Machado Lake Nutrients TMDL
Lake Water Quality Management Plan

FINAL

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Prepared for:

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Acronyms

µg/L	micrograms per liter
AOC	Administrative Oversight Committee
Basin Plan	Los Angeles Region Basin Plan for the Coastal Watersheds of Los Angeles and Ventura Counties
BMP	Best Management Practice
BOE	Bureau of Engineering
BOS	Bureau of Sanitation
Caltrans	California Department of Transportation
CDFG	California Department of Fish and Game
CDS®	Continuous Deflection Separation
cfs	cubic feet per second
City	City of Los Angeles
COAC	Citizens Oversight Advisory Committee
COC	chain-of-custody
County	County of Los Angeles
CSTR	continuously stirred tank reactor
CWA	Clean Water Act
DDT	dichlorodiphenyltrichloroethane
DO	dissolved oxygen
ELAP	Environmental Laboratory Approval Program
EMC	Event Mean Concentrations
EMD	Environmental Monitoring Division
ET	evapotranspiration
FOMA	Ferric Oxide Media Adsorption
HDSFR	high density single family residential
ICSD	Information Control Systems Division
KMHRP	Ken Malloy Harbor Regional Park
LA	Load Allocation
LACDPW	Los Angeles County Department of Public Works
LACFCD	Los Angeles County Flood Control District
LIMS	Laboratory Information Management System
LWQMP	Machado Lake Water Quality Management Plan
MF/RO	microfiltration/reverse osmosis
MFR	multi-family residential
mg/L	milligrams per liter
MOA	Memorandum of Agreement
MRP	Monitoring and Reporting Plan
MS4	Municipal Separate Storm Sewer System
MSDS	Material Safety Data Sheets
msl	mean sea level

NPDES	National Pollutant Discharge Elimination System
PCB	polychlorinated biphenyls
PCH	Pacific Coast Highway
PPE	personal protective equipment
PVC	polyvinyl chloride
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
RAP	City of Los Angeles, Department of Recreation and Parks
Regional Board	Los Angeles Regional Water Quality Control Board
SAA	Streambed Alteration Agreement
SEA	Significant Ecological Area
SOPS	Standard Operating Procedures
State Board	California State Water Resources Control Board
SUSMP	Standard Urban Stormwater Mitigation Plan
SWAMP	Surface Water Ambient Monitoring Program
TDS	total dissolved solids
TIN	total inorganic nitrogen
TIWRP	Terminal Island Water Reclamation Facility
TMDL	total maximum daily load
TSS	total suspended solids
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
WI DNR	Wisconsin Department of Natural Resources
WISARD	Wastewater Information System and Analytical Research Database
WLA	Waste Load Allocation
WPD	Watershed Protection Division

Section 1
Regulatory Background

1.1 Introduction

The Machado Lake Nutrients Total Maximum Daily Load (Nutrients TMDL) which was developed by the Los Angeles Regional Water Quality Control Board (Regional Board) and became effective on March 11, 2009, establishes numeric targets, load allocations (LAs), waste load allocations (WLAs), and an implementation schedule that set forth the compliance requirements of the Nutrients TMDL. The LA establishes a limit for the amount of each pollutant that can enter the lake from nonpoint sources. Nonpoint sources include nutrients entering Machado Lake from runoff flowing directly from Ken Malloy Harbor Regional Park (KMHRP), atmospheric deposition, and nutrients generated from internal nutrient loading in the lake itself. The other component of the TMDL is the WLA. The WLA establishes a limit for the amount of each pollutant that can enter the lake from point sources, which includes storm drain discharges. A complete set of supporting documentation for the *Total Maximum Daily Load for Eutrophic, Algae, Ammonia, and Odors (Nutrients) in Machado Lake* can be viewed at: http://www.waterboards.ca.gov/losangeles/board_decisions/basin_plan_amendments/technical_documents/bpa_64_2008-006_td.shtml .

The Nutrients TMDL states that responsible jurisdictions can either jointly prepare a Lake Water Quality Management Plan (LWQMP) with the party responsible for the lake, or responsible jurisdictions can separately prepare TMDL Implementation Plans to illustrate compliance with their WLAs as measured in the storm drains. This distribution of water quality management responsibility is outlined in *Attachment A to Resolution No. R08-006* of the Los Angeles Region Basin Plan Amendment, which states that:

> "*Stormwater Permittees and the responsible party for the lake may work together to implement the LWQMP and reduce external nutrient loading to attain the TMDL waste load allocations measured in the lake.*"

In the Nutrients TMDL, responsible jurisdictions are identified for meeting LAs and WLAs. For Machado Lake, meeting the WLA is the responsibility of the following jurisdictions: the Municipal Separate Storm Sewer System (MS4) Permittees (including Los Angeles County; Los Angeles County Flood Control District (LACFCD); the cities of Carson, Lomita, Los Angeles, Palos Verdes Estates, Rancho Palos Verdes, Redondo Beach, Rolling Hills, Rolling Hills Estates, and Torrance); California Department of Transportation (Caltrans); and the National Pollutant Discharge Elimination System (NPDES) General Construction and Industrial Stormwater Permittees. Meeting the LA is the responsibility of the City of Los Angeles Department of Recreation and Parks.

This Machado Lake LWQMP has been prepared by two of the listed responsible agencies—the City of Los Angeles (City), Department of Recreation and Parks (RAP) and the City of Los Angeles Department of Public Works, Bureau of Sanitation (BOS).

The City has jurisdiction over 13 percent of the Machado Lake watershed. Therefore, the City acknowledges that compliance with the Nutrients TMDL depends on the cumulative reductions achieved through the commitments of the City and other responsible jurisdictions upstream of Machado Lake. This LWQMP has been prepared to summarize the best management practices (BMPs), specific monitoring program, and reporting requirements that the City will implement to demonstrate compliance within its portion of the Machado Lake watershed.

The assumption has been made that the other responsible jurisdictions will independently be in compliance with the WLAs, as required by the TMDL. The other responsible jurisdictions are required to prepare and submit separate TMDL Implementation Plans.

1.2 Objectives

The implementation of this LWQMP will achieve multiple objectives shared by the City and the Regional Board in their joint efforts to fulfill their responsibilities associated with improving water quality and enhancing the overall health of Machado Lake and the surrounding ecosystem. These objectives, which are defined to address the City's portion of the requirements under the Nutrients TMDL include:

1. Restore and maintain the beneficial uses of Machado Lake.

2. Attain the City's commitment to interim and final LAs and WLAs of the Nutrients TMDL.

3. Remove Machado Lake from the California Clean Water Act (CWA) §303(d) List on or before September 11, 2018.

4. Establish the tactical plan and implementation schedule between the City and the Regional Board for all implementation actions aimed at nutrient reductions within the portion of the Machado Lake watershed under the jurisdiction of the City.

5. Satisfy the requirements of Regional Board Resolution No. 2008-006 and the Water Quality Control Policy for Addressing Impaired Waters: Regulatory Structure and Options (State Board Resolution 2005-0050) section 2 (c) (ii).

6. Implement an effective, long-term monitoring program that provides the data necessary to demonstrate compliance with numeric targets and provides sufficient data to identify when changes to implementation are necessary.

1.3 Regulatory Requirements

The purpose of this section is to summarize the regulatory requirements that drive the legal and technical underpinnings of the LWQMP. Regulatory requirements include a discussion of the regulatory background, adopted beneficial uses, and TMDL requirements. The detailed discussion on the components of the Nutrients TMDL can be found in Section 1.4.

1.3.1 General

In California, water quality management programs are governed by the federal CWA and the State of California Porter-Cologne Water Quality Control Act. The regulatory hierarchy is illustrated in Figure 1-1.

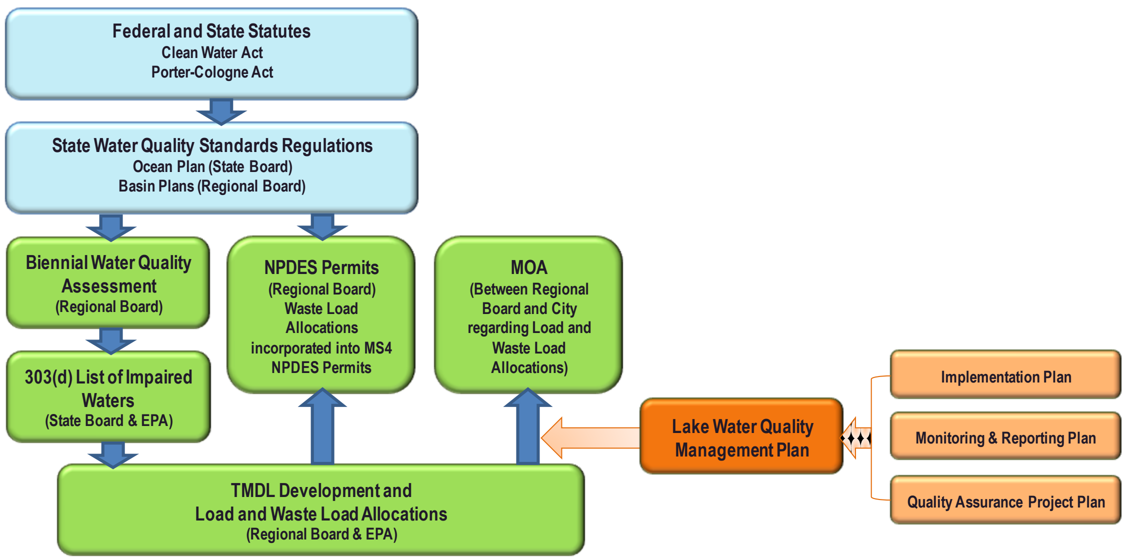


Figure 1-1
Regulatory Framework

The CWA provides the basis for the protection of all inland surface waters, estuaries, and coastal waters. The U.S. Environmental Protection Agency (USEPA) is responsible for ensuring the implementation of the CWA and its governing regulations. Authority for implementing the CWA has been delegated to the State of California. The state, at its own discretion, has in many instances established requirements that are more stringent than federal requirements.

California's primary statute governing water quality is the Porter-Cologne Water Quality Control Act of 1970 (Porter-Cologne Act). The Porter-Cologne Act grants the California State Water Resources Control Board (State Board) and nine California Regional Water Quality Control Boards broad powers to protect water quality and is the primary vehicle for implementation of California's responsibilities under the CWA. The governing regional board for the Los Angeles area watersheds is the Los Angeles Regional Water Quality Control Board. Through a formal rule-making process, the Regional Board has adopted surface water quality standards that establish the beneficial uses, numeric and narrative water quality criteria or objectives used to protect those uses, and an antidegradation policy. These water quality standards become a part of each region's Basin Plan, which locally is the *Los Angeles Region Basin Plan for the Coastal Watersheds of Los Angeles and Ventura Counties* (Basin Plan 1994, as amended).

The CWA further requires entities that discharge to waters of the United States to receive a permit to do so as part of the NPDES permit program, and it is through this permitting program, which is regulated locally by the Regional Board, that water quality requirements are enforced. NPDES permitting requirements state that among other dischargers, any MS4 must also hold an NPDES permit. A municipal MS4 is essentially a municipality owned and operated network of storm drains that are not combined with sanitary sewers, which drain to a receiving waterbody rather than a wastewater treatment plant. The City's storm drains are within the area covered by the County of Los Angeles (County) MS4 NPDES permit, which lists the County and 84 cities (all of the cities in the County with the exception of Long Beach) as the Permittees. This permit allows these agencies to discharge storm water to inland waterbodies and ultimately the Pacific Ocean. The permit was first issued in 1990 (Order No. 90-079) and was designed to prevent pollutants from being directly discharged into the MS4 or from being washed by runoff into the MS4 and subsequently discharged into local waterbodies. The most recent MS4 permit renewal was in December 2001 (Order No. R4-01-182). The Permit has a normal 5-year renewal cycle but re-issuance has been deferred pending the outcome of the re-issuance of the Ventura County Permit by the Regional Board. In the interim period pending a full re-issuance, the Permit has been amended several times to incorporate requirements from adopted TMDLs such as the Machado Lake TMDL and various other specific issues.

1.3.2 Beneficial Uses and Section 303d List of Impaired Waterbodies

The establishment of "beneficial uses" and the periodic evaluation of these uses are two fundamental programmatic requirements of the CWA that are used by the Regional Board and USEPA to evaluate water quality statewide.

Beneficial Uses

The Regional Board designates specific "beneficial uses" for each waterbody in a watershed. These uses are protected by the establishment of specific numeric or narrative criteria or water quality objectives. For example, waterbodies designated for water contact recreation (REC-1) have applicable bacterial water quality objectives to protect the health of swimmers from risks associated with ingestion of water.

The Regional Board established beneficial uses (see Table 1-1) for Machado Lake, which was formerly known as Bixby Slough and Harbor Lake, in the Basin Plan. The Basin Plan does not identify beneficial uses specifically for Wilmington Drain. Although no uses have been designated for the Drain, the CWA and state law require that discharges from Wilmington Drain to Machado Lake not cause a violation of the lake's water quality objectives.

Table 1-1
Beneficial Uses Identified for Machado Lake[1]

Use Category	Beneficial Use (Abbreviation)	Definition
Existing Uses		
Recreation Uses	Water Contact Recreation (REC-1)	Uses of water for recreational activities involving body contact with water, where ingestion of water is reasonably possible. These uses include, but are not limited to, swimming, wading, water-skiing, skin and scuba diving, surfing, white water activities, fishing, or use of natural hot springs
	Non-Contact Water Recreation (REC-2)	Uses of water for recreational activities involving proximity to water, but not normally involving body contact with water, where ingestion of water is reasonably possible. These uses include, but are not limited to, picnicking, sunbathing, hiking, beachcombing, camping, boating, tide-pool and marine life study, hunting, sightseeing, or aesthetic enjoyment in conjunction with the above activities.
Habitat Related Uses	Wetland Habitat (WET)	Uses of water that support wetland ecosystems, including, but not limited to, preservation or enhancement of wetland habitats, vegetation, fish, shellfish, or wildlife, and other unique wetland functions which enhance water quality, such as providing flood and erosion control, stream bank stabilization, and filtration and purification of naturally occurring contaminants.
	Wildlife Habitat (WILD)	Uses of water that support terrestrial ecosystems including, but not limited to, preservation and enhancement of terrestrial habitats, vegetation, wildlife (e.g., mammals, birds, reptiles, amphibians, invertebrates), or wildlife water and food sources.
	Rare, Threatened, or Endangered Species (RARE)	Uses of water that support habitats necessary, at least in part, for the survival and successful maintenance of plant or animal species established under state or federal law as rare, threatened, or endangered.
	Warm Freshwater Habitat (WARM)	Uses of water that support warm water ecosystems including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates.
Potential Uses		
Municipal Supply	Municipal and Domestic Supply (MUN)	Uses of water for community, military, or individual water supply systems including, but not limited to, drinking water supply.

Notes:
[1] Source: Los Angeles Region Basin Plan for the Coastal Watersheds of Los Angeles and Ventura Counties" (Basin Plan 1994, as amended)
[2] Machado Lake is listed in the Basin Plan as Bixby Slough and Harbor Lake.

303(d) List of Impaired Waters

Section 303(d) of the CWA requires states to identify waterbodies not supporting their beneficial uses even after all required effluent limitations have been implemented (e.g., through a discharge permit) [see Figure 1-1]. These waters are often referred to as "303(d) listed" or "impaired" waters. Water bodies that are on the §303(d) list require the development of TMDLs. The USEPA-approved §303(d) list for California was most recently updated in 2006. Both Machado Lake and Wilmington Drain are listed on the 2006 California §303(d) list of impaired water bodies. Table 1-2 presents the current §303(d) listings for Machado Lake and Wilmington Drain based on the 2008 California §303(d) list of impaired water bodies (Regional Board 2009). Once a TMDL is developed, for a specific pollutant that pollutant is removed from the 303(d) list of impairments.

Table 1-2
Current 303(d) Listings for Machado Lake and Wilmington Drain

Water body	Pollutant / Stressor	TMDL Adoption
Machado Lake	Trash	March 2008
Machado Lake	Algae, ammonia, eutrophic, odor Chlordane, DDT, dieldrin, PCBs	March 2009 Under Development
Wilmington Drain	Coliform bacteria, copper, lead	To be determined

Source: State Board 2008 303(d) list:
http://www.swrcb.ca.gov/rwqcb4/water_issues/programs/303d/2008_integrated_report_303(d)_list.shtml

With respect to the specific remaining listings for Wilmington Drain (bacteria and metals), it is anticipated that when the Regional Board initiates development and adoption of TMDLs for these constituents, the emphasis for reduction and implementation will be targeted at the watersheds upstream rather than in the lower reach of the drain itself since it is the waterbody that requires protection. The Dominguez Watershed Master Plan prepared for Los Angeles County Department of Public Works (LACDPW) and the cities in the watershed was adopted in 2004. The plan identified a wide range of projects and activities through the watershed including the Wilmington Drain/Machado Lake portion of the watershed that will help address these listings.

Also, a TMDL for trash has been approved by USEPA (March 6, 2008 effective date) and a TMDL for chlordane, dichlorodiphenyltrichloroethane (DDT), dieldrin, and polychlorinated biphenyls (PCBs) is being developed for Machado Lake (no draft issued to date).

1.3.3 Nutrients TMDL Development

All waterbodies on the §303(d) list are subject to the development of a TMDL for the constituents listed (Figure 1-1). A TMDL establishes the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards. Depending on the nature of the pollutant, TMDL implementation requires a reduction of pollutant contributions from point sources (WLAs), nonpoint sources (LAs), or both.

The development of TMDLs affecting waters in the Los Angeles area watersheds is the responsibility of the Regional Board. Adoption of a TMDL requires an amendment to the Basin Plan and is subject to a substantial public review process. After the Regional Board adopts a TMDL as a Basin Plan amendment, it is submitted to the State Board for approval. Once the State Board approves a TMDL, it is submitted to USEPA Region 9 for final review and federal approval. A TMDL is not in effect until USEPA has issued its formal approval.

Once a TMDL is established, the numeric limits and LAs or WLAs become part of the Basin Plan. The following subsections describe the process that resulted in the establishment of the Nutrients TMDL.

Regulatory Components of the Nutrients TMDL

The Regional Board developed the Nutrients TMDL for Machado Lake in accordance with the TMDL schedule dictated in the consent decree (Heal the Bay Inc., et al. v. Browner C 98-4825 SBA) approved on March 22, 1999. The Regional Board amended the Basin Plan to incorporate the Nutrients TMDL, which was adopted on May 1, 2008 and approved by the State Board on December 2, 2008. The Nutrients TMDL became effective with USEPA approval on March 11, 2009 (see http://63.199.216.6/larwqcb_new/bpa/docs/2008-006/2008-006_RB_BPA.pdf).

The Basin Plan amendment that incorporated the Nutrients TMDL is enforceable through the MS4 NPDES permit, which is the permit used to enforce water quality in discharges from the storm drains. City of Los Angeles storm drain discharges are managed by the BOS. Since the Nutrients TMDL also includes the RAP, as a responsible jurisdiction, an entity not specifically regulated under the NPDES permit, a Memorandum of Agreement (MOA) was developed between the City and the Regional Board in April 2010 to include RAP, consistent with the requirements of the Nutrient TMDL. The MOA, which is included in Appendix A, and the Nutrients TMDL, stipulate the requirements for the City to prepare and submit to the Regional Board this LWQMP for review and approval. The following section describes the specific requirements of the Nutrients TMDL.

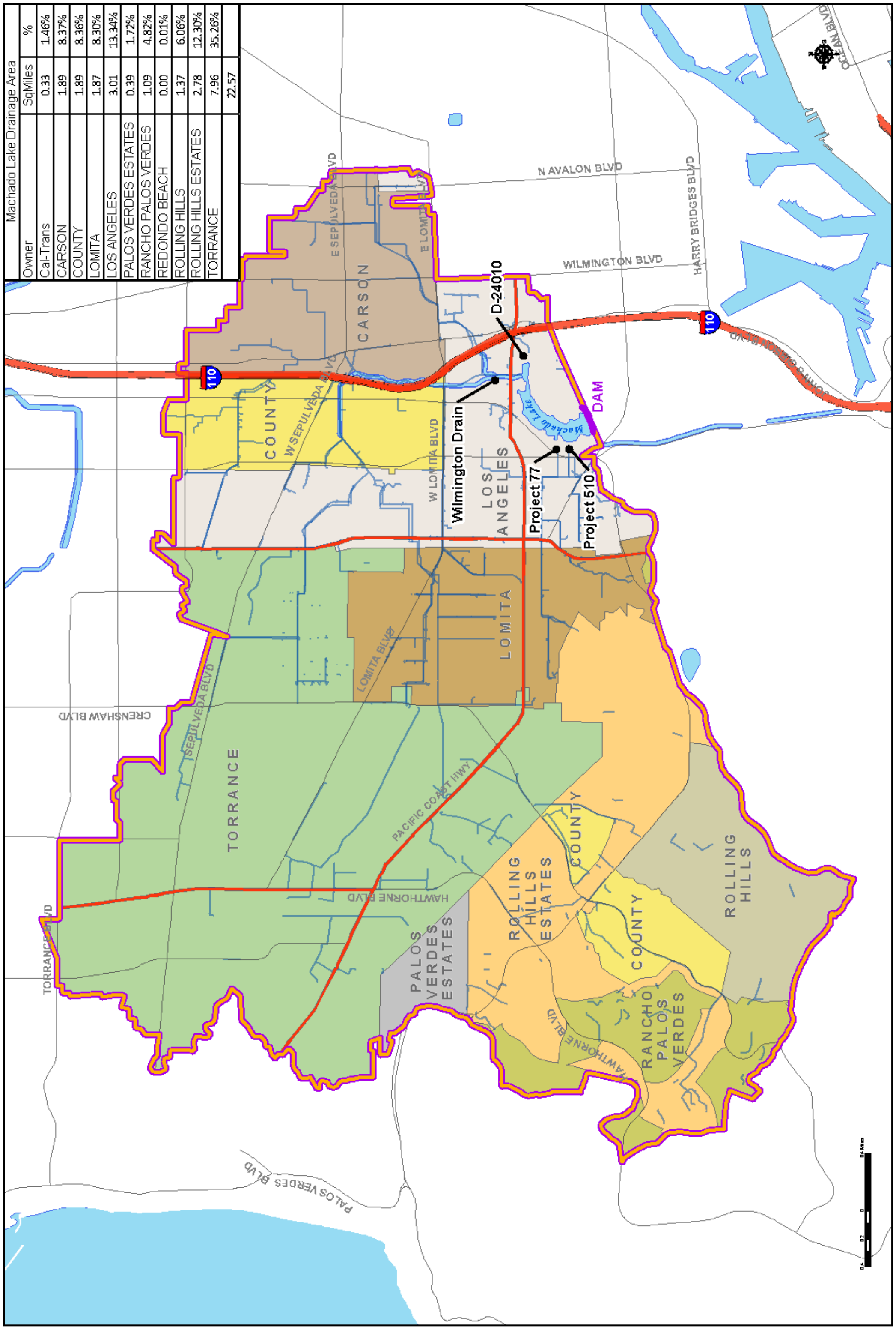
1.4 Machado Lake Nutrients TMDL Components

Nutrient impairment in Machado Lake is a factor of both external pollutant loading and internal nutrient cycling, described as follows:

- **External Loading:** Phosphorus and nitrogen are introduced to the lake through urban runoff when the runoff transports nutrients and other contaminants to the lake. Atmospheric deposition is also a nonpoint source of total nitrogen and phosphorus. External loading is a product of nutrient sources predominantly from permitted urban runoff discharges delivered from an approximately 22.6-square-mile (14,444-acre) watershed draining into the lake (see Figure 1-2). A small percentage of external pollutant loading originates from the park areas directly surrounding Machado Lake, which is considered non-permitted stormwater or a nonpoint source of pollution.

- **Internal Loading:** When oxygen is depleted at the sediment/water interface, anoxic conditions occur. Under these conditions, phosphorus and nitrogen can disassociate from the nutrient-rich sediment on the bottom of the lake and diffuse upward into the water column (James 2006), which contributes to algae growth and increased chlorophyll *a* concentrations (Wisconsin Department of Natural Resources [WI DNR] 2003). When oxygen levels are sufficiently high (i.e., greater than 2.0 milligrams per liter [mg/L]), phosphorus typically remains bound to the sediment.

Using existing available data, the Regional Board initiated the Nutrients TMDL in 2007 and selected the use of a steady-state Nutrient Numeric Endpoints BATHTUB spreadsheet tool as the modeling method for estimating nutrient loadings and establishing pollutant load and waste load allocations. Storm drain discharges (point sources) are required to meet the WLAs defined in the Nutrients TMDL, while the internal nutrient loading and nonpoint sources (specifically runoff from KMHRP) must meet the LAs defined in the Nutrients TMDL.



Machado Lake Drainage Area

Owner	SqMiles	%
Cal-Trans	0.33	1.46%
CARSON	1.89	8.37%
COUNTY	1.89	8.36%
LOMITA	1.87	8.30%
LOS ANGELES	3.01	13.34%
PALOS VERDES ESTATES	0.39	1.72%
RANCHO PALOS VERDES	1.09	4.82%
REDONDO BEACH	0.00	0.01%
ROLLING HILLS	1.37	6.06%
ROLLING HILLS ESTATES	2.78	12.30%
TORRANCE	7.96	35.26%
	22.57	

Figure 1-2
Machado Lake Watershed
Source: Machado Lake Nutrients TMDL Reference Guide

1.4.1 Numeric Targets

Adoption of TMDLs provides a formal process for setting numeric targets to ensure protection of all beneficial uses of surface waterbodies. The Machado Lake Nutrients TMDL established specific numeric targets to restore and maintain the beneficial uses assigned by the Regional Board under the Habitat Related Uses category. Table 1-3 summarizes the numeric targets, documented in the Nutrients TMDL. The use of multiple water quality targets for Machado Lake establishes a conservative approach for improving lake water quality and provides additional key indicators to track the symptoms of eutrophication.

Table 1-3
Numeric Targets for Nutrients TMDL

Indicator	Numeric Target
Total Phosphorus	0.1 mg/L monthly average
Total Nitrogen	1.0 mg/L monthly average
Ammonia	5.95 mg/L one hour average
Ammonia	2.15 mg/L 30 day average
Dissolved Oxygen	5 mg/L single sample minimum measured 0.3 meters above the sediments
Chlorophyll-*a*	20 µg/L monthly average

Source: Regional Board *Attachment A to Resolution No. R08-006*, Amendment to the Water Quality Control Plan Los Angeles Region.

The Basin Plan Amendment documents that these impairments are caused by excessive loading of nutrients, including nitrogen and phosphorus in Machado Lake. Ammonia concentrations were found to be below toxicity levels, but still contributed to the total nitrogen loading.

