204	0.0553	30	80	3.18
2B	96.4	7,580	204	62	0.0187	65	90	8.4
3	240.7	6,928	1340	240	0.1588	35	80	1.09
4	288	6,722	1060	206	0.127	65	90	3.02
5	260.4	7,630	235	62	0.0227	70	90	6.67
6	220.4	5,830	102	30	0.0123	65	90	7.37
7	130.7	4,818	40	5	0.0073	85	91	8.26
8	393.6	9,452	1190	158	0.1092	70	90	7.06
9	215.3	16,238	1190	150	0.064	70	85	14.09
10	244	5,612	400	173	0.0404	70	90	5.29
11	164.4	5,193	198	107	0.0175	70	90	4.69
12	629.8	7,747	172	69	0.0133	70	90	14.69
13	346.4	8,429	88	12	0.009	70	90	12.24
14	17.1	371	44	0	0.1186	10	79	0.10
15	37.8	1,957	22	0	0.0112	90	81	0.08
16	50	3,092	50	22	0.0091	90	81	0.14
17	18.7	1,297	36	22	0.0108	90	81	0.09
18	46.6	3,136	55	21	0.0108	90	81	0.14
19	21.9	1,377	40	21	0.0138	90	81	0.06
20	36.3	1,452	57	8	0.0337	90	81	0.11
21	20.7	921	41	3	0.041	90	81	0.10
22	112.5	n/a	0	0	n/a	n/a	n/a	n/a
23	8.6	n/a	0	0	n/a	n/a	n/a	n/a

The SCS Unit Hyetograph procedure was used within the HMS Model to calculate the runoff that would result from the design storm precipitation. This procedure involves calculating the direct runoff from a basin after fulfilling the requirements of initial abstraction and basin storage. The basic methodology was developed by the Soil Conservation Service (SCS 1972). Numerically the process is shown in Equations 1 through 3 below:

Equation 1:
$$Q = \frac{(P - I_a)^2}{(P - I_a) + S}$$

Equation 2:
$$S = \frac{25400 - (254 - CN)}{CN}$$

Equation 3:
$$I_a = 0.2 \cdot S$$

Where:

Q = direct runoff
P = precipitation
Ia = initial abstraction
S = maximum storage

Two additional key parameters in the SCS Unit Hyetograph procedure are the runoff lag time and the runoff curve number. The lag time is the time (in hours) between the center of mass of the excess rainfall to the time to the peak discharge. This lag time can be estimated by Equation 4.

Equation 4: $T_{Lag} = 0.6 \cdot T_C$

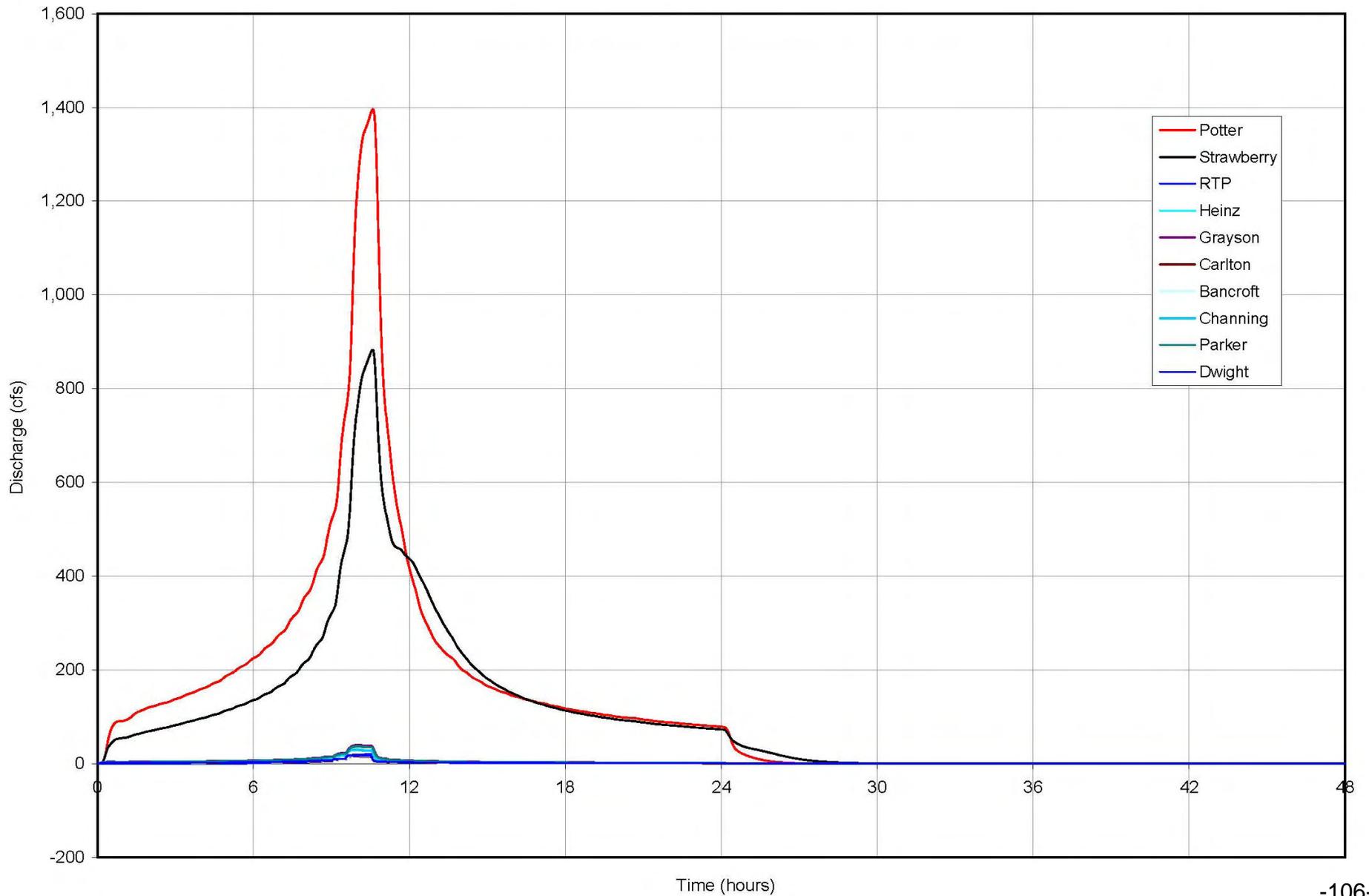
Where:

T_{Lag} = the lag time in hours
T_C = the time of concentration of runoff to the point of discharge

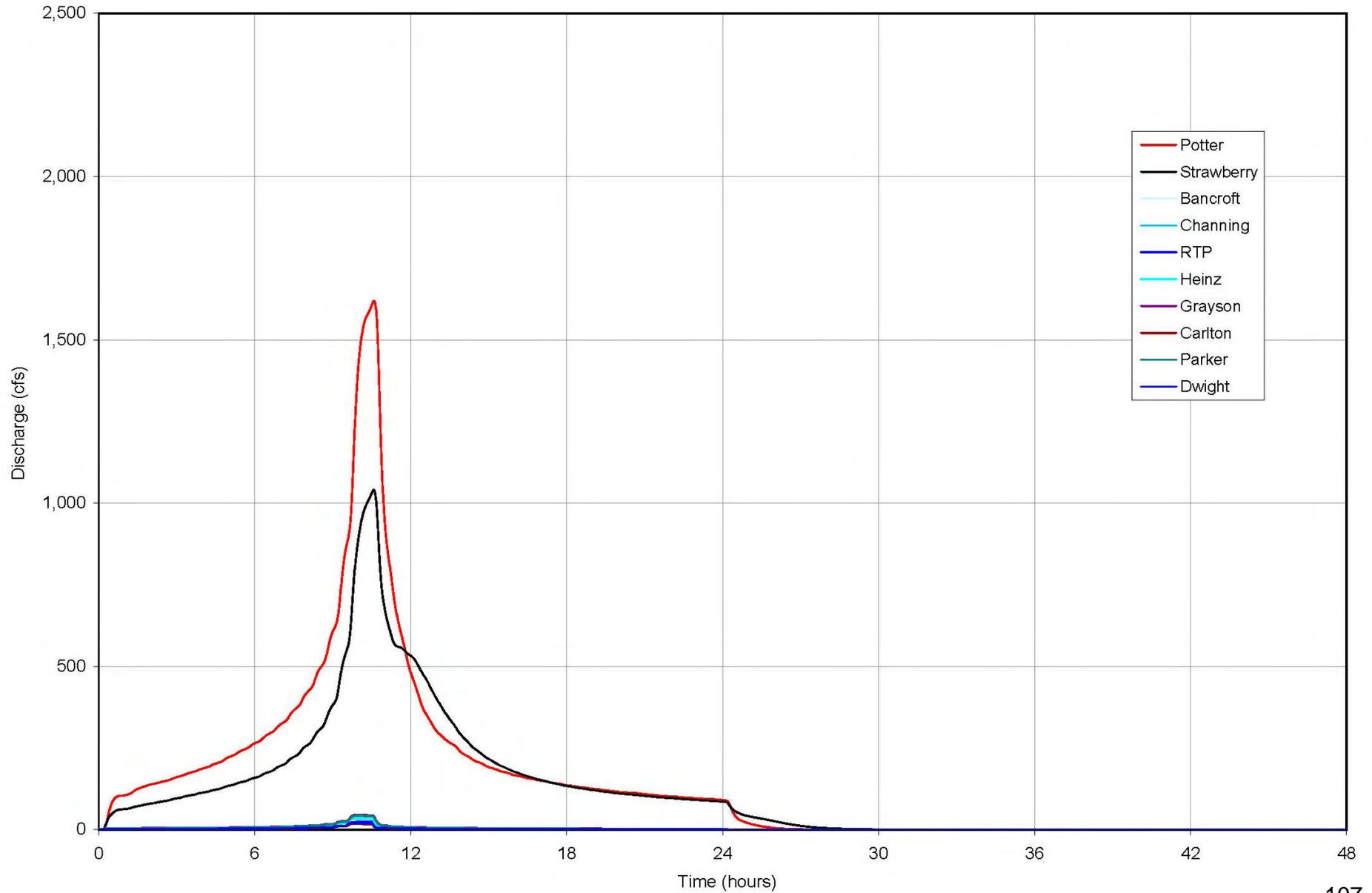
Given the indicated runoff characteristics for each basin and the applicable precipitation hyetograph, the HMS model produced runoff hydrographs for each design storm.

Table 16 is a listing of the runoff volumes that were computed for each of the sub-basins adjacent to the park. The Strawberry Stormdrain and Potter Street Stormdrain flows represent the cumulative flow and volume from the watershed upstream of the park. Appendix B provides detailed information on each of the individual watersheds within the model. Figures 69 through 72 are plots of the runoff hydrographs for the 5-, 10-, 25-, and 100-year 24-hour storm events.

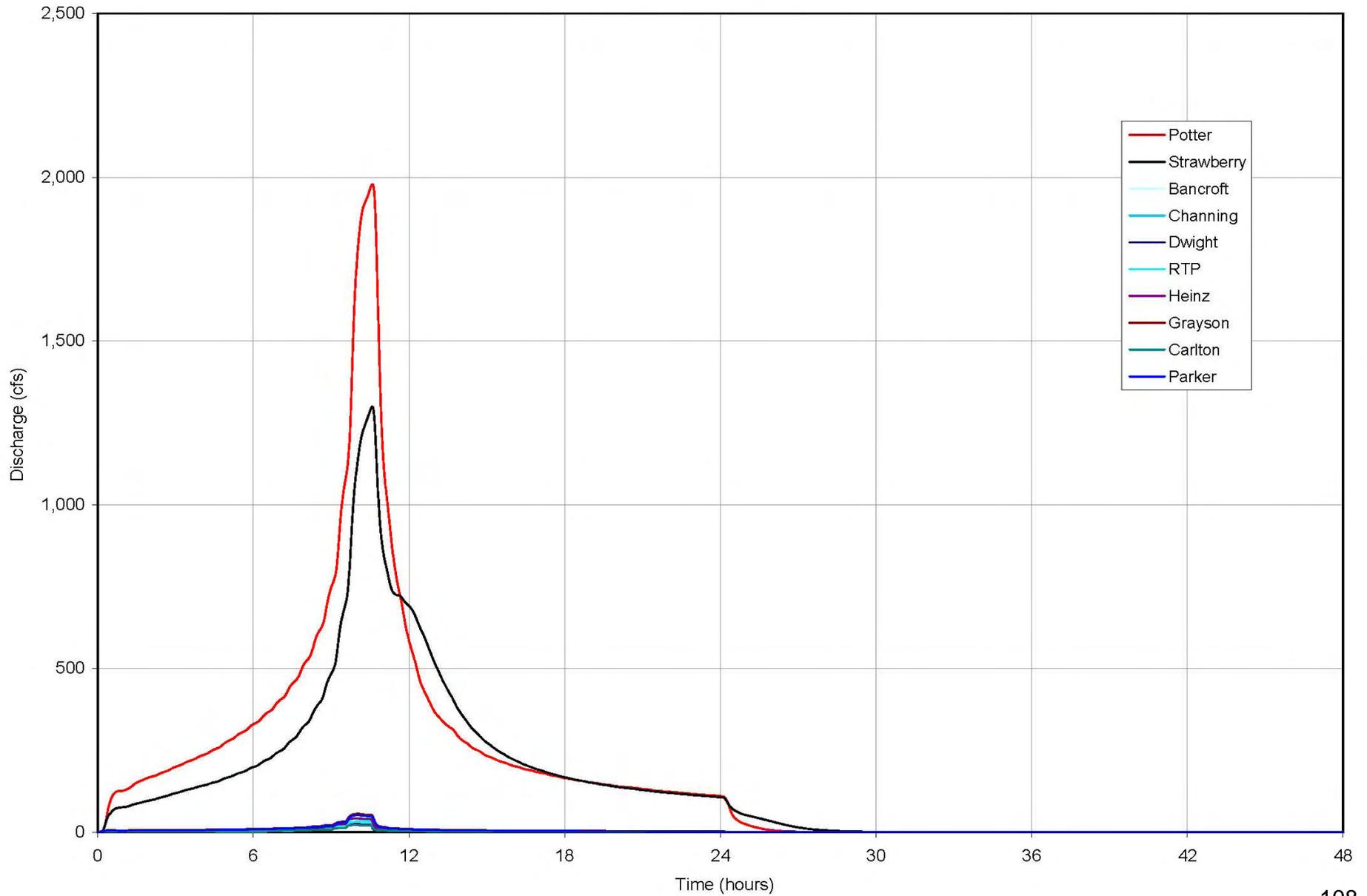
**Figure 69: Aquatic Park Watershed Hydrology Model
24-Hour, 5-Year Storm Runoff**



**Figure 70: Aquatic Park Watershed Hydrology Model
24-Hour, 10-Year Storm Runoff**



**Figure 71: Aquatic Park Watershed Hydrology Model
24-Hour, 25-Year Storm Runoff**



**Figure 72: Aquatic Park Watershed Hydrology Model
24-Hour, 100-Year Storm Runoff**

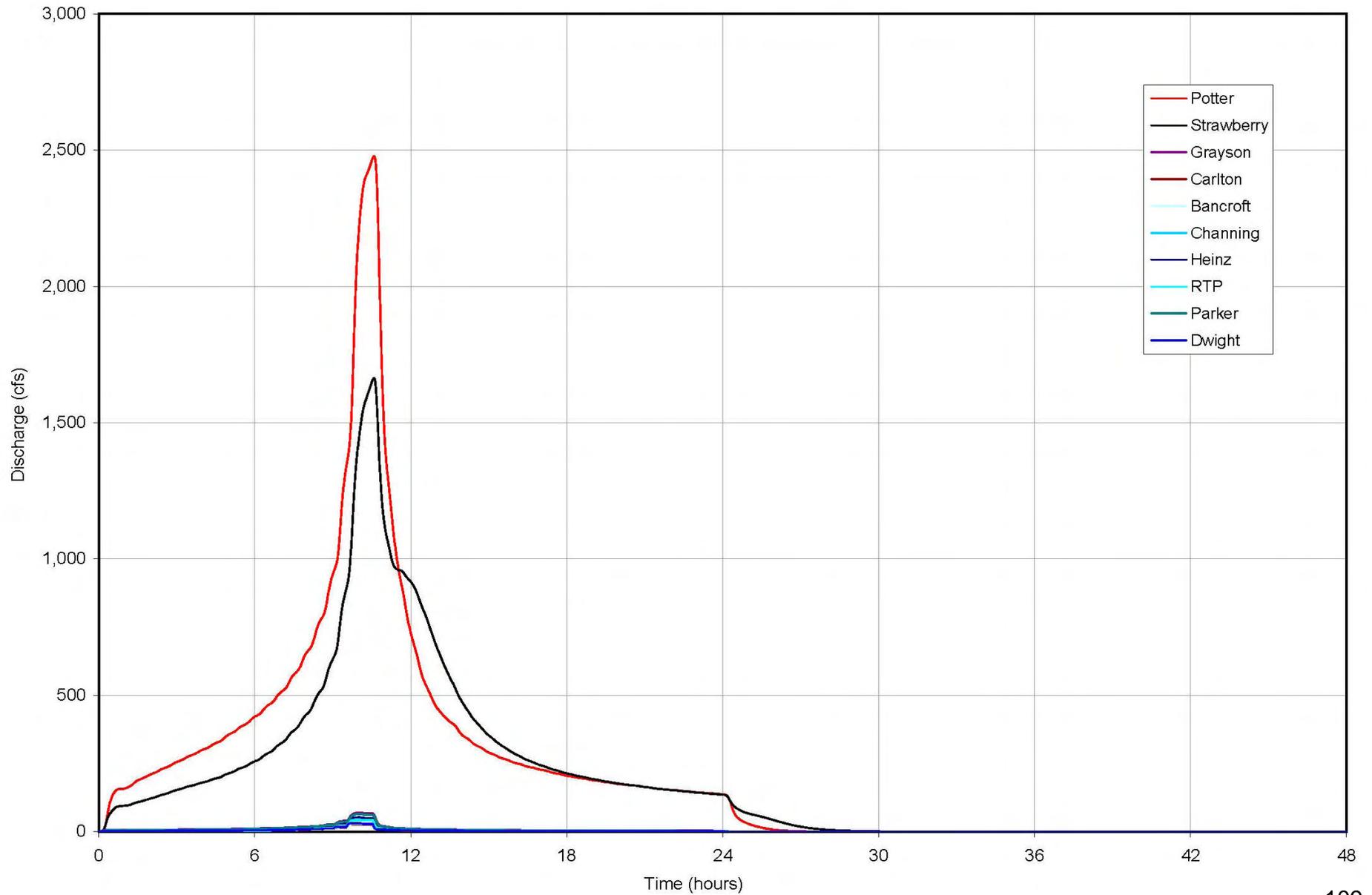


Table 16: Summary of Watershed Model Output

Basin Designation	Entering the Lagoon and the Bay		Entering Radio Tower Pond (1)	Directly Entering the Lagoon						
	Strawberry	Potter	Radio Tower Pond	Heinz	Grayson	Carlton	Parker	Dwight	Channing	Bancroft
	J 6	J 12	Sub-basin-14	Sub-basin-15	Sub-basin-16	Sub-basin-17	Sub-basin-18	Sub-basin-19	Sub-basin-20	Sub-basin-21
Basin Area (ac)	2,022.00	1,995.20	30.7	37.5	49.6	19.2	46.0	21.9	36.4	20.7
First Flush (0.3-Yr event, 1.0 inches total over 24 hours)										
Peak Flow (cfs)	211.8	357.9	1.7	8.5	11.2	4.3	10.4	5.0	8.3	4.7
Total Outflow (ac-ft)	84.3	133.5	0.5	2.9	3.8	1.5	3.5	1.7	2.8	1.6
5-Yr, 24-Hour Storm Event										
Peak Flow (cfs)	882.8	1,395.90	20.4	30.1	39.7	15.4	36.8	17.7	29.3	16.6
Total Outflow (ac-ft)	394.8	511.3	5.3	9.9	13.2	5.1	12.2	5.8	9.6	5.5
10-Yr, 24-Hour Storm Event										
Peak Flow (cfs)	1,040.10	1,618.60	25	34.8	45.9	17.8	42.5	20.4	33.8	19.2
Total Outflow (ac-ft)	469.2	593.9	6.6	11.5	15.2	5.9	14.1	6.7	11.1	6.3
25-Yr, 24-Hour Storm Event										
Peak Flow (cfs)	1,298.70	1,978.30	32.5	42.3	55.8	21.7	51.7	24.8	41.1	23.4
Total Outflow (ac-ft)	592.3	727.9	8.7	13.9	18.5	7.1	17.1	8.2	13.5	7.7
100-Yr, 24-Hour Storm Event										
Peak Flow (cfs)	1,664.20	2,477.30	43.2	52.9	69.7	27	64.6	31.0	51.3	29.2
Total Outflow (ac-ft)	768.3	915.5	11.9	17.4	23.1	8.9	21.4	10.2	16.9	9.6

(1) The Radio Tower Pond drainage does not contain any industrial, commercial, or residential land use.

Urban Stormwater

Stormwater enters the Main Lagoon from stormdrains and from direct street runoff (Figures 60 and 73). Typically, urban runoff carries higher concentrations of contaminants during the first flush, the first rainstorm of the winter season, or during storms separated by a relatively long dry period. The types of contaminants carried in urban runoff include metals such as lead, copper, zinc, nickel, and mercury; polychlorinated byphenols (PCBs); DDT and other persistent pesticides; oil and gas residues or polyaromatic hydrocarbons (PAHs); trash, organophosphate and pyrethrin pesticides and fine sediment. The contaminants that are primarily carried on clay particles in fine sediment include the metals, DDT, PCBs, and PAHs. These particles can deposit out when they reach slow-moving water in creeks, the lagoon system or San Francisco Bay.

There is no water quality monitoring data for the stormwater entering Aquatic Park. There is stormwater monitoring data for Codornices Creek in Berkeley completed by the Alameda Countywide Clean Water Program from 1989 to 1991. The Codornices Creek Watershed is similar to the watersheds which drain to Aquatic Park in many aspects. It consists primarily of impervious surfaces with a mix of residential, commercial, and light industrial uses. This program included fixed station wet weather monitoring of five storm events in December 1989. The sample station S1 was located at 6th Street. Sediment chemistry was also completed in the 1989-1990 season consisting of eight grab samples taken during a dry weather period. Analysis was completed for conventional metal and organics along with basic water quality parameters. The monitoring found a number of persistent pollutants in Codornices Creek stormwater, including: zinc, copper, lead, nickel, mercury, PAHs, organochloride pesticides, and tetrachloroethene. The majority of these pollutants are transported on suspended sediment particles in the stormwater.

After a first flush storm washes contaminants from roofs, streets and gardens, most of the subsequent runoff will have much lower concentrations of contaminants. If there is a long dry period, the next storm can be a second first flush event. The two large stormdrains at Aquatic Park currently operate differently in terms of first flush inputs to the lagoons. The Potter Street Stormdrain is directly connected to the Model Yacht Basin by two 24 inch culverts set about 3 ft. above the bottom of the stormdrain pipe (Figure 18). When flow levels reach these connections, the first flush stormwater enters the Model Yacht Basin. An inflowing tide can also raise water levels in the pipe and result in stormwater inflows into the Model Yacht Basin. In the Strawberry Stormdrain there is an overflow pipe which only carries stormwater to the Main Lagoon when flows reach about 5.5 ft. in the pipe (Figure 18).

The lagoons also receive direct street runoff from Addison and Bancroft streets as well as the roads and parking lots in and near the park (Figure 74). During intense rainstorms some runoff from I-80 may also enter the lagoons.



Figure 73: Urban Stormwater Runoff in Lagoon Area



Addison Street



Bancroft Street

Figure 74: Urban stormwater runoff goes directly into the Main Lagoon.



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Figure 75: Aquatic Park
Stormdrain Pipe Network

— Stormdrain



Based on City of Berkeley GIS

The “local” watershed stormdrains at Channing, Dwight, Parker, Carleton, Grayson, and Heinz streets will carry first flush flow either directly into the Main Lagoon, or via a connector pipe, to the Potter Street Stormdrain and either out to the Bay or into the Model Yacht Basin, depending on tide and flow conditions (Figure 75). The Heinz, Grayson, Carleton, and Parker Street stormdrains each have a flow separator which allows low- and medium-level storm flows to pass through an oil/water separator and trash collector before being discharged to the Main Lagoon (Figures 76, 77, and 78). As part of this system which was installed in the 1970s, a transite pipe moves high flows from these four stormdrains directly into the Potter Street Stormdrain. If high tide is occurring in the Potter Street Stormdrain, the transite pipe can fill up with tide water and back up stormwater into the Main Lagoon. The trash collectors and oil/water separators require maintenance after every major storm to remove accumulated material. Field inspection of these facilities in 2007 showed little to no maintenance and that two of the four facilities were completely clogged.

Analysis of the residence time for stormwater from a large storm event was completed. The analysis found that under existing conditions stormwater from a 100-year event that enters the Main Lagoon is retained for up to 48 days as the water circulation volumes are very low. This long residence time may allow sediment, the primary transport mechanism for persistent contaminants, to deposit and remain in the lagoon with contaminants potentially becoming bioavailable. Increasing the circulation volume will allow the stormwater that comes into the Main Lagoon to move out quickly and avoid retaining sediment which may carry contaminants.



Flow Separator (indicated by red arrow) along Park Side of Railroad Tracks

Figure 76: Stormdrain from Local Watershed with Outlet into Main Lagoon

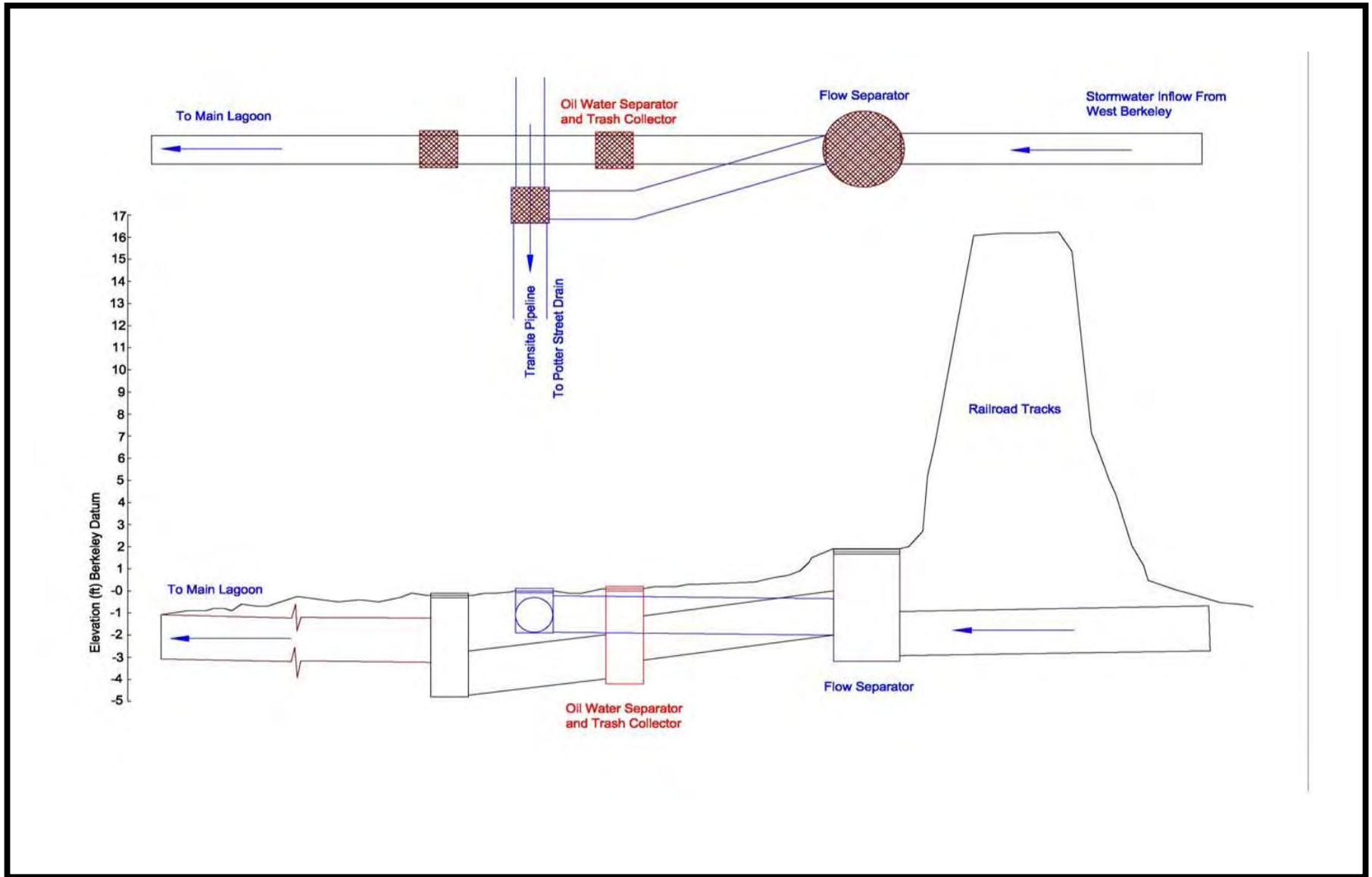


Figure 77: Schematic of flow separator with oil/water separator and trash collector. The facilities occur on the in-park portions of the Heinz, Carleton, Grayson, and Parker stormdrains.



**Above: Clean Flow Separator
Below: Clogged Flow Separator**



**Above: Clogged Inlet Pipe to Flow Separator
Below: Clogged Trash Collector**



Figure 78: Inside of Flow Separators

Watershed Hydrology and Urban Stormwater-Constraints

1. Aquatic Park is one of the lowest points in Berkeley and where stormwater flows in large floods.
2. Stormwater flows into the Main Lagoon from the two major stormdrains under certain conditions: in Strawberry Stormdrain when flows overtop a weir and from the Potter St Stormdrain.
3. Stormwater can flow into the Main Lagoon from localized stormdrains along the eastern edge of the park.
4. Stormwater flows directly into the lagoon from several adjacent streets.
5. Summer urban flows provide additional nutrients and likely increase algal blooms and subsequent low dissolved oxygen levels in the Main Lagoon.
6. Urban stormwater varies in the concentrations of contaminants over the winter season. The first flush of runoff in the fall/winter typically carries the highest concentration of contaminants.
7. There is limited water quality monitoring data for the lagoons and for stormwater in the Berkeley area.
8. There is limited area in the park to treat stormwater.
9. Regulations may restrict directing additional stormwater to freshwater wetlands for bio-treatment.
10. Maintenance is a requirement for stormwater treatment facilities.

Watershed Hydrology and Urban Stormwater-Opportunities

In the Park:

1. Control structures can be installed at Potter Street Stormdrain and Strawberry Stormdrain to limit stormwater inflows into the lagoons.
2. A bioswale could be installed along the road/lawn on the northern end of the park to treat stormwater flowing directly from streets into the park.
3. Increased water circulation in the lagoon system will remove stormwater at a much faster rate.

Outside the Park:

1. There are numerous locations in the urban area which could have biofiltration facilities installed on streets, parking lots and other locations.
2. The eastern edge of the railroad/western ends of streets could accommodate a series of large vortex filters to cleanse stormwater before entering the park.
3. The Aquatic Park area could be used as a regional demonstration project for integrated ultra urban stormwater treatment, habitat restoration, monitoring and adaptive management.

Freshwater Wetlands

There are a series of small freshwater wetlands on the eastern border of the park adjacent to the railroad berm. These freshwater wetlands are located on the edge of the original tidal area (Figure 2).

The freshwater wetlands were delineated and mapped in the field by a wetland specialist based upon saturated soil conditions, hydrophytic plant species and hydrology (Figure 79). Plant species such as cattails and tules are considered wetland indicators as they require saturated soils. Willows, due to their deep-rooting ability, are not considered a wetland indicator plant. The wetlands total 1.1 acres. Each wetland was given a number starting on the north end of the park. There are six separate wetlands. Several have a small creeklet draining into the Main Lagoon. The freshwater wetlands have mostly saturated muddy soils with wetland plants. Figures 80-90 illustrate some of the features of the freshwater wetlands.

The dry season source of the water for the freshwater wetlands is not known. In freshwater wetland FW-1, water bubbles up next to the railroad berm and flows south and into the Main Lagoon. The other wetlands may also receive groundwater. Leaking pipes are not believed to be the water source. The stormdrain at Dwight Way releases flow into the wetland directly. The freshwater wetland at the Radio Tower Pond (FW-6) is a seep in the bank of the lagoon with a dense willow grove. Herons and egrets roost in this willow grove.

The native plant species in the freshwater wetlands include cattails (*Typha latifolia*), tules (*Schoenoplectus acutus*, formerly *Scirpus acutus*), California bulrushes (*Schoenoplectus californicus*, formerly *Scirpus californicus*), willows (*Salix laevigata*), planted white alder (*Alnus rhombifolia*), watercress (*Rorippa nasturtium-aquaticum*), and non-native weeping willow (*Salix babylonica*). Freshwater wetland plants have different tolerances for inundation. Both cattails and tules grow in areas with shallow water or continuously wet soil. Alders and willows grow in periodically wet areas. Watercress grows in areas with standing water.

Most of the wetlands at Aquatic Park have dense cattails or tules due to the soggy soil conditions. Grass areas next to the freshwater wetlands are also often saturated. Freshwater wetland areas are relatively rare in the East Bay and can have high habitat values for a variety of birds. However, there are many features of Aquatic Park's freshwater wetlands which



**AQUATIC PARK
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Figure 79: Freshwater
Wetlands

 Freshwater Wetlands



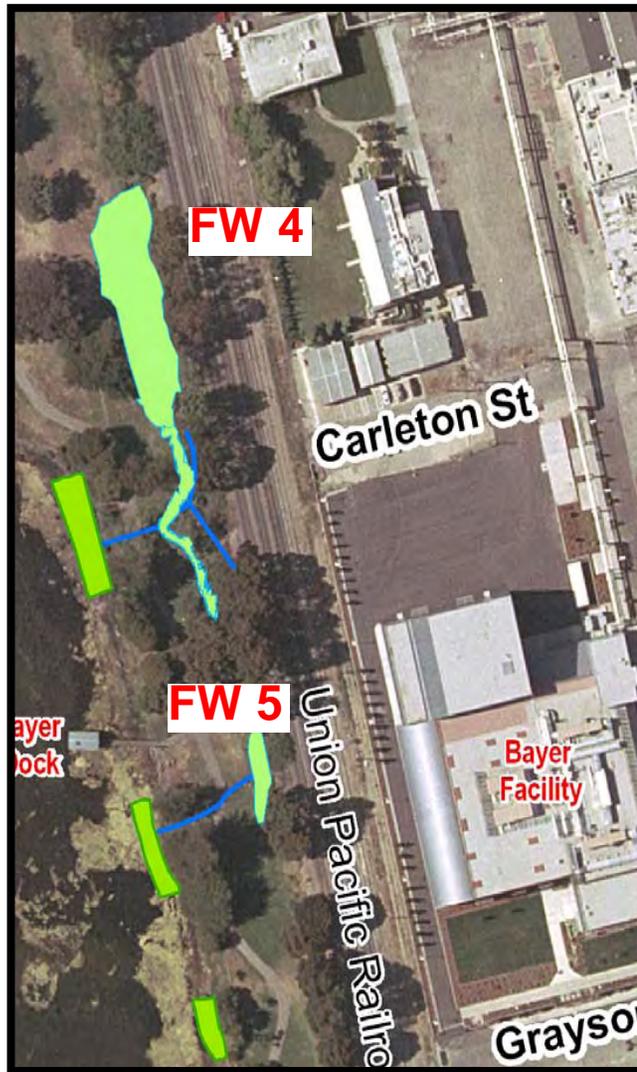


Figure 80: There are six small freshwater wetlands on the east side of the park, covering a total of 1.1 acres.

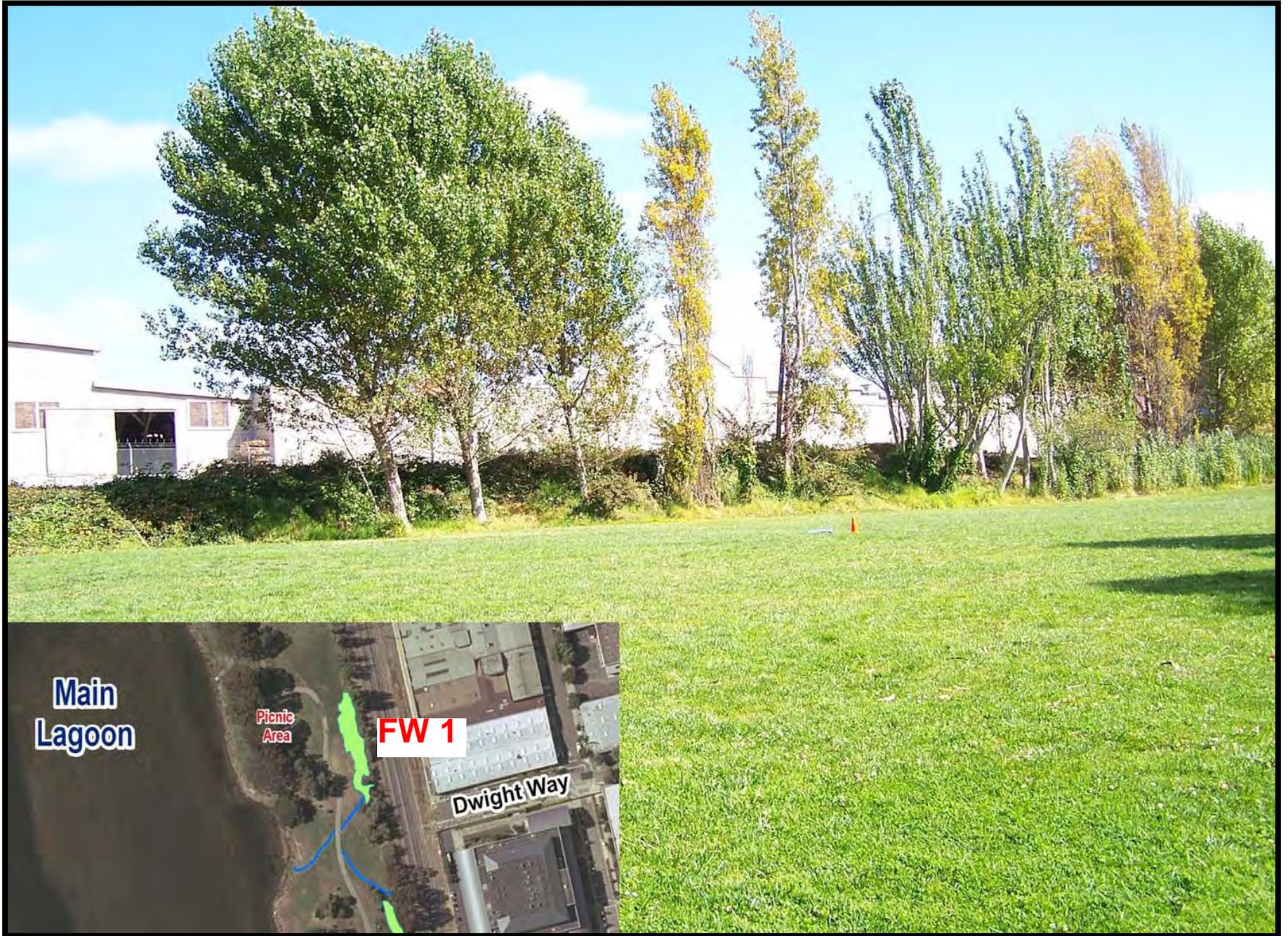


Figure 81: Freshwater Wetland #1 has a narrow strip of non-native poplars and native cattails.



Figure 82: Water bubbles out at Freshwater Wetland #1 and runs over the turf area. Cattails grow in the saturated soils.

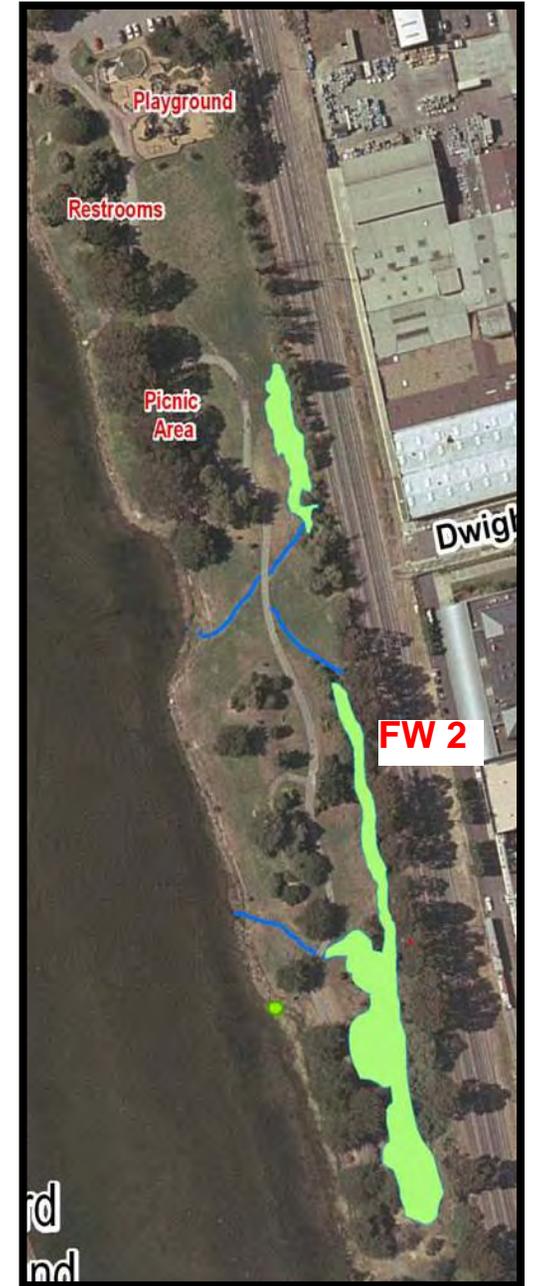


Figure 83: Freshwater Wetland #2

Figure 84: Freshwater Wetland #3





of

Figure 85: Recreational trails directly border many of the freshwater wetlands, causing frequent disturbance and reducing wildlife habitat values.





Figure 86: Three of the small creeks or creeklets which drain from the freshwater wetlands to the Main Lagoon



Figure 87: Freshwater Wetland #4 has some dense willow areas used by migrating songbirds.





Figure 88: Freshwater Wetlands #4 and #5



Figure 89: Freshwater Wetland #6



Figure 90: Freshwater wetlands with a mixture of open water and vegetation types provide the best habitat for nesting ducks and other birds. Limited disturbance by humans and dogs is also needed.

greatly reduce their value as wildlife habitat. Wetlands FW-1 through FW-5 are immediately adjacent to active recreation areas where disc golf, hiking, walking, dog walking, and other sports are played. In a two hour period, our biologists counted ten separate incidents of humans or dogs entering the wetlands. There is a homeless encampment in one wetland. Since there is no buffer or deterrent to this type of disturbance, wildlife use is limited. Additionally, most of these wetlands are small dense patches of tules or cattails with various invasive plants. They lack the patchwork of open water and vegetation favored by ducks for nesting and feeding (Figure 90). Revising the wetlands to provide deeper water would create vegetative diversity and improved habitat for ducks and songbirds.

The freshwater wetlands also have a significant infestation of invasive non-native plants dominated by Himalayan blackberry and English ivy, and include small areas of broom, pampas grass, and giant reed (Figures 54 A and B).

The creeklets which drain the wetlands to the Main Lagoon are lined with grass. Some of the creeklets flow into culverts, then into the Main Lagoon.

Freshwater Wetlands-Constraints

1. The freshwater wetlands have shallow ponding and saturated soil encouraging the growth of dense cattails with little vegetative diversity or open water. Water flows are likely from groundwater seeps and aesthetics of wetlands are low. Water flows saturate lawn areas.
2. Water from the marshes flows through narrow channels into the lagoon. Changing the narrow deep channels to wide shallow channels would create more cattails and muddy areas.
3. Invasive ivy is killing some of the willow trees and other invasive plants also occur.
4. Areas next to freshwater wetlands are used for active recreation which involves people and unleashed dogs walking through the marshes, creating a very high level of disturbance and diminishing value for wildlife habitat.
5. There are homeless encampments in the wetlands which reduce habitat values.
6. Wetlands are not large enough, even if doubled in area, to adequately filter and treat winter stormwater from the stormdrains in the park. Wetlands could possibly filter and treat summer nuisance flows.
7. Regulations may restrict increasing urban runoff into the wetlands and changing their form.

8. It may be difficult to find funding for changes and improvements to the freshwater wetlands due to the negative effects of the high disturbance levels on habitat values and the small area of the marshes set in a recreational area.

Freshwater Wetlands-Opportunities

1. Wetlands could be deepened into ponds so that cattails will not dominate marshes allowing for greater water flow, vegetative diversity, aesthetic appeal, creation of water-isolated, less disturbed habitat areas and less maintenance.
2. Habitat for a wider diversity of bird species could be created if vegetation is changed and disturbance is significantly reduced.
3. Freshwater wetlands could be altered and expanded to filter summer nuisance flows and improve the quality of water entering the Main Lagoon. Currently summer flows either directly flow into the Main Lagoon or into the transit pipe and into Potter Street Stormdrain.
4. Several willow groves in the wetland area support songbirds and could be enhanced.
5. Removal of invasive plants should be an initial step in wetland improvements.
6. The disc golf course would need to be revised and integrated into any changes in the wetlands to reduce incursions and disturbance.
7. Signs, low fencing, and potentially some type of enforcement may be needed to keep dogs and people out of the freshwater wetlands.
8. Changes to the wetlands could reduce saturation of the lawn areas and trails and maintenance needs.

IV. RESTORATION ANALYSIS

Tidal System

Approach

One of the goals of the APIP is to improve water quality in the lagoon system. Some of the existing water quality problems result directly from elevated temperatures and nutrients in the lagoon, especially during the late summer and spring. Improved circulation would allow for a greater exchange of the lagoon water with the cleaner and cooler water of San Francisco Bay.

Initial evaluation of the system showed that the limited size and number of connections between the lagoon and the bay inhibit water circulation. Increasing the size of these connections will result in a direct increase in their capacity to allow water into and out of the lagoon.

A hydrodynamic model was developed to evaluate the existing pipe network and circulation characteristics of the lagoon system. The model selected for this analysis was the Environmental Protection Agency's Surface Water Management Model (SWMM) (EPA 2008). This model is a fully dynamic unsteady flow model capable of evaluating the interconnected system of pipes and ponds under unsteady tidal conditions.

SWMM Model Description

SWMM was first developed in 1971, and has been upgraded numerous times since then. It continues to be widely used for planning, analysis and project design related to stormwater runoff, combined sewers, sanitary sewers, and other drainage systems in urban areas, with many applications in non-urban areas as well.

SWMM also contains a flexible set of hydraulic modeling capabilities used to route runoff and external inflows through a drainage system network of pipes, channels, storage/treatment units and diversion structures. These include the ability to:

- evaluate drainage networks of unlimited size
- use a wide variety of standard closed and open conduit shapes as well as natural channels
- model special elements such as storage/treatment units, flow dividers, pumps, weirs, and orifices
- apply external flows and water quality inputs from surface runoff, groundwater interflow, rainfall-dependent infiltration/inflow, dry weather sanitary flow, and user-defined inflows
- utilize either kinematic wave or full dynamic wave flow routing methods
- model various flow regimes, such as backwater, surcharging, reverse flow, and surface ponding
- apply user-defined dynamic control rules to simulate the operation of pumps, orifice openings, and weir crest levels

The SWMM model uses a set of differential equations to represent gradually varied one-dimensional unsteady flow within the pipe and lagoon system. These shallow water equations, also known as the St. Venant equation, combine the equations for momentum and continuity within each pipe. These equations are basically represented by the differential equation shown below.

$$\frac{\partial Q}{\partial t} = gAS_f - 2V \frac{\partial A}{\partial t} - V^2 \frac{\partial A}{\partial x} + gA \frac{\partial H}{\partial x} = 0$$

Where:

Q=discharge along the conduit,
V = velocity in the conduit,
A = cross-sectional area of the flow,
H = hydraulic head, and
S_f= friction slope

Model Input

To evaluate the circulation system between the lagoons and the bay, information on the existing pipe network was obtained from the City of Berkeley. This information was entered into the project GIS and subsequently exported to the SWMM model. The city data included pipe shape and diameter, invert elevations, lengths, and pipe material types. Figure 58 shows the storm drainage system that connects the lagoon with the bay immediately to the west. The storm drainage system was converted into a series of pipes and nodes, with a pipe representing a drain line or tide tube and a node representing a manhole, pipe junction, or lagoon. This modeled version of the pipe network is shown in Figure 23. A description of the main pipe connections in the system was provided in the Tidal Connections section (pp. 5-8).

In 2006 and 2007 HSI implemented a QA/QC program to verify the pipe network information that was supplied by the City of Berkeley. The culverts in the immediate vicinity of the lagoons were surveyed, and when possible, the pipes were entered through manholes for visual verification of the existing data. The data for the pipes and nodes used in the model are provided in Appendix C.

To evaluate the proposed changes to the lagoon system, a SWMM model was developed to represent the existing condition. All of the existing tide tubes and storm drains pertinent to the circulation system were simulated within the model. The lagoon stage and storage data, collected in the bathymetric survey, were entered into the model to represent the storage in the lagoon. The model was then calibrated to one-month of measured lagoon and San Francisco Bay tide data that was collected in the monitoring program. The details of this monitoring program are described in the Tidal Hydrology section of this report.

The data used in the calibration phase was collected between January 1, 2007 and January 31, 2007. The primary calibration parameters were pipe roughness and entrance/exit losses. This calibrated model was used as the baseline condition to which all of the proposed modifications

were compared. It was felt that a one-month simulation period would provide for a variety of tidal variations without creating excessively long run times. The average execution time for the model was approximately 45 minutes.

The calibrated model was subsequently altered with proposed modifications to the circulation system. This allowed us to evaluate each change to the system in isolation or as a group of changes. Once a proposed scenario was developed, the modified model was run through the same one-month period that was used in the calibration phase. This allowed for a direct comparison of the water levels and flow rates within the system between the existing condition and the proposed modification. The bay tidal cycle used in the analysis is shown in Figure 19.

The model was set up to evaluate the movement of water through the pipe system and the three lagoons. The volume of each lagoon was analyzed from the bathymetric survey conducted in 2002. Plots of the stage-storage and stage-area relationship for each lagoon are shown in Figures 7 and 8. The bay tide elevation was supplied as a boundary condition at each of the pipes that discharges to the bay. As the tide level rises, gravity forces water through the pipe system and into the lagoons. As the tide level falls, water will drain from the lagoon and back out into the bay.

Since the model is unsteady (it can evaluate changes in the system with respect to time), a 15-second time step was selected to evaluate the propagation of the tidal wave through the system. A small time step is required due to the complexity of the pipe and lagoon system. Output from the model simulation was saved every 10 minutes.

The model was run for the existing condition to determine the volume of water that is presently flowing into and out of the lagoons. A description of the existing condition is provided on pages 8-10.

Model Scenarios

Various project components were evaluated in an effort to determine the most effective modifications that could be made to the connections with the bay. One or all of the following four components were analyzed.

1. Increasing the capacity of the connection at the Strawberry Stormdrain. Increasing the capacity of the connection will allow more water to enter and leave the lagoon during a tidal cycle. Under the existing condition, the Strawberry Stormdrain does not let any water into the lagoon. This is due to a weir located between the Strawberry Stormdrain and the pipe leading to the lagoon. The weir only allows water into the Main Lagoon during high flow periods.
2. Increasing the capacity of the Potter St. Stormdrain connection. Increasing the capacity of this connection will allow more water to enter and leave the lagoon during a tidal cycle. This connection already allows water in and out of the lagoon during a tidal cycle. It also allows water into the lagoon during periods of high stormwater runoff.

3. Improving the connection between the Model Yacht Basin and the Main Lagoon. Presently the two 24 inch culverts allow very little water to be exchanged between the Model Yacht Basin and the Main Lagoon.
4. Opening up the Northern Tide Tube. The bay side outlet of this tide tube is presently buried. Assuming that it can be found and re-connected with the bay, the effects of this connection were evaluated.

The above project components were modeled separately and in combination under three separate scenarios. The first scenario was to only allow the water to flow through the lagoon system in a south to north direction. This was accomplished through the use of flap gates. The second scenario only allowed the water to flow through the lagoon system in a north to south direction. The third scenario allowed the water to enter and exit the lagoon in any direction based on the hydraulics of the connection. The objective of the one-way scenarios was to force a positive circulation through the system. A one-way flow pattern would minimize stagnant areas in the lagoons and force a positive flushing action. For each of the three scenarios the four components described above were analyzed.

The effectiveness of each scenario was evaluated on the net flux of water into and out of the lagoon in an average tidal cycle. This provided a basis of comparison that was directly related to the objective of increasing the amount of tidal circulation through the lagoon system.

In modifying the connections, an attempt was made to make each of the connections as reasonably large as possible, given the existing connections. This would provide for the maximum inflow and outflow that the connection could deliver. The connection sizes were also limited to those that could be constructed reasonably, providing for an analysis of the maximum potential for any connection to improve inflow into the lagoon system.

A constraint on the connection sizing came from the location and elevation of structures on the shoreline of the lagoons. The highest allowable lagoon tide elevation was based on the elevation of the lowest structure that was adjacent to each lagoon. Table 17 provides the elevation of the lowest structure and the highest allowable water surface elevation. The highest allowable water surface elevation was assumed to be 1 foot below the lowest building elevation. That would provide for 1 foot of freeboard above the mean high tide level.

Water Body	Lowest Building Elevation (ft.)	Recommended Minimum Building Buffer (ft.)	Maximum Water Level (ft.)	Existing High Water Level (ft.)	Allowable Rise (ft.)
Radio Tower Pond	-1.5	1	-2.5	-2	-0.5
Model Yacht Basin	2	1	1	-0.2	0.8
Main Lagoon	0.5	1	-0.5	-2.4	1.9
All elevations are in feet, Berkeley Datum					

No attempt was made to enlarge the pipes that pass under Interstate 80, due to the extreme cost involved in enlarging existing pipes, or installing new pipes. With this restriction, all alternatives involved modification to the connections to take advantage of as much of the existing capacity of each pipe as possible.

Model Results

Each of the components described in the previous section were evaluated within the three scenarios. An additional scenario was added, which was an analysis of several different components individually to determine their relative importance to circulation in the lagoons. The results of each model scenario are presented in Tables 18 through 22.

The calibrated model was run for a one month period to determine the volume of water that circulates through the lagoon system. The mean volume of water that moved through the system was used to compare each of the alternatives. The volume of water exchanged for an average tidal cycle for the existing condition and each alternative is shown in Tables 18 through 21.

