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GEOMATRIX

March 2000
Project No.4593

Mr. Lance Bryant
Public Works Superintendent
Public Works Department
1616 Fortmann Way
Alameda, California 94501

Subject: Long Term Management Plan
Alameda West Lagoons
Alameda, California

Dear Mr. Bryant:

Geomatrix Consultants, Inc. (Geomatrix), is pleased to submit the attached Long Term Management Plan to you for use by the City of Alameda and the Alameda West Lagoon Homeowners Association (AWLHOA). Geomatrix has enjoyed working with you and the AWLHOA on the development of this Plan and hopes that this Plan will contribute significantly to the successful management of the Alameda West Lagoons. Please note that the enclosed Plan should be considered a living document and amended as appropriate. Feel free to contact me if you have any questions or require additional information regarding this Plan.

Sincerely,
GEOMATRIX CONSULTANTS, INC.

Jeffrey C. Nelson

Jeffrey C. Nelson, P.E.
Principal Engineer

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GEOMATRIX

Long Term Management Plan

Alameda West Lagoons

Alameda, California

Prepared for:

Alameda West Lagoon Homeowners Association and The City of Alameda
Alameda, California

Prepared by:

Geomatrix Consultants, Inc.
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March 2000

Project No. 004593.000.0

GEOMATRIX

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ACRONYMS AND ABBREVIATIONS

ACEHS	Alameda County Environmental Health Services
ACOE	Army Corps of Engineers
AWLHOA	Alameda West Lagoons Home Owners Association
BOD	biochemical oxygen demand
°C	degrees Celsius
CDHS	California Department of Health Services
DO	dissolved oxygen
E. coli	Escherichia coli
FC	fecal coliform
FS	fecal streptococcus
µg/l	micrograms per liter
mg/l	milligrams per liter
NPDES	National Pollution Discharge Elimination System
SFB	San Francisco Bay
O&M	operations and maintenance
ppt	parts per thousand
Region Board	California Regional Water Quality Control Board, San Francisco Bay Region
TC	Total coliform
TOC	total organic carbon
USGS	United States Geological Survey

LONG TERM MANAGEMENT PLAN
Alameda West Lagoons
Alameda, California

1.0 INTRODUCTION

The Alameda West lagoon system consists of five individual lagoons connected in series and extends over approximately 2 miles of the southwestern shoreline of Alameda (Figure 1). This management plan was developed at the request of the Alameda West Lagoon Homeowners Association (AWLHOA) and the City of Alameda to assist them in preserving and managing the five lagoons that make up the lagoon system. The plan considers the importance of predictable and reasonable operating and maintenance costs for the lagoons, while optimizing the recreational amenities of the lagoons. To best serve the AWLHOA and the City of Alameda, this management plan should be considered a 'living document.' That is, a document that is to be added to and modified by the AWLHOA, the City of Alameda, and their consultants and contractors as more knowledge about the lagoon system is gained and new approaches for managing the lagoons are developed. This document is made up of four primary sections, including:

Section 1 - Introduction: this background section describes the regulatory framework, site setting, and beneficial uses of the lagoons.

Section 2 - Water Quality Concerns: this section describes water quality concerns as they impact the lagoon system

Section 3 - Lagoon Water Quality Parameters: this section describes the important water quality parameters for the lagoons, a monitoring program for these parameters, and recommendations for establishing a database for managing and utilizing the water quality parameters.

Section 4 - Recommendations: this section presents recommendations for managing conditions and practices that affect the water quality and health of the lagoons as well as response actions for incidents that may impact the health of the lagoon system.

The objective of the management plan is to assist in the preserving and maintaining the lagoon system. The components of the management plan include:

- monitoring of water quality parameters;
- vegetation management;
- lagoon maintenance programs;
- public notification programs including prohibition of activities and homeowner best management practices;
- establishing a water quality data base; and
- response and reporting requirements.

1.1 BACKGROUND

The following background section briefly describes the regulatory framework, site setting, and beneficial uses of the lagoons.

1.2 REGULATORY FRAMEWORK

Several regulatory agencies may have influence over the Lagoons, depending on the activities and/or actions that occur at or are planned for the Lagoons. These agencies include the following:

City of Alameda - Urban Runoff Program - The City of Alameda is legally required by its National Pollution Discharge Elimination System (NPDES) permit to implement a stormwater management program. The intent of the NPDES program is to prohibit the discharge of any pollutant to the waters of the United States, unless the discharge is authorized by a NPDES permit. The current permit for the agencies of Alameda County (No. CAS0029831), including the City of Alameda, was adopted by the Regional Water Quality Control Board (Regional Board) on February 19, 1997 as Order No. 97-030; this five-year permit expires on February 19, 2002. The City of Alameda's Urban Runoff Program is part of the Alameda County stormwater management program, and controls discharges of pollutants in runoff into the storm drain conveyance system including the lagoon system.

Regional Water Quality Control Board - The Regional Board regulates surface water and groundwater quality in the San Francisco Bay. By law, the Regional Board is required to

develop, adopt (after public hearing), and implement a Water Quality Control Plan (Basin Plan) for the San Francisco Bay Region. The Basin Plan is the master policy document that contains descriptions of the laws, policies, regulations and programmatic basis of water quality regulation in the San Francisco Bay Region. Based on the Basin Plan, the Regional Board has the authority to regulate the management of lakes and lagoons where water quality may be impaired as a direct or indirect result of the impoundment or when discharges of pollutants occur to or from the lagoon system. The intent of this authority is to encourage responsible water body management and preserve the beneficial uses of lakes, lagoons and contiguous waters. More information can obtained at the Regional Board's web site at www.swrcb.ca.gov, under Region 2.

U.S. Army Corps of Engineers - the U.S. Army Corps of Engineers (ACOE) has been regulating activities in the nation's waterways since 1890. Since the 1960's, the ACOE's program has been broadened to include the protection and utilization of water resources. Specifically, the regulatory authorities and responsibilities of the ACOE pertain to the obstruction or alteration of navigable water ways, discharge of dredged or fill material into water ways of the United States, and the transportation of dredged material for the purpose of dumping it into ocean waters. The ACOE - San Francisco District has jurisdiction over the lagoon system, with its main involvement being related to dredging and disposal of lagoon sediment, and for any proposed change in the lagoon configuration. More information can be obtained about ACOE-San Francisco District's policies regarding sediment dredging and disposal at their website www.spn.usace.army.mil.

Alameda County Environmental Health Services - The mission of the ACEHS is to protect the health, safety, and well being of the public through promotion of environmental quality. As part of this mission, the ACEHS conducts inspections of public swimming pools and beaches; investigates water related illnesses and complaints; and inspects residential, business and public properties including water front areas. More information on the ACEHS can be obtained by visiting their website at www.co.alameda.ca.us.

California Department of Fish and Game - The mission of the Department of Fish and Game (DFG) is to manage California's diverse fish, wildlife, and plant resources and the habitats upon which they depend, for their ecological values and for their use and enjoyment by the public. More information about the DFG can be found by visiting their website at www.dfg.ca.gov.

Governor's Office of Emergency Services - The Governor's Office of Emergency Services (OES) coordinates overall state agency response to major disasters in support of local government. Once called by the City of Alameda, the OES will notify other appropriate government agencies to respond to the situation. More information about the OES can be found by visiting their website at www.oes.ca.gov.

This management plan was developed to be consistent with the policies of the above mentioned regulatory bodies.

1.3 SITE SETTING

The Alameda lagoons were constructed in the 1960s as part of a fill project to create additional residential and commercial properties south of the historic San Francisco Bay shoreline in the Southshore area of Alameda. The AWLHOA was formed to manage the lagoons, along with the City of Alameda, for the benefit of residents in the area.

The lagoon system consists of five individual lagoons connected in series and extends over approximately 2 miles of the southwestern shoreline of Alameda (Figure 2). The primary facilities along the lagoons are residential homes. Estimates of surface area based on orthographic photographs are approximately 17.9, 10.9, 6.8, 4.7, and 4.4 acres for lagoons one, two, three, four and five, respectively.

The lagoons receive water from central San Francisco Bay. Bay water is pumped into the lagoons at an inlet structure located at the west end of Lagoon 1 and exits by gravity through a weir structure, known as the Bayview weir, located at the east end of Lagoon 5 and flows back into the Bay via a gravity drain. The lagoon pump operates at high tide levels only; except for their effect on pumping schedules, tides have only a minor influence on the lagoons. The grated inlet structure is exposed in the Bay at lower tides. The normal operation is to operate the pump continuously at high tide levels during the dry season and intermittently during wet weather. The pumping rate is constant, and variation in flow can only be accomplished by running the pump for shorter periods of time or intermittently. Lagoons 3, 4 and 5 are approximately 1 to 3 feet lower in elevation than Lagoons 1 and 2. This elevation difference allows for the partial flushing of the lower lagoons during the tidal cycle. Flow between Lagoons 2 and 3 are controlled by an additional weir structure, known as the Willow weir. Several storm drains discharge into the lagoons; the water level in the lagoons is lowered during wet weather to provide capacity for the storm run-off into the lagoons.

1.4 BENEFICIAL USES OF THE LAGOONS

The Regional Board has not formally considered designation of beneficial uses for Alameda West Lagoons. Beneficial uses of the lagoons include water contact recreation (REC1), the non-contact recreation (REC2),scenic and recreational amenity, stormwater conveyance, and biological habitat. The lagoons' uses include contact and non-contact water recreation for use by adjacent homeowners as well as wildlife habitat.