1.4.2 Waste Load Allocations

As previously discussed, the Nutrients TMDL assigned WLAs to point sources that include the MS4 permitted stormwater discharges, Caltrans, and general construction and industrial discharges. Since there is no wastewater effluent discharged directly into Wilmington Drain or Machado Lake, the entire WLA, comprised of permitted stormwater, is incorporated into the applicable NPDES MS4 permits covering the Machado Lake watershed.

The Nutrients TMDL includes two interim compliance milestones in addition to the final compliance date. Table 1-4 summarizes the WLAs and associated interim and final compliance dates. The WLAs are expressed as concentrations of nutrients. The product of these concentrations and the annual average runoff volumes provides an equivalent estimate of allocated mass loads.

Table 1-4
Interim and Final Waste Load Allocations for Total Phosphorus and Total Nitrogen

Waste Load Allocations	Compliance Date	Interim Total Phosphorus WLAs (mg/L)	Interim Total Nitrogen[2] WLAs (mg/L)
MS4 Permittees[1], Caltrans, General Construction and Industrial Stormwater permits	Interim - March 11, 2009	1.25	3.50
	2nd Interim – March 11, 2014	1.25	2.45
	Final – September 11, 2018[3]	0.10	1.00

Source: Regional Board Attachment A to Resolution No. R08-006, Amendment to the Water Quality Control Plan Los Angeles Region.

Notes:
1 MS4 Permittees that are responsible for discharges to Machado Lake include: Los Angeles County, Los Angeles County Flood Control District, and the Cities of Carson, Lomita, Los Angeles, Palos Verdes Estates, Rancho Palos Verdes, Redondo Beach, Rolling Hills, Rolling Hills Estates, and Torrance.
2 Total nitrogen is TKN + NO_3-N + NO_2-N
3 The compliance point for all year 5 interim and final WLAs is measured as specified in Implementation Plan Section II of the Basin Plan Amendment Table 7-29-1 of the Machado Lake Nutrients TMDL Staff Report, 2008.

1.4.3 Load Allocations

LAs are defined as the portion of a receiving water's loading capacity that is attributed to existing or future nonpoint sources of pollution or to natural background sources (State Board 2005). Therefore, LAs in TMDLs are assigned to mitigate nonpoint sources of pollution. LAs can range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading. The primary nonpoint sources of nutrients to Machado Lake are sediment loading originating from storm drains including Wilmington Drain, internal nutrient loading from lake bottom sediments, atmospheric deposition, birds, wind re-suspension, bioturbation, and general surface runoff from KMHRP. Recreational and maintenance activities associated with the lake and KMHRP are the responsibility of RAP. Table 1-5 provides the LA established by the Nutrients TMDL.

Table 1-5
Interim and Final Load Allocations for Total Phosphorus and Total Nitrogen

Load Allocations	Compliance Date	Interim Total Phosphorus WLAs (mg/L)	Interim Total Nitrogen[1] WLAs (mg/L)
Nonpoint Source Nutrient Load (City of Los Angeles Department of Recreation and Parks)	Interim - March 11, 2009	1.25	3.50
	2nd Interim – March 11, 2014	1.25	2.45
	Final – September 11, 2018	0.10	1.00

Source: Regional Board *Attachment A to Resolution No. R08-006*, Amendment to the Water Quality Control Plan Los Angeles Region.

Notes:
1 Total nitrogen is TKN + NO_3-N + NO_2-N.

1.4.4 Summary of Compliance Dates

Table 1-6 summarizes the compliance dates associated with the Nutrients TMDL.

Table 1-6
Compliance Deadlines for Load Allocation Requirements of the Nutrients TMDL

Compliance Date	TMDL Requirement
March 11, 2009	Meet 1st interim WLAs and LAs (see Table 1-4 and 1-5)
March 11, 2010	Enter into an MOA with the Regional Board to implement WLAs and LAs[1].
Sept. 11, 2010	Submit LWQMP to the Regional Board for approval.
60 days from date of LWQMP approval	Begin monitoring and implementation as outlined in the MRP section of the LWQMP.
Annually from date of LWQMP approval	Submit annual monitoring reports.
March 11, 2014	Meet 2nd interim LAs (see Tables 1-4 and 1-5)
Sept. 11, 2016	TMDL re-opener period.
Sept. 11, 2018	Meet final LAs and numeric targets (see Table 1-4 and 1-5)

Source: Regional Board *Attachment A to Resolution No. R08-006*.

Note 1: The City of Los Angeles Department of Recreation and Parks is required to enter into the MOA as it is not regulated under the MS4 NPDES permit and the MOA will serve as the agreement to meet the TMDL load allocation requirements. However, since the City of Los Angeles Department of Public Works must meet the WLA, the two departments have jointly entered into the MOA with the Regional Board effective April 7, 2010 (Appendix A) and have collaborated in the preparation of this LWQMP.

1.4.5 Wasteload and Load Allocation Implementation

Compliance with the WLA, LA, and nutrient targets will require the implementation of BMPs that reduce external loadings to Machado Lake and reduce in-lake concentrations of nutrients. A variety of BMPs to address external and internal nutrient loading were identified in the Nutrient TMDL, which along with other BMPs were evaluated during the preliminary design phase of the *Machado Lake Ecosystem Rehabilitation and Wilmington Drain Multi-Use Project.* The recommended BMPs summarized in Section 3 of this LWQMP are being implemented to restore water quality and improve the health of Machado Lake. This LWQMP is the summary of the action items and commitments that will be implemented to achieve compliance with the Nutrients TMDL.

1.5 Components of the LWQMP

Based on the regulatory requirements described previously, the Machado Lake LWQMP is organized to meet the elements stipulated by the Regional Board in the MOA and the Nutrients TMDL. The LWQMP includes the following components:

- Implementation Plan and Compliance Analysis
- Monitoring and Reporting Plan (MRP)
- Quality Assurance Project Plan (QAPP)

Collectively, Sections 1 through 6 and the Appendices in this LWQMP provide a detailed plan describing the commitments and management strategies necessary to attain the interim and final LAs and WLAs set forth in the Nutrients TMDL. This LWQMP focuses only on the portion of the Machado Lake watershed within the City's jurisdiction. This LWQMP addresses both point and nonpoint sources contributing to nutrient loading in

Machado Lake. The LWQMP also provides a summary of how existing data and a lake water quality model are used to demonstrate compliance over time with the water quality targets and a compliance schedule set forth in the Nutrients TMDL.

1.5.1 Implementation Plan and Compliance Analysis

The implementation plan presented in Section 3 of this LWQMP describes the integration of actions and strategies that the City will take towards meeting the objectives and requirements of the Nutrients TMDL and other local, regional, and federal water quality management programs. The compliance analysis presented in Section 5 provides a summary of how existing data and a lake water quality model are used to demonstrate the City's compliance with its portion of the LAs and WLAs of the Nutrients TMDL. Other programs that are advanced through the implementation of this LWQMP include the California Nonpoint Source Management Program, the rules and regulations administered by the California Department of Fish and Game (CDFG), and the City of Los Angeles Watershed Protection Division's Water Quality Compliance Master Plan for Urban Runoff (May 2009), as well as actions by other MS4 Permittees in the watershed.

1.5.2 Monitoring and Reporting Plan

Section 4 of this LWQMP provides a MRP, which is the City's strategic approach for collecting data and information to evaluate, summarize, and report on the monitoring results, changes in water quality, and progress toward achieving interim and final LAs and WLAs for Machado Lake. Other responsible agencies are responsible for preparation of separate MRPs for their portion of the watershed. The MRP, developed in accordance with California's Surface Water Ambient Monitoring Program (SWAMP) guidance, defines the City's monitoring program commitments necessary to meet the requirements stipulated in the Nutrients TMDL. To achieve these monitoring requirements, the MRP includes well defined data quality objectives that are critical to ensure appropriate data are collected to demonstrate compliance with interim and long-term nutrient targets as measured in the lake. The MRP also outlines the health and safety principles the City adheres to in conducting business to protect the well being of its employees.

1.5.3 Quality Assurance Project Plan

As required by the MOA, and in accordance with the City's comprehensive water quality monitoring program, a QAPP is provided in Appendix B. The QAPP includes the protocols for sample collection, standard analytical procedures, laboratory certification, and corrective action measures all of which adhere to the California SWAMP guidance. The purpose of the QAPP is to ensure that data quality objectives are met and the monitoring program produces consistent, reliable data that meet the project's overall goals. The QAPP is necessary to effectively implement the MRP found in Section 4.

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Section 2
Watershed Characteristics and Baseline Conditions for Water Quality Modeling

This section serves to illustrate the existing conditions within Machado Lake and the upstream watershed. These baseline conditions form the foundation from which improvements to the lake are based.

Described here are the watershed's current and historic conditions, followed by a summary of the baseline water quality from the upstream watershed as well as the water quality in the lake. Based upon these baseline conditions in the lake and watershed, a Lake Water Quality Model was developed to evaluate the effectiveness of various BMPs (which are described in Section 3) at reducing nutrient concentrations in the lake. The Lake Water Quality Model is summarized in Section 2.3.3 and Appendix C. Future BMPs are described in Section 3.

2.1 Watershed Description

Wilmington Drain accounts for approximately 88 percent of the portion of the Machado Lake subwatershed that drains to the lake. The remaining 12 percent comes from five additional storm drains, of which Project 77 has the largest drainage area, and sheet flow from the KMHRP that surrounds Machado Lake. After the runoff passes through Machado Lake and the downstream Freshwater Marsh, it flows directly to the West Basin of the Los Angeles Harbor.

The Machado Lake and Wilmington Drain ecosystem, which includes Machado Lake, KMHRP, and the half-mile long soft bottom section of Wilmington Drain between Pacific Coast Highway (PCH) and the I-110 freeway, is one of the largest remaining coastal wetland ecosystems in Southern California (CDM and Parsons 2008). The KMHRP, a 291-acre park that is owned, operated, and maintained by the RAP, is located in the Wilmington and Harbor City communities of the City of Los Angeles, approximately 15 miles south of downtown Los Angeles. The Wilmington Drain section is located north of the lake in the Cities of Carson, Lomita, and Los Angeles and unincorporated Los Angeles County, and is operated by LACFCD.

Harbor Park Golf Course borders the northeast banks of Machado Lake and the Los Angeles Harbor College borders the Freshwater Marsh located south of Machado Lake. PCH and residential development borders KMHRP to the north, Vermont Avenue and a Kaiser Permanente facility borders KMHRP to the west, and Anaheim Street and Conoco-Phillips Oil Refinery are located to the south of the KMHRP (Figure 2-1). The dominant land use in the Machado Lake subwatershed is high density single family residential, which accounts for approximately 45 percent of the total land use (Regional Board 2008).

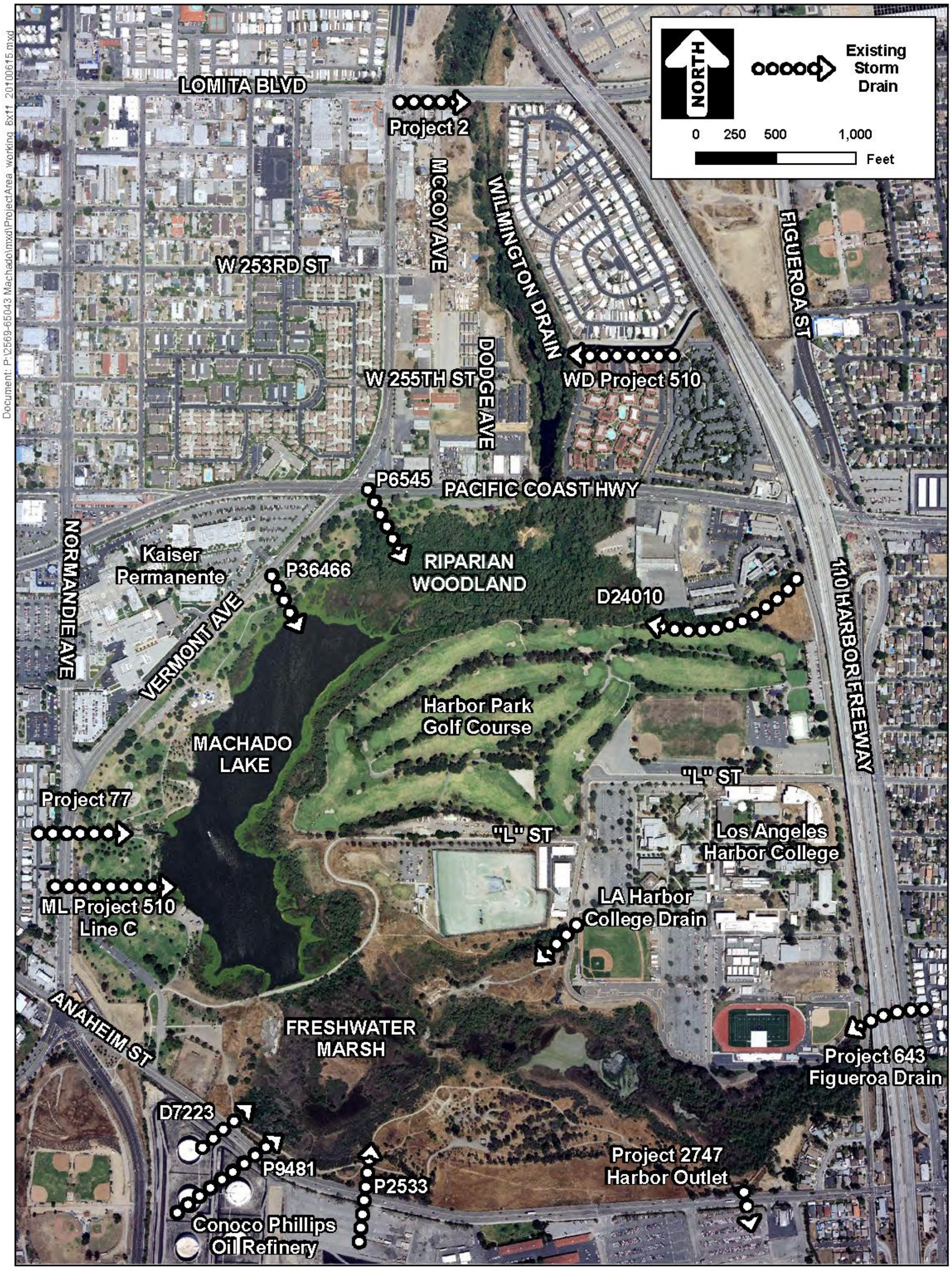

Figure 2-1
KMHRP and Wilmington Drain Location Map

2.1.1 Wilmington Drain

Wilmington Drain looking downstream from Lomita Boulevard

Wilmington Drain is a LACFCD facility managed by the LACDPW. It is characterized by an approximately 150-foot wide soft bottom channel, coastal sage scrub plant communities, non-native plants, urban litter, and riprap-filled gabions. From PCH to Lomita Boulevard, the Wilmington Drain is bordered on both sides by residential development. North of Lomita Boulevard, the western bank provides habitat for the endangered least Bell's Vireo and other native species, while north of I-110 the channel is concrete lined. Wilmington Drain collects stormwater runoff from a 19-square-mile watershed consisting of residential and industrial development. Wilmington Drain conveys stormwater to Machado Lake and also functions as a sedimentation basin.

2.1.2 Machado Lake and Ken Malloy Harbor Regional Park

KMHRP is one of the largest parks in the City, and has one of the most diverse habitats in the region, including the 40-acre Machado Lake, a 63-acre seasonal freshwater marsh, and a riparian woodland. Because of these resources KMHRP has been designated as a Significant Ecological Area (SEA) by Los Angeles County Regional Planning. To Harbor and South Bay residents, Machado Lake and the KMHRP are recreational and natural resources in the park-poor urban Harbor City area. They are a popular recreation destination for local residents who enjoy the picnic spaces, fishing, bird watching, and hiking.

KMHRP Open Space Park Area

Machado Lake was formed either as a small canyon at the mouth of a former path of the Los Angeles River and/or by land subsidence, possibly following an earthquake. It was first reported in its original characteristic horseshoe shape with two upper arms in 1873 and was shown as either a lake or wetland as early as 1784.

Machado Lake

In the 1920 to 1930 period the lake was partially de-watered to allow surface mining of drilling clay and used as a site of multiple oil well drilling platforms, which had numerous oil spills. During World War II the lake was a disposal site for Los Angeles harbor dredge spoils.

Above-average wet years caused the lake to expand north and south, causing flooding to highways as they were constructed near the lake in the 1930s and '40s. This resulted in construction of flood control structures in 1955 that lowered the average lake level as much as 5 feet. The earthen dam was designed to maintain the level of the lake at a maximum of 10 feet mean sea level (msl). During almost all but possibly very minor storm events, water flows over the dam into the lower basin and ultimately to the Harbor Outfall at the southeastern corner of the park, where it is discharged to the West Channel of the Los Angeles Harbor.

The upper quarter of the original lake was lost by 1964 due to a combination of lowered lake level, high rates of sediment inflow, and invasion by willows. It is now a riparian woodland. The lower section of the lake, below the dam was lost about the same time. Some of the original lake in this area remains as isolated pools and wetlands. The 40-acre remaining lake is thus shallower and smaller, perhaps about half of its original size.

Today Machado Lake has a very high ratio of watershed to lake surface area, at 389:1 acres. Typical watershed to lake ratios are less than 100:1. Ratios greater than 40:1, and certainly greater than 100:1, indicate eutrophic conditions (Horne & Goldman 1994).

Conversion of most of the watershed from open plains or farmland to urban conditions increased inflow so that the lake water residence time in winter falls to a very short 5 days, or 0.0014 years. This is a very low water residence time, since a typical water residence time for natural lakes is 3 to 100 years.

Eutrophication of Machado Lake and the accumulation of toxic sediment has damaged habitat, degraded water quality, and negatively impacted recreational uses such as boating. Warning signs about the dangers of eating fish from the lake are now posted. In the mid-1980's, a portion of the lake was dredged.

2.2 Historic Lake Conditions as Determined from Sediment Analysis

In 2009, a paleolimnological study was conducted to investigate the historic conditions at Machado Lake through analysis of sediment (Horne 2010). This section includes a summary of the results of this report related to sedimentation rates and the nutrients and algae grown in the lake.

Paleo-Dating of Core Samples

Sixteen samples were taken from two cores in Machado Lake in August 2009. Since the depth of the lake was not known, assuming a typical urban sedimentation rate of 0.5 inches per year (1 foot per 24 years), a 5-foot deep sample was expected to be 120 years old, which would have been a sufficiently aged sample that would be representative of a period of time prior to substantial development in the area. Based on the expected sedimentation rates, a core from the lake bed surface to about 12 feet deep was taken at one site in the northern part of the lake, which would presumably represent almost 300 years of sediment record. Another sediment core was taken in the central part of the lake to a depth of approximately 7 feet, but this location may have been affected by dredging in the mid 1980s.

The results of the paleo-dating show sedimentation rates, measured at the north and central sections of the current lake using the isotopes of lead (210Pb) and cesium (137Cs), were much more rapid than expected in both cores, especially the northern core. For this site the deepest sample at almost 12 feet was dated using 210Pb at only 66 years old, or from 1943. This date indicates an extremely high annual sedimentation rate of 2.1 inches/year (11.6 feet or 139.2 inches/66 years from 1943 to 2009). Thus sedimentation rates were over four times rates anticipated based on other studies on urban water bodies. For the central core, which although possibly dredged in the 1980s, the deepest core sample at 6.7 feet was dated by 208Pb at 1914. The preliminary sedimentation rate was thus a more typical 0.85 inches/year (6.7 feet or 80.4 inches/95 years). However, previous dredging activities may have affected this sample.

Further study of the samples indicated that the annual rates of sedimentation accumulation have been increasing in Machado Lake since 1914. The sedimentation at both Machado sites showed two periods—a high but not unexpected 0.6 inches/year at the central site and 1.9 inches/year at the northern site between 1914 or 1943 and approximately 1996, with rates greatly increasing over the last 12 years. The reason for this increase over is not clear but may be due to increased soil erosion and scouring in the storm drain channels as more water is discharged from developing urban land with more impervious surfaces.

Therefore, as shown, Machado Lake has had high sedimentation rates over the past 66 to 95 years, and rates have been increasing even more over the past 12 years.

Paleolimnology Study

Using the samples from the north section of Machado Lake, a paleolimnology study was also conducted (Horne, 2010). The purpose of the study was to determine if any changes in algae had occurred and if so, could the changes be attributed to increases in nutrients or other pollutants over the last 66 years (from 1943 to 2009).

The "fossil" remains of algae from these core samples were analyzed for species composition and abundance. Only diatoms with their glass-like silica frustules (cell walls or cases) are well preserved in sediment. Thirty-seven species of diatoms were found commonly (top 10 by abundance) out of a total of over 100 kinds. The most common were phytoplankton diatoms that grow in the open water but benthic forms that live in the mud were also present.

Surprisingly, given the large amount of development and drainage changes in this densely populated area, five centric (pill-box or barrel-shaped) diatoms species dominated the lake phytoplankton over the 66-year record. These species had in common an ability to tolerate a wide range of salinity (euryhaline) such as naturally occurred in the past and still occurs to some degree today (though limited by the dam). Looking at the abundance ranking of the five most common centric diatoms in Machado Lake sediments between 1943 and 2009 showed that no change in abundance is apparent.

The five most common diatoms formed two super-groups. Since the two super-groups dominated the phytoplankton for all of the 66 year record, it can be concluded that the waters of Machado Lake have been mesotrophic to eutrophic over this time and no change in trophic state can be determined from the kinds of algae present. The conclusion that can be made from this is that no change in trophic state has occurred since 1943. It is likely that such a small shallow lake with a large drainage basin and natural salinity stress would have few dominant species and ample nutrients even in 1700. To determine conditions prior to European settlement, deeper cores would be required. However, those conditions would not be comparable with current conditions since at that time Machado Lake was either part of the Los Angeles River, a fully tidal estuary or some combination of these alternatives.

Although many diatoms are indicators of trophic states, all of the members of super-groups 1 and 2 could be expected to be found in association with high nutrients due to their size. The individual cells and chains of all of super-groups 1 and 2 were quite large. Large cells have a smaller ratio of cell surface (where uptake of nutrients occurs) to cell volume (where nutrients are used to make biomass) than small algae. Although not all of the individual members of these first two groups are described specifically as being indicators of high nutrients or tolerant of pollution, they will normally be found in waters with relatively high nutrients. Machado Lake currently has high levels of most nutrients during the spring through fall growth season so the members of super-groups 1 and 2 were by definition at least tolerant of high nutrients.

A separate examination was done using a strict numerical ranking, which unlike the ranking of the top few species (described above as super-groups) where individuals were almost always in the top 10 (species of diatoms, top 10 by abundance), the numerical ranking tracks algae that were less common as well as those not found in all or most of the sediment depths sampled.

Examination of the top 20 species showed the presence of 8 species of the pennate benthic diatom *Nitzschia*. These species of *Nitzschia* in the top 20 have been described as favored by high nutrient concentrations or tolerant of "heavy pollution." This indicates that over this 53 year period, high nutrient concentrations are concluded to have been present.

The composite rankings for the three most common *Nitzschia* species showed clearly that the numbers of the three most common species of nutrient or heavy pollution tolerant *Nitzschia* increased about 25 percent (approximately 3 to 4.1) over the period of about 53 years (1953-2006). A larger increase of about 150 percent is seen between 1953 and 2009 but the later year may be an anomaly due to the very low water level which greatly increased the mud and submerged plant habitat for benthic species such as *Nitzschia* just as it decreased the habitat for the planktonic species like *Aulacoseira*.

The results of the paleolimnology study indicate that Machado Lake has been mesotrophic to eutrophic over the 66 year record, with high nutrients concentrations indicated over the 53 year record.

2.3 Baseline Nutrient Loads and the Lake Water Quality Model

BOS conducted in-lake water quality monitoring in Machado Lake at two in-lake locations from June 2006 to September 2008. Table 2-1 presents a summary of the data collected.

Table 2-1
Machado Lake In-Lake Water Quality Storm Drain Water Quality and Field Collected Monitoring Data (June 2006 – September 2008)

In-Lake Water Quality Monitoring[1]				
		Minimum	Average	Maximum
Total Phosphorus (P)	mg/L	0.3	0.8	1.4
Total Nitrogen (N)	mg/L	0.3	1.8	4.6
Chlorophyll a	µg/L	3.4	72.6	337.7
Ammonia-N	mg/L	0.03	0.04	0.6
Dissolved Oxygen (lake bottom)	mg/L	0.5	4.7	16.5

Note:
[1] Lake grab samples were taken at two in-lake locations from June 2006 to September 2008. Most in-lake water quality samples were collected during dry weather periods with low base flow in the drains. No samples were collected during wet weather; however, a few samples were collected one or two days after wet weather events. Minimum and maximum values shown are the minimum and maximum values of all the four sampling locations (not averages of minimum/maximum, but actual minimum/maximum measured values).

The in-lake nutrient concentrations presented here are the result of two types of nutrient loading processes (Figure 2-2):

- **External Loading:** phosphorus and nitrogen are introduced to the lake through urban runoff when the runoff transports nutrients and other contaminants to the lake. Additionally, atmospheric deposition is a source of total nitrogen.

- **Internal Loading:** When oxygen is depleted at the sediment/water interface anoxic (low oxygen) conditions occur. Under these conditions, phosphorus can disassociate from the nutrient rich sediment on the bottom of the lake and diffuse upward in the water toward the lake surface (James 2006), which contributes to algae growth and increased chlorophyll-*a* concentrations (WI DNR 2003). When oxygen levels are sufficiently high (i.e., greater than 2.0 mg/L), phosphorus typically remains bound to the sediment.