Table 18: Aquatic Park Circulation Modeling - Scenario 1 Component Evaluation
Comparison of Average Volume Exchange Per Tidal Cycle for Various Improvement Scenarios
Volumes are in (ac-ft)

Model No.	Existing Condition	Element Evaluation		
	Model 1a	Model 1b	Model 1c	Model 1e
Connection Location and Flow Direction	Existing Condition	12 inch Drain From Strawberry Creek (in only)	Northern Tide Tube (out only)	Enlarged Opening Between ML and MYB
Inflow through Potter Street	12.1	11.8	12.4	12.5
Outflow to Potter Street	9.4	10.0	9.3	3.1
Inflow from Model Yacht Basin to Main Lagoon	4.0	1.9	3.1	11.2
Outflow from Main Lagoon to Model Yacht Basin	0.0	-0.1	0.0	2.3
Inflow from Bay through 5 Main Culverts	10.0	8.6	11.0	7.5
Outflow to Bay through 5 Main Culverts	12.8	15.5	10.8	17.2
Inflow through Northern Tide Tube	0.0	0.0	0.0	0.0
Outflow through Northern Tide Tube	0.0	0.0	3.6	0.0
Inflow through Strawberry 12 inch Low Flow Drain Connection	0.0	5.9	0.0	0.0
Inflow through Strawberry 12 inch Low Flow Drain Connection	0.0	0.0	0.0	0.0
Inflow through the Strawberry Drain Weir Connection	0.0	0.0	0.0	0.0
Outflow through the Strawberry Drain Weir Connection	0.0	0.0	0.0	0.0
Total New Water In	22.2	26.3	23.4	20.0
Total Water Out	22.2	25.5	23.7	20.3
Tidal Range:				
Model Yacht Basin High	-0.5	-0.5	-0.5	-1.9
Model Yacht Basin Low	-2.7	-2.7	-2.8	-2.2
Maximum Tidal Range	2.3	2.2	2.3	0.4
Main Lagoon High	-2.3	-1.9	-2.3	-1.9
Main Lagoon Low	-2.8	-2.6	-3.0	-2.2
Maximum Tidal Range	0.5	0.7	0.7	0.4
Mean Water Level	-2.5	-2.3	-2.7	-2.1

**Table 19: Aquatic Park Circulation Modeling - Scenario 2 One Way Flow North To South
Comparison of Average Volume Exchange Per Tidal Cycle for Various Improvement Scenarios
Volumes are in (ac-ft)**

Model No.	Model 2a	Model 2b	Model 2c
Connection Location and Flow Direction	In through Improved Potter Street Connection. Out through 5 Main Tide Tubes.	In through Improved Potter Street Connection. Out through 5 Main Tide Tubes and Improved Strawberry Drain.	In through Improved Potter Street Connection. Out through 5 Main Tide Tubes, Improved Strawberry Drain, and Northern Tide Tube.
Inflow through Potter Street	43.0	51.7	58.0
Outflow to Potter Street	0.0	0.0	0.0
Inflow from Model Yacht Basin to Main Lagoon	43.2	51.8	57.9
Outflow from Main Lagoon to Model Yacht Basin	0.2	0.1	0.1
Inflow from Bay through 5 Main Culverts	0.0	0.0	0.0
Outflow to Bay through 5 Main Culverts	40.5	33.8	30.4
Inflow through Northern Tide Tube	0.0	0.0	0.0
Outflow through Northern Tide Tube	0.0	0.0	9.4
Inflow through Strawberry 12 inch Low Flow Drain Connection	0.0	0.0	0.0
Inflow through Strawberry 12 inch Low Flow Drain Connection	0.0	0.0	0.0
Inflow through the Strawberry Drain Weir Connection	0.0	0.1	0.0
Outflow through the Strawberry Drain Weir Connection	0.0	19.2	14.1
Total New Water In	43.0	51.8	58.0
Total Water Out	40.5	53.1	53.9
Tidal Range:			
Model Yacht Basin High	-0.6	-0.8	-1.1
Model Yacht Basin Low	-1.3	-1.6	-2.0
Maximum Tidal Range	0.7	0.8	0.9
Main Lagoon High	-0.7	-0.9	-1.2
Main Lagoon Low	-1.3	-1.6	-2.0
Maximum Tidal Range	0.7	0.8	0.8
Mean Water Level	-1.0	-1.3	-1.6

**Table 20: Aquatic Park Circulation Modeling - Scenario 3 One Way Flow South To North
Comparison of Average Volume Exchange Per Tidal Cycle for Various Improvement Scenarios
Volumes are in (ac-ft)**

Model No.	Model 3a	Model 3b	Model 3c
Connection Location and Flow Direction	In Through 5 Main Tubes. Out through Improved Potter Street connection.	In Through 5 Main Tubes and Improved Strawberry Drain Connection. Out through Improved Potter Street connection.	In Through 5 Main Tubes, Strawberry Drain Connection, and Northern Tide Tube. Out through Improved Potter Street connection.
Inflow through Potter Street	0.0	0.0	0.0
Outflow to Potter Street	27.4	61.5	66.9
Inflow from Model Yacht Basin to Main Lagoon	0.0	0.1	0.1
Outflow from Main Lagoon to Model Yacht Basin	27.4	61.5	66.8
Inflow from Bay through 5 Main Culverts	26.2	17.4	16.4
Outflow to Bay through 5 Main Culverts	0.0	0.0	0.0
Inflow through Northern Tide Tube	0.0	0.0	8.1
Outflow through Northern Tide Tube	0.0	0.0	0.0
Inflow through Strawberry 12 inch Low Flow Drain Connection	0.0	0.0	0.0
Inflow through Strawberry 12 inch Low Flow Drain Connection	0.0	0.0	0.0
Inflow through the Strawberry Drain Weir Connection	0.0	40.7	40.4
Outflow through the Strawberry Drain Weir Connection	0.0	0.0	0.0
Total New Water In	26.2	58.1	65.0
Total Water Out	27.4	61.5	66.9
Tidal Range:			
Model Yacht Basin High	-2.0	-0.9	-1.9
Model Yacht Basin Low	-2.4	-2.2	-2.7
Maximum Tidal Range	0.5	1.3	0.8
Main Lagoon High	-2.0	-0.9	-0.9
Main Lagoon Low	-2.4	-2.2	-2.2
Maximum Tidal Range	0.5	1.3	1.3
Mean Water Level	-2.2	-1.6	-1.6

Table 21: Aquatic Park Circulation Modeling - Scenario 4 Flow In and Out in Both Directions
Comparison of Average Volume Exchange Per Tidal Cycle for Various Improvement Scenarios
Volumes are in (ac-ft)

Model No.	Model 4a	Model 4b	Model 4c	Model 4d
Connection Location and Flow Direction	Flow Allowed in and out through the new Potter Street connection and 5 Main Tide Tubes.	Flow Allowed in and out through the Improved Potter Street connection, 5 Main Tide Tubes, and Improved Strawberry Drain connection.	Flow Allowed in and out through the Improved Potter Street connection, 5 Main Tide Tubes, Improved Strawberry Drain connection, and Northern Tide Tube.	Flow allowed in and out at Strawberry Drain weir. No other improvements to the lagoon system.
Inflow through Potter Street	66.0	60.0	59.6	11.0
Outflow to Potter Street	55.9	68.3	71.0	12.0
Inflow from Model Yacht Basin to Main Lagoon	60.7	57.8	57.3	0.4
Outflow from Main Lagoon to Model Yacht Basin	51.1	66.3	68.6	1.5
Inflow from Bay through 5 Main Culverts	18.4	15.9	15.6	5.1
Outflow to Bay through 5 Main Culverts	25.5	28.6	28.9	24.1
Inflow through Northern Tide Tube	0.0	0.0	7.8	0.0
Outflow through Northern Tide Tube	0.0	0.0	13.5	0.0
Inflow through Strawberry 12 inch Low Flow Drain Connection	0.0	0.0	0.0	0.0
Inflow through Strawberry 12 inch Low Flow Drain Connection	0.0	0.0	0.0	0.0
Inflow through the Strawberry Drain Weir Connection	0.0	39.4	39.2	38.2
Outflow through the Strawberry Drain Weir Connection	0.0	12.8	13.6	17.2
Total New Water In	84.3	115.3	122.2	54.4
Total Water Out	81.5	109.7	127.0	53.4
Tidal Range:				
Model Yacht Basin High	-1.3	-1.1	-0.8	-0.3
Model Yacht Basin Low	-2.2	-2.2	-2.2	-2.6
Maximum Tidal Range	0.9	1.1	1.5	2.3
Main Lagoon High	-1.4	-1.1	-0.8	-0.7
Main Lagoon Low	-2.2	-2.1	-2.2	-2.2
Maximum Tidal Range	0.8	1.0	1.4	1.5
Mean Water Level	-1.8	-1.6	-1.5	-1.4

Table 22: Aquatic Park Circulation Modeling - Scenario 4 Radio Tower Pond	
Average Volume Exchange Per Tidal Cycle	
Volumes are in (ac-ft)	
	Flow in and out at one location
Model No.	Model 5
Connection Location and Flow Direction	Flow allowed in and out at a single connection to the Potter Street Stormdrain.
	3.4
Outflow to Potter Street	3.3
Maximum Radio Tower Pond	-1.10
Minimum Radio Tower Pond	-2.50
Maximum Tidal Range	1.40
Mean Water Level	-1.80

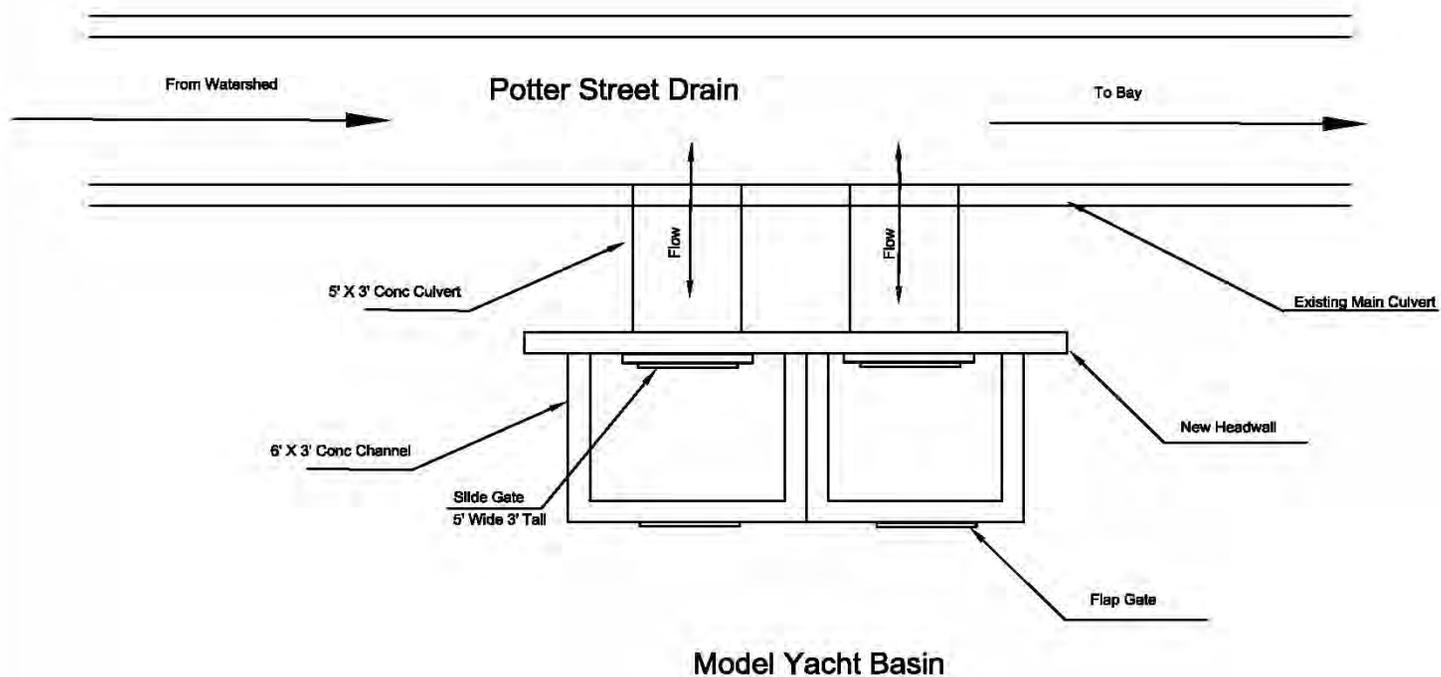
Table 23 provides a summary of the different alternatives. An evaluation of the results of the circulation model shows that Scenario 4, with flow going in and out at each connection, provides the greatest improvement in circulation. Specifically, Alternative 4B provides for a 420% increase in water exchange per tidal cycle compared to the existing condition. Alternative 4C was not seriously considered because the outlet for the Northern Tide Tube has not been found. While there is a benefit to having one-way flow, the increase in the volume of water exchanged under the two-way scenario is so much greater that it is the preferred alternative.

Table 23: Comparison of Modeling Results			
Average Volume Exchange Per Tidal Cycle, (acre-feet)			
Model Scenarios		Volume (ac-ft)	% Improvement
Existing Condition	Model 1	22.15	0%
	Model 1b	26.32	19%
	Model 1c	23.41	6%
	Model 1e	20.02	-10%
One-Way South to North	Model 2a	43.01	94%
	Model 2b	51.8	134%
	Model 2c	58.03	162%
One-Way North to South	Model 3a	26.15	18%
	Model 3b	58.1	162%
	Model 3c	64.96	193%
Two-Way Flow	Model 4a	84.32	281%
	Model 4b	115.26	420%
	Model 4c	122.16	452%
	Model 4d	54.38	146%

Implementation of Recommended Alternative 4B Hydrologic Elements

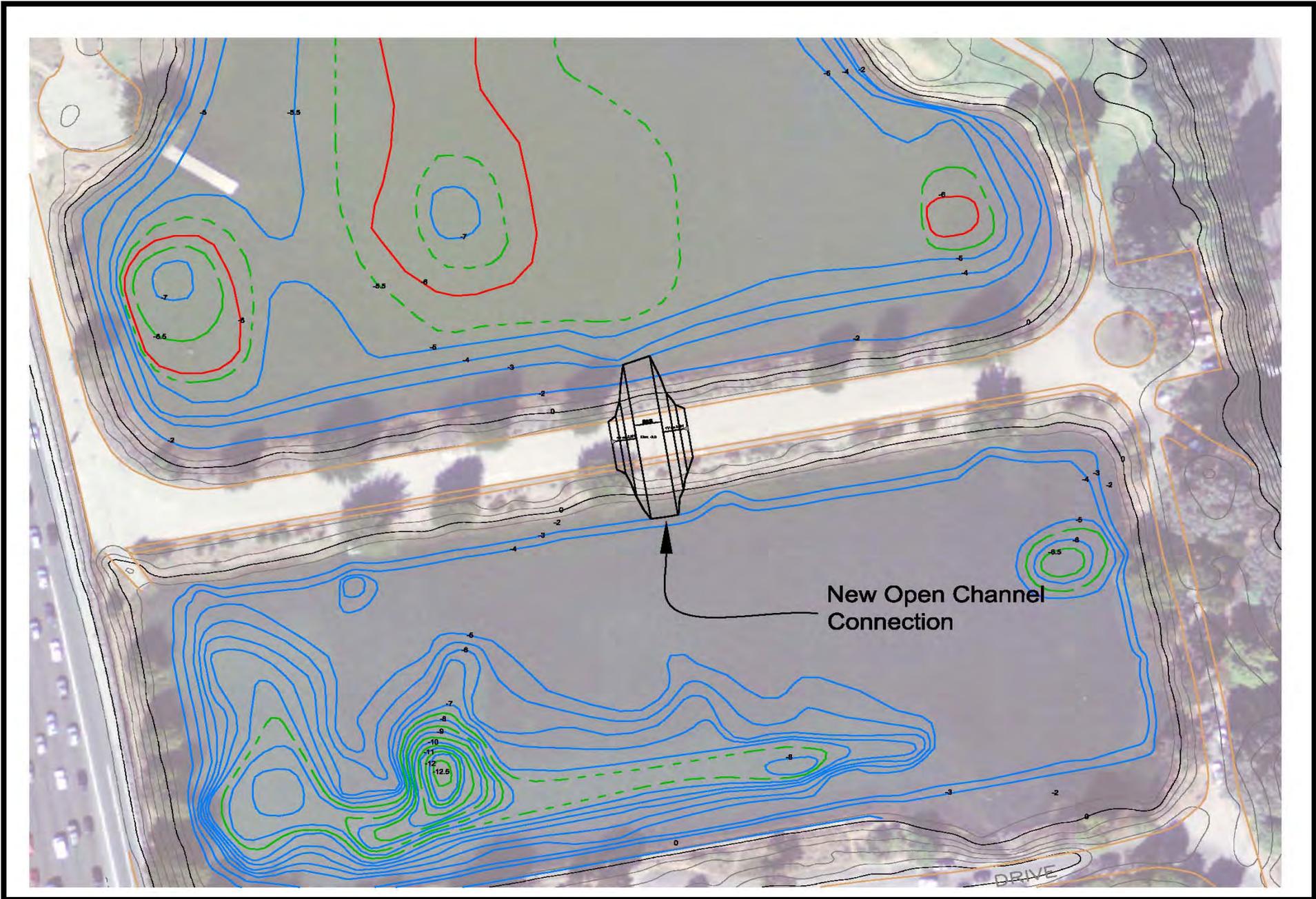
Based on the model analysis, Alternative 4B was selected as the preferred alternative. This alternative involves the following elements:

1. Enlarging the connection between the Potter Street Stormdrain and the Model Yacht Basin. This connection currently consists of two 24-inch concrete pipes. This connection will be increased to 2-3 ft. by 5 ft. box culverts. Figure 91 is a plan view showing a conceptual drawing of the new connection.
2. Constructing a 20 ft. wide channel in the berm that separates the Model Yacht Basin from the Main Lagoon by excavating 714 cubic yards of dirt. This berm presently contains two 24-inch concrete pipes. The pipes will be replaced by the open channel connection. A plan view of the connection is shown in Figures 92 and 93. A bridge will be placed over the channel to allow access to the western shore of the park. A small bridge, such as a modified railcar, would be appropriate for this location. It is economical but still strong enough to allow for emergency vehicle passage. The soils at this site will need to be tested for contaminants and to determine the potential for reuse of the soil in other park projects.
3. The Strawberry Stormdrain connection will be modified to allow tidal flow to enter and exit the Main Lagoon. Presently, the connection has a weir that prevents tidal water from entering the lagoon. Only stormwater can enter the lagoon by overtopping the weir. The weir will be removed so that the Strawberry Stormdrain overflow connection will connect with the Main Lagoon at an elevation that will allow tidal flow to enter and leave the lagoon. Figure 94 shows a cross-section through the existing connection showing the low-flow weir and a photograph of the weir looking upstream from the Main Lagoon Connection. Figure 95 is a plan view showing the layout of the new connection between the Main Lagoon and the Strawberry Stormdrain.
4. The five main tide tubes that connect the Main Lagoon with the bay will be repaired so that the bay side of the tubes will be stabilized. Presently the bay-side exit is collapsing and the culvert outlets are becoming blocked with riprap and broken pipe debris (Figure 14). A headwall will be constructed at the outlet of the culverts to stabilize the culvert ends and keep the frontage road riprap from blocking the culvert flow. Figure 96 is a schematic of the proposed modification to the culvert outlet.
5. To replace the collapsing tide tube that connects the Radio Tower Pond with the bay, a new connection will be constructed that connects the Radio Tower Pond with the Potter Street Stormdrain. This connection will provide tidal circulation to the pond. To protect the Radio Transmitter Building from high tide levels, a new berm will be constructed around the facility. Under the existing condition, the building is periodically flooded from high tides. Figure 111 is a plan view of the berm surrounding the facility. The top of the berm will be set at elevation 1.0 ft. Berkeley Datum. The side slopes will be set at 1 vertical to 2 horizontal.



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	Drawn By: _____ Checked By: Tom Burke	Size A	Project No. 1238	DWG NO. _____ Date: February 2008

Figure 91: Schematic of New Culvert Connections between Model Yacht Basin and Potter Street Stormdrain



**Figure 92: New Open Channel Connection
between Model Yacht Basin and Main Lagoon**

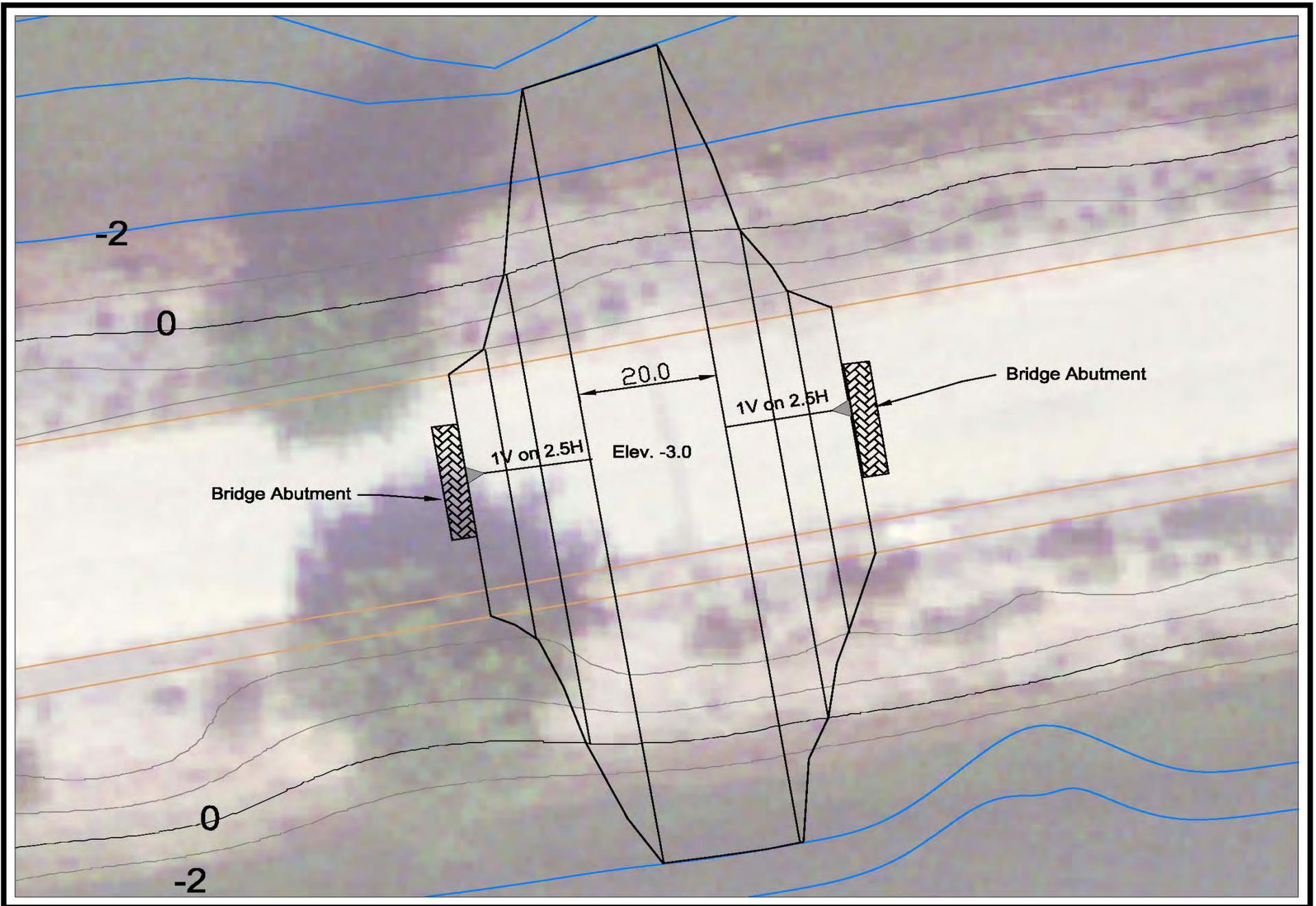


Figure 93: Close-up of New Open Channel between Model Yacht Basin and Main Lagoon

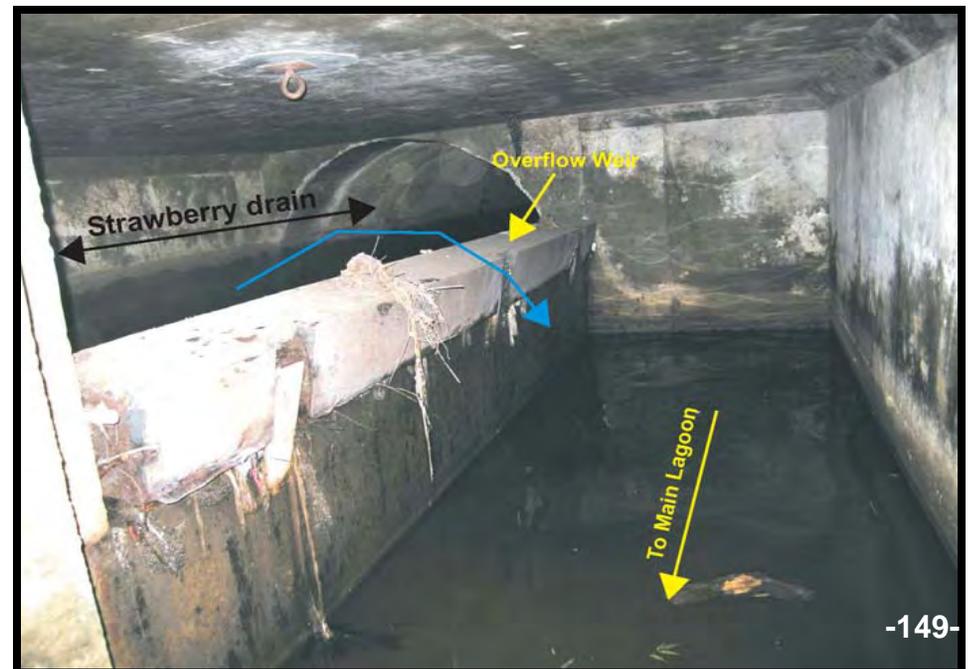
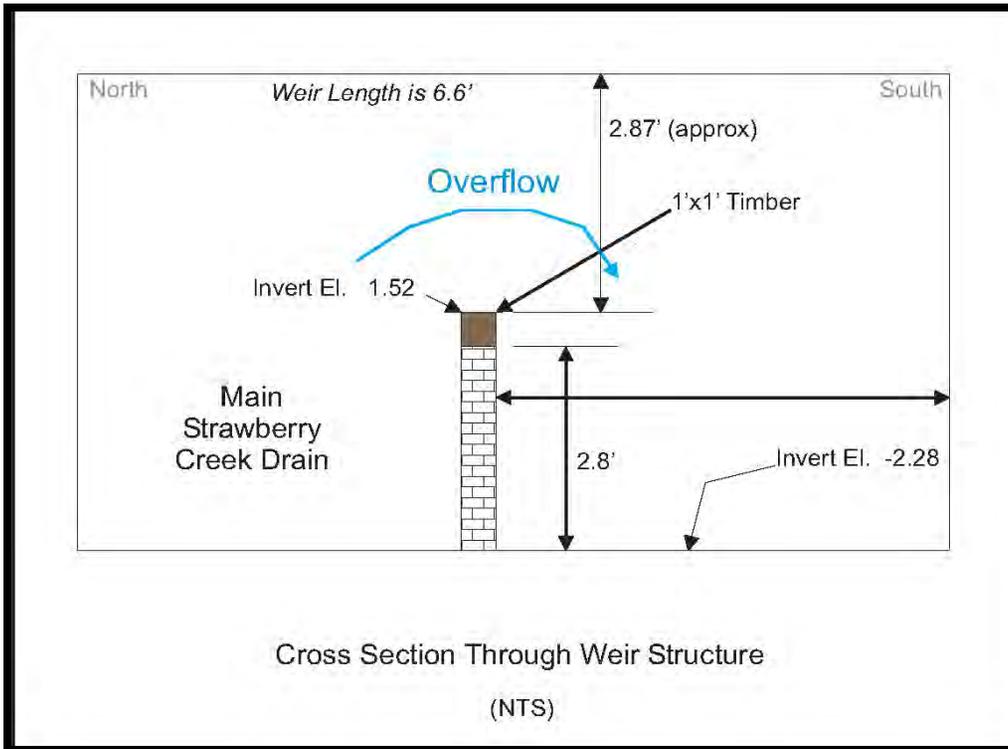


Figure 94: Drawing and Photograph of Weir between Strawberry Stormdrain and Connection to Main Lagoon. Currently, weir restricts any tidal inflows.

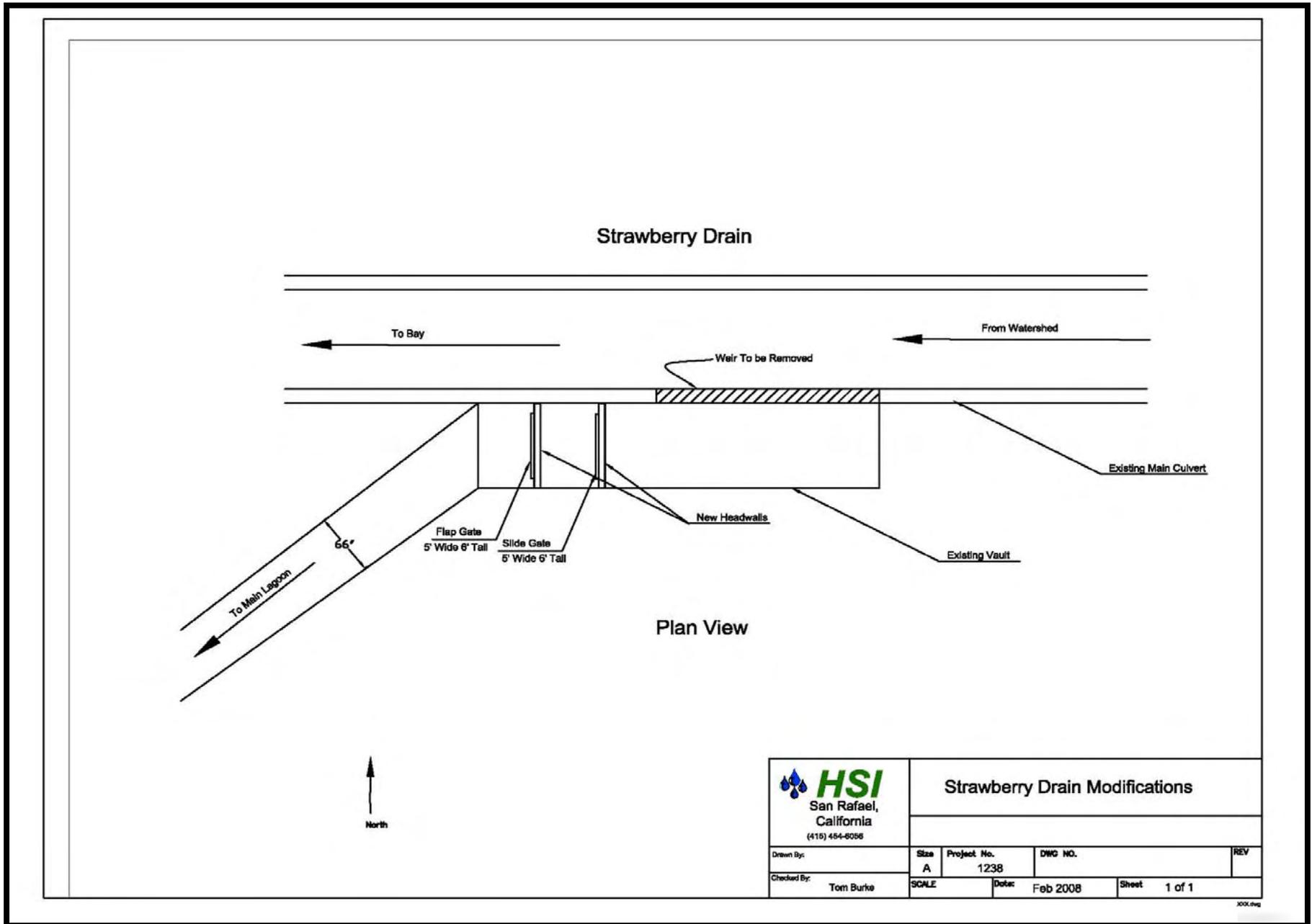


Figure 95: Schematic of New Connections between Strawberry Stormdrain and Connection Pipe to Main Lagoon

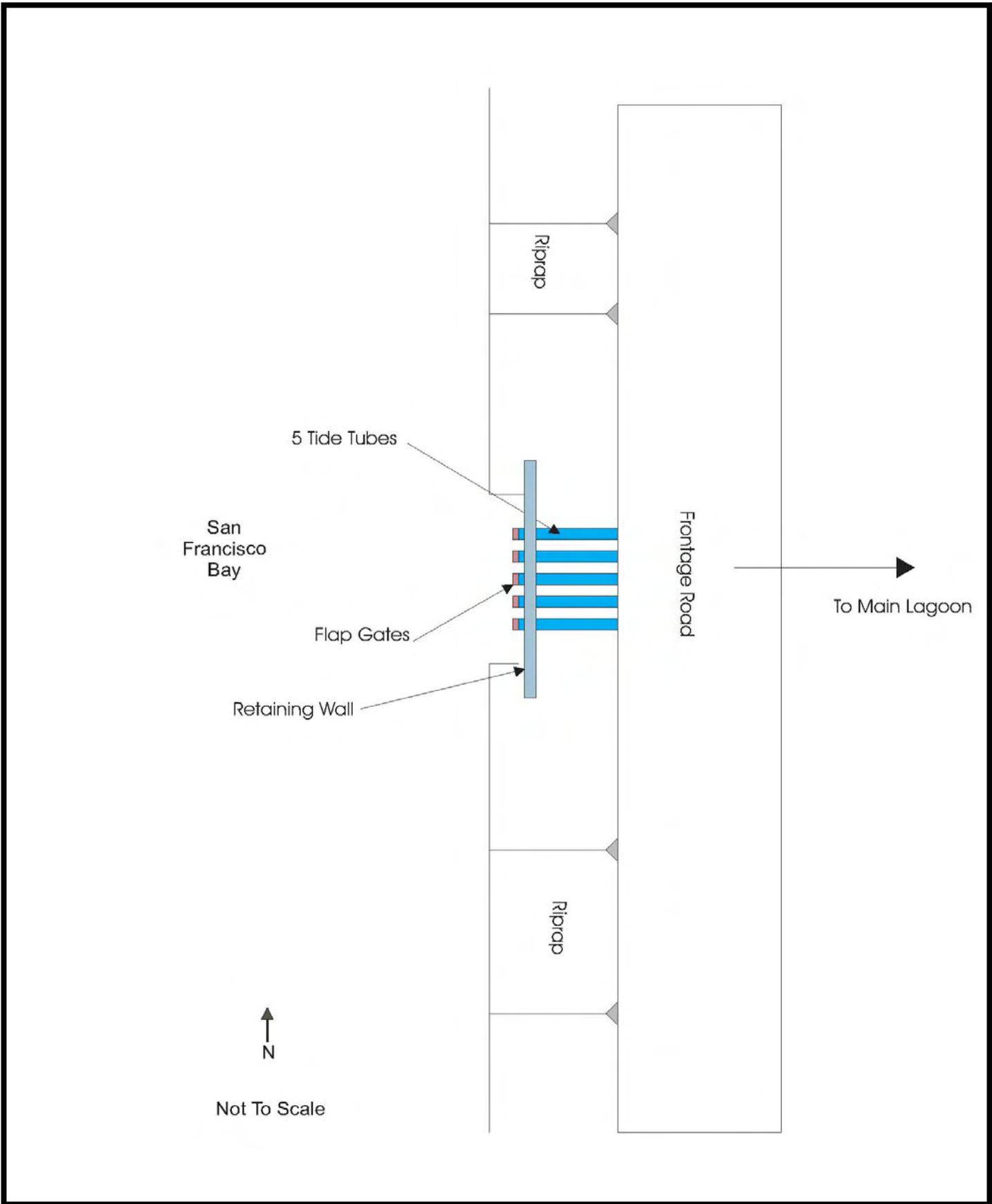


Figure 96: Proposed Structure to Stabilize Bay Side of Five Main Tide Tubes in Main Lagoon

6. To control stormwater inflow to the lagoon, each of the four connection modifications described will be fitted with a combination of flap and/or slide gates. These gates will provide the ability to reduce or completely eliminate stormwater from entering the lagoon from the Potter Street Stormdrain and the Strawberry Stormdrain. It is also recommended that a real-time monitoring station be set up at the different gates, so that the gate position and lagoon level can be monitored by park staff and public works staff. This type of system can be easily set up to be displayed in real time over the Internet.

Condition of the Existing Culvert Connections

The main elements of the proposed alternatives will require modifications to the existing Strawberry and Potter Street stormdrain connections. To determine if there were any structural problems in modifying these connections, the existing structures were evaluated. Tests were performed on the existing concrete, the culvert thickness, and the condition and spacing of any steel reinforcing at the connection sites.

The results from the concrete analysis showed that the concrete in the Potter Street Stormdrain pipe was approximately 6 inches thick and had a compressive strength of 3,170 psi. No reinforcing steel could be detected. The five main tide tubes have a wall thickness of 3.5 inches and a compressive strength of 6,820 psi. The Strawberry Stormdrain weir was approximately 18 inches thick and had a compressive strength of 7,000 psi. A detailed description of the analysis is provided in Appendix D.

Four core borings were also developed so that an evaluation of the subsurface conditions in the vicinity of the existing pipes could be conducted. An evaluation of the conditions that may affect construction of facilities at the park was conducted. The logs for the borings and the results from the soils tests are provided in Appendix E.

Shallow Subtidal Aquatic Habitat and Water Quality

Open water habitat is the major type of wildlife habitat in Aquatic Park. Water quality monitoring shows that temperatures become too warm in the Main Lagoon for most bay fish species. The monitoring also shows dissolved oxygen dipping below levels needed for fish in both June and September sampling. These conditions limit the value of aquatic habitats in the Main Lagoon for bay fish. A lack of water circulation and very small tidal range and volume are the main causes of poor aquatic habitat conditions. Revising water circulation and increasing the volume of tidal water entering and exiting the lagoon system could dramatically improve water quality and aquatic habitat. The greater the increase in tidal volume exchange the greater the improvement of the aquatic system. The highest priority of APIP should be major improvements to the aquatic habitats in the three lagoons. To achieve the greatest level of habitat improvement, Alternative 4B is recommended.

Under this alternative, both winter and summer conditions for fish would be improved. During summer the greater volume of tidal exchange should reduce stagnant water conditions by

moving a total of 115 acre-feet of tidal water in and out at three different locations in the Model Yacht Basin/Main Lagoon. This is a 420% increase in the volume of tidal exchange on each tidal cycle and should decrease water temperature and increase dissolved oxygen. All of the common fish species found in San Francisco Bay near Aquatic Park require cooler water than currently exists in the Main Lagoon. These improvements in water quality could allow greater numbers of fish and additional species from the central bay to use the lagoons.

During winter the improved system will allow for direct control of first flush inflows. The improved circulation system will also likely affect salinities in the lagoons. Currently, freshwater stormflows which enter the Main Lagoon may remain for several weeks after large floods (100 year events). Implementing Alternative 4B would reduce the residence time of freshwater inflows for this same large flood from forty-eight to only ten days. When the central bay receives flood waters, salinity levels drop for a short period primarily in shallow shoreline areas. The fish and invertebrate species in the central bay are adapted to mostly oceanic salinity conditions. Revising the Main Lagoon system to allow for salinity conditions closer to those of the central bay will benefit fish and invertebrates most likely to use the Aquatic Park lagoons.

Once water quality improvements are made, additional enhancements of the aquatic habitat may be possible. Monitoring of the improved conditions will allow analysis of the potential for planting eelgrass beds and native oyster beds. Eelgrass (*Zostera maritima*) is a rooted marine flowering plant that grows in dense beds in shallow subtidal areas of Pacific estuaries (Figure 97). Eelgrass requires very clear spring and summer water conditions and relatively low water velocities. Eelgrass also needs oceanic salinity conditions. After tidal improvements are made, monitoring can determine if conditions in the Main Lagoon will support eelgrass.

The small, slow-growing native Olympia oyster (*Ostrea conchaphila*) population has been reduced in San Francisco Bay due to over-harvesting, pollutants and competition from non-native invertebrates which dominate the bay benthos. The Institute for Fisheries Resources is working with the NOAA Restoration Center to restore the natural reef habitat of the native San Francisco Bay oyster on a portion of intertidal bayland in San Mateo County. To date, residual oyster populations have been found in Richardson Bay and near Bair Island. Attempts to re-establish native oysters in several areas of the south and central bay are being monitored currently. Monitoring of the restored conditions in the Main Lagoon will determine if oyster restoration is possible.

Salt/Brackish Wetland and Shoreline Habitats

Salt/brackish wetlands are very limited in the Main Lagoon and Model Yacht Basin (Figure 43). There are small areas with wetland plants but none of these areas are adequate in size to provide wildlife habitat. Additionally, most of the small salt/brackish wetlands along the eastern shoreline are very disturbed by adjacent recreational uses.



Figure 97: Eelgrass (*Zostera marina*)

Wetlands require a nearly flat surface which is inundated regularly by the tides. With the implementation of Alternative 4B the maximum tidal range of the Main Lagoon will be 1.1 ft. at its greatest. This is still not comparable to the tidal range of San Francisco Bay but is a major improvement for the Main Lagoon. Wetland restoration requires that the slopes of the Main Lagoon be changed to create a flat area near the Mean Tide Level (-1.6 ft.). This can be accomplished by filling the lagoon, or by excavating an area along the shoreline. Filling the lagoon would reduce the tidal volume, conflict with water quality improvements, and require extensive permit approvals and mitigation. Therefore, several shoreline areas were evaluated for excavation for wetland restoration.

Four “bulbouts” occur along the western shoreline, indicated as P1, P2, and P3 and the Rowing Club area on Figure 98, and encompass a vegetated area and a parking area. The western side of the Main Lagoon is less used and has fewer wind-driven waves to erode the shoreline. These areas are mostly above water level and consist of uplands and old asphalt parking areas. Restoring upland to wetlands is a net benefit to the bay system and more favorable to permit agency policies. P1 is a small area very close to the pedestrian overpass. P1 is 0.41 acres (Figure 99). P2 is primarily weedy and ornamental vegetation with a derelict “Old Restroom Building.” There are homeless encampments on P2 as well. P2 covers 1.47 acres (Figures 99 and 100). P3 hosts the Waterskiing Club building and shoreline facilities and has the greatest degree of pavement of the three bulbouts. P3 is 1.24 acres (Figure 101). The southernmost site is the Rowing Club area and has the temporary drying/storage area for mud excavated from the Main Lagoon in November 2007. This site is 1.48 acres (Figure 102).

Salt/Brackish Wetland Restoration

The Rowing Club site was selected as the salt/brackish wetland restoration site due to its larger size and few shoreline trees. There is also an intertidal flat and narrow strip (0.1 acre) of pickleweed marsh along the lagoon shoreline (Figure 102). Creating a salt/brackish wetland adjacent to an intertidal area will create a larger, more valuable wildlife area. Larger patches of habitat with variation in tidal levels provides for a number of different types of birds. The intertidal flat lies at the -1.0 to -3.0 ft. Berkeley Datum elevation. The narrow band of pickleweed lies at the -1.0 to 0.0 ft. Berkeley Datum elevation. The Rowing Club site would be excavated down to the elevation of -1.5 ft. Berkeley Datum. Measures would be taken to avoid affecting the existing strip of pickleweed and the intertidal flat during construction but subsequent tidal cycles could affect this small strip of pickleweed. The outer edge of the excavation would extend to near the road edge but the Monterey cypress trees along the southern edge of the site would be retained. A buffer of 25 ft. would be retained between the Rowing Club building and the wetland site.

Even with the hydrologic improvements under Alternative 4B, the maximum tidal range is limited in the Main Lagoon to 1.0 ft. This limits the slope of the wetland restoration to a nearly flat elevation. Currently the road on the western edge of the site is at elevation +3.0 ft. Berkeley Datum. In order to maximize the intertidal area, the excavation will be extended to 20 ft. from the eastern edge of the road. There are two options for the road edge of the new wetland: a retaining structure on the wetland edge and a small vegetated berm in the buffer (Figure 103) or a 3:1 slope from the wetland to the buffer with a small vegetated berm (Figure

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**Figure 98: Potential Salt/Brackish
Wetland Creation Sites**

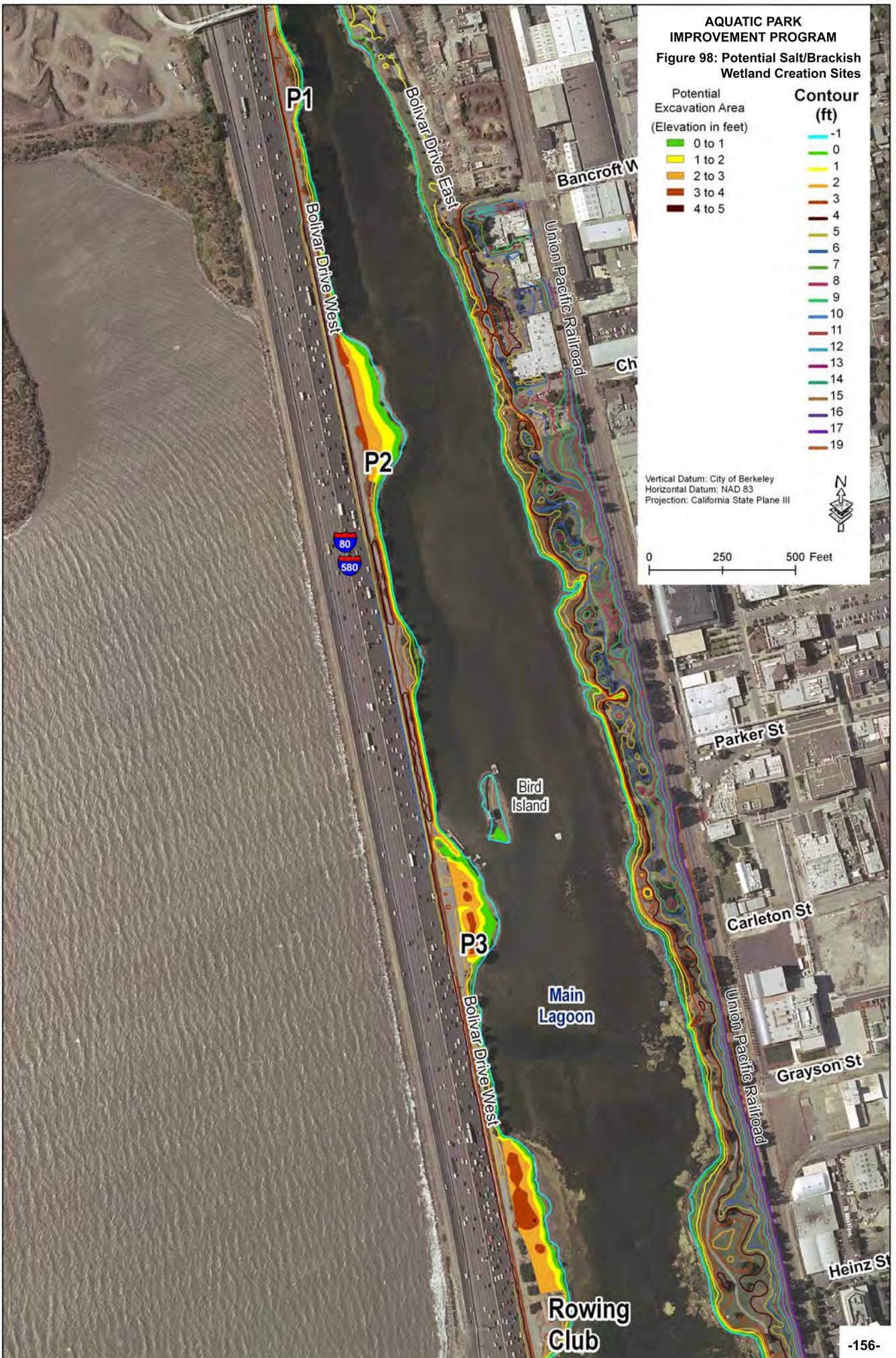
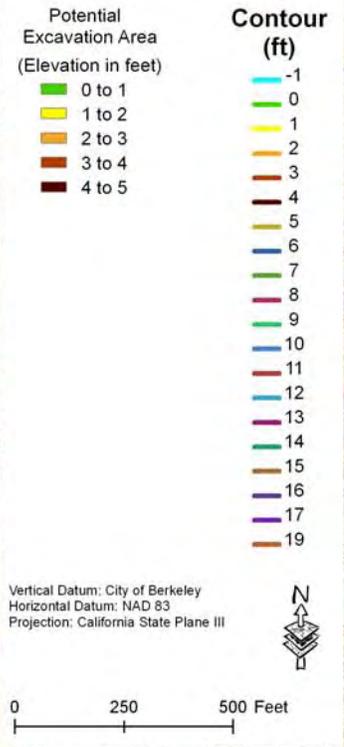




Figure 99: Parking Areas 1 and 2 along Western Side of Main Lagoon





Figure 100: Site P2 as viewed from the Main Lagoon.





Figure 101: Site P3 has a recreational building and is close to Bird Island.





Figure 102: Rowing Club Site



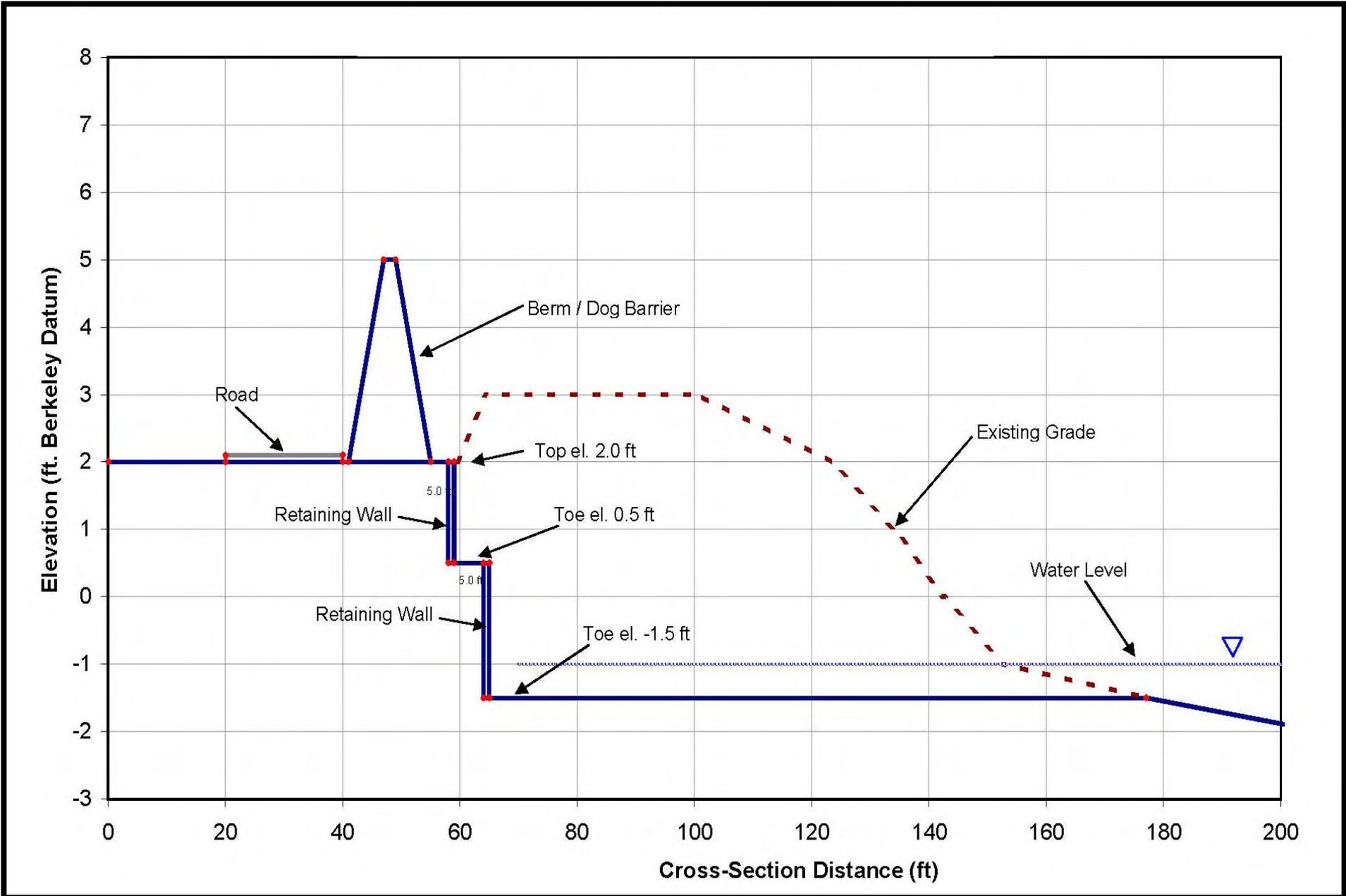


Figure 103: Rowing Club Wetland - Proposed Slope Option 1

104). The berm will visually screen the road from the wetland and reduce disturbance to wildlife from dogs and people (Figure 105). Figure 106 shows a plan view of the site.

Excavation to create the salt/brackish wetland will generate approximately 6,282 cubic yards of soil and use 560 cubic yards to create the berm. The remaining excavated material could be used for a number of park projects including: a berm in the Radio Tower Pond to protect the Radio Transmitter Building from flooding; increasing the elevation of Bird Island to provide an improved bird roosting area; replacement of the asphalt former parking areas with upland native planting areas. The excavated material will need to be tested before the wetland project moves forward to assure there are no contaminants in the material.

Once the wetland site is excavated, some salt marsh plants would be planted and some would be expected to colonize. Pickleweed will be retained along the site's eastern edge and is expected to spread and colonize the new excavated area. The western edge of the site would be planted with high marsh plants—alkali heath (*Frankenia grandifolia*), fat hen (*Atriplex patula*), jaumea (*Jaumea carnosa*), salt grass (*Distichlis spicata*), gumplant (*Grindelia stricta* var. *stricta*), and salt marsh rosemary (*Limonium californicum*). Transition zone plants—California buckwheat (*Erigonum sp.*), coyote brush (*Baccharis pilularis*), bunchgrass, and others—would be planted along the berm (Appendix A).

Shoreline Areas

The shoreline areas of the rest of the Main Lagoon and the other two lagoons offer an opportunity to eradicate invasive non-native plants (Figures 54A and 54B) and revegetate with high marsh/transition zone native plants. The mapped invasive plants were split into three stages of removal (Table 24). Stage 1 includes all of the shoreline invasive plants including ice plant, tamarisk, cotoneaster, fennel, pepperweed, firethorn, and ivy in the Radio Tower Pond. Invasive removal in Stage 1 also includes other areas of the park which have invasive plants that spread by stem, seed, and berry, such as Himalayan blackberry, pampas grass, broom, and giant reed. Acacia and eucalyptus seedlings on the shoreline would also be removed. Stage 3 includes large eucalyptus and acacia trees which make up the majority of the acreage of invasive plants in the park (Table 24). Stage 2 includes additional invasive plant removal in the freshwater wetlands. Stage 3 invasives removal would not be completed until replacement trees had been installed.

Following invasives removal along the lagoon shoreline, wetland species including gumplant, pickleweed, salt marsh rosemary, saltgrass, jaumea, and alkali heath could be planted along the tidal shoreline on the Main Lagoon, Model Yacht Basin, and Radio Tower Pond. Away from the tidal shoreline on the edges of the grass, plants such as beach aster (*Erigeron glaucus*), Douglas iris (*Iris douglasiana*), monkey flower (*Mimulus sp.*), and other low-growing natives could be planted. It is not advisable to try to plant native species under the existing cypress trees; however, cypress seedlings could be planted in areas where restricting lagoon views is acceptable. It is also not advisable to plant native species in heavily used recreational areas.

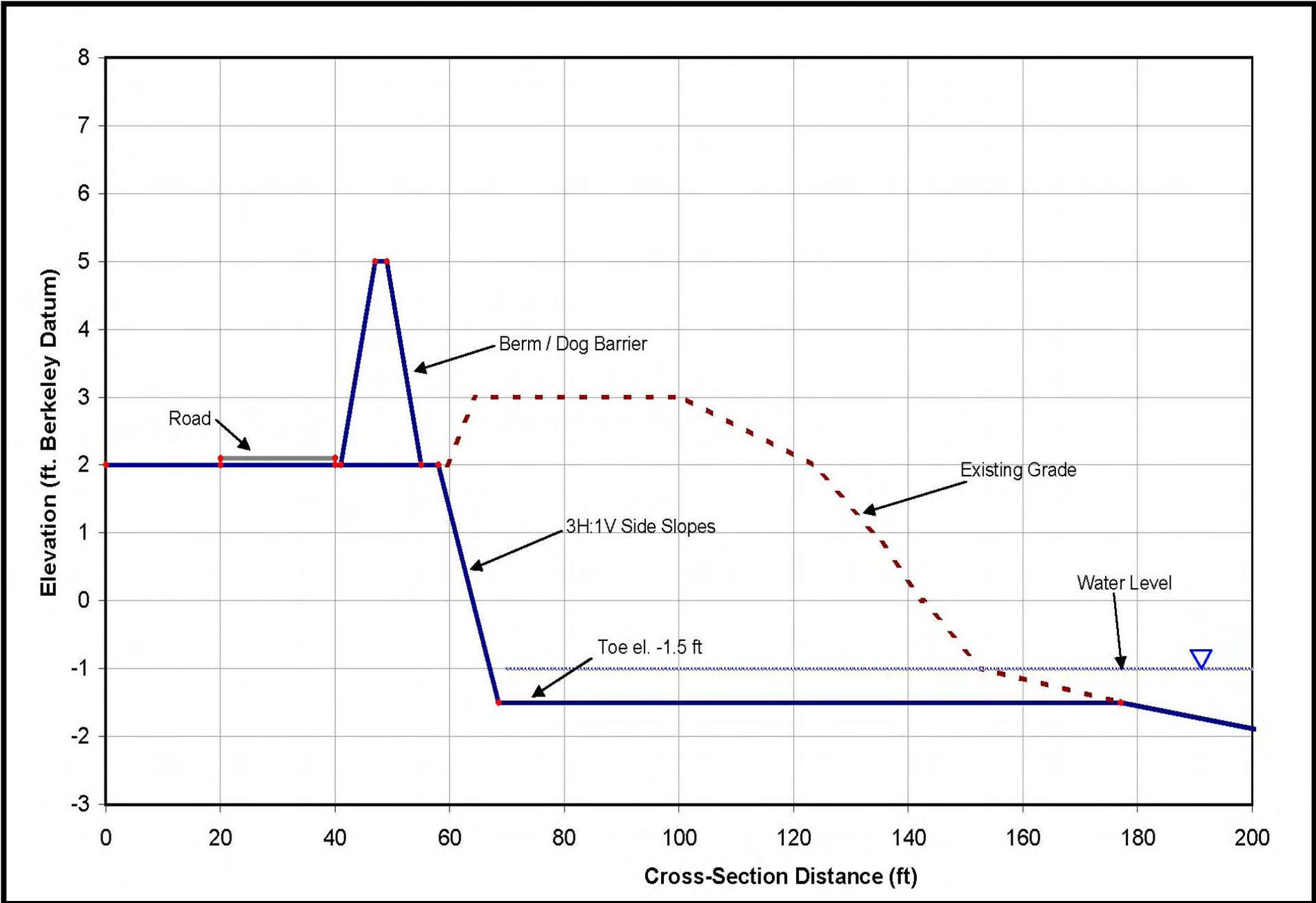


Figure 104: Rowing Club Wetland - Proposed Slope Option 2



Figure 105: Dogs run off- and on-leash throughout the park.



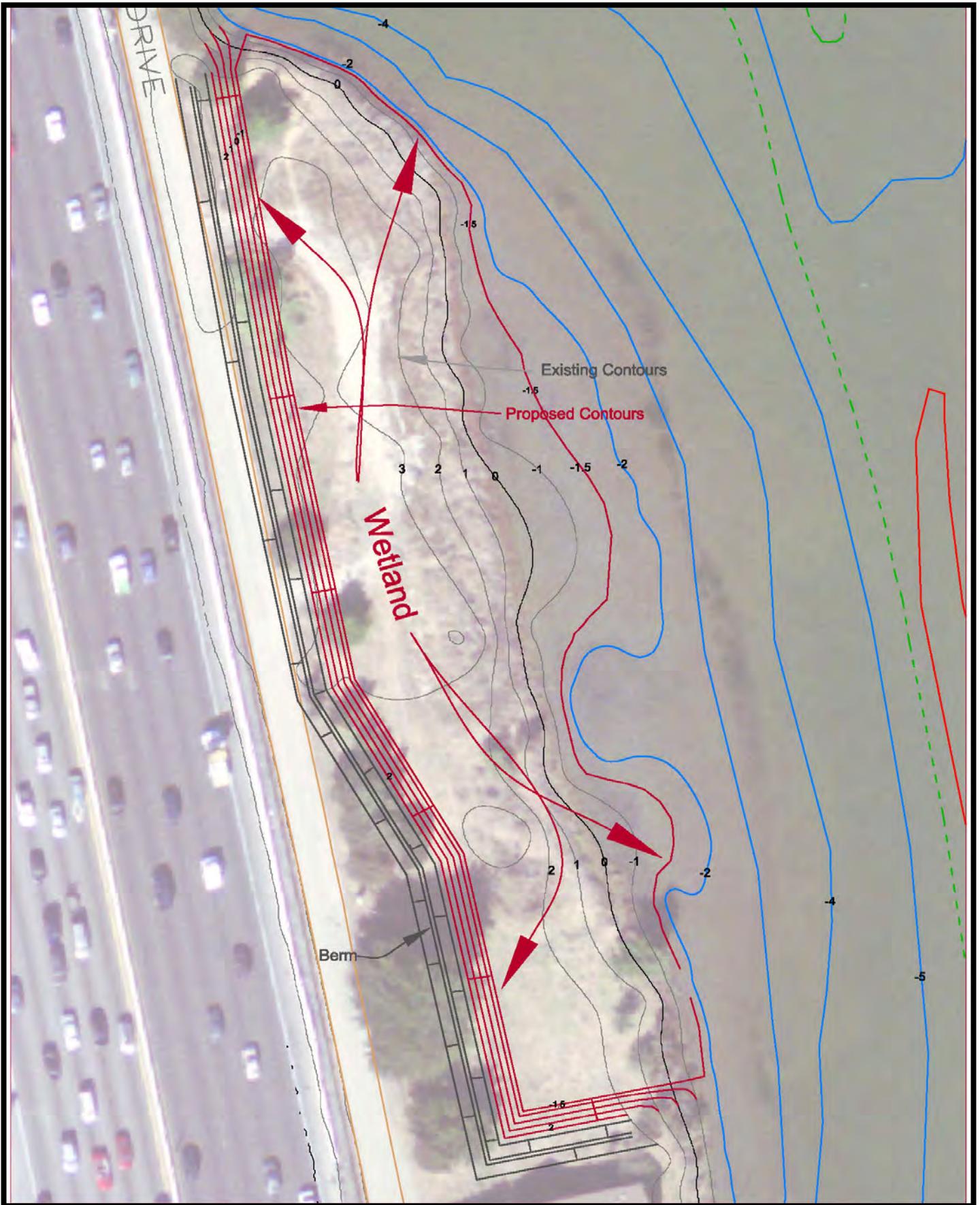


Figure 106: Plan View of Salt/Brackish Wetland Restoration Site

Planting willows has been suggested along shoreline sections of the Main Lagoon to provide a visual screen between recreational trails and winter birds. Willows do not tolerate saline or even brackish soils. Willows would need to be planted away from the tidal zone, particularly if freshwater (stormwater) is restricted from the lagoon system. In locations along the Main Lagoon where the creeks and stormdrains discharge to the lagoon, willows may be able to grow along the shoreline, but this would produce spotty coverage.