2.0 WATER QUALITY CONCERNS

According to the AWLHOA and the City of Alameda, problems that have occurred in the lagoons include excessive algal growth, accumulation of debris and organic matter, objectionable odors, siltation, stagnation, and occasional high bacterial counts. The primary sources of accumulated sediment appear to be plant material, storm drains, and supply pump inlet detritus.

2.1 SUBMERGED AQUATIC VEGETATION

The lagoons afford a very favorable environment for growth of submerged aquatic vegetation due to the readily available nutrients such as nitrogen and orthophosphates. Aquatic plant growth can vary between the lagoons and is mostly dependent on the nutrient distribution found in each lagoon. For this reason, growth of aquatic plants can explode uncontrollably in some lagoons and not others. The most abundant species of aquatic vegetation are phytoplankton, filamentous algae, and widgeon grass. Limited amounts of sea lettuce have also been observed on the lagoons. Several factors appear to affect the growth of plants in the lagoons:

- Sunlight penetration into the water column – the lagoons relatively calm water surface allows more sunlight penetration and thereby increases plant growth.
- Nutrient input – nitrogen is input into the lagoon system by several means including: runoff of fertilizers from lawns and gardens; avian droppings; inflow from the Bay; decaying vegetation (both terrestrial and aquatic); and sediment generated ammonia.
- Temperature - temperature has a powerful effect on both the rate and the total extent of growth in aquatic vegetation. Increased temperatures in the lagoons usually result in increased growth rates for aquatic plants.

2.2 URBAN RUNOFF

A significant source of chemical input into the lagoon system is from stormwater inflow during wet weather. In general, Central Avenue divides the Island of Alameda into two watersheds resulting in most runoff originating south of Central Avenue in the vicinity of the lagoons flowing into the lagoons. This area is highly urbanized and does not have any significant industrial operations; therefore, primary constituents in runoff are likely to be chemicals associated with operation of motor vehicles, residential fertilizer and pesticide applications, and pollutants deposited from the atmosphere.

Municipal and industrial discharges can play a key role in the water quality of the Bay; however, as there are no municipalities discharging near the lagoons, they are unlikely to severely affect conditions in the lagoons.

3.0 LAGOON WATER QUALITY MONITORING

This section describes important water quality parameters for the lagoons, a monitoring program for these parameters, and recommendations for establishing a database for managing and utilizing the water quality parameter data. The primary water quality parameters for lagoon systems are chlorophyll *a*, temperature, dissolved oxygen (DO), salinity, pH, nutrients, bacteria (including total coliform (TC), fecal coliform (FC), fecal streptococcus (FS), and escherichia coli (E coli)), and clarity (secchi disk measurement).

3.1 WATER QUALITY PARAMETERS

Between July 1998 and April 1999, Geomatrix performed 5 monitoring events at the lagoons and made measurements of temperature, DO, salinity, and pH in the lagoons. In general, Geomatrix measured the water quality parameters at several locations in each lagoon (Figure 2). DO and temperature measurements were made from both near the surface and near the bottom of the lagoons at each monitoring location. Except for the August 1998 event, these parameters were measured in all five lagoons; in August, 1998, these parameters were measured only in Lagoon 3. Geomatrix also collected water samples during each of the monitoring events and had the samples analyzed for the various bacteria parameters described above. In addition, Geomatrix collected water samples for nutrient analysis (orthophosphate and nitrate/nitrite) in October 1998. The results from the monitoring events described above are provided in tabular form in Appendix A. Bacterial data has also been collected by the

AWLHOA and the City of Alameda and is included in Appendix A. Geomatrix did not identify any additional data regarding the above parameters for the lagoons.

These parameters should continue to be measured on a regular basis and input into a database so a baseline can be determined and seasonal and annual trends in water quality can be observed. Once a baseline for the parameters has been established, additional data should be added to the database so that long-term trends in the lagoon system can be determined. The development and maintenance of a water quality parameter database will be a critical component in understanding and managing the lagoon system. A more detailed discussion of these water quality parameters is presented below.

3.1.1 Chlorophyll *a*

Chlorophyll *a* is used as an indicator for measuring the phytoplankton community. Phytoplankton is the largest component of living biomass in the Bay. Patterns of phytoplankton blooms vary from year to year, with large and prolonged blooms during years of exceptionally high fresh-water inflows and associated large nutrient inputs. In general, phytoplankton blooms are large from spring to fall and small during the winter due to decreased sunlight. Peak phytoplankton blooms were documented by the USGS in the spring of 1998 after high runoff entered the Bay.

Generally, chlorophyll *a* is the parameter used to measure the phytoplankton biomass. High concentrations of chlorophyll *a* are indicative of large phytoplankton biomass and potential algal blooms, resulting in dissolved oxygen (DO) depletion and fish kills. Between 1995 and the date of this report, the normal concentration of chlorophyll *a* measured in the Bay ranged from approximately 1.0 to 159.0 µg/l (United States Geological Survey [USGS], 1998). Geomatrix did not collect any lagoon water samples for analysis for chlorophyll *a* and was not able to locate any other chlorophyll *a* data for the lagoon system.

3.1.2 Temperature

The water temperature in the San Francisco Bay ranges from about 8 degrees Celsius (°C) to 20°C, being warmest in August and September and coldest in December and January. It is believed that the lagoon system follows a similar trend as the Bay. Geomatrix collected water temperature measurements from two different depths at each monitoring location. The ranges of the temperature measurements Geomatrix made in each individual lagoon are presented below; complete temperature measurements are included in Appendix A.

- Lagoon L-1 9.3 °C (January 1999) to 23.2°C (July 1998)
- Lagoon L-2 9.7 °C (January 1999) to 24.3°C (July 1998)
- Lagoon L-3 11.0°C (January 1999) to 27.0°C (July 1998)
- Lagoon L-4 11.7°C (January 1999) to 25.2°C (July 1998)
- Lagoon L-5 11.4°C (January 1999) to 25.2°C (July 1998)

Temperature is an important measurement because biological systems are sensitive to temperature fluctuations. Of particular importance to the lagoon system, higher temperatures lead to a higher growth rate for phytoplankton and bacteria. Understanding temperature trends can be used to better manage phytoplankton and bacterial propagation in the lagoon system.

3.1.3 Dissolved Oxygen

DO is an indicator of water quality conditions and can be used to assess the intensity of phytoplankton activity. When DO concentrations are less than saturation, organisms such as fish, invertebrates and aerobic bacteria consume organic matter faster than the phytoplankton can produce oxygen. Conversely, when DO concentrations exceed saturation, oxygen is produced faster than organisms can consume organic matter. Between 1995 and the date of this document, DO concentrations in San Francisco Bay have normally ranged from 6.6 to 15.0 milligrams per liter (mg/l; USGS, 1998).

In general, lower concentrations of DO are stressful to the aquatic environment and its inhabitants and promotes increases in anaerobic conditions resulting in accumulation and release of nutrients on the lagoon bottoms. According to the Basin Plan, concentrations of DO less than 5 mg/l indicate conditions that are stressful to fish; however, DO concentrations can vary with depth at the same location due to rates of photosynthesis and biochemical oxygen demand (BOD). For example, during optimum sunlight conditions, photosynthesis by phytoplankton can produce DO levels above saturation in the water near the surface, while aerobic processes near the lagoon bottom will consume oxygen resulting in DO concentrations approaching zero.

DO measurements were collected from both near the surface and near the bottom of the lagoons to evaluate the degree of stratification or layering that occurs in the lagoons. Stratified, or unmixed water bodies are more likely to develop hyper-euthrophic conditions resulting in

accelerated vegetative growth such as algal blooms which can result in fish kills. Based on our observations, it appears that the lagoons are susceptible to hyper-eutrophic conditions.

The ranges of the DO measurements Geomatrix made in each individual lagoon are presented below; complete DO measurements are included in Appendix A.

- Lagoon L-1 0.17 mg/l (October 1998) to 14.02 mg/l (April 1999)
- Lagoon L-2 2.4 mg/l (July 1998) to 10.9 mg/l (January 1999)
- Lagoon L-3 3.03 mg/l (October 1998) to 13.15 mg/l (April 1999)
- Lagoon L-4 5.68 mg/l (October 1998) to 13.67 mg/l (April 1999)
- Lagoon L-5 4.86 mg/l (October1998) to 11.2 mg/l (July 1998)

The DO measurements below 5.0 mg/l were observed in bottom measurements and are indicative of areas where aerobic processes have utilized the available oxygen; this condition is common in eutrophic water bodies and near water body bottoms. In addition, the variations with depth of DO concentrations indicate that the lagoons are poorly mixed.

DO concentrations may vary seasonally and with depth. Therefore, collecting DO data from throughout the water column is a better indicator of DO distribution in the lagoon systems. Collecting periodic DO measurements will help the AWLHOA and the City of Alameda better understand DO distribution and trends in the lagoon system resulting in better management of the lagoon system.