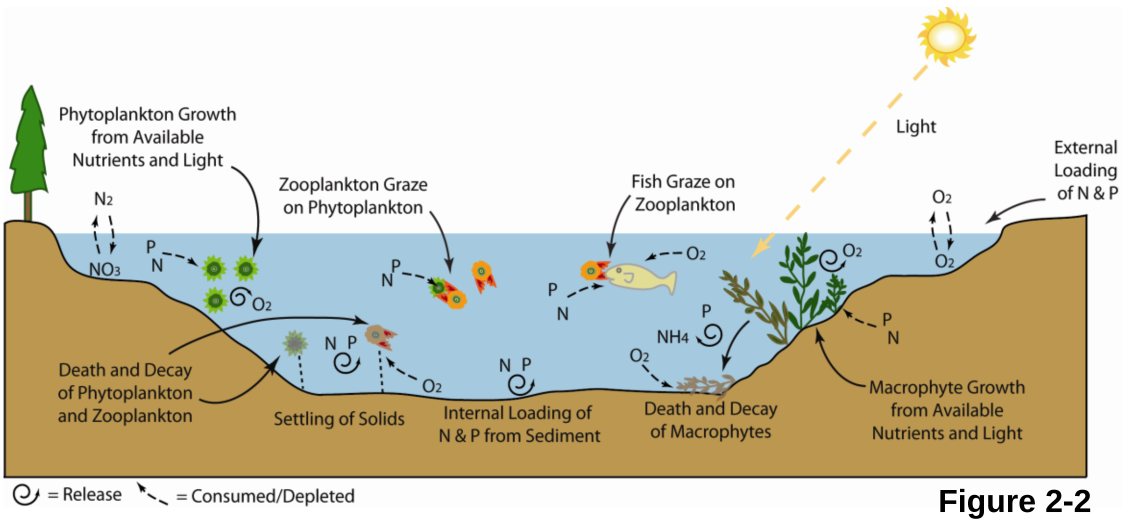

Figure 2-2
Phosphorus and Nitrogen Cycles in Lakes

Mass balance summaries were developed for the existing condition (see Sections 2.3.1 and 2.3.2) to provide insight to the systems' water quality drivers. Mass balance calculations, in terms of total nutrient loadings, were performed for both the entire water year (October through September) and for the dry season only (April through September). Results of these calculations are provided in Table 2-2. As shown, on an annual basis, nutrient loadings are dominated by wet weather runoff. However, in terms of the summer critical low water period, internal loadings from sediment are the predominant source of both N and P. Note that the "start season load" shown in the dry season graphs refers to the nutrient mass in the lake water column at the start of the dry season (residual from wet season loads).

Table 2-2
Internal vs. External Nutrient Load at Machado Lake

	Annual Load (kg)		Dry Season Load (kg)	
Source	**Total P**	**Total N**	**Total P**	**Total N**
External Load	7,840	31,509	256	968
Internal Load	288	1,997	276	1,006
Total Annual Load	8,128	33,506	532	1,974

Source: lake water quality model calibration

The external and internal nutrient loadings are used in the Lake Water Quality Model to estimate future nutrient concentrations in the lake. This dynamic model uses Machado Lake specific monitoring data and study results as inputs to the model. As such, the external and internal loadings are described in subsections 2.3.1 and 2.3.2, respectively.

2.3.1 Baseline External Pollutant Loads

External loading is a product of nutrient sources predominantly from permitted urban runoff discharges delivered from an approximately 22.6-square-mile (14,444-acre) watershed draining into the lake. Additional external pollutant loads from permitted stormwater discharges are delivered directly to Machado Lake or the upper riparian woodland area from the following storm drains listed in Table 2-3. Wilmington Drain, Project 77, and Project 510 Line C are Los Angeles County-owned storm drains, while the D24010, P6545, and P36466 drains are Los Angeles City-owned storm drains. The sheet flow to Machado Lake comes from KMRHP and the golf course adjacent to Machado Lake.

Table 2-3
Characteristics of Storm Drains to Machado Lake

Subwatershed	Area (acres)	Description
Wilmington Drain	12,097	Concrete Lined Open Channel
Project 77 Drain	1,604	102-inch RCP Drain
Project 510 Line C	81	72-inch RCP Drain
D24010	158	78-inch RCP Drain
P6545	71	36-inch RCP Drain
P36466	37	36-inch RCP Drain
Sheet Flow to Machado Lake	108	NA
Total	**14,156**	**NA**

Note: an additional 1,337 acres of the Machado Lake Watershed are tributary to the areas below the lake (freshwater marsh) and are therefore excluded from this table. As such, only the area tributary to Machado Lake is shown here.

Historical water quality monitoring data was compiled and compared to establish the most appropriate data set to use as input to the Lake Water Quality Model.

The data sets that were reviewed include the following:

- BOS, Watershed Protection Division (WPD) water quality monitoring data from 2006-2008
- LACDPW water quality monitoring data from 1987-1995

- LACDPW Regional Event Mean Concentrations (EMCs) derived from data collected from 1994-2000

City of Los Angeles, Bureau of Sanitation Watershed Protection Division, Water Quality Monitoring Data from 2006-2008

Water quality monitoring of inflows to the lake was conducted by the BOS WPD in three storm drains that discharge to Machado Lake. The storm drain samples were taken from June 2007 through September 2008. Table 2-4 summarizes the data collected (refer to Appendix C for additional information). For dry weather, 102 samples were taken during this period. However, during wet weather only a limited number of samples were taken (nine were taken during a rain event, and another nine were taken between one and three days following a rain event).

Table 2-4
Machado Lake Storm Drain Water Quality and Field Collected Monitoring Data (June 2006 – September 2008)[1]

	Units	Minimum	Average	Maximum
Total Phosphorus (P)				
Dry Weather	mg/L	0.03	0.6	4.66
Wet Weather	mg/L	0.13	0.6	1.99
Total Nitrogen (N)				
Dry Weather	mg/L	1.29	2.7	18.42
Wet Weather	mg/L	1.77	2.8	5.71
Organic N				
Dry Weather	mg/L	0.42	1.6	15.4
Wet Weather	mg/L	0.76	1.1	2.3
Ammonia-N				
Dry Weather	mg/L	0.03	0.3	1.44
Wet Weather	mg/L	0.14	0.5	0.86
Total Suspended Solids (TSS)				
Dry Weather	mg/L	0.5	12	181
Wet Weather	mg/L	7	96	311
Total Hardness as $CaCO_3$				
Dry Weather	mg/L	134	360	1,000
Wet Weather	mg/L	15	120	264
Turbidity (dry and wet)	NTU	0[2]	6.93	131.20
Temperature (dry and wet)	Deg C	9.24	18.04	23.60
pH (dry and wet)	SU	7.53	8.09	9.09

Notes:
1 Storm Drain samples were taken at three storm drain outfalls (Wilmington Drain above Lomita Blvd, Project 77 storm drain on the west side of Machado Lake, Project 510-Line C storm drain outfall on the west side of Machado Lake). The storm drain samples were taken from June 2007 through September 2008.
2 Rounded to zero from a negative reading.

Additional wet weather sampling was performed for the City (CDM & Parsons 2010) during seven wet weather days from October 2009 through January 2010. Two samples were taken at each location for each rain event. A summary of the average at each of the three sampling locations is presented in Table 2-5.

Table 2-5
Machado Lake Wet Weather Sampling (2009 –2010 Wet Season)

Location	Total P (mg/L)	Dissolved Orthophosphate as P (mg/L)	Total N (mg/L)	Ammonia as N (mg/L)	Nitrate + Nitrite (mg/L)	Suspended Solids (mg/L)
Wilmington Drain	0.83	0.31	4.77	1.12	1.05	102.05
Project 77	0.82	0.53	5.77	1.26	1.5	104.27
Machado Lake Dam	0.53	0.28	1.48	2.82	0.33	101.49

Notes:
Samples were taken during the 2009-2010 wet season as part of a State Coastal Conservancy Grant for the City of Los Angeles. Seven rain events were sampled, with generally two samples taken per rain event per location. Sampling locations include Wilmington Drain south of PCH, at the Project 77 drain, at the Machado Lake dam.

Los Angeles County Department of Public Works, Water Quality Monitoring Data from 1987-1995

The LACDPW collected water quality samples at several locations within the Dominguez Watershed from 1987 through 1995. One sampling location was in the Machado Lake subwatershed, located in Wilmington Drain upstream of the PCH. These data are presented in the Dominguez Watershed Management Master Plan (LACDPW 2004) and below in Table 2-6. It is assumed that these data were collected during wet weather events based on the placement of the table within the Master Plan (within a subsection titled stormwater monitoring) but that is not stated explicitly.

Table 2-6
LACDPW Sampling Results for Wilmington Drain Sampling Location, 1987-1995

Pollutant	Units	Sample Results[1, 2]		
		Minimum	Average	Maximum
TSS	mg/L	13	225.2	1,143
Total P	mg/L	0.08	0.3	1.3
Ammonia-N	mg/L	0	1.0	15
(Nitrate+Nitrite)-N	mg/L	0	1.1	10.83

Notes:
1 Average concentrations presented in the Dominguez Watershed Management Master Plan in Table 2.3-24 Summary of historic water quality data for the Dominguez Watershed.
2 Presented are the Wilmington Drain sampling location results. From 1994-2000 there were 72 composite samples and 4 grab samples collected at another Dominguez Channel monitoring location but the number of samples taken at the Wilmington Drain monitoring location are not stated.

Los Angeles County Department of Public Works Regional Event Mean Concentration Monitoring Results Derived from Data Collected from 1994-2000

LACDPW maintains a data set of land use-based EMCs that were derived from the Los Angeles County's 1994-2000 monitoring data (LACDPW 2006). For the Los Angeles area as a whole, this data set is considered the most extensive, locally-derived data for a variety of land use types. The City of Los Angeles maintains a pollutant load model that utilizes these EMCs to simultaneously calculate loads and concentrations for each of the constituents of concern based on watershed land use and historical rainfall. The average wet weather water quality concentrations were calculated by the pollutant load model for the land use mix within the Wilmington Drain subwatersheds. These values are presented in Table 2-7.

Table 2-7
Comparison of Actual and Theoretical Wet Weather Pollutant Load Concentrations

Pollutant	Units	Sample Results			(Column D) Pollutant Load Model-Derived Concentrations[4]	(Column E) Average of Columns A-C
		(Column A) LA BOS 2006-2008[1]	(Column B) LACDWP 1987-1995[2]	(Column C) CDM & Parsons 2009-2010[3]		
Total P	mg/L	0.62	0.3	0.82	0.36	0.58
Dissolved P	mg/L	NA[5]	NA	0.42	0.27	0.42
Total N	mg/L	2.76	NA	5.27	3.77	4.02
Organic N	mg/L	1.14	NA	NA	2.22	1.14
Ammonia-N	mg/L	0.52	1.0	1.19	0.49	0.90

Notes:
1 See Tables 2-4. Total P, dissolved-P, all nitrogen species, and TSS data are average concentrations of these constituents sampled at Wilmington Drain above Lomita Boulevard, Project 77, and Project 510 Line C under wet weather conditions. Data provided by WPD on December 1, 2008.
2 See Table 2-6. Average concentrations presented in Table 2.3-24. Summary of historic water quality data for the Dominguez Watershed, in the Dominguez Watershed Management Master Plan.
3 See Table 2-5. Average concentrations of storm drain samples at Wilmington Drain and Project 77 outfall under wet weather conditions.
4 Using the City of Los Angeles pollutant load model that is based on LA County derived land use based event mean concentrations (EMCs), the land use in the Machado Lake watershed and historical rainfall. Does not account for possible load removed from Walteria Lake subwatershed, which usually retains stormwater after rain events. This practice could remove 50-60% of TSS and up to 40% of metals from the fraction of flow that is detained/retained. Walteria Lake is 25% of the tributary area to Machado Lake, so this would translate to loads to Machado Lake potentially being on the order of 10-15 percent lower than predicted.
5 NA – not analyzed

Wet Weather Data Set Used in Lake Water Quality Model

Table 2-7 presents the average wet weather sampling data for Machado Lake and Wilmington Drain collected by BOS, LACDPW, and CDM & Parsons (from Tables 2-4, 2-5 and 2-6) as well as the predicted wet weather concentrations derived by the pollutant load model using the Los Angeles County EMC data. Column E is the average of the three actual wet weather sampling data sets. Following is a summary of the comparison of these three sets of data:

- In general, analytical results from the sampling programs are of a similar order of magnitude as the values derived using the area-wide EMC data in the pollutant load model.

- Total phosphorous estimated by the pollutant load model (Column D) is somewhat lower compared to the average of the three data sets (Column E).

- Total nitrogen estimated by the pollutant load model (Column D) is slightly higher compared to the average of the three data sets (Column E).

Since the data set for the measured wet weather monitored data (columns A, B and C) is representative of current conditions, it was used calibrate the lake water quality model. However, it was determined that the pollutant load model results (Column D) would be used in the Lake Water Quality Model to represent future conditions since the area-wide

EMC data set used in the pollutant load model is considered more representative of long-term wet weather nutrient concentrations. Also, due to the upstream BMPs, including public education and outreach the future runoff to the lake is expected to have relatively lower total nitrogen and total phosphorus values.

Dry Weather Data Set Used in Lake Water Quality Model

For dry weather conditions, available water quality data for key parameters in dry weather urban runoff were reviewed. Based on the limited data sets available, it was determined that the most appropriate data set to use was the monitored data from the City of Los Angeles BOS water quality monitoring program, which is presented in Table 2-4. As such, this data set was used as the dry weather baseline concentrations input into the Lake Water Quality Model.

2.3.2 Internal Nutrient Load Determination

To establish the internal nutrient loading in Machado Lake, a study was conducted in 2009 for Machado Lake that estimated the flux of nutrients in the lake (Horne 2009). The laboratory study used undisturbed sediment cores and natural lake water contained in flux chambers to provide experimental values for the flux of nutrients from surface sediment layers. The results from the nutrient flux study were used to estimate baseline internal loading of nutrients in the lake from the sediment water interface. This data was used in the development of the baseline conditions in the Lake Water Quality Model.

In the laboratory study, sediment flux chambers were used to simulate the conditions in the lake. For several days the sediment flux chambers were maintained with gentle air bubbles to simulate aeration in the lake, followed by several days where the chambers were maintained at anoxic conditions via gentle nitrogen bubbling to simulate anoxic conditions that can occur in the summer and in the upper sediments. Following anoxic conditions, air was again bubbled in the chambers. A typical suite of nutrient measurements were made at each stage. A brief summary of the results are presented in Table 2-8.

Table 2-8
Nutrient Flux Results[1]

Parameter	Soluble Phosphate (mg/L)	Ammonia-N (mg/L)	Nitrate+ Nitrite-N (mg/L)	TIN[2] (mg/L)
Aeration (air, 2 days)	0.36 (0.40)	0.5 (0.43)	0.05	0.55
Anoxic (N_2 gas, 4 days)	(1.26)	(4.0)	0.05	4.8
Re-aeration (air; 15 days)	(1.1)	0.3 (0.02)	3.3	3.3

Note:
1 Values not shown in parenthesis are from a certified lab; values in parentheses from a Hatch kit.
2 TIN = total inorganic nitrogen; (nitrate + nitrite + ammonia).

2.3.3 Lake Water Quality Model

The Lake Water Quality Model is a numerical model that was constructed to evaluate the complex dynamics within the lake, including internal and external loading of nutrients. As such, the model is based on in-lake dynamics, historic pollutant loading (see Section 2.3.1), and the nutrient flux study performed for Machado Lake (see Section 2.3.2). The Lake Water Quality Model is described in detail in Appendix C and summarized here.

Model Development

The lake water column is simulated as a fully mixed system, also termed a "continuously stirred tank reactor," or CSTR. This assumption is known to approximate lake dynamics for small, shallow lakes, such as Machado Lake, where mixing (e.g., diffusion, wind turbulence) dominates over advection (e.g., transport of pollutants by the motion of flowing water). Lake volumes are assumed steady on a daily basis (outflow = inflow) but can be varied monthly to account for summer losses (e.g., evapotranspiration [ET]). The model targets the key parameters of this eutrophic lake: phytoplankton (as chl-*a*), phosphorus (P), and nitrogen (N). The model was constructed in Microsoft *Excel* to allow for easy adaptation of code to address various potential rehabilitation options and alternatives.

Internal loads of N and P, released by the sediments back to the water column, are calculated with a separate module. For these calculations, a second vertical layer was added to the fully mixed water column to represent surface, biologically-active sediments. The size of this layer is defined by a user-specified depth (d) and porosity (ρ). Within the sediment layer, the following sediment nutrient dynamics are simulated:

- Lumped nutrient mineralization (of organic particulate nutrients) and desorption (of sediment-bound nutrients)
- Nutrient adsorption (from pore water to sediments)

Note that the model requires both oxic and anoxic rate constants for defining these two processes, where the extent of surface sediment anoxia (by percentage of lake bottom) is specified on a monthly basis by the user.

A conceptual depiction of the model mechanics is provided in Figure 2-3. The model simulates total phosphorus and total nitrogen on a daily timestep. Particulate and dissolved fractions are estimated based on user-input constant particulate fractions. Simulated external sources of phosphorus and nitrogen include: wet weather runoff, dry weather baseflow, and supplemental "make-up" water pumped into the lake during summer months. Other potential external sources of nutrients, including wildlife and atmospheric deposition of nitrogen, are not explicitly included in the model.

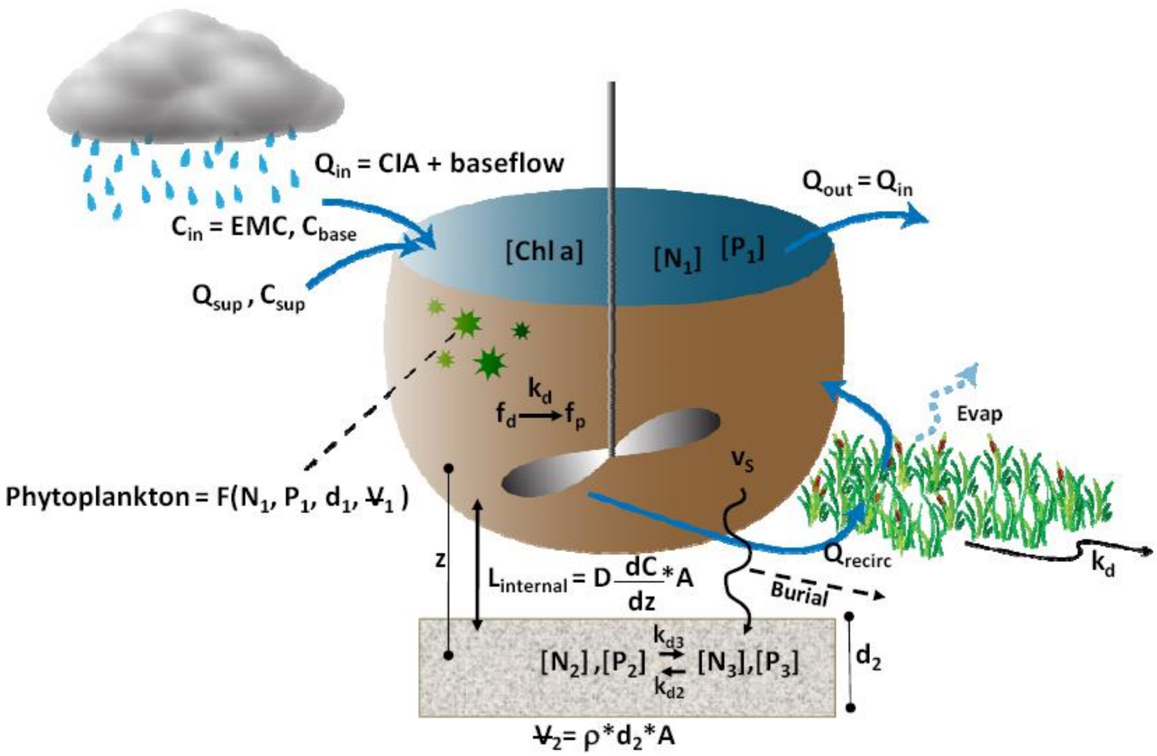

Figure 2-3 Machado Lake Water Quality Model

Internal processes included in the model are:

- N and P settling (particulate fractions only),
- First-order assimilation of N and P (dissolved fractions only), and
- Internal loading of dissolved N and P from the sediment to the water column.

First-Order Assimilation of N and P

Dissolved nutrient removal (uptake) from the water column, parameterized by k_d, is included as an inflow load to the particulate nutrient pool. In other words, this process is a transformation of nutrient forms (from dissolved to particulate), rather than a complete removal of dissolved nutrients. This captures the dynamic of phytoplankton uptake, which is believed to be driving water column nutrient assimilation during the summer, and also facilitates the coupling between water column and sediment layer calculations. The importance of this phenomenon to the lake nutrient cycle is supported by historical measured in-lake particulate fractions of both N and P.

Both k_d (first order removal rate constant for water column) and v_s (particulate fraction settling rate) are allowed to vary seasonally. This is done to capture the seasonal dynamics of phytoplankton in the lake. Uptake is believed to be highest during the summer months, while net settling rates are believed to be lower during the summer when live phytoplankton, rather than sediment, dominates the particulate nutrient pool.

Internal Loading of N and P

Internal loads of N and P, released by the sediment back to the water column, are calculated with a separate module. For these calculations, a second vertical layer was added to the fully mixed water column to represent surface, biologically-active, sediment (Figure 2-3). The size of this layer is defined by a user-specified depth (d) and porosity (ρ). Both sediment-bound and porewater nutrient concentrations are calculated within this layer based on standard formulations found in the literature (e.g., Cerco & Cole 1993; Pollman 2000). Sediment-bound nutrients are replenished via settling of particulate fraction nutrients in the water column. Movement from the sediment-bound nutrient pool to the porewater pool occurs via a first order lumped mineralization/desorption rate. Movement in the opposite direction (porewater to sediment) occurs via a first order adsorption rate. Both rates are variable depending on the oxic state of the sediment. Transport of nutrients from the sediment porewater to the lake water column, and at times vice versa, is calculated following a standard Fickian diffusion formula.

Based on this model, predicted nutrient concentrations in the lake after the implementation of the various in-lake BMPs (see Section 3) is summarized in the compliance analysis section (see Section 5). Refer to Appendix C for a detailed discussion on the Lake Water Quality Model.

Section 3
Implementation Plan

Residents of Los Angeles approved Proposition O, a $500-million bond measure, in 2004 to improve water quality for water bodies within the City. The City prepared Concept Reports for both the Machado Lake and Wilmington Drain projects in December 2006, identifying the funding needed for design and construction. Based on the Citizens Oversight Advisory Committee (COAC) and Administrative Oversight Committee (AOC) recommendation, City Council authorized $117 million of Proposition O funding for the two projects. The project, now a combination of the two and referred to as the *Machado Lake Ecosystem Rehabilitation and Wilmington Drain Multi-Use Project*, is currently in the design phase, and the construction phase will involve installation of a number of BMPs that will restore water quality and comply with TMDL targets for Machado Lake.

The Implementation Plan component of the LWQMP describes the specific BMPs that will be constructed by the City within Wilmington Drain and the portion of the KMHRP from PCH to the Machado Lake dam that are necessary to meet the City's TMDL responsibilities to restore water quality in Machado Lake. The cumulative effect of the BMPs selected for construction will enhance Machado Lake water quality, achieve ecosystem restoration objectives, and mitigate the City's contribution of nutrient loading to Machado Lake.

3.1 Implementation Plan Approach

The planning, design, and construction of the *Machado Lake Ecosystem Rehabilitation and Wilmington Drain Multi-Use Project* was guided by four main objectives outlined in Proposition O—1) water quality improvement,; 2) flood control, 3) ecosystem restoration, and 4) recreation enhancement. The management strategies (i.e., the integrated group of recommended BMPs) selected for Wilmington Drain acknowledge the function of the channel as a sedimentation basin, and those selected for Machado Lake acknowledge the cumulative impacts of external loading and internal lake loading. Selecting the most effective suite of BMPs evolved through a detailed evaluation, ranking, and prioritization process that was driven by the over-arching goal of restoring lake water quality and meeting the regulatory requirements set forth in the Nutrients TMDL. The final design solution derived after a thorough evaluation of three different alternatives for Wilmington Drain and six different alternatives for Machado Lake will serve as the foundation of the Implementation Plan for this LWQMP. Construction of the final design of the two projects is slated to begin in 2011. The integration of the management strategies summarized below will achieve the City's Proposition O objectives, Most of the BMPs provide some pollutant load reduction (some more quantifiable than others) necessary to meet the LA and WLA established for the City in the Nutrients TMDL.

3.1.1 Description of Management Strategies

Table 3-1 provides the comprehensive list of management strategies that are being constructed to accomplish the necessary reductions in pollutant loads to Machado Lake and to achieve the objectives of the *Machado Lake Ecosystem Rehabilitation and Wilmington Drain Multi-Use Project*. Table 3-1 also lists the partner agencies within the Machado Lake watershed responsible for implementation. The management strategies, which focus on reducing external or internal nutrient loads, are organized into two general categories—1) nonpoint source BMPs, and 2) point source BMPs. Nonpoint source BMPs include strategies that are designed to achieve LAs; point source BMPs are targeted to achieve WLAs.

Table 3-1
Management Strategies to Reduce Nutrient Loading In Machado Lake

Management Strategy	Location	Implementation Lead
Nonpoint Source BMPs		
Lake Dredging	Machado Lake	LA City
Add Supplemental Water – microfiltration/reverse osmosis	Machado Lake	LA City
Oxygenation System	Machado Lake	LA City
Off-line Treatment Wetland	Machado Lake	LA City
Phosphorus Removal System	Machado Lake	LA City
Aquatic Plant Management and Littoral Zone Enhancements, including Ludwigia Removal	Machado Lake	LA City
Shoreline Erosion Control (Lake Edge) Treatments	Machado Lake	LA City
Floating Islands (aquatic)	Machado Lake	LA City
Golf Course Maintenance Yard Site BMPs	KMHRP	LA City
KMHRP Design Improvements (WQ benefits), including Southern Tarplant enhancement	Wilmington Drain, Machado Lake	LA City
Point Source BMPs		
In-Lake Sediment Basin – North (captures inflows from Drain P6545, Drain D24010, and Wilmington Drain)	Machado Lake	LA City
In-Lake Sediment Basin - West/Project 77 Drain and Project 510 Drain	Machado Lake	LA City
Re-grade entire Wilmington Drain channel bottom	Wilmington Drain	LACDPW
Clean box culverts at Lomita Blvd.	Wilmington Drain	LACDPW
Clearing and annual maintenance of channel vegetation	Wilmington Drain	LACDPW
CDS at D24010 Drain	KMHRP	LA City
Bioengineered swale at Project 77 Drain (dry weather treatment)	KMHRP	LA City
Bioengineered swale at Project 510 Line C Drain (dry weather treatment)	KMHRP	LA City
Trash Nets at Wilmington Drain/110 Fwy; Project 510 (Pine Creek) Channel; Project 77 Storm Drain	Wilmington Drain, Machado Lake	LA City

The collective integration of all BMPs coupled with long-term operation and maintenance activities is necessary to meet the water quality objectives of Nutrients TMDL. Therefore, inter-agency and inter-departmental collaboration are essential to advancing stewardship, implementation, maintenance, water quality monitoring, and the evaluation of progress.

The construction and operation of these management strategies is necessary to meet the City's commitment toward TMDL implementation.

Table 3-2 lists other voluntary strategies that are important design components of the *Machado Lake Ecosystem Rehabilitation and Wilmington Drain Multi-Use Project*.

Table 3-2
Additional Management Strategies for Machado Lake Ecosystem Restoration

Management Strategy	Location	Implementation Lead
Wilmington Drain Pocket Park	Wilmington Drain	City
Dam Improvements	Machado Lake	City
Invasive Plant Removal - Riparian Woodland and Freshwater Marsh	KMHRP	City

Figure 3-1 on the following page displays the general location of the various BMPs that are listed in Table 3-1 and Table 3-2. Descriptions of each management strategy are provided in the following subsections.