Species	Total acres in park	Acres to be removed in Stage 1	Acres to be removed in Stage 2	Acres to be removed in Stage 3
Wattle (<i>Acacia sp.</i>)	2.0 acres total	0.45 at RTP	0	1.55
Giant reed (<i>Arundo donax</i>)	0.01	0.01	0	0
Himalayan blackberry (<i>Rubus discolor</i>)	0.53	0.53	0	0
Cotoneaster (<i>Cotoneaster sp.</i>)	0.02	0.02	0	0
Blue gum (<i>Eucalyptus globulus</i>)	3.79	0	0	3.79
Fennel (<i>Foeniculum vulgare</i>)	0.02	0.02	0	0
Broom (<i>Cytisus scoparius</i> , <i>Genista monspessulana</i> , <i>Genista juncea</i>)	0.03	0.03	0	0
Ice plant (<i>Carpobrotus edulis</i>)	0.26	0.26	0	0
English ivy (<i>Hedera helix</i>)	1.28	.11 in RTP shoreline area	1.17	0
Pampas grass (<i>Cortaderia selloana</i>)	<0.01	<0.01	0	0
Pepperweed (<i>Lepidium latifolium</i>)	<0.01	<0.01	0	0
Firethorn (<i>Pyracantha sp.</i>)	0.02	0.02	0	0
Salt cedar (<i>Tamarix sp.</i>)	0.01	0.01	0	0
TOTAL	7.99	1.47	1.17	5.34

Upland and Bird Roosting Habitat

Bird Island

Improvement of Bird Island and upland areas on the western side of the Main Lagoon are included in the APIP. These areas have a greater degree of isolation from recreational use and a higher potential for a successful habitat restoration. Bird Island is 0.45 acres, lies at 0.0 to -2.0 ft. (Berkeley Datum), and is inundated in storms. The island needs to be raised up to +5.0 ft. (Berkeley Datum) in order to revegetate for bird roosting habitat and create potential nesting habitat for dabbling ducks. The isolation of the island makes it the best location in the park for these habitats. The City will need to revise their lease with the Waterski Club to allow removal of the building and fence and abandon recreational use of the island.

In order to increase the elevation of Bird Island, the height of the rock riprap around the island periphery will be increased first. The rock will serve to contain the fill material and to break up wind-driven waves which can erode the shoreline. Approximately 230 cubic yards of riprap will be required and will extend 1 foot higher than the high water level. The bridge that will be used for the new connection between the Model Yacht Basin and the Main Lagoon will be used to bridge between the Main Lagoon shore and Bird Island and truck the fill material to the island. Approximately 2,230 cubic yards of material will be placed on Bird Island. The material will be placed to create a variable, hummocky topography with two mounds and a lower area inside the island (Figure 107). There are several water lines which go out to the island. A source of freshwater will be needed to irrigate plants and if possible to create a small freshwater source for ducks in the interior area.

Erosion blankets or other measures will be needed to stabilize the new fill until plants establish. Native trees such as Monterey cypress (*Cupressus macrocarpa*), California bay laurel (*Umbellularia californica*), Monterey pine (*Pinus radiata*), and potentially others will be planted on the island to provide roosting habitat. These species can withstand wind and often grow on coastal bluffs and hills. These trees will take five years to grow large enough for bird roosting and soil stability. Erosion control measures will need to be in place during this time. Bunchgrasses, rushes, sedges, and low-growing shrubs such as coyote brush and gumplant will also be planted to provide refuge areas.

Additional upland areas can be improved using the soil excavated from the wetland restoration and channel between the Model Yacht Basin and the Main Lagoon (Tables 25 and 26). The abandoned parking lots at P1, P2, P3, and adjacent vegetated bulbout areas could be enhanced as native upland habitats (Figure 98). The asphalt in the parking area would be broken up and removed, and the under-soil broken up to allow plant roots to penetrate. The asphalt can be recycled. The parking areas to the edge of the access road and into the western edge of the bulbout would have about 2.5 ft. of soil placed once the asphalt is removed. The soil will be placed in a hummocky configuration similar to coastal bluff/sand dune areas. Larger native trees on these sites would be retained. Erosion blankets will be used to stabilize the soil surface while revegetation is occurring.

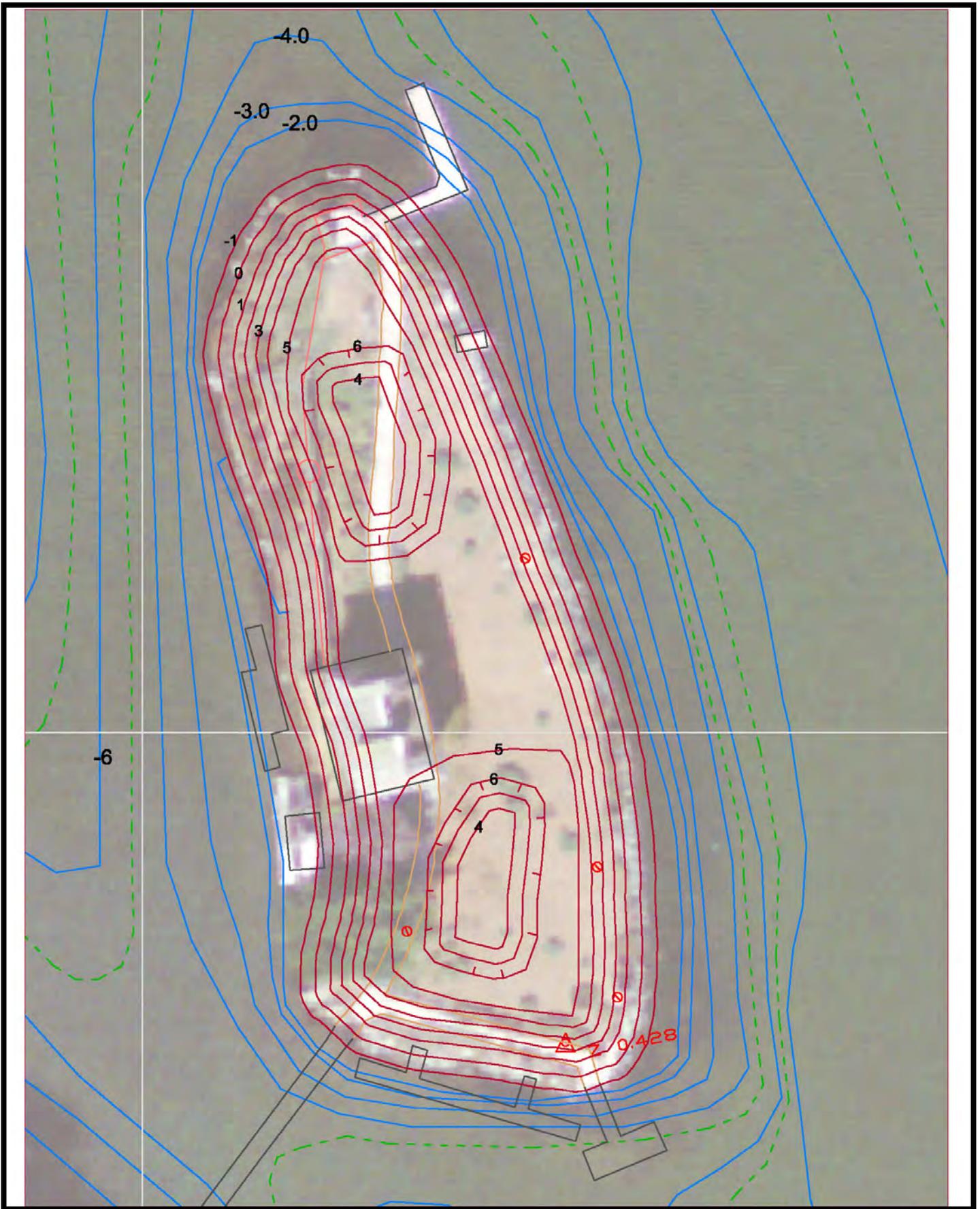


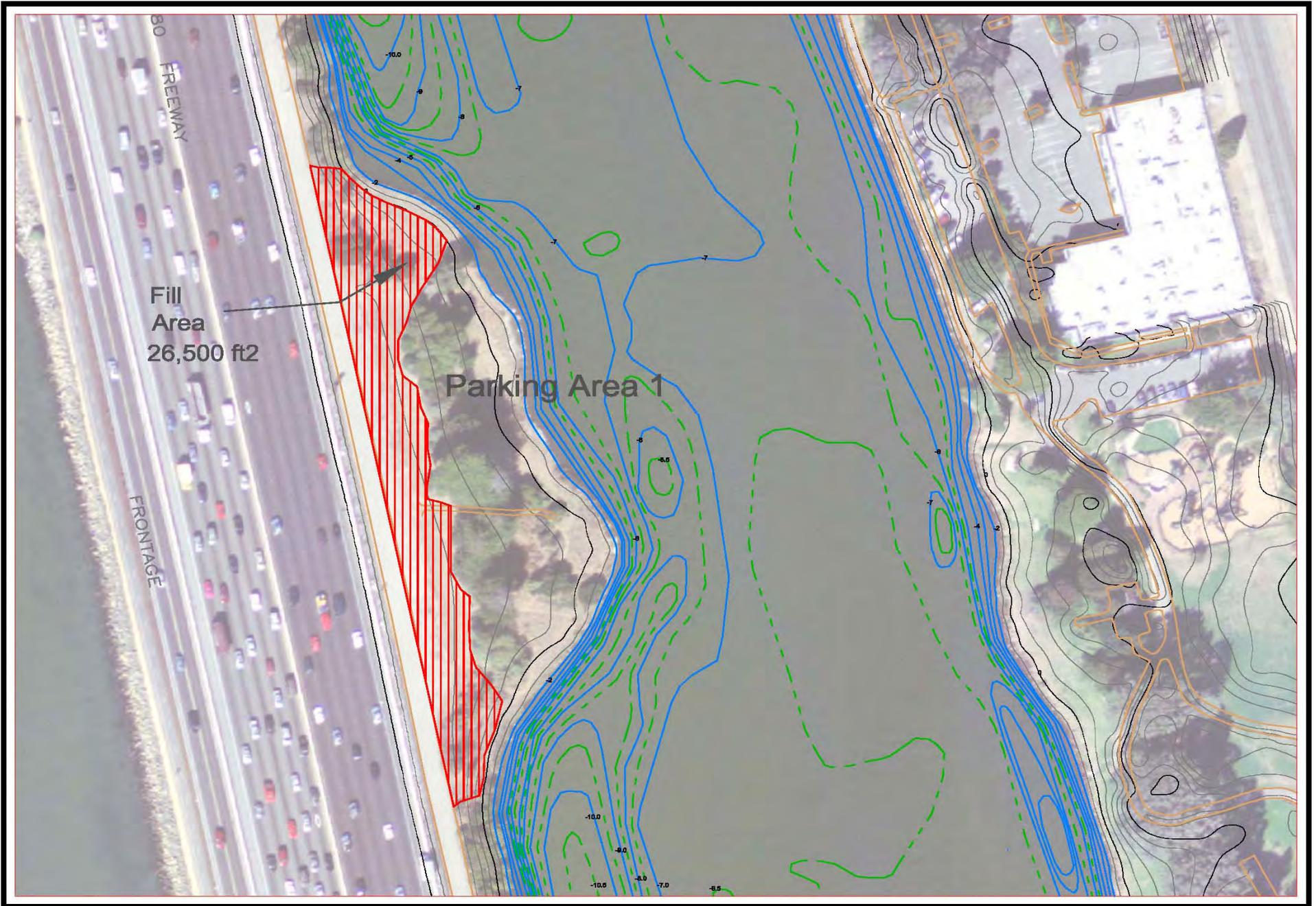
Figure 107: Improvements to Create Bird Roosting Habitat at Bird Island

The parking areas restored as upland habitat could support a variety of native plants such as buckwheat, native bunchgrasses, coyote brush, silk tassel (*Garrya elliptica*), California blue blossom (*Ceanothus sp.*), coffeeberry (*Rhamnus californica*), manzanita (*Arctostaphylos sp.*), sagebrush (*Artemisia californica*), ocean spray (*Holodiscus discolor*), redbud (*Cercis occidentalis*), toyon (*Heteromeles arbutifolia*), black sage (*Salvia mellifera*), Douglas iris (*Iris douglasiana*), monkey flower (*Mimulus sp.*), California poppy (*Eschscholzia californica*), lupine (*Lupinus sp.*), California fuschia (*Epilobium canum*), beach aster (*Erigeron glaucus*), California saltbush (*Atriplex californica*), and yarrow (*Achillea millefolium*). Native sand dune species such as beach strawberry (*Fragaria chiloensis*), silver beachweed (*Ambrosia chamissonis*), and yellow sand verbena (*Abronia latifolia*) could also be planted. Appendix A shows many of these plant species.

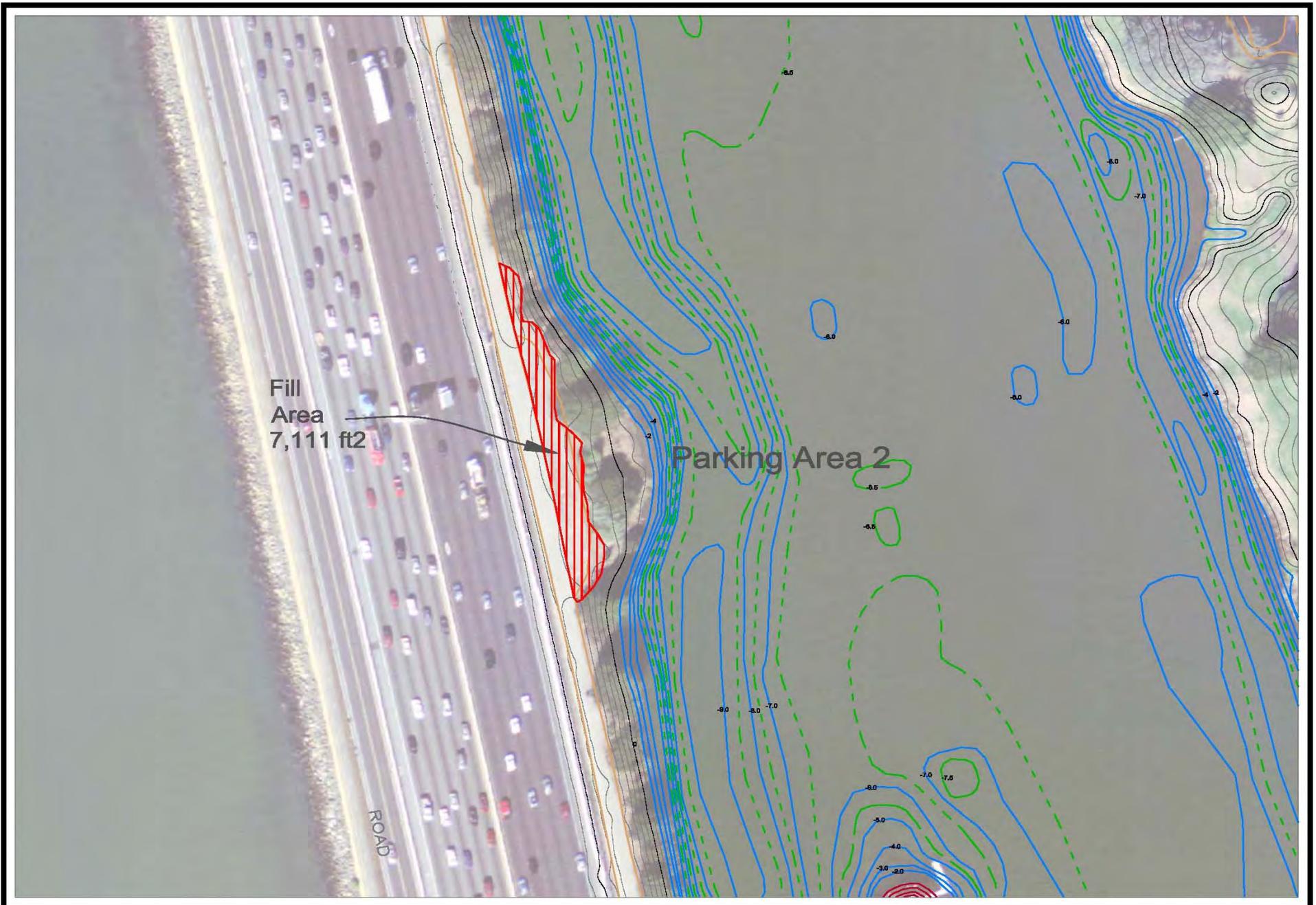
Revegetation along the western side may require some experimentation to determine which native species will grow in this area. A drip irrigation system will be needed for plant watering, or a hand-watering system should be employed. These areas may require temporary fencing to allow plants to become established and eliminate trampling, digging, and other destructive actions. In many sand dune/coastal bluff areas revegetation requires the removal of park users and then the creation of a dedicated walkway through the restored area. Pathways from the access road to the lagoon shoreline should be established as part of the revegetation project. Figures 108-110 show the P1, P2, and P3 areas and the footprint of the soil and revegetation. The revegetation areas include the parking areas and a small part of the vegetated area.

An additional option for re-use of the excavated soil is the creation of a berm around the Radio Transmitter Building in the Radio Tower Pond. The berm will protect the building from flooding at high tide and allow for improvements in tidal circulation in the Radio Tower Pond. The berm would be approximately 2 ft. in height with a top elevation of 1.0 ft. Berkeley Datum. Sideslopes would be 2:1 and the berm would re-use 273 cubic yards of the excavated material (Figure 111). If the Radio Transmitter Building berm is not constructed, more parking area will need to be filled in order to re-use the excavated material (Tables 25 and 26).

Additional bird roosting areas could be created by placing floating platforms in the open water of the lagoons 30 ft or more from the shoreline. The platforms could be made of wood or plastic and anchored to the bottom. Another potential type of roost would be the placement of rock in the lagoon 30 ft from the shoreline. Both of these improvements would need to be placed out of the area used for water recreation.



**Figure 108: Proposed Fill and Upland
Revegetation Area in Parking Area 1**



**Figure 109: Proposed Fill and Upland
Revegetation Area in Parking Area 2**



Figure 110: Proposed Fill and Upland Revegetation Area in Parking Area 3

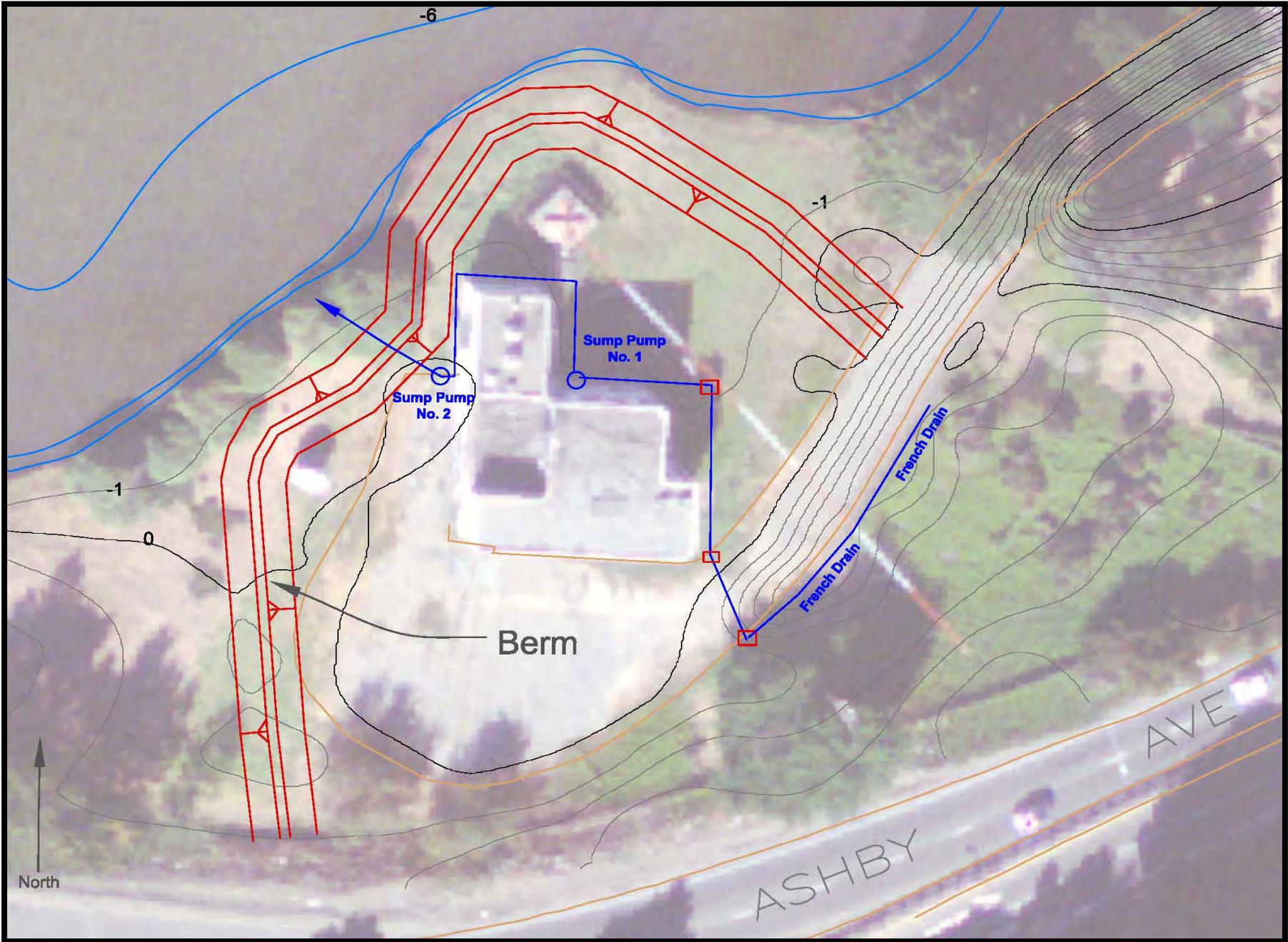


Figure 111: Proposed Berm to Protect Radio Transmitter Building from Flooding

Table 25:			
Cut and Fill Quantities including the Radio Tower Berm			
Average Depth of Fill is 2.5 feet			
Location	Approximate Area (sq. ft.)	Cut (cubic yds.)	Fill (cubic yds.)
Rowing Club Wetlands	58,000	6,282	560
Model Yacht Basin-Main Lagoon Connection	5,582	714	0
Bird Island	19,000	0	2,331
Radio Tower Berm	6,750	0	273
Parking Area 1	23,223	0	1,876
Parking Area 2	7,112	0	574
Parking Area 3	17,100	0	1,381
Net		6,996	6,996

Table 26:			
Cut and Fill Quantities without the Radio Tower Berm			
Average Depth of Fill is 2.4 feet			
Location	Approximate Area (sq. ft.)	Cut (cy)	Fill (cy)
Rowing Club Wetlands	58,000	6,282	560
MYB-ML Connection	5,582	714	0
Bird Island	19,000	0	2,331
Parking Area 1	23,223	0	2,009
Parking Area 2	7,112	0	615
Parking Area 3	17,100	0	1,479
Net		6,996	6,996

Urban Stormwater

Lagoon Circulation

Increasing water circulation volumes over current conditions will allow the stormwater that comes into the lagoon to move out much more quickly and avoid the deposition of sediment which may carry contaminants. The model was used to evaluate retention time of stormwater in the Main Lagoon from two different size storms under existing conditions and under the recommended alternative.

The model evaluated the 100-year storm event under the existing condition and under the proposed circulation improvement plan (Alternative 4B). A comparison was conducted to determine how long it would take for the stormwater to exit the lagoon, and how long it would take to restore the natural salinity to the lagoon under normal tidal action.

A review of the existing condition model for the 100-year storm results shows that it takes 25.7 days for the Main Lagoon to return to its normal stage level. Once the stage has returned to normal, it is assumed that the normal salinity levels have returned to the lagoon after a volume of bay water equal to two times the lagoon volume has entered the lagoon.

There are a total of 239 acre-feet in the Main Lagoon and the Model Yacht Basin. Under the existing tidal inflow conditions, 22 acre-feet of bay water enter the lagoon per tidal cycle. Given this inflow rate, it will take an additional 22.7 days to remove the remaining residual stormwater from the lagoon. The total time to remove stormwater from the Main Lagoon is equal to the time to bring the lagoon down from the storm level to the natural lagoon level plus the time it takes to remove the residual stormwater that is in the lagoon after the storm. This is equal to 48.5 days for a 100-year event.

The hydraulic model of the lagoon was run for the proposed Alternative 4B with the 100-year storm event. Under the proposed alternative, the lagoon level is returned to the normal water level in 5.9 days. This is primarily due to the enlarged connections to the bay.

After the lagoon level returns to a normal level, typical tidal flushing resumes. The volume of bay water entering the lagoon during each tidal cycle is 115 acre-feet. Given this rate of bay water inflow, it takes 4.5 days to provide two complete exchanges of lagoon water with the bay or a total of 10.4 days to remove the stormwater following a 100-year event. Table 27 and Figures 112 and 113 provide a comparison between the pre- and post-project flushing rates for the 2-year and 100-year storm events.

Table 27: Flushing Rate Analysis for the 2-Year and 100-Year Storm Event

	2-Year Storm Event				100-Year Storm Event			
	Existing Condition		Project Condition		Existing Condition		Project Condition	
Volume of New Bay Water Entering per Tidal Cycle	22	ac-ft	115	ac-ft	22	ac-ft	115	ac-ft
Volume of Stormwater Entering the Lagoon	753	ac-ft	753	ac-ft	1,836	ac-ft	1,836	ac-ft
Normal Volume of Main Lagoon and Model Yacht Basin	208	ac-ft	262.4	ac-ft	208	ac-ft	262	ac-ft
Time to Return to Normal Lagoon Level	535	hours	131	hours	618	hours	141	hours
	22.3	days	5.5	days	25.7	days	5.9	days
Time to Flush out Stormwater	454	hours	110	hours	545	hours	110	hours
	18.9	days	4.5	days	22.7	days	4.5	days
Total Time to Remove Stormwater from the Main Lagoon	989	hours	144	hours	1163	hours	251	hours
	41.2	days	10.0	days	48.5	days	10.4	days

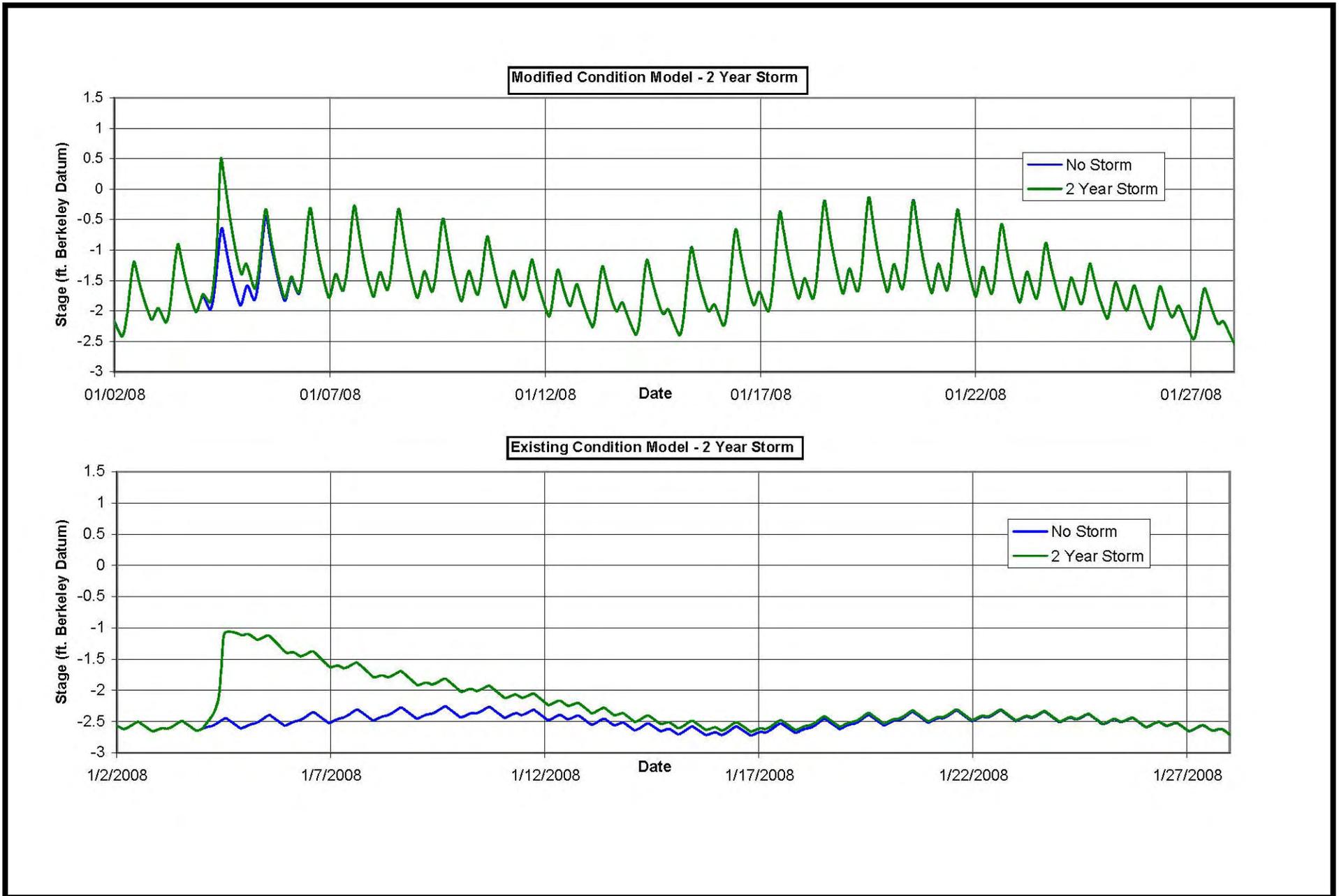


Figure 112: Existing and Post-Project Main Lagoon Water Level Before, During, and After a 2-Year Storm Event

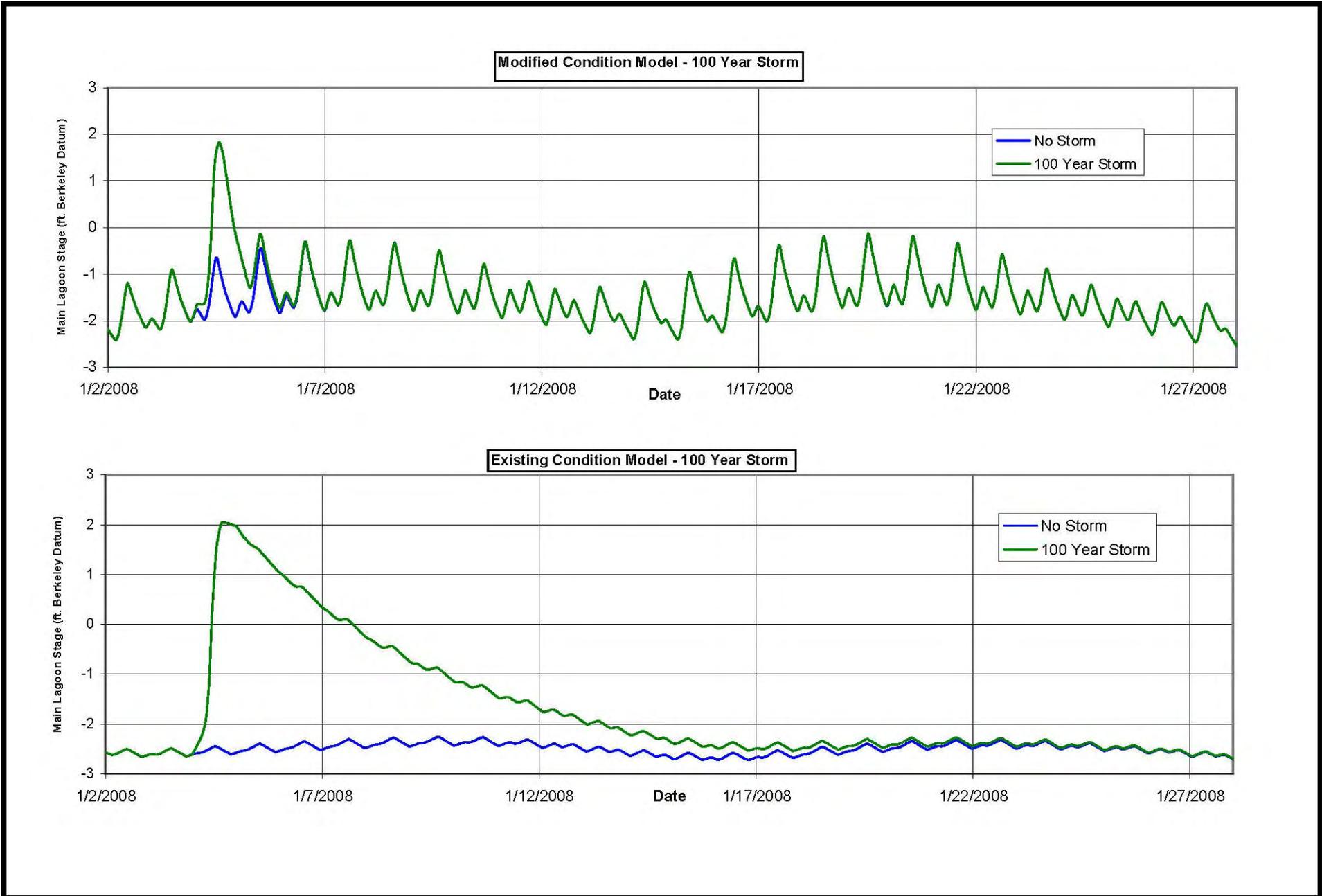


Figure 113: Existing and Post-Project Main Lagoon Water Level Before, During, and After a 100-Year Storm Event

As can be seen in the table, under the proposed condition, the time it takes for the storm water to be removed from the lagoon is reduced by greater than 50 percent.

Aquatic Park Watershed

The persistent contaminants that pose the greatest biological problems in the tidal lagoons of Aquatic Park as well as San Francisco Bay are transported on clay particles moving as suspended sediment in stormwater. Revising the water circulation in the lagoons to move stormwater out quickly will reduce the deposition of clay particles in the lagoons; however, these particles will still move into the bay.

The most direct way to reduce stormwater pollutants is to reduce it in the watershed of Aquatic Park. Figure 59 shows the various sub-basins in the Aquatic Park watershed. Most of this area drains either to the Strawberry or the Potter Street stormdrains. Stormwater from these two areas will be blocked by gates from entering the lagoons during first flush when the highest concentrations of pollutants occur. An alternative which could eliminate all stormwater inflows to the lagoons from the two large stormdrains will be evaluated in the CEQA process for the APIP. However, for the “local” watershed of the park, it is not possible to block stormwater flows from entering the lagoons.

There are a number of smaller stormdrains and runoff areas that contribute stormwater directly into the Main Lagoon. Watershed flow modeling showed that 30% of stormwater entering the lagoons originated not from the Potter and Strawberry stormdrains, but from stormdrains and urban runoff along the east side of the park. Addison and Bancroft Streets have street runoff that flows directly into the Main Lagoon. This runoff would be directed into a bioswale constructed parallel to the Main Lagoon on the northeastern shoreline.

Biofiltration

The urban streets, parking lots, and buildings of the local watershed could be retrofitted with stormwater biofiltration facilities. These types of facilities are installed along sidewalks, in parking lots, and along street edges to catch and filter out trash and contaminants while also providing tree and planting areas. An “Ultra Urban Stormwater Demonstration Project” area is proposed for the area bounded by Ashby Avenue, Addison Street, Seventh Street, and the park in which biofiltration improvements would be made through grant funding and potentially redevelopment processes (Figure 114).

Biofiltration facilities provide treatment of stormwater as it flows along streets and through parking lots and before it enters the stormdrain system. Biofiltration facilities provide a medium which can rapidly and effectively remove trash and a high percentage of the fine sediment particles, bacteria, and nutrients, and biologically treat these contaminants. The facilities are designed not to pond or detain stormwater but to infiltrate and/or bypass water and be an aesthetically pleasing amenity in the urban environment. Figure 115 shows a schematic of a biofiltration facility. Biofiltration facilities have been found to remove 80 percent or greater of the total suspended sediments (TSS) from stormwater and therefore a high



**AQUATIC PARK
IMPROVEMENT PROGRAM**

**Figure 114: Proposed
Demonstration Ultra Urban
Stormwater Biofiltration Area**

— Boundary of Area



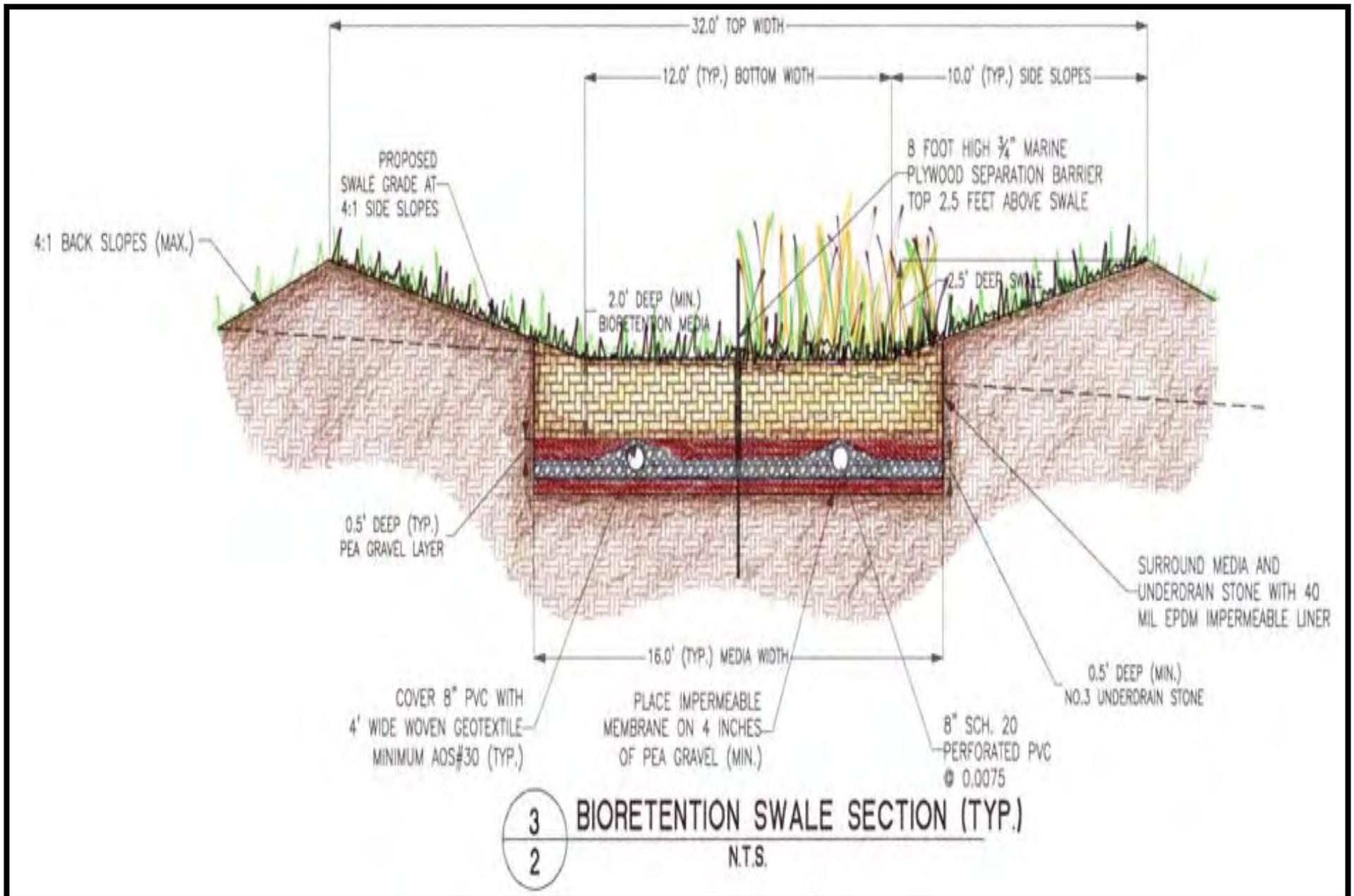


Figure 115: Bioretention is defined as filtering stormwater through a terrestrial aerobic plant/soil/microbe complex to capture, remove, and cycle pollutants through a variety of physical, chemical, and biological processes.

percentage of the metals, organochlorides, nutrients, pesticides, coliform bacteria, oil and gas, and other contaminants.

Each facility has a surface mulch layer which catches particles. Shredded hardwood, pine bark, tree chips, or coarse peat moss are typical mulch materials. Leaf or grass compost is not recommended. Stormwater is directed into the biofiltration facility through a curb cut in the street or parking lot. There needs to be a large number of these small facilities distributed over the drainage. As the stormwater filters through the mulch layer, the trash and particulates are caught. Beneath the mulch are rapid infiltration layers of coarse sand and gravel. It is important to limit clay and silt in this layer to less 5 percent of the total volume. At the base is an underdrain which takes the filtered water into the stormdrain system. It is also possible to infiltrate the filtered water if soil types and groundwater levels are appropriate. Each facility has plants, trees, shrubs, and lower growing herbs or rushes which are part of the filtration system. As nutrients such as nitrate fertilizers are filtered out, the plant roots uptake these materials.

The San Francisco Bay Regional Board recommends as a minimum a 5 inch per hour infiltration rate for these facilities and a minimum of 18 inches of media for filtration. The biofilters can accommodate a certain volume of runoff during rainstorms. When runoff volumes are high, a percentage of the stormwater flow bypasses the filters and directly enters the stormdrain system. Most biofiltration facilities also have clean out/observation wells.

There are a variety of examples of biofiltration facilities from other cities in Figures 116-120. For the Aquatic Park watershed, design of these facilities will need to take into account soil conditions, rainfall amounts, land uses, utility and pipe systems, land ownership, and overall redevelopment planning. In general, one biofiltration unit should accommodate storm runoff from 0.3-0.4 acres in commercial/industrial areas and 0.8 acres in residential areas.

Additional stormwater facilities that could be included in the Aquatic Park watershed are stormwater detention facilities such as cisterns and rain barrels (Figures 121 and 122). Rain barrels typically hold runoff from the roof of a single residence and slowly release it or allow use for gardens. Cisterns can be large holding tanks beneath parking lots which hold and slowly release water, or dry wells which impound roof and building runoff (Figure 123). These facilities detain water during high runoff events and either release it when runoff levels are lower or allow use of the water for landscape irrigation.

Another practice that could be incorporated into the Aquatic Park watershed is the use of porous pavement (Figure 124). Residential driveways, commercial and industrial area landscaping, walkways and even parking lots can use paving stones set over base rock and sand which provide for infiltration of stormwater instead of runoff. Porous pavement can be incorporated into landscaping using biofiltration measures and rain gardens. Rain gardens are built at the outlets of roof and gutter downspouts. They provide a rock dissipater or stilling basin and biofiltration to treat the runoff depending on the site (Figure 125). Grass or bioswales are wide vegetated channels that allow stormwater to flow through and deposit particulates and infiltrate before leaving the site (Figure 126).

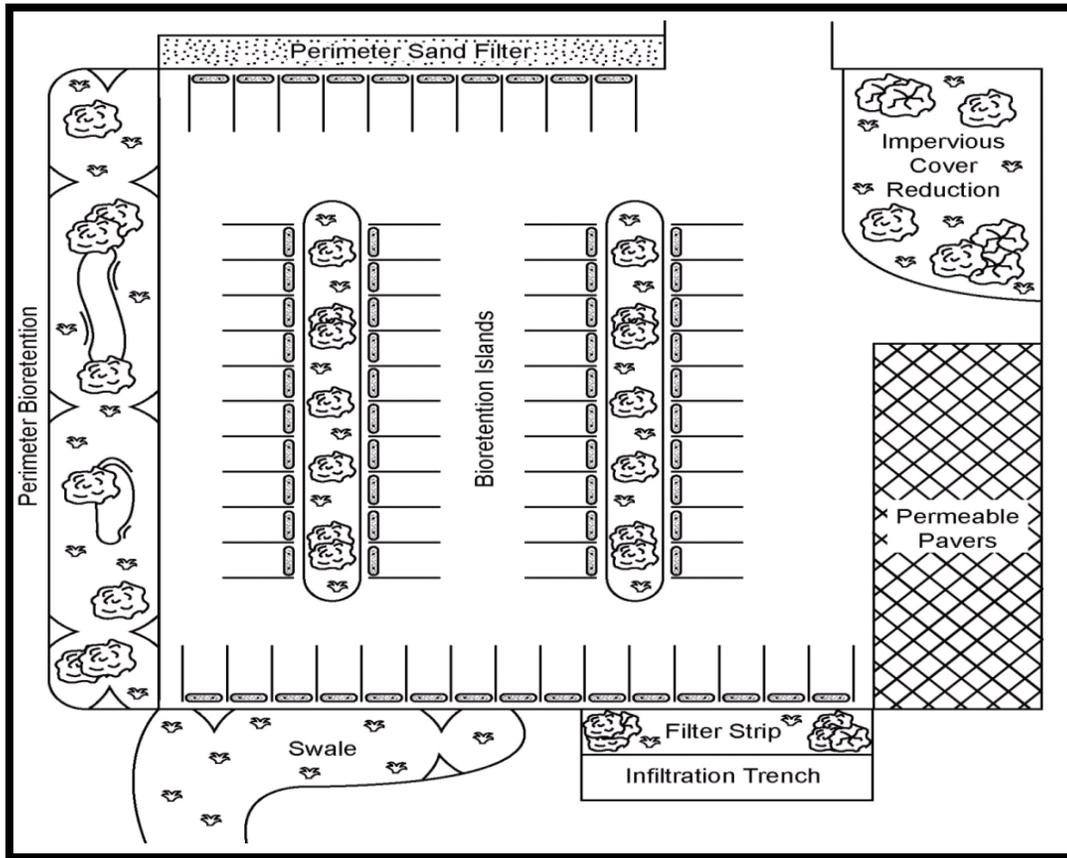


Figure 116: Biofiltration in Parking Lots





**Figure 117: Biofiltration Units in
Downtown Portland, Oregon**





Figure 118: Biofiltration Swale in Seattle, Washington



Figure 119: Newly installed bioswale in Seattle showing temporary erosion blanket and new native plantings.



Figure 120: Bioretention Swale on Hill -- In order to increase the time and space for runoff to be absorbed by the landscape, this project uses a series of swale cells down one side of the street.

Each cell is divided by a series of weirs with flow control notches, creating a “staircase” for water flowing down the slope.



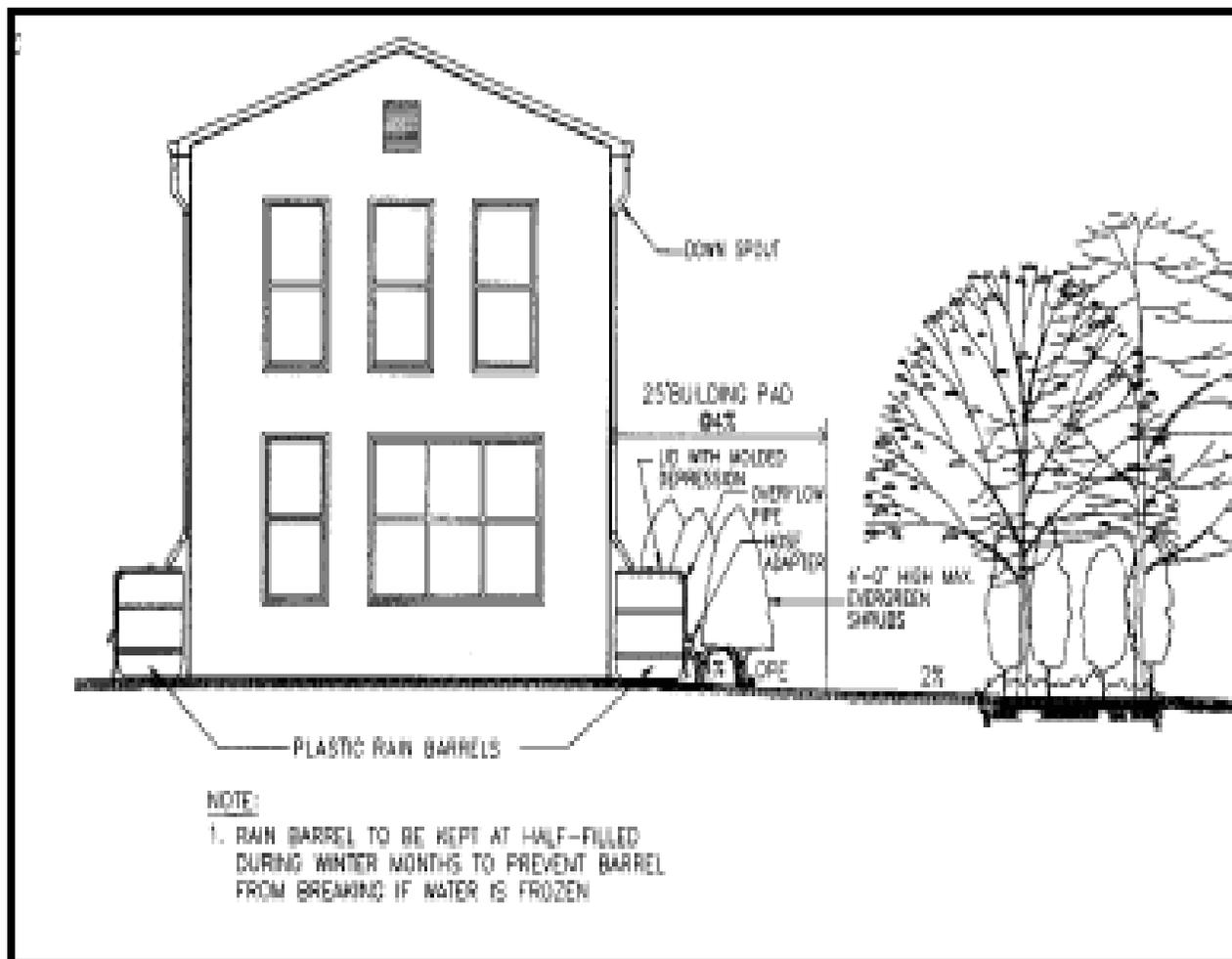


Figure 121: Typical Rain Barrel

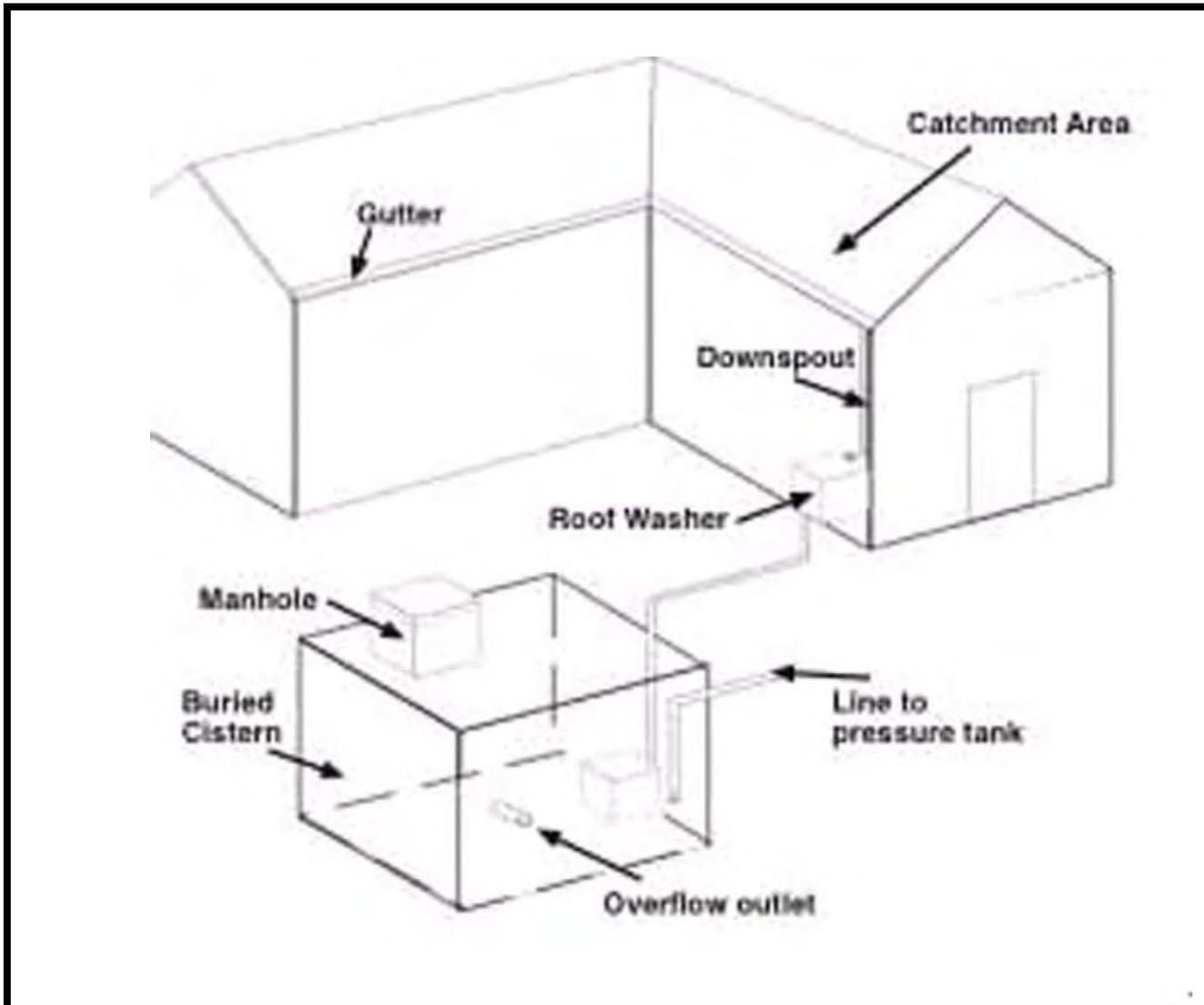


Figure 122: Cistern

If soils are not well suited for drainage, a cistern can be employed. A tank retains the water generated from roof runoff. Collected water can then be pumped out for non-potable applications. From an energy perspective, a cistern placed above ground level could benefit from the force of gravity for lawn or garden watering, which would reduce the energy load. Alternatively, the tank can be placed below ground level and pumped as needed.

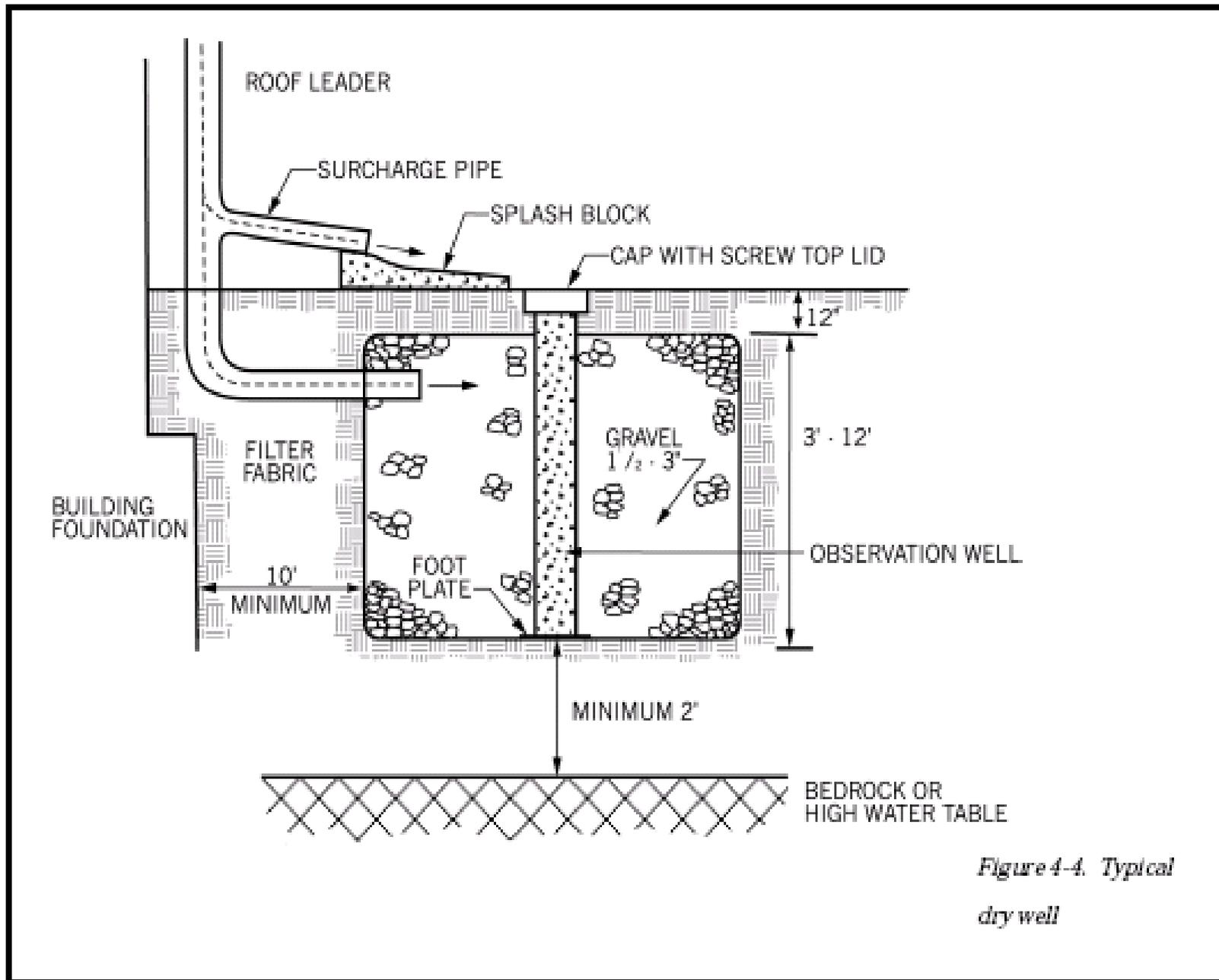


Figure 123: Typical Dry Well

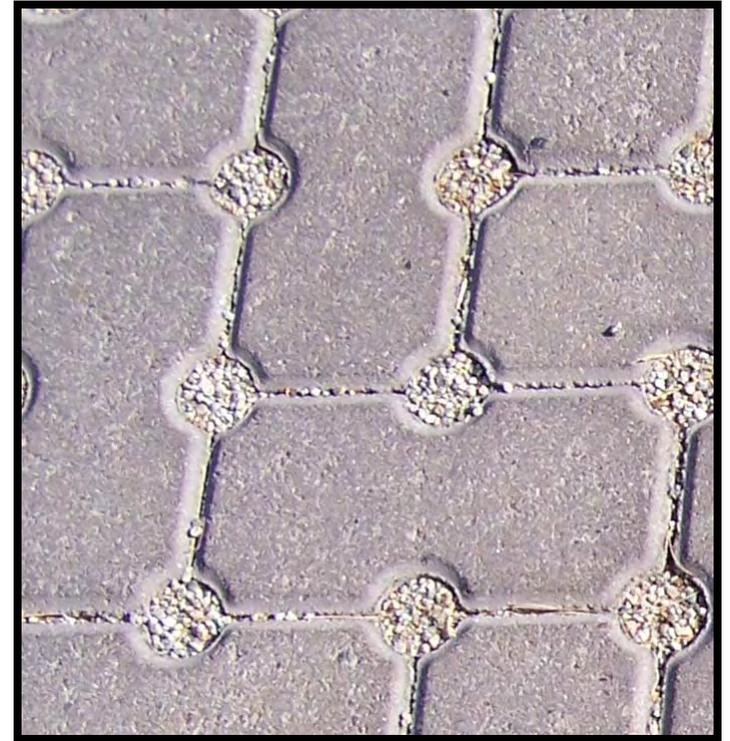


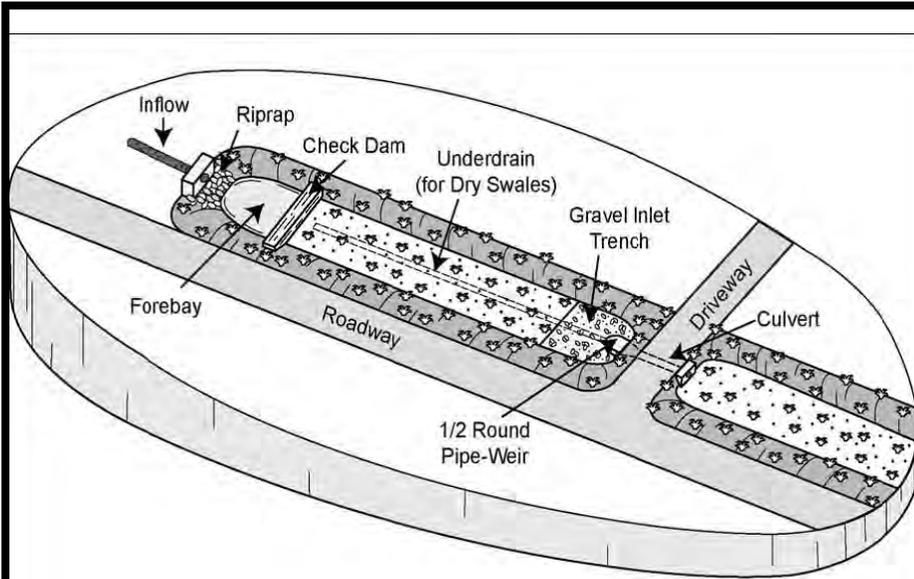
Figure 124: Porous Pavement

Permeable pavement allows water to infiltrate into the ground through the spaces between the blocks filled with fine rock. Two layers of rock below the pavers provide a strong base for the street and help the infiltration process.