3.1.4 Salinity

Salinity, defined as the mass in grams of chlorine equivalent to the mass of halogens contained in 1 kilogram of sea water (Riley, 1971), typically ranges from 0.1 to 33 parts per thousand (ppt) for natural salt water systems. The salinity of fresh water is near zero. The salinity for estuary water, which may contain approximately two-thirds fresh water and one-third seawater, is approximately 11 ppt. Salinity density gradients regulate biological niches in the Bay and can influence water circulation. Salinity in the Bay changes seasonally, in general decreasing during the rainy season (due to dilution) and increasing during summer and autumn. Geomatrix measured salinity in the lagoons from July 1998 through January 1999 (Appendix A). Geomatrix did not identify any other salinity data for the lagoons. Salinity ranges measured by Geomatrix are listed below:

- Lagoon L-1 6.9 ppt (October 1998) to 28.0 ppt (January 1999)
- Lagoon L-2 10.8 ppt (October 1998) to 26.5 ppt (January 1999)
- Lagoon L-3 13.8 ppt (October 1998) to 24.8 ppt (January 1999)
- Lagoon L-4 13.8 to ppt (October 1998) to 22.1 ppt (January 1999)
- Lagoon L-5 17.1 ppt (April 1999) to 24.8 ppt (January 1999)

These data indicate that the salinity differs in each lagoon and fresh water lenses may be present on the surface of the lagoons during the rainy season. However, it appears that salinity values near the bottom of the channels remain relatively constant throughout the year. Salinity data can be useful in identifying fresh water inflows such as storm water runoff and large water main or sewer leaks or excessive irrigation.

3.1.5 pH

pH, which is the measure of the effective hydrogen ion concentration in water, affects chemical reactions and biological systems. The pH of seawater generally is consistent, typically about 8.2 (Riley, 1971). pH can be lower due to respiration from aquatic organisms at night and higher when photosynthesis is occurring during the day. In general, pH should be lower during the winter and early spring months during periods of high freshwater input and low photosynthesis activity and higher during the summer and late fall months.

Geomatrix collected pH measurements from the lagoons from July 1998 through January 1999. pH measurements made by Geomatrix ranged from 6.55 to 8.97 (Appendix A).

According to the Basin Plan, pH should not be depressed below 6.5 or raised above 8.5. At times, pH measurements in the lagoons exceed 8.5; this is most likely due to high rates of photosynthesis during warm, sunny days. Average pH measurements in the lagoons likely approach 8.0. Because of the natural buffering effect of salt water in the lagoon system, pH measurements in the lagoons should not vary greatly. However, pH measurements less than 7.0 may indicate pollutants, such as acids, may have entered the lagoon system.

3.1.6 Nutrients

San Francisco Bay is an estuary rich in nutrients. The nutrients originate from runoff, municipal treatment discharges, and biological recycling. Due to the relatively high concentrations of orthophosphates in both the Bay and the lagoons, nitrogen is a limiting

nutrient in the Bay and the lagoons. To be utilized by plants, nitrogen must be in mineral form such as ammonium (NH_4^+) or nitrate (NO_3^-). Nitrite is another chemical species of nitrogen that can contribute to the overall nitrogen load in the lagoons; however nitrite is very reactive and does not persist in nitrite form for very long or in significant quantities. Typical nutrients and their background concentrations in the Bay are listed below (USGS, 1998).

- orthophosphate (0.026 to 0.36 mg/l)
- silicate (0.058 to 0.91 mg/l)
- nitrite (0.0008 to 0.03 mg/l)
- nitrate/nitrite (0.03 to 1.5 mg/l)
- ammonium (0.0007 to 0.03 mg/l)

In October 1998, Geomatrix collected water samples from each lagoon for analysis for orthophosphates and nitrates (Appendix A).

Of the nutrients listed above, we recommend the periodic measurement of orthophosphates and nitrate. These parameters can be used to monitor changes in rates of nutrients entering the lagoon system.

3.1.7 Bacteria

An important parameter of water quality is the concentrations of water borne bacteria, including total coliform (TC), fecal coliform (FC), fecal streptococcus (FS), and Escherichia coli (E coli). For the Bay in general, TC concentrations are spatially variable and tend to increase during periods of increased rainfall. The Alameda County Environmental Health Services (ACEHS) reportedly has not performed routine bacterial monitoring off Crown Beach or ambient waters offshore of Alameda. However, TC, FC, FS data has been collected by Geomatrix, and the City of Alameda and the AWLHOA (Appendix A); measured ranges for TC, FC and FS in the lagoon system are presented below.

- Lagoon 1 – TC (12 to 80 Most Probable Number per 100 milliliter [MPN/100 ml]) and FC (2 to 50 MPN/100 ml)
- Lagoon 2 – TC (11 to 22 MPN/100 ml) and FC (2 MPN/100 ml)
- Lagoon 3 – TC (2 to 3000 MPN/100 ml), FC (2 to 900 MPN/100 ml), FS (2 to 80 MPN/100 ml), and E coli (2 to 900 MPN/100 ml)

- Lagoon 4 – TC (30 to 110 MPN/100 ml) and FC (17 MPN/100 ml)
- Lagoon 5 – TC (13 to 50 MPN/100 ml), FC (2 to 30 MPN/100 ml)

The ACEHS and the City of Alameda are primarily responsible for public health issues at the lagoons. Many factors can affect the level of TC, FC and FS detected in water samples, such as bird and animal activity in the area of sample collection and source of Bay water. If the concentrations of TC, FC and/or FS are elevated above typical values at a sample location within the lagoons, additional sampling and analysis may be necessary to estimate the potential for water-borne pathogens and human health issues. TC, FC and FS measurements can also serve as an early warning for conditions that are favorable for other waterborne pathogens, such as S. faecium, S. avium and S. gallinarum.

The Basin Plan includes water quality objectives for coliform bacteria. These objectives are based on a minimum of five consecutive samples equally spaced over a 30-day period. These objectives are listed below.

Water Quality Objectives for Coliform Bacteria

Beneficial Use	Fecal Coliform (MPN/100 ml)	Total Coliform (MPN/100 ml)
Water Contact/Recreation	Log mean <200 90th percentile <400	Median <240 No sample >10,000
Non-contact Water Recreation	Mean < 2,000 90th Percentile <4,000	-

3.1.8 Clarity

Clarity is an important water quality parameter. The Basin Plan has water quality objectives for color, suspended material and turbidity; in all three cases, the Basin Plan states that these parameters should not exceed levels that cause a nuisance or adversely affect beneficial uses. A common way to measure clarity is with the Secchi disk. Secchi disk measurements give an indication of the clarity of the water, or how much light can penetrate through the water column. Secchi disk readings can also help define the depth of the euphotic zone where DO is the greatest and pH the highest. Currently, there is no clarity data available for the lagoon system.

3.1.9 Field Observations

In addition to the actual measurement of the parameters discussed above, several conditions that may affect water quality are often noticeable from field observations. These conditions can be monitored by volunteers. Observing and documenting conditions in the lagoons such as changes in water color, odors, unusual bird and fish activity, excessive floating or suspended matter and algae, and effects of changing weather conditions on the lagoons can help in assessing the health of the lagoon system. These conditions can be correlated with water quality parameters and could be used as advance indicators of potential water quality problems. Therefore, it is recommended that field observations of conditions be made on a regular basis; these observations can be made by the AWLHOA "Lagoon Watch" volunteers who live adjacent to the lagoons. Forms for recording field observations are included in Appendix B.

Normally, Bay water is olive-green in color; lagoon system water is generally similar to Bay water in color. However, this color can change from seasonal effects. Color changes can range from olive-green, brown-green to amber. These color changes can be the result phytoplankton blooms and turbidity. This change can be quick and persist for several months. Color changes caused by phytoplankton should not be confused with color changes caused by heavy runoff. Notable color changes usually occur during extreme hot spells in the weather caused by phytoplankton blooms and a change in water quality.

3.2 LAGOON MONITORING PROCEDURES

Initially, monitoring of temperature, DO, salinity, pH, and clarity as measured with a Secchi disk should be performed at least monthly from at least one, and preferably two, locations in each lagoon and from the lagoon system influent and effluent. To be consistent with data already collected, lagoon monitoring locations should be selected from the locations shown on Figure 2. Please note that it is important to collect water quality data from different depths in the water column at each sampling location to help monitor mixing processes in the lagoons. Field observations such as floating debris, odors, weather conditions, and water color should also be noted during monitoring.

Bacterial analysis samples should be collected quarterly during the winter months (once between November and January, and once between February and April) and monthly from May through October. Water samples collected for bacterial analysis should be submitted to a State-of-California certified analytical laboratory for analysis. The analytical laboratory should be

able to provide the City of Alameda and the AWLHOA with sampling containers and sampling procedures.

In the event of a severe algae bloom, water samples should be collected and analyzed for nutrients (nitrate and orthophosphate) and chlorophyll *a*. The water samples should be collected from approximately one-foot above the bottom of the lagoons for nutrients and near the water surface for chlorophyll *a* and submitted to a State-of-California certified analytical laboratory for analysis. Again, the analytical laboratory should be able to provide the city of Alameda and AWLHOA with appropriate sampling containers.

Procedures for measuring these parameters and collecting water samples for chemical analysis are as follows:

- DO, pH, salinity, and temperature should be measured at 3-foot intervals, starting 1-foot from the water surface down to the bottom of the lagoons.
- bacterial samples should be collected from about one foot below the water surface.
- If necessary, samples for nutrients should be collected from 1-foot from the bottom and samples for chlorophyll *a* should be collected from just below the water surface.

A suggested monitoring program is presented in Table 1. The monitoring of the water quality parameters should be performed by someone trained in the procedures and protocols associated with collecting and measuring the above described water quality parameters. Water quality data sheets for recording the measured water quality parameters are included in Appendix B. After approximately two years of monitoring, the monitoring program should be reviewed, trends evaluated, and monitoring frequency modified as appropriate.

3.3 WATER DATA ANALYSIS QUALITY

The reason for collecting and analyzing water quality data is to help provide an objective basis for lagoon operation decision-making, including assessing water quality episodes and managing aquatic vegetation. A general set of criteria that are useful in assessing whether a water quality episode is in progress or imminent include:

- Significant deviations from database trends
- DO concentrations averaging less than 2.0 mg/l in the water column.