3.1.2 Strategies to Meet Load Allocations

Management strategies necessary to achieve the LA consist of BMPs that are designed to specifically target in-lake nutrient loads and nonpoint source runoff transported from KMHRP to Machado Lake via overland flow.

The nonpoint source BMPs provide specific reductions in nutrient loads by removing a large amount of nutrient-rich lake-bottom sediments and reducing sediments and nutrients transported to Machado Lake from the golf course and KMHRP. Some of the BMPs indirectly address related water quality issues and can provide additional reasonable assurances that compliance with lake nutrient targets can be achieved. The strategies designed to meet the LA are the direct responsibility of BOS and RAP. The list of in-lake nonpoint source BMPs that will be implemented to achieve the LA are summarized below.

3.1.2.1 In-Lake BMPs

An integrated suite of lake rehabilitation strategies will be implemented to address recycling of in–lake nutrient loads. Key components include dredging to an average depth of 8 feet and maintaining a constant lake water surface elevation by using a supplemental water source. Recycled microfiltration/reverse osmosis (MF/RO) water will be used for lake augmentation purposes to maintain full lake levels in the summer. An offline-treatment wetland, an aeration system, and phosphorus removal system will also help satisfy the water quality objectives of the project. Each strategy must be implemented in concert with the others to meet water quality objectives and goals.

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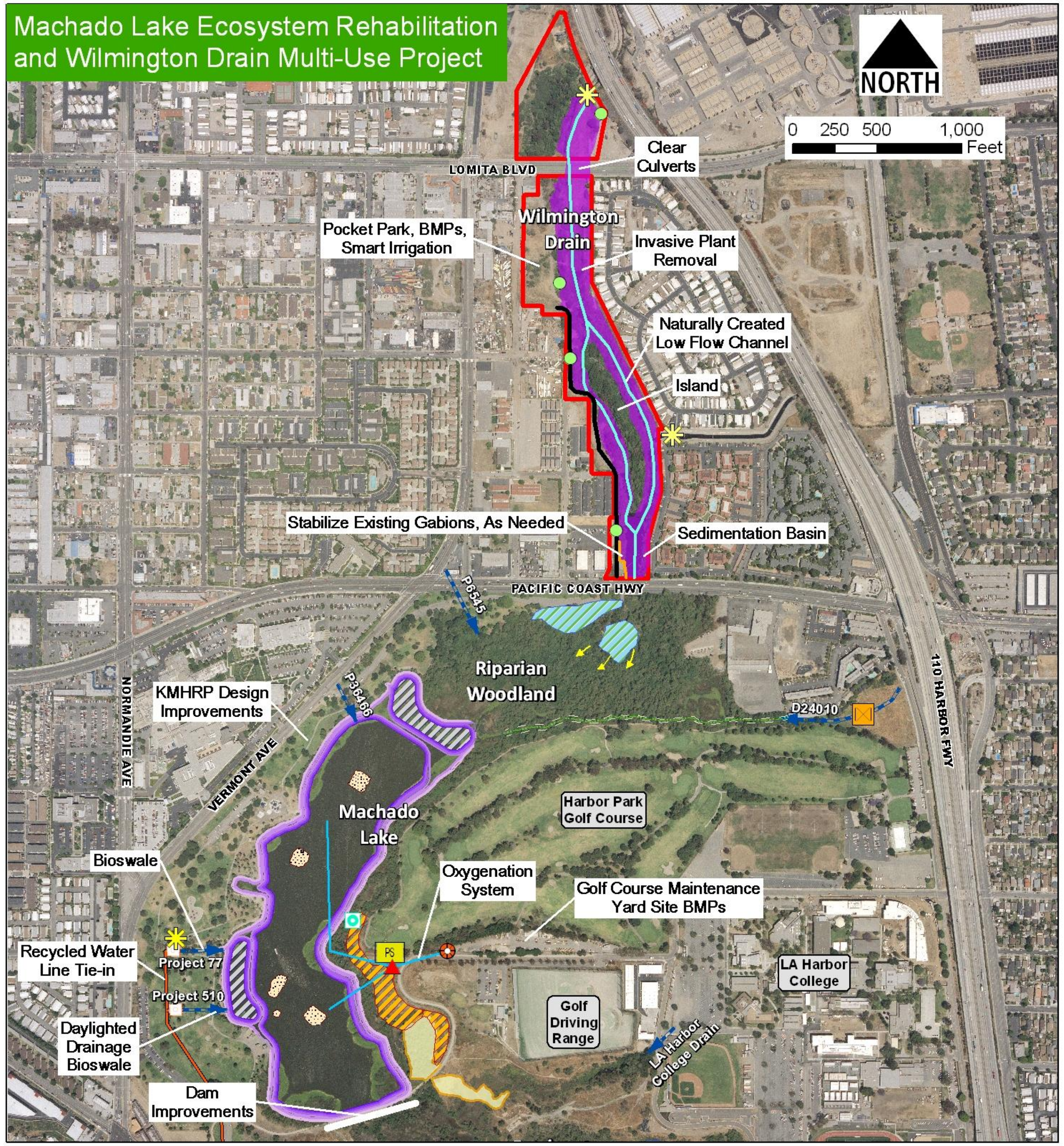

Legend

- Trash Nets
- Access Ramps
- Channel Centerline
- 10 Ft Offset
- Floating Islands
- Gabion
- Maintenance Road
- Regrade
- LA County Flood Control District
- Speece Cone
- Oxygen Tank
- Pump Station
- Phosphorus Removal System
- Hydrodynamic Separator
- Oxygenation System Piping
- Drainage Improvements
- Existing Storm Drain
- Supplemental Water
- Emergent Wetlands
- Off-Line Treatment Wetland (approximate boundary)
- In-Lake Sediment Basin
- Non-Native Grasslands Replaced with Southern Tarplant in Select Areas (approximate boundary)

Approximate Lake Elevation

- 8.1' - 10.0'
- 6.1' - 8.0'
- 4.1' - 6.0'
- 2.1' - 4.0'
- 2.0'

Notes:

1. Includes invasive plant removal in the riparian woodland and freshwater marsh and aquatic vegetation removal in Machado Lake.
2. Includes in-lake Ludwigia removal.
3. Includes aquatic plant managment and littoral zone enhancements.

Figure 3-1 Schematic Layout of Management Strategies

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Details of the suite of in-lake rehabilitation strategies include:

- **Hydraulic dredging to remove nutrient-rich lakebed and lake edge sediment**. Sediment is a two-fold problem in Machado Lake: (1) Sediment accumulation decreases the lake depth, which over time allows increased macrophyte and algae growth; and (2) internal nutrient loading from lakebed sediment into the water column is believed to be a major contributor to water quality degradation in Machado Lake. Lake edge dredging will primarily focus on reshaping the east and west banks to diversify the lake edge configuration and environment. Dredging activities will create a shallow, contoured underwater shelf or terrace in these areas suitable for establishing a littoral zone with desirable aquatic vegetation. Lake edge improvements include re-contouring portions of the lake that have been highly impacted by elevated levels of sediment inflow in ways that will benefit water quality and habitat and stabilize lake edges by removing soft sediment down to a more firm substrate layer. Implementation of this BMP requires the removal of approximately 250,000 cubic yards of sediment from Machado Lake. This volume may increase based on recommendations associated with the implementation of Toxics TMDL for Machado Lake which is being finalized. It is the most costly in-lake sediment management option; however, because of the additional benefits received by dredging, including increasing/creating recreational opportunities, and improving aquatic habitat, it is considered cost-effective for Machado Lake.

- **Supplemental water (low-nutrient) to maintain lake levels** during the dry season. Field data from Machado Lake has shown that the lake loses approximately 2 feet of water due to evaporation during each summer dry season (RWQCB 2008). Additionally, water quality analysis results reveal that nutrient levels in the lake tend to increase during the dry season due mainly to evaporation and conditions of the lake that promote internal nutrient recycling as a result of the lack of inflow from any source (City of Los Angeles 2004). This decrease in water depth contributes to the overall water quality problem in the lake. Recycled MF/RO water from Terminal Island Water Reclamation Facility (TIWRP) will be piped as the source of supplemental water for Machado Lake. Data on the nutrient levels contained in the TIWRP recycled water are provided in TIWRP's Monthly Title 22 Compliance Report.

- **An oxygenation system** will supplement dissolved oxygen (DO) to enhance water quality and mitigate the potential for eutrophication and odor. The water quality model demonstrates that significant water quality improvements can be achieved through oxygenation, particularly during the hot, dry months from May through October, when DO in the water column is most critical. The Speece Cone, Downflow Bubble Contact Oxygenator, is the recommended oxygenation system for Machado Lake. The system directly targets the sediment/water interface for the delivery of oxygen. This is accomplished by taking water near the bottom of the south end of the lake, where the temperature is lowest and the water most dense, pumping the water through the Speece Cone, and then discharging the oxygenated water again near the bottom of the north end of the lake. While the capital costs are side of the lake adjacent to the treatment wetland and phosphorous removal system.

- Construction of an **off-line treatment wetland** that circulates lake water through a nutrient and sediment removal wetland to further reduce nutrients within the lake and improve water quality. To implement this BMP, a treatment wetland will be constructed along the east side of Machado Lake to provide a means of long-term, nutrient removal.

- Construction of a **phosphorus removal system using Media Adsorption**. The concept of a Media Adsorption method involves pumping lake water continuously through a set of pressure rated treatment vessels containing an industry approved adsorption media. Water is pumped either directly from the lake in winter months or from the end of the re-circulating treatment wetland in summer months. Water entering the treatment system is conditioned with an in-line carbon dioxide gas diffusion to lower pH to optimal levels (~7.4) for phosphorus adsorption. Water then continues through two treatment vessels in a lead-lag configuration to first remove the bulk of phosphorus from the water in the first tank and then polish any remaining phosphorus out of the water in the second tank. Water exiting the second tank is discharged directly back to the lake. The media used in the treatment system has a limited lifetime dependent upon phosphorus concentrations and the levels of other constituents in the water. After a period of time, some media may lose its ability to adsorb phosphorus resulting in the need for periodic maintenance. At this point, the media can be regenerated with a caustic backwash to remove bound phosphorus, other constituents, and clogging particulates. The media will typically be able to undergo three regeneration cycles before needing to be replaced with fresh media. Caustic backwash solution is conveyed to the site for use during backwash events and removed from the site when backwashing is complete, eliminating the need to store caustic solution. Spent media can be disposed of as non-hazardous material at a standard landfill.

- **Aquatic plant management**, including macrophyte management and littoral zone modifications/enhancements that would improve overall water quality and reduce vector breeding grounds. Aquatic plant management refers to controlling nuisance species (i.e., primarily *Ludwigia*, but to a lesser extent, also tules and cattails), to maximizing beneficial aspects of plants in water bodies, and to restructure plant communities. Management activities will emphasize the establishment of diverse native macrophyte communities (emergent and submerged) along an underwater shelf (e.g., terrace) as well as the removal of selected invasive macrophytes. Implementation of this BMP also provides secondary benefits through periodic removal of nutrient rich sediments along the lake shoreline.

- **Shoreline stabilization** to enhance aquatic and riparian habitat and limit nutrients and sediment entering the lake from lake shore erosion. This BMP incorporates highly refined design elements that seek to restore the entire edge of the lake with appropriate slopes and aquatic vegetation species that will prolong the ability of the littoral zone to uptake nutrients. Shoreline stabilization will be implemented in conjunction with the aquatic plant management activities.

- **Floating islands** to provide terrestrial habitat for birds and aquatic habitat for fish. Floating islands, which are pre-engineered masses made from recycled plastic or other engineered materials, will be constructed in Machado Lake. The islands are planted with emergent and submerged aquatic vegetation. A floating island provides more heterogeneous habitat for fish (e.g., shade and hiding places) as well as different types of habitat for bird species, than what is currently present along the lakeshore. While there are field scale and multiple-year investigations underway to establish the role that floating islands could play in improving overall lake water quality through nutrient uptake, the primary intent of this BMP is to provide habitat.

3.1.2.2 Park BMPs

Additional BMPs will target nonpoint source loading that originates from the riparian woodland area upstream of Machado Lake and the portion of KMHRP that surrounds Machado Lake. Although the expected pollutant load reductions attributable to these BMPs cannot be quantified, these management strategies will improve stewardship of the Machado Lake ecosystem, provide additional potential nonpoint source reductions, and offer additional efforts toward achieving a healthier Machado Lake. The BMPs targeting nonpoint source runoff that may reduce a portion of the nutrient loading assigned to the LA include:

- **Habitat and Park Design**—An intensive program of invasive plant species removal will take place throughout KMHRP. Invasive species like *Ludwigia* will be removed, while the Southern Tarplant and the Coastal Sage Scrub will be replanted to enhance habitat. The design elements of the new park design will enhance the recreational benefits of the project and promote ecosystem restoration and nonpoint source pollution abatement and education.

- **BMPs to mitigate storm water runoff from City Golf Course Maintenance Yard.** Several improvements are proposed to the existing Golf Course maintenance yard, including a new vehicle wash rack, expanded improved bulk storage bins, and BMPs to treat runoff. The existing wash rack will be demolished to construct a 47-foot by 28-foot, roofed structure. The wash rack will be sloped to direct flows into a catch basin that captures grass clippings and large debris and can be manually cleaned. From the catch basin, runoff will flow into an underground clarifier before discharging into the sanitary sewer line. The existing bulk storage bins will be demolished to build larger bins with higher walls, which will completely contain the stored material. Tarps will be provided to cover stored materials. A small berm at the exterior of the storage bins will direct runoff to the west into a dry well structure designed for Standard Urban Stormwater Mitigation Plan (SUSMP) storm. During larger storm events, the dry well will overflow into an earthen swale that will also capture runoff from the entire west portion of the maintenance yard. The swale will discharge into an infiltration basin designed to capture the SUSMP storm. Treated runoff will then be drained to the lake.

- **Wetlands—In addition to the offline treatment wetland adjacent to the lake** (**see abov**e), emergent wetland improvements will also be made in the riparian woodland and lower freshwater marsh. The objectives of the wetland improvements are to provide additional filtration of storm water runoff from Wilmington Drain, D24010 Drain, and other storm water drains that discharge into these areas as well as providing new and better quality wetland habitat for wildlife associated with these areas. The emergent wetlands will be planted with southern bulrush, which is recognized for its sediment retention and water quality improvement capabilities. The riparian woodland areas north of the lake will be planted with willow, cottonwood, and other woody species to help keep trash and other coarse debris from entering the lake during major storm runoff events.

3.1.3 Strategies to Meet Waste Load Allocation

Other BMPs that will be constructed are specifically designed to mitigate point source loading from upstream permitted stormwater discharges. These BMPs will contribute to improving the health of Machado Lake and achieving compliance with the nutrient water quality targets set by the WLA. These BMPs will provide positive benefits to the water quality in Machado Lake by reducing the long-term build-up of sediments in the lake and thereby maintaining deeper lake levels which is a one of the key implementation strategies for improving lake water quality. BMPs will focus on reducing pollutant loads conveyed from Wilmington Drain and three major storm drain outfalls—D24010, Project 510 Line C Drain, and Project 77 Drain. The BMPs targeted for Wilmington Drain focus on increasing the hydraulic capacity of the channel as well as the sediment storage capacity thereby decreasing the sediment loads transported to Machado Lake. Wilmington Drain BMPs include:

- **Re-grade the Wilmington Drain channel bottom** creating an in-channel sediment basin at the south end, immediately north of PCH. The flat channel bottom will result in the removal of more than 30,000 cubic yards of sediment. This will remove accumulated sediment that currently hampers stormwater conveyance and provide significant future sediment storage capacity.

- **Clean out box culverts** under Lomita Boulevard and PCH and re-grade transition zone in channel above and below box culverts as necessary. This will also diminish the amount of sediment available for transport down stream each culvert.

- **Clear vegetation from the channel bottom** and selectively remove invasive plant species on channel banks on an annual basis. This will improve the hydraulic storage capacity of Wilmington Drain.

Re-grading Wilmington Drain and removing approximately 30,000 cubic yards of sediment provides significant additional needed sediment storage capacity. The clearing and excavation of the channel does not impact the island north of PCH or other documented sensitive habitat.

Other BMPs that will address stormwater discharges to Machado Lake include:

- **Installation of a hydrodynamic separation device at storm drain D24010**, the Continuous Deflection Separation (CDS®) system manufactured by Contech Construction Products Inc. A CDS® is a widely-used structural BMP device designed to capture pollutants such as trash and sediments in storm drain systems. This technology typically consists of flow-through structures that use the passive energy of the flow to separate the solids from liquid through a non-blocking, non-mechanical screening chamber and settles the pollutants into a sump for storage and eventual collection. The primary benefit of this BMP is derived from its ability to remove sediment loads that would be transported to Machado Lake. This is another BMP that aims to reduce the amount of sediment deposition occurring in Machado Lake.

- **In-lake sediment traps** to improve water quality by localizing sediment deposition to facilitate more frequent removal and thereby extend the timeframe for a deeper lake. In-lake sediment traps are depressions created at storm drain outfalls. At two key locations, the north edge of the lake and Project 77 Drain, the lake would be graded a few feet deeper than the surrounding lakebed and lined with a structural material to reinforce the bottom. The intent is to create a submerged stilling basin at the drain outfall that will collect sediment in a defined, localized area that can be easily accessed for removal. Material used to protect the basin structure includes interlocking articulated open-cell or closed-cell varieties of concrete blocks and should extend the full length of the basin. An access road will be constructed to allow equipment to reach these areas of the lake for long-term maintenance.

- **Construction of bioengineered swales at the stormwater outfalls of Project 510 Line C and Project 77 Drain**, which are effective at reducing nutrient levels from dry weather flows delivered to Machado Lake.

- **Trash Nets at Wilmington Drain/110 Freeway; Project 510 (Pine Creek) Channel; Project 77 Storm Drain** are not designed to specifically reduce sediment or nutrient loading to Machado Lake. However, they are an important BMP that will allow the City to advance the goal of a healthy lake and achieve other water quality program requirements.

  <u>Wilmington Drain @ 110 Freeway</u> The trash net structure will be an in-line, 22-net system as manufactured by Fresh Creek Technologies, Inc. The trash net structure would be located within Wilmington Drain just downstream of the concrete channel discharge under the 110 Freeway. The system will use the passive energy of the influent stream to drive the trash/floatables into the disposable nets. The nets will collectively treat a design flow rate of 764 cfs with an anticipated head loss of approximately 3 inches. The nets will have the capability to collapse to pass the higher storm events (peak flow rate of 5,028 cfs) in order to minimize system head loss while still retaining previously captured trash. The nets will be serviceable from the south side of the structure with a truck-mounted crane and several dump trucks.

Project 510 (Pine Creek) Channel The trash net structure will be an in-line, 3-net system as manufactured by Fresh Creek Technologies, Inc. The trash net structure will be located within the Project 510 trapezoidal concrete channel just east of Wilmington Drain. The system will use the passive energy of the influent stream to drive the trash/floatables into the disposable nets. The nets will collectively treat a design flow rate of 133 cfs with an anticipated head loss of approximately 0.1 inches. The system will have the capability to pass the higher storm events (peak flow rate of 638 cfs) in order to minimize system head loss while still retaining previously captured trash. The nets will be serviceable from the south bank of the trapezoidal channel with a truck-mounted crane and a dump truck.

Project 77 Storm Drain The trash net structure will be off-line, 3-net system as manufactured by Fresh Creek Technologies, Inc. The trash nets will be installed inside a precast underground concrete chamber that would be located parallel to the main 102-inch Project 77 storm drain. A diversion structure/weir on the 102-inch storm drain will divert a flow rate of up to 230 cfs to the offline trash net chamber for treatment while bypassing flows from higher storm events up to the peak flow rate of 823 cfs. Treated flows will return to the 102" storm drain prior to the outfall next to Machado Lake. Confined space entry is not typically required to service the nets; the underground system will be serviceable from the ground surface with a truck-mounted crane and a dump truck.

3.1.4 Miscellaneous Design Components

Other design elements that are incorporated into the *Machado Lake Ecosystem Rehabilitation and Wilmington Drain Multi-Use Project,* which support the Proposition O ecosystem restoration and recreation goals, are summarized below. While these BMPs do not have a direct effect on the health of Machado Lake they are important components of the overall project design and do advance environmental improvement.

- **Construct park on west side of Wilmington Drain, south of Lomita Boulevard** to advance education and outreach on ecosystem restoration. Site specific BMPs will be incorporated to capture runoff from the park and pet waste disposal bags will also be provided in the park.

- **Dam modifications for operational flexibility and public safety.** Several design features are proposed to improve the lake level control, safety, and the visual appearance of the Machado Lake Dam. To provide the maximum flexibility for regulating lake water levels, a combination of a high level box culvert system and a low level pump system will be incorporated as part of the Machado Lake Dam improvements. The high level culverts can lower the lake level to 9 feet msl for maintenance purposes or in advance of small storms. With the addition of the pumps, it is possible to draw the entire lake water surface to elevation 7 feet msl (or below). The dam crest will be overlain with 4 inches of decorative concrete and a decorative guard rail will be added to the upstream face for safety considerations. As part of the improvements, water levels will be monitored in Machado Lake. The operational flexibility created by these dam modifications can provided added benefits such as additional flow during dry seasons to maintain wetland functions in the freshwater marsh below the dam and allow for necessary maintenance of in-lake sediment basins and vegetation terraces.

- **Invasive plant removal from riparian areas.** Restoration and enhancement of the habitat in the riparian woodlands includes managing a number of nonnative plant species that are cumulatively contributing to a degraded community. These species include salt cedar, giant reed, ash, Himalayan blackberry, Brazilian pepper tree, passion flower, blue gum, and others. Nonnative species will be selectively removed throughout KMHRP and replaced with native plant species typically observed in riparian habitats. Landscape plantings associated with both the Wilmington Drain Pocket Park and KMHRP will also be selected from an appropriate list of native species. An adaptive management approach will be used to cultivate a more robust riparian habitat that will benefit the overall function, health, and diversity of the plant and wildlife community of the Wilmington Drain and Machado Lake ecosystem.

3.2 Implementation Plan Schedule

The implementation schedule consists of construction, monitoring, and compliance/ reporting phases. The implementation plan begins with the construction of the *Wilmington Drain Multi-use Project* and the *Machado Lake Ecosystem Rehabilitation Project*.

Construction activities for *Wilmington Drain Multi-use Project* are tentatively scheduled to begin in June 2011 and conclude in November 2012. The construction phase of the *Machado Lake Ecosystem Rehabilitation Project* is scheduled begin in November 2011 and finish in July 2014. The monitoring requirements of the implementation plan will begin 60 days after approval of the MRP and QAPP provided in this LWQMP. The water quality monitoring outlined in Section 3 is an ongoing program commitment of the City. The compliance and reporting phase of implementation will begin in 2012 and is also an ongoing commitment of the City. Figure 3-2 provides an estimated project time line for implementation of the requirements outlined in this LWQMP based on the current Proposition O project schedule. These dates are subject to change due to potential project delays. Once a contractor has been awarded for the construction phase of the Prop O projects, a more detailed construction schedule can be provided.

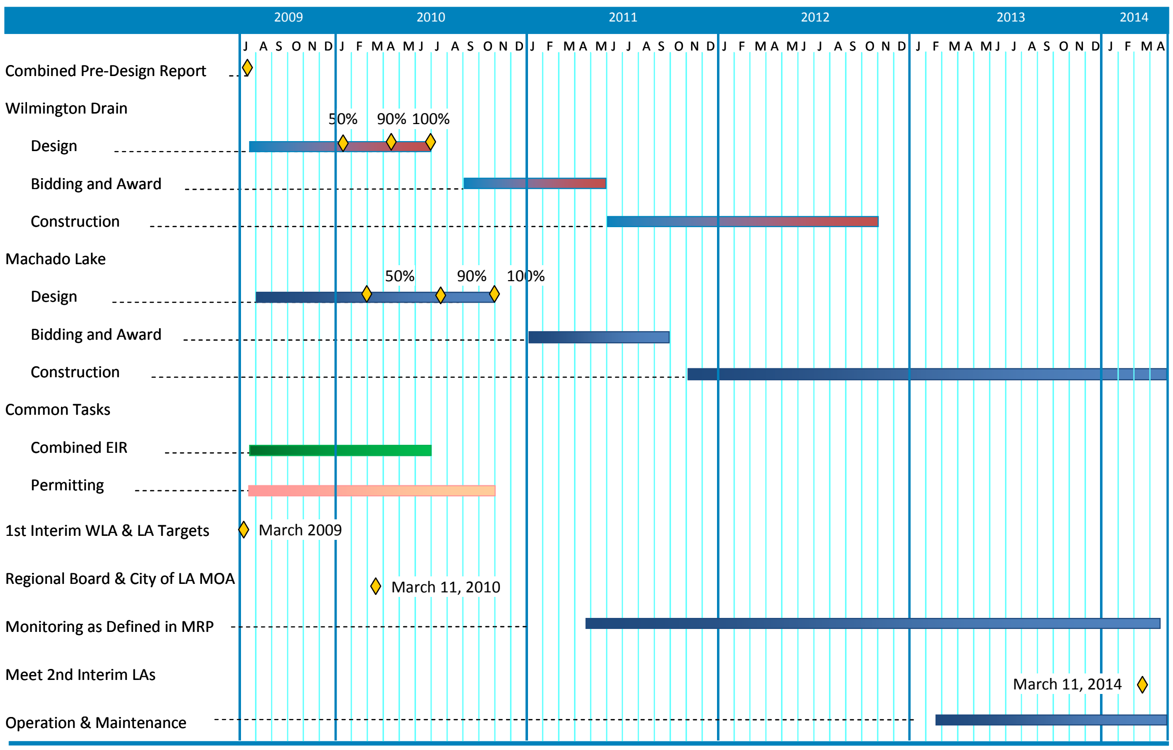

Figure 3-2
Implementation Plan Schedule

Section 4
Monitoring and Reporting Plan

4.1 Sampling Procedures and Analytical Methods

4.1.1 Monitoring Sites

Water samples and *in-situ* measurements will be collected from two mid-lake monitoring sites, ML-1 and ML-2, respectively (Figure 4-1). As specified in the Basin Plan Amendment, ML-1 (33°47'16.14"N and 118°17'34.68"W) and ML-2 (33°47'03.72"N and 118°17'37.98"W) are located in the open water portion of the lake with one in the northern portion and one in the southern portion of the lake. Buoys will be used to identify and mark both sampling locations at ML-1 and ML-2. The average of these two sampling locations shall be used to determine compliance with the LAs and attainment of numeric targets.