Figure 125: Rain Gardens



Dry Swale (above); Wet Swale (below)

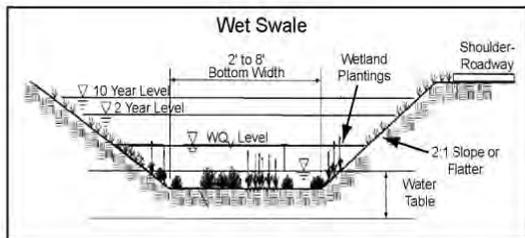
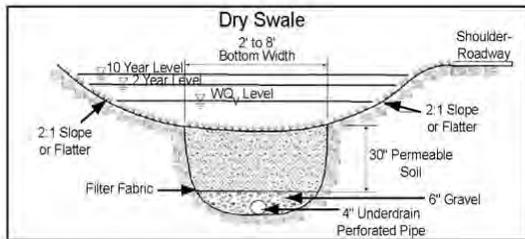


Figure 126: Grassy Bioswales

All of these measures will need to be retrofit into the Aquatic Park watershed to effectively reduce contaminants out before stormwater reaches the lagoon system. This watershed is ultra-urban: it contains no open land and is almost entirely paved over. Currently the “local” watershed offers a number of retrofit opportunities. Many streets and sidewalks in the area are very wide, creating large areas of impervious surface that worsen stormwater problems (Figure 127). The problem can be reduced by taking a portion of the sidewalk/street area to install biofiltering swales, planter boxes, curb cuts, or other facilities. Very few streets in the area have extensive trees or other landscaping. There are also a large number of parking lots which could accommodate biofiltration planter boxes as part of parking “islands,” swales, or porous pavement installed in the down gradient area (Figure 128). It is also possible to break parking lots into sub-drainages to install treatment measures. Many of the larger industrial buildings could unhook roof downspouts from the stormwater drain system and integrate biotreatment for parking areas and building runoff.

The entire “local” watershed of Aquatic Park is 232 acres and includes seven different sub-basins named for the major street where a storm pipe is located: Heinz, Grayson, Carleton, Parker, Dwight, Channing, and Bancroft. Table 28 outlines the acreage of each sub-basin.

For each sub-basin, 3 to 5 percent of the land area must be used to treat stormwater to attain water quality improvements. This acreage may be spread over numerous small biofiltration and stormwater treatment facilities. The following steps are recommended for implementing stormwater filtration projects in the Aquatic Park “local” watershed:

1. Complete a GIS analysis of the seven sub-basins to compare acres in residential, commercial, and light industrial uses; street and sidewalk width, location, and extent; parking lot size and location; soil types; rainfall intensity; existing stormdrain network; parcel size and ownership; public lands; other utilities or conditions which could limit drainages.
2. Using GIS and field review, evaluate and rate sub-basins for features which could make stormwater retrofit more successful and identify candidate sub-basins for demonstration projects. The selected sub-basin should include a variety of land uses, densities, and types of development.
3. Apply for design and public outreach funding to implement stormwater treatment in two sub-basins. Present idea to City Council for endorsement. Include preparation of detailed design guidelines for rest of the city in grant application and make Aquatic Park watershed a demonstration project. Using GIS, produce an inventory of potential sites in each sub-basin and determine the feasibility of each site. Evaluate a variety of implementation mechanisms, including redevelopment, special assessment districts, business district funding, mitigation funding, residential owners retrofit tax credits, and others. Annual maintenance for these facilities is simple (Figure 129) but essential, and costs will need to be covered in some manner.

The design of stormwater biofiltration will require a detailed review of site runoff, soil, and land use conditions once available sites are identified. It may also be possible to work with a company such as Americast which produces pre-fabricated biofilter units (Filterra® units).



Figure 127: The local watershed of Aquatic Park has very wide streets and sidewalks, and could accommodate biofiltration facilities in public rights-of-way.



Figure 128: Parking Lots
The local watershed of Aquatic Park has many large parking lots (right) which could accommodate stormwater treatment areas like the one above.



Open and remove the tree grate halves.



Dispose of the entire mulch layer using a rake.



Remove the captured trash and leaves.



Replace the old mulch layer with 3" thick of fresh mulch.



5
Water as necessary and clean up the area!

Figure 129: Maintenance for Biofiltration Facilities

There are a number of documents and websites for biofiltration and stormwater treatment design in the reference section.

Table 28: Aquatic Park East Side Drainage Basins		
NAME	Hydrology Model Sub-basin	Area (acres)
Heinz	15	37.8
Grayson	16	50.0
Carleton	17	18.7
Parker	18	46.6
Dwight	19	22.5
Channing	20	35.9
Bancroft	21	20.7
Total		232.2

Option: Vortex Filters

Stormdrains run along Channing, Dwight, Parker, Carleton, Grayson, and Heinz Streets through the railroad berm and into the Main Lagoon. The Parker, Carleton, Grayson, and Heinz Streets stormdrains are each fitted with an oil/water separator and a high- and low-flow pipe system constructed in the early 1970s. Depending on the tide and lagoon and storm intensity levels, stormwater from these four drains may flow into the Potter Street drain via a transite pipe or directly into the Main Lagoon.

Depending on the extent of the ultra urban stormwater biofiltration improvements, vortex filters could be installed on the storm pipes on the upslope/east side of the railroad berm as a final treatment facility before the stormwater enters the park. These filters would remove trash, large particulates, and oil and grease and would consist of a unit placed in the stormdrain as an in-line facility or next to the pipe as an off-line unit. Vortex separation units, made by several manufacturers, can remove oil and grease, trash, and sand. They also have the ability to be expanded to remove other chemicals and contaminants. They operate by separating the debris from the water through centrifugal acceleration, and collecting the trash in a sump located below the unit. Figure 130 is a schematic showing the general concept of how these units work. This particular image shows an additional disinfection unit added on to the end of the separator. This is one of the many add-on units that can be used to treat different contaminants in the water. Figure 131 has conceptual drawings of an in-line unit and an off-line unit. These in-line filtering systems could be installed for the stormdrains at Dwight, Channing, and Bancroft Streets. For the stormdrains at Parker, Carleton, Grayson, and Heinz Streets, vortex filter units can be installed in the park to replace the oil/water separators. The vortex filters would not remove the small particulates which transport many of the persistent pollutants. This type of filter would not take the place of the biofilters but could provide a treatment option while the biofiltration program is implemented.

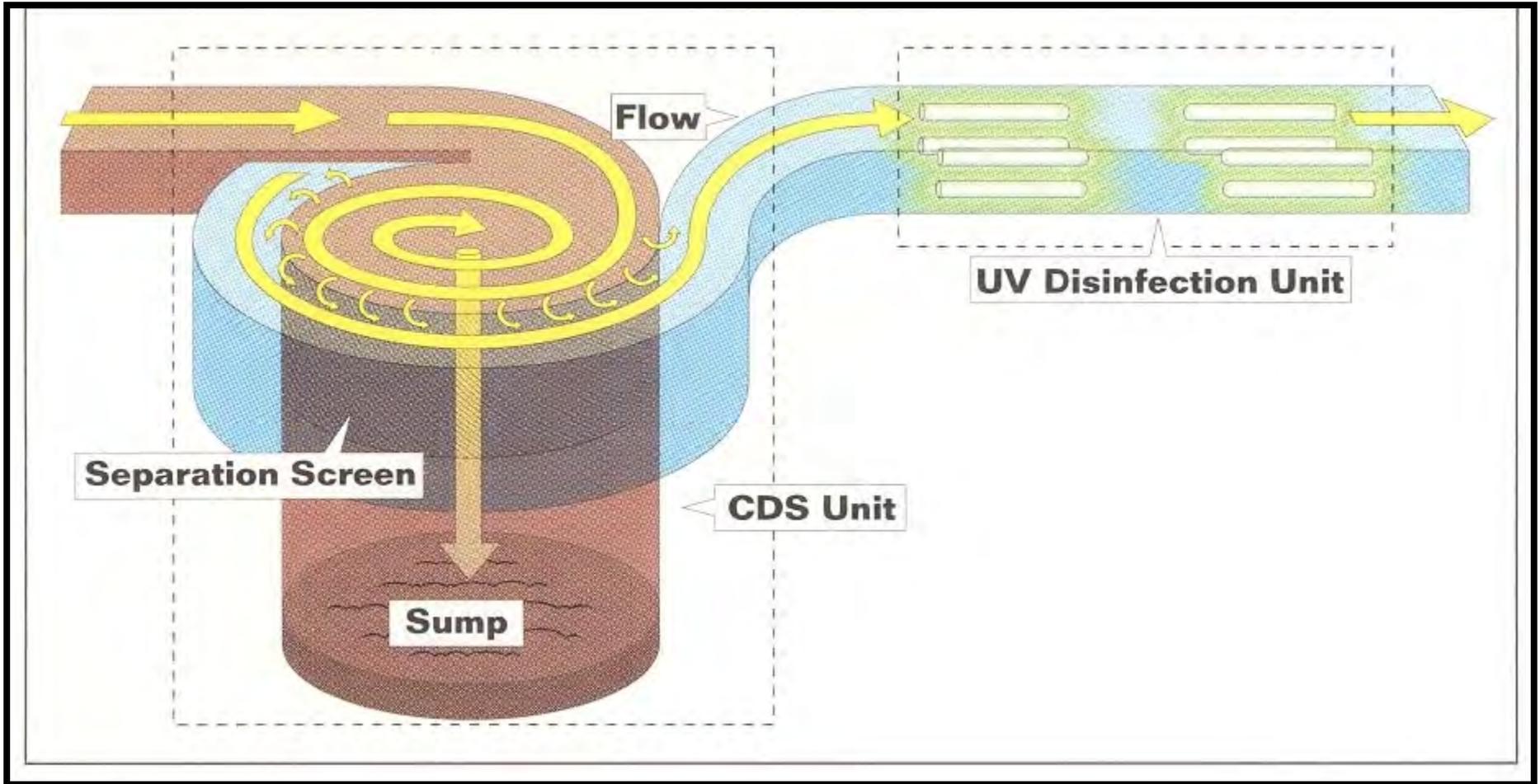


Figure 130: Schematic of In-Line Vortex Filtration Unit

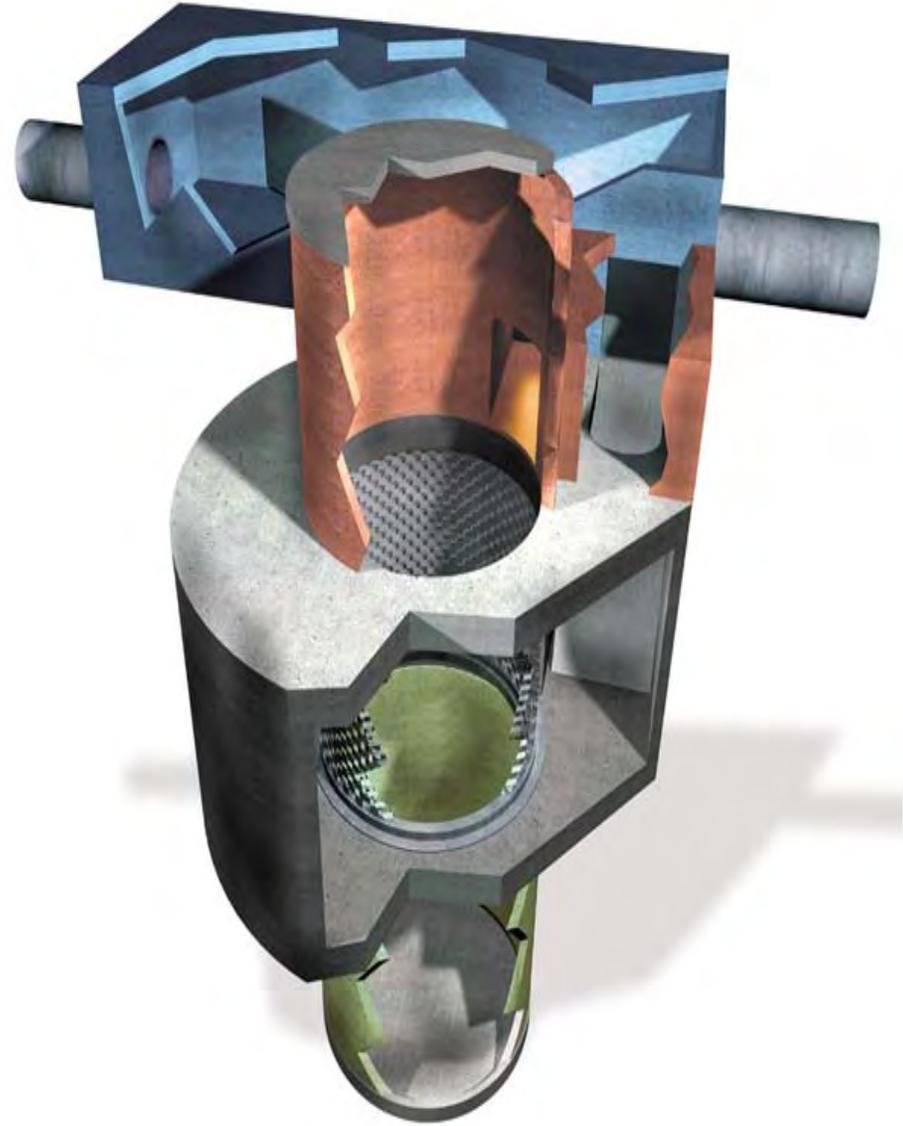
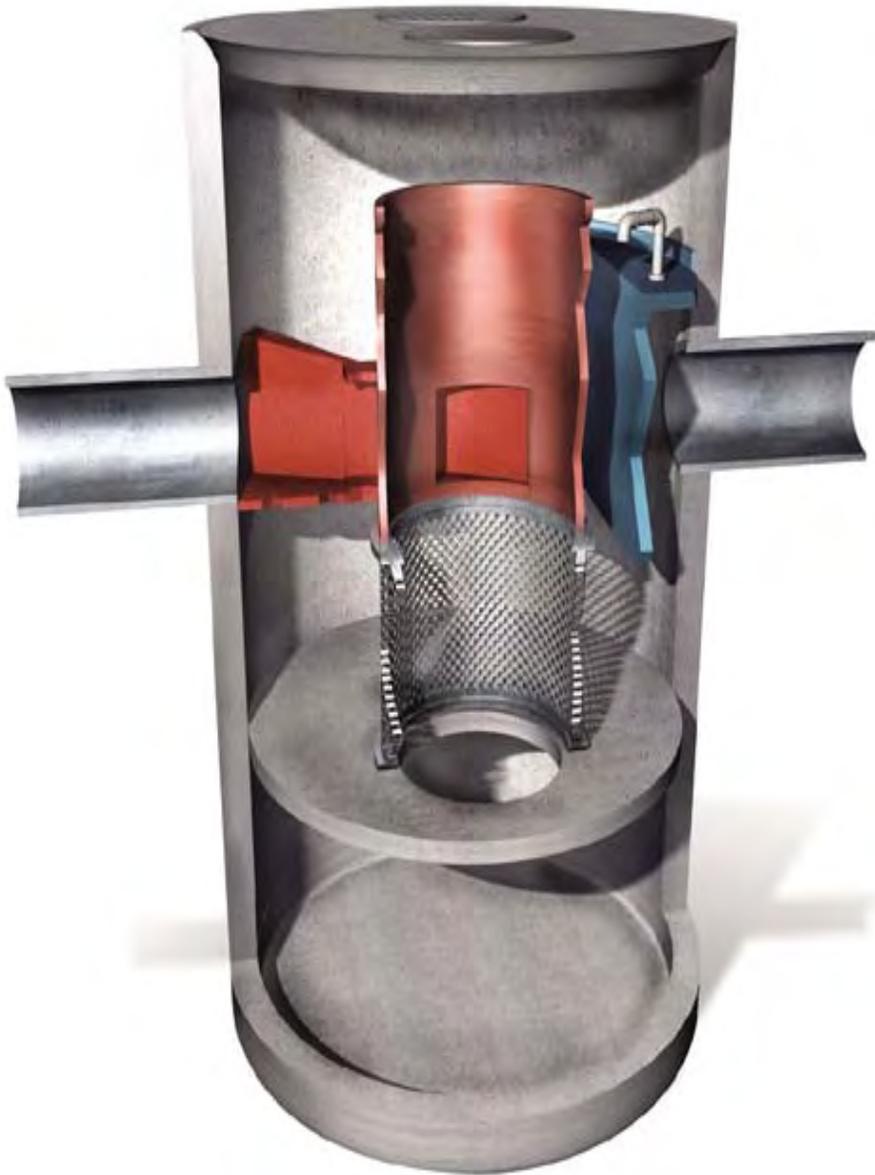


Figure 131: In-Line and Off-Line Vortex Filtration Units

Freshwater Wetlands

There is a limited range of enhancement options for the freshwater wetlands. Most of the wildlife habitat values of freshwater wetlands are found along the open water/vegetation interface. Dabbling ducks and marsh birds such as the red-winged blackbird and marsh wren inhabit freshwater marshes. Dabbling ducks prefer open water areas with adjacent dense shoreline vegetation where they can nest and hide from predators.

The freshwater wetlands in Aquatic Park are completely accessible to numerous predators of wetland birds including dogs. Additionally, human disturbance levels are very high and include homeless encampments. Change to the vegetation of the freshwater wetlands is unlikely to increase habitat values unless disturbance levels can be reduced. Two different options are proposed for the freshwater wetlands: a pilot wetland restoration project and riparian revegetation.

Option: Pilot Freshwater Wetland

Deepening and revegetating the freshwater wetlands to produce a shoreline ring and islands of native vegetation within an open water pond system would benefit wildlife. This type of change could make use of summer flows from several of the local stormdrains. Freshwater wetlands have been documented to filter out and treat particulates, nutrients, bacteria and other pollutants. It is important to design the wetlands to create isolated areas for ducks and other marsh birds, protect several existing willow areas (FW-4) used by songbirds, provide for nearby recreational uses and provide for filtering functions. It is also important to assure that the deeper water does not become a safety hazard and interfere with recreational activities.

The Aquatic Park Subcommittee suggested that the APIP include a pilot freshwater wetland. The pilot would take summer flows from the Dwight Street Stormdrain and would be 1.02 acres in size and located in the northernmost area of the freshwater wetlands. Two different concept designs were prepared (Figure 132 and 133). In Concept Design 1, the edges of the pilot wetland will have a gentle 3:1 slope planted with native rushes, sedges and islands of vegetation. The 3:1 edge will allow for anyone who wanders into the wetland to easily walk out. Water depth would be 7 ft. to limit the growth of tules and cattails to wetland edges and islands. In Concept Design 2, the edges of the wetland will have a rock lining at 1:1 and would maximize water area. A perimeter of sedges, rushes, and cattails would provide a screen for ducks using the deeper water area. As with Concept Design 1, water depth would be 7 ft. For both concepts, a small sediment/trash basin would be created where the stormdrain outlet reaches the park edge. Two small creeklets would carry the flows from the ponds into the Main Lagoon and be planted with *Juncus* sp. and other rush species and be stabilized with rock ledges across the channel in various locations. There will be log weirs in the upstream ends of the creeklet channels to control water levels in the pond. Planting larger riparian species along the creeklets would pose restrictions on use of the grass for recreation and supply little habitat value due to the disturbance and small narrow area.

The pilot freshwater wetland would be excavated from the turf area and FW-1 and the shoreline would have one of the two edge treatments. All invasive plants near the site would

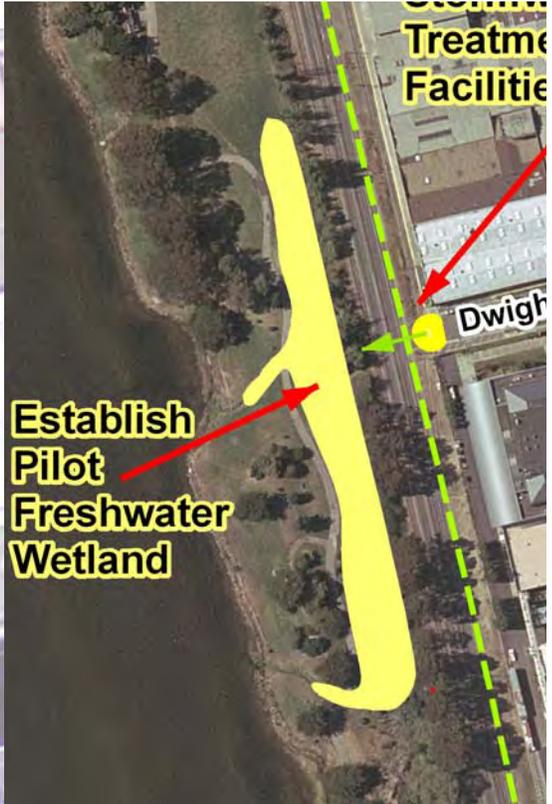
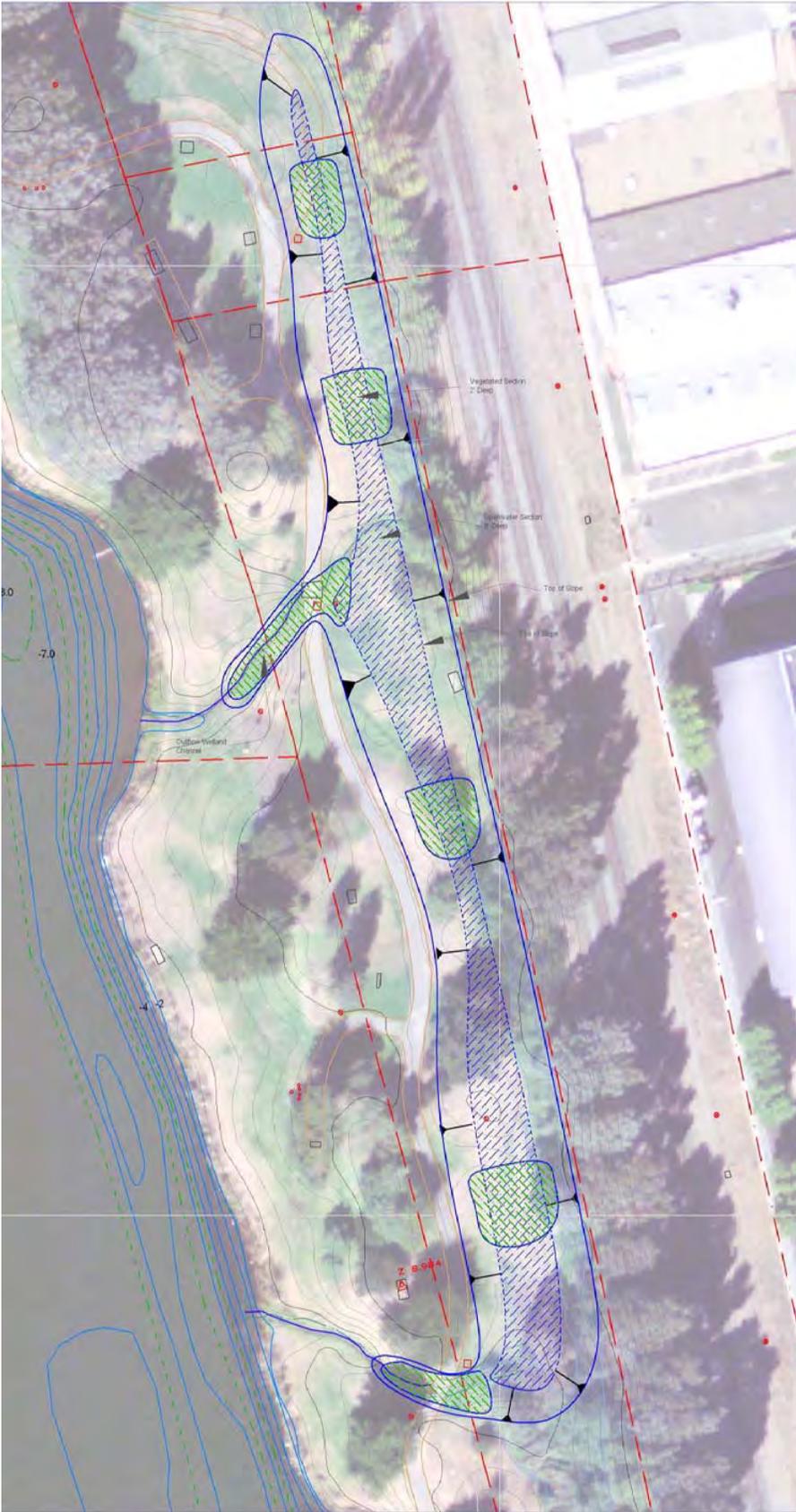


Figure 132: Optional Pilot Freshwater Wetland Concept Design #1 with 3:1 Sideslopes

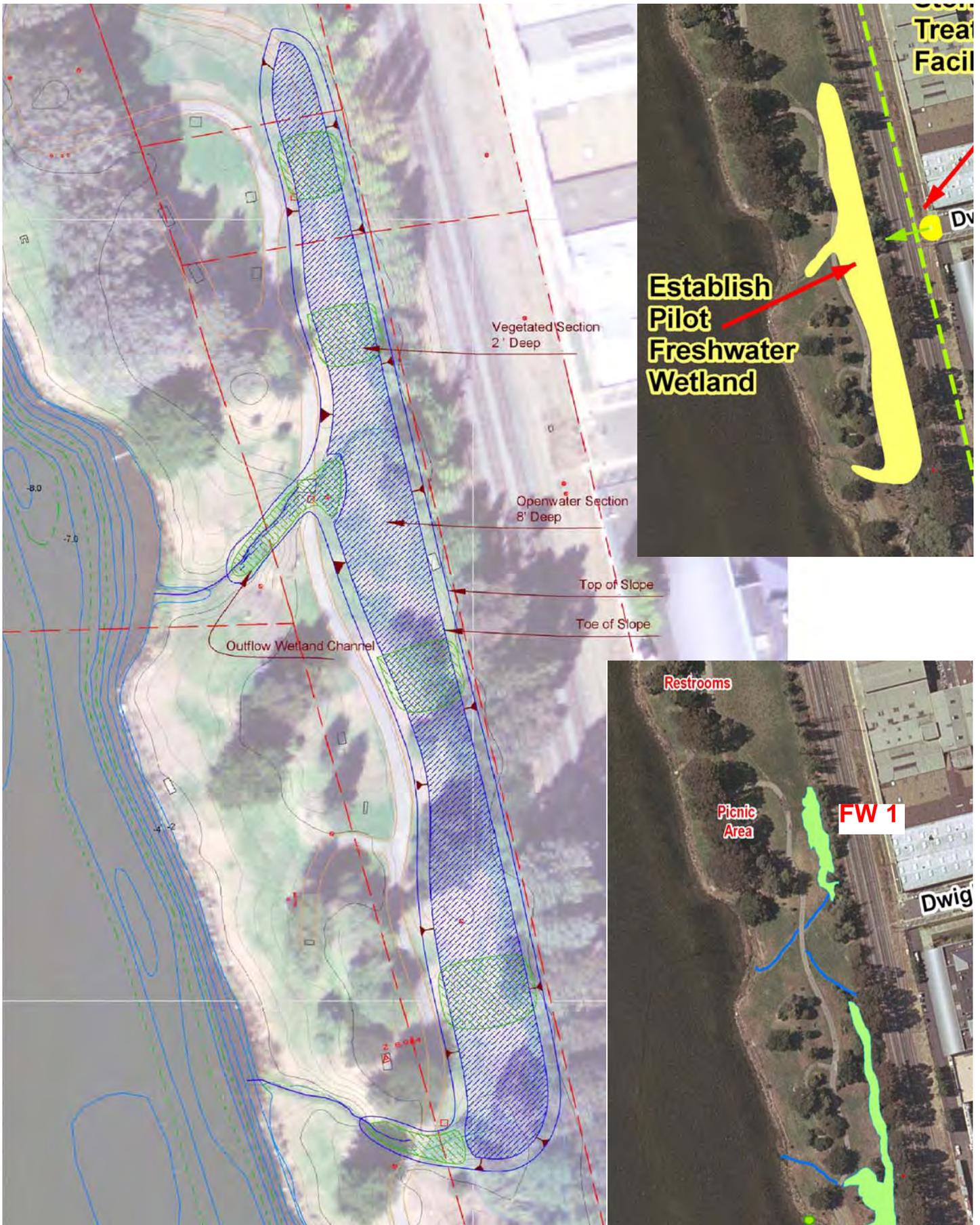


Figure 133: Optional Pilot Freshwater Wetland Concept Design #2 with Hard Edge

be removed prior to excavation. Plugs of native sedges (*Schoenoplectus americanus*, *Schoenoplectus acutus*, *Schoenoplectus californicus*) and rushes (*Juncus balticus*) would be planted along the shoreline and in Concept Design 1 in islands in the pond. Cattails and willow are also likely to colonize the shoreline and island areas.

The proposed pilot project would reconfigure a one acre area to create an open water/vegetation interface to both isolate some habitat areas and produce a more attractive habitat for wetland birds. However, in order to have an adequate water level in the created pond, surface water from the park watershed will be needed in the summer and can be moved from one of the stormdrains into the pond. The Regional Board has a policy which limits the use of existing wetlands for treatment of stormwater. The pilot wetland would use the FW-1 wetland but would be mostly lawn converted to wetland, so it's not clear how this policy will apply. If, due to Regional Water Quality Control Board concerns, additional water is not available from the stormdrains, then creation of the pilot wetland should not move forward.

If the freshwater wetland cannot be adequately improved, then the saturated soils could be used to increase the riparian habitat in the area. Red willow (*Salix laevigata*), white alder (*Alnus rhombifolia*), dogwood (*Cornus sericea*), currant (*Ribes sanguineum*), and other native riparian species could be planted in wetland FW-3 or FW-4. The English ivy that covers many trees in this area should be removed. This is listed as Stage 2 of invasives removal in Table 24. The other invasive plants—broom, pampas grass, and Himalayan blackberry—will be removed as part of Stage 1 of invasives control. A strategy to remove disturbance other than building an isolating water feature would be needed if the new vegetation is to support wildlife.

For the five small creeklet channels that cross through the turf from the freshwater wetlands to the Main Lagoon, some vegetation is needed (Figure 86). These small creeklets would look better with a treatment of rock and low-growing native plants such as rushes (*Juncus*) and sedges (*Carex* and *Cyperus*). The use of larger species such as cattails and willows would interfere with current recreational uses and dissect the grass into small areas and probably show considerable trampling. In general these creeklets are not large enough to provide an adequate area for wildlife use; they are also highly disturbed since they are located in the middle of a recreational area. The creeklets should retain a narrow form and be planted with low-growing wetland plants. If the creeklet channels are widened, it is likely that cattails will grow and the ground will be very muddy. For these reasons, changing the form of the creeklet channels is not recommended.

Reducing Disturbance in Habitat Areas

The greatest challenge to creating viable wildlife habitats at Aquatic Park is buffering habitat areas from the high level of human activity and unleashed dogs in the park. The eastern side of the park has the highest amount of human activity, but both the east and west sides of the park suffer from unleashed dogs disturbing birds and wildlife and sometimes chasing them into the lagoons. The west side is the primary focus for habitat improvements to take advantage of the lower level of disturbance.

The following recommendations should be implemented to assure that restored habitats can support wildlife:

- Restrict off-leash dogs and people from the restoration areas through the use of signs, leash-law enforcement and, if required, fencing
- Restrict homeless encampments and trash dumping through focused enforcement and signage

Adaptive Management

Adaptive management is an approach used in ecological restoration projects and involves changing management strategies as ecosystem monitoring and performance is evaluated. There are several types of management strategies at Aquatic Park that should use this approach.

Prior to implementing the water circulation improvements, a water and sediment quality characterization study of the Main Lagoon could be done. This study will establish the baseline conditions in the system and allow long-term comparison with post-project conditions. Sediment quality characterization involves collecting sediment samples from a variety of locations in each lagoon. The samples would be analyzed for sediment grain size (sand vs. mud), bulk chemistry (presence and concentrations of contaminants) and bioassays (acute toxicity of sediment and/or elutriate to typical marine invertebrate test organisms). Because most persistent urban contaminants, such as heavy metals, PCBs, DDT, oil and gas (PAHs), are transported into tidal areas on clay particles, nearshore estuarine areas have greater contaminant levels in sediments rather than the water column. The sediment characterization study would provide the baseline for comparison with future tests and a determination of the suitability of placing oyster beds in the Main Lagoon.

Water quality monitoring should also be done and should use continuous monitoring devices to track basic indicators – temperature, dissolved oxygen, salinity, and pH. In addition, a number of other parameters should be measured less frequently including nutrients (nitrate, ammonia, total phosphorus); organophosphate pesticides, total dissolved solids (TDS) and total suspended sediment (TSS), a range of polycyclic aromatic hydrocarbons (PAHs), PCBs, metals and trace elements, coliform and chlorophyll to evaluate algal growth. Water quality monitoring should be done to characterize summer/fall conditions under the current system once the water circulation improvements are implemented. Post-project monitoring of water clarity and salinity can be used to evaluate if eelgrass should be planted in the Main Lagoon.

Another component of the baseline and on-going monitoring could be characterization of the benthic invertebrates which inhabit various areas of the lagoons. The diversity and abundance of invertebrates provides an indicator for the ecological health of the lagoon system. Worms, mollusks and crustaceans would be expected to live in the intertidal and subtidal mud layers. The diversity, abundance and distribution of these animals would be characterized as a baseline condition, and then at annual intervals, as part of the lagoon monitoring program.

The water circulation improvements and their predicted outcomes are based on a detailed computer model of the watershed and lagoon system. The model has field data to describe the

system and simulate the complex of fresh and tidal water flows into and out of the system. The choice of a particular improvement, Alternative 4B, is based on the model's analysis and on professional judgment. However, no model perfectly simulates real world conditions. Therefore, once the project is built, monitoring of water levels and water quality is recommended. The system will be built to allow flap gates to be installed on the various inlet/outlet connections to change tidal flow direction or level if needed.

The detailed pre- and post-project monitoring can be used in evaluating the effects on the aquatic habitat of various settings of the gates on the tide connections. The monitoring results for salinity at surface and at depth and other water quality parameters, along with the extent and abundance of the invertebrate communities in the lagoons, will indicate the overall health of the aquatic habitat and the need for management changes. This monitoring data should be evaluated by an independent Technical Advisory Committee, composed of concerned scientists and agencies, to determine if the water gate settings for the lagoons should be changed.

For the upland habitat areas, adaptive management practices could be used in revising revegetation and replanting practices and/or species. Monitoring of planting success should be done, recording growth/density measurements along with location, irrigation volumes, wind exposure, sun/shade conditions, and noting whether protective hardware and/or weed mat was used. This information can be used to guide replanting efforts and choice of species as the revegetation project progresses.

A final level of adaptive management should review the success of first step efforts to control human and unleashed dog disturbance to habitat areas. The habitat areas should be photographed regularly and inspected for dog tracks. If signs and periodic enforcement do not decrease disturbance from unleashed dogs, the next step of fencing the areas may need to be implemented. The success of efforts to reduce homeless encampments and any other activities that are used to reduce habitat disturbance should be reviewed no less frequently than yearly and revised as needed to increase effectiveness.

SUMMARY OF RECOMMENDATIONS

The Aquatic Park Implementation Program includes the following recommendations:

Hydrology Improvements

1. Aquatic habitat improvement is the highest priority action for park enhancement.

Aquatic habitat is the primary habitat in Aquatic Park and suffers from poor water quality conditions in the summer and fall. A major increase in water circulation and tidal exchange is needed to improve habitat to support fish and other aquatic life.

2. Maximize the increase in tidal circulation and tidal volume. The current five tide tubes that provide tidal water to the Main Lagoon are falling apart. A new and improved tidal connection and water circulation system is needed. Alternative 4B would create larger connections at the Potter Street and Strawberry stormdrains, and would include excavation of 214 cubic yards to create a new open channel between the Model Yacht Basin and the Main Lagoon, and a structure to protect the bay side of the five tide tubes. This alternative would increase the volume of tidal water entering the Main Lagoon from 22 acre-feet to 115 acre-feet per tidal cycle. Alternative 4B provides the largest tidal range and the greatest water quality improvement. Due to the low elevation of the Radio Transmitter Building, the tidal range at the Radio Tower Pond cannot be changed unless a berm is constructed around the building.

3. Block stormwater inflow volumes at new connections. Enlarging the connections at the Potter Street and Strawberry stormdrains could allow more urban runoff into the lagoon. Slide gates will be installed at the new connections. The gates will be able to block first flush flows which carry the largest concentrations of pollutants. The gates will also be used to block the maximum amount of stormwater. In addition, increasing tidal circulation will remove stormwater at a much faster rate than under current conditions and will reduce effects on aquatic life.

4. Consider installing a bioswale along the road/lawn on the northeastern end of the park to filter stormwater flowing directly from streets into the park.

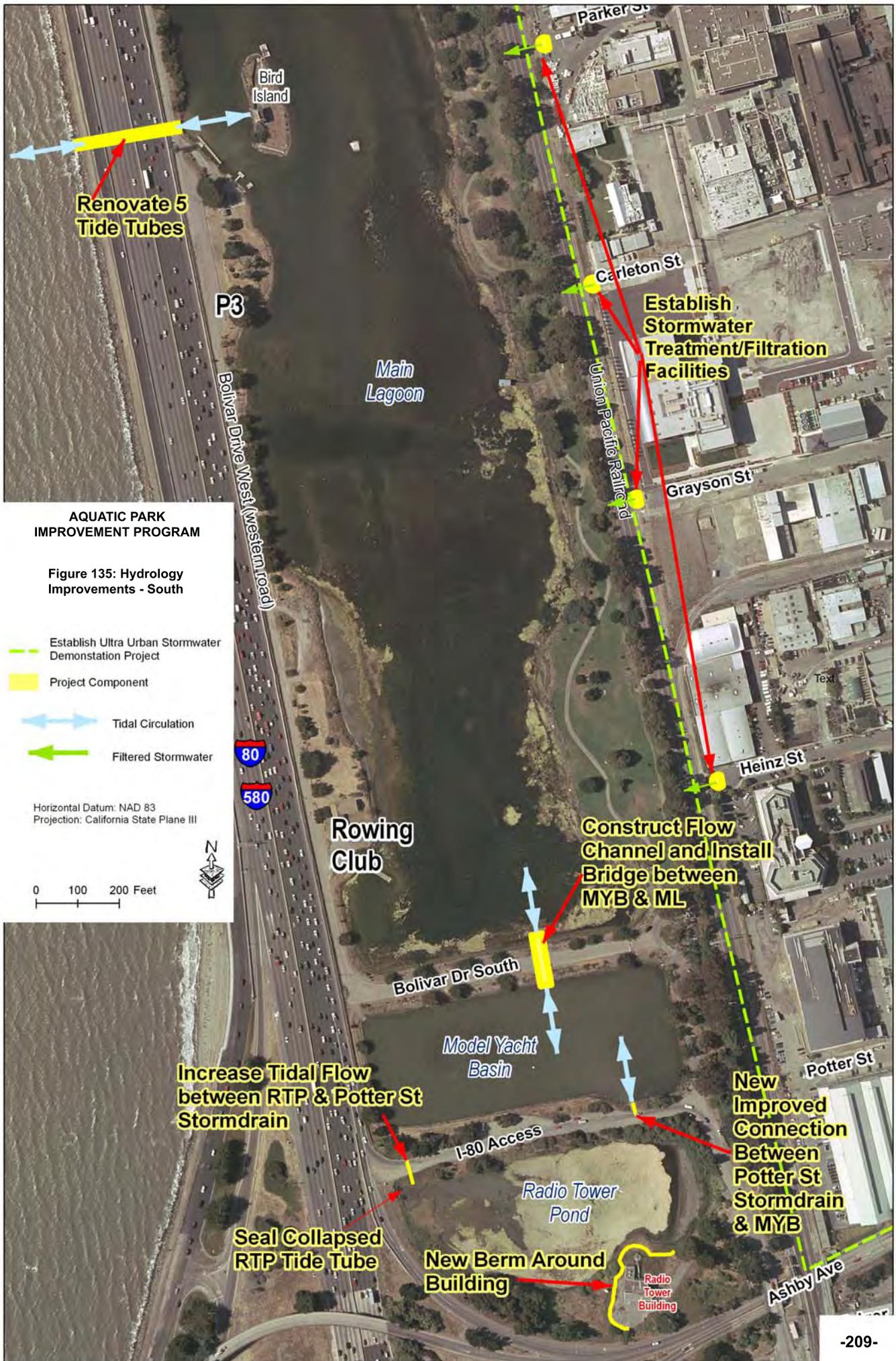
5. Consider creating a demonstration area for ultra urban stormwater treatment using biofiltration facilities installed on streets, parking lots and other locations in the Aquatic Park watershed. These facilities will reduce the concentration of pollutants in stormwater which directly enters the Main Lagoon.

OPTIONAL ACTION

Consider installation of in-line vortex filtration units on stormdrains at the eastern edge of the railroad/western ends of Dwight, Channing, and Bancroft Streets. For the stormdrains at Parker, Carleton, Grayson, and Heinz Streets, vortex filter units can be installed in the park to replace the oil/water separators. The vortex filters would not remove the small particulates which transport many of the persistent pollutants, but would provide a treatment option while the biofiltration program is implemented.

Figures 134 and 135 depict the recommended actions for hydrology improvements.





**AQUATIC PARK
IMPROVEMENT PROGRAM**

**Figure 135: Hydrology
Improvements - South**

- Establish Ultra Urban Stormwater Demonstration Project
- Project Component
- ⇔ Tidal Circulation
- ← Filtered Stormwater

Horizontal Datum: NAD 83
Projection: California State Plane III

0 100 200 Feet



Habitat Improvements

1. **Implement a salt/brackish wetland restoration on 1.3 acres at the Rowing Club site.** Excavate the site to the -1.5 ft. (Berkeley Datum) elevation to create salt marsh and high marsh transition areas. Install a berm along the road edge of the site to serve as a vegetated transition area and barrier to unleashed dogs.
2. **Reuse excavated material from wetland creation to restore additional areas.** The Rowing Club site elevations are -1 to +4 ft. and will require excavation of 6,230 cubic yards of soil. If soils tests show the material is acceptable, the excavated material could be used for improving bird roosting habitat on Bird Island and native plant re-vegetation areas (P-1, P-2 and P-3).
3. **Remove invasive plants in all shoreline areas and all stem and seed-reproducing invasive plants in other areas of the park.** Invasive plants on and near existing wetlands, especially in the Radio Tower Pond and near the wetland restoration site, need to be eradicated to make the wetland restoration a success.
4. **Replant shoreline areas with native plants.** Remove dead trees on the shoreline and replant with cypress seedlings and native vegetation.
5. **Fill Bird Island with soil excavated from the wetland creation to create areas for tree planting for bird roosting habitat.**
6. **Install additional nearshore roosting structures** for birds made up of anchored floating platforms, rock or large wood
7. **Asphalt parking areas on the western side of the Main Lagoon (P1, P2, and P3) are no longer used and would be removed and covered with 2.5 feet of excavated soil and revegetated with native plants.**
8. **Eradicate ivy in freshwater wetlands and increase riparian habitat in FW-3 and FW-4 areas.**
9. **Monitor water quality and aquatic life.** Increasing the tidal volume and circulation will reduce stagnant warm water conditions and increase dissolved oxygen. As part of the implementation of tidal improvements, both water quality and aquatic life should be monitored. The results of the monitoring should be used to revise management and, if possible, implement additional subtidal habitat improvements such as eelgrass plantings, creation of oyster beds and placement of rocks for herring spawning.
10. **Post and enforce wildlife protection regulations, including leash laws, throughout the park.** Shoreline improvements recommended in the 2005 Bird Study include planting willow or other dense vegetation and fencing the shoreline to reduce disturbance from recreation and dogs. The fencing recommendation will conflict with other recreational uses. Posting and enforcing rules against off-leash dogs and informing park visitors of how to

behave to reduce negative effects on the birds should be tried prior to fencing the shoreline on new habitat areas.

11. Address homeless encampments and evaluate the number and location of trash cans to reduce dumping and littering.

OPTIONAL AND FUTURE ACTIONS

12. Evaluate construction of a 1.0 acre pilot freshwater wetland incorporating FW 1 and the adjacent lawn. Summer water from the stormdrain system would be needed for the wetland.

13. Plan a tree replacement program. Eucalyptus and Acacia make up the largest area of invasive non native plants in the park. As part of future efforts to remove these trees, a tree replacement planting program should be initiated to evaluate the locations and species for replacement trees well in advance of the removal of Acacia and Eucalyptus. As the outer railroad tracks are returned to active use there is high likelihood that the Eucalyptus will be trimmed or cut.

Figures 136 and 137 depict the recommended actions for habitat improvements.

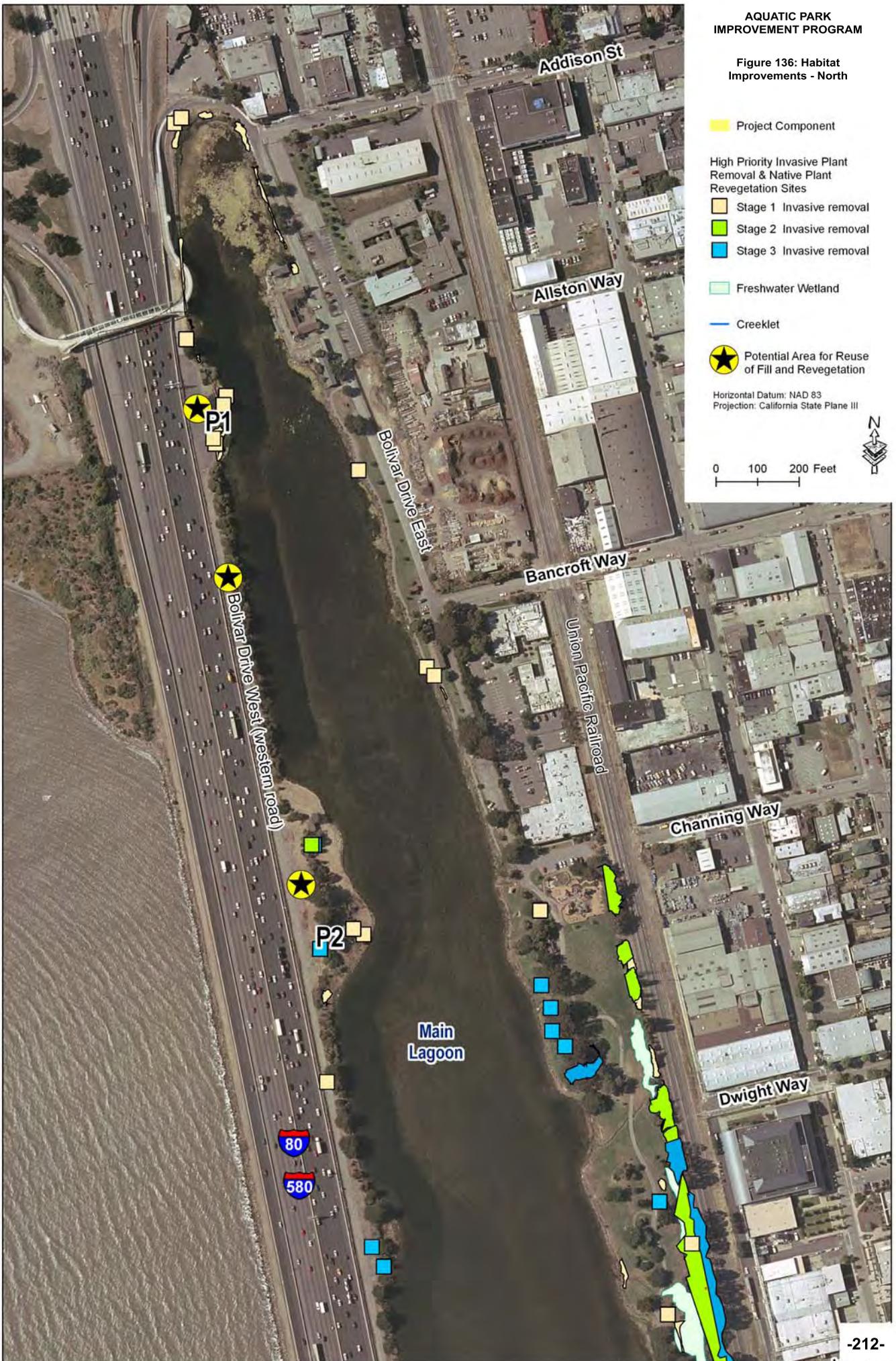
**AQUATIC PARK
IMPROVEMENT PROGRAM**

**Figure 136: Habitat
Improvements - North**

- Project Component
- High Priority Invasive Plant Removal & Native Plant Revegetation Sites
 - Stage 1 Invasive removal
 - Stage 2 Invasive removal
 - Stage 3 Invasive removal
- Freshwater Wetland
- Creeklet
- ★ Potential Area for Reuse of Fill and Revegetation

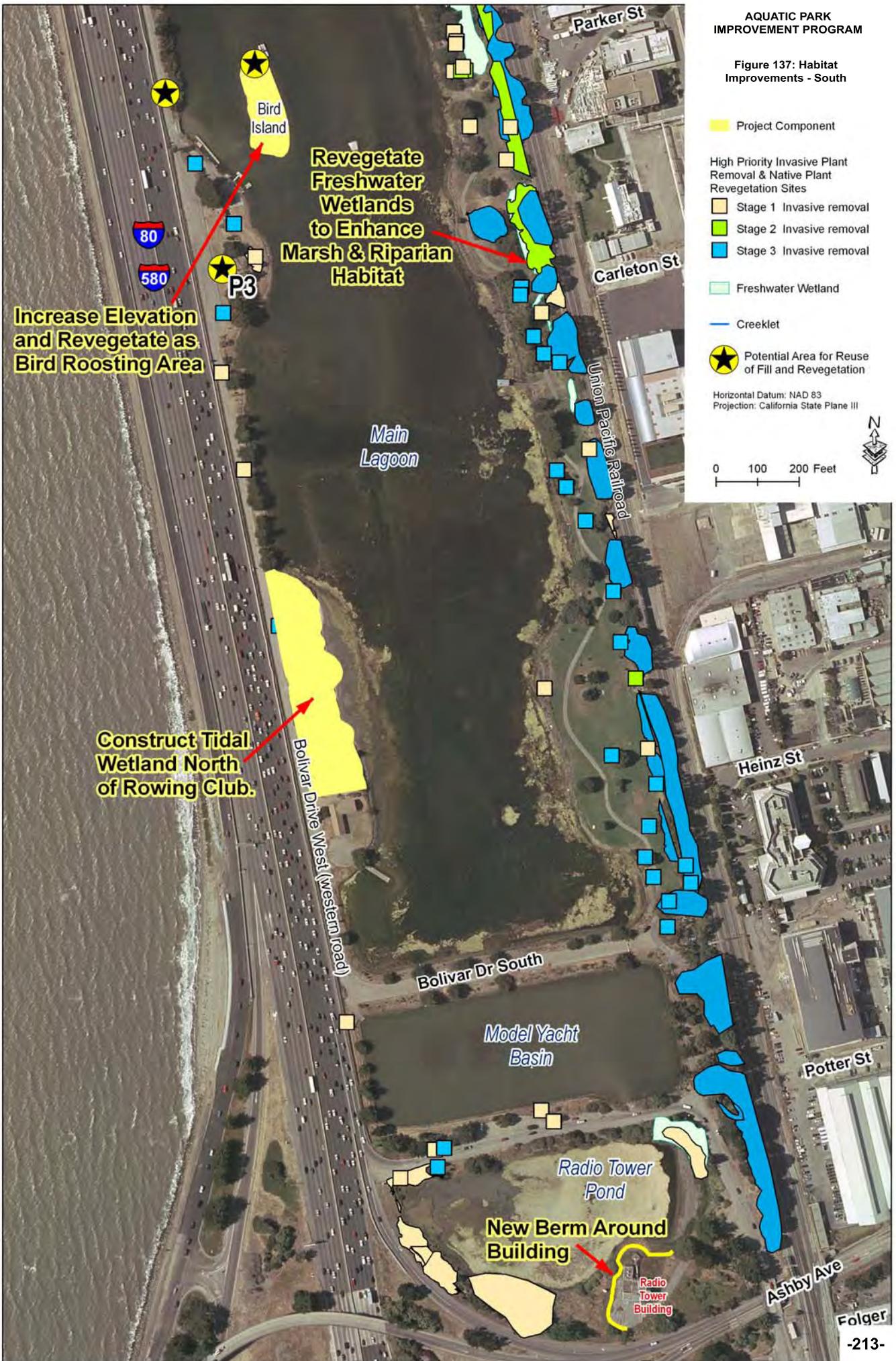
Horizontal Datum: NAD 83
Projection: California State Plane III

0 100 200 Feet



**AQUATIC PARK
IMPROVEMENT PROGRAM**

**Figure 137: Habitat
Improvements - South**



ADDITIONAL STUDIES AND ENVIRONMENTAL REVIEW

The next steps in the implementation of the Aquatic Park Improvement Program are to:

- 1) Complete several studies;
- 2) Complete a CEQA (California Environmental Quality Act) document on the project;
- 3) Complete a grant process with the Coastal Conservancy;
- 4) Complete the permit process.

There are several features of the recommended project that need additional analysis:

1. Soils in the salt/brackish wetland excavation area and Model Yacht Basin to Main Lagoon channel excavation area need to be tested. These tests would determine if there are any contaminant levels which would limit re-use of the soil for restoration projects on Bird Island and the P1, P2, and P3 upland sites.
2. The City of Berkeley will serve as the lead agency for the CEQA review.

Public Scoping Session*

Prepare Draft Initial Study (DIS)—by City/Consultant

30 day Public Review Period for DIS*

Prepare Special Studies, if needed—by City/Consultant

Prepare Draft Mitigated Negative Declaration (MND) or Environmental Impact Report (EIR)—by City/Consultant

30 days Public Review Period of MND (or 45 days Public Review Period if EIR)*

Public Hearing at Commission*

Response to Comments/Final EIR or MND—by City/Consultant

Public Hearing at Commission*

Public Hearing at Council*

*indicates a public meeting

3. Once CEQA is completed, the City can work with the California Coastal Conservancy to gain approval of the proposed \$2.0 million in funding. This funding is expected to cover only parts of the APIP including hydrology improvements for aquatic habitat, salt/brackish wetland creation, shoreline invasives removal and revegetation, and

enhancement of Bird Island and areas P1, P2, and P3. Table 29 summarizes the cost of the program components and potential funding sources.

4. Concurrent with the CEQA process, the City will need to apply for permits to implement the APIP from the Regional Water Quality Control Board, the Army Corps of Engineers and the California Department of Fish and Game for most of the project components, and the San Francisco Bay Conservation and Development Commission and the Army Corps of Engineers for the bay side structure to protect the five tide tubes.