- Chlorophyll *a* concentrations exceeds 50 µg/l
- Concentrations of indicator bacteria organisms exceeding the limits specified in section 3.1.7.
- Nitrate concentrations greater than 1.5 mg/l in the lagoons.

Specific evaluation criteria and recommended actions include the following:
Salinity, pH - If salinity and/or pH measurements are abnormal based on the background data described above and/or historical trends, the following actions are recommended.

- Make confirmation measurements at the shallow, mid-depth and bottom monitoring locations within the water column at the monitoring locations.
- Evaluate the latest rainfall data; large rainfall events may result in lower salinity. In the absence of significant rainfall, low salinity may be indicative of a water main or sewer release into the lagoons.
- Compare salinity value with respect to pH of the sample; low pH with normal salinity may be indicative of a release of pollutants such as acids into the lagoons.
- Flush the lagoons, if deemed appropriate.

Dissolved Oxygen - If DO concentrations are judged to be abnormally low relative to baseline data or average below 2.0 mg/l in the water column, the following actions are recommended.

- Measure DO concentrations at additional locations near the location(s) where the abnormally low measurement(s) were taken and reconfirm measurements at initial sampling location(s). Measurements should follow procedures described above.
- If abnormally low DO concentrations are confirmed, other water quality parameters can be assessed to determine if an algae bloom (chlorophyll *a*), chemical spill, or sewer leak has occurred (salinity, pH, bacteria).
- If DO concentrations remain low or decrease, maintain maximum pumping rates. If deemed necessary, initiate aeration, if available, in the respective lagoon(s) to raise DO concentrations in the lagoon(s) and lower the likelihood of a significant fish kill. The lagoon system supply pump should be operated at maximum capacity during this time to maintain circulation and bring DO-enriched water into the lagoon.
- In the event of a fish kill, all dead marine organisms should be removed from the lagoon and disposed of properly. Notify the City of Alameda and the OES if there is a significant fish kill in the lagoon system.

- Measure DO concentrations twice daily as close as possible to sunrise and sunset to assess diurnal DO distribution at all locations until DO concentrations increase to normal levels.

Clarity - If clarity (secchi disk readings) is determined to be abnormally low, the following actions are recommended.

- Other water quality parameters should be assessed to determine if an algae bloom (chlorophyll a), chemical spill, or sewer leak has occurred (salinity, pH, bacteria).

Temperature - If measured temperatures are not consistent with historical trends, the following actions are recommended.

- Confirm temperature measurements with another meter.
- Review weather patterns from previous weeks and correlate with ambient temperature data.

Bacteria - to measure bacterial parameters, lagoon water samples should be analyzed for total coliform (TC), fecal coliform (FC), and fecal streptococci (FS). It has been observed that quantities of fecal coliforms and fecal streptococci that are discharged by humans are significantly different from the quantities discharged by animals (Tchobanoglous and Schroeder, 1985). Therefore it has been suggested that the ratio of FC count to FS count in a sample can be used to show whether the suspected contamination derives from human waste or from animal waste. A FC/FS ratio of 4:1 or higher is indicative of domestic waste composed of human wastes whereas a FC/FS ratio of 1:1 or less is indicative of domestic animal wastes. Intermediate FC/FS ratios (1:1 to 4:1) do not provide a clear indication of source and composition of bacteria. Additionally, analytical results should consider field observations (i.e., presence of birds) and weather conditions. If bacterial values are high, but do not exceed the Basin Plan based limits, resampling may be required to assess any public health issues. If bacterial counts exceed the Basin Plan based limits listed above and if the fecal coliform/fecal streptococcus ratio exceeds 4 to1, the following actions are recommended.

- Resample background locations (lagoon influent), neighboring lagoon monitoring locations, and runoff (if available), and re-evaluate data to confirm bacterial concentrations.
- Notify the City of Alameda of the possible presence of human waste.
- Collect and analyze samples for E coli.

Indicator organism data should be continuously evaluated to assess its effects on recreational use of the lagoons in conjunction with the Basin Plan guidance.

Nutrients - Sampling and analyzing for nutrients (nitrate and orthophosphate) can help in assessing the health of the lagoons. The evaluation of these analytes will enable the AWLHOA Board and the City of Alameda to assess the degree of nutrient and organic loading in the lagoon system. The degree of nutrient and organic loading should be assessed based on seasonal and historical trends and field observations. If the concentrations of nutrients or organic loading appear higher than normal, the following actions are recommended.

- Resample water in the lagoon with high nutrient concentrations and simultaneously resample at lagoon system effluent.
- Resample and investigate background conditions in the lagoon.
- Identify the source of nutrient loading, if possible.

Chlorophyll *a* - Data from other lagoon systems have indicated that when chlorophyll *a* concentrations are exceptionally high (exceeding 50 µg/l), phytoplankton blooms can occur in the lagoons, possibly resulting in fish kills. Increased monitoring should be performed during these cases. If high chlorophyll *a* concentrations are measured in samples from the lagoons, the following actions are recommended.

- Collect confirmation samples at the monitoring locations and from the lagoon system influent. Collect samples from other locations in the lagoon(s) as deemed necessary by field observations (i.e. areas of concentrated fish kills or algal blooms). Have samples analyzed on an accelerated turnaround time basis.
- Monitor DO twice daily at locations where chlorophyll *a* samples were collected. If DO is decreasing, increase pumping or initiate aeration in the lagoon to raise DO concentrations in the lagoons and lower the likelihood of a significant fish kill. The lagoon supply pump should be operated at maximum capacity during this time to maintain circulation and DO-enriched water into the lagoon. Flushing of the lagoon system by utilizing tides and weirs should also be considered.
- In the event of a fish kill, all dead marine organisms should be removed from the lagoon and disposed of properly.
- Notify the City of Alameda and the OES if there is a significant fish kill.
- Notify the City of Alameda if the concentration of chlorophyll *a* exceeds 50 µg/l.

3.4 WATER QUALITY DATA MANAGEMENT

Water quality data should be entered into an electronic database for storage and management. Field data should be reviewed and checked before being entered in the database. The database should have at a minimum, the following fields:

- Name of data recorder
- Date
- Time
- Lagoon number and monitoring/sampling location
- Water quality parameters discussed above and listed in Table 1
- General comments

After the data has been stored, figures and graphs can be plotted to monitor specific trends for water quality during the seasons. As the database is built and maintained, seasonal and long-term trends can be identified and evaluated. Data should be entered and evaluated as soon as it is obtained. Rapid evaluation of data can assist in the early identification of trends and potential problems in the lagoon system. Databases such as Microsoft EXCEL and ACCESS are well suited for managing water quality data from the lagoons.

4.0 RECOMMENDATIONS

The following section presents recommendations for managing conditions and practices that impact or affect the water quality and health of the lagoon system. These recommendations are also summarized in Table 3.

4.1 VEGETATION MANAGEMENT

Managing the aquatic vegetation in the lagoon system is a high priority for the City of Alameda and the AWLHOA. Growth of aquatic plants can impair the recreational use of the lagoons and result in rafts of decaying vegetation which cause insect and odor problems. Several approaches to managing aquatic vegetation in the lagoons are described below.

4.1.1 Nitrogen Management

The primary approach to control aquatic vegetation should focus on reducing nutrients, especially nitrogen, in the lagoons. The nutrients nitrate and orthophosphate are necessary

components to promote the growth of aquatic vegetation. As described above, both the Bay water and the lagoons are rich in orthophosphates. Lagoon water has been analyzed for nitrogen (total kjeldhal nitrogen [TKN] and nitrate) and orthophosphate; results of these analyses indicate that orthophosphate is found in excess in the lagoons, making nitrogen the limiting nutrient for aquatic vegetative growth. Two approaches can be taken to reduce nitrogen in the lagoons.

One approach should focus on managing or reducing the amount of nitrogen that enters the lagoons. Inputs of nitrogen into the lagoon system (such as runoff from fertilized lawns, pet feces, and bird droppings) can cause rapid growth of weedy plant species such as periphyton (attached algae) and widgeon grass in addition to phytoplankton and filamentous algae. Sources of nitrogen that enter the lagoons that can be controlled include: pet and bird feces, runoff tainted with lawn fertilizer, sewer line leaks, discharges of ammonia based cleaners, and re-suspension of nutrient rich sediment. Recommendations for controlling the input of nitrogen are discussed later in this management plan.

A second approach should focus on long-term control measures to reduce the available nitrogen that is in the lagoon system by promoting the nitrification/denitrification process. Nitrification/denitrification results in dissolved nitrogen (nitrate) being converted to nitrogen gas. With the lack of a significant nitrification/denitrification process, much of the nitrogen that is introduced into the biota of the lagoons continues to remain in the lagoon system available as a nutrient source for the propagation of aquatic plants. Therefore, any sustainable vegetation management plan should focus on maximizing nitrification/denitrification processes. Such a plan would require creation of aerobic and anaerobic zones in the lagoons consisting of small islands of more acceptable aquatic vegetation, and is likely the only effective way to remove nitrogen from aquatic systems. These processes have been shown to occur relatively rapidly in wetland type environments. The municipal wastewater treatment plant in Arcata, California reportedly has constructed wetlands that effectively promote the nitrification/denitrification process resulting in the removal of nutrients, including nitrogen, from municipal wastewater. The City of Arcata Public Works Department can be contacted for more information regarding this approach.