Sometimes safety and access issues are problematic when conducting field sampling, such as adverse weather conditions and/or lake management activities. In the case of any unforeseen event, every effort will be made to collect another representative sample in a timely manner. If possible, sample collection will move to a nearby location if the sample can still be considered "representative" of lake conditions. Otherwise, the site will be reported as "inaccessible" and sampling will be skipped at that site until the next scheduled sampling event.

Figure 4-1
Mid-lake Sampling Locations

4.1.2 Sample Types and Sampling Frequency

Monitoring will be conducted bi-weekly, on a year-round basis, resulting in 26 sample events per year. For consistency purposes, sample collection will typically be conducted on the same time and day of the week. However, depending upon operational needs, sample collection may occur earlier or later during the designated sampling week.

Grab samples will be collected at each site and analyzed for the following parameters:

- Total Nitrogen (sum of Organic-N + Ammonia-N + Nitrate/Nitrite-N)
- Total Phosphorus
- Ortho-Phosphorus (PO_4)
- Total Dissolved Solids (TDS)
- Total Suspended Solids (TSS)
- Chlorophyll-*a*
- Turbidity

In addition, the following physical parameters will be measured *in-situ*, at the time of sample collection:

- Temperature
- pH
- Specific conductivity
- Dissolved oxygen
- Secchi depth
- Lake elevation (using a staff gauge)

4.1.3 Sample Collection and Delivery Procedures

Water samples will be collected from a boat. The motor will be turned off prior to reaching the sampling location, allowing the boat to coast to the anchoring point. This will be done to prevent contamination of the water sample by motor exhaust and to avoid agitation of benthic sediments by the propeller. Once the boat has reached the sampling location, an anchor will be lowered to keep the boat from drifting offsite while measurements are recorded and the samples are collected.

To account for stratification of the water column, samples will be depth-integrated. A custom-made sampling device will be used for this procedure. The device consists of a polyvinyl chloride (PVC) pipe (2-inch diameter) with a "flapper valve" attached to the lower end (Figure 4-2).

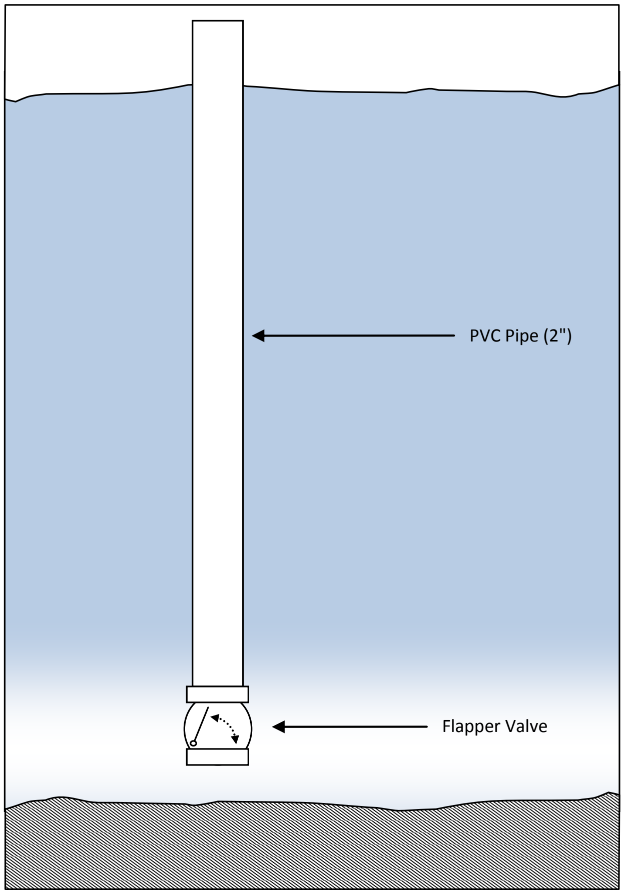

Figure 4-2
Depth Integrated Sampler with Flapper Valve

As the sampler is lowered vertically into the lake, water fills the PVC pipe, such that the entire water column is represented in the sample. As the device is lifted out of the water, the flapper valve closes and retains the sample within the PVC pipe. The sampler can be configured with various lengths of PVC pipe to match the depth of the water at each sampling station. Under typical conditions at Machado Lake, the depth integrated sampler will collect about 2 liters of sample each time it is lowered into the water. To collect sufficient volume for all of the laboratory-analyzed parameters, the sampler must be lowered multiple times at each station. To ensure consistency of the sample, the samples from each "plunge" are poured into a clean bucket where they are mixed and composited. Once sufficient volume is collected in the compositing bucket, the water sample is poured into the appropriate bottles for the analyses being requested. Refer to Table 4-1 for the types of bottles to be used for each analysis, along with handling requirements. The date and time of sample collection, field measurements, and ambient conditions will be recorded. Additionally, field staff will measure the changes in lake elevation by recording the water level on a staff gauge that will be installed at an appropriate location in the lake.

Table 4-1
Sample Types, Required Volume, and Handling Requirements

Constituents	Sample Volume	Containers (#, size and type)	Preservation	Holding Time
Total Suspended Solids	1000 mL	(1) 1000 mL Plastic Bottle	Store Cool at 4ºC	7 days
Total Dissolved Solids	1000 mL	(1) 1000 mL Plastic Bottle	Store Cool at 4ºC	7 days
Total Ammonia (NH_3-N) Total Nitrogen Total Phosphorus	500 mL	(1) 500 mL Plastic Bottle	Store Cool at 4ºC Add sulfuric acid, pH < 2	28 days
Nitrate (NO_3-N) Ortho-Phosphorus (PO_4)	500 mL	(1) 500 mL Plastic Bottle	Store Cool at 4ºC	7 days
Chlorophyll-*a*	1000 mL	(1) 1000 mL Brown Plastic Bottle	Filter and then freeze at 0ºC	14 days
Turbidity	125 mL	(1) 125 mL Plastic Bottle	Store Cool at 4ºC	48 hours

For *in-situ* measurements of water quality parameters, staff will utilize a multi-parameter sonde (e.g., YSI model 6600), or comparable instruments to measure temperature, DO, pH, and electrical conductivity. Field measurements will be made after sample collection is complete unless the measurements can be made in a way that will not contaminate or influence the samples. To determine attainment of numeric targets for DO concentrations, readings must be taken 0.3 meters above the bottom of the lake. Prior to lowering the DO sensor in the water, field staff will measure the depth of the water to determine how far the sensor should be lowered. Once the desired depth is obtained, field staff will lower the probe to the appropriate depth, and allow the instrument to stabilize before recording the DO reading.

In addition to the DO reading at 0.3 meters above the bottom of the lake, staff will submerge the sonde slowly into the lake to measure each of the parameters throughout the entire water column. Once the data are obtained throughout the entire water column, the median value of each parameter will be reported for every 0.5 meter depth interval. In addition to these water quality measurements with the sonde, field staff will also determine Secchi depth, using a standard 8-inch diameter Secchi disc with alternating black and white quadrants, to gauge the turbidity and clarity of the water.

After water samples are collected, they must be stored on ice in a cooler with the lid closed during transport to the laboratory. Chain-of-custody (COC) forms are completed by the sampler for all samples, placed in a plastic envelope, and kept inside the cooler with the samples. Upon delivery to the laboratory, the laboratory staff inspects the condition of the samples, signs the COC, and reconciles the label information to the COC form. Time of sample collection is noted, and the samples are stored at the appropriate temperature until analysis is begun, always within the holding time limitation. At this point, the laboratory becomes responsible for sample custody. Samples may be disposed of when analysis is complete and all analytical quality assurance/quality control procedures are reviewed and accepted.

To ensure the accuracy and thoroughness of the dataset, field duplicates will be collected at one of the monitoring sites, along with field blanks for each of the analytes being tested. When preparing the field duplicates, water from a single sampling vessel is to be split into two identical bottles (one for the regular sample and one as the duplicate). The sample will be well-mixed before splitting. For reporting purposes, only the data for the regular sample will be used, whereas the data for the duplicate will be used for quality assurance purposes. Field sampling staff will record the location where the duplicate samples were taken, but this information will not be shared with the laboratory.

4.1.4 Analytical Methods

All water samples will be analyzed by Environmental Monitoring Division (EMD). Laboratory will be ELAP certified for each of the methods. All lab samples will be analyzed in accordance with SWAMP-approved (or comparable) analytical methods. However, if alternate methods are chosen, the Regional Board will be notified before any analyses are performed.

Table 4-2
Laboratory Analytical Methods and Detection Limits

Parameter	Laboratory	Analytical Method	ML Limit	MDL Limit
Total Suspended Solids	EMD	SM 20th ed. 2540 D		1.0 mg/L
Total Dissolved Solids	EMD	SM 20th ed. 2540 D		28 mg/L
Organic Nitrogen	EMD	EPA 351.2	0.1 mg/L	0.1 mg/L
Total Ammonia (NH_3-N)	EMD	EPA 350.1	0.1 mg/L	0.05 mg/L
Nitrate/Nitrite	EMD	EPA 300.0	0.1 mg/L	0.02 mg/L
Total Nitrogen	EMD	Sum of NH3, NO3, NO2, and Organic-N.		
Ortho-Phosphorous	EMD	SM 4500-P E	0.1 mg/L	0.05 mg/L
Total Phosphorous	EMD	SM 4500-P E	0.1 mg/L	0.05 mg/L
Chlorophyll-*a*	EMD	SM 20th ed. 10200 H	10 µg/l	6 µg/l
Turbidity	EMD	SM 20th ed. 2130 B	1.5 NTU	0.3 NTU

4.2 Data Quality Objectives

4.2.1 Quality Assurance Project Plan

A QAPP is included in this document and is meant to supplement this Monitoring and Reporting Plan (see Appendix B). The purpose of the QAPP is to ensure that the monitoring program produces consistent, reliable data that meet the project's overall goals, and data quality objectives are met. Data quality objectives are discussed in detail in the QAPP. In general, the QAPP will ensure that methods for sample collection and laboratory analysis are consistent with guidelines established by the State of California's SWAMP. The QAPP also specifies the corrective actions to be taken when data quality objectives are not being met.

4.3 Data Management and Reporting

4.3.1 Database Management

Data management will be a collaborative effort involving field staff from the WPD, as well as laboratory staff from the EMD. WPD will record and maintain all field data collected during sampling events. A field log sheet will be used to register all information during a particular sampling event, such as date, time, name of field personnel, sampling location, sample ID, name of sampling program, and visual inspection of the site as well as additional comments that may be relevant to the project. All field data will be entered into an electronic database following each sampling event. EMD will record and log all samples that are analyzed at the laboratory, and all laboratory data will be entered into EMD's Laboratory Information Management System (LIMS). Upon validation from each respective laboratory supervisor, EMD will upload the validated data into the Bureau of Sanitation's Wastewater Information System and Analytical Research Database (WISARD). Likewise, WPD field staff will upload the required *in-situ* measurements and other pertinent field observations into WISARD. The WISARD database is maintained by the Information Control Systems Division (ICSD) and is used extensively by the Bureau of Sanitation for legal reporting of data for various NPDES and TMDL monitoring programs. Custom report templates will be developed for the Machado Lake Nutrients TMDL Monitoring Program, so that data are reported in a timely, consistent manner, with systems in place to maintain the integrity of the data. Data within WISARD can only be edited with administrative approval, and will have an access log showing activities and changes made to the file. WISARD files are stored on a secure server, and are backed up on a daily basis.

In addition, hard copies of the Field log sheets and laboratory results will be filed in project specific folders at WPD and EMD, respectively. All electronic data files, at WPD and EMD, are saved on a network drive and are backed-up in an archive. Records will be maintained for a minimum of 5 years after submission of the data to the Regional Board. However, it is the practice of the Bureau of Sanitation (including WPD and EMD) to maintain monitoring records indefinitely.

4.3.2 Reporting Guidelines and Distribution

As specified in the TMDL, data for this monitoring program must be reported to the Regional Board on an annual basis. Monitoring shall begin within 60 days following final approval of this plan by the Regional Board's Executive Officer. The annual monitoring report shall be submitted within 6 months after the completion of the final sampling event of the year. Thus, a report must be submitted before June 30th of each year, and it will include any data collected from January 1st through December 31st, from the preceding year. The annual report will also include the following information:

- Introduction and background information
- Documentation and summary of each sampling event
- Discussion of compliance or noncompliance with interim or final waste load allocations
- Tabular results of all samples, including quality assurance quality control samples
- Evaluation of data quality based on QAPP requirements
- Summary of overall LWQMP implementation including a progress report on management strategy implementation (will be included up until the end of the construction of the Prop O project)

The Legal Reporting Unit of the EMD will be responsible for compiling the required data for each annual report. Report templates will be set up in the WISARD database, so that compiling the data will be an automated process, ensuring that data transcription errors are eliminated at this step in the reporting process. Since WPD staff is responsible for the *in-situ* measurements and the collection of samples, a preliminary draft of the report will be provided to WPD for review. Any discrepancies identified in the report will be discussed and resolved through a coordinated effort by WPD and EMD staff. Upon approval of the report, the Division Managers of WPD and EMD will certify the integrity of the data, and the Legal Reporting Unit of EMD will send a hard copy (with approval signatures) of the finalized report to the Executive Officer of the Regional Board. Electronic copies of the final report will also be sent to various stakeholders, and technical staff at the Regional Board. An email distribution list will be created for this purpose, and interested parties can request to be included on this list by contacting the Division Managers at WPD or EMD. The Legal Reporting Unit at EMD

4.3.4 Unofficial Reports

In addition to the required annual report, WPD and/or EMD may develop other standardized reports that summarize monitoring data more frequently (e.g., monthly reports). These reports will be for the purpose managing and assessing the data, as well as providing essential information for lake water quality management. These data would be available to employees in the Bureau of Sanitation who possess a WISARD login ID. For those unable to acquire a WISARD login ID, the data could be emailed to a distribution list set up by the Legal Reporting Unit at EMD. It should be noted, that these reports would be considered "unofficial results" since they will not be certified by WPD and EMD Division Managers, and the data contained would still be subject to review with respect to Data Quality Objectives.

4.4 Health and Safety Plan

In an effort to improve employee safety, health awareness, and prevent occupational-related injuries and illness, participating laboratories and field sampling groups must have a safety program that satisfies applicable federal, state, and local regulations. It is the policy of the City to have a safe working environment for all of their employees and that all field and laboratory work be performed in a manner that provides the maximum level of safety for the protection of every employee.

4.4.1 Health and Safety Plans

EMD maintains it own chemical hygiene plan for its employees, and this plan is deemed sufficient for the protection of EMD staff when handling, analyzing, and disposing of samples.

WPD also maintains its own Health and Safety Plan, including safety considerations that are unique to conducting field work at Machado Lake. A dedicated binder has been established, that holds pertinent information related to the sampling locations for this monitoring program. The binder will be updated as more information is discovered. The Health and Safety Binder will reside at WPD offices, and relevant parts will be reproduced for each field crew before the first sampling event. The binder will contain the following types of items:

- Maps showing nearest hospitals and quickest routes from key locations
- Map showing location of Police headquarters, Fire Departments, and other emergency resources
- All contact information of emergency resources
- Map showing areas of concern or potential hazards as gleaned in the reconnaissance activities and updated over time
- Checklists: vehicle safety, Personal Protective Equipment (PPE), etc.
- Material Safety Data Sheets (MSDS) of chemicals used in the field or calibration room
- Instructions for chemical spill, automotive accident and personal injury response

4.4.2 Sampling Constraints

The health and safety of field and laboratory staff is always the primary concern when conducting monitoring activities. If a sample location is inaccessible or deemed to be unsafe, no sample is required to be collected and comments should be noted on the field log sheet. During wet weather, safety considerations may preclude collection of a sample. In the case of an unforeseen event, every effort will be made to collect another representative sample in a timely manner. Furthermore, certain management practices and/or rehabilitation activities may cause samples from the lake to be "non-representative" of true conditions. If this is deemed to be the case, sampling may be postponed or cancelled until the conditions return to equilibrium.

Section 5
TMDL Compliance Analysis

5.1 Overview

This section describes the anticipated ability of the City to achieve compliance with its responsibilities under the Nutrients TMDL based on the implementation of the BMPs described in Section 3 and utilizing information obtained from the monitoring and reporting plan described in Section 4. As discussed in Section 1, compliance with the TMDL involves the implementation of the following two components:

- **Load allocation (LA)** – TMDL limit applicable to nonpoint sources. At Machado Lake nonpoint sources include nutrients entering the lake from overland flows from the surrounding parkland as well as nutrients generated from internal loading in the lake itself. The agency responsible for nonpoint sources of pollutants is identified in the TMDL as the City of Los Angeles, Department of Recreation and Parks.

- **Waste load allocation (WLA)** – TMDL limit applicable to each point source, including storm drain discharges. The WLA is the responsibility of the following jurisdictions: the MS4 Permittees (including Los Angeles County; LACFCD; the Cities of Carson, Lomita, Los Angeles, Palos Verdes Estates, Rancho Palos Verdes, Redondo Beach, Rolling Hills, Rolling Hills Estates, and Torrance); Caltrans; and the NPDES General Construction and Industrial Stormwater Permittees.

As previously discussed, this LWQMP has been prepared by the City to address actions taken by two of the listed responsible agencies: RAP and BOS. The other responsible jurisdictions will submit separate plans. As such, the compliance analysis detailed here serves to illustrate how the City will comply with its responsibilities under the Nutrients TMDL. It should be noted that this compliance analysis assumes the other responsible jurisdictions will independently be in compliance with the WLAs, as required by the TMDL.

5.2 Compliance Analysis

The City will be implementing a wide range of strategies and BMPs that will work toward reducing nutrient loads in the lake and from the surrounding land within KMHRP as well as reducing sediment loads in runoff from surrounding watersheds. As allowed by the Nutrients TMDL supporting documentation, compliance with the City's commitment to WLAs and LAs under the TMDL can be demonstrated by a combination of documentation of BMPs being implemented and analysis of improvements in lake water quality expected to be achieved by these BMPs. As such, since the LAs and WLAs have the same numeric values as the in-lake numeric water quality targets, overall compliance with targets will be demonstrated through predicting and monitoring concentrations of nutrients within the lake. The analysis contained in this section is based on representing current in-lake and post-BMP in-lake conditions as predicted by the Lake Water Quality Model (see Section 2 and Appendix C).

5.2.1 Interim Compliance

The TMDL includes two interim compliance dates with corresponding interim compliance LAs and WLAs. These dates are March 11, 2009, and September 11, 2014. The final LAs and WLAs must be met by September 11, 2018. Table 5-1 summarizes current water quality conditions as compared to the two interim and one final LAs and WLAs.

Currently, in-lake water quality conditions meet the two interim compliance LAs and WLAs for Total P and Total N as shown in Table 5-1, while there are no interim compliance targets for chlorophyll-*a*, or ammonia-N. Therefore, BMPs that will be implemented are intended to achieve compliance with the final LAs and WLAs.

Table 5-1
Current Conditions Compared to Load Allocations and Waste Load Allocations

Constituent	Current Measured Conditions (average)[1]	Compliance Date and Load/Waste Load Allocations (mg/L)[2]		
		Interim: March 11, 2009	Interim: March 11, 2014	Final: Sept. 11, 2018
Total Phosphorus (mg/L)	0.8	1.25	1.25	0.10
Total Nitrogen (mg/L)	1.8	3.5	2.45	1.0
Chlorophyll-*a* (ug/L)	73	NA	NA	20
Ammonia-N (mg/L)	0.04[3]	NA	NA	5.95 (1-hr)[4] 2.15 (30-day)[4]
Dissolved Oxygen (mg/L)	4.7[5]	NA	NA	5[6]

Current conditions: In-Lake samples were taken at four in-lake locations from June 2006 to September 2008. Note that in-lake measurements include phosphorus concentrations from both internal and external loads.

Notes:
1 See Table 2-1 in Section 2. City of Los Angeles, Watershed Protection Division sampling program. Monthly Average of water quality samples taken at four in-lake locations from June 2006 to September 2008 Most in-lake water quality samples were collected during dry weather periods with low base flow in the drains. No samples were collected during wet weather; however, a few samples were collected one or two days after wet weather events.
2 TMDL Load Allocations as presented in the Amendment to the Water Quality Control Plan – Los Angeles Region to Incorporate the TMDL for Nutrients in Machado Lake.
3 Overall Ammonia-N Average (Table 2-1). Note that the maximum is 0.58 mg/L, also below the load allocations.
4 One hour average and 30 day average, 5.95 mg/L and 2.15 mg/L respectively.
5 The average concentration of oxygen at the bottom depth is 4.7 mg/L, while the minimum measured is 0.46 mg/L.
6 Single sample minimum measured 0.3 meters above the sediment.

5.2.2 Final Compliance Analysis

Currently the concentrations of total nitrogen, total phosphorus and chlorophyll-*a* in the lake exceed the final numeric targets (Table 5-1). Concentrations for ammonia-N are far below the final numeric targets and average values of dissolved oxygen are slightly below the final numeric target. In order to reduce sources and loadings of nutrients and sediment and improve in-lake conditions that will contribute to achieving the targets, the City will implement the following BMPs (see Section 3 for more detailed BMP descriptions):

Non-Point Source:

1. Lake Dredging
2. Add Supplemental Water - Recycled
3. Oxygenation System
4. Off-line treatment wetland
5. Phosphorus removal system
6. Aquatic Plant Management and Littoral Zone Enhancements
7. Shoreline Erosion Control (Lake Edge) Treatments
8. Floating Wetlands (aquatic)
9. Golf Course Maintenance Yard Site BMPs
10. KMHRP Design Improvements (WQ benefits), including Southern Tarplant enhancement

Point Source:

11. In-Lake Sediment Basin - North
12. In-Lake Sediment Basin - West/Project 77 Drain
13. Re-grade Entire Wilmington Drain Channel Bottom
14. Clean box culverts at Lomita Blvd.
15. Clearing and Annual Maintenance for Channel Vegetation
16. CDS at D24010 Drain
17. Bioengineered swale at Project 77 Drain (dry weather treatment)
18. Bioengineered swale at Project 510 Line C Drain (dry weather treatment)

Other:

19. Public Education and Outreach

BMPs Included in the Lake Water Quality Model

The Lake Water Quality Model was developed to estimate nutrient concentrations in Machado Lake after the installation of the first five BMPs listed above (lake dredging, addition of supplemental water, oxygenation system, off-line treatment wetland, and a phosphorus removal system). The nutrient removal potential resulting from these BMPs are included directly in the model because of the substantial amount of data that exists to support their performance, as well as the significant amount of studies done specifically at Machado Lake to establish input assumptions (see Section 2 and Appendix C for a discussion on the model).

The potential contributions to nutrient uptake and removal from the remaining 15 BMPs, numbers 6 through 19 above, were included in the model in two ways.

- **In Lake BMPs:** BMPs 6 through 10 as well as number 19 (public education and outreach) are expected to reduce the internal loading of nutrients in the lake. Since sufficient supporting documentation does not exist to individually quantify the reduction associated with these BMPs, no further reduction was directly accounted for in the model. In affect this adds a minor, though not quantifiable factor of safety to the interpretation of the results.

- **Watershed BMPs:** BMPs 11 through 18 are expected to reduce the concentration of nutrients in the runoff from the upstream watershed. As with the in lake BMPs discussed above, each of these BMPs could not be simulated individually due to insufficient supporting documentation. Again, no overt reduction was taken to account for these BMPs. However, the previously discussed use of long-term average EMC values rather than the short term monitoring data to represent runoff from the upstream watersheds also accounts for miscellaneous upstream BMPs that are part of the project as well as good source control measures that the City will continue to implement within its portion of the watershed.

The following sections describe the predicted post-BMP nutrient concentrations in the lake based on the benefits that can be quantified from the first five BMPs listed above.

5.2.2.1 Predicted In-Lake Nutrient Concentrations after BMP Implementation

The Lake Water Quality Model (Section 2 and Appendix C) was used to simulate the water quality results of implementing these BMPs. Table 5-2 presents predictions of the mean summer water quality conditions expected in 2014, 2018 and 2024, representing one year, five years, and ten years, respectively, after the implementation of the BMPs described in Section 5.2.2 above. The 2014 and 2018 dates also serve as predictions of the second interim and final compliance milestones. Table 5-3 presents the monthly concentrations of total phosphorus, total nitrogen, and chlorophyll-*a* after implementation of all of the BMPs. Summer (May to September) represents the critical period with respect to sustained elevated nutrient concentrations and phytoplankton growth. However, as shown, increases in monthly nutrient concentration can occur during the winter months due to large spikes in loading from rain events.

Table 5-2
Predicted In-Lake Nutrient Concentrations with Current Runoff Concentrations

Constituent	TMDL Numeric Targets (Final Compliance)[1]	Model Predictions[2] 2014 Mean Summer	2018 Mean Summer	2024 Mean Summer
Total Phosphorus (mg/L)	0.1[3]	0.12	0.15	0.16
Total Nitrogen (mg/L)	1.0[3]	1.19	1.21	1.22
Chlorophyll-*a* (ug/L)	20[3]	17	18	19
Ammonia-N (mg/L)	5.95 (1-hr)[4] 2.15 (30-day)[4]	NA[5]	NA[5]	NA[5]
Dissolved Oxygen (mg/L)	5[6]	NA[7]	NA[7]	NA[7]

Notes:
[1] TMDL Load Allocations: Nutrients TMDL.
[2] Predicted concentrations: Machado Lake Lake Water Quality Model described in Appendix C. Assumes that BMPs are installed by 2013. 2014 is therefore 1 year post BMP installation, and 2018 is 5 years post BMP installation, and 2024 is 10 years after BMP installation.
[3] Monthly Average
[4] One hour average and 30 day average, 5.95 mg/L and 2.15 mg/L respectively.
[5] The model does not predict ammonia. BMPs included in Machado Lake Rehabilitation Project are expected to directly decrease ammonia levels in the lake as discussed in Section 5.2.2.4.
[6] Single sample minimum measured 0.3 meters above the sediment.
[7] The model does not predict dissolved oxygen. BMPs included in the Machado Lake Rehabilitation Project directly increase oxygen levels in the lake as discussed in Section 5.2.2.3.