Table 29 - Aquatic Park Improvement Program			
Preliminary Draft Planning Level Cost Estimate - Capitol Cost Summary			
No.	Project Component	Cost (\$)	Potential funding source
1	Strawberry Drain Improvement	\$230,000.00	State Coastal Conservancy grant
2	Main Culvert Structure	\$250,000.00	State Coastal Conservancy grant
3	Model Yacht Basin - Main Lagoon Connection	\$190,000.00	State Coastal Conservancy grant
4	Potter Street Connection	\$300,000.00	State Coastal Conservancy grant
5	Radio Tower Pond Connection	\$130,000.00	CalTrans
6	Salt/Brackish Wetland Creation, Upland Area Creation/Bird Island	\$420,000.00	State Coastal Conservancy grant
7	Invasive Plant Removal/one re-treatment	\$230,000.00	State Coastal Conservancy grant
8	Native Plantings/replanting for first 3 years	\$230,000.00	State Coastal Conservancy grant
Subtotal	State Coastal Conservancy grant	\$2,000,000.00	
Subtotal	CalTrans - Radio Tower Pond	\$130,000	
9	Biofiltration - Demonstration project one sub-basin	\$2,430,000.00	Stormwater grants, CalTrans Stormwater mitigation funds
OPTIONAL TASKS			
10	Vortex filters outside of park at Dwight, Channing, and Bancroft Street stormdrains	\$1,540,000.00	Stormwater grants redevelopment funds, CalTrans
11	Biofiltration - Additional sub-basins up to 200 acres of watershed	\$9,800,000.00	Stormwater grants redevelopment funds, CalTrans
12	Vortex filters to replace oil/water separators in park on Heinz, Grayson, Carleton, and Parker Street stormdrains	\$790,000.00	Stormwater grants redevelopment funds, CalTrans
13	Freshwater Wetland Creation	\$160,000.00	Stormwater grants redevelopment funds, CalTrans

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- Low Impact Development Center: www.lowimpactdevelopment.org
- Stormwater Manager's Resource Center: www.stormwatercenter.net
- National NEMO Network: www.nemonet.uconn.edu
- LID Urban Design Tools: www.lid-stormwater.net

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AQUATIC PARK IMPROVEMENT PROGRAM TECHNICAL REPORT APPENDICES



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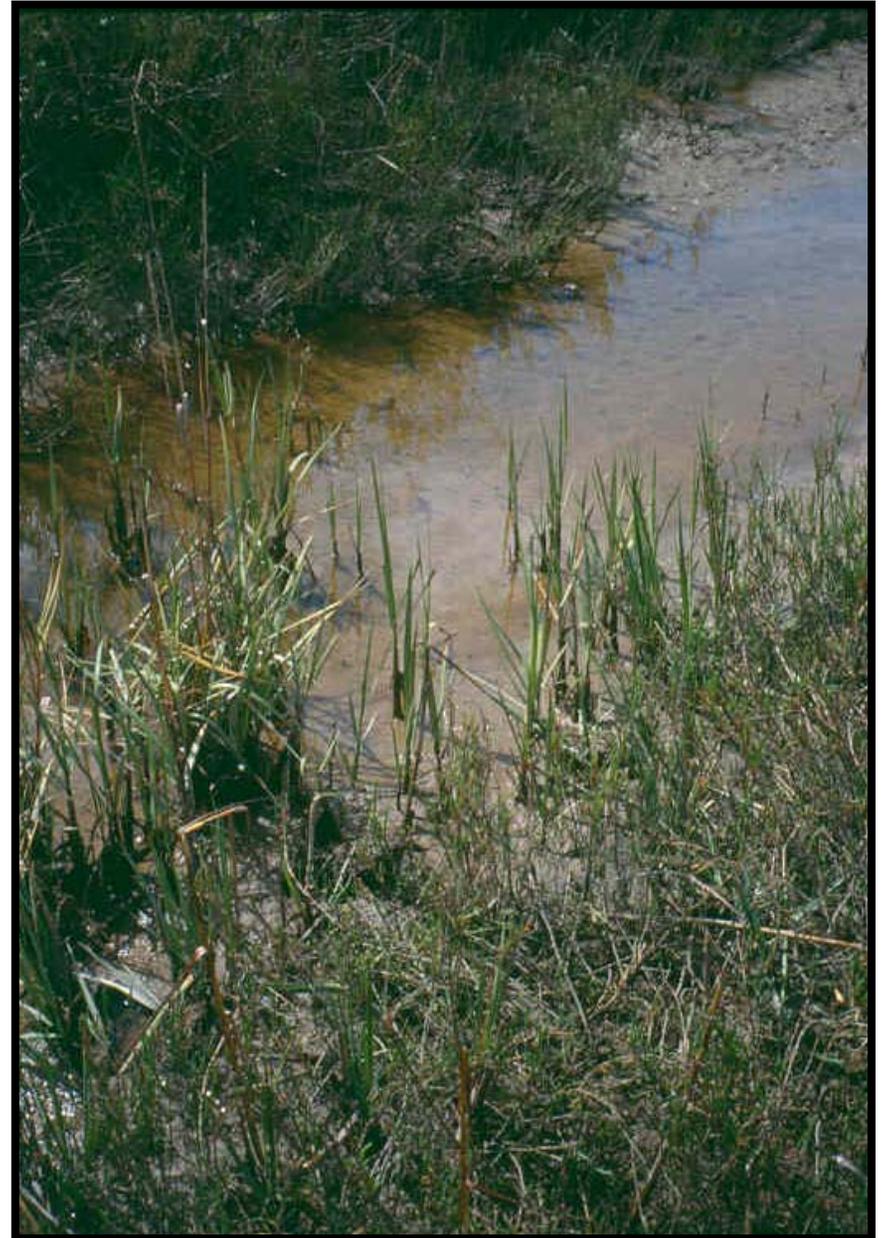
APPENDIX A

Plants

**Salt/Brackish Wetland Plant
Species**



Cordgrass (*Spartina foliosa*)



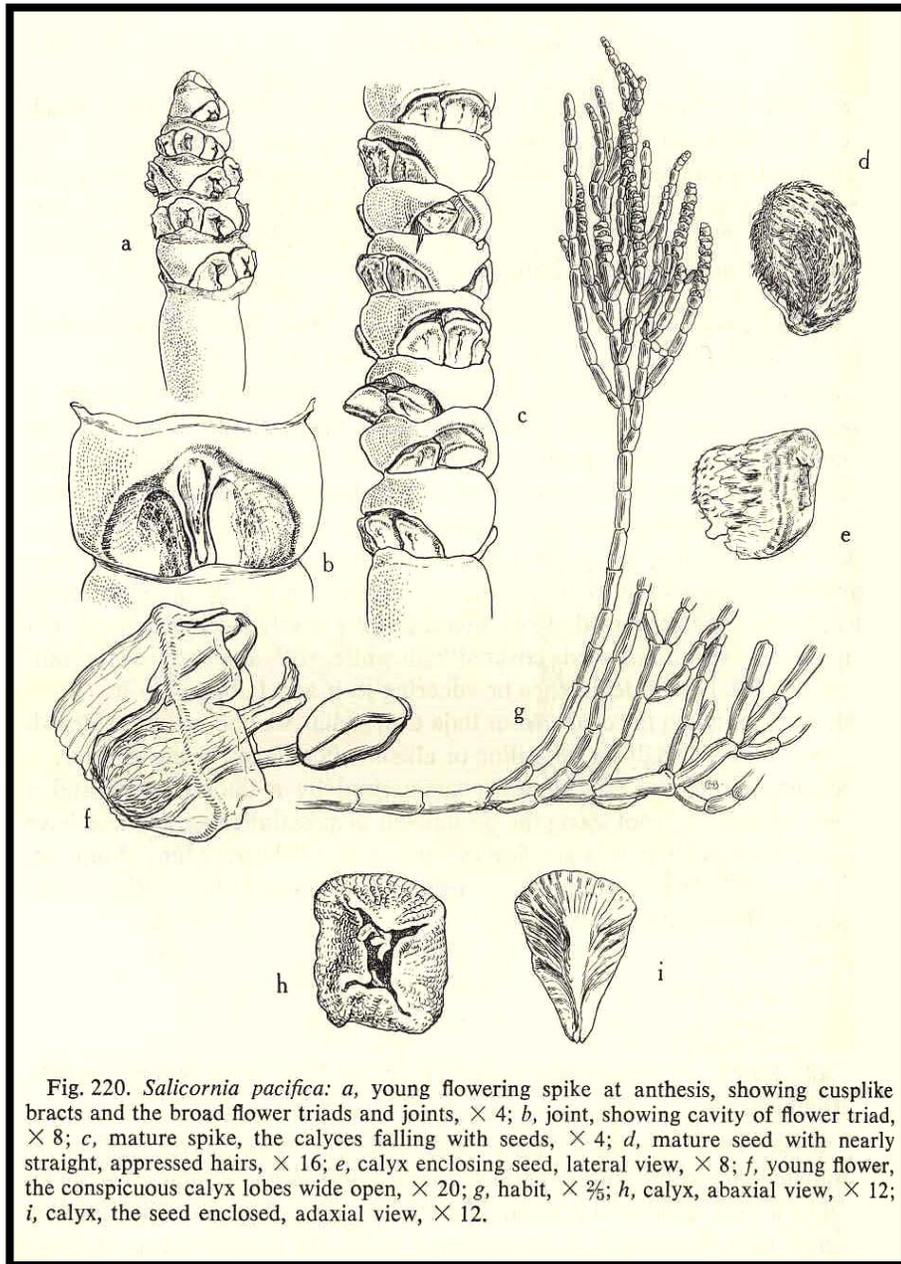


Fig. 220. *Salicornia pacifica*: a, young flowering spike at anthesis, showing cusplike bracts and the broad flower triads and joints, $\times 4$; b, joint, showing cavity of flower triad, $\times 8$; c, mature spike, the calyces falling with seeds, $\times 4$; d, mature seed with nearly straight, appressed hairs, $\times 16$; e, calyx enclosing seed, lateral view, $\times 8$; f, young flower, the conspicuous calyx lobes wide open, $\times 20$; g, habit, $\times \frac{2}{5}$; h, calyx, abaxial view, $\times 12$; i, calyx, the seed enclosed, adaxial view, $\times 12$.

Pickleweed (*Salicornia pacifica*)



Salt grass (*Distichlis spicata*)

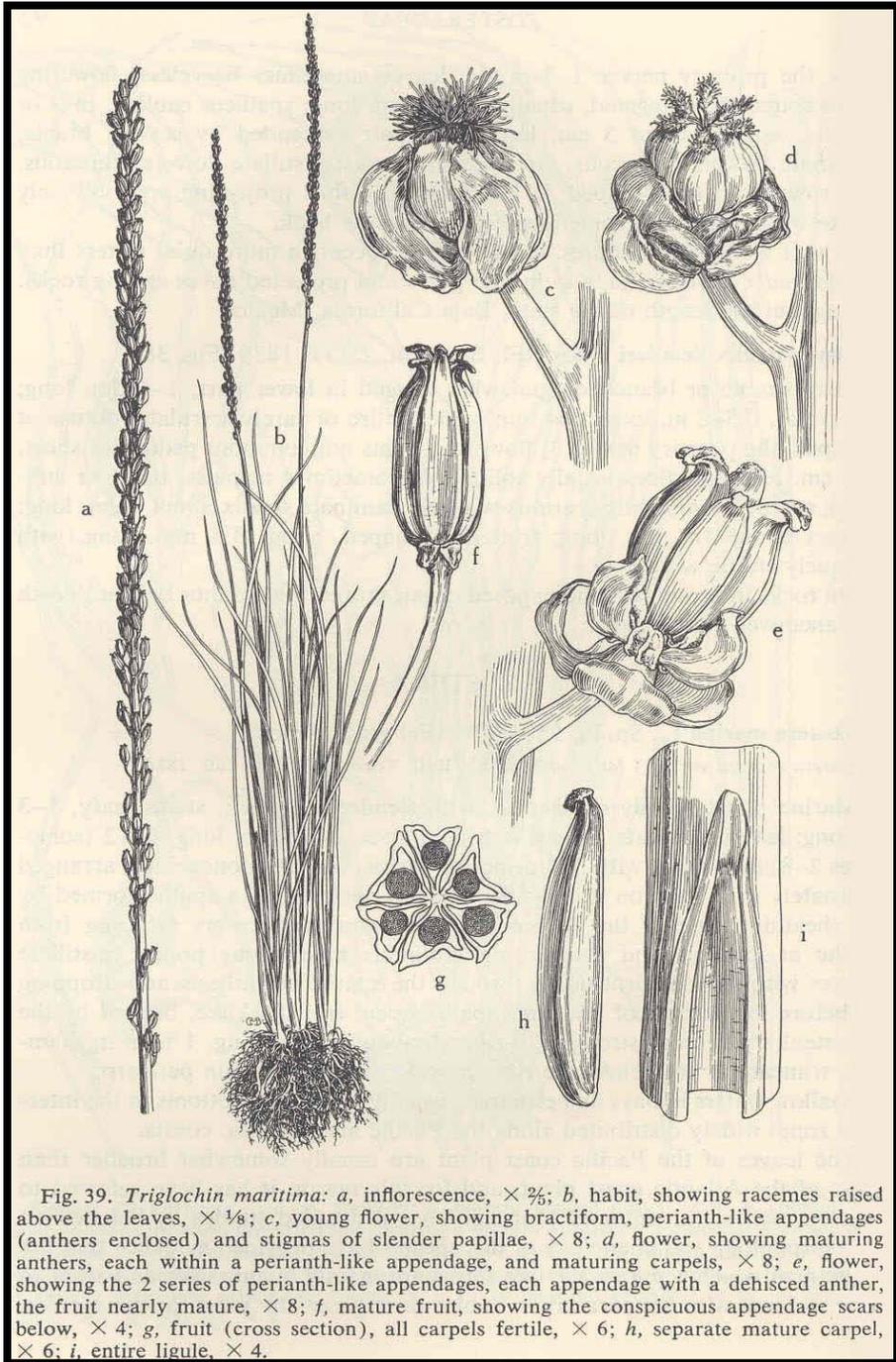
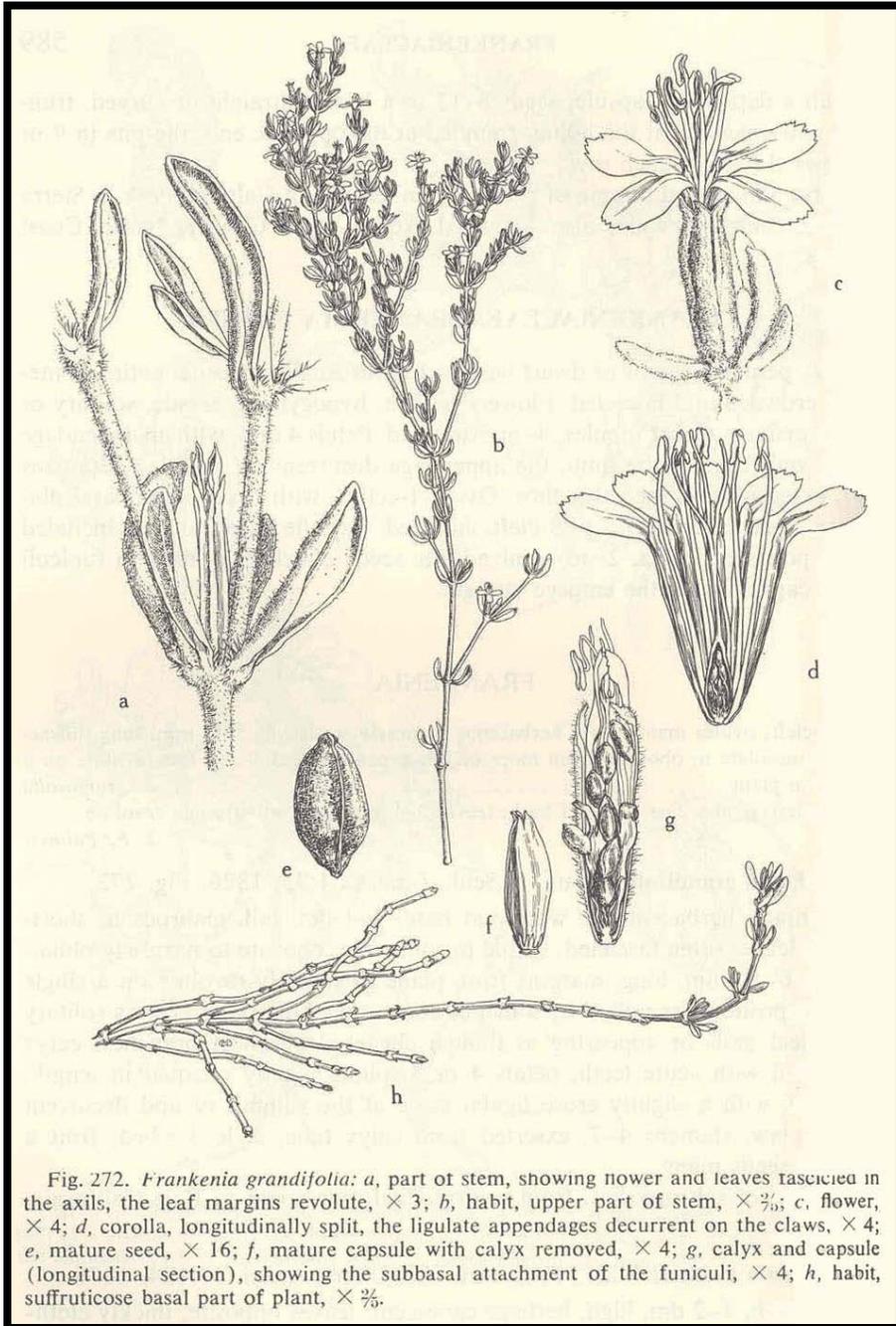


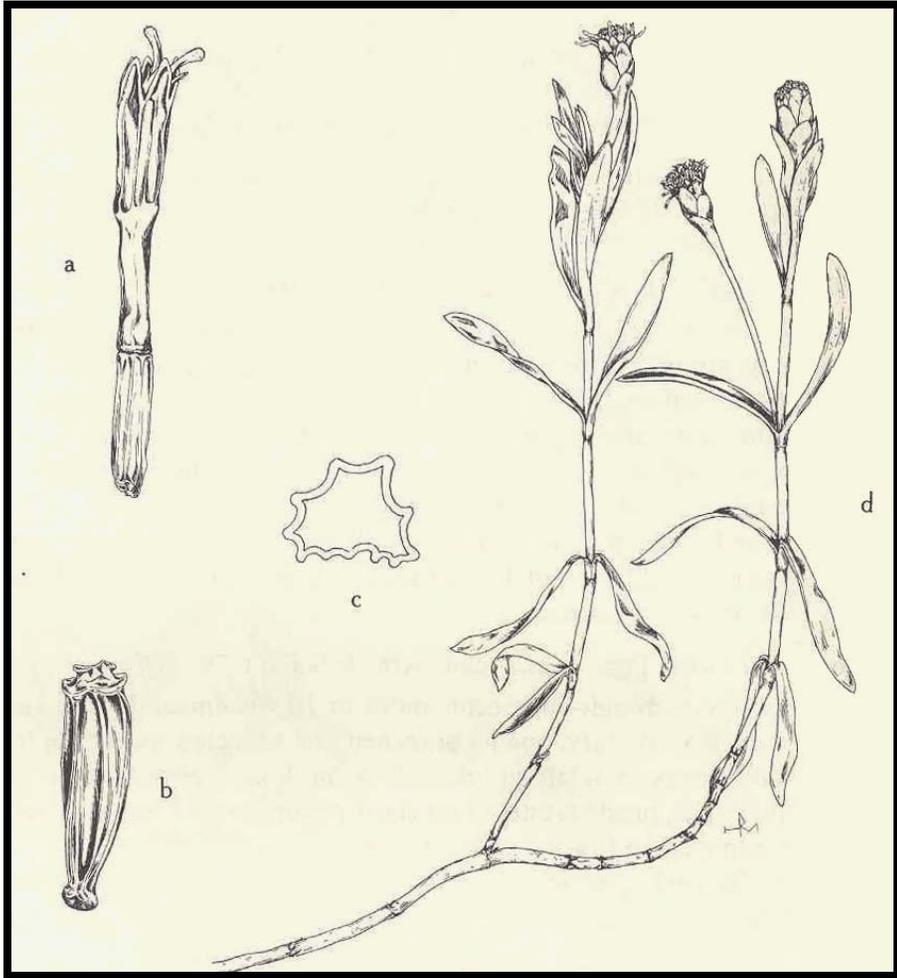
Fig. 39. *Triglochin maritima*: a, inflorescence, $\times \frac{2}{5}$; b, habit, showing racemes raised above the leaves, $\times \frac{1}{8}$; c, young flower, showing bractiform, perianth-like appendages (anthers enclosed) and stigmas of slender papillae, $\times 8$; d, flower, showing maturing anthers, each within a perianth-like appendage, and maturing carpels, $\times 8$; e, flower, showing the 2 series of perianth-like appendages, each appendage with a dehiscent anther, the fruit nearly mature, $\times 8$; f, mature fruit, showing the conspicuous appendage scars below, $\times 4$; g, fruit (cross section), all carpels fertile, $\times 6$; h, separate mature carpel, $\times 6$; i, entire ligule, $\times 4$.



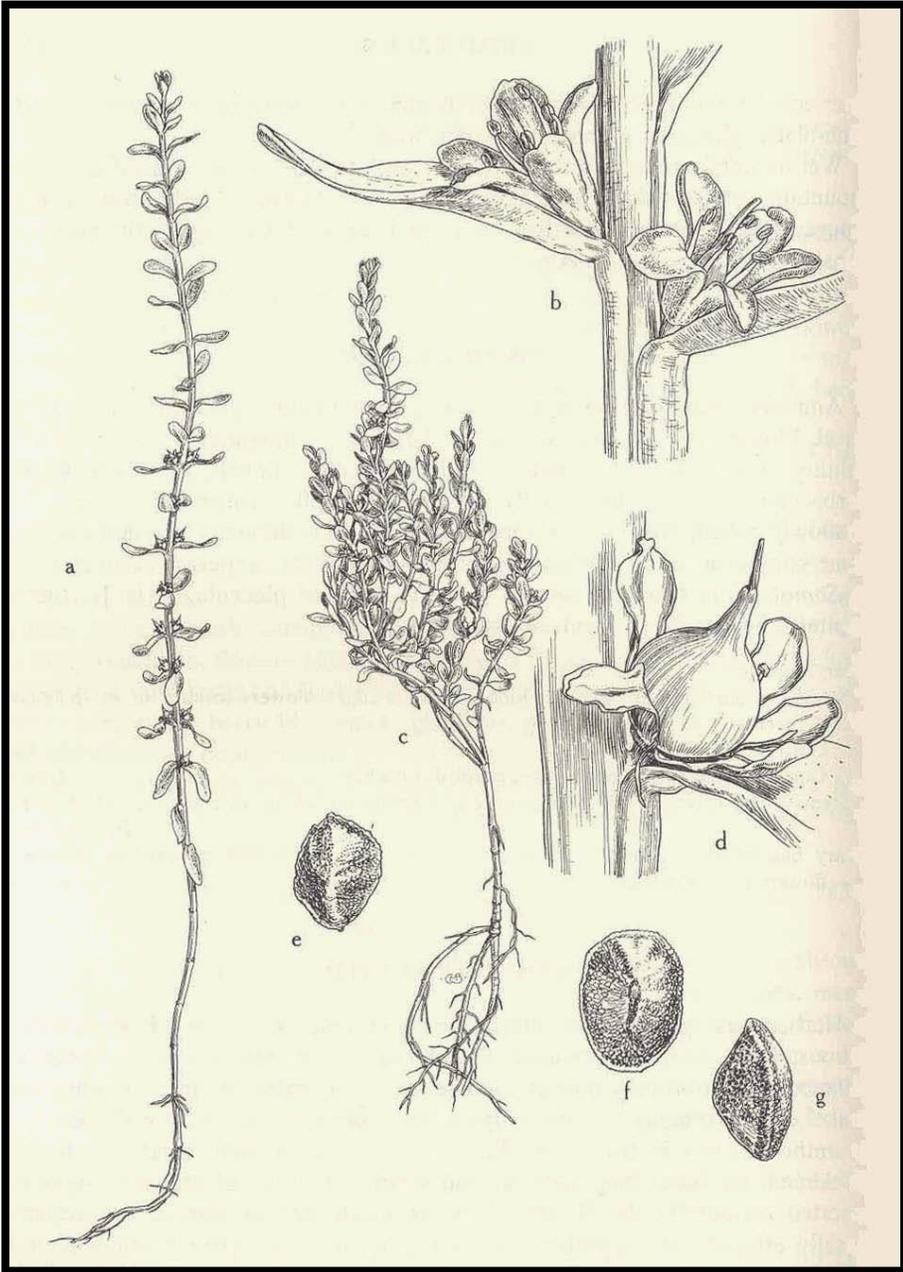
**Sea arrow grass
(*Triglochin maritima*)**



Alkali heath (*Frankenia grandifolia*)



Jaumea (*Jaumea carnosa*)



J. E. (Jed) and Bonnie McClellan © California Academy of Sciences

Sea milkwort (*Glaux maritima*)



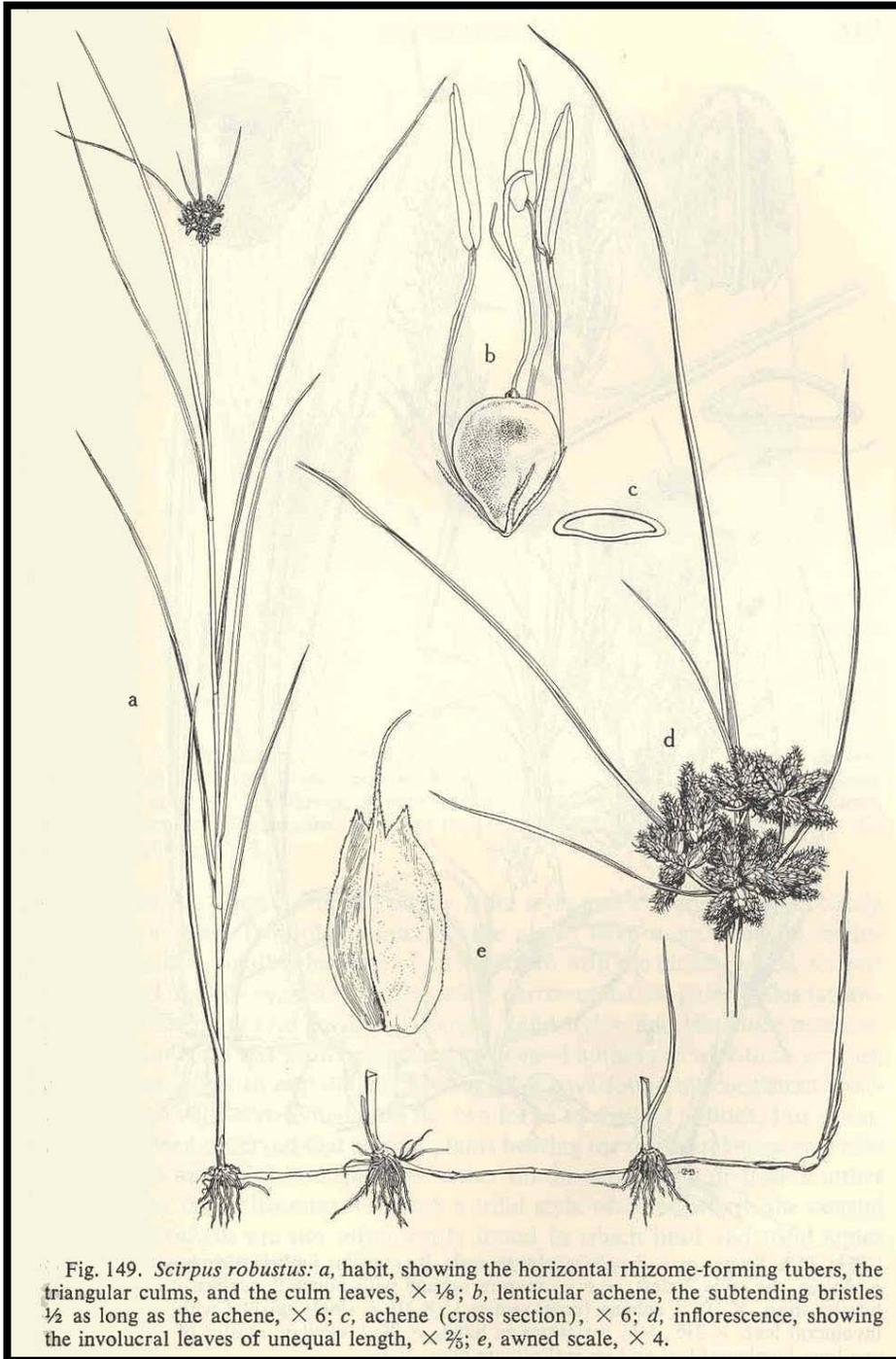
Alkali weed (*Cressa truxillensis*)



Salt marsh rosemary (*Limonium californicum*)



Salt marsh gumplant (*Grindelia stricta*)



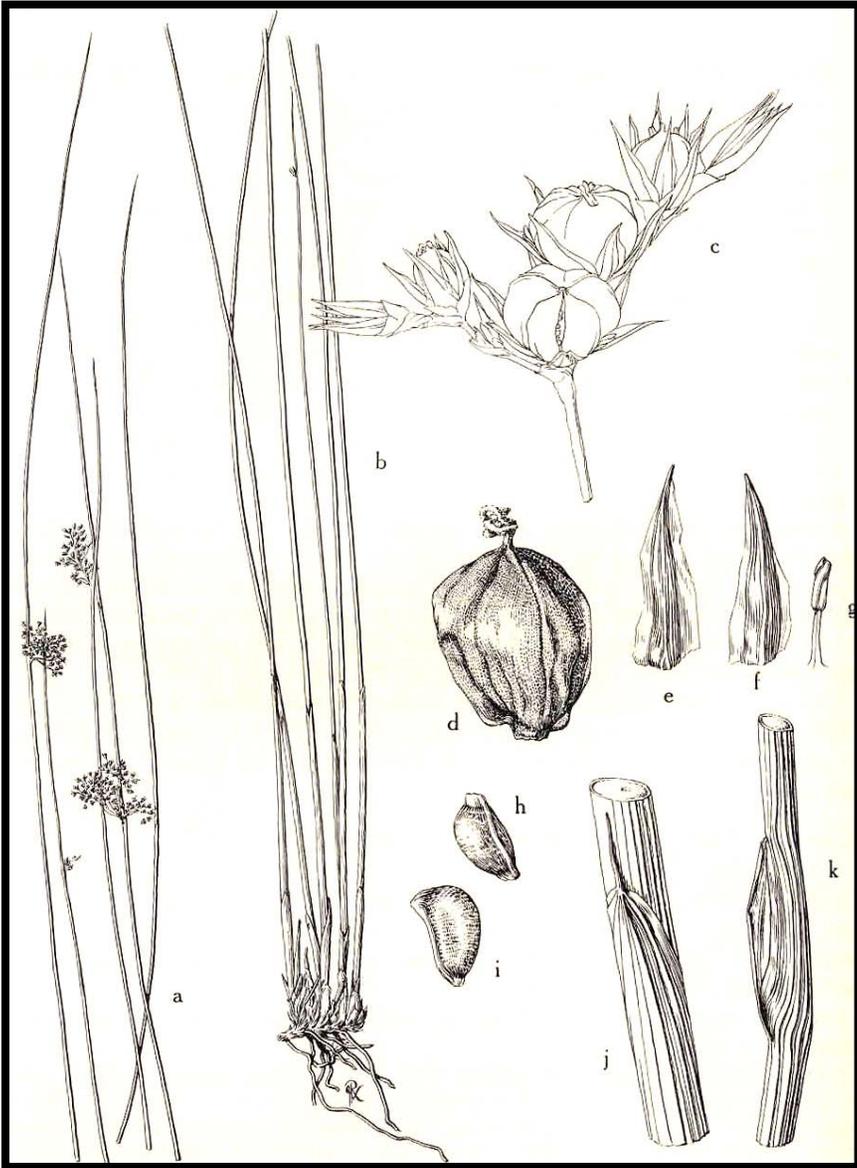
Alkali bulrush (*Schoenoplectus robustus*, formerly *Scirpus robustus*) -- brackish wetlands only

Beatrice F. Howitt © California Academy of Sciences



Fat hen (*Atriplex patula*)

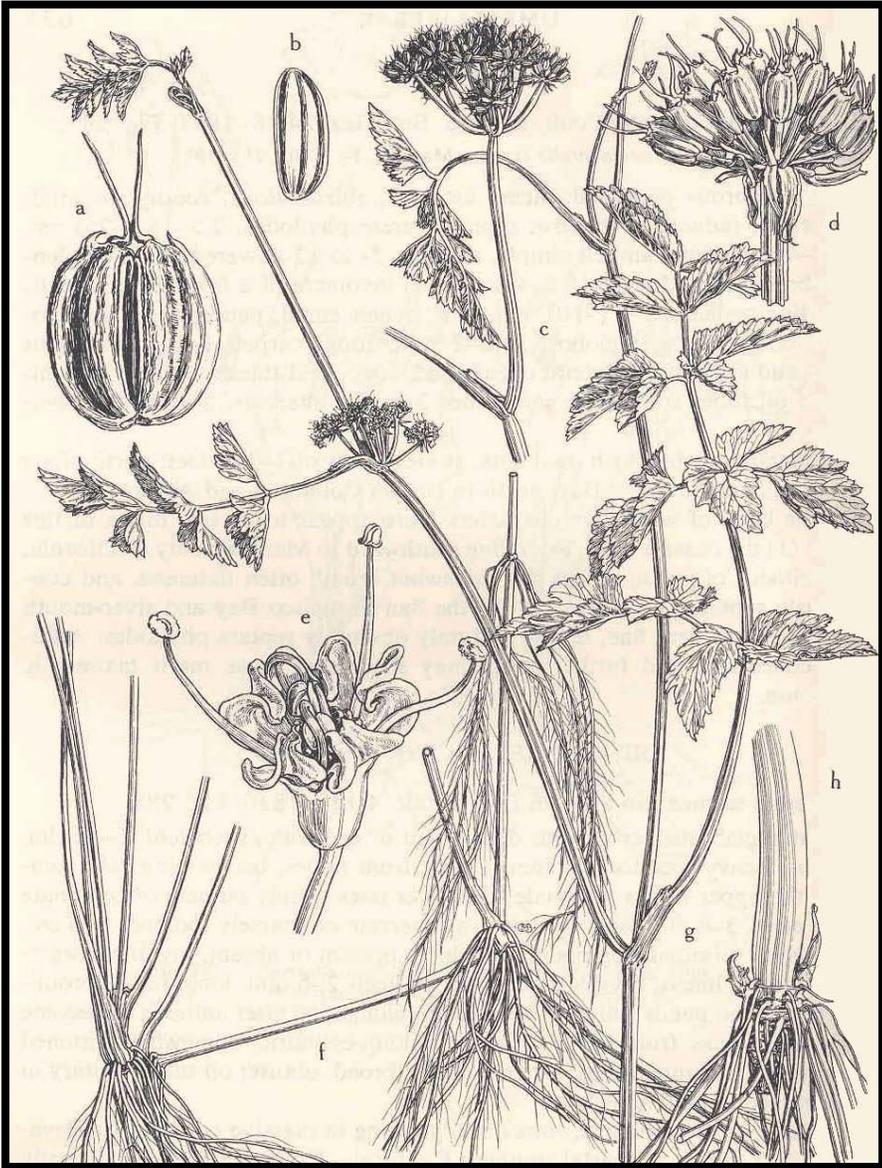
**Freshwater Wetlands Plant
Species**



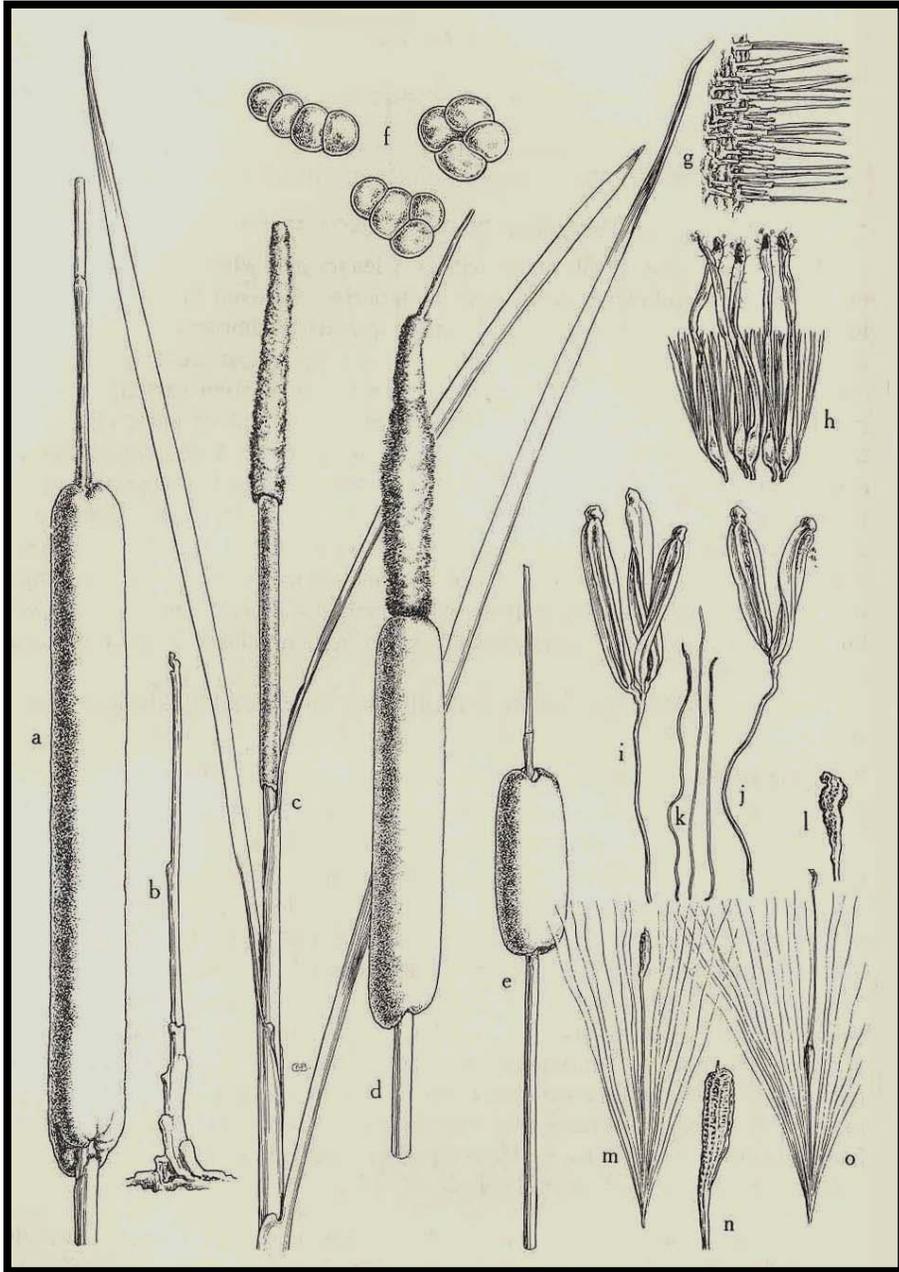
Rush (*Juncus patens*)



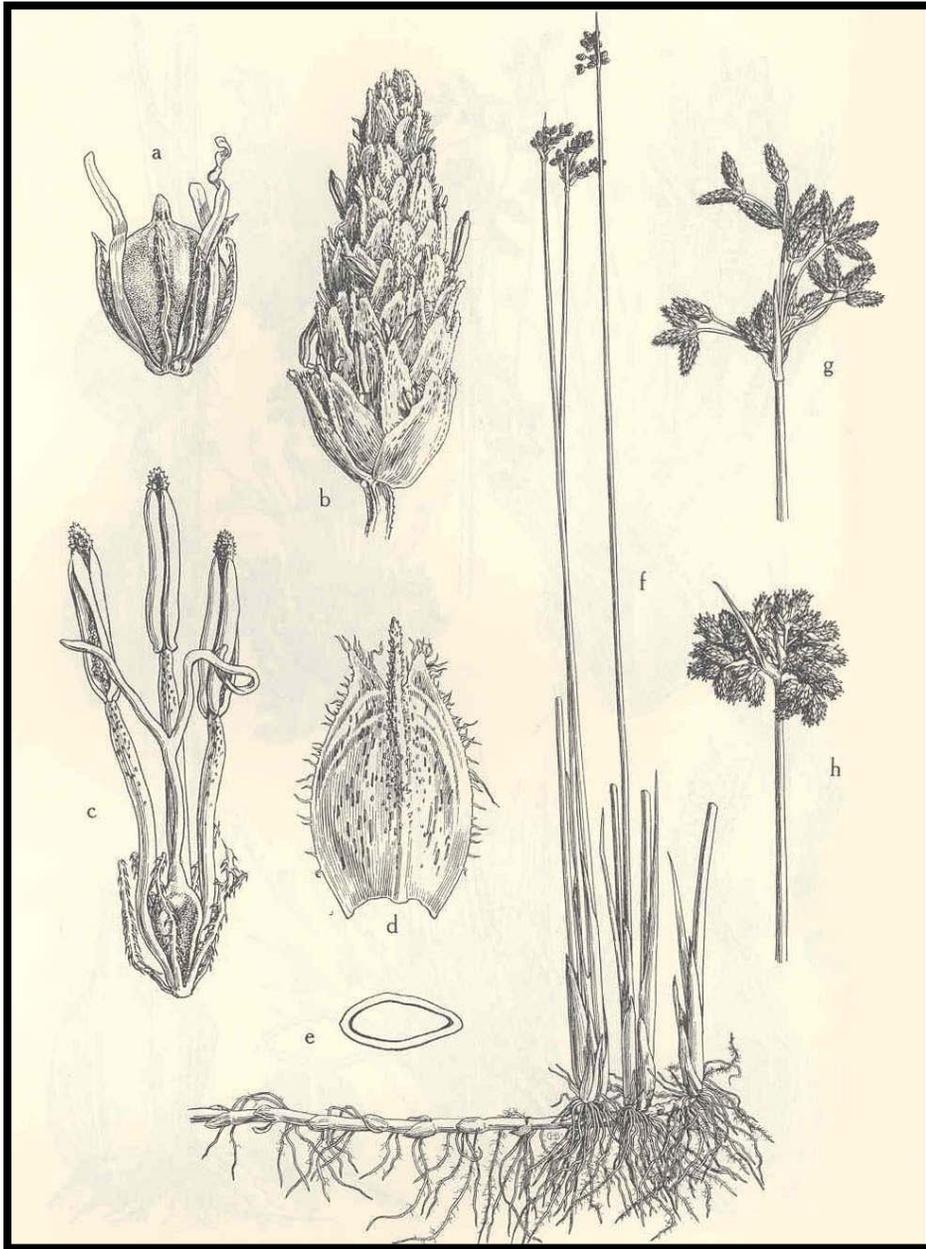
Common rush (*Juncus effusus*)



Water parsley (*Oenanthe sarmentosa*)



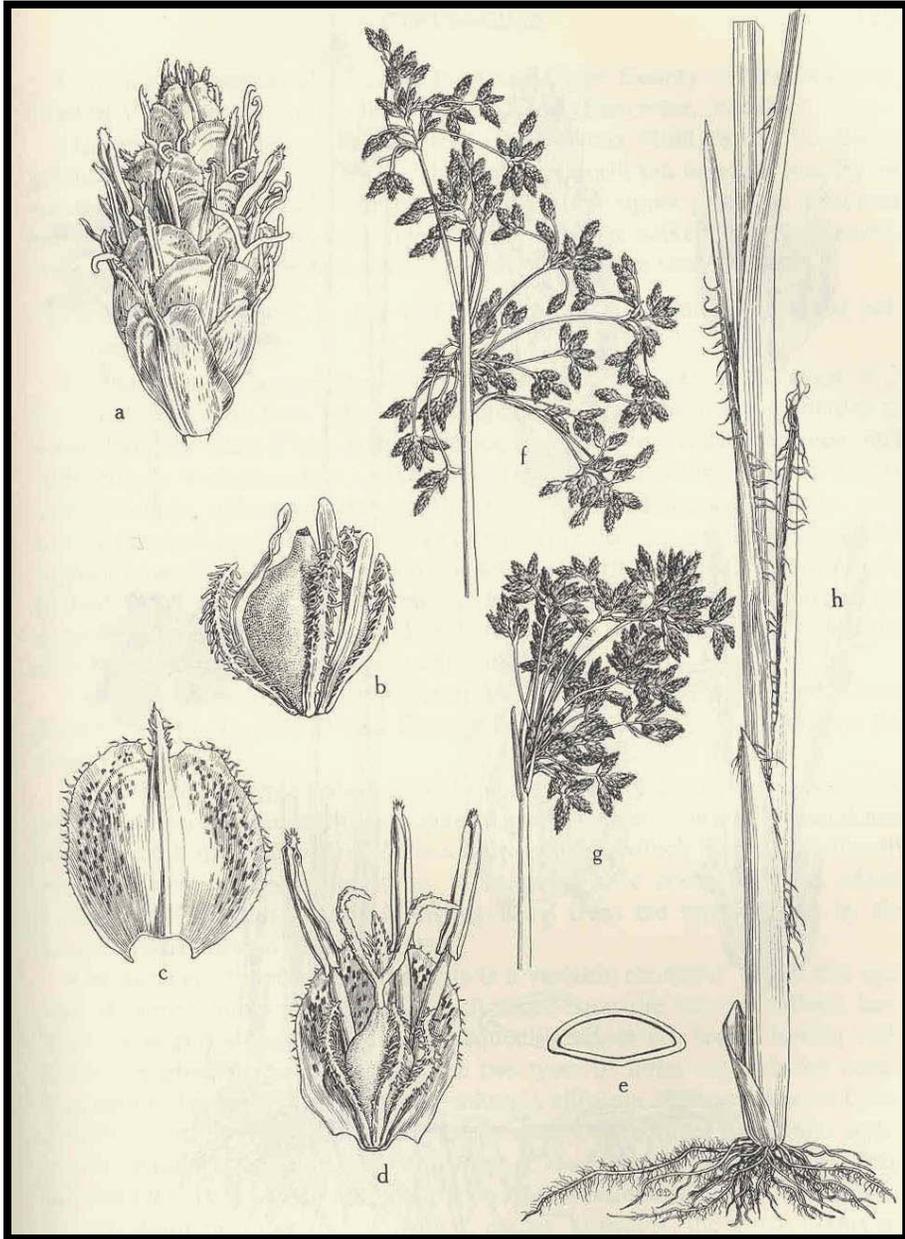
Common cattail (*Typha latifolia*)



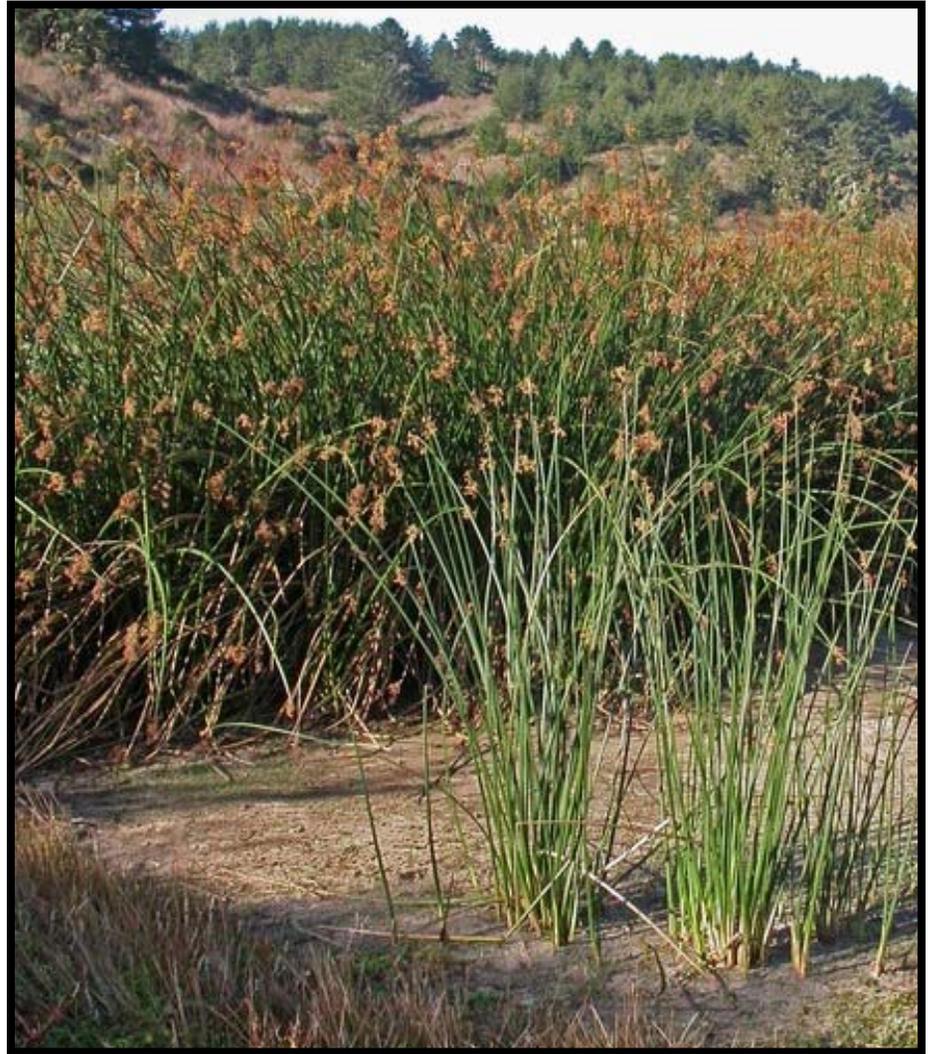
Walter Knight © California Academy of Sciences



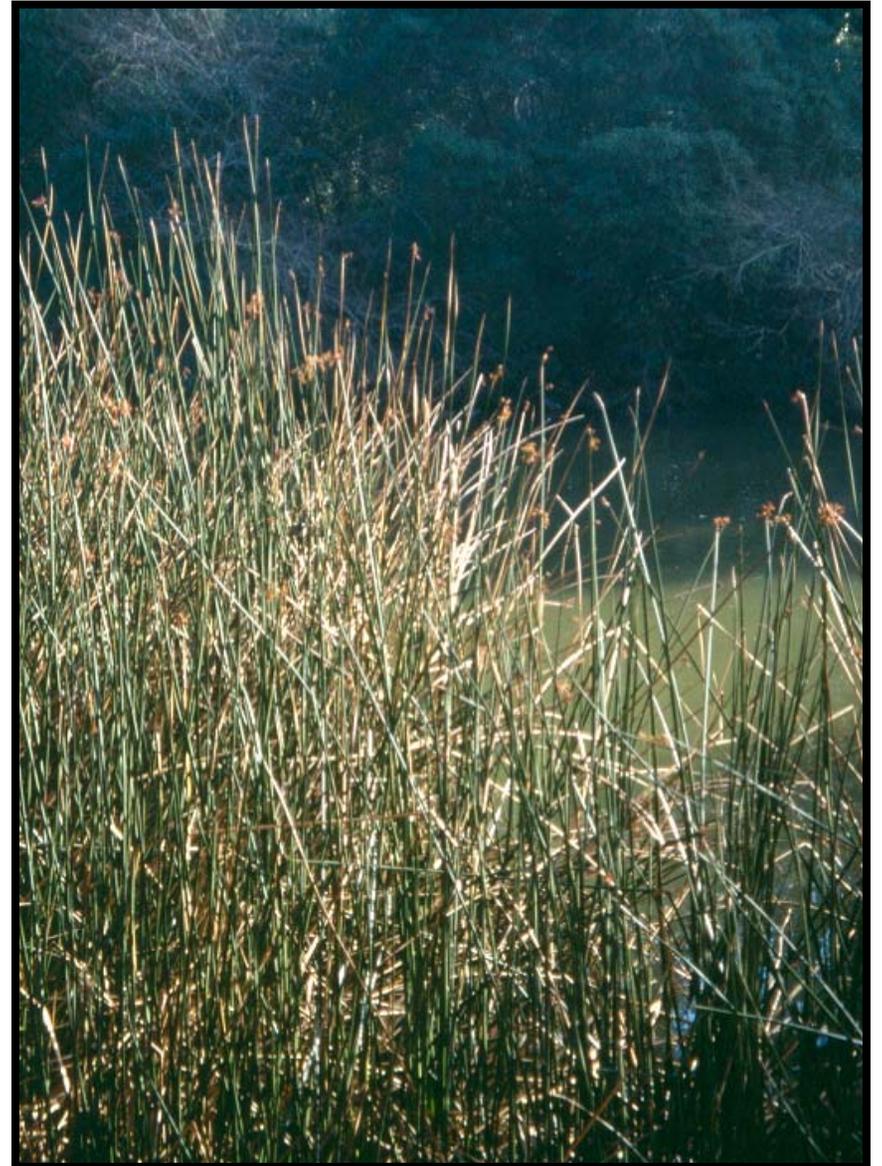
Common tulle (*Schoenoplectus acutus*, formerly *Scirpus acutus*)



© 2007 Neal Kramer



**California bulrush (*Schoenoplectus californicus*,
formerly *Scirpus californicus*)**



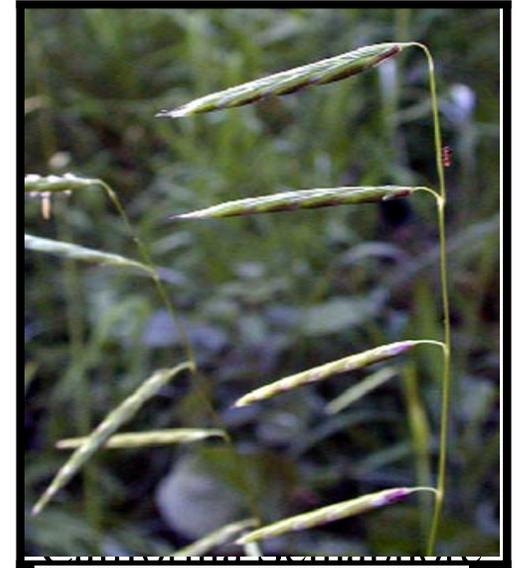
**Three square (*Schoenoplectus americanus*,
formerly *Scirpus americanus*)**



Red willow (*Salix laevigata*)



Meadow barley (*Hordeum branchyantherum*)



Grass (*Pleuropogon californicus*)

Little quaking grass (*Bryza minor*)



Alder (*Alnus rhombifolia*)



California rose (*Rosa californica*)



In periodically flooded areas

Native Upland Plant Species



Silk tassel (*Garrya elliptica*)

Coffeeberry (*Rhamnus californica*)



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California blue blossom (*Ceanothus sp.*)

Manzanita (*Arctostaphylos sp.*)





Sagebrush (*Artemisia californica*)

Toyon (*Heteromeles arbutifolia*)

© 2003 Margo Bors



Redbud (*Cercis occidentalis*)

Ocean spray (*Holodiscus discolor*)





Beach Aster (*Erigeron glaucus*)

Douglas Iris (*Iris douglasiana*)



M onkey flower (*Mimulus sp.*)



Lupine (*Lupinus*)

Black sage (*Salvia mellifera*)



©2004 Hartmut Wisch



California poppy (*Eschscholzia californica*)

California fuschia (*Epilobium canum*)



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California buckwheat (*Eriogonum* sp.)

© 2002 Lynn Watson



Coyote brush (*Baccharis pilularis*)



California saltbush (*Atriplex californica*)

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Yarrow (*Achillea millefolium*)



Beach strawberry (*Fragaria chiloensis*)

Yellow sand verbena (*Abronia latifolia*)



Dr. G Dallas and Margaret Hanna ©
California Academy of Sciences



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Silver beachweed (*Ambrosia chamissonis*)

Invasive Plant Species

Iceplant (*Carpobrotus edulis*)

Iceplant is a ground-hugging succulent perennial whose roots and nodes have a creeping habit and often forms deep mats covering large areas. It has been widely planted for soil stabilization and landscaping. Native to coastal areas in South Africa, it was brought to California in the early 1900s for stabilizing soil along railroad tracks. It spreads both vegetatively and by seed. It can reproduce roots and shoots at every node and any shoot segment can become a propagule, making it important to remove all material from the site when attempting eradication. It can establish and grow in the presence of competitors and herbivores and can form impenetrable mats that dominate resources, including space. It can suppress the growth of native seedlings and mature shrubs.



Recommended Removal Method: Physical Control - Manual/ Mechanical Removal

Iceplant is easily removed by hand pulling. As mentioned above, because the plants can grow roots and shoots at every node, all live shoot segments must be removed from contact with the soil to prevent re-sprouting.

Alternate Removal Method: Chemical Control

The herbicide glyphosate, in concentrations of 2 percent or higher, has been effectively used to kill Iceplant clones. It takes several weeks for the clones to die off, and re-sprouting can occur for several months. Subsequent growth from seedlings needs to be controlled.

Tamarisk or Saltcedar (*Tamarix sp.*)

Tamarisk is a many-branched shrub or tree less than 26 ft. tall that can generate up to 100 seeds per inch, or 500,000 tiny seeds per year. It spreads by seeds and vegetative growth, is very aggressive and once established, is difficult to eliminate. It uses far more water than native plants and is abundant where surface or subsurface water is available for most of the year, thriving in saline soils and disturbed sites. It can withstand salinities up to 36 ppt (seawater). Native to central Asia, it was planted for erosion control, as a windbreak, for shade, and as an ornamental.



Recommended Removal Method: Chemical Control

Several proven methods exist for removing tamarisk. The most frequently used method in California, Arizona and Utah is to cut the shrub near to the ground before it has had a chance to flower, and apply triclopyr with a paintbrush. Remove duff with seeds to the greatest extent possible. Pull out all seedlings and re-treat any re-sprouting stumps with foliar application of an herbicide, such as glyphosate in late spring or early fall.

Alternate Removal Method: Physical Control - Manual/Mechanical Removal

Saltcedar is difficult to kill with mechanical methods, as it is able to re-sprout vigorously. Root plowing and cutting are effective initially, but are successful only when combined with follow-up treatment with herbicide. Mechanical control has proven unsuccessful in the Colorado River system.

Giant reed (*Arundo donax*)

Giant reed is a robust perennial grass growing up to 30 ft. tall, growing in many-stemmed clumps, spreading from horizontal rootstocks below the soil, and often forming large, dense colonies. It spreads vegetatively by rhizomes or fragments. Giant reed displaces native plants and associated wildlife species because of the massive stands it forms. It monopolizes soil moisture and shades out competing native species. As it replaces native vegetation, it reduces habitat and food supply, particularly insect populations.

Recommended Removal Method: Chemical Control

In many, if not all, situations it may be necessary to use chemical methods to achieve eradication of *Arundo*, especially in combination with mechanical removal. In late August to early November, cut stalks within 2 to 4 inches of the substrate. Immediately apply concentrated glyphosate with a paintbrush directly to cut stems. Solution must be applied within 30 seconds from cutting because translocation ceases within minutes of cutting. It may be helpful to add a dye or food coloring to the solution to identify treated material. Follow-up assessment and treatment should be conducted.

Alternate Removal Method: Physical Control - Manual Removal

Hand pulling is effective with new plants under six feet tall. This method works best in loose soils after rain has made substrate workable. Plants can be dug up using hand tools (pick-ax, mattock, and shovel), in combination with cutting stems near the base with pruning shears, machete, or chainsaw. All stems and roots have to be removed from the site to avoid re-sprouting. Follow-up assessment and treatment should be conducted. *Arundo* can also be cut to ground level and covered with thick black tarps for 12 months.



Broom - Scotch (*Cytisus scoparius*) or French (*Genista monspessulana*)

Broom is a perennial shrub up to ten feet tall that produces abundant seed and spreads rapidly. One medium-sized shrub can produce over 12,000 seeds a year. It is a strong competitor and can dominate a plant community, forming a dense monoculture; it is also very fire prone. Native to Europe and North Africa, it was first introduced to California in the 1850's as an ornamental in the Sierra Nevada foothills; it was later used to prevent erosion and stabilize dunes.

Recommended Removal Method: Physical Control - Manual/ Mechanical Removal

Pulling with weed wrenches in late spring, after seed germination period, is recommended because it removes the entire mature shrub, eliminating resprouting. Remove as much of the seed duff layer as possible. However, the resultant soil disturbance tends to increase depth of seed-bank (Bossard 1991, Utery and Krannitz 1998). This method is labor-intensive, but can be used in most kinds of terrain and allows targeting of broom plants with low impact on desirable species in the area. Broom seedlings must be monitored and removed for ten years.



Alternative Removal Method: Chemical Control

For larger shrubs, cut stalks within 2 to 4 inches of the substrate. Apply concentrated glyphosate with a paintbrush directly to cut stems within 30 seconds. Solution must be applied immediately following cutting because translocation ceases within minutes of cutting. Follow-up assessment and treatment should be conducted with hand removal of seedlings.

Pampas grass (*Cortaderia sellonana*)

Pampas grass is a perennial grass up to 15 ft. tall with long leaves arising from a tufted base or tussock. It reproduces vegetatively and from seed. It creates a fire hazard and can slow the establishment and growth of natives. Common as an ornamental in California, it has escaped cultivation and spread throughout coastal regions. It is native to Argentina, Brazil, and Uruguay and was first introduced to California in 1848.



Recommended Removal Method: Physical Control - Manual Removal

Pulling or hand grubbing seedlings is highly effective. For removing established clumps, a Pulaski, mattock, or shovel are the safest and most effective. It should always have its flowering stalks removed prior to seeding and it is important to remove the entire crown and top section of roots to prevent re-sprouting. Remove all material from site to avoid re-sprouting. A large chainsaw or weed eater can expose the base of the plant, allowing better access for removal of the crown and making disposal of the detached plant more manageable. The clump and rootball can be mechanically removed.

Alternate Removal Method: Chemical Control

Control of pampas grass can be achieved by spot treatment of glyphosate at about 2 percent solution. Fall applications result in better control compared to summer applications.

English ivy (*Hedera helix*)

English ivy is a perennial, evergreen woody vine with deep green, glossy leaves. It is especially common in forests and wet areas near urban areas. It spreads vegetatively, by runners, as well as by seed. English ivy creates a dense ground cover suppressing all other plants and climbs up trees, often debilitating or killing them. It also kills trees in the understory and overstory by shading them out. Removal of ivy should be a very high priority.

Recommended Removal Method: Physical Control - Manual/ Mechanical Removal

The best method for controlling English ivy is hand removal of vines using pruners to cut the vines and then pulling the plants up from the ground and down from the trees. Removing and killing vines that spread up into trees is especially important because the fertile branches grow primarily on upright portions of the vine. If vines are cut at the base of the tree, the upper portions will die quickly, but may persist on the tree for some time; vines on the ground around the tree should also be removed to prevent re-growth up the tree.



Alternate Removal Method: Chemical Control

Spray with glyphosate and remove and re-spray all survivors until it is gone.

Himalayan blackberry (*Rubus discolor*)

Himalayan blackberry grows as a dense thicket of long, bending branches, appearing as tall 10-foot mounds. It is an invasive plant that will take over native areas. Asexual reproduction contributes to its aggressive spreading capabilities, as well as large production of berries.

Recommended Removal Method: Physical Control - Manual/ Mechanical Removal

Cutting with hand-pruners or using a weed wrench can effectively remove canes, but crowns will re-sprout more aggressively than before. If infestation is small, removing rootstocks by hand digging is a slow, but effective way of removal. Each piece of root that breaks off and remains in the soil may produce a new plant. Cutting should occur when plant begins to flower. Very thick gloves should be used and yearly maintenance is needed.



Alternative Removal Method: Chemical Control

Spray with glyphosate in areas where other native plants will not be affected. Cutting and painting stems with glyphosate is also effective.