4.1.2 Aeration

Aeration involves the mechanical introduction of dissolved oxygen into the water column. DO measurements taken at the lagoons indicate that additional DO can be utilized by the lagoons.

Adding DO can increase the rate of nitrogen removal during the denitrification phase of the nitrogen cycle through facultative aerobic bacteria.

Adding DO also adds to the existing DO concentrations generated by phytoplankton and encourages aerobic breakdown of organic matter such as dead algae and plant matter that may accumulate on the lagoon bottoms. This in turn reduces the available nutrient supply (orthophosphates and nitrogen) for phytoplankton, filamentous, and vascular plants such as widgeon grass.

In addition, increased DO by phytoplankton can result in higher pH during warm sunny afternoons when photosynthesis is at a peak. Large pH swings can have a greater disinfecting affect on pathogens that might be present in the lagoons.

4.1.3 Chemical Controls

While chemical controls can play an important role in management of nuisance vegetation, there are significant limitations associated with their use and their use should be avoided whenever possible. However, when chemical control is necessary, we recommend the use of pre-emergent herbicides which are much more useful as long-term management measures because they affect only the target plants and do not dramatically alter water quality or adversely affect fish populations.

Unfortunately, pre-emergent herbicides are only effective at the beginning of the growing season, and cannot kill plants after growth has occurred. In addition, too frequent application of broad-spectrum aquatic herbicides can create a cycle whereby only the most noxious plants can proliferate within the lagoons as they tend to reduce the diversity of species of aquatic vegetation in the lagoons. Rapid growing species such as widgeon grass and filamentous algae then tend to proliferate unchecked by competition from slower growing, less bothersome plants. To make matters worse, liberal application of contact killers can result in fish kills, thereby reducing natural grazing by fish.

If chemical controls are used, chemicals must be applied by a State licensed applicator registered with the Department of Pesticides Regulation as a certified Pest Control Advisor, and hold an applicators license - Category F, for aquatic systems.

4.1.4 Harvesting

For instances where the growth of periphyton is unacceptable, we recommend using mechanical harvesting in lieu of broad-spectrum contact killers where feasible. Because of the high cost of mechanical harvesting, it should be reserved for intolerable levels of proliferation.

4.1.5 Other potential measures

There are additional potential measures that may be helpful in managing aquatic vegetative growth in the lagoons. These methods include:

- Reducing light penetration into the water column by increasing the depth of the lagoons in shallow areas would reduce the propagation of aquatic vegetation attached to the lagoon bottom. Other methods of reducing light penetration include perturbation of the surface or the addition of chemicals such as Aquashade; however, due to the size and uses of the lagoons, these methods are probably not practical for use in the lagoon system.

- Frequent monitoring of Bay intake water and curtailing pump operation during periods of high nitrogen concentrations such as during winter and early spring seasons when heavy rainfall and runoff is expected.

- During drawdown of the lagoons, the nitrogen cycle is likely to be accelerated resulting in the increased dissolved nitrogen levels in lagoon water. Sampling and analysis of lagoon bottom sediments for nitrogen and ammonia can help determine if this is occurring. If so, reducing the duration and frequency of lagoon drawdown may reduce the production of dissolved nitrogen in the lagoon waters and reduced growth of aquatic vegetation.

- Volunteer monitoring can be a useful tool for monitoring and collecting data. The development of a volunteer monitoring program should be considered.

4.2 LAGOON MAINTENANCE

Proper maintenance of the lagoons can play a significant role in the protecting the water quality and health of the lagoon system. This section presents some recommendations for maintenance and management practices that can help protect the lagoons.

4.2.1 General Maintenance

The AWLHOA and the City of Alameda contract for general maintenance of the lagoons. The general maintenance activities include clearing weirs, removing floating debris, abating aquatic weeds, and removing dead wildlife. It is also recommended that the contractor observe and document the conditions of the lagoons, so as to provide a broader basis for management

decisions. Primarily, the AWLHOA and its maintenance contractor(s) should assure that weirs do not become obstructed with floating debris and that nuisance conditions do not arise. Additional tasks to consider include:

- Remove and document general contents and volume of floating debris to determine possible sources.
- Remove and document dead wildlife or animals, especially waterfowl to evaluate if avian diseases are present.
- Removal of algal blooms by skimming rather than spraying. Spraying results in the accumulation of algae on the lagoon bottoms and recycling nitrogen back into the lagoon system.
- Remove accumulations of decaying vegetation such as algal mats, which unless removed, will recycle nutrients back into the lagoons and cause more algal growth. Documenting the location of the mats can help focus abatement efforts and thereby minimize chemical usage.
- Document discharges that appear to be illicit, cause a visually observable color change in the lagoons, or create a petroleum sheen.

4.2.2 Sediment Management

The AWLHOA and the City of Alameda should develop criteria for determining when sediment removal from the lagoons should be considered and establish a budget for sediment removal activities. Criteria for sediment removal should consider water circulation requirements and accumulation of excessive bottom sediments. Shallowing of the lagoon results in an environment more suited for propagation of aquatic vegetation and the accumulation of undesirable components such as metals.

Removal or dredging of sediment from the lagoon system is regulated by the U.S. Army Corps of Engineers (ACOE) under a nationwide permit and the Regional Board. Prior to any sediment removal activities, the appropriate permits must be obtained and the proper agencies notified. Currently, the ACOE and the Regional Board should be notified, and a permit obtained from the ACOE.

As part of the permitting process, the dredged sediments will require characterization prior to disposal. Disposal characterization requirements generally consist of the collection and chemical analysis of dredge sediment samples. Actual characterization requirements may vary depending on where the dredge sediments are to be disposed; however, analysis for the metals

arsenic, lead, total chromium, copper, and zinc are typically required. In July 1998, Geomatrix collected sediment samples and had the samples analyzed for arsenic, lead, total chromium, copper, and zinc. The ranges of concentrations are presented below; complete analytical results of the metals detected in the sediment samples are included in Appendix A. These ranges of metal concentrations are generally within background concentrations and are below concentrations for these metals that would result in classification as a hazardous waste.

Arsenic	2.1 to 4.8 mg/kg
Lead	18 to 35 mg/kg
Total Chromium	21 to 47 mg/kg
Copper	16 to 43 mg/kg
Zinc	55 to 89 mg/kg

4.3 HOMEOWNER BEST MANAGEMENT PRACTICES

This section describes some recommended management practices and suggestions for raising homeowners' awareness of practices that have negative impacts on the lagoons. Many of these suggestions are included in the Urban Runoff Program. This information can be distributed door to door in the form of pamphlets or flyers, posted in public gathering areas, or directly mailed to individual homeowners.

4.3.1 Landscaping and Fertilization Practices

As discussed above, the lagoons are sensitive to nutrient loading, particularly nitrogen. Improper application of fertilizers by residents adjacent to and near the lagoons is likely a major contributor to nutrient loading in the system. Bird droppings, both near and in the lagoons, are also likely a major source of nutrients to the lagoon. In rare cases, organic material can enter the lagoons through grass cuttings or thatch. Public education about fertilization practices is likely the best means by which to reduce nutrient loading. The following practices are recommended to minimize nutrient input to the lagoons.

- Encourage residents to apply only the amount of fertilizer that is absolutely necessary; reduce or eliminate the amount of fertilizer applied in the immediate area of the lagoons (e.g., within 25 to 100 feet of any bank, depending on drainage patterns).
- Apply very little or no fertilizer if rain is expected, to reduce runoff.
- Control watering, so that applied water is absorbed by the turf, minimizing runoff into the lagoons.

For more information on this subject, please contact the City of Alameda Urban Runoff Program.

4.3.2 Maintenance of Docks and Watercraft

Some homeowners have structures or floating docks on the lagoons for boats or other watercraft. The use of detergents is not allowed on any floating docks or recreational devices on the lagoons. Please contact the Regional Board or the City of Alameda Urban Runoff Program for more information on this subject.

Paint and stains may also be applied to these structures and spills may result. Homeowners should be encouraged to prevent spills and take precautions such as draping plastic sheeting under structures when applying finishes.

The repair of water related recreational devices should be performed away from the lagoon system.

Guano and macroalgae accumulations should be visually monitored. If guano and macroalgae interfere with daily routines, homeowners should attempt to physically remove them on an as needed basis and compost or dispose of the materials with residential refuse. Excessive macroalgae can often times be removed by rakes. Leaving the algae along the shoreline will recycle the nutrients back into the lagoons and create aesthetic problems such as odors and flies.

4.3.3 Prohibition of Activities

Raising public awareness by prohibiting certain activities can help reduce negative impacts to the lagoon system. In addition, many common activities are considered to either be in violation of applicable environmental laws or require special permits. Recommended activities to consider prohibiting, consistent with the California Water Code, include the following:

- Discharge of any waste or substance that could impair water quality. This includes, discharge of washwater containing masonry, soap, grease, petroleum, or fecal matter into storm drains, curb gutters, or directly to the lagoons.
- Discharge or placement of fill material into water bodies and wetlands.
- Disposal of waste automotive fluids, household chemicals, and other wastes by pouring them on the ground surface.

- Use of pesticides and herbicides in a manner inconsistent with the label instructions.

4.4 RESPONSES TO WATER QUALITY PROBLEMS

When an emergency condition exists, the Alameda Fire Department should be called at (510) 748-4508 ext. 3311. If field observations or water quality monitoring results indicate that potentially adverse water quality conditions exist in the lagoon system, and it is determined that the conditions **are not an emergency condition**, the following actions should be taken.