Table 5-3
Modeled Monthly Nutrient Concentrations After Implementation of BMPs

	Monthly mean[1, 2, 3] 2014			Monthly mean[1, 2, 3] 2018			Monthly mean[1, 2, 3] 2024		
Month	TP (mg/L)	TN (mg/L)	Chl-*a* (ug/L)	TP (mg/L)	TN (mg/L)	Chl-*a* (ug/L)	TP (mg/L)	TN (mg/L)	Chl-*a* (ug/L)
April	0.13	0.58	9	0.15	0.60	9	0.16	0.63	10
May	0.12	0.90	13	0.14	0.84	12	0.15	0.75	11
June	0.17	1.73	23	0.19	1.76	24	0.21	1.81	25
July	0.14	1.62	22	0.17	1.65	23	0.19	1.69	24
Aug	0.13	1.48	20	0.15	1.51	21	0.17	1.54	22
Sept	0.08	0.88	12	0.10	1.14	16	0.12	0.90	14
Oct	0.13	0.74	-	0.13	0.70		0.12	0.64	
Nov	0.11	0.34	-	0.12	0.27		0.14	0.32	
Dec	0.24	1.33	-	0.24	1.36		0.23	1.25	
Jan	0.26	1.72	-	0.25	1.52		0.25	1.37	
Feb	0.26	1.61	-	0.26	1.63		0.27	1.70	
March	0.20	0.94	-	0.22	1.15		0.24	1.32	

Note:
[1] Predicted concentrations: Machado Lake Lake Water Quality Model described in Appendix C. Assumes that BMPs are installed by 2013. 2014 is therefore 1 year post BMP installation, 2018 is 5 years post BMP installation, and 2024 is 10 years after BMP installation.
[2] Summer months are the worst case with respect to sustained elevated nutrient concentrations and phytoplankton growth. However, increases in nutrient concentrations can occur during the winter months due to large spikes in loading from rain events. These become more pronounced in the model as summer internal loads are addressed with dredging. Additionally the model assumes that the wetlands only operate during the summer.
[3] The model does not simulate winter phytoplankton. The empirical formulation is intended for summer mean concentration. It is assumed that winter phytoplankton is not the concern due to lower temperatures and sunlight.

Based on the in-lake and other BMPs that the City will be implementing to address nutrient loadings, it is predicted that the lake will meet the chlorophyll-*a* load on a summer time average and may only very slightly exceed the average in a few peak summer months. Implementation of the BMPs is also predicted to substantially reduce the nutrient concentrations in the lake below the current conditions. Phosphorus is predicted to be reduced from a current mean summer value of 0.8 mg/L to a mean summer value of 0.12 mg/L (85 percent reduction) in the first year, while nitrogen is predicted to be reduced from a current mean of 1.8 mg/L to a summer mean of 1.19 mg/L (34 percent reduction) (see Tables 5-1 and 5-2). However, the mean phosphorus and nitrogen concentrations are still predicted to exceed the in-lake numeric targets. Chlorophyll-*a* is predicted to be reduced from its current average concentration of 73 ug/L to 17 ug/L, a 77 percent reduction.

5.2.2.2 Treatment of External Load to meet Nutrients Load and Waste Load Allocations

As shown in Table 2-4 in Section 2, water quality monitoring in the storm drains indicates that phosphorus concentrations in runoff from the watershed may average 0.6 mg/L during both dry and wet weather, and nitrogen concentrations average 2.7 mg/L for dry weather and 2.8 mg/L for wet weather, values that exceed the LAs and WLAs. The tributary area to Machado Lake is approximately 14,156 acres, which is approximately 389 times the surface area of the lake (see Figure 1-2 in Section 1), resulting in substantial runoff loads entering the lake predominantly from wet weather urban runoff. Since the external load of nutrients is substantial, and there is a large tributary area compared to the lake area, the external load will have to be significantly reduced prior to discharge to the lake in order for the lake to consistently attain the nitrogen and phosphorus numeric targets established for the lake. It should also be noted that it is the high external load that causes the elevated internal load to occur during the summer months. As the nutrients are brought to the lake via the urban runoff, they settle within the lake and re-suspend during the summer months. The high load during the winter months is due to spikes in nutrient loads during rain events, which are directly related to the nutrient load in the runoff.

The City of Los Angeles' upstream portion of the watershed is 1,800 acres, or 13 percent of the total watershed. Therefore, 87 percent of the watershed is not within the City of Los Angeles' jurisdiction. As stated previously, since the other upstream jurisdictions are not participating in the activities and BMPs described in this LWQMP, they are required to separately meet their TMDL WLAs by reducing the nutrient concentrations in the runoff from their areas. If the quality of the runoff from the portion of the upstream watershed that is attributed to these responsible jurisdictions were to be reduced through various BMP approaches to achieve the TMDL WLAs of 0.1 mg/L – P and 1.0 mg/L – N, then the external load to Machado Lake would be substantially reduced.

Table 5-4 presents the 2014 summer average concentrations of total phosphorus, total nitrogen, and chlorophyll-*a* assuming in-lake BMPs are installed by 2013. Table 5-4 also presents the model results for 2018 and 2024, which further assumes that by 2018 the other responsible jurisdictions will be meeting their final TMDL WLAs.

Table 5-4
Predicted In-Lake Nutrient Concentrations with Upstream Jurisdictions Meeting the TMDL Waste Load Allocations

Constituent	TMDL Numeric Targets (Final Compliance by 2018)[1]	Model Predictions[2]		
		2014 Mean Summer	2018 Mean Summer	2024 Mean Summer
Total Phosphorus (mg/L)	0.1[3]	0.12	0.08	0.08
Total Nitrogen (mg/L)	1.0[3]	1.19	0.58	0.57
Chlorophyll-*a* (ug/L)	20[3]	17	8	8
Ammonia-N (mg/L)	5.95 (1-hr)[4] 2.15 (30-day)[4]	NA[5]	NA[5]	NA[5]
Dissolved Oxygen (mg/L)	5[6]	NA[7]	NA[6]	NA[6]

Notes:
1 TMDL Load Allocations: Nutrients TMDL. Final compliance targets are shown, which must be met by 2018. Interim compliance targets are presented in Table 5-1.
2 Predicted concentrations: Machado Lake Lake Water Quality Model described in Appendix C. Assumes that BMPs are installed by 2013. 2014 is therefore 1 year post BMP installation, and 2018 is 5 years post BMP installation, and 2024 is 10 years after BMP installation. It is assumed that the other responsible jurisdictions, which account for 87 percent of the tributary drainage area, are in compliance with their WLA starting in 2018.
3 Monthly Average
4 One hour average and 30 day average, 5.95 mg/L and 2.15 mg/L respectively.
5 The model does not predict ammonia. BMPs included in Machado Lake Rehabilitation Project are expected to directly decrease ammonia levels in the lake as discussed in Section 5.2.2.4.
6 Single sample minimum measured 0.3 meters above the sediment.
7 The model does not predict dissolved oxygen. BMPs included in the Machado Lake Rehabilitation Project directly increase oxygen levels in the lake as discussed in Section 5.2.2.3.

Table 5-5 presents the 2014, 2018 and 2024 monthly concentrations (one year, five years, and ten years after BMP implementation) of total phosphorus, total nitrogen, and chlorophyll-*a* also assuming the in-lake BMPs are installed by 2013 in addition to the other responsible jurisdictions meeting their TMDL WLAs by 2018.

Assuming that these other upstream responsible jurisdictions were to fully meet the TMDL WLAs in runoff reaching the lake, the model predicts the in-lake nutrient concentrations will be consistently at or below the total phosphorus, total nitrogen and chlorophyll-*a* targets throughout the year.

Table 5-5
Modeled Monthly Nutrient Concentrations Based on In-Lake BMPs and Assuming Other Jurisdictions Meeting TMDL WLAs

	Monthly mean[1, 2, 3] 2014			Monthly mean[1, 2, 3] 2018			Monthly mean[1, 2, 3] 2024		
Month	**TP (mg/L)**	**TN (mg/L)**	**Chl-*a* (ug/L)**	**TP (mg/L)**	**TN (mg/L)**	**Chl-*a* (ug/L)**	**TP (mg/L)**	**TN (mg/L)**	**Chl-*a* (ug/L)**
April	0.13	0.58	9	0.07	0.25	2	0.07	0.25	2
May	0.12	0.90	13	0.07	0.39	4	0.07	0.35	3
June	0.17	1.73	23	0.09	0.76	11	0.09	0.76	11
July	0.14	1.62	22	0.09	0.78	12	0.09	0.78	12
Aug	0.13	1.48	20	0.09	0.78	12	0.09	0.78	12
Sept	0.08	0.88	12	0.07	0.50	6	0.07	0.49	6
Oct	0.13	0.74	-	0.07	0.34	-	0.05	0.27	-
Nov	0.11	0.34	-	0.06	0.14	-	0.06	0.13	-
Dec	0.24	1.33	-	0.09	0.50	-	0.09	0.46	-
Jan	0.26	1.72	-	0.10	0.59	-	0.10	0.50	-
Feb	0.26	1.61	-	0.10	0.60	-	0.10	0.62	-
March	0.20	0.94	-	0.09	0.39	-	0.09	0.47	-

Note:
[1] Predicted concentrations: Machado Lake Lake Water Quality Model described in Appendix C. Assumes that BMPs are installed by 2013. 2014 is therefore 1 year post BMP installation, and 2018 is 5 years post BMP installation, and 2024 is 10 years after BMP installation. It is assumed that the other responsible jurisdictions, which account for 87 percent of the tributary drainage area, are in compliance with their WLA starting in 2018.
[2] Summer months are considered the worst case with respect to sustained elevated nutrient concentrations and phytoplankton growth. However, increases in nutrient concentrations can occur during the winter months due to large spikes in loading from rain events. These become more pronounced in the model as summer internal loads are addressed with dredging. Additionally the model assumes that the wetlands only operate during the summer.
[3] The model does not simulate winter phytoplankton. The empirical formulation is intended for summer mean concentration. It is assumed that winter phytoplankton is not the concern due to lower temperatures and sunlight.

5.2.2.3 Dissolved Oxygen Numeric Target

The TMDL also sets a minimum concentration of DO in the lake at 5 mg/L, measured 0.3 meters above the sediment. As shown in Table 2-1 in Section 2, the current minimum observed DO concentration is 0.5 mg/L, while the current average is 4.7 mg/L on the bottom of the lake. While the Lake Water Quality Model does not predict the concentration of DO in the lake, the Machado Lake Rehabilitation Project includes installation of an oxygenation system which will increase DO levels in the lake. The oxygenation system will inject pure oxygen into the lake through a Speece cone. The Speece cone involves a downflow bubble contactor that will extract water from the bottom of the lake and inject pure oxygen at the top of the device. This will create a "bubble swarm" in the center of the cone, which will achieve a 95 percent transfer of oxygen to the water. Through a pipe with increasing diameter (allowing the velocity to slow as the water flows downward) the water will be re-injected back into the bottom of the lake. This system will be used primarily during the period of March through November when the oxygen levels are lower. The system will be designed to be able to maintain DO concentrations at or above 5 mg/L.

5.2.2.4 Ammonia Numeric Target

The TMDL also sets a minimum concentration of ammonia (NH4) in the lake as both a 1-hour average limit of 5.95 mg/L and a 30-day average of 2.15 mg/L. As shown in Table 2-1 in Section 2, the current monitoring data shows that the average in-lake measurement was 0.04 mg/L NH4, which is substantially below the numeric targets.

Further, the ratio of NH4:TN is expected to remain consistent. The average ratios of NH4:TN (ammonia to total nitrogen) from historical measured data in the lake is 0.04 mg/L NH4 : 1.8 mg/L TN (average values presented in Table 2-1), which means that the TN concentration is 45 times the NH4 concentration. Since the future TN value following full implementation of the BMPs is predicted to be 0.6 mg/L (Table 5-4) then using the same ratio of NH4:TN, the NH4 concentration would be 45 times less than 0.6 mg/L TN, or 0.001 mg/L NH4. As this value is far below the numeric limit for NH4, it is expected that the ammonia concentration would meet the TMDL numeric target.

Moreover, the oxygenation system will increase the DO levels in the lake thus promoting greater nitrification; consequently, the ratio of NH4:TN will likely be even lower in the future.

5.3 Sensitivity Analysis

In order to assess the sensitivity of the lake water quality model to individual model input parameters, a "jack-knifing" procedure was employed. The term "jack-knifing" commonly refers to the process of varying individual model parameters, in isolation and within reasonable ranges, to assess model sensitivity. In general, the analysis shows moderate to low model sensitivity (within $\pm$ 25%) to the majority of input parameters for the given perturbation ranges, indicating a robust model. More importantly, for the specific application of the model presented in this document, none of the perturbations resulted in excursions above the TMDL targets for any of the three output variables. The analysis identified the greatest model sensitivity is related to lake depth, sediment nitrogen parameters, and wetland and water column nitrogen uptake rates. Details of the analysis are provided in Appendix C.

5.4 Uncertainty Analysis

The jack-knife analysis described above provides useful information on model sensitivities to individual parameters and also provides initial steps in quantifying model prediction uncertainty. As described in Appendix C, a moderate level of uncertainty in model predictions can be attributed to model parameterization, although this is lessened by the fact that the parameterization is supported by measured data, model calibration efforts, and sound engineering judgment and experience. However, an additional source of significant uncertainty in the model predictions is that associated with input parameters that we know to be "naturally" variable. In the lake water quality model, such parameters are generally linked to weather and hydrology, both of which introduce elements of randomness and unpredictability. To address this category of uncertainty, a stochastic version of the Machado Lake Water Quality model was developed.

The stochastic version of the Machado Lake Water Quality model was constructed using the @RISK software (*Palisade Corporation*), an add-in to Excel (*Microsoft)*. In this version of the model, selected model parameters were allowed to vary stochastically during model simulation, rather than assumed constant. Probability distribution functions were fit to available data for each stochastic variable. These probability distribution functions describe the expected variability of each stochastic variable using continuous functions. Model output (N, P, and Chl-a concentrations) are presented as cumulative probability distribution functions across a range of values, rather than as single concentrations. This type of output provides valuable insight into the risk of concentration target exceedances and the level of uncertainty associated with each output parameter due to natural random variability.

Results show that all of the calculated output concentration probability curves for the baseline (post-BMP) system are relatively flat, indicating limited sensitivity to the inflow concentration and flow variability modeled. It is also noteworthy that both the N and chl-a output curves lie fully below the TMDL targets, while the P curve extends slightly above the target only at approximately the 40% exceedance level. We can conclude from these results that, given the assumed effectiveness of in-lake and watershed mitigation efforts, the risk of exceeding TMDL targets as a result of randomness in weather and inflow concentration patterns is low. Further details of this analysis are provided in Appendix C.

5.5 Healthy Lake Goals

The historical trophic state of Machado Lake was investigated in the paleolimnologic study summarized in Section 2.2, which states that it is likely that the waters of Machado Lake have been mesotrophic to eutrophic for the past 66 years (1943 to 2009). Further, the diatoms that have persisted over this time period indicated that the lake has consistently had high nutrient concentrations.

Additionally, whereas typical lakes have lake to watershed ratios less than 1: 100, Machado Lake has a very high surface area to watershed area of 1: 389 acres, which is indicative of a lake that would have eutrophic conditions (Horne & Goldman, 1994).

These two pieces of information indicate that the lake not only has been eutrophic historically, but also that the nature of the drainage area nearly guarantees that the lake would be eutrophic.

Phosphorus and nitrogen are the key nutrients for photoplankton growth in lakes, and are responsible for the eutrophication of surface waters (Regional Board, 2008). However, ultimately the most direct measure of a healthy lake with respect to eutrophication is the concentration of algal biomass, as measured by chlorophyll-*a*. While N and P concentrations are primary drivers of algal growth, they are not the only drivers. Lake morphology, sunlight, and temperature are examples of other variables that impact algal concentrations. Consequently, N and P concentrations in the lake should be viewed as indirect measures of a healthy lake, with respect to eutrophication. The relationship between nutrient concentrations and chlorophyll-*a* concentrations varies by lake and is impossible to define exactly even with the most robust of models. Therefore, it is recommended that focus the water quality management be placed on the chlorophyll-*a* concentration reduction rather than N and P concentrations. The TMDL acknowledges that:

> *"If water quality improves and the numeric targets for chlorophyll a and dissolved oxygen are achieved and the allocations and/or numeric targets for nitrogen and phosphorus have not been achieved, the TMDL may be reconsidered to adjust the allocations and targets. Moreover, if nitrogen and phosphorus allocations and numeric targets are met and the chlorophyll a and dissolved oxygen numeric targets are exceeded, the TMDL may be reconsidered to adjust the allocations and targets."*

The analysis conducted to support this LWQMP indicates that is it likely that with implementation of all the proposed BMPs and management activities, the targets for chlorophyll-*a* and dissolved oxygen can be achieved at Total-P and Total-N concentrations somewhat higher than the established numerical targets. It is anticipated that this condition can be consistently achieved and demonstrated through monitoring following completion and operation and maintenance of the BMPs, therefore reconsideration of targets and/or allocations in the TMDL would be warranted.

5.6 Summary

The lake is currently in compliance with the LAs and WLAs for the two interim compliance dates. The City is currently in the design phase of the *Machado Lake Ecosystem Rehabilitation and Wilmington Drain Multi-Use Project*, and the in-lake BMPs and other activities that are part of this project are predicted by the Lake Water Quality Model to reduce phosphorus concentrations in the lake by 85 percent and nitrogen concentrations by 34 percent. Chlorophyll-*a* is predicted to be reduced 77 percent, and effectively below the numeric target of the TMDL. Dissolved oxygen and ammonia are also predicted to maintain or achieve levels that will consistently meet the numeric targets of the TMDL.

The Machado Lake Water Quality Model has illustrated that full implementation of the BMPs that the City of Los Angeles is committed to will not result in the lake consistently meeting the total phosphorus and total nitrogen targets in the TMDL due to the substantial external annual wet weather runoff loading of phosphorus and nitrogen to the lake. Therefore, if the nutrient targets are to be consistently met in addition to the chlorophyll-*a* targets, concentrations of phosphorus and nitrogen in the runoff of the entire watershed must be reduced prior to discharge to the lake.

Eighty-seven percent (87%) of the upstream portion of the watershed consists of land and other features that are outside of the City of Los Angeles' jurisdiction. The Lake Water Quality Model shows that if the other responsible jurisdictions located upstream of the lake reduced nitrogen and phosphorous in the runoff to achieve the required TMDL WLAs prior to its discharge to the lake by 2018, the in-lake nutrient concentrations should be at or below the total phosphorus, total nitrogen and chlorophyll-*a* targets throughout the year. In the event that the targeted nutrient reductions in the upstream watersheds are not fully achieved by 2018, it should be noted that chlorophyll-*a* and dissolved oxygen targets could still be met, and if this is demonstrated through monitoring following completion and operation and maintenance of the BMPs, reconsideration of targets and/or allocations in the TMDL would be warranted.

Section 6
Capital Costs and Long-Term Maintenance Requirements

A construction cost estimate based on the 50 percent design drawings prepared for the *Machado Lake Ecosystem Rehabilitation and Wilmington Drain Multi-Use Project* is summarized in Section 6. A summary of general long-term maintenance strategies associated with the some of the BMPs outlined in Section 3 is also provided. Through the collaborative effort of the City and LACDPW the construction and long-term maintenance of BMPs will result in water quality compliance and ecosystem restoration.

6.1 Capital Costs for Construction

Detailed capital cost estimates for construction were developed according to City of Los Angeles Bureau of Engineering guidelines and Proposition O estimating procedures. These guidelines and procedures include using the following estimating factors:

- Mobilization allowance – 4 percent
- Permitting Allowances – 3 percent
- Other Allowances – 5 percent
- Estimating contingency – 20 percent
- Construction cost escalation – 6 percent per year (to mid-point of construction)
- Construction contingency – 10 percent (allows for construction change orders)

Table 6-1 provides costs for the construction of the management strategies presented in Section 3. Table 6-1 does not mimic line for line Tables 3-1 and 3-2 for costs because there are other necessary construction components or steps associated with various BMPs that were itemized in Table 6-1. These cost estimates will be further refined for the City prior to release of the bidding package.

The construction cost estimate shown in Table 6-1 is subdivided into three parts: City costs for construction of BMPs for Machado Lake, City costs for construction of BMPs for Wilmington Drain, and LACDPW costs for Wilmington Drain. For Wilmington Drain, the estimate assumes that a portion of the work will be funded by LACDPW, such as those features proposed to improve flood control capacity. All other costs are assumed to be funded through Proposition O and are shown as City costs. The cost allocated to the City is $82,762,000 with the 10 percent construction contingency. The cost allocated to LACDPW is $4,140,000. The total estimated cost is $86,902,000. Costs are not provided for any of the additional design elements that are part of the Machado Lake Ecosystem Rehabilitation and Wilmington Drain Multi-Use Project below the Machado Lake dam (e.g., in the Freshwater Marsh). This preliminary cost summary is provided to demonstrate the magnitude of the commitment from the City and LACDPW to water quality and ecosystem restoration.

Table 6-1 Cost Estimate for Wilmington Drain and Machado Lake Construction

DESCRIPTION	50% Design Estimate[1]
MACHADO LAKE	
Lake Dredging	$33,852,000
Lake Edge Treatment	$1,020,000
SUBTOTAL	**$34,872,000**
Storm Water BMPs	
D24010 Drain	$266,000
Project 77 Drain	$352,000
Site Source Control	$274,000
Bioengineered Swale @ Project 77	$175,000
510 Swale & Headwall	$101,000
Wetlands	
Riparian Area	$328,000
Offline Recirculation Wetlands	$735,000
Lake Rehabilitation	
Oxygenation system	$2,191,000
Phosphorus Removal System	$622,000
Dam Improvements	$709,000
Storm Drain	$22,000
Park Components	$4,741,000
Invasive Plant Removal	$1,984,000
Recycled Water Make-up MF/RO	$137,000
SUBTOTAL	**$12,637,000**
SUBTOTAL	**$47,509,000**
Mobilization	$1,503,000
Permit Allowances	$1,127,000
Other Allowances	$1,879,000
Contingency Costs	$19,466,000
TOTAL	**$71,484,000**
WILMINGTON DRAIN	
Los Angeles City	
Invasive/Exotic Plant Removal	846,000
Landscape	2,886,000
Landscape Maintenance	209,000
110 Freeway Trash Net Unit	3,336,000
510 Drain Trash Net Unit	305,000
Vegatative Swale	13,000
Rip Rap	9,000
Catch Basins for Access Road and Pocket Park	58,000
Concrete Pipe with Headwall	45,000
Retaining Wall	131,000
SUBTOTAL	**7,838,000**
Mobilization	132,000
Permit Allowance	99,000
Other Allowance	165,000
Contingencies	3,044,000
TOTAL	**11,278,000**
Los Angeles County	
Channel Contouring-Between Lomita and PCH (26,450.00 cy)	2,425,000
Channel Contouring-North of Lomita (550.00 cy)	55,000
Channel Contouring-South of PCH (300.00 cy)	30,000
Channel Contouring-Maintenance Roads (750.00 cy)	91,000
Turf Reinforcement Mat (5,485.00 sy)	22,000
Ramps (5,600.00 sf)	164,000
SUBTOTAL	**2,787,000**
Mobilization	83,000
Permit Allowance	63,000
Other Allowance	104,000
Contingencies	1,103,000
TOTAL	**4,140,000**
GRAND TOTAL	**$86,902,000**

1 Cost subject to change, long-term maintenance costs are not included.

6.2 Long-term Maintenance Requirements

Many of the BMPs selected for inclusion in the *Machado Lake Ecosystem Rehabilitation and Wilmington Drain Multi-Use Project* will require ongoing operational oversight and periodic, routine maintenance. Long-term maintenance is necessary for the optimal performance of each BMP to achieve the greatest capacity for pollutant reductions and improved ecosystem functioning. The City and LACDPW are in the process of establishing a Memorandum of Understanding to outline the roles and responsibilities that will guide the routine maintenance activities which include:

- Inspections
- Reporting and information management
- Equipment maintenance and repair
- Trash removal from the trash net systems
- Sediment and trash removal from the CDS units
- Potential caustic solution removal and disposal from phosphorus removal system
- Lake aquatic vegetation and biomass management and removal
- Terrestrial vegetation management with trash and minor debris removal
- Park facilities and structures maintenance
- Vector control

Other corrective and infrequent maintenance activities (e.g., unplanned and/or every 3 years or more) include:

- Wetland and channel aquatic vegetation and biomass management and removal
- Dredging of sedimentation basins and channel area (as necessary)
- Intermittent facility maintenance
- Sediment removal from Wilmington Drain and other Machado Lake storm water BMPs

Maintenance activities in Wilmington Drain and KMHRP are subjected to stipulations in three permits:

- California Department of Fish and Game (CDFG) – Streambed Alteration Agreement (SAA)
- Regional Water Quality Control Board – Section 401 Water Quality Certification
- Unites States Army Corps of Engineers (USACE) 404 Permit

These permits will be issued prior to the start of construction.

The City and LACDPW have existing standard operating procedures (SOPs) for maintenance requirements associated with some of the recommended BMPs. Additional SOPs may need to be developed by both agencies in conjunction with various vendors associated with some of the storm water BMPs. The two agencies prepared Table 6-2 to provide a roadmap of future operations and maintenance strategies that, with appropriate resources, can be implemented over time. Table 6-2 provides a summary of the BMPs discussed in Section 3, the agency responsible for operation and maintenance, and a general description of the recommendation associated with maintenance to ensure optimum performance of each BMP.