Eucalyptus (Eucalyptus globulus)

Eucalyptus trees are tall (150-180 foot), aromatic, with bark that sheds in long strips. Adult leaves are waxy blue, sickle-shaped and hang vertically. Fruits are blue-gray, woody and ribbed. Native to Australia, widespread commercial planting of eucalyptus occurred after 1870, primarily for timber and fuel. By the 1930's planting of eucalyptus in California for timber had lost popularity because of unsuitable characteristics of the wood for lumber. However, eucalyptus was recommended by the federal government for windrows in pastureland to reduce erosion of soil by wind. Eucalyptus continues to be used throughout California as an ornamental plant despite its invasive nature. Because stringy bark is carried away while burning, eucalyptus forests are considered the worst in the world for spreading spot fires. The Oakland Hills firestorm was both intense and difficult to control because of the many stands of eucalyptus. Eucalyptus is a fire tolerant species, so fire is not an effective method for control.

Eucalyptus is most frequently found growing in groves or windbreaks within grassland habitats where initial plantings took place. In some locations of the Oakland hills and East Bay where eucalyptus was planted large single species forests occur completely replacing native trees. It grows well on a wide range of soils, but requires good drainage, low salinity and a soil depth of two feet or more.

Eucalyptus reproduce by seed and resprouting. In California flowering occurs from November to April. Newly released seeds germinate within a few weeks under suitable conditions.

Recommended Removal Method:

Removing trees is a difficult task and can be expensive.





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Wattle (*Acacia sp.*)



© 2001 Redwood National and State Parks

Cotoneaster (*Cotoneaster sp.*)



Pepperweed (*Lepidium latifolium*)

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Firethorn (*Pyracantha sp.*)

© 2001 Joe DiTomaso

Appendix B
SWMM Model Culvert Data

Appendix B - SWMM Culvert Data - Existing Condition

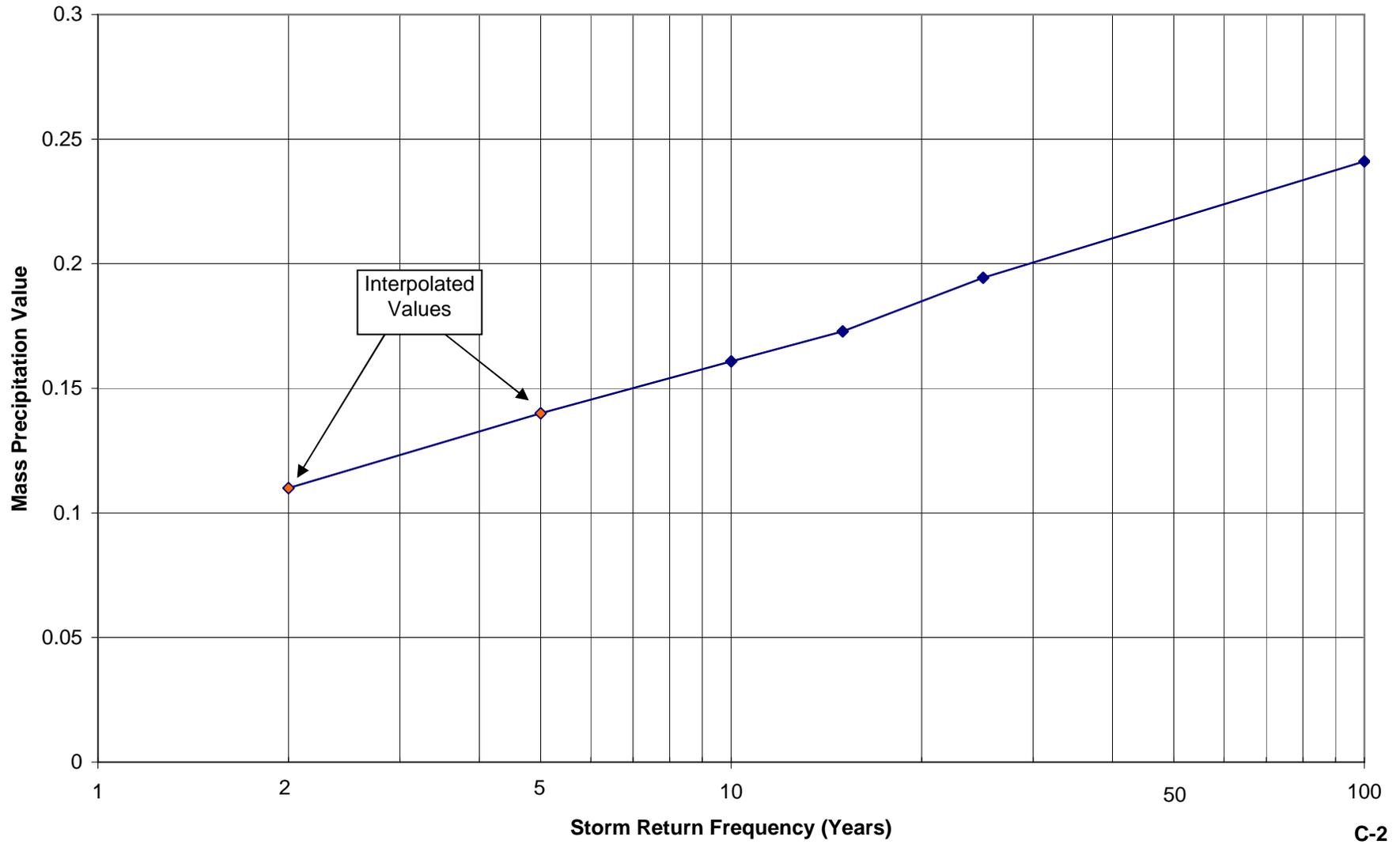
Name	Link Name	Shape	Length (ft)	Diameter/ Height (ft)	Bottom Width (ft)	Roughness	Entrance Loss	Exit Loss	Upstream Invert Elevation (ft. Berkeley Datum)	Downstream Invert Elevation (ft. Berkeley Datum)
C Str 3	C Str 3	Rectangular	299	8.5	9	0.018	0.20	0.20	-6.33	-7.34
C Str 2	C Str 2	Rectangular	181	8.5	9	0.018	0.20	0.20	-7.34	-7.92
C Str 1	C Str 1	Rectangular	288	8.5	9	0.018	0.20	1.00	-7.92	-8.30
C Str 4	C Str 4	Rectangular	345	8.5	9	0.018	0.20	0.20	-5.24	-6.33
C Str 6	C Str 6	Rectangular	76	8.5	9	0.018	0.20	0.20	-4.99	-5.21
C Str 10	C Str 10	Rectangular	26	7	9	0.018	0.20	0.20	-4.11	-4.50
Strawberry Side Weir	C Str 12	Circular	10	0.05	0	0.014	0.20	0.20	0.05	0.00
C Str 11	C Str 11	Circular	343	7	9	0.018	0.20	0.20	-2.80	-4.11
Straw_66	Straw_66	Circular	330	5.5	0	0.014	0.50	0.20	-2.28	-9.00
Straw_90	Straw_90	Circular	141	7.5	0	0.018	0.20	1.00	-9.00	-9.33
Main Culv1	5 Bay Culv	Circular	252	1.9	0	0.036	2.00	1.00	-4.57	-4.86
Main Culv2	5 Bay Culv	Circular	252	1.4	0	0.036	5.00	1.00	-4.57	-4.86
C Str 5	C Str 5	Rectangular	17	8.5	9	0.018	0.20	0.20	-5.21	-5.24
C Str 7	C Str 7	Rectangular	53	8.5	9	0.018	0.20	0.20	-4.82	-4.99
C Str 8	C Str 8	Rectangular	159	7	9	0.018	0.20	0.20	-4.60	-4.82
C Str 9	C Str 9	Rectangular	76	7	9	0.018	0.20	0.20	-4.50	-4.60
culvert 1	Link121	Circular	95	1	0	0.055	1.50	1.00	-4.20	-4.30
culvert 2	Link121	Circular	95	1	0	0.055	1.50	1.00	-3.70	-3.80
Link59	Link59	Rectangular	15	7	9	0.018	0.20	0.20	-5.63	-5.73
Link120	Link120	Circular	33	1.95	6	0.055	2.00	1.00	-3.56	-3.53
Link60	Link60	Rectangular	557.38	7	9	0.018	0.20	0.20	-5.73	-4.55
Link118	Link118	Circular	33	1.95	6	0.055	2.00	1.00	-3.68	-3.29
Link64	Link64	Rectangular	33	7	8	0.014	0.20	0.20	-4.45	-4.48
Link58	Link58	Rectangular	179	7	9	0.014	0.20	0.20	-4.07	-5.63
Link66	Link66	Rectangular	198	7	8	0.014	0.20	1.00	-4.03	-6.50
Link62	Link62	Circular	278	2	0	0.014	0.20	0.20	-4.48	-4.03
Link63	Link63	Circular	209	2	0	0.014	0.20	1.00	-4.03	-4.04
Link65	Link65	Rectangular	277	7	8	0.014	0.20	0.20	-4.48	-4.03
Link61	Link61	Circular	88	0.5	0	0.014	0.50	0.20	-5.80	-4.48

Appendix B - SWMM Culvert Data - Modified Condition Model 4B

Name	Link Name	Shape	Length (ft)	Diameter/ Height (ft)	Bottom Width (ft)	Roughness	Entrance Loss	Exit Loss	Upstream Invert Elevation (ft. Berkeley Datum)	Downstream Invert Elevation (ft. Berkeley Datum)
C Str 3	C Str 3	Rectangular	299	8.5	9	0.018	0.20	0.20	-6.33	-7.34
C Str 2	C Str 2	Rectangular	181	8.5	9	0.018	0.20	0.20	-7.34	-7.92
C Str 1	C Str 1	Rectangular	288	8.5	9	0.018	0.20	1.00	-7.92	-8.30
C Str 4	C Str 4	Rectangular	345	8.5	9	0.018	0.20	0.20	-5.24	-6.33
C Str 6	C Str 6	Rectangular	76	8.5	9	0.018	0.20	0.20	-4.99	-5.21
C Str 10	C Str 10	Rectangular	26	7	9	0.018	0.20	0.20	-4.11	-4.50
Weir	C Str 12	Circular	33	1	0	0.014	0.50	1.50	0.00	0.00
Low Flow	C Str 12	Circular	33	1	0	0.014	0.50	1.50	-2.00	-2.00
Strawberry Side Weir	C Str 12	Circular	33	1	0	0.014	0.50	1.50	0.00	0.00
C Str 11	C Str 11	Circular	343	7	9	0.018	0.20	0.20	-2.80	-4.11
Straw_66	Straw_66	Circular	330	5.5	0	0.014	0.50	0.20	-2.28	-9.00
Straw_90	Straw_90	Circular	141	7.5	0	0.018	0.20	1.00	-9.00	-9.33
Main Culv1	5 Bay Culv	Circular	252	1.9	0	0.036	2.00	1.00	-4.57	-4.86
C Str 5	C Str 5	Rectangular	17	8.5	9	0.018	0.20	0.20	-5.21	-5.24
C Str 7	C Str 7	Rectangular	53	8.5	9	0.018	0.20	0.20	-4.82	-4.99
C Str 8	C Str 8	Rectangular	159	7	9	0.018	0.20	0.20	-4.60	-4.82
C Str 9	C Str 9	Rectangular	76	7	9	0.018	0.20	0.20	-4.50	-4.60
Link67	Link67	Circular	196	1	0	0.035	1.00	1.00	-4.70	-4.50
Open Ditch	Link121	Rectangular	75	6	20	0.035	0.25	0.25	-4.20	-4.30
Link59	Link59	Rectangular	15	7	9	0.018	0.20	0.20	-5.63	-5.73
Link60	Link60	Rectangular	557.38	7	9	0.018	0.20	0.20	-5.73	-4.55
Potter Con	Potter Con	Rectangular	33	3	5	0.024	0.50	1.50	-3.50	-3.55
Link64	Link64	Rectangular	33	7	8	0.014	0.20	0.20	-4.45	-4.48
Link58	Link58	Rectangular	179	7	9	0.014	0.20	0.20	-4.07	-5.63
Link66	Link66	Rectangular	198	7	8	0.014	0.20	1.00	-4.03	-6.50
Link62	Link62	Circular	278	2	0	0.014	0.20	0.20	-4.48	-4.03
Link63	Link63	Circular	209	2	0	0.014	0.20	1.00	-4.03	-4.04
Link65	Link65	Rectangular	277	7	8	0.014	0.20	0.20	-4.48	-4.03
Link68	Link68	Circular	199	0.2	0	0.014	5.00	5.00	-4.50	-4.00
Link61	Link61	Circular	88	0.5	0	0.014	0.50	0.20	-5.80	-4.48

**Appendix C
Precipitation Data**

Interpolation of Mass Precipitation Values for the 2-Year and 5-Year 24-Hour Storm Events



24-Hour Design Storm Calculations

Mean Annual Precipitation	Aquatic Park Mass Precipitation Factor*		
	2-yr	5-yr	10-yr
24 in	0.1100	0.1400	0.1608

		Aquatic Park Precipitation Design Storms					
Time (hr)	Rainfall Ratio*	2-yr Accumulated	2-yr Incremental	5-yr Accumulated	5-yr Incremental	10-yr Accumulated	10-yr Incremental
0.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.5	0.0135	0.0356	0.0356	0.0454	0.0454	0.0521	0.0521
1.0	0.0251	0.0663	0.0306	0.0843	0.0390	0.0969	0.0448
1.5	0.0382	0.1008	0.0346	0.1284	0.0440	0.1474	0.0506
2.0	0.0518	0.1368	0.0359	0.1740	0.0457	0.1999	0.0525
2.5	0.0660	0.1742	0.0375	0.2218	0.0477	0.2547	0.0548
3.0	0.0810	0.2138	0.0396	0.2722	0.0504	0.3126	0.0579
3.5	0.0967	0.2553	0.0414	0.3249	0.0528	0.3732	0.0606
4.0	0.1131	0.2986	0.0433	0.3800	0.0551	0.4365	0.0633
4.5	0.1304	0.3443	0.0457	0.4381	0.0581	0.5032	0.0668
5.0	0.1491	0.3936	0.0494	0.5010	0.0628	0.5754	0.0722
5.5	0.1690	0.4462	0.0525	0.5678	0.0669	0.6522	0.0768
6.0	0.1903	0.5024	0.0562	0.6394	0.0716	0.7344	0.0822
6.5	0.2135	0.5636	0.0612	0.7174	0.0780	0.8239	0.0895
7.0	0.2389	0.6307	0.0671	0.8027	0.0853	0.9220	0.0980
7.5	0.2675	0.7062	0.0755	0.8988	0.0961	1.0323	0.1104
8.0	0.3001	0.7923	0.0861	1.0083	0.1095	1.1581	0.1258
8.5	0.3385	0.8936	0.1014	1.1374	0.1290	1.3063	0.1482
9.0	0.3862	1.0196	0.1259	1.2976	0.1603	1.4904	0.1841
9.5	0.4570	1.2065	0.1869	1.5355	0.2379	1.7637	0.2732
10.0	0.5806	1.5328	0.3263	1.9508	0.4153	2.2407	0.4770
10.5	0.6975	1.8414	0.3086	2.3436	0.3928	2.6918	0.4511
11.0	0.7304	1.9283	0.0869	2.4541	0.1105	2.8188	0.1270
11.5	0.7552	1.9937	0.0655	2.5375	0.0833	2.9145	0.0957
12.0	0.7760	2.0486	0.0549	2.6074	0.0699	2.9947	0.0803
12.5	0.7935	2.0948	0.0462	2.6662	0.0588	3.0623	0.0675
13.0	0.8093	2.1366	0.0417	2.7192	0.0531	3.1233	0.0610
13.5	0.8246	2.1769	0.0404	2.7707	0.0514	3.1823	0.0590
14.0	0.8379	2.2121	0.0351	2.8153	0.0447	3.2336	0.0513
14.5	0.8502	2.2445	0.0325	2.8567	0.0413	3.2811	0.0475
15.0	0.8616	2.2746	0.0301	2.8950	0.0383	3.3251	0.0440
15.5	0.8724	2.3031	0.0285	2.9313	0.0363	3.3668	0.0417
16.0	0.8826	2.3301	0.0269	2.9655	0.0343	3.4061	0.0394
16.5	0.8923	2.3557	0.0256	2.9981	0.0326	3.4436	0.0374
17.0	0.9016	2.3802	0.0246	3.0294	0.0312	3.4795	0.0359
17.5	0.9104	2.4035	0.0232	3.0589	0.0296	3.5134	0.0340
18.0	0.9188	2.4256	0.0222	3.0872	0.0282	3.5458	0.0324
18.5	0.9269	2.4470	0.0214	3.1144	0.0272	3.5771	0.0313
19.0	0.9347	2.4676	0.0206	3.1406	0.0262	3.6072	0.0301
19.5	0.9422	2.4874	0.0198	3.1658	0.0252	3.6361	0.0289
20.0	0.9494	2.5064	0.0190	3.1900	0.0242	3.6639	0.0278
20.5	0.9565	2.5252	0.0187	3.2138	0.0239	3.6913	0.0274
21.0	0.9633	2.5431	0.0180	3.2367	0.0228	3.7176	0.0262
21.5	0.9698	2.5603	0.0172	3.2585	0.0218	3.7427	0.0251
22.0	0.9762	2.5772	0.0169	3.2800	0.0215	3.7674	0.0247
22.5	0.9824	2.5935	0.0164	3.3009	0.0208	3.7913	0.0239
23.0	0.9884	2.6094	0.0158	3.3210	0.0202	3.8144	0.0232
23.5	0.9943	2.6250	0.0156	3.3408	0.0198	3.8372	0.0228
24.0	1.0000	2.6400	0.0150	3.36	0.0192	3.86	0.0220
Max			0.33		0.42		0.48
Total			2.64		3.36		3.86

* Based on Hydrology and Hydraulics Criteria Summary for Western Alameda County, 1989

24-Hour Design Storm Calculations

Mean Annual Precipitation	Aquatic Park Mass Precipitation Factor *		
	15-yr	25-yr	100-yr
24 in	0.1728	0.1944	0.2411

		Aquatic Park Precipitation Design Storms					
Time (hr)	Rainfall Ratio*	15-yr Accumulated	15-yr Incremental	25-yr Accumulated	25-yr Incremental	100-yr Accumulated	100-yr Incremental
0.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.5	0.0135	0.0560	0.0560	0.0630	0.0630	0.0781	0.0781
1.0	0.0251	0.1041	0.0481	0.1171	0.0541	0.1452	0.0671
1.5	0.0382	0.1584	0.0543	0.1782	0.0611	0.2210	0.0758
2.0	0.0518	0.2148	0.0564	0.2417	0.0635	0.2997	0.0787
2.5	0.0660	0.2737	0.0589	0.3079	0.0663	0.3819	0.0822
3.0	0.0810	0.3359	0.0622	0.3779	0.0700	0.4687	0.0868
3.5	0.0967	0.4010	0.0651	0.4512	0.0732	0.5595	0.0908
4.0	0.1131	0.4690	0.0680	0.5277	0.0765	0.6544	0.0949
4.5	0.1304	0.5408	0.0717	0.6084	0.0807	0.7545	0.1001
5.0	0.1491	0.6183	0.0776	0.6956	0.0872	0.8628	0.1082
5.5	0.1690	0.7009	0.0825	0.7885	0.0928	0.9779	0.1151
6.0	0.1903	0.7892	0.0883	0.8879	0.0994	1.1012	0.1233
6.5	0.2135	0.8854	0.0962	0.9961	0.1082	1.2354	0.1342
7.0	0.2389	0.9908	0.1053	1.1146	0.1185	1.3824	0.1470
7.5	0.2675	1.1094	0.1186	1.2480	0.1334	1.5479	0.1655
8.0	0.3001	1.2446	0.1352	1.4001	0.1521	1.7365	0.1886
8.5	0.3385	1.4038	0.1593	1.5793	0.1792	1.9587	0.2222
9.0	0.3862	1.6016	0.1978	1.8019	0.2225	2.2347	0.2760
9.5	0.4570	1.8953	0.2936	2.1322	0.3303	2.6444	0.4097
10.0	0.5806	2.4079	0.5126	2.7088	0.5767	3.3596	0.7152
10.5	0.6975	2.8927	0.4848	3.2543	0.5454	4.0360	0.6764
11.0	0.7304	3.0291	0.1364	3.4078	0.1535	4.2264	0.1904
11.5	0.7552	3.1320	0.1029	3.5235	0.1157	4.3699	0.1435
12.0	0.7760	3.2182	0.0863	3.6205	0.0970	4.4902	0.1204
12.5	0.7935	3.2908	0.0726	3.7022	0.0816	4.5915	0.1013
13.0	0.8093	3.3563	0.0655	3.7759	0.0737	4.6829	0.0914
13.5	0.8246	3.4198	0.0635	3.8473	0.0714	4.7715	0.0885
14.0	0.8379	3.4749	0.0552	3.9093	0.0621	4.8484	0.0770
14.5	0.8502	3.5259	0.0510	3.9667	0.0574	4.9196	0.0712
15.0	0.8616	3.5732	0.0473	4.0199	0.0532	4.9856	0.0660
15.5	0.8724	3.6180	0.0448	4.0703	0.0504	5.0481	0.0625
16.0	0.8826	3.6603	0.0423	4.1179	0.0476	5.1071	0.0590
16.5	0.8923	3.7005	0.0402	4.1631	0.0453	5.1632	0.0561
17.0	0.9016	3.7391	0.0386	4.2065	0.0434	5.2170	0.0538
17.5	0.9104	3.7756	0.0365	4.2476	0.0411	5.2679	0.0509
18.0	0.9188	3.8104	0.0348	4.2868	0.0392	5.3165	0.0486
18.5	0.9269	3.8440	0.0336	4.3245	0.0378	5.3634	0.0469
19.0	0.9347	3.8764	0.0323	4.3609	0.0364	5.4085	0.0451
19.5	0.9422	3.9075	0.0311	4.3959	0.0350	5.4519	0.0434
20.0	0.9494	3.9374	0.0299	4.4295	0.0336	5.4936	0.0417
20.5	0.9565	3.9668	0.0294	4.4626	0.0331	5.5347	0.0411
21.0	0.9633	3.9950	0.0282	4.4944	0.0317	5.5740	0.0393
21.5	0.9698	4.0220	0.0270	4.5247	0.0303	5.6117	0.0376
22.0	0.9762	4.0485	0.0265	4.5546	0.0299	5.6487	0.0370
22.5	0.9824	4.0742	0.0257	4.5835	0.0289	5.6846	0.0359
23.0	0.9884	4.0991	0.0249	4.6115	0.0280	5.7193	0.0347
23.5	0.9943	4.1236	0.0245	4.6390	0.0275	5.7534	0.0341
24.0	1.0000	4.15	0.0236	4.67	0.0266	5.79	0.0330
Max			0.51		0.58		0.72
Total			4.15		4.67		5.79

* Based on Hydrology and Hydraulics Criteria Summary for Western Alameda County, 1989

Appendix D
Structural Evaluation of Existing Connections

Project No.
7522.1.001.01

February 23, 2007

Mr. Tom Burke
HSI Hydrologic Systems, Inc.
2175 East Francisco Blvd., Suite A
San Rafael, CA 94901

Subject: Aquatic Park Water Quality Improvement Project
Berkeley, California

EVALUATION OF EXISTING WEIR STRUCTURE

Dear Mr. Burke:

With your authorization, ENGEO Incorporated performed various tests and observations to provide as-built information related to the existing weir structure located at the Strawberry Creek Drain for the subject project in Berkeley, California. The weir structure is located at 2nd Street under University Avenue.

Our services consisted of the following:

- Measure the interior dimensions and the thickness of the walls and ceiling and locate the reinforcing steel of the weir structure as best we can to determine if the as built condition of the structure is similar to the plans provided.
- Sample the existing concrete of the structure and test for in-place compressive strength.

Based on our measurements of the interior of the structure, the overall dimensions are as indicated on the as built drawings dated July 27, 1965 (approved February 1968). The height of the overflow section of the structure was measured at 6' – 5" which is greater than indicated on the drawings. The height of the interior wall measured on the overflow side was 30" as shown on the drawings. It appears the interior wall between the Strawberry Creek Drain and the overflow area is approximately 6 ½" inches shorter than as indicated. Also, we attempted to drill through the wall of the structure to determine the thickness and found the wall was greater than the 1' – 6" thickness as indicated on the as built drawings.

An M-Scope was used to locate the reinforcing steel in the walls of the structure. Due to the walls and ceiling being greater than eight inches thick and the limitations of the locating equipment, we were only able to locate the steel at the interior surface and not the exterior surface. Based on what we were able to locate, the reinforcing steel appears to have been placed in general accordance to the as built drawings.

Three cores were drilled from one of the walls and sent to our laboratory for compressive strength testing. The results of the testing indicate the in-place compressive strength of the concrete for the weir structure exceeds 7,000 psi. The results of the compressive strength testing of the cores are attached.

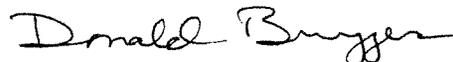
We make no representation as to the accuracy of dimensions, calculations, or any portion of the design for this project. If you have any questions or comments, please contact us.

Very truly yours,

ENGEO INCORPORATED


James K. Auser, PE
jka/smc:weir




Don Bruggers, GE

Attachments: Core Sampling and Test Report

CORE SAMPLING & TEST REPORT

PROJECT Aquatic Park Water Quality Improvement Project Berkeley, CA	REPORT DATE February 23, 2007	JOB NO. 7522.1.001.01
	SPECIMEN PREPARED BY: ENGEO X OTHERS	MIX IDENTIFICATION N/A
CLIENT HSI - Hydrologic Systems, Inc.	CONTRACTOR N/A	DATE SPECIMEN RECVD February 12, 2007
	CONCRETE SUPPLIER N/A	SPECIFIED STRENGTH (psi) 3,000

SAMPLING DATA

SAMPLE LOCATION 2nd Street Weir Structure				
Date of Concrete Pour N/A	Date of Core Sampling February 12, 2007	NO. SAMPLED 3	SET NO. 1	FIELD TECHNICIAN B. Spalding

COMPRESSION TEST RESULTS

SPECIMEN ID NUMBER	LAB NUMBER	TEST AGE (Days)	DATE OF TEST	TOTAL LOAD (lbs)	CORE HIEGHT (in)	Correction Factor	CORE DIAMETER (in)	CORE AREA (in ²)	COMPRESSIVE STRENGTH (psi)
1	217		23-Feb-07	47,950	6.25	1.00	2.92	6.70	7,160
2	217		23-Feb-07	49,020	6.19	1.00	2.92	6.70	7,320
3	217		23-Feb-07	51,180	6.13	1.00	2.92	6.70	7,640
								Average Compressive Strength =	7,370
								85% of Specified Strength =	2,550
								75% of Specified Strength =	2,250

Compression Strength Results <input checked="" type="checkbox"/> Comply with specified strength <input type="checkbox"/> Do not comply with specified strength <input type="checkbox"/> No strength criteria specified	Break was Conical (unless otherwise noted): Noted Defects: None Specimen tested per ASTM-C-42
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REVIEWED BY: JKA

Project No.
7522.1.001.01

April 27, 2007

Mr. Tom Burke
HSI Hydrologic Systems, Inc.
2175 East Francisco Blvd., Suite A
San Rafael, CA 94901

Subject: Aquatic Park Water Quality Improvement Project
Berkeley, California

**EVALUATION OF EXISTING STORM DRAIN AND CONCRETE
CULVERTS**

Dear Mr. Burke:

With your authorization, ENGEO Incorporated performed various tests and observations to provide as-built information related to various existing box culverts located at the Model Yacht Basin, Radio Tower Pond and Main Lagoon for the subject project in Berkeley, California.

Our services consisted of the following:

- Determine the spacing and depth of the reinforcing steel in the Potter Street Drain located under Bay Street between the Model Yacht Basin and the Radio Tower Pond. Also, sample and test the existing concrete of the drain for compressive strength.
- Sample and test the existing concrete of the group of five culverts running from the Main Lagoon to the San Francisco Bay located approximately at the middle of the lagoon.
- Search for the outlet of the northern culvert from the Main Lagoon to the San Francisco Bay and, if found, sample and test the concrete from the culvert.

The Potter Street Drain appears to be a cast-in-place concrete pipe with six inch thick walls. A ferrosan was used to determine the spacing and depth of the reinforcing steel in the concrete for the Potter Street Drain at four locations along the exposed portion the drain along Bay Street at the east end of the Radio Tower Pond and Model Yacht Basin, east of the outlet culverts to the Model Yacht Basin. The results of the ferrosan indicated no conclusive detection of reinforcing steel in the concrete for the drain. There was a trace detection of metal that indicated the possibility of No. 3 rebar present approximately three to four inches in depth and at approximately twelve inches on center running longitudinally. However, as previously indicated, the ferrosan results were inconclusive. Three core samples were drilled from the concrete at the same location and were tested for in-place compressive strength. The compressive strength tests indicate the in-place concrete is an average of 3,170 psi. The results of the compressive strength testing of the cores are attached.

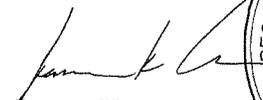
The five culverts which are located approximately at the middle of the Main Lagoon and run from the lagoon to the San Francisco Bay appear to be pre-cast concrete pipe with 3 ½ inch thick walls. Three core samples were drilled from one of the pipes at the outlet end into the San Francisco Bay and were tested for in-place compressive strength. The compressive strength tests indicate the concrete is an average of 6,820 psi. The results of the compressive strength testing of the cores are attached. The core samples also shown the pre-cast pipes were reinforced with wire mesh.

On April 25, 2007, a backhoe was used to search for the outlet of the northern culvert from the Main Lagoon to the San Francisco Bay. Trenching began along the west side of the bike trail at the location of two 2-foot-diameter black corrugated PVC drain pipes which are located approximately 400 feet south of the pedestrian bridge at University Avenue. Trenching revealed that the 2-foot-diameter black corrugated PVC drain pipes connect to each other, but this connection runs parallel to the bike trail and does not connect to the outlet of the northern culvert from the Main Lagoon. The search continued south from this location for approximately 180 feet, crossing the predicted location of the outlet. The trenches were dug twelve inches wide to a depth of about five to six feet below ground surface. The outlet for the culvert was expected to be at about four feet deep below ground surface. We were unable to locate the outlet at this location.

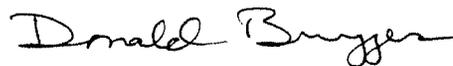
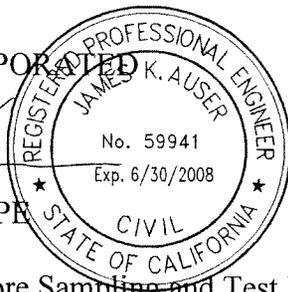
We make no representation as to the accuracy of dimensions, calculations, or any portion of the design for this project. If you have any questions or comments, please contact us.

Very truly yours,

ENGEO INCORPORATED



James K. Auser, PE



Don Bruggers, GE

Attachments: Core Sampling and Test Reports

CORE SAMPLING & TEST REPORT

PROJECT Aquatic Park Water Quality Improvement Project Berkeley, CA				REPORT DATE February 23, 2007			JOB NO. 7522.1.001.01		
				SPECIMEN PREPARED BY: ENGEO X OTHERS			MIX IDENTIFICATION N/A		
CLIENT HSI - Hydrologic Systems, Inc.				CONTRACTOR N/A			DATE SPECIMEN RECVD February 12, 2007		
				CONCRETE SUPPLIER N/A			SPECIFIED STRENGTH (psi) N/A		
SAMPLING DATA									
SAMPLE LOCATION Set of Five Culvert Outlets to Bay at Middle Section of the Main Lagoon									
Date of Concrete Pour N/A		Date of Core Sampling February 12, 2007			NO. SAMPLED 3		SET NO. 2	FIELD TECHNICIAN B. Spalding	
COMPRESSION TEST RESULTS									
SPECIMEN ID NUMBER	LAB NUMBER	TEST AGE (Days)	DATE OF TEST	TOTAL LOAD (lbs)	CORE HIEGHT (in)	Correction Factor	CORE DIAMETER (in)	CORE AREA (in ²)	COMPRESSIVE STRENGTH (psi)
1	218		23-Feb-07	12,975	1.46	0.92	1.23*1.24	1.52	7,850
2	218		23-Feb-07	7,580	2.70	1.00	1.22*1.25	1.52	4,990
3	218		23-Feb-07	8,995	1.38	0.94	1.05*1.06	1.11	7,620
Average Compressive Strength =								6,820	
85% of Specified Strength =									
75% of Specified Strength =									
Compression Strength Results					Break was Conical (unless otherwise noted): Noted Defects: None Specimen tested per ASTM-C-42				
<input type="checkbox"/> Comply with specified strength									
<input type="checkbox"/> Do not comply with specified strength									
<input checked="" type="checkbox"/> No strength criteria specified									

REVIEWED BY: JKA

CORE SAMPLING & TEST REPORT

PROJECT Aquatic Park Water Quality Improvement Project Berkeley, CA				REPORT DATE February 23, 2007			JOB NO. 7522.1.001.01		
				SPECIMEN PREPARED BY: ENGEO X OTHERS			MIX IDENTIFICATION N/A		
CLIENT HSI - Hydrologic Systems, Inc.				CONTRACTOR N/A			DATE SPECIMEN RECVD February 12, 2007		
				CONCRETE SUPPLIER N/A			SPECIFIED STRENGTH (psi) N/A		
SAMPLING DATA									
SAMPLE LOCATION Potter Street Drain									
Date of Concrete Pour N/A		Date of Core Sampling February 12, 2007			NO. SAMPLED 3		SET NO. 2	FIELD TECHNICIAN B. Spalding	
COMPRESSION TEST RESULTS									
SPECIMEN ID NUMBER	LAB NUMBER	TEST AGE (Days)	DATE OF TEST	TOTAL LOAD (lbs)	CORE HIEGHT (in)	Correction Factor	CORE DIAMETER (in)	CORE AREA (in ²)	COMPRESSIVE STRENGTH (psi)
1	216		23-Feb-07	2,680	2.55	1.00	1.28*1.24	1.59	1,690
2	216		23-Feb-07	37,925	3.28	0.90	2.92	6.70	5,090
3	216		23-Feb-07	28,070	3.19	0.89	2.92	6.70	3,730
4	216		23-Feb-07	3,570	2.80	1.00	1.27*1.29	1.64	2,180
Average Compressive Strength =								3,170	
85% of Specified Strength =									
75% of Specified Strength =									
Compression Strength Results					Break was Conical (unless otherwise noted): Noted Defects: None Specimen tested per ASTM-C-42				
<input type="checkbox"/> Comply with specified strength									
<input type="checkbox"/> Do not comply with specified strength									
<input checked="" type="checkbox"/> No strength criteria specified									

REVIEWED BY: JKA

Appendix E
Geotechnical Evaluation

**GEOTECHNICAL EXPLORATION
AQUATIC PARK WATER QUALITY
IMPROVEMENT PROJECT
BERKELEY, CALIFORNIA**

**SUBMITTED
TO
HSI HYDROLOGIC SYSTEMS, INC.
SAN RAFAEL, CALIFORNIA**

**PREPARED
BY
ENGEO INCORPORATED
PROJECT NO. 7522.1.001.01**

MAY 4, 2007

Project No.
7522.1.001.01

May 4, 2007

Mr. Thomas Burke
HSI Hydrologic Systems, Inc.
2175 East San Francisco Boulevard, Suite A
San Rafael, CA 94901

Subject: Aquatic Park Water Quality Improvement Project
Berkeley, California

GEOTECHNICAL EXPLORATION

Dear Mr. Burke:

With your authorization, ENGEO Incorporated conducted a geotechnical exploration for the design of the proposed new culverts as part of the Aquatic Park Water Quality Improvement Project in Berkeley, California.

This report provides geotechnical parameters for design of the proposed new culvert connections to the Potter Street Drain from the Model Yacht Basin and the Radio Tower Pond and the proposed new culverts from the Model Yacht Basin to the Main Lagoon.

We are pleased to be of service to you on this project. If you have any questions regarding the contents of this report, do not hesitate to contact us.

Very truly yours,

ENGEO INCORPORATED


Benjamin Serna
bs/jb


Donald E. Bruggers, GE



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INTRODUCTION

Purpose and Scope

The purpose of this geotechnical report is to provide geotechnical parameters for design of the proposed new culvert connections to the Potter Street Drain from the Model Yacht Basin and the Radio Tower Pond and the proposed new culverts from the Model Yacht Basin to the Main Lagoon.

The scope of our services included the following:

- Reviewing available literature and geologic maps pertinent to the site.
- Exploratory drilling of four test borings at the proposed culvert locations.
- Sampling and laboratory testing of subsurface materials from the boreholes.
- Analyzing the geotechnical data.
- Reporting our findings and recommendations.

This geotechnical exploration was conducted as part of a larger investigation for the Aquatic Park Water Quality Improvement Project and included testing and observations to provide as-built information related to various existing box culverts located at the Model Yacht Basin, Radio Tower Pond and Main Lagoon.

This report was prepared for the exclusive use of HSI Hydrologic Systems, Inc., and its design team consultants. In the event that any changes are made in the character, design or layout of the proposed culverts, the conclusions and recommendations contained in this report must be reviewed by ENGEO Incorporated to determine whether modifications to the report are necessary. This document may not be reproduced in whole or in part by any means whatsoever, nor may it be quoted or excerpted without the express written consent of ENGEO Incorporated.

Site Location and Description

The site is located within the Berkeley Aquatic Park in the City of Berkeley, California as shown in the Vicinity Map (Figure 1). The Berkeley Aquatic Park consists of three ponds named from north to south: the Main Lagoon, Model Yacht Basin, and Radio Tower Pond. The Potter Street Drain culvert runs along Potter Street between the Model Yacht Basin and the Radio Tower Pond, exiting into the San Francisco Bay in a horseshoe-shaped culvert. The Potter Street Drain culvert reportedly transitions to a circular culvert at the proposed connection locations and that the City of Berkeley has not been able to locate any as-built plans for the culvert.

Proposed Improvements

We understand it is proposed to structurally connect new culverts from the Model Yacht Basin and the Radio Tower Pond to the Potter Street Drain with a pre-cast concrete gated culvert or weir structure. Borings B-3 and B-4 (Figure 2) were advanced in the approximate location of the proposed connections. In addition, we understand it is proposed to connect the Main Lagoon to the Model Yacht Basin with two new culverts, likely pre-cast concrete culvert pipes, at the approximate locations of B-1 and B-2 on Figure 2.

GEOLOGIC CONDITIONS

Site Geology

The site is situated in the Coast Ranges geomorphic province of California, which is characterized by a series of parallel, northwesterly trending, folded and faulted mountain ranges and valleys. As shown on the Geologic Map (Figure 3) by Graymer (2000), the area of the project site is mapped as artificial fill (af).

Site Seismicity

The site is located in a region that contains numerous active¹ earthquake faults. Nearby active faults include the Hayward Fault, located about 2.9 miles east of the site; the Calaveras Fault, located approximately 14.3 miles southeast of the site; the San Andreas Fault, located about 15.5 miles southwest of the site; and the Rodgers Creek Fault, located about 16.6 miles to the northwest.

Numerous small earthquakes occur every year in the San Francisco Bay Region, and larger earthquakes have been recorded and can be expected to occur in the future. Figure 4 shows the approximate locations of these faults and significant historic earthquakes recorded within the San Francisco Bay Region.

¹ An active fault is defined by the State Mining and Geology Board as one that has had surface displacement within Holocene time (about the last 11,000 years) (Hart, 1997).

FIELD EXPLORATION

Laboratory Testing

The field exploration was conducted on January 26, 2007, and consisted of drilling four soil borings (B-1 through B-4) to a maximum depth of approximately 21.5 feet below the existing ground surface. The test borings were drilled using a truck-mounted CME-75 drill rig using mud rotary drilling methods. Soil samples recovered during drilling were from a 3-inch O.D. California-type split-spoon sampler fitted with 6-inch-long brass liners. The drill rig was equipped with a cathead and pulley system to raise the down-hole hammer. The samplers driven into the ground require a 140-pound hammer with a 30-inch drop. The penetration of the samplers into the materials was field recorded as the number of blows needed to drive the sampler eighteen inches in 6-inch increments. The results on the boring logs were recorded as the number of blows required for the last one foot of penetration and are presented without correction factors.

The boring was logged in the field by an ENGEO engineer. The field log was then used to develop the boring logs (Appendix A). The logs depict subsurface conditions within the borings for the date of drilling; however, subsurface conditions may vary with time.

Laboratory Testing

Selected samples recovered during drilling were tested to determine the following soil characteristics:

Soil Characteristic	Test Method	Location of Results
Natural Unit Weight and Moisture Content	ASTM D-2216	Boring Logs, Appendix A
Atterberg Limits	ASTM D-4318	Appendix B
Gradation and Percent Passing No. 200 Sieve	ASTM D-422	Appendix B
Unconfined Compression Strength	ASTM D-2166	Appendix B

The applicable laboratory test results are shown on the boring logs in Appendix A and individual test results are presented in Appendix B.

Subsurface Stratigraphy

Based on the boring logs, the on-site soils consist of approximately 4-inch-thick asphalt concrete on Bolivar Drive to about 5-inch-thick asphalt concrete on Potter Street, over aggregate base. The asphalt concrete and aggregate base are underlain by undocumented fill, with a generally discontinuous stratigraphy throughout the site. The fill along Bolivar Drive generally consists of a layer of silty sand, underlain by clayey sand and sandy clay, or silty and sandy clay with interbedded layers of clayey sand. The fine-grained soils (silts and clays) are generally stiff to very stiff and the more granular deposits are loose to medium dense. The fill along Potter Street consists of a layer of silty sand underlain by silty and sandy clay, or clay underlain by clayey gravel, clayey sand, and gravelly clay. The fine-grained soils are generally medium stiff to stiff, with a soft to medium stiff layer. The more granular deposits are generally very loose to loose with a medium dense to dense layer.

Groundwater Conditions

The groundwater level was obscured by the mud rotary drilling fluid in soil borings at the time of drilling; however, we anticipate that the groundwater level is at the level of the adjacent ponds, approximately 6 feet below the ground surface in the location of the soil borings.

Fluctuations in groundwater levels may occur seasonally and over a period of years because of tidal effects, precipitation, changes in drainage patterns, irrigation and other factors that may not be present at the time of this geotechnical exploration. Based on the cross section through the Potter Street drain pipe provided by you, the location of the proposed culverts connecting the drain to the Model Yacht Basin and Radio Tower Pond will lie within the tide range. Therefore, dewatering of the soils in this area should be anticipated during the construction of the proposed culverts along Potter Street and Bolivar Drive.

DISCUSSION AND CONCLUSIONS

Seismic Hazards

Seismic hazards can generally be classified as primary and secondary. The primary hazard is ground rupture, also called surface faulting or ground rupture. Common secondary seismic hazards include ground shaking, lurch cracking, soil liquefaction, lateral spreading, landslides, and tsunamis and seiches.

Since there are no known active faults crossing the site and the site is not within a State of California Earthquake Fault Hazard Zone, the risk of ground rupture related to faulting is considered remote.

Based on topographic and lithologic data, risk from earthquake-induced lurch cracking, regional subsidence or uplift, or landslides are considered low to negligible at the site.

The risk of earthquake-induced ground shaking, liquefaction, densification, lateral spreading, tsunamis and seiches are discussed below.

Ground Shaking. An earthquake of moderate to high magnitude generated within the San Francisco Bay Region could cause considerable ground shaking at the site. To mitigate the shaking effects, all structures should be designed using sound engineering judgment and the latest California Building Code (CBC, 2001) requirements as a minimum.

Based on site conditions, the soil profile at the site can be classified as S_D , as defined in CBC Table 16-J. According to CBC Tables 16-S and 16-T, near-source factors, N_a of 1.23 and N_v of 1.64, are based on the Hayward fault being seismic sources type A, approximately 2.9 miles (4.7 km) to the east. The CBC parameters are presented in the following table.

2001 CALIFORNIA BUILDING CODE – Chapter 16

ITEM	DESIGN VALUE	SOURCE
Seismic Zone	4	Figure 16-2
Seismic Zone Factor	0.40	Table 16-I
Soil Profile Type	S _D	Table 16-J
Seismic Source Type	A	Table 16-U
Near Source Factor, N _a	1.23	Table 16-S
Near Source Factor, N _v	1.64	Table 16-T
Seismic Coefficient, C _a	0.54	Table 16-Q
Seismic Coefficient, C _v	1.05	Table 16-R

Liquefaction. Liquefaction is a phenomenon in which saturated cohesionless soils are subject to a temporary, but essentially total, loss of shear strength because of pore pressure build-up under the reversing cyclic shear stresses associated with earthquakes.

As shown on the log of Boring B-1, a layer of saturated, loose sand and silty sand is found at depths of about 6 to 15 feet below ground surface. In addition, the log of Boring B-3 shows a layer of saturated, loose silty gravel and very loose silty sand at a depth of about 6 to 15 feet below ground surface. The particle size gradation test results of the soil samples recovered from Borings B-1 and B-3 are presented in Appendix B. The soil sample recovered from Boring B-1 at 8½ feet is poorly graded sand with a low proportion of fines (less than 15 percent passing the No. 200 sieve) and is considered liquefiable. The soil sample recovered from Boring B-1 at 11 feet is silty sand with a low proportion of fines and is considered liquefiable. The soil sample recovered from Boring B-3 at 9 feet is sandy silty gravel with a relatively low proportion of fines and is considered susceptible to liquefaction. The soil sample recovered from Boring B-3 at 11 feet is silty sand with a moderate proportion of fines (approximately 26 percent passing the No. 200 sieve). Accordingly, the silty sandy soils are considered potentially

vulnerable to liquefaction. Measures to address the potential for earthquake induced settlement/densification are included in the following section of this report.

Densification Due to Earthquake Shaking. Densification of the sandy soils above and below the groundwater level can cause settlement/densification during an earthquake. Since some of the granular materials encountered in Borings B-1 and B-3 were characterized as very loose to loose and liquefiable, we estimate that settlement due to seismic shaking in the localized sand layers is estimated to be approximately 2 inches. We recommend that the culvert structures planned in the areas of Borings B-1 and B-3 be designed to accommodate 2 inches of differential settlement over the length of the structure.

Lateral Spreading. Lateral spreading is a failure within a nearly horizontal soil zone (possibly due to liquefaction) that causes the overlying soil mass to move toward a free face or down a gentle slope. Due to the anticipated subsurface conditions and the purposes of the project, it is our opinion that the potential for adverse effects of lateral spreading at the improvement location is low.

Tsunamis and Seiches. A tsunami is a series of waves generated by substantial seafloor displacements caused by an event such as an earthquake. Seiches are a series of standing waves of a body of water, such as the San Francisco Bay, caused by earthquake shaking. The site is mapped in an area of potential tsunami inundation within the San Francisco Bay (Ritter and Dupre, 1972). Accordingly, it is possible that the location of the improvements will be temporarily inundated during a tsunami or seiche event; however, it is our opinion that the potential for adverse effects of tsunamis and seiches on the culvert improvements is low.

Existing Fill

As described previously, undocumented fill was encountered at the property. The fill along Bolivar Drive generally consists of a layer of silty sands, underlain by clayey sand and sandy clay, or silty and sandy clay with interbedded layers of clayey sand. The fill along Potter Street consists of a layer of silty sand underlain by silty and sandy clay, or clay underlain by clayey gravel, clayey sand, and gravelly clay.

We recommend that the soft fine-grained soil (silt and clay) and loose granular soil be overexcavated and recompacted to provide a firm bearing surface for foundation elements. Dewatering of the soil in this area is necessary before recompaction. Any debris should be removed at this time. Localized shoring of the existing roadways may be required, depending on the depth of fill removal.

Expansive Soil

Laboratory testing of the clayey soil report Plastic Indices ranging from 24 to 41. This is an indication that the clayey site soils exhibit a high to very high expansion potential. Expansive soils shrink and swell as a result of moisture changes. This can cause heaving and cracking of structures founded within the area of seasonal moisture variation. It is expected that the proposed culvert structures will be founded below the area of seasonal moisture variation, mitigating the effects of the expansive soils.

Corrosion Potential

An evaluation of possible corrosion impacts to site improvements has not been conducted. The primary purpose of this evaluation will be to determine if sulfate-resistant concrete is needed for culvert construction. In lieu of performing chemical testing to assess the corrosion potential, the

concrete should be designed for the severe corrosion condition as defined in the 1997 UBC; such as Type 5 cement, a water/cement ratio no greater than 0.45, and a compressive strength of at least 4,500 psi.

Conclusions

It is our opinion, based on the exploration data and laboratory test results, that construction of the improvements along the proposed alignments is suitable from a geotechnical standpoint. The recommendations included in this report, along with other sound engineering practices, should be incorporated in the design and construction of the project.

RECOMMENDATIONS

Grading

Grading directly associated with the culverts should be performed in accordance with the recommendations provided in this report. We anticipate grading will consist of excavation of soil as necessary to expose the connection location of the existing culvert on Potter Street and excavation of soil along the footprint of the proposed culverts on Potter Street and Bolivar Drive.

All grading and foundation plans should be coordinated with the Geotechnical Engineer to tailor the plans for any known soil conditions. The final plans should be reviewed by the Geotechnical Engineer prior to contract bidding for conformance with the recommendations contained in this report.

A notification of 48 hours prior to grading is needed in order for ENGEO to coordinate with the grading contractor.

Dewatering

We anticipate grading will consist of excavation along the footprint of the proposed culverts on Potter Street and Bolivar Drive, and that the excavations will extend below the groundwater table. Therefore, temporary localized shoring and dewatering will be required. Adequate dewatering should be accomplished to keep the excavations free from water during culvert construction and prior to compaction of the culvert subgrade and backfill material.

Excavation Safety and Shoring

All excavations should be properly excavated, and shored as applicable, to create a stable and safe condition. All shoring and/or sloping and construction within the excavations should conform to Cal-OSHA requirements. It is recommended that excavated soils from construction not be stockpiled within 5 feet of the top edge of excavation to reduce potential adverse effect on excavation stability. The contractor should thoroughly understand the subsurface conditions prior to selecting an appropriate shoring system.

The owner and contractor should make themselves aware of and become familiar with the applicable local, state, and federal safety regulations, including the current Occupational Safety and Health Agency (OSHA) Excavations and Trench Safety Standards. Construction site safety is the sole responsibility of the contractor, who should be solely responsible for the means, methods, and sequencing of construction operations.

It is the responsibility of the Contractor to provide such stable, safe trench and construction slope conditions and to follow OSHA safety requirements. Since excavation procedures may be very dangerous, it is also the responsibility of the Contractor to provide a trained “competent person” as defined by OSHA to supervise all excavation operations, ensure that all personnel are working in safe conditions, and have thorough knowledge of OSHA excavation safety requirements.

Demolition and Stripping

Site improvements should commence with the removal of existing construction debris and improvements. In addition, the soft fine-grained soils (silt and clay) and loose soils within the new culvert area must be overexcavated and recompacted.

The excavation for the removal for the materials described above should extend to a firm, competent soil surface as approved by the Geotechnical Engineer or qualified representative in the field at the time of grading. If soft unacceptable soils exist at the design subgrade surface, additional subexcavation and replacement with granular backfill may be required. The requirement for additional subexcavation should be determined in the field during construction.

No loose or uncontrolled backfilling of depressions resulting from stripping, demolition, or other removals are permitted.

Selection of Materials

With the exception of any organically contaminated soil containing more than 2 percent organics, the site soils are suitable for use as engineered fill. The Geotechnical Engineer should be informed when import materials are planned for the site. Import materials should conform to Section 2.02B of Part I of the “Guide Contract Specifications” and must be approved by the Geotechnical Engineer. A sample of such material should be submitted to the Geotechnical Engineer for evaluation prior to delivery.

Fill Placement

The material utilized in culvert backfilling should be in accordance with the manufacturer’s recommendations. All backfill should be placed in thin lifts as engineered fill. The lift thickness should not exceed 8 inches or the depth of penetration of the compaction equipment used, whichever is less. Within the roadway area, the backfill material should terminate at the top of the box culverts and Class 2 aggregate base material should then be used for the balance of the backfill up to street subgrade. Soil backfill may be used in the slope bank area with finished slope grades matching existing grades.

The following compaction requirements apply to clayey soil backfill materials:

Test Procedures:	ASTM D-1557-78.
Required Moisture Content:	Not less than 3 percentage points above optimum moisture content.
Minimum Relative Compaction:	Not less than 90 percent.

The following compaction requirements apply to granular and Class 2 aggregate base material:

Test Procedures:	ASTM D-1557-78.
Required Moisture Content:	Not less than optimum moisture content.
Minimum Relative Compaction:	Not less than 95 percent.

It is important that all site preparation be done under the observation of a Geotechnical Engineer or his/her field representative and should be carried out according to the requirements contained in the Guide Contract Specifications in Appendix C. The Geotechnical Engineer or his/her qualified representative should be present full time during all phases of the grading operations to observe demolition, site preparation, and grading procedures. Care should be taken so that equipment used to place the backfill material does not over-stress the culverts.

Foundations

As stated earlier, it is proposed to structurally connect new culverts from the Model Yacht Basin and Radio Tower Pond to the Potter Street Drain with a pre-cast concrete box culvert. A maximum allowable bearing pressure of 2,000 psf may be used in the design of the culvert. In addition, we understand it is proposed to connect the Main Lagoon to the Model Yacht Basin with two new culverts, likely pre-cast concrete culvert pipes. Recommendations for the backfilling of pre-cast concrete culvert pipes are provided in a subsequent section of this report.

The concrete box culvert structure should be placed on a 6-inch leveling course of Class 2 AB that is placed on the prepared subgrade. Filter fabric, such as Mirafi 600X or equivalent, should be placed below the subgrade material to prevent pumping during compaction. It is important that the foundation soils be observed by a representative of ENGEO at the time they are exposed, to confirm that adequate bearing soils are present. If unsuitable soils are encountered, various options to improve the subgrade soils are available and may be provided upon request.

At-Rest Pressures. The walls of the proposed box culvert should be designed to resist at-rest lateral fluid pressures as shown below. These pressures include a hydrostatic load component, assuming the walls of culvert structure will lie below the zone of groundwater fluctuation, a condition for which drainage is not practical. Backfill of walls should be observed and tested by a field representative from ENGEO.

At-Rest Earth Pressures

Backfill Condition	Restrained Wall (pcf)
Level backfill	90

In addition, traffic surcharge loading of 75 percent of any uniform vertical surcharge pressure should be applied horizontally to the upper 5 feet of the culvert wall.

Lateral Resistance. Lateral loads may be resisted by frictional resistance between the foundation concrete and the subgrade soils and by passive earth pressure acting against the side of the foundation. The friction factor for sliding resistance may be assumed as 0.30. In addition, an allowable passive pressure based on an equivalent fluid weighing 250 (pcf) can be used in the design.

The final foundation plans should be reviewed by the Geotechnical Engineer when they become available to check for conformance with these recommendations.

Roof Loading. The roof of the culverts should be designed for static vertical load equal to the weight of the soil, roadway surface and appropriate vehicle load as determined by Caltrans standard specifications.

Pre-Cast Concrete Culvert Pipes

We understand it is proposed to connect the Main Lagoon to the Model Yacht Basin with two new culverts, likely pre-cast concrete culvert pipes. It is recommended that culvert trench backfilling be done under the observation of a Geotechnical Engineer. Culvert pipe zone backfill (i.e. material beneath and immediately surrounding the culvert pipe) may consist of a well-graded import or native material less than $\frac{3}{4}$ inch in maximum dimension compacted in accordance with recommendations provided above for engineered fill. Culvert trench zone backfill (i.e. material placed between the culvert pipe zone backfill and the ground surface) may consist of native soil compacted in accordance with recommendations for engineered fill.

Where import material is used for culvert pipe zone backfill, we recommend it consist of fine- to medium-grained sand or a well-graded mixture of sand and gravel and that this material not be used within 2 feet of finish grades. In general, uniformly graded gravel should not be used for culvert pipe or culvert trench zone backfill due to the potential for migration of: (1) soil into the relatively large void spaces present in this type of material, and (2) water movement along trenches backfilled with this type of material. All culvert trenches entering paved areas must be provided with an impervious seal consisting of native materials or concrete where the trenches pass under the pavement edges. The impervious plug should extend at least 4 feet to either side of the crossing. This is to prevent surface water percolation into the sands under pavements where such water would remain trapped in a perched condition, allowing clays to develop their full expansion potential.

Care should be exercised where culvert trenches are located beside foundation areas. Culvert trenches constructed parallel to foundations should be located entirely above a plane extending down from the lower edge of the footing at an angle of 45 degrees. The contractor should be made aware of this information.

Culvert trenches in areas to be paved should be constructed in accordance with local agency requirements. Compaction of native trench backfill by jetting should not be allowed at this site. If there appears to be a conflict between the City or other agency requirements and the recommendations contained in this report, this should be brought to the Owner's attention for resolution prior to submitting bids.

Preliminary Pavement Design

Pavement reconstruction and all materials should conform to the specifications and requirements of the Standard Specifications by the Division of Highways, Department of Public Works, State of California, latest edition, City requirements, and the following minimum requirements.

- All pavement subgrades should be scarified to a depth of 12 inches below finished subgrade elevation; moisture conditioned to 3 percent above optimum, and compacted to at least 90 percent relative compaction and in accordance with city requirements.
- Subgrade soils should be in a stable, non-pumping condition at the time aggregate baserock materials are placed and compacted.
- Adequate provisions must be made such that the subgrade soils and aggregate baserock materials are not allowed to become saturated.
- Aggregate baserock materials should meet current Caltrans specifications for Class 2 aggregate baserock and should be compacted to at least 95 percent of maximum dry density.
- Asphalt paving materials should meet current Caltrans specifications for asphalt concrete.

LIMITATIONS AND UNIFORMITY OF CONDITIONS

This report is issued with the understanding that it is the responsibility of the owner to transmit the information and recommendations of this report to contractors, engineers, and designers for the project so that the necessary steps can be taken by the contractors and subcontractors to carry out such recommendations in the field. The conclusions and recommendations contained in this report are solely professional opinions.

The professional staff of ENGEO Incorporated strives to perform its services in a proper and professional manner with reasonable care and competence but is not infallible. There are risks of earth movement and property damages inherent in land development. We are unable to eliminate all risks or provide insurance; therefore, we are unable to guarantee or warrant the results of our work.