- Visit the lagoon system with the person who first observed the change.
- Report results to the City of Alameda Public Works Department.
- Collect water quality and/or biological samples as necessary to confirm the condition.

In addition, the AWLHOA, the City of Alameda and their consultant should review historical trends to determine if the conditions are a result of episodic events or long-term changes. Past observations should be compared to seasonal weather conditions and water quality.

4.5 PUBLIC NOTIFICATION PROGRAMS

AWLHOA members should be informed of potentially adverse water quality conditions in the lagoon system so as to be able to protect the public from potential water quality problems if abnormal trends in water quality are observed.

The following agencies should be notified if the conditions listed below occur.

California Office of Emergency Services, City of Alameda - Department of Public Works

- Significant fish kills.
- Bird kills suspected to be caused by viruses or bacteria.
- Chemical spills that occur in or adjacent to the Lagoon.

Alameda County Department of Environmental Health Services and City of Alameda - Department of Public Works

- An exceedance of bacterial guidance as presented in section 3.1.7.

The Alameda Fire Department

- Any emergency condition

A complete list of agencies, with contact information is included in Table 2.

4.6 LAGOON MANAGEMENT PLAN UPDATES

This management plan should be reviewed annually and updated as necessary.

5.0 REFERENCES

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California Water Code, 1999.

California Regional Water Quality Control Board - San Francisco Bay Region, Water Quality Control Plan (Basin Plan), June 21, 1995.

Guidance Document for the Need for and Preparation of Pond, Lagoon, and Lake Management Plans, David W. Smith, Ph.D., Consulting Engineer for Regional Water Quality Control Board, Dan Francisco Bay Region, December 1989.

Riley, J.P. and Chester, R., 1971, Introduction to Marine Chemistry, Academic Press, London and New York.

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U.S. Geological Survey (USGS), 1998, Water Quality of San Francisco Bay: USGS, Menlo Park, California, June 9.

Viessman, W., Jr. and Hammer, M.J., 1985, Water Supply and Pollution Control, Harper and Row, Publishers, New York.

GLOSSARY OF TERMS

Anthropogenic:	Man-made.
Benthic:	Bottom-dwelling.
Euphotic:	Area in the water column where oxygen production exceeds respiration.
Eutrophic:	Water that is nutrient-rich.
Guano	A subsistence composed chiefly of the dung of sea birds or bats, accumulated along certain coastal areas or in caves.
Macroalgae	Large algae that is easily seen without a microscope. These algae usually have leaf like structures and are attached to substrates.
Oligotrophic:	Water that is nutrient-poor.
Periphyton:	Attached algae that grow on the bottom and shallow periphery of a water body.
Phytoplankton:	Free-floating unicellular algae.
Primary Productivity:	Energy supplied by sunlight, which enables phytoplankton populations to grow if amounts of nutrients are adequate.
Saturation:	The concentration of dissolved oxygen (DO) is dependent on temperature, salinity, and biotic effects. Temperature has the greatest effect on DO. The concentration of DO is inversely proportional to temperature (i.e., the higher the temperature, the less DO in solution). Increasing salinity has only a minor effect on DO unless the salinity is very high, such as in salt ponds. Dissolved salts in water reduce the intermolecular space available for oxygen. Biotic effects (photosynthesis and respiration) can alter DO concentrations in either direction. At a certain temperature and salinity, DO reaches equilibrium and is said to be saturated. However, with biotic effects, DO can be above or below saturation due to photosynthesis and respiration.
Secondary Productivity:	The growth of organisms such as invertebrate (zooplankton) and vertebrate (juvenile fish) populations from assimilating organisms produced from primary productivity: carnivorous animals assimilate the herbivores.
Sessile:	Attached non-moving life forms (e.g., mussels, barnacles, and sponges)
Zooplankton	Free-drifting invertebrates and vertebrates that can be herbivores or carnivores.

TABLES

TABLE 1

LAGOON MANAGEMENT PLAN MONITORING PROGRAM [1]

Alameda West Lagoons
Alameda, California

Test	Location		
	Lagoon 1 through 5	Influent	Effluent
Temperature[2]	M	M	M
DO[2]	M	M	M
Salinity	M	M	M
pH	M	M	M
Clarity (secchi disk)	M	M	M
Field Observations	M	M	M
Total / Fecal Coliform / Fecal Streptococcus[3]	M[3] & Q	M[3] & Q	M[3] & Q
Nutrients: Nitrate and Orthophosphate	AN	AN	AN
Chlorophyll *a*	AN	AN	AN

Notes:

[1] For each test and location the frequency for monitoring events is given.
M = Monthly
Q = Quarterly
AN = As necessary

[2] Measurements to be taken at 3-foot intervals beginning at 1-foot from the water surface toward the bottom of the Lagoon.

[3] Bacterial sampling to be performed monthly from May through October and quarterly from November through April.

GEOMATRIX

TABLE 2

LAGOON MANAGEMENT PLAN CONTACT INFORMATION

Alameda West Lagoon
Alameda, California

Alameda County Environmental Health Services Administration
1131 Harbor Bay Parkway
Alameda, California 94502
(510) 567-6700
www.co.alameda.ca.us

California Regional Water Quality Control Board
San Francisco Bay Region
1515 Clay Street, Suite 1400
Oakland, California 94612
(510) 622-2300
www.swrcb.ca.gov (Region 2)

California Department of Fish and Game
P.O. Box 47
Yountville, California 94599
(707) 576-2220
www.dfg.ca.gov

City of Alameda
Department of Public Works
1616 Fortmann Way
Alameda, California 94501
(510) 748-4520

City of Alameda Fire Department
(510) 748-4508 ext. 3311

City of Alameda Urban Runoff Program
(510) 749-5864

Governor's Office of Emergency Services (OES)
(800) 852-7550
www.oes.ca.gov

U.S. Army Corps of Engineers – San Francisco District
333 Market Street
San Francisco, California 94105
(415) 977-8462
www.spn.usace.army.mil

TABLE 3

WATER QUALITY MANAGEMENT RECOMMENDATIONS

Alameda West Lagoons
Alameda, California

Recommendations	Pros	Cons
Nitrogen Management - A primary recommendation; focuses on reducing or eliminating nutrient sources that result in the discharge of nutrients, especially nitrogen, into the lagoons. Potential sources include fertilizer, pet feces, bird droppings, sewer leaks, ammonia based cleaners, and other nutrient rich sediment. Actions include monitoring and maintenance, developing homeowner best management practices, and prohibition of activities.	Long term solution; focuses on eliminating source of nutrients necessary for nuisance aquatic plant proliferation; low capital cost; community approach; enhances overall water quality.	Constant vigilance required; may be 'inconvenient' to some homeowners.
Aeration - Aeration involves the mechanical introduction of dissolved oxygen (DO) into the water column.	Long term solution; very effective at controlling the growth of nuisance vegetation; no adverse affects to water quality or aquatic animals; increases the rate of nutrient (nitrogen) removal from lagoon system; and may have disinfecting effect on pathogens; can target problem areas.	Fairly high initial capital cost; ongoing operation and maintenance costs; and noise and visual considerations.
Chemical Controls - chemical controls involve the application of herbicides to control the proliferation of nuisance vegetation. Pre-emergent herbicides are recommended when chemical control is necessary.	Relatively inexpensive; can target specific plant species; proper application may not dramatically affect water quality or aquatic animals.	Must be applied at beginning of growing season; too frequent of application can result in cycle where only most noxious plants proliferate; does not reduce nitrogen in system and therefore, is only a short-term solution; must be applied by a State licensed applicator.
Harvesting - Mechanical harvesting can be utilized to remove nuisance vegetation.	Can target specific plant species; does not adversely affect water quality or aquatic animals.	Can be relatively high cost and labor intensive; not a long term solution to nutrient reduction in lagoon system.
Sediment Management involves the periodic removal of sediment accumulations in the lagoons. Accumulation of sediment results in the shallowing of the lagoons and creating an environment more suitable for propagation of aquatic vegetation, affects navigation of the lagoons, and results in the accumulation of undesirable components such as nutrients and metals.	Deepens lagoons resulting in less favorable environment for aquatic plant growth; nutrients, metals and other chemicals in sediment are removed from system; navigation is improved.	Expensive; requires permit from Army Corps of Engineers; logistics of dredging are complicated and will be disruptive.