Table 6-2
Operations and Maintenance Recommendations for Management Strategies

Management Strategy	Operations and Maintenance Responsibility	Operations and Maintenance Recommendations	Proposed Reporting and Information Management
Lake Dredging	LA City	Re-evaluate every 10 years	Yes –tons of sediment removed from system
Add Supplemental Water – microfiltration/reverse osmosis	LA City	Annual valve inspection and water use tracking: SOPs established between TIWRP and City	Yes – monthly water use
Oxygenation System	LA City	Annual pump station maintenance, SOP established between Speece Cone manufacturer and City	Yes – changes in DO concentrations within lake
Off-line Treatment Wetland	LA City	Annual pump station maintenance, inspection of valves and inlet and discharge facilities. Biomass harvesting ~ 3-yr cycle; SOPs established by City	None.
Phosphorus Removal System	LA City	Annual maintenance of treatment vessels and media filters; potential for caustic solution disposal; SOPs established between manufacturer and City	Yes – changes in phosphorus concentrations
Aquatic Plant Management and Littoral Zone Enhancements, including Ludwigia removal	LA City	Seasonal maintenance as needed; SOPs established by City	Yes – tons of plant biomass removed
Shoreline Erosion Control (Lake Edge) Treatments	LA City	Maintenance program for all park design elements and facilities; SOPs established by City	None.
Floating Islands (aquatic)	LA City	Biomass harvesting ~ 3-yr cycle: SOPs established by City	Yes – tons of plant biomass removed
Golf Course Maintenance Yard Site BMPs	LA City	Maintenance program for all design elements and facilities; SOPs established by City	None.
KMHRP Design Improvements (WQ benefits), including Southern Tarplant enhancement	LA City	Maintenance program for all park design elements and facilities; SOPs established by City	None.
In-Lake Sediment Basin – North (captures inflows from Drain P6545, Drain D24010, and Wilmington Drain)	LA City	Sediment, trash removal and disposal as needed; SOPs established by City	Yes –tons of sediment removed from system

Table 6-2
Operations and Maintenance Recommendations for Management Strategies

Management Strategy	Operations and Maintenance Responsibility	Operations and Maintenance Recommendations	Proposed Reporting and Information Management
In-Lake Sediment Basin - West/Project 77 Drain (and Project 510)	LA City	Sediment, trash removal and disposal as needed; SOPs established by City	Yes - tons of sediment removed from system
Re-grade entire Wilmington Drain channel bottom (2011)	LACDPW	Re-evaluate every 10 years	Yes - tons of sediment removed from system
Clean box culverts at Lomita Blvd.	LACDPW	Re-evaluate every 10 years	Yes - tons of sediment removed from system
Clearing and annual maintenance of channel vegetation	LACDPW	Annual maintenance program required to maximize hydraulic capacity of Wilmington Drain; SOPs established by LACDPW	Yes – annual biomass removed
CDS at D24010 Drain	LA City	Sediment, trash removal and disposal as needed; SOPs established between manufacturer and City	Yes –tons of trash or sediment removed from system
Bioengineered swale at Project 77 Drain (dry weather treatment)	LA City	Maintenance as needed: SOPs established by City	None.
Bioengineered swale at Project 510 Line C Drain (dry weather treatment)	LA City	Maintenance as needed; SOPs established by City	None.
Trash Nets (Wilmington Drain at Fwy 110; Wilmington Drain Project 510 Drain; Project 77 Drain	LA City	Seasonal maintenance as needed; SOPs established by City	Yes –tons of trash removed from system.
Wilmington Drain Pocket Park	LA City	Maintenance program for all park design elements and facilities; SOPs established by City	None.
Dam Improvements	LA City	Maintenance as needed; SOPs established by City	None.
Invasive Plant Removal - Riparian Woodland	LA City	Annual maintenance program for all park design elements and facilities; SOPs established by City	Yes - annual biomass removed

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Section 7
Data and References

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Appendix A:
Memorandum of Agreement
Between
California Regional Quality Control Board
And
City of Los Angeles

For

The Machado Lake Nutrient TMDL Monitoring & Reporting Program

Prepared by
City of Los Angeles
Department of Public Works
Bureau of Sanitation
Watershed Protection Division

August 18, 2010

MEMORANDUM OF AGREEMENT

BETWEEN

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD
LOS ANGELES REGION

AND

CITY OF LOS ANGELES

REGARDING IMPLEMENTATION OF LOAD ALLOCATIONS FOR THE TOTAL MAXIMUM DAILY LOAD FOR EUTROPHIC, ALGAE, AMMONIA, AND ODORS (NUTRIENTS) IN MACHADO LAKE

This MOA is made and entered into as of the date of the last Party signature set forth below by and among the City of Los Angeles, a body corporate and politic, through its Departments of Recreation and Parks ("Rec & Parks") and Public Works (collectively referred to as "City of Los Angeles"); and the Los Angeles Regional Water Quality Control Board; (individually "Party" and collectively, "Parties").

Whereas, on May 1, 2008 the Los Angeles Regional Water Quality Control Board (Regional Board) adopted an amendment to the Water Quality Control Plan for the Los Angeles Region (Basin Plan) to incorporate a Total Maximum Daily Load for Eutrophic, Algae, Ammonia, and Odors (Nutrients) in Machado Lake (TMDL) (Resolution No. 2008-006);

Whereas, the amendment incorporating the TMDL was subsequently approved by the State Water Resources Control Board on December 2, 2008, the Office of Administrative Law on February 19, 2009, and the United States Environmental Protection Agency on March 11, 2009;

Whereas, the TMDL became effective on March 11, 2009;

Whereas, TMDLs are not self-executing and are, therefore, implemented through regulatory and non-regulatory programs appropriate to the source and nature of the pollutant discharges;

Whereas, the TMDL addresses nutrient loading to Machado Lake from both point and nonpoint sources;

Whereas, the TMDL provides that the interim and final load allocations assigned to nonpoint sources may be implemented through a Memorandum of Agreement (MOA);

Whereas, the MOA may be entered into by the Regional Board and the party assigned responsibility for the interim and final load allocations established in the Machado Lake Nutrient TMDL;

Whereas, the City of Los Angeles, Department of Recreation and Parks is the responsible jurisdiction assigned interim and final load allocations in the TMDL for non-point sources, and the City of Los Angeles, Department of Public Works is identified as one of the responsible jurisdictions assigned interim and final waste load allocations in the TMDL;

Whereas, the MOA must meet the requirements for development of a non-regulatory implementation program as presented in the *Water Quality Control Policy for Addressing Impaired Waters: Regulatory Structure and Options* (State Board Resolution 2005-0050) section 2 (c) (ii);

Whereas, the implementation of the Lake Water Quality Management Plan (LWQMP), as described in Section IV, must result in attainment of the interim and final load allocations;

Now, Therefore, in consideration of the mutual benefits and promises made herein, the Parties do hereby agree as follows:

AGREEMENT

I. PURPOSE

1. It is the joint goal of the City of Los Angeles and the Regional Board to protect and improve the water quality in Machado Lake.

2. This MOA is established to implement the LWQMP to attain the interim and final load allocations (LAs) of the Machado Lake Nutrient TMDL and restore the lake's beneficial uses. Responsible parties shall comply with numeric interim LAs or may be deemed in compliance with the interim LAs through implementation of lake sediment removal and/or lake management implementation actions in accordance with the LWQMP schedule as approved by the Regional Board Executive Officer.

3. This MOA is intended to create a partnership between the City of Los Angeles and the Regional Board to implement actions to achieve the interim and final load allocations.

4. The Parties shall cooperate fully with one another to attain the purposes of this MOA.

5. This MOA satisfies the requirements of Regional Board Resolution No. 2008-006 and the *Water Quality Control Policy for Addressing Impaired Waters: Regulatory Structure and Options* (State Board Resolution 2005-0050) section 2 (c) (ii).

II. CITY OF LOS ANGELES RESPONSIBILITIES

1. The City of Los Angeles shall develop a LWQMP for approval by the Regional Board Executive Officer.

2. The LWQMP shall meet the criteria described in Tables 7-29.1 and 7-29.2 of the Basin Plan in Attachment A to Resolution R08-006 (Attachment A).

3. The City of Los Angeles shall provide the monitoring services required in the LWQMP based on the requirements of the TMDL per Attachment A to Regional Board Resolution No. R08-006 (Attachment A).

4. The LWQMP shall include a list of cooperating parties. Cooperating parties includes stormwater permittees, who have chosen to demonstrate compliance by actively participating in a LWQMP and reducing external nutrient loading to attain waste load allocations measured in the lake.

5. The LWQMP shall address appropriate water quality monitoring and a timeline for the implementation of management strategies as described in paragraph 7 below. The timeline shall ensure that the implementation actions are underway prior to the Regional Board's scheduled reconsideration of the TMDL in September 2016.

6. The LWQMP shall present a comprehensive management plan and strategy for achieving the interim and final load allocations in Machado Lake and attaining numeric targets and beneficial uses.

7. The LWQMP shall achieve compliance with the interim and final load allocations through the implementation of lake management strategies to reduce and manage internal nutrient sources. The lake management implementation actions may include, but are not limited to the following:

   - Wetland restoration
   - Aeration system
   - Hydraulic Lake dredging
   - Hydroponic Islands
   - Alum treatment
   - Fisheries Management
   - Macrophyte Management and Harvesting
   - Maintain Lake Level – Supplemental Water

8. The LWQMP shall include a Monitoring and Reporting Program (MRP) Plan. The MRP Plan shall include submission of an annual monitoring report to the Regional Board.

9. The MRP Plan shall also include a requirement that the City of Los Angeles and cooperating parties report attainment and non-attainment with interim and final load allocations as part of the annual monitoring reports. Attainment of the interim and final load allocations shall be based on measurements in the lake at two locations, one in the north portion and one in the south. The average (arithmetic mean) total nitrogen (TN) concentration from these two sampling locations shall determine attainment of the TN interim and final load allocation. The average (arithmetic mean) total phosphorus (TP) concentration from these two sampling locations shall determine attainment of the TP interim and final load allocation.

10. MRP Plan protocols shall be based on Surface Water Ambient Monitoring Program (SWAMP) protocols for water quality monitoring or alternative protocols proposed by the City of Los Angeles and cooperating parties and approved by the Regional Board Executive Officer.

11. A Quality Assurance Project Plan (QAPP) shall be submitted to the Regional Board for approval by the Regional Board Executive Officer to ensure data quality. The QAPP shall include protocols for sample collection, standard analytical procedures, and laboratory certification. The QAPP shall be based on SWAMP protocols for water quality monitoring and quality assurance or alternative protocols proposed by the City of Los Angeles and cooperative parties and approved by the Regional Board Executive Officer.

12. The LWQMP, MRP Plan, and QAPP shall be submitted by September 11, 2010, for approval by the Regional Board Executive Officer.

13. Implementation of the LWQMP program shall include a Health and Safety Plan to protect personnel.

III. Regional Board Responsibilities

1. Regional Board staff shall provide assistance to the City of Los Angeles in the form of technical guidance and timely review and approval of the LWQMP, MRP Plan, and QAPP.

2. Regional Board staff shall review the annual monitoring report in a timely manner, in order to evaluate the progress of lake management activities and ensure attainment of interim and final load allocations.

3. Regional Board staff shall solicit input from the City of Los Angeles and other stakeholders regarding the TMDL reconsideration scheduled for September 2016.

4. Regional Board staff will share information (e.g. monitoring data), provided by other responsible jurisdictions in compliance with their waste load allocation, with the City of Los Angeles.

IV. Evaluation

Any evaluation of the MOA should be a cooperative process between the Regional Board and the City of Los Angeles. The intent of the evaluation is to identify those aspects of the MOA that are producing the desired result and those that need improvement.

This MOA may be reviewed and re-negotiated at any time based on the LWQMP annual monitoring report.

No part of this MOA shall be amended except upon formal written agreement of the Parties to do so.

This MOA shall be reviewed, by the Regional Board Executive Officer and the City of Los Angeles, six months after the scheduled TMDL reconsideration (March 11, 2017) to be consistent with any potential changes to the TMDL made as part of the reconsideration.

V. GENERAL PROVISIONS

Governing Law – This MOA is governed by, interpreted under, and construed and enforced in accordance with the laws of the State of California

Severability – If any provision of this MOA shall be determined by any court to be invalid, illegal or unenforceable to any extent, the remainder of this MOA shall not be affected and this MOA shall be construed as if the invalid, illegal or unenforceable provision had never been contained in this MOA, subject to the Parties right to terminate in Section IX below.

VI. DURATION

Subject to the provisions of Part VII, this MOA shall remain in effect unless an evaluation, as specified in Part IV, or review of annual monitoring reports as specified in Part III provides cause for termination by the Regional Board Executive Officer due to non-attainment of load allocation compliance.

VII. TERMINATION

The Regional Board and the City of Los Angeles shall be responsible for ensuring that the terms of the MOA are enforced. If an evaluation shows that the Regional Board or the City of Los Angeles is not carrying out its responsibilities as required by the MOA and the Regional Board or the City of Los Angeles does not amend its process per agreement, the Regional Board or the City of Los Angeles may terminate this MOA for cause. The party proposing to terminate the MOA for cause shall provide the other party written notice charging failure of MOA responsibilities. The party proposing to terminate the MOA shall provide a reasonable amount of time for the other party to address the charges. If the charges are not adequately addressed and/or the parties MOA responsibilities not carried out, the MOA may be terminated upon thirty-day written notice.

This MOA may be renegotiated by request of the Regional Board or the City of Los Angeles. Either party may terminate this MOA without cause upon thirty-day prior written notice to the other party.

The Basin Plan requires that the implementation of this MOA must result in attainment of the Machado Lake Nutrient TMDL interim and final load allocations. If this MOA and the LWQMP are not implemented or otherwise do not result in attainment of the interim and final load allocations, the Basin Plan requires that the MOA shall be terminated by the Regional Board and the interim and final load allocations shall be implemented through an appropriate regulatory order such as a cleanup and abatement order pursuant to Water Code section 13304.

VIII. Effective Date

The effective date of this MOA shall be the date of the last Party's signature. The MOA shall be binding upon and shall inure to the benefit of the respective successors, heirs and assigns of each Party.

IX. Acceptance

In Witness Whereof, the Parties to this MOA have caused this MOA to be executed on their behalf, respectively, as follows:

3/11/10
Date

Executive Officer
Los Angeles Regional Water Quality Control Board

CITY OF LOS ANGELES DEPARTMENT OF PUBLIC WORKS

By: Cynthia M. Ruiz
Cynthia M. Ruiz, President
Board of Public Works

Date: 3/10/2010

APPROVED AS TO FORM:

Carmen A. Trutanich
City Attorney

By: Ed M. Jordan
Edward M. Jordan
Assistant City Attorney

Date: 3-4-2010

CITY OF LOS ANGELES DEPARTMENT OF RECREATION AND PARKS

By: ______________________
Barry A. Sanders, President
Board of Recreation and Parks

Board Secretary

Date: 4-7-10

APPROVED AS TO FORM:

Carmen A. Trutanich
City Attorney

By: ______________________
Mark Brown
Sr. Assistant City Attorney

Appendix B:
Quality Assurance Project Plan

For

The Machado Lake Nutrient TMDL Monitoring & Reporting Program

Prepared by
City of Los Angeles
Department of Public Works
Bureau of Sanitation
Watershed Protection Division

Version 1.0
August 18, 2010

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Appendix B
Quality Assurance Project Plan

Group A Elements:
Project Management
B.1 Title and Approval Sheets

PROJECT NAME:	The Machado Lake Nutrient TMDL Monitoring Program
PROPOSAL IDENTIFICATION NUMBER:	N/A
DATE:	August 18, 2010
NAME OF RESPONSIBLE ORGANIZATION:	City of Los Angeles, Department of Public Works

Approval Signatures

PROJECT ORGANIZATION:

Title:	Name:	Signature:	Date:
Project Director	**Shahram Kharaghani**		
Project QA Officer	**Vivian Marquez**		

LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD (RWQCB):

Title:	Name:	Signature:	Date:
RWQCB Interim Executive Officer	**Sam Unger**		

RWQCB SQA Officer	**Rebecca Veiga Nascimento**		

B.2 Distribution List

Table 1. QAPP Distribution List and Contact Information

Agency	Role	Contact Name	Contact Information	Copy #
Los Angeles Regional Water Quality Control Board	RWQCB Executive Officer	Sam Unger	Phone: 213-576-6607 Email: sunger@ waterboards.ca.gov	Original
Los Angeles Regional Water Quality Control Board	RWQCB QA Officer	Rebecca Veiga Nascimento	Phone: 213-576-6784 Email:	1
City of Los Angeles Watershed Protection Division	Project Director	Shahram Kharaghani	Phone: 213-485-0587 Email: Shahram.Kharaghani@lacity.org	2
City of Los Angeles Watershed Protection Division	Project Manager	Donna Chen	Phone: 213-485-3928 Email: Donna.Chen@lacity.org	3
City of Los Angeles Watershed Protection Division	Project QA Officer	Vivian Marquez	Phone: 323-342-1556 Email: Vivian.Marquez@lacity.org	4
City of Los Angeles Watershed Protection Division	Technical Leader	Sofia Mohaghegh	Phone: 213-485-0526 Email: Sofia.Mohaghegh@lacity.org	5
City of Los Angeles Watershed Protection Division	Field Team Coordinator	Jonathan Ball	Phone: 323-342-1557 Email: Jon.Ball@lacity.org	6
City of Los Angeles Environmental Monitoring Division	Laboratory Manager	Mas Dojiri	Phone: 310-648-5610 Email: Mas.Dojiri@lacity.org	7
City of Los Angeles Environmental Monitoring Division	Laboratory QA Officer	Mahesh Pujari	Phone: 310-648-5836 Email: Mahesh.Pujari@lacity.org	8
City of Los Angeles Department of Recreation & Parks	Environmental Supervisor	David Attaway	Phone: 213-202-2660 Email: David.Attaway@lacity.org	9
City of Los Angeles Bureau of Engineering	Principal Civil Engineer	Kendrick Okuda	Phone: 213-485-1165 Email: Kendrick.Okuda@lacity.org	10

B.3 Project/Task Organization

B.3.1 Involved Parties and Roles

The City of Los Angeles (City) owns and operates the Ken Malloy Harbor Regional Park (KMHRP), where Machado Lake is located. The Department of Recreation and Parks (RAP) manages the lake and is working with other City departments to comply with the Load Allocations specified in the Machado Lake Nutrient total maximum daily load (TMDL). RAP will play a significant role in the daily operations at the lake, including maintaining the water level, general observations of lake conditions, and possibly a role in the maintenance of structural best management practices (BMP).

Water quality data from this Monitoring and Reporting Plan (MRP) will be critical to their efforts.

Watershed Protection Division (WPD) is a division in the Bureau of Sanitation (BOS), Department of Public Works. WPD is the lead entity to oversee and coordinate TMDL-related activities for the City. For the Machado Lake Nutrients TMDL, WPD is responsible for developing and implementing the MRP, which is required by the TMDL. The Pollution Assessment Section WPD's monitoring team that is responsible for conducting the field work for the MRP, including water quality sampling and field measurements.

Environmental Monitoring Division (EMD) is a division within the BOS, Department of Public Works, and will serve as the contract laboratory that performs all water quality analyses for this monitoring program (excluding sampling and field measurements). EMD is certified by the State of California Department of Health Services Environmental Laboratory Accreditation Program (ELAP). EMD is located at the Harry Pregerson Building: Hyperion Treatment Plant, 12000 Vista Del Mar, Playa Del Rey, California 90293.

The ***Bureau of Engineering*** (BOE) is a bureau within the Department of Public Works. BOE has a significant role in the design and construction activities for the Machado Lake Ecosystem Rehabilitation Project, which is a major component of the City's TMDL implementation strategy. BOE will examine water quality data from the City's MRP in order to evaluate the efficacy of the lake improvements.

A ***Consulting Team*** consisting of staff from the engineering firms of CDM and Parsons will be Project Advisors for this MRP. This consulting team was hired by the City to assist in the development of the City's TMDL implementation plan and the Machado Lake Rehabilitation Project. They will use water quality data generated from this MRP to refine nutrient fate/transport models that will guide future water quality management strategies for the lake.

Shahram Kharaghani is WPD's Project Director for this monitoring program. The Project Director is the WPD representative for TMDL coordination with the Los Angeles Regional Water Quality Control Board (Regional Board), and will be primary point of contact between the Regional Board and the City. Mr. Kharaghani will also be the co-signer on the annual reports that are generated by this MRP.

Donna Chen is WPD's Project Manager for this monitoring program. The Project Manager is responsible for oversight of the monitoring program, and providing the deliverables required by the TMDL. The Project Manager is the lead liaison for the day-to-day administration of the project and has full authority to act on behalf of the Project Director. The Project Manager will work with the Laboratory Manager to ensure that project deliverables (i.e., the annual report) are submitted to the Regional Board in a timely manner.

Sofia Mohaghegh is WPD's Technical Leader for this monitoring program. The Technical Leader responsible for technical dialogs with advisors and experts, and for collaboration with other agencies and stakeholders involved in this project. Among other TMDL-related activities, the Technical Leader is responsible for reviewing the results generated from this monitoring program, and discussing their significance with the Project Advisors and stakeholders.

Jonathan Ball is WPD's Field Team Coordinator. As the Field Team Coordinator, Mr. Ball is responsible for developing the Monitoring Plan and this QAPP. This is done in consultation with the Project Manager, Technical Leader, and QA Officer, so that the monitoring program meets the requirements of the Machado Lake Nutrients TMDL and employs the appropriate data quality objectives. The Field Team Coordinator is also responsible for the scientific integrity of the data collection effort throughout the life of the project. He is responsible for organization of field staff, scheduling sampling days, maintaining field sampling equipment, data collection and management, and coordination with the contract laboratory where samples are analyzed. Additionally, the Field Team Coordinator is responsible for overseeing training of WPD field staff. All WPD field staff will receive an extensive on-the-job training under Mr. Ball's supervision.

Mas Dojiri is EMD's Laboratory Manager. Dr. Dojiri is responsible for training of all EMD staff, in conformity with the EMD Quality Assurance Manual (EMD QA Manual). He is also the point of contact for all laboratory analytical work.

Mahesh Pujari is EMD's Laboratory QA Officer. Mr. Pujari is responsible for maintaining the EMD QA Manual, and ensuring that the laboratory is conforming to quality assurance goals.

David Attaway is an Environmental Supervisor with the RAP, and will serve as the representative for the department. Mr. Attaway will work closely with the Technical Leader and Project Manager in order to receive data, make recommendations, as well as provide logistical support for the field crews (e.g., arranging for the use of the boat/operator).

Kendrick Okuda is a Principal Civil Engineer within BOE, and will serve as the bureau's representative. Mr. Okuda will work closely with the Technical Leader and Project Manager in order to obtain monitoring data from this monitoring program, and to provide technical support for lake water quality management practices.

B.3.2 Quality Assurance Officer Role

The QA Officers are responsible for guaranteeing the overall quality of the data produced and reported for this monitoring program. Specific duties of the QA Officers include conducting audits of ongoing tests, data packages and completed reports, conducting audits of the routine quality control documentation of laboratory procedures, communicating potential quality control problems to the staff, and assuring that any problems are resolved. They are responsible for issuing QA Reports to Management, maintaining a current QA Manual, and issuing Quality Assurance Project Plans (QAPP) as required. The QA Officers also ensure that data being reported have been generated in compliance with the QA Manual and the appropriate protocols. The QA Officers are knowledgeable in the quality system standard defined under ELAP.

Vivian Marquez is WPD's QA Officer. The QA Officer works independently from the Project Manager and Field Team Coordinator and is responsible for the data meeting all data quality objectives. Ms. Marquez will review and assess all procedures during the life of the project against QAPP requirements. She will report all findings to the Project Manager, including all requests for corrective action. Ms. Marquez may stop all actions, including those conducted by WPD or EMD if there are significant deviations from required practices or if there is evidence of a systematic failure. Ms. Marquez is responsible for reviewing and maintaining this QAPP and will also work with Mahesh Pujari, the QA Officer for EMD, by communicating all quality assurance and quality control issues. Additionally, she will provide input and resolve technical questions related to this monitoring program.

B.3.3 Persons Responsible for QAPP Update and Maintenance

Changes and updates to this QAPP may be made after a review of the evidence for change by WPD's, Project Director, Project Manager, Field Team Coordinator, and QA Officer. WPD's Field Team Coordinator will be responsible for making the required changes and will submit amended drafts to WPD's QA Officer for review. Upon the QA officer's approval, the final amended copy of the Plan will be provided to the Technical Leader, who will distribute copies to all parties listed in Table 1.

B.3.4 Organizational Chart and Responsibilities

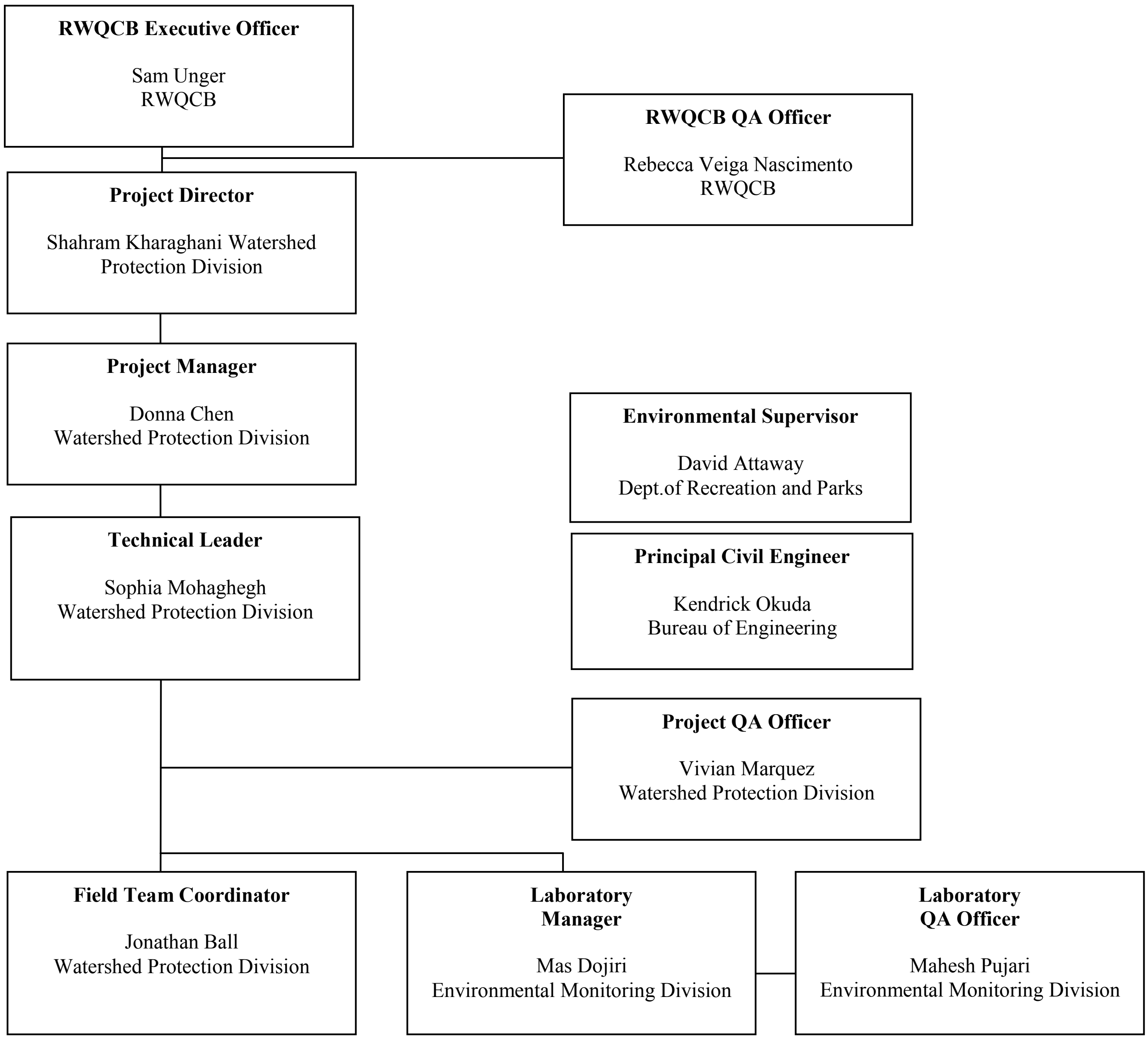


Figure 1. Organizational Chart

B.4 Problem Definition/ Background

B.4.1 Background

The Regional Board has listed the following nutrient-related impairments on the 303(d) list for Machado Lake: algae, ammonia, eutrophic, and odor. To address these impairments, the Regional Board drafted the Machado Lake Nutrient TMDL, which was approved by the United States Environmental Protection Agency (US EPA) on March 11, 2009. The Nutrient TMDL requires designated responsible parties to institute a monitoring program and implement BMPs to mitigate the identified nutrient impairment at Machado Lake.