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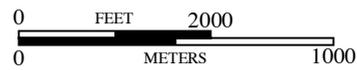
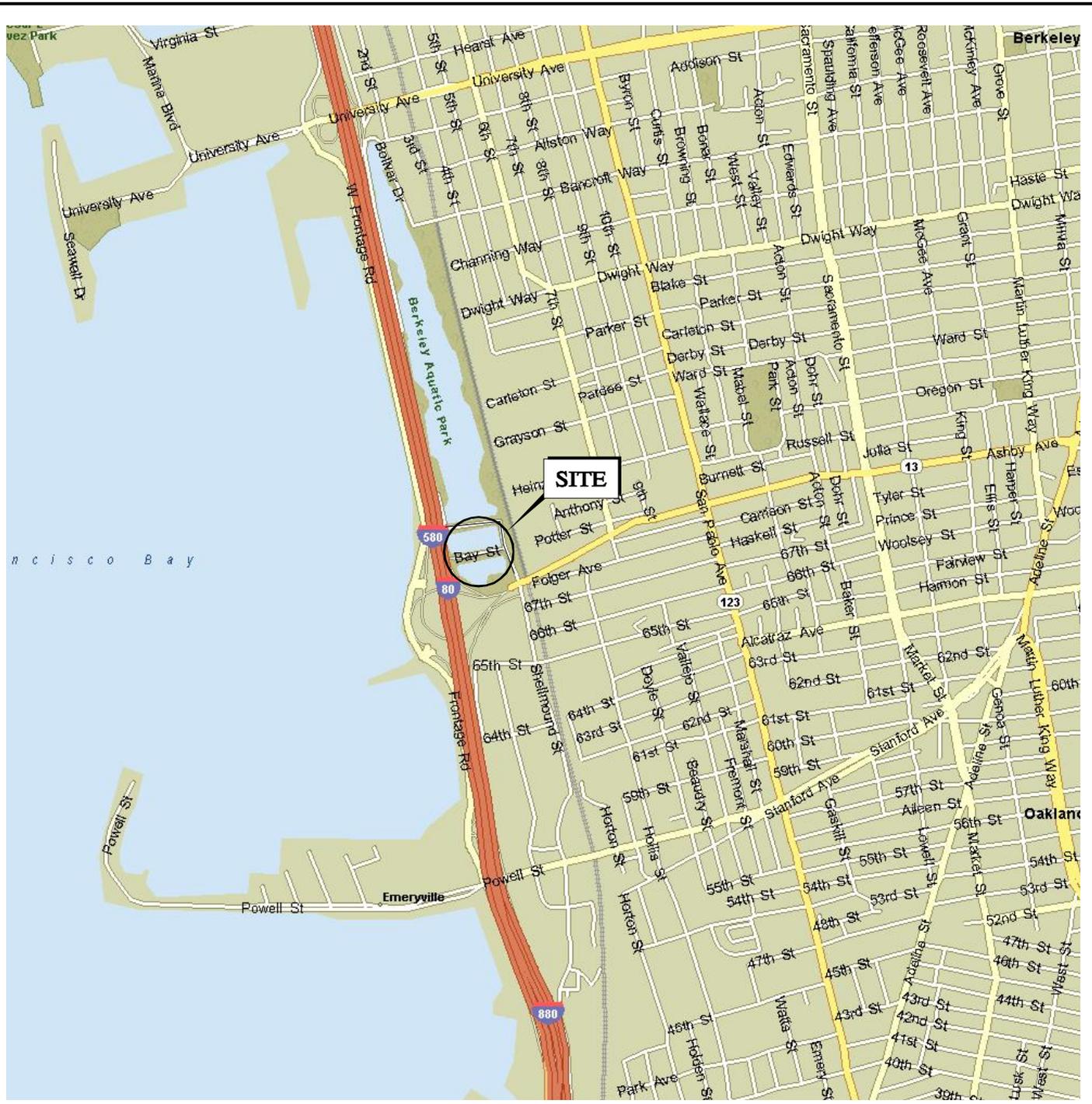
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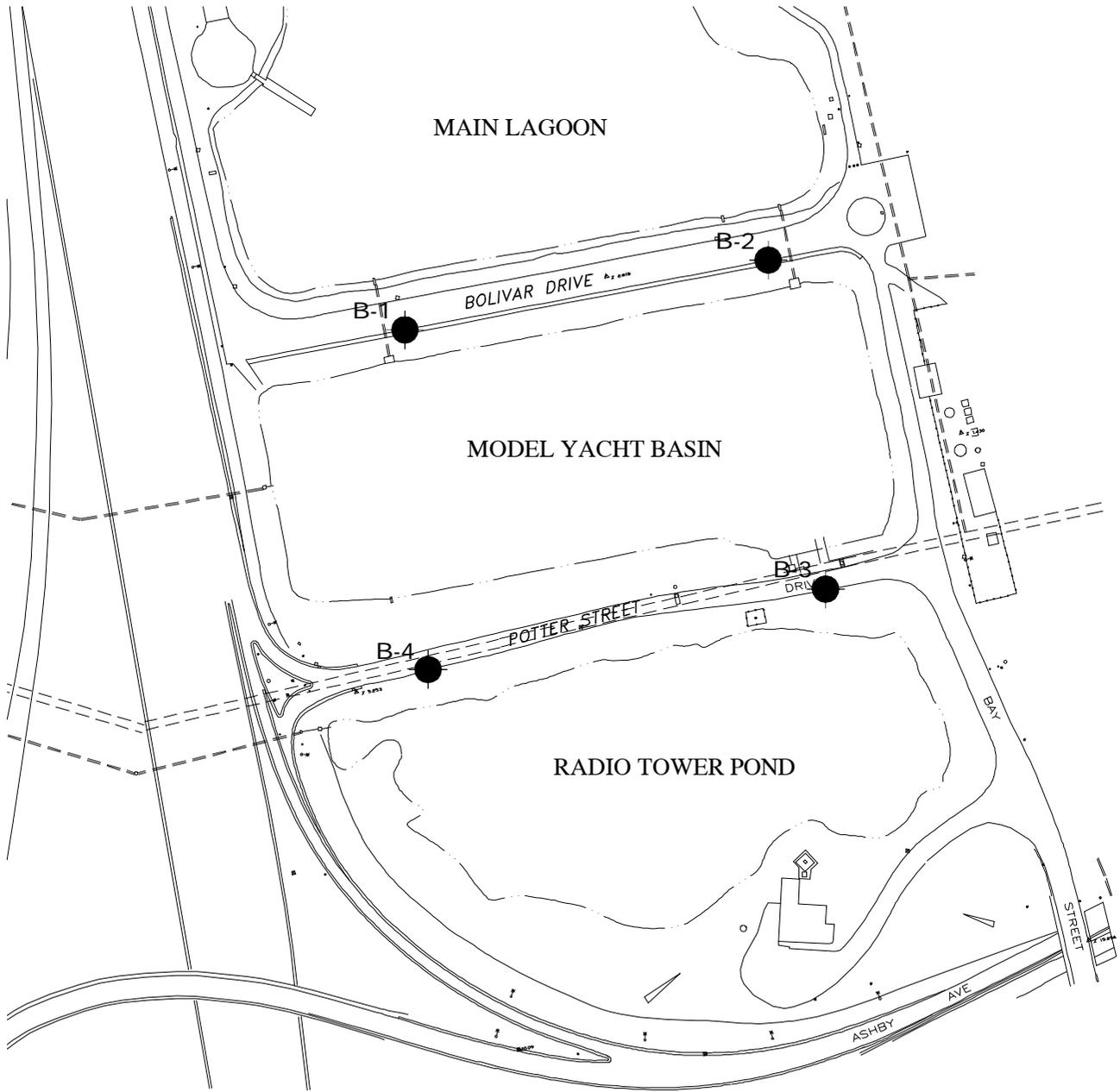
BASE MAP SOURCE: MS STREETS AND TRIPS



VICINITY MAP
AQUATIC PARK WATER QUALITY IMPROVEMENT PROJECT
BERKELEY, CALIFORNIA

PROJECT NO.: 7522.1.001.01	FIGURE NO. 1
DATE: MAY 2007	
DRAWN BY: SRP CHECKED BY: DEB	

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EXPLANATION

B-4 ● APPROXIMATE LOCATION OF BORING



BASE MAP SOURCE: HSI



SITE PLAN
AQUATIC PARK WATER QUALITY IMPROVEMENT PROJECT
BERKELEY, CALIFORNIA

PROJECT NO.: 7522.1.001.01

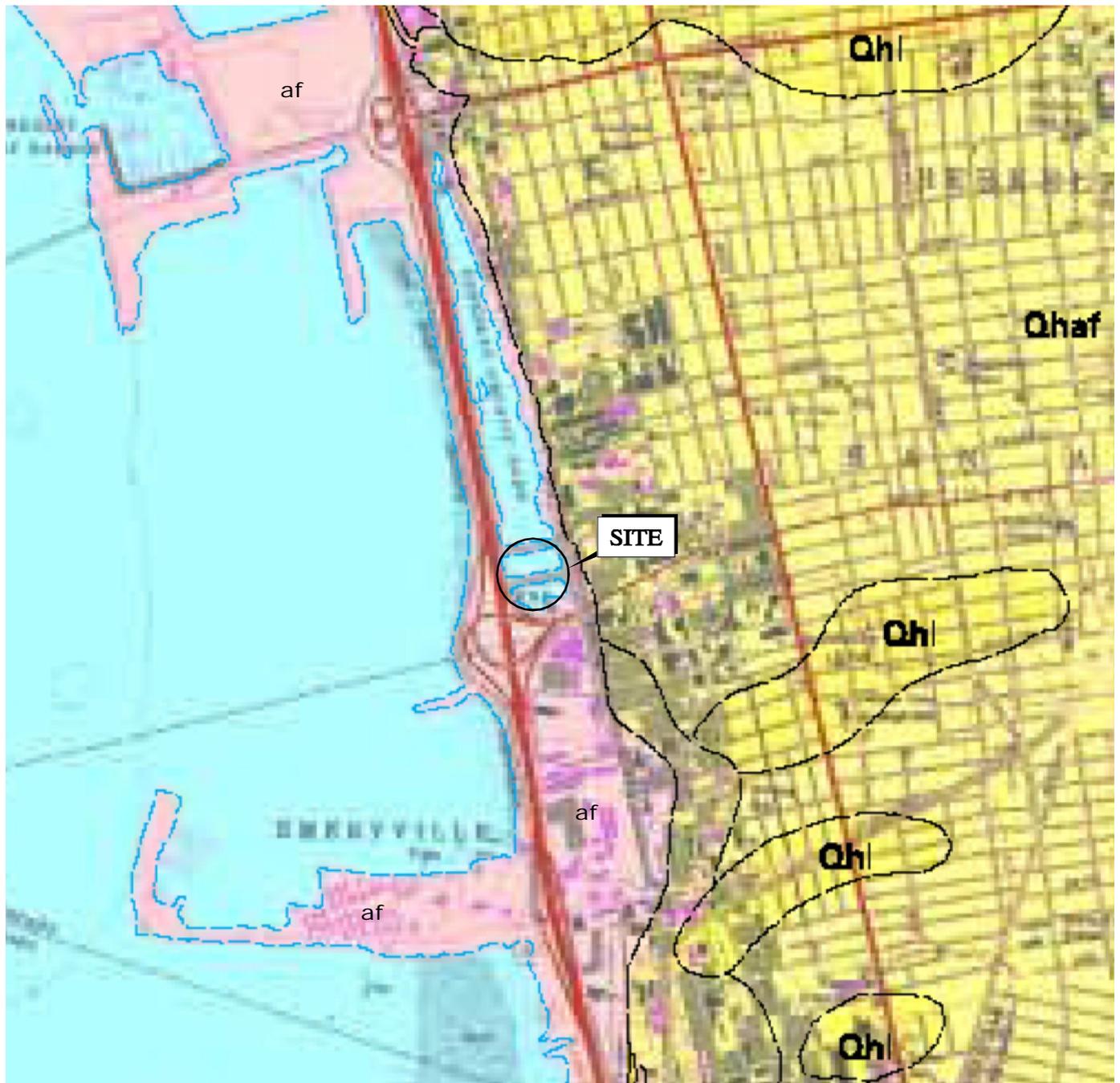
DATE: MAY 2007

DRAWN BY: SRP

CHECKED BY: DEB

FIGURE NO.

2



EXPLANATION

- Qh1 ALLUVIAL FAN AND FLUVIAL DEPOSITS (HOLOCENE)
- Qhaf NATURAL LEVEE DEPOSITS (HOLOCENE)
- af ARTIFICIAL FILL



BASE MAP SOURCE: GRAYMER, 2000



GEOLOGIC MAP
 AQUATIC PARK WATER QUALITY IMPROVEMENT PROJECT
 BERKELEY, CALIFORNIA

PROJECT NO.: 7522.1.001.01

DATE: MAY 2007

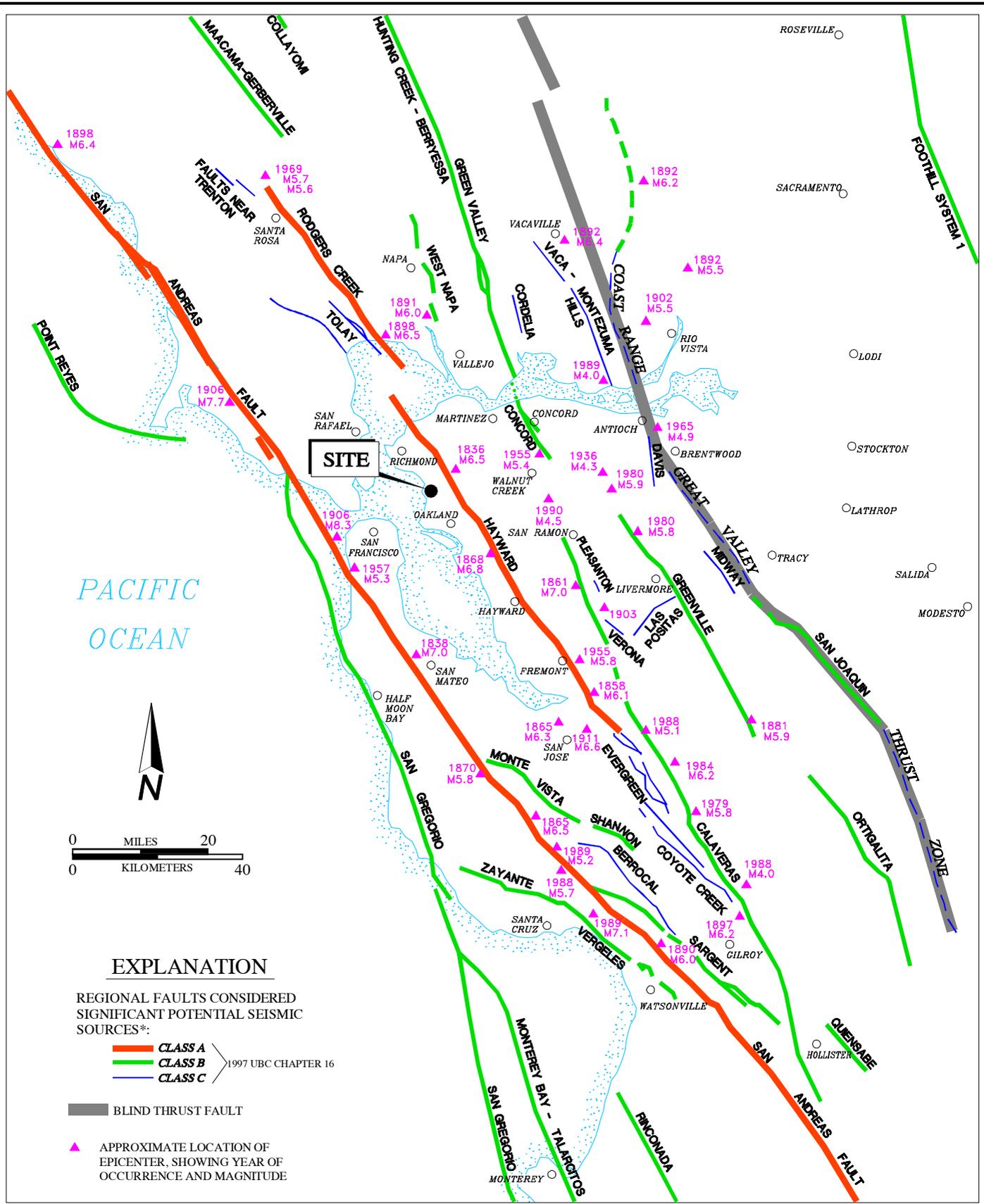
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CHECKED BY: DEB

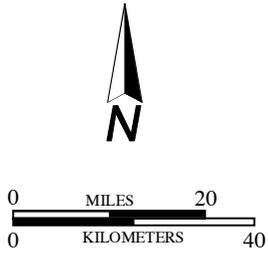
FIGURE NO.

3

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PACIFIC OCEAN



EXPLANATION

- REGIONAL FAULTS CONSIDERED SIGNIFICANT POTENTIAL SEISMIC SOURCES*:
- CLASS A
 - CLASS B
 - CLASS C
- } 1997 UBC CHAPTER 16
- BLIND THRUST FAULT
 - ▲ APPROXIMATE LOCATION OF EPICENTER, SHOWING YEAR OF OCCURRENCE AND MAGNITUDE

*BASED ON USGS OPEN FILE 96-706



REGIONAL FAULTING AND SEISMICITY
AQUATIC PARK WATER QUALITY IMPROVEMENT PROJECT
BERKELEY, CALIFORNIA

PROJECT NO.: 7522.1.001.01	
DATE: MAY 2007	
DRAWN BY: SRP	CHECKED BY: DEB

FIGURE NO.
4

APPENDIX A

ENGEO INCORPORATED

Boring Logs

7522.1.001.01
May 4, 2007

KEY TO BORING LOGS

MAJOR TYPES

DESCRIPTION

COARSE-GRAINED SOILS MORE THAN HALF OF MAT'L LARGER THAN #200 SIEVE	GRAVELS MORE THAN HALF COARSE FRACTION IS LARGER THAN NO. 4 SIEVE SIZE	CLEAN GRAVELS WITH LITTLE OR NO FINES		GW - Well graded gravels or gravel-sand mixtures
		GRAVELS WITH OVER 12 % FINES		GP - Poorly graded gravels or gravel-sand mixtures
	SANDS MORE THAN HALF COARSE FRACTION IS SMALLER THAN NO. 4 SIEVE SIZE	CLEAN SANDS WITH LITTLE OR NO FINES		SW - Well graded sands, or gravelly sand mixtures
		SANDS WITH OVER 12 % FINES		SP - Poorly graded sands or gravelly sand mixtures
FINE-GRAINED SOILS MORE THAN HALF OF MAT'L SMALLER THAN #200 SIEVE	SILTS AND CLAYS LIQUID LIMIT 50 % OR LESS		ML - Inorganic silt with low to medium plasticity	
			CL - Inorganic clay with low to medium plasticity	
			OL - Low plasticity organic silts and clays	
	SILTS AND CLAYS LIQUID LIMIT GREATER THAN 50 %		MH - Inorganic silt with high plasticity	
			CH - Inorganic clay with high plasticity	
			OH - Highly plastic organic silts and clays	
HIGHLY ORGANIC SOILS		PT - Peat and other highly organic soils		

GRAIN SIZES

U.S. STANDARD SERIES SIEVE SIZE				CLEAR SQUARE SIEVE OPENINGS			
200	40	10	4	3/4 "	3"	12"	
SILTS AND CLAYS	SAND			GRAVEL		COBBLES	BOULDERS
	FINE	MEDIUM	COARSE	FINE	COARSE		

RELATIVE DENSITY

SANDS AND GRAVELS	BLOWS/FOOT (S.P.T.)
VERY LOOSE	0-4
LOOSE	4-10
MEDIUM DENSE	10-30
DENSE	30-50
VERY DENSE	OVER 50

CONSISTENCY

SILTS AND CLAYS	STRENGTH*	BLOWS/FOOT (S.P.T.)
VERY SOFT	0-1/4	0-2
SOFT	1/4-1/2	2-4
MEDIUM STIFF	1/2-1	4-8
STIFF	1-2	8-15
VERY STIFF	2-4	15-30
HARD	OVER 4	OVER 30

MOISTURE CONDITION

DRY	Absence of moisture, dusty, dry to touch
MOIST	Damp but no visible water
WET	Visible freewater
SATURATED	Below the water table

MINOR CONSTITUENT QUANTITIES (BY WEIGHT)

TRACE	Particles are present, but estimated to the less than 5%
SOME	5 to 15%
WITH	15 to 30%
.....Y	30 to 50%

SAMPLER SYMBOLS

-  Modified California (3" O.D.) sampler
-  California (2.5" O.D.) sampler
-  S.P.T. - Split spoon sampler
-  Shelby Tube
-  Continuous Core
-  Bag Samples
-  Grab Samples
- NR No Recovery

LINE TYPES

-  Solid - Layer Break
-  Dashed - Gradational or approximate layer break

GROUND-WATER SYMBOLS

-  Groundwater level during drilling
-  Stabilized groundwater level

(S.P.T.) Number of blows of 140 lb. hammer falling 30" to drive a 2-inch O.D. (1-3/8 inch I.D.) sampler

* Unconfined compressive strength in tons/sq. ft., asterisk on log means determined by pocket penetrometer



LOG OF BORING 1

Hydrologic Systems
Berkeley Aquatic Park
Berkeley, CA
7522.1.001.01

DATE DRILLED: 1/26/2007
HOLE DEPTH: Approx. 21½ ft.
HOLE DIAMETER: 5.0 in.
SURF ELEV (FT): Approx. 10 ft.

LOGGED / REVIEWED BY: B. Serna / DEB
DRILLING CONTRACTOR: Pitcher Drilling Co.
DRILLING METHOD: Mud Rotary
HAMMER TYPE: 140 lb. Rope and Cathead

Depth in Feet	Depth in Meters	Sample Type	DESCRIPTION	Log Symbol	Water Level	Blow Count/Foot	Atterberg Limits			Fines Content (% passing #200 sieve)	Moisture Content (% dry weight)	Dry Unit Weight (pcf)	Unconfined Strength (tsf) *field approx
							Plastic Limit	Liquid Limit	Plasticity Index				
			Approx. 4" asphalt concrete.										
			Sandy clayey gravel (GC), light brown, moist (fill).										
1			Silty sand (SM), light brown to gray, medium dense, moist, fine-grained (fill).			30				8			
5													
2			Silty sand (SM), light brown to gray, loose, wet, fine-grained (fill).		▽	13							
			Sand (SP), light brown to gray, loose, wet, fine-grained, trace shell fragments (fill).			13				10			
10													
			Clayey sand (SC), bluish gray, loose, wet, fine-grained, trace fine-grained gravel and shell fragments (fill).			13				13			
4													
15													
5			Sandy clay (CL), light grayish brown, stiff, wet, fine to coarse-grained sand, trace gravel and shell fragments (fill).			23				24	103	1.6	
20													
			Sandy clay (CL), light grayish brown, very stiff to hard, wet, fine- to coarse-grained sand, trace shell fragments (fill).			55				26	98	1.25*	
			Bottom of boring at approximately 21½ feet. Groundwater level approximated from level of adjacent ponds.										



LOG OF BORING 2

Hydrologic Systems
Berkeley Aquatic Park
Berkeley, CA
7522.1.001.01

DATE DRILLED: 1/26/2007
HOLE DEPTH: Approx. 21½ ft.
HOLE DIAMETER: 5.0 in.
SURF ELEV (FT): Approx. 10 ft.

LOGGED / REVIEWED BY: B. Serna / DEB
DRILLING CONTRACTOR: Pitcher Drilling Co.
DRILLING METHOD: Mud Rotary
HAMMER TYPE: 140 lb. Rope and Cathead

Depth in Feet	Depth in Meters	Sample Type	DESCRIPTION	Log Symbol	Water Level	Blow Count/Foot	Atterberg Limits			Fines Content (% passing #200 sieve)	Moisture Content (% dry weight)	Dry Unit Weight (pcf)	Unconfined Strength (tsf) *field approx
							Plastic Limit	Liquid Limit	Plasticity Index				
			Approx. 4" asphalt concrete.										
			Sandy clayey gravel (GC), light brown, moist (fill).										
1			Silty sand (SM), light brown to gray, medium dense, moist, fine-grained (fill).			24							
5													
2			Silty sand (SM), light brown to gray, loose, wet, fine-grained (fill).		▽	13				20			
			Clayey sand (SC), dark olive gray, medium dense, wet, some coarse gravel, trace shell fragments (fill).										
			Sandy clay (CL), light reddish brown with orange and black mottling, medium stiff to stiff, wet, fine-grained sand (fill).			18				30	98	1.0*	
10			Silty clay (CL), light reddish brown with orange mottling, stiff to very stiff, wet, with fine-grained sand (fill).			17	14	38	24	20	110	3.1	
4													
15			Silty clay (CL), light grayish brown, stiff to very stiff, moist, with fine-grained sand, trace shell fragments (fill).			30						2.0*	
5													
20			Gravelly clayey sand (SC), light reddish brown with orange mottling, medium dense, wet, fine- to coarse-grained sand, fine to coarse gravel (fill).			40				19	109	2.0*	
			Silty clay (CL), olive green, stiff to very stiff, wet, orange mottling, trace fine-grained sand (fill)										
			Bottom of boring at approximately 21½ feet. Groundwater level approximate from level of adjacent ponds.										



LOG OF BORING 3

Hydrologic Systems
Berkeley Aquatic Park
Berkeley, CA
7522.1.001.01

DATE DRILLED: 1/26/2007
HOLE DEPTH: Approx. 21½ ft.
HOLE DIAMETER: 5.0 in.
SURF ELEV (FT): Approx. 10 ft.

LOGGED / REVIEWED BY: B. Serna / DEB
DRILLING CONTRACTOR: Pitcher Drilling Co.
DRILLING METHOD: Mud Rotary
HAMMER TYPE: 140 lb. Rope and Cathead

Depth in Feet	Depth in Meters	Sample Type	DESCRIPTION	Log Symbol	Water Level	Blow Count/Foot	Atterberg Limits			Fines Content (% passing #200 sieve)	Moisture Content (% dry weight)	Dry Unit Weight (pcf)	Unconfined Strength (tsf) *field approx
							Plastic Limit	Liquid Limit	Plasticity Index				
			Approx. 5" asphalt concrete.										
			Sandy clayey gravel (GC), reddish brown, fine gravel, fine- to coarse-grained sand (fill).										
1			Silty clay (CH), olive gray to brown with orange and white mottling, medium stiff to stiff, moist, trace shell fragments (fill).			10	17	58	41	35	85	1.0*	
5		NR	No sample recovery.										
2			Sandy clayey gravel (GC), dark gray, loose, wet, fine to coarse gravel, fine- to coarse-grained sand (fill).		▽	Push							
10			Sandy clayey gravel (GC), olive gray, loose, wet, fine to coarse gravel, fine- to coarse-grained sand, some red brick and concrete fragments (fill).			9				15			
15			Clayey sand (SC), olive gray, very loose, wet, fine- to coarse-grained sand, with fine gravel, some red brick and concrete fragments (fill).			5				26			
4													
15			Gravelly clay (CL), light brown to olive gray, stiff to very stiff, wet, coarse gravel, some fine- to coarse-grained sand (fill).			14				25	102	2.6	
20			Clayey sand (SC), light brown, medium dense to dense, wet, coarse-grained sand, grades to fine-grained sand, trace gravel (fill).			48							
			Bottom of boring at approximately 21½ feet. Groundwater level approximated from level of adjacent ponds.										



LOG OF BORING 4

Hydrologic Systems
Berkeley Aquatic Park
Berkeley, CA
7522.1.001.01

DATE DRILLED: 1/26/2007
HOLE DEPTH: Approx. 21½ ft.
HOLE DIAMETER: 5.0 in.
SURF ELEV (FT): Approx. 10 ft.

LOGGED / REVIEWED BY: B. Serna / DEB
DRILLING CONTRACTOR: Pitcher Drilling Co.
DRILLING METHOD: Mud Rotary
HAMMER TYPE: 140 lb. Rope and Cathead

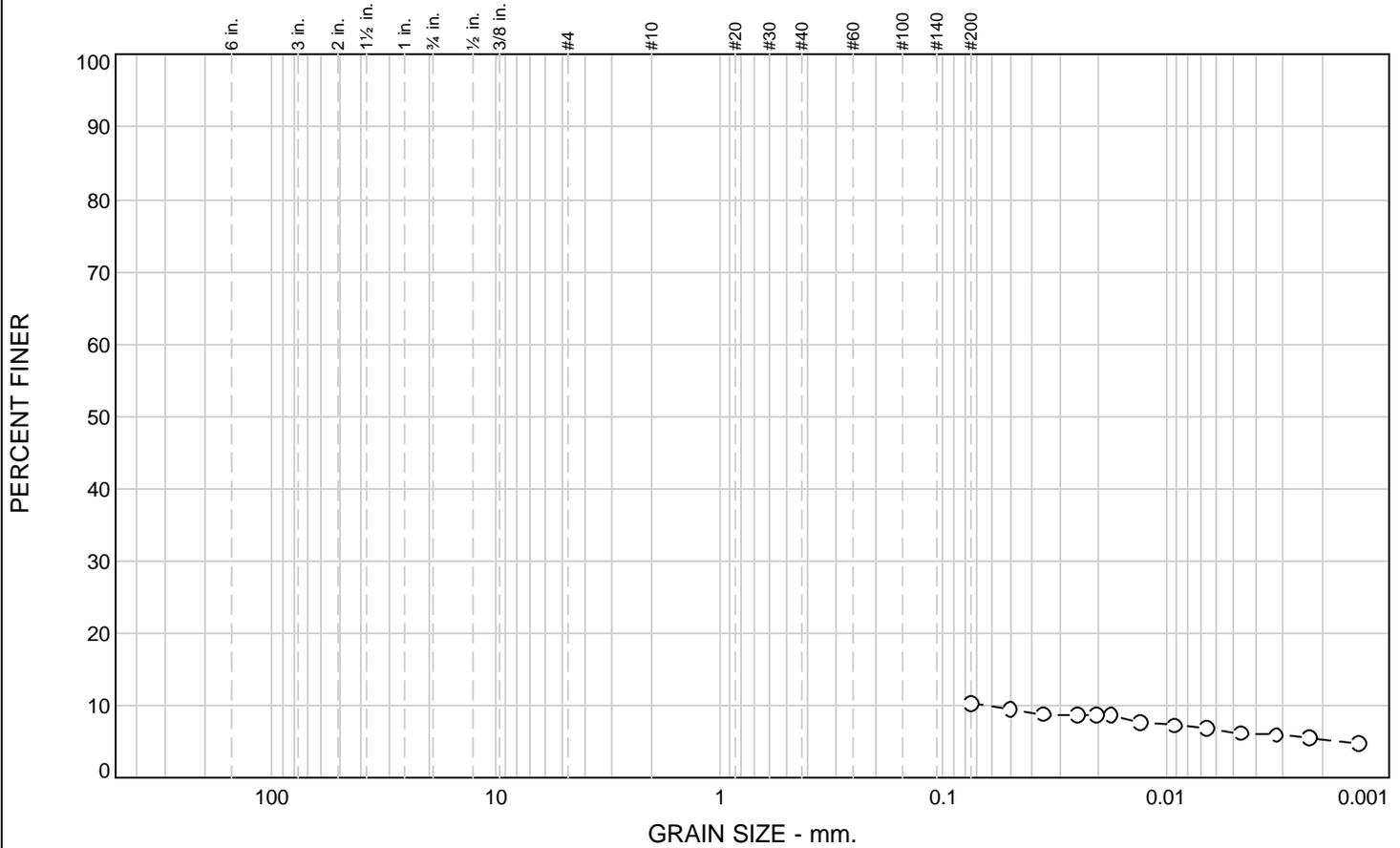
Depth in Feet	Depth in Meters	Sample Type	DESCRIPTION	Log Symbol	Water Level	Blow Count/Foot	Atterberg Limits			Fines Content (% passing #200 sieve)	Moisture Content (% dry weight)	Dry Unit Weight (pcf)	Unconfined Strength (tsf) *field approx
							Plastic Limit	Liquid Limit	Plasticity Index				
			Approx. 5" asphalt concrete.										
			Sandy clayey gravel (GC), reddish brown, moist, fine gravel, fine- to coarse-grained sand (fill).										
			Silty sand (SM), light brown to gray, moist, fine-grained (fill).										
1													
5													
2			Sandy clay (CL), olive green to light brown with orange and black mottling, medium stiff, moist, fine- to coarse-grained sand, trace brick fragments and rootlets (fill).		▽	10				29	89	0.75*	
			Silty clay (CL), olive gray to light brown with orange mottling, medium stiff to stiff, wet, with fine-grained sand (fill).			13				33	90	1.25*	
10			Silty clay (CL), olive gray with light brown mottling, soft to medium stiff, wet, with fine-grained sand, trace gravel and shell fragments (fill).			4	15	47	32	25	97	0.7	
4													
15			Sandy clay (CL), light reddish brown with dark brown mottling, stiff, moist, fine-grained sand (fill).			23						1.75*	
5													
20			Sandy clay (CL), light grayish brown with orange mottling, stiff, moist, fine-grained sand, some fine gravel (fill).			21				27	100	1.75*	
			Bottom of boring at approximately 21½ feet. Groundwater level approximated from level of adjacent ponds.										

APPENDIX B

ENGEO INCORPORATED

Laboratory Results

Particle Size Distribution Report



% Cobbles	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						5.1	5.3

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	10.4		

Material Description

Dark grayish brown SAND with silt.

Atterberg Limits

PL= LL= PI=

Coefficients

D₈₅= D₆₀= D₅₀=
D₃₀= D₁₅= D₁₀= 0.0633
C_u= C_c=

Classification

USCS= SP-SM AASHTO=

Remarks

* (no specification provided)

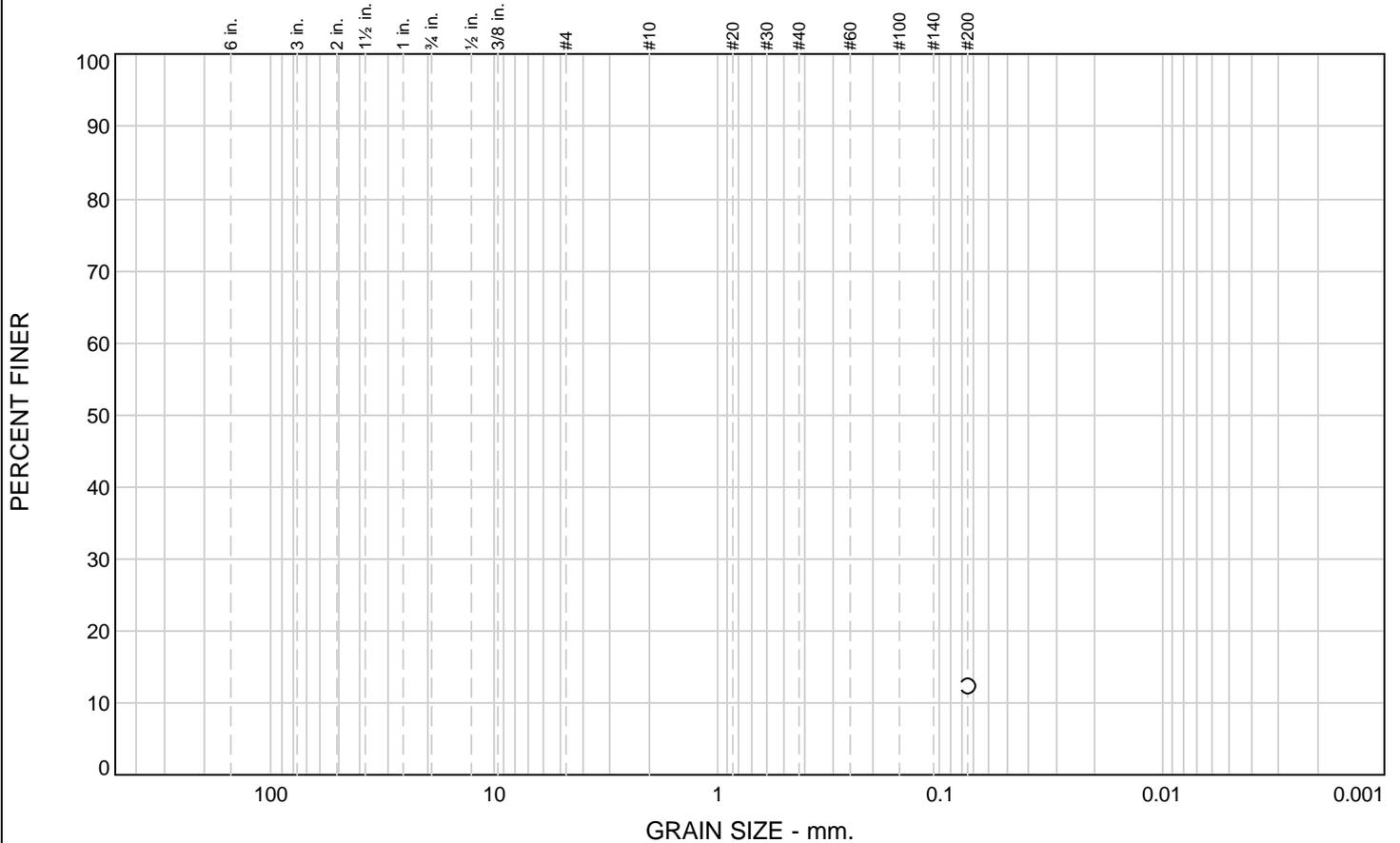
Sample Number: B1 @ 8.5'

Date: 02/14/07



Client:
Project: Aquatic Water Quality Improvement
Project No: 7522.1.001.01

Particle Size Distribution Report



% Cobbles	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						12.5	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	12.5		

Material Description

Very dark gray SAND with some silt.

Atterberg Limits

PL= LL= PI=

Coefficients

D₈₅= D₆₀= D₅₀=
D₃₀= D₁₅= D₁₀=
C_u= C_c=

Classification

USCS= SP-SM AASHTO=

Remarks

* (no specification provided)

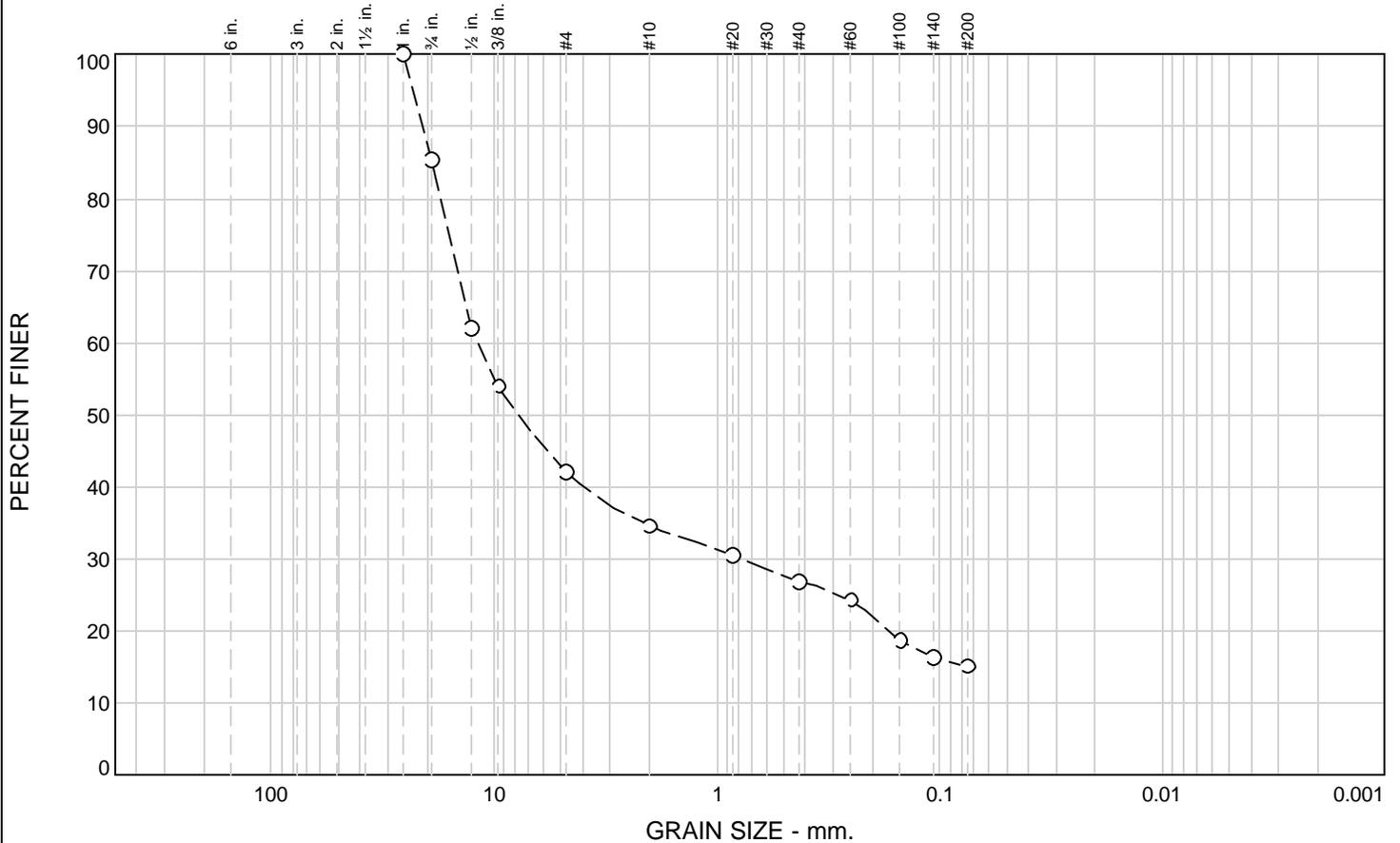
Sample Number: B1 @ 11'

Date: 02/14/07



Client:
Project: Aquatic Water Quality Improvement
Project No: 7522.1.001.01

Particle Size Distribution Report



% Cobbles	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	14.7	43.2	7.4	7.9	11.6	15.2	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1	100.0		
3/4	85.3		
1/2	62.1		
3/8	54.0		
#4	42.1		
#10	34.7		
#20	30.5		
#40	26.8		
#60	24.3		
#100	18.7		
#140	16.5		
#200	15.2		

Material Description

Greenish gray sandy GRAVEL with silt.

Atterberg Limits

PL= LL= PI=

Coefficients

D₈₅= 18.9433 D₆₀= 12.0370 D₅₀= 7.7475
D₃₀= 0.7792 D₁₅= D₁₀=
C_u= C_c=

Classification

USCS= AASHTO=

Remarks

* (no specification provided)

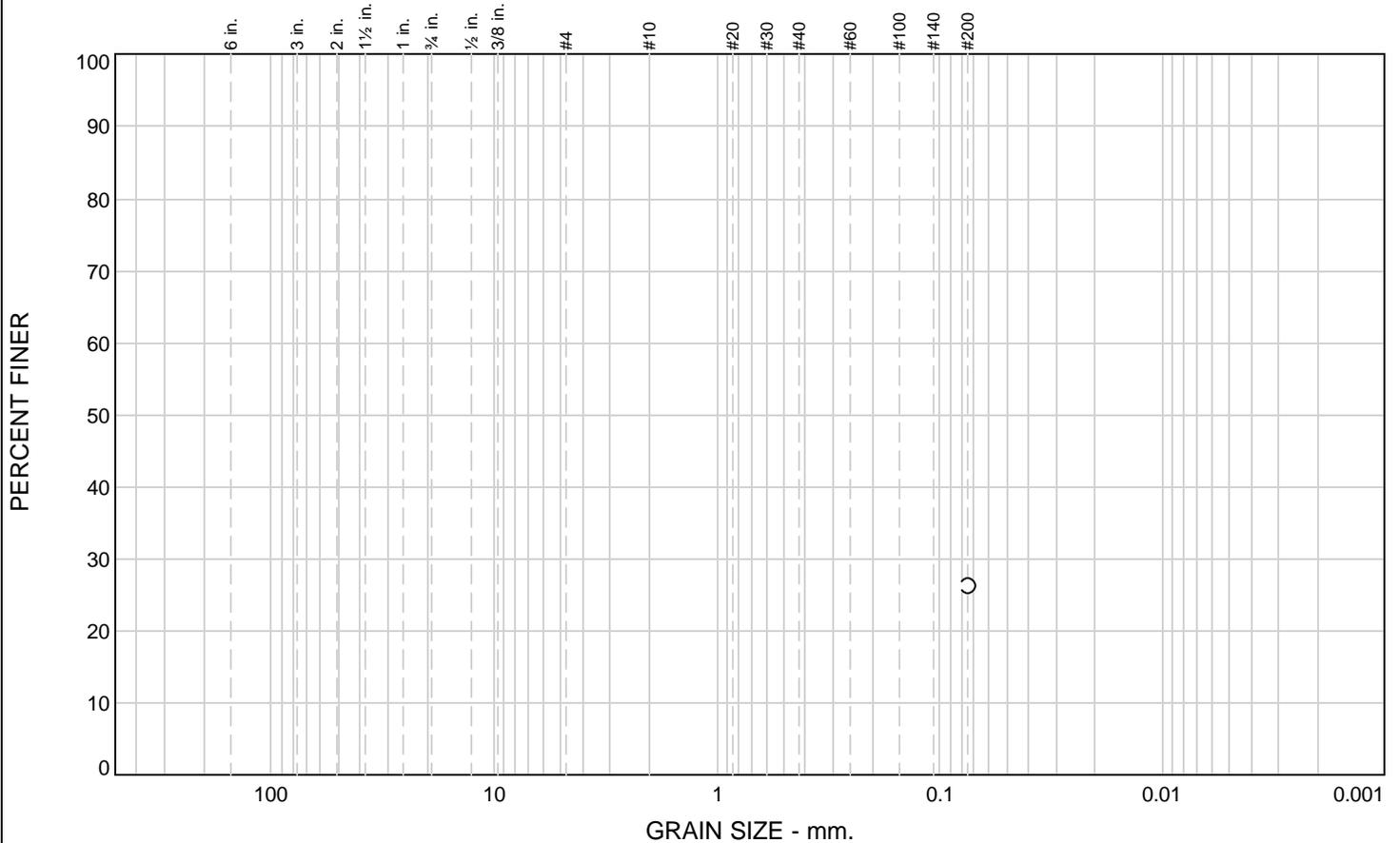
Sample Number: B3 @ 9'

Date: 02/14/07



Client:
Project: Aquatic Water Quality Improvement
Project No: 7522.1.001.01

Particle Size Distribution Report



% Cobbles	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						26.3	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	26.3		

Material Description

Dark greenish gray silty SAND.

Atterberg Limits

PL= LL= PI=

Coefficients

D₈₅= D₆₀= D₅₀=
D₃₀= D₁₅= D₁₀=
C_u= C_c=

Classification

USCS= AASHTO=

Remarks

* (no specification provided)

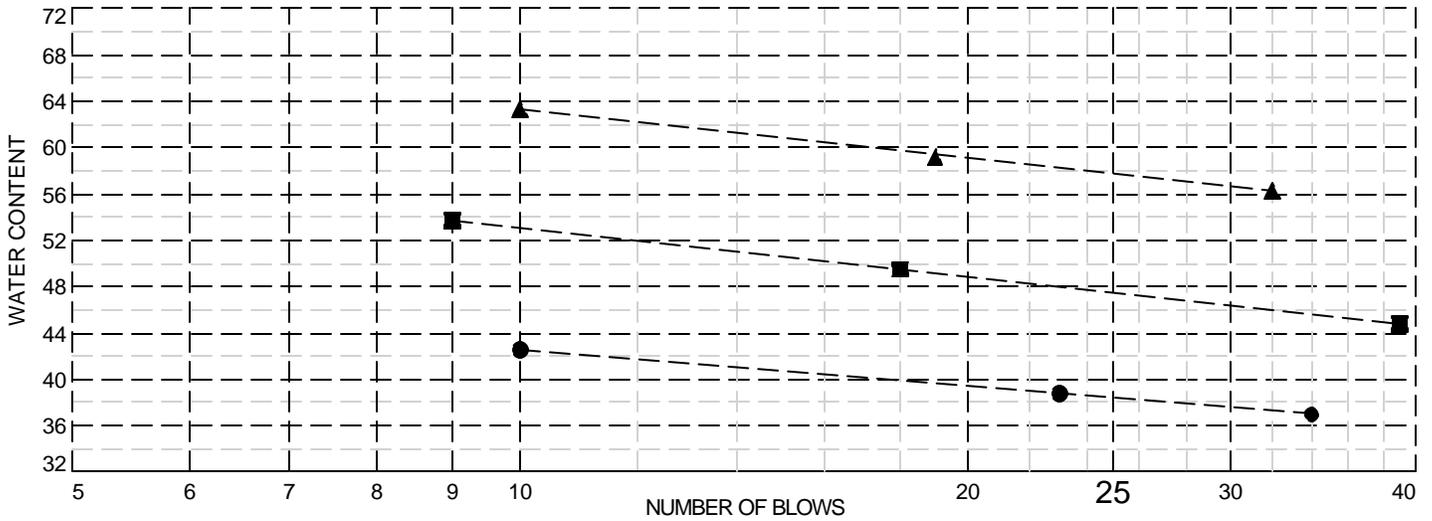
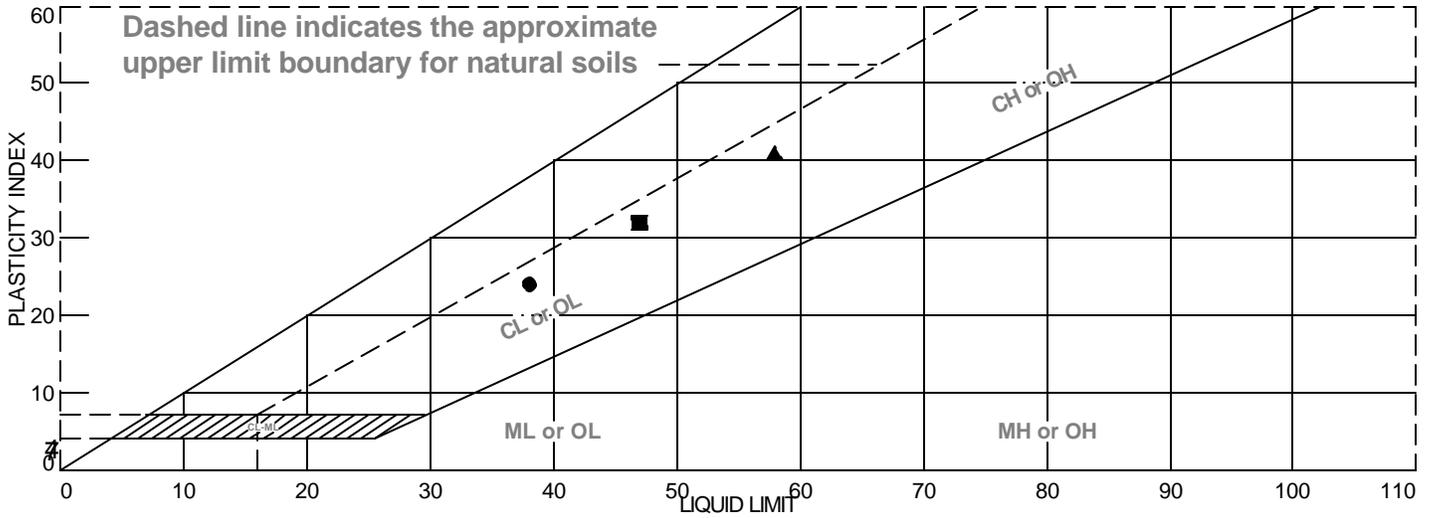
Sample Number: B3 @ 11'

Date: 02/14/07



Client:
Project: Aquatic Water Quality Improvement
Project No: 7522.1.001.01

LIQUID AND PLASTIC LIMITS TEST REPORT



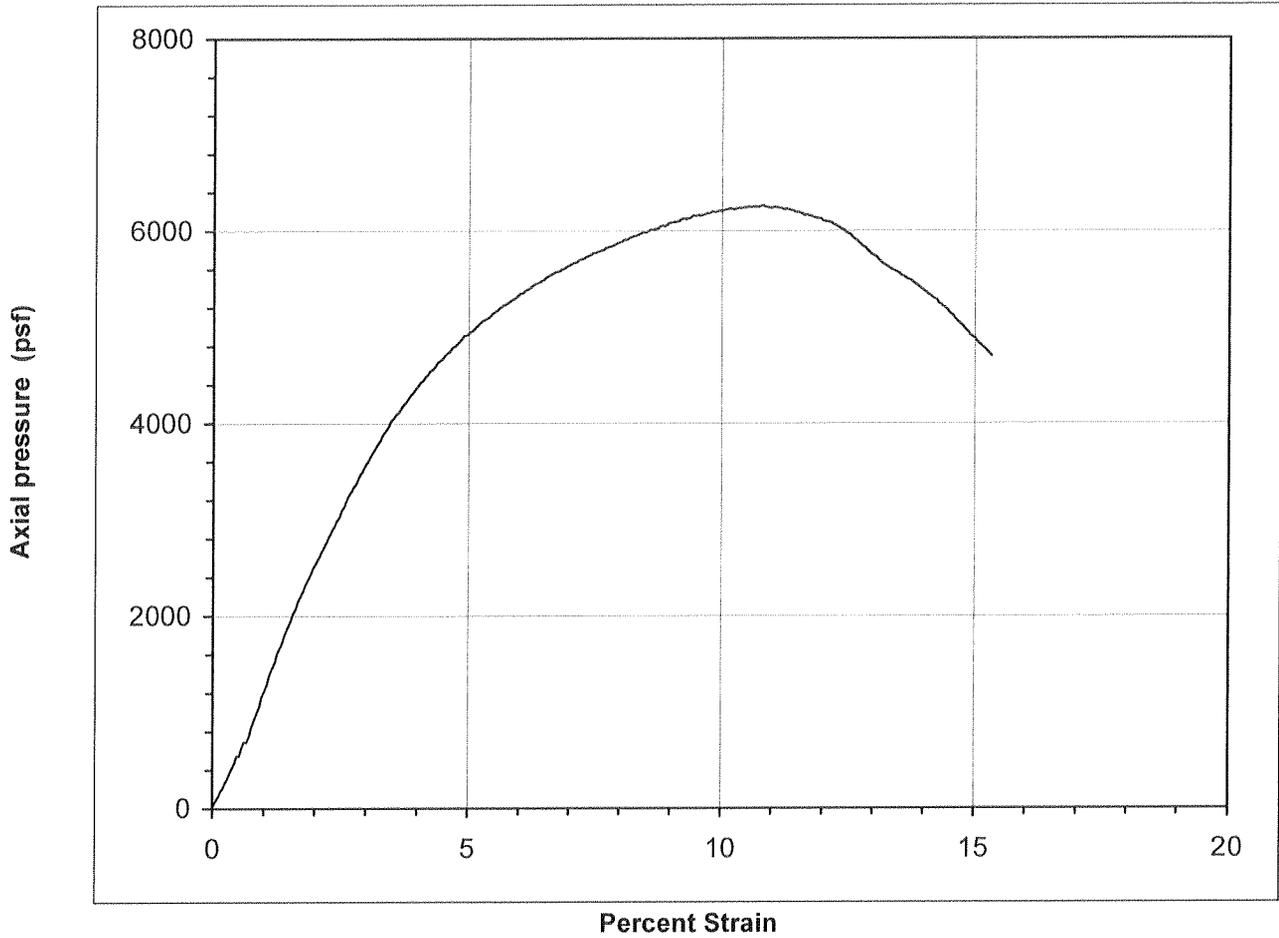
	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Dark yellowish brown silty CLAY.	38	14	24			CL
■	Dark greenish gray silty CLAY to CLAY.	47	15	32			CL-CH
▲	Dark grayish brown CLAY.	58	17	41			CH

Project No. 7522.1.001.01 **Client:**
Project: Aquatic Water Quality Improvement

- **Sample Number:** B2 @ 11'
- **Sample Number:** B4 @ 11'
- ▲ **Sample Number:** B3 @ 3.5'

Remarks:

**Unconfined Compression Test
ASTM Test Method D2166**



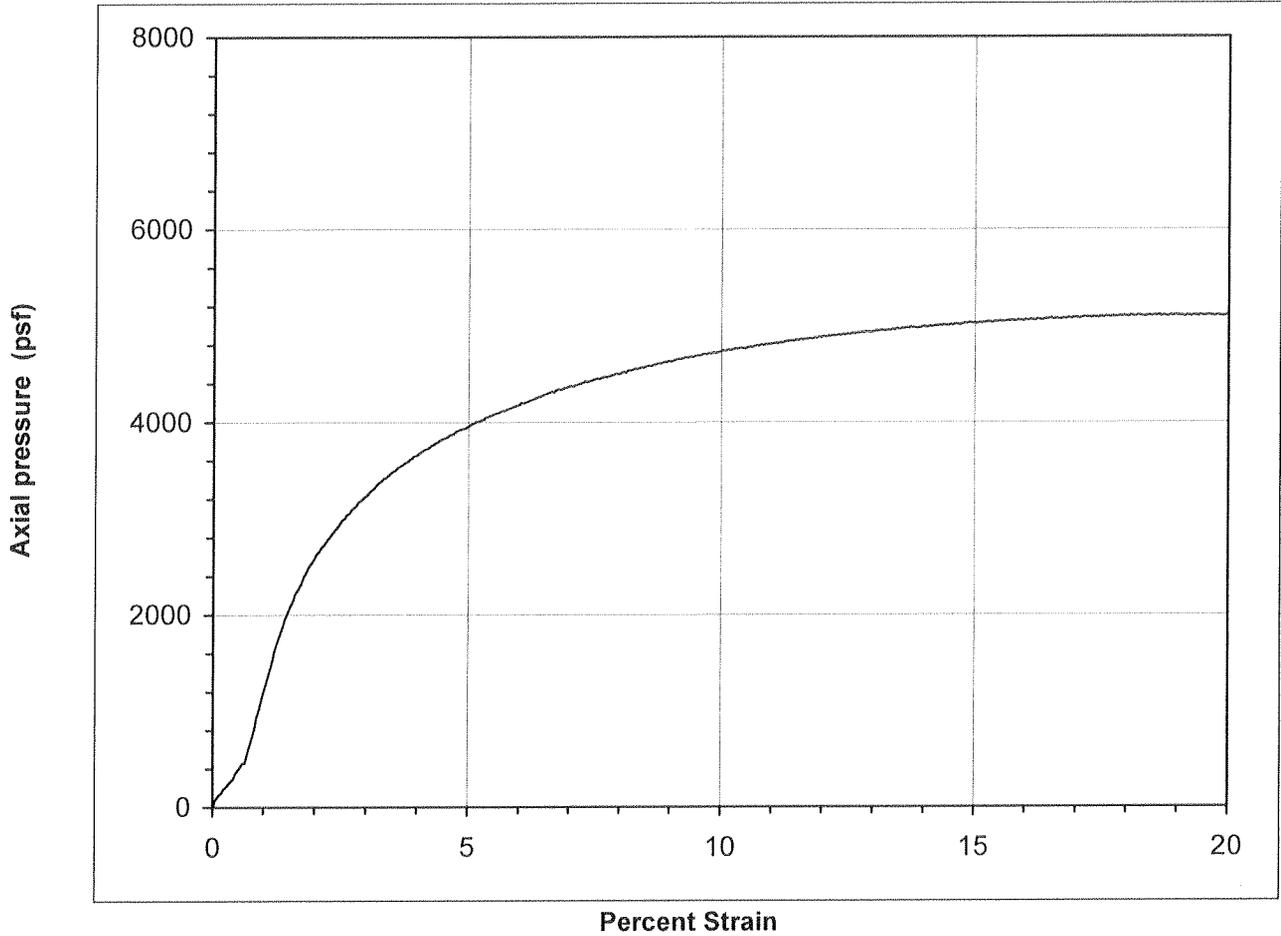
Unconfined Compressive Strength: 6250 psf 3.1 tsf

Sample Description: Dark yellowish brown silty CLAY

Initial Diameter:	2.420 in.	Sample Number:	B2@11
Initial Height:	5.02 in.	Dry Unit Weight:	109.7 pcf
Strain Rate:	1.424 %/min	Moisture Content:	19.9 %
Total Strain:	15.34 %	Depth of Sample:	11.0 ft.

ENGEO INCORPORATED	AQUATIC PARK WATER QUALITY Berkeley, California	Job No.: 7522.1.001.01	Figure No.
		Sample Number: B2@11	
		Date: 2/8/2007	

**Unconfined Compression Test
ASTM Test Method D2166**



Unconfined Compressive Strength: 5100 psf 2.6 tsf

Sample Description: Light olive brown CLAY

Initial Diameter:	2.420 in.	Sample Number:	B3@16
Initial Height:	5.02 in.	Dry Unit Weight:	102.0 pcf
Strain Rate:	1.397 %/min	Moisture Content:	24.6 %
Total Strain:	20.02 %	Depth of Sample:	16.0 ft.