FIGURES

GEOMATRIX

APPENDIX A

Water Quality Parameter Monitoring Results and Metals in Sediment Analytical Results Alameda West Lagoons

GEOMATRIX

APPENDIX A

WATER QUALITY PARAMTERS
JULY 7, 1998 RESULTS
Alameda West Lagoons
Alameda, California

Lagoon	Location	Date	Time	$DO_{surface}$ (mg/l)	$Temperature_{surface}$ (C)	DO_{bottom} (mg/l)	$Temperature_{bottom}$ (C)	pH	Salinity (ppt)	Depth (feet)	Total Coliform (cfu/100ml)
1	A	7/7/98	9:15	8.7	22.4	8.55	21.4	8.2	21.5	4	14
1	B	7/7/98	9:53	8.6	22.5	4.8	21.9	8.24	20	9	NA
1	C	7/7/98	10:19	8.2	22.6	4.7	22.7	8.48	19.8	NA	NA
1	D	7/7/98	10:34	7.73	22.9	6	22.5	8.46	19.8	8	NA
1	E	7/7/98	10:41	7.35	23.2	6.17	22.9	8.42	20	5	NA
2	A	7/7/98	11:05	7.8	23.4	2.4	24.3	8.41	17	8	22
2	B	7/7/98	11:10	7.68	23.9	3.3	24.7	8.4	17	7	NA
2	C	7/7/98	11:20	7.9	24	3.9	24.3	8.39	16.5	8	NA
2	D	7/7/98	11:37	7.26	24.3	7.05	24.2	8.39	18	10	NA
3	A	7/7/98	NA	NA	NA	NA	NA	NA	NA	NA	1600
3	B	7/7/98	NA	NA	NA	NA	NA	NA	NA	NA	NA
3	C	7/7/98	14:17	7.3	27	NA	NA	8.3	16.2	2	170
4	A	7/7/98	14:00	8.4	24.9	8.6	25.2	8.37	18	2	NA
4	B	7/7/98	NA	NA	NA	NA	NA	NA	NA	NA	30
5	A	7/7/98	13:17	8.5	24.8	9.5	23.3	8.34	19.1	5	NA
5	B	7/7/98	13:37	9.6	24.6	11.2	24.5	8.4	19.6	4	13
5	C	7/7/98	13:50	8.5	25.2	9.3	24.8	8.29	20	3	NA

DO = dissolved oxygen
mg/l = milligrams per liter
C = degrees Celsius
ppt = parts per thousand
cfu = colony forming units
ml = milliliters
NA = not analyzed

GEOMATRIX

APPENDIX A

WATER QUALITY PARAMETERS
AUGUST 5, 1998 RESULTS

Alameda West Lagoons
Alameda, California

Lagoon	Location	Date	Time	Air Temp (C)	$DO_{surface}$ (mg/l)	$Temperature_{surface}$ (C)	DO_{bottom} (mg/l)	$Temperature_{bottom}$ (C)	pH	Salinity (ppt)	Fecal Coliform (cfu/100ml)	E. Coli (cfu/100ml)	Fecal Streptococci (cfu/100ml)
3	A	8/5/98	9:15	24.4	7.60	25.50	7.50	25.6	8.26	18.5	7	4	11
3	B	8/5/98	9:30	24.4	6.85	25.20	5.50	25.2	8.34	18.9	900	900	7
3	C	8/5/98	9:50	25	7.60	25.70	7.23	25.4	8.4	19.2	70	50	9

DO = dissolved oxygen
mg/l = milligrams per liter
C = degrees Celsius
ppt = parts per thousand
cfu = colony forming units
ml = milliliters

GEOMATRIX

APPENDIX A

WATER QUALITY PARAMETERS
OCTOBER 16, 1998 RESULTS

Alameda West Lagoons
Alameda, California

Lagoon	Location	Date	Time	$DO_{surface}$ (mg/l)	$Temperature_{surface}$ (C)	DO_{bottom} (mg/l)	$Temperature_{bottom}$ (C)	pH	Salinity (ppt)	Depth (feet)	Ortho-phosopate (mg/l)	Nitrate/ Nitrite (mg/l)	Total Coliform (cfu/100ml)	Fecal Coliform (cfu/100ml)	E. Coli (cfu/100ml)
1	A	10/16/98	16:10	5.92	19.60	0.17	18.8	8.02	15.1	8.0	0.16	0.07	NA	NA	NA
1	B	10/16/98	16:15	7.00	19.60	1.78	18.4	8.12	6.9	9.0	NA	NA	NA	NA	NA
1	C	10/16/98	16:20	5.85	19.80	4.13	19.0	8.07	13.4	8.8	NA	NA	NA	NA	NA
1	D	10/16/98	16:30	7.62	20.30	3.09	19.1	8.30	13.1	8.5	NA	NA	NA	NA	NA
1	E	10/16/98	16:00	6.81	20.20	4.86	19.4	8.20	13.1	8.0	NA	NA	NA	NA	NA
1	F	10/16/98	15:55	7.35	20.40	6.86	19.6	8.31	13.1	8.5	0.12	<0.05	NA	NA	NA
2	A	10/16/98	16:45	7.63	20.20	4.95	19.5	8.36	13.2	6.5	NA	NA	NA	NA	NA
2	C	10/16/98	17:15	6.32	19.90	4.62	19.1	8.35	10.8	7.0	NA	NA	NA	NA	NA
2	D	10/16/98	17:01	6.78	20.00	5.40	19.4	8.37	12.5	6.5	0.08	0.06	NA	NA	NA
3	A	10/16/98	10:26	8.01	18.60	3.04	NA	8.55	13.8	6.0	0.03	<0.05	3000	50	50
3	B	10/16/98	10:42	7.26	18.60	5.36	NA	8.51	15	3.0	<0.03	<0.05	4	2	2
3	C	10/16/98	9:37	3.03	17.30	NA	NA	8.21	14.8	1.0	0.1	0.11	500	110	110
4	A	10/16/98	15:03	7.13	19.50	6.26	19.0	8.42	13.8	3.0	0.03	<0.05	NA	NA	NA
4	B	10/16/98	15:18	7.09	20.10	5.68	19.6	8.4	20.8	4.5	NA	NA	NA	NA	NA
5	A	10/16/98	12:30	6.30	19.50	4.86	19.0	8.31	19.2	4.5	0.04	0.05	NA	NA	NA
5	B	10/16/98	13:00	6.73	19.60	5.53	18.8	8.29	21.2	6.5	0.04	0.09	NA	NA	NA
5	C	10/16/98	13:30	6.47	19.80	5.35	19.2	8.24	23	3.0	0.05	0.07	NA	NA	NA
ADDITIONAL SAMPLING LOCATIONS															
3	A1	10/16/98	11:38	7.53	18.80	3.35	NA	8.50	19.5	3.5	0.04	<0.05	27	2	2
3	A2	10/16/98	11:51	6.84	18.90	3.00	NA	8.47	17.3	7.3	0.03	<0.05	12	4	4
3	B1	10/16/98	11:14	6.78	18.70	0.60	NA	8.48	30.5	6.5	<0.03	<0.05	2	2	2
3	B2	10/16/98	10:59	6.90	19.00	2.54	NA	8.49	28.7	6.0	<0.03	<0.05	27	22	14

DO = dissolved oxygen
mg/l = milligrams per liter
C = degrees Celsius
ppt = parts per thousand
cfu = colony forming units
ml = milliliters
NA = not analyzed

GEOMATRIX

APPENDIX A

WATER QUALITY PARAMETERS
JANUARY 25, 1999 RESULTS

Alameda West Lagoons
Alameda, California

Lagoon	Location	Date	Time	$DO_{surface}$ (mg/l)	$Temperature_{surface}$ (C)	DO_{bottom} (mg/l)	$Temperature_{bottom}$ (C)	pH	Salinity (ppt)	Fecal Coliform (cfu/100ml)	E. Coli (cfu/100ml)	Fecal Streptococci (cfu/100ml)
1	A	1/25/99	12:00	11.00	9.30	7.10	11.9	8.20	28	80	50	NA
2	D	1/25/99	11:30	10.90	9.70	NA	NA	8.31	26.5	11	2	NA
3	A	1/25/99	11:00	9.20	11.00	6.00	13.3	8.2	24.8	3000	70	17
3	B	1/25/99	10:50	10.30	11.10	5.60	13.4	8.01	19.1	800	22	80
3	C	1/25/99	10:35	11.03	11.90	5.50	13.4	8.3	18	300	30	50
4	B	1/25/99	9:15	8.70	11.70	NA	NA	8.3	22.1	110	17	NA
5	C	1/25/99	9:00	7.60	11.40	NA	NA	8.3	24.8	50	30	NA
ADDITIONAL SAMPLING LOCATIONS												
3	A1	1/25/99	10:55	10.20	11.10	6.10	13.40	8.10	17.8	220	17	NA
3	B1	1/25/99	10:40	11.10	11.70	6.00	13.30	8.20	18.5	350	13	NA

DO = dissolved oxygen
mg/l = milligrams per liter
C = degrees Celsius
ppt = parts per thousand
cfu = colony forming units
ml = milliliters
NA = not analyzed

APPENDIX A

WATER QUALITY PARAMETERS
APRIL 14, 1999
RESULTS

Alameda West Lagoons
Alameda, California

Lagoon	Site	Date	Time	Temperature (C)	Secchi (feet)	Bottom (feet)	Euphotic			Middle		Bottom	
							Temperature (C)	pH	Salinity (ppt)	pH	Salinity (ppt)	pH	Salinity (ppt)
1	L-1A	4/14/99	13:47	16.3	4.50	7.25	16.3	8.68	22.0	6.82	24	NA	NA
1	L-1B	4/14/99	13:21	17.8	7.00	8.00	17.8	8.64	22.0	6.76	24	8.78	NA
1	L-1C	4/14/99	13:03	18.7	6.50	7.17	18.7	8.66	22.0	6.91	24	8.76	26.0
2	L-2	4/14/99	9:50	16.0	6.50	7.00	16.0	8.77	22.0	8.75	25.5	8.80	25.5
3	L-3A	4/14/99	8:29	17.9	5.50	6.00	17.9	8.30	12.6	7.33	13.6	6.69	NA
3	L-3B	4/14/99	8:51	18.0	6.00	6.00	18.0	8.80	15.5	6.55	18.75	6.52	NA
3	L-3C	4/14/99	9:07	18.1	5.17	5.17	18.1	8.97	15.5	6.61	20.25	6.61	NA
4	L-4	4/14/99	10:30	16.2	4.83	4.83	16.2	8.89	15.5	6.81	18	NA	NA
5	L-5A	4/14/99	11:57	17.3	6.25	6.25	17.3	8.75	18.0	6.79	18.75	NA	NA
5	L-5B	4/14/99	11:35	17.5	6.50	7.83	17.5	8.75	18.0	6.93	18.75	8.68	20.3
5	L-5C	4/14/99	11:20	17.8	4.50	4.50	17.8	8.58	17.1	6.78	18.75	NA	NA