ENGEO
INCORPORATED

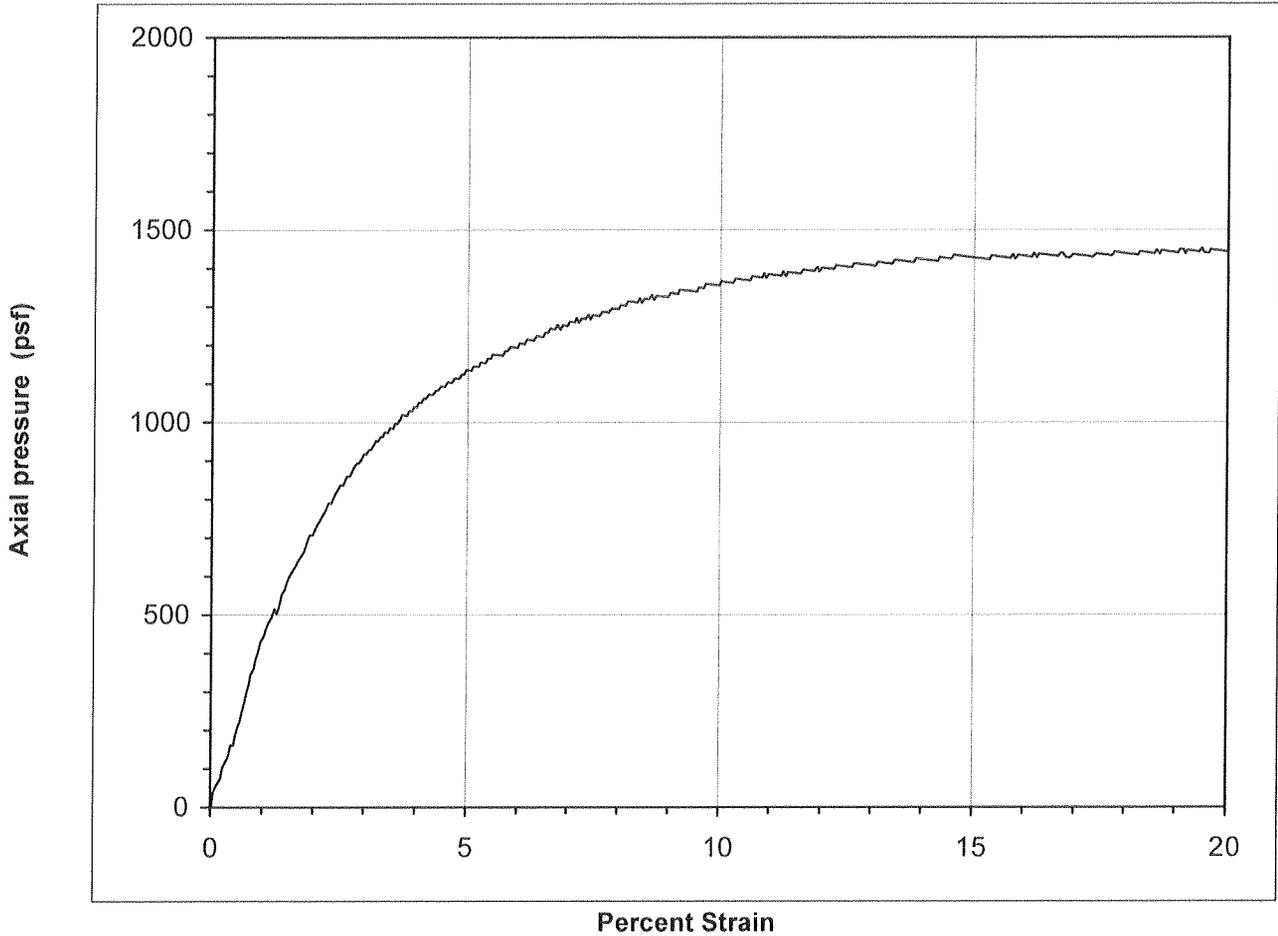
AQUATIC PARK WATER QUALITY

Berkeley, California

Job No.:	7522.1.001.01
Sample Number:	B3@16
Date:	2/8/2007

Figure No.

**Unconfined Compression Test
ASTM Test Method D2166**



Unconfined Compressive Strength: 1440 psf 0.7 tsf

Sample Description: Dark greenish gray silty CLAY to CLAY

Initial Diameter:	2.420 in.	Sample Number:	B4@11
Initial Height:	5.02 in.	Dry Unit Weight:	97.3 pcf
Strain Rate:	1.399 %/min	Moisture Content:	25.4 %
Total Strain:	20.00 %	Depth of Sample:	11.0 ft.

EN GEO INCORPORATED	AQUATIC PARK WATER QUALITY Berkeley, California	Job No.: 7522.1.001.01	Figure No.
		Sample Number: B4@11	
		Date: 2/8/2007	

APPENDIX C

Guide Contract Specifications

GUIDE CONTRACT SPECIFICATIONS

PART I - EARTHWORK

PREFACE

These specifications are intended as a guide for the earthwork performed at the subject development project. If there is a conflict between these specifications (including the recommendations of the geotechnical report) and agency or code requirements, it should be brought to the attention of ENGEO and Owner prior to contract bidding.

PART 1 - GENERAL

1.01 WORK COVERED

- A. Grading, excavating, filling and backfilling, including trenching and backfilling for utilities as necessary to complete the Project as indicated on the Drawings.
- B. Subsurface drainage as indicated on the Drawings.

1.02 CODES AND STANDARDS

- A. Excavating, trenching, filling, backfilling, and grading work shall meet the applicable requirements of the Uniform Building Code and the standards and ordinances of state and local governing authorities.

1.03 SUBSURFACE SOIL CONDITIONS

- A. The Owners' Geotechnical Exploration report is available for inspection by bidder or Contractor. The Contractor shall refer to the findings and recommendations of the Geotechnical Exploration report in planning and executing his work.

1.04 DEFINITIONS

- A. Fill: All soil, rock, or soil-rock materials placed to raise the grades of the site or to backfill excavations.
- B. Backfill: All soil, rock or soil-rock material used to fill excavations and trenches.
- C. On-Site Material: Soil and/or rock material which is obtained from the site.

- D. Imported Material: Soil and/or rock material which is brought to the site from off-site areas.
- E. Select Material: On-site and/or imported material which is approved by ENGEO as a specific-purpose fill.
- F. Engineered Fill: Fill upon which ENGEO has made sufficient observations and tests to confirm that the fill has been placed and compacted in accordance with specifications and requirements.
- G. Degree of Compaction or Relative Compaction: The ratio, expressed as a percentage, of the in-place dry density of the fill and backfill material as compacted in the field to the maximum dry density of the same material as determined by ASTM D-1557 or California 216 compaction test method.
- H. Optimum Moisture: Water content, percentage by dry weight, corresponding to the maximum dry density as determined by ASTM D-1557.
- I. ENGEO: The project geotechnical engineering consulting firm, its employees or its designated representatives.
- J. Drawings: All documents, approved for construction, which describe the Work.

1.05 OBSERVATION AND TESTING

- A. All site preparation, cutting and shaping, excavating, filling, and backfilling shall be carried out under the observation of ENGEO, employed and paid for by the Owners. ENGEO will perform appropriate field and laboratory tests to evaluate the suitability of fill material, the proper moisture content for compaction, and the degree of compaction achieved. Any fill that does not meet the specification requirements shall be removed and/or reworked until the requirements are satisfied.
- B. Cutting and shaping, excavating, conditioning, filling, and compacting procedures require approval of ENGEO as they are performed. Any work found unsatisfactory or any work disturbed by subsequent operations before approval is granted shall be corrected in an approved manner as recommended by ENGEO.
- C. Tests for compaction will be made in accordance with test procedures outlined in ASTM D-1557, as applicable. Field testing of soils or compacted fill shall conform with the applicable requirements of ASTM D-2922.
- D. All authorized observation and testing will be paid for by the Owners.

1.06 SITE CONDITIONS

- A. Excavating, filling, backfilling, and grading work shall not be performed during unfavorable weather conditions. When the work is interrupted by rain, excavating, filling, backfilling, and grading work shall not be resumed until the site and soil conditions are suitable.
- B. Contractor shall take the necessary measures to prevent erosion of freshly filled, backfilled, and graded areas until such time as permanent drainage and erosion control measures have been installed.

PART 2 - PRODUCTS

2.01 GENERAL

- A. Contractor shall furnish all materials, tools, equipment, facilities, and services as required for performing the required excavating, filling, backfilling, and grading work, and trenching and backfilling for utilities.

2.02 SOIL MATERIALS

- A. Fill
 - 1. Material to be used for engineered fill and backfill shall be free from organic matter and other deleterious substances, and of such quality that it will compact thoroughly without excessive voids when watered and rolled. Excavated on-site material will be considered suitable for engineered fill and backfill if it contains no more than 3 percent organic matter, is free of debris and other deleterious substances and conforms to the requirements specified above. Rocks of maximum dimension in excess of two-thirds of the lift thickness shall be removed from any fill material to the satisfaction of ENGEO.
 - 2. Excavated earth material which is suitable for engineered fill or backfill, as determined by ENGEO, shall be conditioned for reuse and properly stockpiled as required for later filling and backfilling operations. Conditioning shall consist of spreading material in layers not to exceed 8 inches and raking free of debris and rubble. Rocks and aggregate exceeding the allowed largest dimension, and deleterious material shall be removed from the site and disposed off site in a legal manner.
 - 3. ENGEO shall be immediately notified if potential hazardous materials or suspect soils exhibiting staining or odor are encountered. Work activities shall be discontinued within the area of potentially hazardous materials. ENGEO environmental personnel

will conduct an assessment of the suspect hazardous material to determine the appropriate response and mitigation. Regulatory agencies may also be contacted to request concurrence and oversight. *ENGEO will rely on the Owner, or a designated Owner's representative, to make necessary notices to the appropriate regulatory agencies. The Owner may request ENGEO's assistance in notifying regulatory agencies, provided ENGEO receives Owner's written authorization to expand its scope of services.*

4. ENGEO shall be notified at least 48 hours prior to the start of filling and backfilling operations so that it may evaluate samples of the material intended for use as fill and backfill. All materials to be used for filling and backfilling require the approval of ENGEO.

- B. Import Material: Where conditions require the importation of fill material, the material shall be an inert, nonexpansive soil or soil-rock material free of organic matter and meeting the following requirements unless otherwise approved by ENGEO.

Gradation (ASTM D-421):	<u>Sieve Size</u>	<u>Percent Passing</u>
	2-inch	100
	#200	15 - 70
Plasticity (ASTM D-4318):	<u>Liquid Limit</u>	<u>Plasticity Index</u>
	< 30	< 12
Swell Potential (ASTM D-4546B): (at optimum moisture)	<u>Percent Heave</u>	<u>Swell Pressure</u>
	< 2 percent	< 300 psf
Resistance Value (ASTM D-2844):	Minimum 25	
Organic Content (ASTM D-2974):	Less than 2 percent	

A sample of the proposed import material should be submitted to ENGEO for evaluation prior to delivery at the site.

2.03 SAND

- A. Sand for sand cushion under slabs and for bedding of pipe in utility trenches shall be a clean and graded, washed sand, free from clay or organic material, suitable for the intended purpose with 90 to 100 percent passing a No. 4 U.S. Standard Sieve, not more

than 5 percent passing a No. 200 U.S. Standard Sieve, and generally conforming to ASTM C33 for fine aggregate.

2.04 AGGREGATE DRAINAGE FILL

- A. Aggregate drainage fill under concrete slabs and paving shall consist of broken stone, crushed or uncrushed gravel, clean quarry waste, or a combination thereof. The aggregate shall be free from fines, vegetable matter, loam, volcanic tuff, and other deleterious substances. It shall be of such quality that the absorption of water in a saturated surface dry condition does not exceed 3 percent of the oven dry weight of the samples.
- B. Aggregate drainage fill shall be of such size that the percentage composition by dry weight as determined by laboratory sieves (U. S. Series) will conform to the following grading:

<u>Sieve Size</u>	<u>Percentage Passing Sieve</u>
1½-inches	100
1-inch	90 - 100
#4	0 - 5

2.05 SUBDRAINS

- A. Perforated subdrain pipe of the required diameter shall be installed as shown on the drawings. The pipe(s) shall also conform to these specifications unless otherwise specified by ENGEO in the field.

Subdrain pipe shall be manufactured in accordance with one of the following requirements:

Design depths less than 30 feet

- Perforated ABS Solid Wall SDR 35 (ASTM D-2751)
- Perforated PVC Solid Wall SDR 35 (ASTM D-3034)
- Perforated PVC A-2000 (ASTM F949)
- Perforated Corrugated HDPE double-wall (AASHTO M-252 or M-294, Caltrans Type S, 50 psi minimum stiffness)

Design depths less than 50 feet

- Perforated PVC SDR 23.5 Solid Wall (ASTM D-3034)
- Perforated Sch. 40 PVC Solid Wall (ASTM-1785)
- Perforated ABS SDR 23.5 Solid Wall (ASTM D-2751)
- Perforated ABS DWV/Sch. 40 (ASTM D-2661 and D-1527)

- Perforated Corrugated HDPE double-wall (AASHTO M-252 or M-294, Caltrans Type S, 70 psi minimum stiffness)

Design depths less than 70 feet

- Perforated ABS Solid Wall SDR 15.3 (ASTM D-2751)
- Perforated Sch. 80 PVC (ASTM D-1785)
- Perforated Corrugated Aluminum (ASTM B-745)

- B. Permeable Material (Class 2): Class 2 permeable material for filling trenches under, around, and over subdrains, behind building and retaining walls, and for pervious blankets shall consist of clean, coarse sand and gravel or crushed stone, conforming to the following grading requirements:

<u>Sieve Size</u>	<u>Percentage Passing Sieve</u>
1-inch	100
3/4-inch	90 - 100
3/8-inch	40 - 100
#4	25 - 40
#8	18 - 33
#30	5 - 15
#50	0 - 7
#200	0 - 3

- C. Filter Fabric: All filter fabric shall meet the following Minimum Average Roll Values unless otherwise specified by ENGEO.

Grab Strength (ASTM D-4632).....	180 lbs
Mass Per Unit Area (ASTM D-4751).....	6 oz/yd ²
Apparent Opening Size (ASTM D-4751)	70-100 U.S. Std. Sieve
Flow Rate (ASTM D-4491) 80 gal/min/ft ²	
Puncture Strength (ASTM D-4833).....	80 lbs

- D. Vapor Retarder: Vapor Retarders shall consist of PVC, LDPE or HDPE impermeable sheeting at least 10 mils thick.

2.06 PERMEABLE MATERIAL (Class 1; Type A)

- A. Class 1 permeable material to be used in conjunction with filter fabric for backfilling of subdrain excavations shall conform to the following grading requirements:

<u>Sieve Size</u>	<u>Percentage Passing Sieve</u>
¾-inch	100
½-inch	95 - 100
⅜-inch	70 - 100
#4	0 - 55
#8	0 - 10
#200	0 - 3

PART 3 - EXECUTION

3.01 STAKING AND GRADES

- A. Contractor shall lay out all his work, establish all necessary markers, bench marks, grading stakes, and other stakes as required to achieve design grades.

3.02 EXISTING UTILITIES

- A. Contractor shall verify the location and depth (elevation) of all existing utilities and services before performing any excavation work.

3.03 EXCAVATION

- A. Contractor shall perform excavating as indicated and required for concrete footings, drilled piers, foundations, floor slabs, concrete walks, and site leveling and grading, and provide shoring, bracing, underpinning, cribbing, pumping, and planking as required. The bottoms of excavations shall be firm undisturbed earth, clean and free from loose material, debris, and foreign matter.
- B. Excavations shall be kept free from water at all times. Adequate dewatering equipment shall be maintained at the site to handle emergency situations until concrete or backfill is placed.
- C. Unauthorized excavations for footings shall be filled with concrete to required elevations, unless other methods of filling are authorized by ENGEO.
- D. Excavated earth material which is suitable for engineered fill or backfill, as determined by ENGEO, shall be conditioned for reuse and properly stockpiled for later filling and backfilling operations as specified under Section 2.02, "Soil Materials."
- E. Abandoned sewers, piping, and other utilities encountered during excavating shall be removed and the resulting excavations shall be backfilled with engineered fill as required by ENGEO.

- F. Any active utility lines encountered shall be reported immediately to the Owner's Representative and authorities involved. The Owner and proper authorities shall be permitted free access to take the measures deemed necessary to repair, relocate, or remove the obstruction as determined by the responsible authority or Owner's Representative.

3.04 SUBGRADE PREPARATION

- A. All brush and other rubbish, as well as trees and root systems not marked for saving, shall be removed from the site and legally disposed of.
- B. Any existing structures, foundations, underground storage tanks, or debris must be removed from the site prior to any building, grading, or fill operations. Septic tanks, including all drain fields and other lines, if encountered, must be totally removed. The resulting depressions shall be properly prepared and filled to the satisfaction of ENGEO.
- C. Vegetation and organic topsoil shall be removed from the surface upon which the fill is to be placed and either removed and legally disposed of or stockpiled for later use in approved landscape areas. The surface shall then be scarified to a depth of at least eight inches until the surface is free from ruts, hummocks, or other uneven features which would tend to prevent uniform compaction by the equipment to be used.
- D. After the foundation for the fill has been cleared and scarified, it shall be made uniform and free from large clods. The proper moisture content must be obtained by adding water or aerating. The foundation for the fill shall be compacted at the proper moisture content to a relative compaction as specified herein.

3.05 ENGINEERED FILL

- A. **Select Material:** Fill material shall be "Select" or "Imported Material" as previously specified.
- B. **Placing and Compacting:** Engineered fill shall be constructed by approved and accepted methods. Fill material shall be spread in uniform lifts not exceeding 8 inches in uncompacted thickness. Each layer shall be spread evenly, and thoroughly blade-mixed to obtain uniformity of material. Fill material which does not contain sufficient moisture as specified by ENGEO shall be sprinkled with water; if it contains excess moisture it shall be aerated or blended with drier material to achieve the proper water content. Select material and water shall then be thoroughly mixed before being compacted.
- C. Unless otherwise specified in the Geotechnical Exploration report, each layer of spread select material shall be compacted to at least 90 percent relative compaction at a moisture content of at least three percentage points above the optimum moisture content. Minimum

compaction in all keyways shall be a minimum of 95 percent with a minimum moisture content of at least 1 percentage point above optimum.

- D. Unless otherwise specified in the Geotechnical Exploration report or otherwise required by the local authorities, the upper 6 inches of engineered fill in areas to receive pavement shall be compacted to at least 95 percent relative compaction with a minimum moisture content of at least 3 percentage points above optimum.
- E. Testing and Observation of Fill: The work shall consist of field observation and testing to determine that each layer has been compacted to the required density and that the required moisture is being obtained. Any layer or portion of a layer that does not attain the compaction required shall be reworked until the required density is obtained.
- F. Compaction: Compaction shall be by sheepfoot rollers, multiple-wheel steel or pneumatic-tired rollers or other types of acceptable compaction equipment. Rollers shall be of such design that they will be able to compact the fill to the specified compaction. Rolling shall be accomplished while the fill material is within the specified moisture content range. Rolling of each layer must be continuous so that the required compaction may be obtained uniformly throughout each layer.
- G. Fill slopes shall be constructed by overfilling the design slopes and later cutting back the slopes to the design grades. No loose soil will be permitted on the faces of the finished slopes.
- H. Strippings and topsoil shall be stockpiled as approved by Owner, then placed in accordance with ENGEO's recommendations to a minimum thickness of 6 inches and a maximum thickness of 12 inches over exposed open space cut slopes which are 3:1 or flatter, and track walked to the satisfaction of ENGEO.
- I. Final Prepared Subgrade: Finish blading and smoothing shall be performed as necessary to produce the required density, with a uniform surface, smooth and true to grade.

3.06 BACKFILLING

- A. Backfill shall not be placed against footings, building walls, or other structures until approved by ENGEO.
- B. Backfill material shall be Select Material as specified for engineered fill.
- C. Backfill shall be placed in 6-inch layers, leveled, rammed, and tamped in place. Each layer shall be compacted with suitable compaction equipment to 90 percent relative compaction at a moisture content of at least 3 percent above optimum.

3.07 TRENCHING AND BACKFILLING FOR UTILITIES

A. Trenching:

1. Trenching shall include the removal of material and obstructions, the installation and removal of sheeting and bracing and the control of water as necessary to provide the required utilities and services.
2. Trenches shall be excavated to the lines, grades, and dimensions indicated on the Drawings. Maximum allowable trench width shall be the outside diameter of the pipe plus 24 inches, inclusive of any trench bracing.
3. When the trench bottom is a soft or unstable material as determined by ENGEO, it shall be made firm and solid by removing said unstable material to a sufficient depth and replacing it with on-site material compacted to 90 percent minimum relative compaction.
4. Where water is encountered in the trench, the contractor must provide materials necessary to drain the water and stabilize the bed.

B. Backfilling:

1. Trenches must be backfilled within 2 days of excavation to minimize desiccation.
2. Bedding material shall be sand and shall not extend more than 6 inches above any utility lines.
3. Backfill material shall be select material.
4. Trenches shall be backfilled as indicated or required and compacted with suitable equipment to 90 percent minimum relative compaction at the required moisture content.

3.08 SUBDRAINS

- A. Trenches for subdrain pipe shall be excavated to a minimum width equal to the outside diameter of the pipe plus at least 12 inches and to a depth of approximately 2 inches below the grade established for the invert of the pipe, or as indicated on the Drawings.
- B. The space below the pipe invert shall be filled with a layer of Class 2 permeable material, upon which the pipe shall be laid with perforations down. Sections shall be joined as recommended by the pipe manufacturer.

- C. Rocks, bricks, broken concrete, or other hard material shall not be used to give intermediate support to pipes. Large stones or other hard objects shall not be left in contact with the pipes.
- D. Excavations for subdrains shall be filled as required to fill voids and prevent settlement without damaging the subdrain pipe. Alternatively, excavations for subdrains may be filled with Class 1 permeable material (as defined in Section 2.06) wrapped in Filter Fabric (as defined in Section 2.05).

3.09 AGGREGATE DRAINAGE FILL

- A. ENGEO shall approve finished subgrades before aggregate drainage fill is installed.
- B. Pipes, drains, conduits, and any other mechanical or electrical installations shall be in place before any aggregate drainage fill is placed. Backfill at walls to elevation of drainage fill shall be in place and compacted.
- C. Aggregate drainage fill under slabs and concrete paving shall be the minimum uniform thickness after compaction of dimensions indicated on Drawings. Where not indicated, minimum thickness after compaction shall be 4 inches.
- D. Aggregate drainage fill shall be rolled to form a well-compacted bed.
- E. The finished aggregate drainage fill must be observed and approved by ENGEO before proceeding with any subsequent construction over the compacted base or fill.

3.10 SAND CUSHION

- A. A sand cushion shall be placed over the vapor retarder membrane under concrete slabs on grade. Sand cushion shall be placed in uniform thickness as indicated on the Drawings. Where not indicated, the thickness shall be 2 inches.

3.11 FINISH GRADING

- A. All areas must be finish graded to elevations and grades indicated on the Drawings. In areas to receive topsoil and landscape planting, finish grading shall be performed to a uniform 6 inches below the grades and elevations indicated on the Drawings, and brought to final grade with topsoil.

3.12 DISPOSAL OF WASTE MATERIALS

- A. Excess earth materials and debris shall be removed from the site and disposed of in a legal manner. Location of dump site and length of haul are the Contractor's responsibility.

PART II - GEOGRID SOIL REINFORCEMENT

1. DESCRIPTION:

Work shall consist of furnishing geogrid soil reinforcement for use in construction of reinforced soil slopes and retention systems.

2. GEOGRID MATERIAL:

2.1 The specific geogrid material shall be preapproved by ENGEO.

2.2 The geogrid shall be a regular network of integrally connected polymer tensile elements with aperture geometry sufficient to permit significant mechanical interlock with the surrounding soil or rock. The geogrid structure shall be dimensionally stable and able to retain its geometry under construction stresses and shall have high resistance to damage during construction, to ultraviolet degradation, and to all forms of chemical and biological degradation encountered in the soil being reinforced.

2.3 The geogrids shall have an Allowable Strength (T_a) and Pullout Resistance, for the soil type(s) indicated, as listed in Table I.

2.4 Certifications: The Contractor shall submit a manufacturer's certification that the geogrids supplied meet the respective index criteria set when geogrid was approved by ENGEO, measured in full accordance with all test methods and standards specified. In case of dispute over validity of values, the Contractor will supply test data from an ENGEO-approved laboratory to support the certified values submitted.

3. CONSTRUCTION:

3.1 Delivery, Storage, and Handling: Contractor shall check the geogrid upon delivery to ensure that the proper material has been received. During all periods of shipment and storage, the geogrid shall be protected from temperatures greater than 140 °F, mud, dirt, dust, and debris. Manufacturer's recommendations in regard to protection from direct sunlight must also be followed. At the time of installation, the geogrid will be rejected if it has defects, tears, punctures, flaws, deterioration, or damage incurred during manufacture, transportation, or storage. If approved by ENGEO, torn or punctured sections may be repaired by placing a patch over the damaged area. Any geogrid damaged during storage or installation shall be replaced by the Contractor at no additional cost to the owner.

- 3.2 On-Site Representative: Geogrid material suppliers shall provide a qualified and experienced representative on site at the initiation of the project, for a minimum of three days, to assist the Contractor and ENGEO personnel at the start of construction. If there is more than one slope on a project, this criterion will apply to construction of the initial slope only. The representative shall also be available on an as-needed basis, as requested by ENGEO, during construction of the remaining slope(s).
- 3.3 Geogrid reinforcement may be joined with mechanical connections or overlaps as recommended and approved by the Manufacturer. Joints shall not be placed within 6 feet of the slope face, within 4 feet below top of slope, nor horizontally or vertically adjacent to another joint.
- 3.4 Geogrid Placement: The geogrid reinforcement shall be installed in accordance with the manufacturer's recommendations. The geogrid reinforcement shall be placed within the layers of the compacted soil as shown on the plans or as directed.

The geogrid reinforcement shall be placed in continuous longitudinal strips in the direction of main reinforcement. However, if the Contractor is unable to complete a required length with a single continuous length of geogrid, a joint may be made with the Manufacturer's approval. Only one joint per length of geogrid shall be allowed. This joint shall be made for the full width of the strip by using a similar material with similar strength. Joints in geogrid reinforcement shall be pulled and held taut during fill placement.

Adjacent strips, in the case of 100 percent coverage in plan view, need not be overlapped. The minimum horizontal coverage is 50 percent, with horizontal spacings between reinforcement no greater than 40 inches. Horizontal coverage of less than 100 percent shall not be allowed unless specifically detailed in the construction drawings.

Adjacent rolls of geogrid reinforcement shall be overlapped or mechanically connected where exposed in a wrap around face system, as applicable.

The Contractor may place only that amount of geogrid reinforcement required for immediately pending work to prevent undue damage. After a layer of geogrid reinforcement has been placed, the next succeeding layer of soil shall be placed and compacted as appropriate. After the specified soil layer has been placed, the next geogrid reinforcement layer shall be installed. The process shall be repeated for each subsequent layer of geogrid reinforcement and soil.

Geogrid reinforcement shall be placed to lay flat and pulled tight prior to backfilling. After a layer of geogrid reinforcement has been placed, suitable means, such as pins or small piles of soil, shall be used to hold the geogrid reinforcement in position until the subsequent soil layer can be placed.

Under no circumstances shall a track-type vehicle be allowed on the geogrid reinforcement before at least six inches of soil have been placed. Turning of tracked vehicles should be kept to a minimum to prevent tracks from displacing the fill and the geogrid reinforcement. If approved by the Manufacturer, rubber-tired equipment may pass over the geosynthetic reinforcement at slow speeds, less than 10 mph. Sudden braking and sharp turning shall be avoided.

During construction, the surface of the fill should be kept approximately horizontal. Geogrid reinforcement shall be placed directly on the compacted horizontal fill surface. Geogrid reinforcements are to be placed within three inches of the design elevations and extend the length as shown on the elevation view unless otherwise directed by ENGEO. Correct orientation of the geogrid reinforcement shall be verified by ENGEO.

Table I Allowable Geogrid Strength With Various Soil Types For Geosynthetic Reinforcement In Mechanically Stabilized Earth Slopes			
(Geogrid Pullout Resistance and Allowable Strengths vary with reinforced backfill used due to soil anchorage and site damage factors. Guidelines are provided below.)			
SOIL TYPE	MINIMUM ALLOWABLE STRENGTH, T _a (lb/ft)*		
	GEOGRID Type I	GEOGRID Type II	GEOGRID Type III
A. Gravels, sandy gravels, and gravel-sand-silt mixtures (GW, GP, GC, GM & SP)**	2400	4800	7200
B. Well graded sands, gravelly sands, and sand-silt mixtures (SW & SM)**	2000	4000	6000
C. Silts, very fine sands, clayey sands and clayey silts (SC & ML)**	1000	2000	3000
D. Gravelly clays, sandy clays, silty clays, and lean clays (CL)**	1600	3200	4800
* All partial Factors of Safety for reduction of design strength are included in listed values. Additional factors of safety may be required to further reduce these design strengths based on site conditions.			
** Unified Soil Classifications.			

PART III - GEOTEXTILE SOIL REINFORCEMENT

1. DESCRIPTION:

Work shall consist of furnishing geotextile soil reinforcement for use in construction of reinforced soil slopes.

2. GEOTEXTILE MATERIAL:

2.1 The specific geotextile material and supplier shall be preapproved by ENGEO.

2.2 The geotextile shall have a high tensile modulus and shall have high resistance to damage during construction, to ultraviolet degradation, and to all forms of chemical and biological degradation encountered in the soil being reinforced.

2.3 The geotextiles shall have an Allowable Strength (T_a) and Pullout Resistance, for the soil type(s) indicated as listed in Table II.

2.4 Certification: The Contractor shall submit a manufacturer's certification that the geotextiles supplied meet the respective index criteria set when geotextile was approved by ENGEO, measured in full accordance with all test methods and standards specified. In case of dispute over validity of values, the Contractor will supply the data from an ENGEO-approved laboratory to support the certified values submitted.

3. CONSTRUCTION:

3.1 Delivery, Storage and Handling: Contractor shall check the geotextile upon delivery to ensure that the proper material has been received. During all periods of shipment and storage, the geotextile shall be protected from temperatures greater than 140 °F, mud, dirt, dust, and debris. Manufacturer's recommendations in regard to protection from direct sunlight must also be followed. At the time of installation, the geotextile will be rejected if it has defects, tears, punctures, flaws, deterioration, or damage incurred during manufacture, transportation, or storage. If approved by ENGEO, torn or punctured sections may be repaired by placing a patch over the damaged area. Any geotextile damaged during storage or installation shall be replaced by the Contractor at no additional cost to the owner.

- 3.2 On-Site Representative: Geotextile material suppliers shall provide a qualified and experienced representative on site at the initiation of the project, for a minimum of three days, to assist the Contractor and ENGEO personnel at the start of construction. If there is more than one slope on a project, this criterion will apply to construction of the initial slope only. The representative shall also be available on an as-needed basis, as requested by ENGEO, during construction of the remaining slope(s).
- 3.3 Geotextile Placement: The geotextile reinforcement shall be installed in accordance with the manufacturer's recommendations. The geotextile reinforcement shall be placed within the layers of the compacted soil as shown on the plans or as directed.

The geotextile reinforcement shall be placed in continuous longitudinal strips in the direction of main reinforcement. Joints shall not be used with geotextiles.

Adjacent strips, in the case of 100 percent coverage in plan view, need not be overlapped. The minimum horizontal coverage is 50 percent, with horizontal spacings between reinforcement no greater than 40 inches. Horizontal coverage of less than 100 percent shall not be allowed unless specifically detailed in the construction drawings.

Adjacent rolls of geotextile reinforcement shall be overlapped or mechanically connected where exposed in a wrap around face system, as applicable.

The Contractor may place only that amount of geotextile reinforcement required for immediately pending work to prevent undue damage. After a layer of geotextile reinforcement has been placed, the succeeding layer of soil shall be placed and compacted as appropriate. After the specified soil layer has been placed, the next geotextile reinforcement layer shall be installed. The process shall be repeated for each subsequent layer of geotextile reinforcement and soil.

Geosynthetic reinforcement shall be placed to lay flat and be pulled tight prior to backfilling. After a layer of geotextile reinforcement has been placed, suitable means, such as pins or small piles of soil, shall be used to hold the geotextile reinforcement in position until the subsequent soil layer can be placed.

Under no circumstances shall a track-type vehicle be allowed on the geotextile reinforcement before at least six inches of soil has been placed. Turning of tracked vehicles should be kept to a minimum to prevent tracks from displacing the fill and the geotextile reinforcement. If approved by the Manufacturer, rubber-tired equipment may pass over the geotextile reinforcement at slow speeds, less than 10 mph. Sudden braking and sharp turning shall be avoided.

During construction, the surface of the fill should be kept approximately horizontal. Geotextile reinforcement shall be placed directly on the compacted horizontal fill surface.

Geotextile reinforcements are to be placed within three inches of the design elevations and extend the length as shown on the elevation view unless otherwise directed by ENGEO. Correct orientation of the geotextile reinforcement shall be verified by ENGEO.

Table II Allowable Geotextile Strength With Various Soil Types For Geosynthetic Reinforcement In Mechanically Stabilized Earth Slopes			
(Geotextile Pullout Resistance and Allowable Strengths vary with reinforced backfill used due to soil anchorage and site damage factors. Guidelines are provided below.)			
SOIL TYPE	MINIMUM ALLOWABLE STRENGTH, T _a (lb/ft)*		
	GEOTEXTILE Type I	GEOTEXTILE Type II	GEOTEXTILE Type III
A. Gravels, sandy gravels, and gravel-sand-silt mixtures (GW, GP, GC, GM & SP)**	2400	4800	7200
B. Well graded sands, gravelly sands, and sand-silt mixtures (SW & SM)**	2000	4000	6000
C. Silts, very fine sands, clayey sands and clayey silts (SC & ML)**	1000	2000	3000
D. Gravelly clays, sandy clays, silty clays, and lean clays (CL)**	1600	3200	4800
* All partial Factors of Safety for reduction of design strength are included in listed values. Additional factors of safety may be required to further reduce these design strengths based on site conditions.			
** Unified Soil Classifications.			

PART IV - EROSION CONTROL MAT OR BLANKET

1. DESCRIPTION:

Work shall consist of furnishing and placing a synthetic erosion control mat and/or degradable erosion control blanket for slope face protection and lining of runoff channels.

2. EROSION CONTROL MATERIALS:

2.1 The specific erosion control material and supplier shall be pre-approved by ENGEO.

2.2 Certification: The Contractor shall submit a manufacturer's certification that the erosion mat/blanket supplied meets the criteria specified when the material was approved by ENGEO. The manufacturer's certification shall include a submittal package of documented test results that confirm the property values. In case of a dispute over validity of values, the Contractor will supply property test data from an ENGEO-approved laboratory, to support the certified values submitted. Minimum average roll values, per ASTM D 4759, shall be used for conformance determinations.

3. CONSTRUCTION:

3.1 Delivery, Storage, and Handling: Contractor shall check the erosion control material upon delivery to ensure that the proper material has been received. During all periods of shipment and storage, the erosion mat shall be protected from temperatures greater than 140 °F, mud, dirt, and debris. Manufacturer's recommendations in regard to protection from direct sunlight must also be followed. At the time of installation, the erosion mat/blanket shall be rejected if it has defects, tears, punctures, flaws, deterioration, or damage incurred during manufacture, transportation, or storage. If approved by ENGEO, torn or punctured sections may be removed by cutting OUT a section of the mat. The remaining ends should be overlapped and secured with ground anchors. Any erosion mat/blanket damaged during storage or installation shall be replaced by the Contractor at no additional cost to the Owner.

3.2 On-Site Representative: Erosion control material suppliers shall provide a qualified and experienced representative on site, for a minimum of one day, to assist the Contractor and ENGEO personnel at the start of construction. If there is more than one slope on a project, this criteria will apply to construction of the initial slope only. The representative shall be available on an as-needed basis, as requested by ENGEO, during construction of the remaining slope(s).

- 3.3 Placement: The erosion control material shall be placed and anchored on a smooth graded, firm surface approved by the Engineer. Anchoring terminal ends of the erosion control material shall be accomplished through use of key trenches. The material in the trenches shall be anchored to the soil on maximum 1½ foot centers. Topsoil, if required by construction drawings, placed over final grade prior to installation of the erosion control material shall be limited to a depth not exceeding 3 inches.
- 3.4 Erosion control material shall be anchored, overlapped, and otherwise constructed to ensure performance until vegetation is well established. Anchors shall be as designated on the construction drawings, with a minimum of 12 inches length, and shall be spaced as designated on the construction drawings, with a maximum spacing of 4 feet.
- 3.5 Soil Filling: If noted on the construction drawings, the erosion control mat shall be filled with a fine grained topsoil, as recommended by the manufacturer. Soil shall be lightly raked or brushed on/into the mat to fill the mat voids or to a maximum depth of 1 inch.

PART V - GEOSYNTHETIC DRAINAGE COMPOSITE

1. DESCRIPTION:

Work shall consist of furnishing and placing a geosynthetic drainage system as a subsurface drainage medium for reinforced soil slopes.

2. DRAINAGE COMPOSITE MATERIALS:

2.1 The specific drainage composite material and supplier shall be preapproved by ENGEO.

2.2 The drain shall be of composite construction consisting of a supporting structure or drainage core material surrounded by a geotextile. The geotextile shall encapsulate the drainage core and prevent random soil intrusion into the drainage structure. The drainage core material shall consist of a three dimensional polymeric material with a structure that permits flow along the core laterally. The core structure shall also be constructed to permit flow regardless of the water inlet surface. The drainage core shall provide support to the geotextile. The fabric shall meet the minimum property requirements for filter fabric listed in Section 2.05C of the Guide Earthwork Specifications.

2.3 A geotextile flap shall be provided along all drainage core edges. This flap shall be of sufficient width for sealing the geotextile to the adjacent drainage structure edge to prevent soil intrusion into the structure during and after installation. The geotextile shall cover the full length of the core.

2.4 The geocomposite core shall be furnished with an approved method of constructing and connecting with outlet pipes or weepholes as shown on the plans. Any fittings shall allow entry of water from the core but prevent intrusion of backfill material into the core material.

2.5 Certification and Acceptance: The Contractor shall submit a manufacturer's certification that the geosynthetic drainage composite meets the design properties and respective index criteria measured in full accordance with all test methods and standards specified. The manufacturer's certification shall include a submittal package of documented test results that confirm the design values. In case of dispute over validity of design values, the Contractor will supply design property test data from an ENGEO-approved laboratory, to support the certified values submitted. Minimum average roll values, per ASTM D 4759, shall be used for determining conformance.

3. CONSTRUCTION:

- 3.1 Delivery, Storage, and Handling: Contractor shall check the geosynthetic drainage composite upon delivery to ensure that the proper material has been received. During all periods of shipment and storage, the geosynthetic drainage composite shall be protected from temperatures greater than 140 °F, mud, dirt, and debris. Manufacturer's recommendations in regards to protection from direct sunlight must also be followed. At the time of installation, the geosynthetic drainage composite shall be rejected if it has defects, tears, punctures, flaws, deterioration, or damage incurred during manufacture, transportation, or storage. If approved by ENGEO, torn or punctured sections may be removed or repaired. Any geosynthetic drainage composite damaged during storage or installation shall be replaced by the Contractor at no additional cost to the Owner.
- 3.2 On-Site Representative: Geosynthetic drainage composite material suppliers shall provide a qualified and experienced representative on site, for a minimum of one half day, to assist the Contractor and ENGEO personnel at the start of construction with directions on the use of drainage composite. If there is more than one application on a project, this criterion will apply to construction of the initial application only. The representative shall also be available on an as-needed basis, as requested by ENGEO, during construction of the remaining applications.
- 3.3 Placement: The soil surface against which the geosynthetic drainage composite is to be placed shall be free of debris and inordinate irregularities that will prevent intimate contact between the soil surface and the drain.
- 3.4 Seams: Edge seams shall be formed by utilizing the flap of the geotextile extending from the geocomposite's edge and lapping over the top of the fabric of the adjacent course. The fabric flap shall be securely fastened to the adjacent fabric by means of plastic tape or non-water-soluble construction adhesive, as recommended by the supplier. Where vertical splices are necessary at the end of a geocomposite roll or panel, an 8-inch-wide continuous strip of geotextile may be placed, centering over the seam and continuously fastened on both sides with plastic tape or non-water-soluble construction adhesive. As an alternative, rolls of geocomposite drain material may be joined together by turning back the fabric at the roll edges and interlocking the cuspidations approximately 2 inches. For overlapping in this manner, the fabric shall be lapped and tightly taped beyond the seam with tape or adhesive. Interlocking of the core shall always be made with the upstream edge on top in the direction of water flow. To prevent soil intrusion, all exposed edges of the geocomposite drainage core edge must be covered. Alternatively, a 12-inch-wide strip of fabric may be utilized in the same manner, fastening it to the exposed fabric 8 inches in from the edge and folding the remaining flap over the core edge.

3.5 Soil Fill Placement: Structural backfill shall be placed immediately over the geocomposite drain. Care shall be taken during the backfill operation not to damage the geotextile surface of the drain. Care shall also be taken to avoid excessive settlement of the backfill material. The geocomposite drain, once installed, shall not be exposed for more than seven days prior to backfilling.

APPENDIX F
DETAILED COST ESTIMATES

Table F-1 - Aquatic Park Improvement Program		
Preliminary Draft Planning Level Cost Estimate - Capitol Cost Summary		
No.	Task	Cost (\$)
1	Strawberry Drain Improvement	\$230,000.00
2	Main Culvert Structure	\$250,000.00
3	MYB - ML Connection	\$190,000.00
4	Potter Street Connection	\$300,000.00
5	Radio Tower Pond Connection	\$130,000.00
6	Salt/Brackish Wetland Creation/Bird Island Habitat Creation	\$420,000.00
7	Invasive Plant Removal/one retreatment	\$230,000.00
8	Native plantings/replanting for first 3 years	\$380,000.00
Subtotal		\$2,130,000.00
9	Biofiltration - Demonstration project for one subbasin only	\$2,430,000.00
Grand Total		\$4,560,000.00
OPTIONAL		
10	East side Vortex filters (Dwight, Channing, Bancroft)	\$1,700,000.00
11	Biofiltration - Additional sub-basins up to 200 acres of watershed	\$10,810,000.00
12	In-Park Filtering Units (Heinz, Grayson, Carlton, Parker)	\$870,000.00
13	Optional Freshwater Wetland Creation	\$180,000.00
Total Optional Tasks		\$13,560,000.00

Table F-2 - Aquatic Park Improvement Program		
Preliminary Draft Planning Level Cost Estimate - Breakdown of Estimated Annual Maintenance Costs		
No.	Task	Cost (\$)
1	Strawberry Drain Improvement	\$3,000.00
2	Main Culvert Structure	\$2,000.00
3	MYB - ML Connection	\$1,000.00
4	Potter Street Connection	\$3,000.00
5	Radio Tower Pond Connection	\$2,000.00
6	Salt/Brackish Wetland Creation/Bird Island Habitat Creation	\$1,000.00
7	Invasive Plant Removal	\$8,000.00
8	Native Plantings	\$8,000.00
9	Biofiltration - Demonstration project for one subbasin only	\$31,000.00
Subtotal		\$59,000.00
	Contingency 15%	\$8,850.00
Grand Total		\$67,850.00

Table F-3 - Aquatic Park Improvement Program								
Preliminary Draft Planning Level Cost Estimate - Breakdown of Charges								
			Quantity	Units	Rate \$/unit	Lump Sum (\$)	Total (\$)	
1	Strawberry Drain Improvement							
	a	Mobilization				\$2,000.00	\$2,000.00	
	b	Demolish Existing Weir 15' Long concrete weir volume = 15'x1'x4' =	2.22	cy	\$3,000.00		\$6,666.67	
	c	Disposal	2.22	cy	\$200.00		\$444.44	
	d	Break walls in existing vault to expand vault for gate 10' long by 5' wide by 4 sides	7.41	cy	\$2,500.00		\$18,518.52	
	e	Disposal	7.41	cy	\$200.00		\$1,481.48	
	f	66" Inch Valve	1.00	ea		\$32,000.00	\$32,000.00	
		Flap Gate	1.00	ea		\$15,000.00	\$15,000.00	
		Shipping				\$1,000.00	\$1,000.00	
		Installation	32.00	hrs	\$80.00		\$2,560.00	
		Hoist	2.00	days	\$500.00		\$1,000.00	
	g	Valve Control Structure				\$30,000.00	\$30,000.00	
	Sub Total							\$110,671.11
	Contingency							25.0% % \$27,667.78
	Engineering							15.0% % \$20,750.83
	Construction Management							15.0% % \$20,750.83
	Permits							15.0% % \$20,750.83
	Project Management							15.0% % \$20,750.83
	Total							\$221,342.22

Table F-3 - Aquatic Park Improvement Program								
Preliminary Draft Planning Level Cost Estimate - Breakdown of Charges								
			Quantity	Units	Rate \$/unit	Lump Sum (\$)	Total (\$)	
2	Main Culvert Structure							
	a	Mobilization				\$2,000.00	\$2,000.00	
	b	Repair Culvert Ends						
		5 - 10' X 24" Concrete Pipes	5.00	ea		\$9,200.00	\$9,200.00	
		Splice Connections				\$2,000.00	\$2,000.00	
	c	Marine Headwall to protect culvert	40.00	ft	\$528.00		\$21,120.00	
	d	Flap Gates	5.00	ea	\$15,000.00		\$75,000.00	
		Shipping				\$1,000.00	\$1,000.00	
		Flapgate Installation Labor	60.00	hrs	\$80.00		\$4,800.00	
		Hoist	2.00	days	\$500.00		\$1,000.00	
	e	Disposal of Old Culvert Ends	50.00	lf	\$20.00		\$1,000.00	
	Sub Total							\$117,120.00
	Contingency		25.0%	%			\$29,280.00	
	Engineering							\$21,960.00
	Construction Management							\$21,960.00
	Permits							\$36,600.00
	Project Management							\$21,960.00
	Total							\$248,880.00

Table F-3 - Aquatic Park Improvement Program							
Preliminary Draft Planning Level Cost Estimate - Breakdown of Charges							
			Quantity	Units	Rate \$/unit	Lump Sum (\$)	Total (\$)
3	MYB - ML Connection						
	a	Mobilization				\$2,000.00	\$2,000.00
	b	Excavation	714.00	cy		\$14,598.00	\$14,598.00
	c	New Bridge	1.00	ea		\$25,000.00	\$25,000.00
	d	Bridge Installation	100.00	hrs	\$80.00		\$8,000.00
	e	Bridge Foundation	2.00	ea	\$15,000.00		\$30,000.00
	f	Erosion Control/Landscaping	5,000.00	sf	\$2.24		\$11,200.00
		Sub Total					\$90,798.00
		Contingency	25.0%	%			\$22,699.50
		Engineering	15.0%	%			\$17,024.63
		Construction Management	15.0%	%			\$17,024.63
		Permits	20.0%	%			\$22,699.50
		Project Management	15.0%	%			\$13,619.70
		Total					\$183,865.95

Table F-3 - Aquatic Park Improvement Program							
Preliminary Draft Planning Level Cost Estimate - Breakdown of Charges							
			Quantity	Units	Rate \$/unit	Lump Sum (\$)	Total (\$)
4	Potter Street Connection						
	a	Mobilization				\$2,000.00	\$2,000.00
	b	Culvert Connection				\$9,688.00	\$9,688.00
	c	Temporary Barrier within Potter				\$10,000.00	\$10,000.00
	d	Demolish and Remove Existing Structure	40.00	lf	\$100.00		\$4,000.00
	e	Headwall	35.00	ft	\$528.00		\$18,480.00
	f	Slide Gates	2.00	ea	\$24,000.00		\$48,000.00
	g	Flap Gates	2.00	ea	\$15,000.00		\$30,000.00
	h	Slide and flap Gate Installation	32.00	hrs	\$80.00		\$2,560.00
	i	Earthwork	37.00	cy	\$2.00		\$1,000.00
	j	Erosion Control/landscaping	600.00	sf	\$2.24		\$1,344.00
	Sub Total						\$127,072.00
	Contingency		40.0%	%			\$50,828.80
	Engineering		15.0%	%			\$26,685.12
	Construction Management		15.0%	%			\$26,685.12
	Permits		20.0%	%			\$35,580.16
	Project Management		15.0%	%			\$26,685.12
	Total						\$293,536.32
* Cost estimate does not include additional culvert strengthening as may be required by the structural engineer but does include high contingency estimate.							

Table F-3 - Aquatic Park Improvement Program							
Preliminary Draft Planning Level Cost Estimate - Breakdown of Charges							
			Quantity	Units	Rate \$/unit	Lump Sum (\$)	Total (\$)
5	Radio Tower Pond Connection						
	a	Mobilization				\$2,000.00	\$2,000.00
	b	Culvert Connection (24" Conc. Culvert)				\$1,122.00	\$1,122.00
	c	Tap Into Culvert Wall					
	c	Headwall	18.00	lf	\$528.00		\$9,504.00
	d	Slide Gates	1.00	ea	\$14,000.00		\$14,000.00
	e	Flap Gates	1.00	ea	\$8,000.00		\$8,000.00
	f	Installation of Slide and Flap Gate					
	f	Earthwork				\$1,000.00	\$1,000.00
		Erosion Control/landscaping	6,930.00	sf	\$2.24		\$15,523.20
	g	Grade and Compaction - Berm Creation	300.00	cy	16.21		\$4,863.00
	h	2 Sump Pumps	2.00	ea	373.76		\$747.52
	i	8" Storm Drains	132.00	ft	8.11		\$1,070.52
	j	French Drain	100.00	ft	15.00		\$1,500.00
	k	3 Catch Basins	3.00	ea	400.00		\$1,200.00
		Sub Total					\$60,530.24
		Contingency	25.0%	%			\$15,132.56
		Engineering	15.0%	%			\$11,349.42
		Construction Management	15.0%	%			\$11,349.42
		Permits	20.0%	%			\$15,132.56
		Project Management	15.0%	%			\$11,349.42
		Total					\$124,843.62

Table F-3 - Aquatic Park Improvement Program							
Preliminary Draft Planning Level Cost Estimate - Breakdown of Charges							
			Quantity	Units	Rate \$/unit	Lump Sum (\$)	Total (\$)
7	Invasive Plant Removal						
	a	Plant Removal					\$110,950.00
	Sub Total						\$110,950.00
		Contingency	25.0%	%			\$27,737.50
		Engineering	15.0%	%			\$20,803.13
		Construction Management	15.0%	%			\$20,803.13
		Permits	15.0%	%			\$20,803.13
		Project Management	15.0%	%			\$20,803.13
	Total						\$221,900.00
8	Revegetation						
	a	Revegetation					\$185,466.00
	Sub Total						\$185,466.00
		Contingency	25.0%	%			\$46,366.50
		Engineering	15.0%	%			\$34,774.88
		Construction Management	15.0%	%			\$34,774.88
		Permits	15.0%	%			\$34,774.88
		Project Management	15.0%	%			\$34,774.88
	Total						\$370,932.00
9	Biofiltration						
	a	Biofiltration select one sub-basin used average of costs for Heinz, Greyson, Carlton and Parker					\$1,212,144.00
	Sub Total						\$1,212,144.00
		Contingency	25.0%	%			\$303,036.00
		Engineering	15.0%	%			\$227,277.00
		Construction Management	15.0%	%			\$227,277.00
		Permits	15.0%	%			\$227,277.00
		Project Management	15.0%	%			\$227,277.00
	Total						\$2,424,288.00

Table F-3 - Aquatic Park Improvement Program							
Preliminary Draft Planning Level Cost Estimate - Breakdown of Charges							
			Quantity	Units	Rate \$/unit	Lump Sum (\$)	Total (\$)
OPTIONAL COMPONENTS							
11	In-Park Filtering Units		(Parker, Carlton, Grayson, Heinz St. stormdrains)				
	a	Filtering Units	4.00		\$42,000.00		\$168,000.00
	b	Installation	4.00		\$60,000.00		\$240,000.00
	c	Piping				\$25,000.00	\$25,000.00
	Sub Total						\$433,000.00
	Contingency		25.0%	%			\$108,250.00
	Engineering		15.0%	%			\$81,187.50
	Construction Management		15.0%	%			\$81,187.50
	Permits		15.0%	%			\$81,187.50
	Project Management		15.0%	%			\$81,187.50
	Total						\$866,000.00

Table F-3 - Aquatic Park Improvement Program							
Preliminary Draft Planning Level Cost Estimate - Breakdown of Charges							
			Quantity	Units	Rate \$/unit	Lump Sum (\$)	Total (\$)
		OPTIONAL COMPONENTS					
12		Biofiltration					
	a	Biofiltration for remaining 6 sub-watershed					\$5,403,786.00
		Sub Total					\$5,403,786.00
		Contingency	25.0%	%			\$1,350,946.50
		Engineering	15.0%	%			\$1,013,209.88
		Construction Management	15.0%	%			\$1,013,209.88
		Permits	15.0%	%			\$1,013,209.88
		Project Management	15.0%	%			\$1,013,209.88
		Total					\$10,807,572.00

Table F-3 - Aquatic Park Improvement Program							
Preliminary Draft Planning Level Cost Estimate - Breakdown of Charges							
			Quantity	Units	Rate \$/unit	Lump Sum (\$)	Total (\$)
	OPTIONAL COMPONENTS						
13	Optional Freshwater Wetland Creation						
	a	Mobilization				\$2,000.00	\$2,000.00
	b	Excavation	7,512.04	cy		\$29,300.00	\$29,300.00
	c	Close Haul and Fill	7,512.00	cy		\$20,000.00	\$20,000.00
	d	Erosion and Sediment Control	24,405.00	sf		\$15,000.00	\$15,000.00
	e	Landscaping				\$10,000.00	\$10,000.00
	g	Soil Laboratory Testing				\$8,000.00	\$8,000.00
	Sub Total						
							\$84,300.00
	Contingency		25.0%	%			\$21,075.00
	Engineering		15.0%	%			\$15,806.25
	Construction Management		15.0%	%			\$15,806.25
	Permits		25.0%	%			\$26,343.75
	Project Management		15.0%	%			\$15,806.25
	Total						
							\$179,137.50

Table F-4 - Aquatic Park Improvement Program						
Preliminary Draft Planning Level Cost Estimate - Breakdown of Estimated Annual Maintenance Costs						
		Quantity	Units	Rate \$/unit	Lump Sum (\$)	Total (\$)
1	Strawberry Drain Improvement					
	Maintenance	36.00	hrs	\$80.00		\$2,880.00
	crew of 2, 6hrs, 3 times a year					
2	Main Culvert Structure					
	Maintenance	16.00	hrs	\$80.00		\$1,280.00
3	MYB - ML Connection					
	Maintenance	12.00	hrs	\$80.00		\$960.00
	crew of 2, 6hrs, 1 time per year					
4	Potter Street Connection					
	Maintenance	36.00	hrs	\$80.00		\$2,880.00
	crew of 2, 6hrs, 3 times a year					
5	Radio Tower Pond Connection					
	Maintenance	24.00	hrs	\$80.00		\$1,920.00
	crew of 2, 6hrs, 2 times per year					
6	Salt/Brackish Wetland Creation/Bird Island Habitat Creation					
	Maintenance	12.00	hrs	\$80.00		\$960.00
	crew of 2, 6hrs, 1 times per year					
7	Invasive Plant Removal					
	Maintenance one follow up is included in proejct costs	100.00	hrs	\$80.00		\$8,000.00
8	Native plantings					
	three years maintenance included in capitol costs see F-6	100.00	hrs	\$80.00		\$8,000.00
	Subtotal					\$26,880.00
9	Biofiltration one basin					
	Maintenance	101		\$300.00		\$30,300.00
	\$300/unit for 99 units in 44.3 acres of watershed					
	GRAND TOTAL					\$57,180.00

Table F-4 - Aquatic Park Improvement Program						
Preliminary Draft Planning Level Cost Estimate - Breakdown of Estimated Annual Maintenance Costs						
		Quantity	Units	Rate	Lump Sum	Total
				\$/unit	(\$)	(\$)
OPTIONS						
10	Eastside Stormwater Facilities					
	Maintenance	48.00	hrs	\$80.00		\$3,840.00
	crew of 2, 3 times a year					
11	Biofiltration one basin					
	Maintenance	407		\$300.00		\$122,100.00
	\$300/unit for 372 units					
12	In-Park Filtering Units					
	Maintenance	48.00	hrs	\$80.00		\$3,840.00
	crew of 2, 3 times a year					
13	Freshwater Wetland Creation					
	Maintenance	32.00	hrs	\$80.00		\$2,560.00
	crew of 2, 8hrs, 2 times per year					
Options Total						\$10,240.00

Table F-5 - Aquatic Park Improvement Program											
Preliminary Draft Planning Level Cost Estimate - Breakdown of Estimated Costs											
Acreage of invasive plants in Aquatic Park						Invasive plant removal one time stage 1 and 2 with one follow up. All mechanical removal, no herbicide. Disposal to landfill					
Invasive Plant	Radio Tower Pond Area (acres)	Total in park (acres)	stage 1	stage 2	stage 3	labor crew	supervision	disposal fees	follow up removal	equipment	total
acacia	0.45	2.00	0.45		1.55	\$10,000.00*	\$2,000.00	\$2,000.00	\$4,000.00		
Arundo donax		0.01	0.01		0.00	\$1,000.00	\$200.00	\$100.00	\$150.00		
blackberry		0.53	0.53		0.00	\$16,000.00	\$3,200.00	\$1,000.00	\$8,000.00		
cottoneaster		0.03	0.03		0.00	\$1,100.00	\$200.00	\$200.00	\$200.00		
dead cypress		0.06	0.06		0.00	\$2,000.00	\$400.00	\$1,000.00			
eucalyptus		3.79	0.00		3.79						
fennel		0.02	0.02		0.00	\$400.00	\$80.00	\$100.00	\$200.00		
french broom		0.03	0.03		0.00	\$1,500.00	\$300.00	\$200.00	\$500.00		
iceplant		0.26	0.26		0.00	\$10,000.00	\$2,000.00	\$1,000.00	\$3,000.00		
ivy	0.11	1.28	0.11	1.17	0.00	\$13,000.00	\$2,500.00	\$1,000.00	\$10,000.00		
pampas grass		0.01	0.01		0.00	\$6,000.00	\$1,200.00	\$1,000.00	\$500.00		
pepperweed		0.01	0.01		0.00	\$100.00	\$20.00	\$20.00			
pyracantha		0.03	0.03		0.00	\$2,000.00	\$400.00	\$200.00	\$200.00		
tamarisk		0.01	0.01		0.00	\$400.00	\$80.00	\$200.00	\$100.00		
Total		8.07	1.56	1.17	5.34	\$53,500.00	\$12,580.00	\$8,020.00	\$26,850.00	\$10,000.00	\$110,950.00
						*acacia removal at RTP only					
						Supervisor: \$50/hour or \$400/day					
						Labor Crew of 6 = \$2000/day					

Table F-7 - Aquatic Park Improvement Program								
Preliminary Draft Planning Level Cost Estimate - Breakdown of Estimated Costs								
	Heinz	Grayson	Carlton	Parker	Dwight	Channing	Bancroft	Total
Basin Acres	37.8	50	18.7	46.6	22.5	35.9	20.7	232.2
acres residential	7.56	0	0	0	4.5	28.72	14.49	55.27
acres commercial	30.24	50	18.7	46.6	18	7.18	6.21	176.93
residential cost	\$118,410	\$0	\$0	\$0	\$70,482	\$449,831	\$226,952	\$747,265
commercial cost	\$982,800	\$1,625,000	\$607,750	\$1,514,500	\$585,000	\$233,350	\$201,825	\$1,020,175
Biofiltering unit costs with installation and 1st year O&M	\$1,101,210	\$1,625,000	\$607,750	\$1,514,500	\$655,482	\$683,181	\$428,777	\$6,615,900

Table F-8 - Aquatic Park Improvement Program			
Preliminary Draft Planning Level Cost Estimate - Breakdown of Estimated Maintenance Costs			
Maintenance			
One subbasin	acres	number of units	annual cost at \$300/unit
residential	7.56	9	\$2,732.53
commercial	36.8	92	\$27,600.00
Total	44.36	101	\$30,332.53
Maintenance			
Remaining basins	acres	number of units	annual cost at \$300/unit
residential	47.71	57	\$17,244.58
commercial	140.13	350	\$105,097.50
Total	187.84	407	\$122,342.08