DO = dissolved oxygen
mg/l = milligrams per liter
C = degrees Celsius
ppt = parts per thousand
cfu = colony forming units
ml = milliliters
% = percent
NA = not analyzed

APPENDIX A

WATER QUALITY PARAMETERS
APRIL 14, 1999
RESULTS

Alameda West Lagoons
Alameda, California

				1 Foot from Surface						4 Feet from Surface			7 Feet from Surface		
Lagoon	Site	Date	Time	Fecal Coliform (cfu/100ml)	Total Coliform (cfu/100ml)	Fecal Streptococci (cfu/100ml)	Tempera-ture (C)	DO (mg/l)	% Oxygen Saturation	Tempera-ture (C)	DO (mg/l)	% Oxygen Saturation	Tempera-ture (C)	DO (mg/l)	% Oxygen Saturation
1	L-1A	4/14/99	13:47	<2	2	NA	16.3	12.11	128.4	15.3	11.11	111.3	NA	NA	NA
1	L-1B	4/14/99	13:21	NA	NA	NA	17.8	10.72	114.0	16.5	12.88	132.3	15.5	13.46	136.1
1	L-1C	4/14/99	13:03	NA	NA	NA	18.7	10.24	110.6	16.8	12.35	127.5	16.8	14.02	141.2
2	L-2	4/14/99	9:50	2	13	NA	16.0	6.72	69.0	17.4	6.88	70.9	18.0	6.84	72.5
3	L-3A	4/14/99	8:29	2	220	2	17.9	8.53	90.9	17.3	12.30	127.0	17.1	3.57	39.0
3	L-3B	4/14/99	8:51	2	2	<2	18.0	13.15	134.6	17.2	10.40	109.2	17.1	7.86	77.4
3	L-3C	4/14/99	9:07	<2	4	<2	18.1	10.91	117.3	17.4	11.70	110.8	NA	NA	NA
4	L-4	4/14/99	10:30	NA	NA	NA	16.2	12.89	125.6	17.7	13.67	142.1	NA	NA	NA
5	L-5A	4/14/99	11:57	NA	NA	NA	17.3	10.94	114.2	18.2	10.20	108.4	NA	NA	NA
5	L-5B	4/14/99	11:35	2	13	NA	17.5	9.79	101.7	17.7	7.83	83.7	17.8	9.2	87.7
5	L-5C	4/14/99	11:20	NA	NA	NA	17.8	8.37	89.3	17.6	10.58	111.9	NA	NA	NA

DO = dissolved oxygen
mg/l = milligrams per liter
C = degrees Celsius
ppt = parts per thousand
cfu = colony forming units
ml = milliliters
% = percent
NA = not analyzed

APPENDIX A

COLIFORM BACTERIAL RECORDS FROM ALAMEDA WEST LAGOONS HOMEOWNERS' ASSOCIATION

Alameda West Lagoons
Alameda, California

Sample Date	Inlet	Minipark	Outlet	Bay
1994				
4/4/94	1	6.4	3	NA
7/1/94	900	7	2	NA
8/2/94	110	3.8	3.8	NA
9/2/94	10	13	20	NA
10/6/94	96	8	188	NA
11/3/94	4	4	10	NA
12/1/94	3.8	3.7	8	NA
TOTAL	**1124.8**	**45.9**	**234.8**	**0**
AVERAGE	**160.7**	**6.6**	**33.5**	**0**
1995				
1/4/95	17	450	930	NA
2/2/95	3.8	42	31	NA
3/7/95	1	11	13	NA
4/4/95	1	6.4	3	NA
5/2/95	1	45	180	NA
7/12/95	4	14	3	NA
8/2/95	1	1	1	NA
9/5/95	1	1	1	NA
10/3/95	1	16	18	NA
11/3/95	200	200	200	NA
12/6/95	20	30	32	NA
12/21/95	1	NA	TNTC	NA
TOTAL	**251.8**	**816.4**	**1412**	**0**
AVERAGE	**21.0**	**68.0**	**117.7**	**0**

APPENDIX A

COLIFORM BACTERIAL RECORDS FROM ALAMEDA WEST LAGOONS HOMEOWNERS' ASSOCIATION

Alameda West Lagoons
Alameda, California

Sample Date	Inlet	Minipark	Outlet	Bay
1996				
1/4/96	1	TNTC	TNTC	NA
1/18/96	0	120	140	NA
2/1/96	0	CG	CG	NA
2/22/96	23	CG	CG	NA
3/5/96	170	300	240	NA
4/3/96	8	900	500	NA
5/1/96	2	2	2	NA
6/6/96	170	23	80	NA
7/22/96	220	70	20	NA
8/15/96	30	23	50	NA
9/16/96	23	13	500	NA
10/4/96	23	110	110	NA
11/18/96	17	30	1600	NA
12/13/96	1600	1600	1600	NA
TOTAL	**2287**	**3191**	**4842**	**0**
AVERAGE	**163.4**	**227.9**	**345.9**	**0**

GEOMATRIX

APPENDIX B

Monitoring and Data Collection Forms

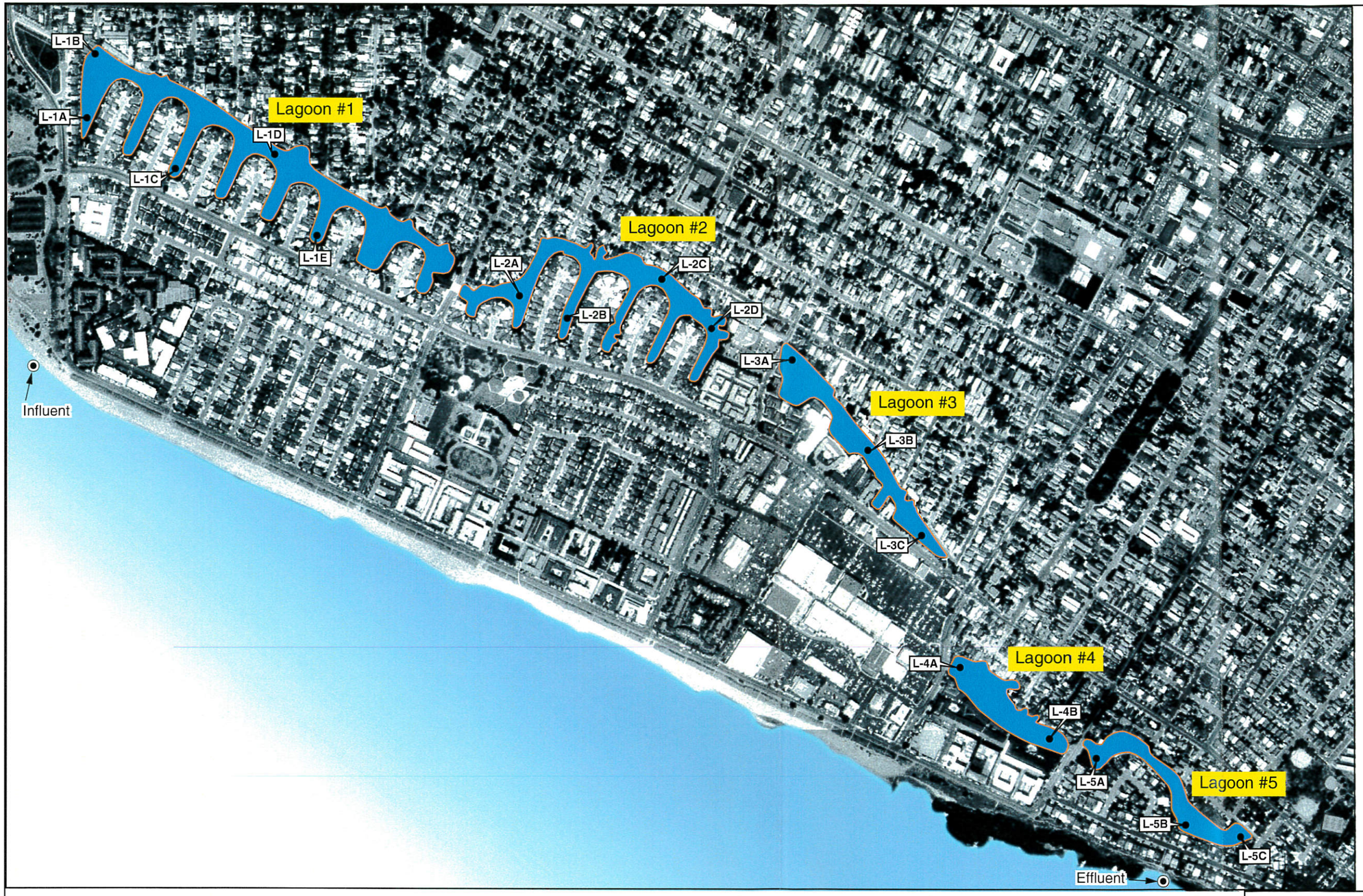
GEOMATRIX

SUMMARY OF FIELD OBSERVATIONS

Date: _____

Alameda West Lagoons
Alameda, California

Location	Floating/ Suspended Matter	Color	Odor	Other	Meteorological Observations		
					Air Temperature (°C)	Wind Speed (mph)	Sky Conditions



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ALAMEDA WEST LAGOONS
Alameda, California

GEOMATRIX

Project No.	Figure
4593	2