The Nutrient TMDL requires reduction of external nutrient loads from point sources and internal nutrient loads from nonpoint sources. Point sources are defined as Municipal Separate Storm Sewer System (MS4) Permittees and Caltrans. Nonpoint sources are considered to be from localized drainage areas from KMHRP, and therefore RAP is identified as the responsible party. The Nutrient TMDL assigned waste load allocations (WLAs) to point sources and load allocations (LAs) to nonpoint sources. In addition, all responsible parties are required to meet the numeric targets set in the Nutrient TMDL. The numeric targets, WLAs, and LAs are shown in Table 2 of this QAPP.

RAP must meet the LA requirements of the Nutrient TMDL as the nonpoint source discharger identified in the TMDL. These requirements include meeting the interim and final LAs, entering into a memorandum of agreement (MOA) with the Regional Board to implement the LA requirements, and preparing a Lake Water Quality Management Plan (LWQMP) encompassing a MRP, a QAPP, and implementation actions. There are two lake sampling sites required for bi-weekly compliance monitoring: one in the northern portion of the lake and one in the southern portion of the lake.

This QAPP is meant to accompany the MRP found in Section 3.0 of the Lake Water Quality Management Plan for Machado Lake. The MRP specifies the overall strategy, sampling locations, constituents to measure, sampling schedule, deliverables, and other details related to this monitoring program.

B.4.2 Decisions or Outcomes

As stated in the TMDL Basin Plan Amendment, the MRP will be designed to monitor and implement the Machado Lake Nutrient TMDL. The monitoring plan is required to measure the progress of pollutant load reductions and improvements in water quality. The monitoring plan shall

- Determine attainment of total phosphorus, total nitrogen, ammonia, dissolved oxygen (DO), and chlorophyll-a numeric targets.

- Determine compliance with the waste load and load allocations for total phosphorus, and total nitrogen.

- Monitor the effect of implementation actions on lake water quality.

B.4.3 Water Quality or Regulatory Criteria

The water quality and regulatory criteria for this project can be found as an amendment to the Water Quality Control Plan for the Los Angeles Region (Basin Plan), Resolution No.R08-006 that was adopted on May 1, 2008.

This Basin Plan document is available online at the following website:

http://www.waterboards.ca.gov/water_issues/programs/tmdl/docs/machadolake/R08_006_machadolake_nutrient.pdf

The Nutrient TMDL requires reduction of external nutrient loads from point sources and internal nutrient loads from nonpoint sources. Point sources are defined as MS4 Permittees and Caltrans. Nonpoint sources are considered to be from localized drainage areas from KMHRP, and therefore RAP is identified as the responsible party. The Nutrient TMDL assigned WLAs to point sources and LAs to nonpoint sources. In addition, all responsible parties are required to meet the numeric targets set in the Nutrient TMDL. The numeric targets, WLAs, and LAs are shown in Table 2.

Table 2. Nutrient TMDL Numeric Targets, Waste Load Allocations, and Load Allocations

Compliance Date	Numeric Targets		Waste Load and Load Allocations
March 11, 2009 **(1st Interim)**	N/A		Total Phosphorus: 1.25 mg/L Total Nitrogen: 3.5 mg/L
March 11, 2014 **(2nd Interim)**	N/A		Total Phosphorus: 1.25 mg/L Total Nitrogen: 2.45 mg/L
Sept. 11, 2018 **(Final)**	Total Phosphorus: (monthly average)	0.1 mg/L	Total Phosphorus: 0.1 mg/L Total Nitrogen: 1 mg/L
	Total Nitrogen: (monthly average)	1 mg/L	
	Ammonia: (hourly average) (monthly average)	5.95 mg/L 2.15 mg/L	
	Dissolved Oxygen: (single sample minimum measured 0.3 meters above sediment)	5 mg/L	
	Chlorophyll-a: (monthly average)	20 µg/L	

B.5 Project/Task Description

B.5.1 Work Statement and Produced Products

Monitoring at Machado Lake will begin within 60 days following approval of the Lake Water Quality Management Plan. WPD field crews will collect water samples and record *in-situ* measurements on a bi-weekly basis. The water samples will be analyzed by the EMD laboratory. Results will be submitted to the Regional Board on an annual basis, by June 30th following each year of sampling. The annual report will compare monitoring results to the numeric targets and interim/final load allocations as specified by the TMDL.

B.5.2 Constituents to be Monitored and Measurement Techniques

Water Quality Parameters

All water samples will be analyzed at the EMD laboratory by the following methods:

- Total suspended solids (TSS) and total dissolved solids (TDS) will be determined by the glass fiber filtration technique as indicated by Standard Methods 2540D.
- Turbidity will be determined by Standard Methods 2130B.
- Chlorophyll-a will be determined by the spectrophotometric method as indicated by Standard Methods 10200H.
- Nutrients samples will be analyzed for Ammonia-N , Total Nitrogen, Nitrite (NO_2), Nitrate (NO_3), Organic Nitrogen, Total Phosphorus, and Ortho-Phosphorus. Ammonia-N will be analyzed by EPA method 350.1; Organic Nitrogen will be analyzed by EPA Method 351.2; Nitrite and Nitrate will be analyzed by EPA Method 300.0; and Total and Ortho-Phosphorus will be analyzed by Standard Methods 4500-P E.

Physical Parameters

All physical parameters will be measured *in-situ*, at the time of sample collection by WPD staff:

- Temperature, pH, specific conductivity, DO will be measured using a water quality sonde or comparable instruments.
- Secchi depth reading will be taken by using an 8-inch diameter Secchi disc with alternating black and white quadrants.
- Lake elevation will be measured using a staff gauge.

B.5.3 Project Schedule

Table 3. Project Activities, Deliverables, and Due Dates

Activity	Date		Deliverable	Deliverable Due Date
	Anticipated Date of Initiation	Anticipated Date of Completion		
Biweekly Water Quality Sampling	January 2011	(ongoing)	Validated data uploaded to WISARD database	Within 30 days of each sample event
1st Quarter Progress Report (Internal)	April 1st	April 30th	Summary of data and QA/QC review (covering January through March data)	n/a
2nd Quarter Progress Report (Internal)	July 1st	July 31st	Summary of data and QA/QC review (covering April through June data)	n/a
3rd Quarter Progress Report (Internal)	October 1st	October 31st	Summary of data and QA/QC review (covering July through September data)	n/a
4th Quarter Progress Report (Internal)	January 1st	January 31st	Summary of data and QA/QC review (covering October through December data)	n/a
Annual Report	January 1st	June 30th	Annual Report (certified by EMD and WPD)	June 30th (each year)

B.5.4 Geographical Setting

Machado Lake is located in the KMHRP, which is a 231-acre Los Angeles City Park serving the Wilmington and Harbor City areas. The park is located west of the Harbor freeway (110) and east of Vermont Avenue between the Tosco Refinery on the south and the Pacific Coast Highway on the North. Machado Lake is one of the last lake and wetland systems in Los Angeles; the area is approximately 103.5 acres in total size. The upper portion, which includes the open water area, is approximately 40 acres and the lower wetland portion is about 63.5 acres. Refer to Figure 2.

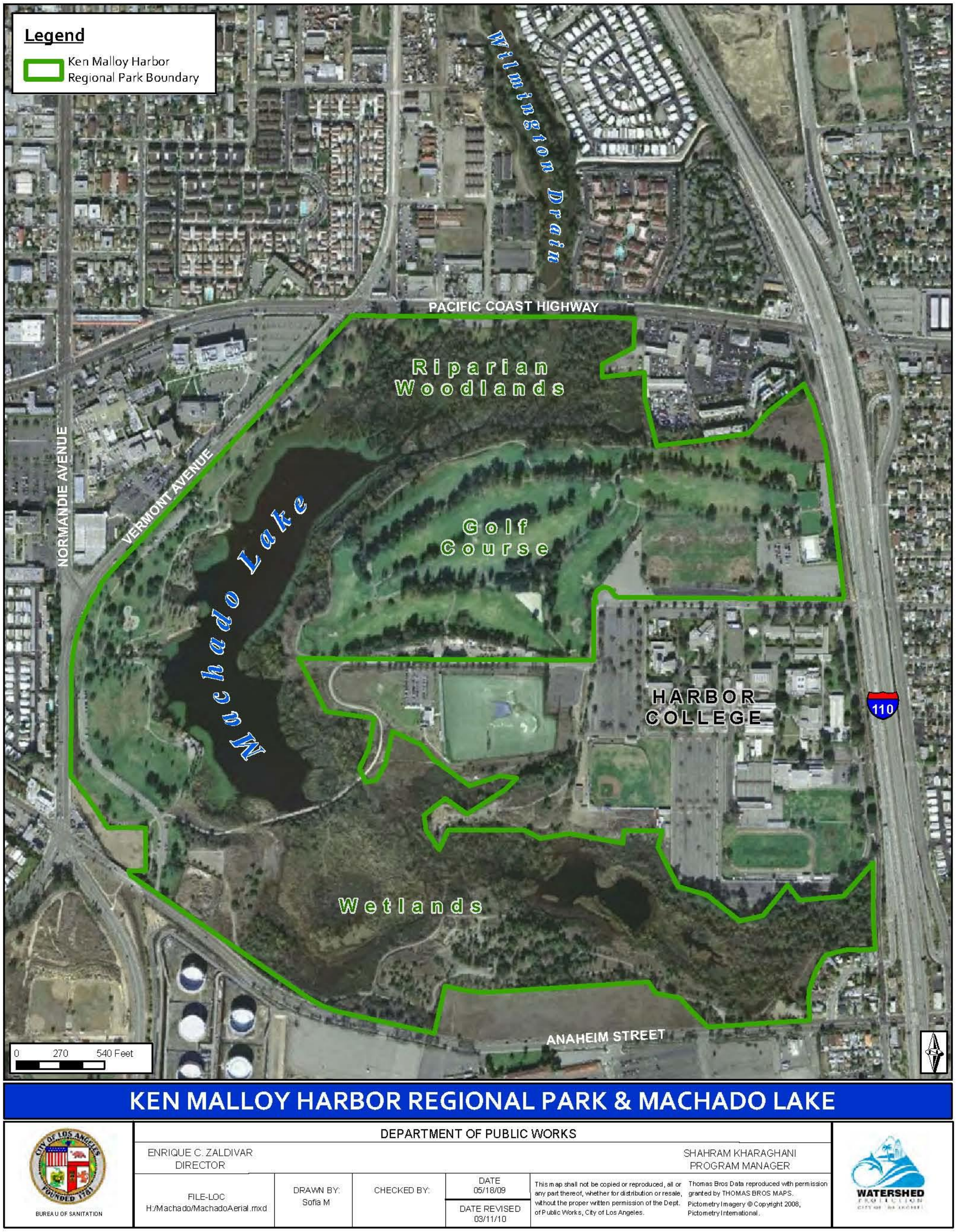


Figure 2. Geographical Location

B.5.5 Constraints

Resource and time constraints may include the following:

- Inclement weather that prohibits safe operation of the boat and monitoring equipment
- Every effort will be made to ensure that equipment is well maintained and adequate back-up is available. However, if any unforeseen issues arise where equipment is rendered inoperable, *in situ* measurements will be unobtainable.
- Sampling in-lake depends on the availability of an operating boat. If for any reason the boat is inoperable, sampling will be affected.
- Safety of field staff is of primary concern. If for any reason sampling at any location is deemed unsafe by field staff, no sample will be taken.

In each scenario, every effort will be made to sample as soon as possible when the constraint is no longer an issue.

B.6 Quality Objectives and Criteria for Measurement Data

Data Quality Objectives for this project are summarized in the following table:

Table 4. Summary of Data Quality Objectives

Measurement or Analyses Type	**Applicable Data Quality Objectives**
Total Suspended Solids (TSS), Total Dissolved Solids (TDS)	*Precision, Completeness*
Chlorophyll-a	*Precision, Completeness*
Turbidity	*Accuracy, Precision, Completeness*
Nutrients (ammonia-N, total nitrogen, nitrite, nitrate, org nitrogen, total phosphorus, ortho-phosphorous)	*Accuracy, Precision, Completeness, Recovery*
Field Measurements	*Accuracy, Precision, Completeness*

B.6.1 Accuracy

Accuracy describes how close a measurement is to its true value. Accuracy of nutrient analysis will be determined by performing one or more measurements on performance testing samples or standard solutions from sources other than those used for calibration. Standard Reference materials are not available for TSS and TDS analysis; therefore, accuracy criteria cannot be applied.

B.6.2 Precision

Precision measurements will be determined on laboratory replicates and/or field duplicates. The number of replicates for laboratory measurements will be based on EMD's QA manual and SOPs. Recovery measurements will be determined by laboratory spiking of a replicate sample (Matrix Spike/Matrix Spike Duplicate) with a known concentration of the analyte. Recovery only applies to the metals (ICP) and nutrient analyses. The target level of addition is based on the EMD QA Manual and its SOPs.

Precision of *in situ* DO at 0.3 m above sediment will be determined by taking three replicate measurements at each monitoring site.

B.6.3 Representativeness

Representativeness is a measure of the extent to which the measurements obtained actually depict the true environmental condition being evaluated. The sampling sites chosen for this monitoring plan are assumed to be representative of the conditions in Machado Lake. Furthermore, the depth-integrated sampling technique (refer to MRP 3.1.3) also ensures that grab samples represent entire water column.

B.6.4 Completeness

Completeness is the fraction of planned data that must be collected so as to fulfill the statistical criteria of the project. Completeness is equal to the number of analyses generating useable data for each analysis divided by the number of samples collected for that analysis. The Project QA Officer will check completeness results accordingly.

B.6.5 Reporting Limits

The Inland Surface Water and Enclosed Bays and Estuaries Policy deal with Method sensitivity by the inclusion of the required SWAMP Target Reporting Limits, where such values exist, and by the application of the definition of a Minimum Level as provided. Reporting Limits must be lower than the numeric targets and compliance limits specified in the TMDL.

B.6.6 Action Limits

There are no applicable Action Limits.

B.6.7 Acceptance Criteria

The scope of this MRP will be limited to the data collected through the proposed monitoring; therefore, acceptance criteria for previously collected data do not apply to this QAPP.

Table 5. Measurement Quality Objectives for Laboratory Analyses

Group	Parameter (Method)	Accuracy	Precision	Recovery	Target Reporting Limits	Completeness
Conventional Analysis	Total Suspend Solids (TSS) (SM 2540D)	N/A	Laboratory duplicates < 10% RPD Blind Field duplicate ≤ 25% RPD.	N/A	2 mg/L	90%
	Total Dissolved Solids (TDS) (SM 2540D)	N/A	Laboratory duplicates < 15% RPD Blind Field duplicate ≤ 25% RPD.	N/A	28 mg/L	90%
	Turbidity (SM 2130B)	Within 10% of the Standard Reference Material	Laboratory duplicates < 15% RPD Blind Field duplicate ≤ 25% RPD.	N/A	0.3 NTU	90%
Nutrients	Ammonia-N (EPA 350.1)	Standard Reference Materials within 90% to 110% of stated value	Laboratory duplicates < 15% RPD Blind Field duplicate ≤ 25% RPD.	*Plus or minus 10% on MS and MSD*	0.1 mg/L	90%
	Chlorophyll-a (SM 10200 H)	N/A	Laboratory duplicates < 10% RPD Blind Field duplicate ≤ 25% RPD.	N/A	10µg/L	90%
	Nitrate, Nitrite (EPA 300.0)	Standard Reference Materials within 90% to 110% of stated value	Laboratory duplicates < 15% RPD Blind Field duplicate ≤ 25% RPD.	*Plus or minus 10% on MS and MSD*	0.1 mg/L	90%
	Organic N (EPA 351.2)	Standard Reference Materials within 85% to 115% of stated value	Laboratory duplicates < 15% RPD Blind Field duplicate ≤ 25% RPD.	*Plus or minus 15% on MS and MSD*	0.1 mg/L	90%
	Total N (By Calculation)	N/A	N/A	N/A	0.1 mg/L	90%
	Total P, Ortho-P (SM 4500-P E)	Standard Reference Materials within 85% to 115% of stated value	Laboratory duplicates < 15% RPD Blind Field duplicate ≤ 25% RPD.	*Plus or minus 15% on MS and MSD*	0.1 mg/L	90%

B.7 Special Training Needs/Certification

B.7.1 Specialized Training or Certifications

Field Sampling

No specialized training or certifications for field sampling is required for this project. Although there is no specialized training required for this project, all field staff receive an initial training program consisting of 8 hours of combined class and field instruction and a 4-hour combined class and field instruction as a refresher every year.

Analytical Laboratory

EMD Laboratory is certified by the California Department of Health Service's Environmental Laboratory Accreditation Program (ELAP) for the analyses of the constituents listed above for both water and wastewater. EMD provides training to its staff as part of its Standard Operating Procedures. EMD's ELAP certification Number is 1723.

B.7.2 Training and Certification Documentation

All personnel are responsible for complying with all quality assurance/quality control (QA/QC) requirements pertaining to their organizational and technical function. Each technical staff member must have a combination of experience and education that adequately demonstrates a specific knowledge of their particular function and a general knowledge of laboratory operations, test methods, QA/QC procedures, and records management.

Field Sampling

The Field Team Coordinator will be responsible for all training of field personnel and for maintaining training records, including those for any subcontractors. Field personnel training will be documented and records maintained in the project's files at WPD's offices.

Analytical Laboratory

EMD maintains records of its training. Those records can be obtained if needed from the EMD QA Officer.

B.7.3 Training Personnel

The Field Team Coordinator and WPD QA Officer provide training for field staff on proper field sampling techniques prior to work initiation to ensure consistent and appropriate sampling methods, sample handling/storage, and chain-of-custody (COC) procedures. EMD Managers, Supervisors and QA Officer provide training to EMD staff.

B.8 Documents and Records

Data management will be a collaborative effort involving field staff from the Watershed Protection Division (WPD), as well as laboratory staff from the Environmental Monitoring Division (EMD). WPD will record and maintain all field data collected during sampling events. A field log sheet will be used to register all information during a particular sampling event, such as date, time, name of field personnel, sampling location, sample ID, name of sampling program, and visual inspection of the site as well as additional comments that may be relevant to the project. All field data will be entered into an electronic database following each sampling event. EMD will record and log all samples that are analyzed at the laboratory, and all laboratory data will be entered into EMD's Laboratory Information Management System (LIMS). Upon validation from each respective laboratory supervisor, EMD will upload the validated data into the Bureau of Sanitation's Wastewater Information System and Analytical Research Database (WISARD). Likewise, WPD field staff will upload the required in-situ measurements and other pertinent field observations into WISARD. The WISARD database is maintained by the Information Control Systems Division (ICSD) and is used extensively by the Bureau of Sanitation for legal reporting of data for various NPDES and TMDL monitoring programs. Custom report templates will be developed for the Machado Lake Nutrients TMDL Monitoring Program, so that data are reported in a timely, consistent manner, with systems in place to maintain the integrity of the data. Data within WISARD can only be edited with administrative approval, and will have an access log showing activities and changes made to the file. WISARD files are stored on a secure server, and are backed up on a daily basis.

In addition, hard copies of the Field log sheets and laboratory data sheets will be filed in project specific folders at WPD and EMD, respectively. Both EMD and WPD will retain hard copies of the COC forms. All electronic data files, at WPD and EMD, are saved on a network drive and are backed-up in an archive. Should a file become corrupted, it can be restored to its original content from archived files.

Copies of this QAPP will be distributed by email to all parties involved with the project by the Project Manager, (Ms. Chen). Updates to this Plan will be distributed in like manner, and all previous versions will be discarded from the project file.

Field Documentation and Records Generated by WPD

- Field Log/Observation Records
- Field Sample Collection Sheet and COC Sheet
- Field Instrument Calibration and Maintenance Records
- Field Data Analysis and Reports

Laboratory Documentation and Records Generated by EMD

- Sample Receiving Records
- Sample Preparation and Analysis Records
- Instrument Calibration and Maintenance Records
- QC Sample Results

- Analytical Samples Results
- Database Data Files in LIMS and Excel format
- Annual Reports

All relevant records from this project will be compiled into the Annual Report prepared by WPD in collaboration with EMD. The Project Director and Laboratory Manager both certify the Annual Report prior to submission to the Executive Office of RWQCB by June 30th of each year. Each annual report will include monitoring data collected from January 1st through December 31st, from the preceding year. Electronic files and hard copies of records for this monitoring program will be maintained for a minimum of five years after submission of the annual report to the Regional Board. However, it is the practice of the Bureau of Sanitation (including WPD and EMD) to maintain monitoring records indefinitely.

GROUP B Elements:
Data Generation & Acquisition

B.9 Sampling Process Design

B.9.1 Water Quality Monitoring

Sample collection sites are described in the MRP (Section 3.1.1). Sample sites were selected based on the TMDL requirements for this lake.

B.9.2 Project Activity Schedule

Official sampling will begin 60 days after the approval of the Lake Water Quality Management Plan will occur on a biweekly schedule at two sampling locations. Delivery of samples to the laboratory will occur immediately after collection. Particular attention will be paid towards required holding time of each analyte (refer to Table 6).

Results will be submitted to the Regional Board on an annual basis, by June 30th succeeding each year of sampling, and it will include any data collected from January 1st through December 31st, from the preceding year.

B.9.3 Sources of Natural Variability and Potential Bias

Sources of variability will include natural patterns in the environment. Seasonal effects (e.g., changes in air/water temperature, number daylight hours, rain events, weather patterns, etc.) are expected to affect monitoring results. By taking biweekly samples, a large dataset will be generated, thus allowing seasonal effects to be detected. Particular attention will be given to addressing the response of water quality parameters to storm events. Certain water parameters, including DO, temperature, and pH are known to fluctuate according to diurnal patterns. In general, WPD field crews will sample at approximately the same time of the day, approximately from 9 am to 10 am. This is considered a conservative approach for measuring DO since oxygen levels are typically at their lowest in the morning hours. In order to account for the spatial distribution of constituents in the lake, two different sampling locations have been selected and their results will be averaged. Furthermore, a depth-integrated grab sample will be taken to account for spatial variability in the water column (see Section 3.1.3, MRP).

Potential sources of bias may include construction and other human activities in the local area, weather conditions, and variability among sampling techniques. In particular, subjective measurements, such as Secchi depth, are prone to bias depending on the individual collecting the data. In order to minimize these sources of bias, field staff will be trained in proper sampling technique, samples will be delivered to the EMD laboratory immediately after sampling, and staff will be instructed to make detailed observations of factors that may influence results.

Lake management activities such as aquatic weed removal, dredging, trash removal, and other in-lake activities may also influence sampling results. If samples are determined to be not representative as a result of these activities, sampling may be rescheduled at the discretion of the Field Team Coordinator.

B.10 Sampling Methods

All sampling procedures will adhere to the guidelines found in the SWAMP Quality Assurance Management Plan, Appendix D, "Field Collection of Water Samples" and are described in the MRP Section 3.1.

For all samples, clean bottles will be used to prevent contamination of the sample. Laboratory staff will carry out bottle cleaning according to EMD's standard operating procedures, which are consistent with Standard Methods and SWAMP requirements.

To ensure that samples represent the entire water column, a depth-integrated sampling device will be used. To ensure the accuracy and thoroughness of the dataset, field duplicates will be collected at one of the monitoring sites, along with field blanks for each of the analytes being tested. When preparing the "blind" field duplicates, water from a single sampling vessel is to be split into two identical bottles (one for the regular sample, and one as the duplicate). The sample will be well mixed before splitting. For reporting purposes, only the data for the regular sample will be used; whereas, the data for the duplicate will be used for quality assurance purposes. Field sampling staff will record the location where the duplicate samples were taken, but this information will not be shared with the laboratory.

Sample containers, volumes, and preservation are listed in Table 6. Sampling equipment is thoroughly cleaned with laboratory detergent and tap water once sampling personnel return from the field. This wash water is discarded into the drain.

In order to monitor the sampling process, the QA Officer will randomly observe sampling and compare the actual actions against guidelines found in the SWAMP field sampling SOP. In the event that sampling protocol was not followed, the field supervisor will address the issue, provide proper training according to established standard operating procedures, and provide documentation of the corrective action to the Project Manager.

Table 6. Required Sample Volume, Container Type, Preservation, and Holding Time for Each Analyte

Constituents	Sample Volume	Containers (#, size and type)	Preservation	Holding Time
Total Suspended Solids	1000 mL	(1) 1000 mL Plastic Bottle	Store Cool at 4ºC	7 days
Total Dissolved Solids	1000 mL	(1) 1000 mL Plastic Bottle	Store Cool at 4ºC	7 days
Total Ammonia (NH_3-N) Total Nitrogen Total Phosphorus	500 mL	(1) 500 mL Plastic Bottle	Store Cool at 4ºC Add sulfuric acid, pH < 2	28 days
Nitrate (NO_3-N) Ortho-Phosphorus (PO_4)	500 mL	(1) 500 mL Plastic Bottle	Store Cool at 4ºC	7 days
Chlorophyll-*a*	1000 mL	(1) 1000 mL Brown Plastic Bottle	Filter and then freeze at 0ºC	14 days
Turbidity	125 mL	(1) 125 mL Plastic Bottle	Store Cool at 4ºC	48 hours

B.11 Sample Handling and Custody

All sample bottles must be identified with the project title, appropriate identification number, analyses to be performed, date and time of sample collection, and sampler's initials. This information will be documented in the field log sheet. Each sampling event will have its own field log sheet and COC. The field log sheet will contain information such as staff initials, collection time, sample ID, comments on weather conditions, quantity of flow to/from the treatment systems, and other observations relative to the study. WPD field staff will retain the field log sheet. Copies will be provided to EMD Sample Receiving staff and will be made available to analysts processing the samples. Proper documentation of the field log sheet will ensure accuracy and consistency during sampling events and will provide laboratory analysts important information regarding the samples.

After samples are collected, they must be stored on ice in a cooler with the lid closed during transport to the laboratory. COC forms are completed by the sampler for all samples, placed in a plastic envelope and kept inside the cooler with the samples.

Upon delivery to the laboratory, the laboratory staff inspects the condition of the samples, signs the COC and reconciles the label information to the COC form. Time of sample collection is noted, and the samples are stored at the appropriate temperature until analysis is begun, always within the holding time limitation (Table 6). At this point, the laboratory becomes responsible for sample custody. Samples may be disposed of when the analysis is completed and all analytical quality assurance/quality control procedures are reviewed and accepted.

B.12 Analytical Methods and Field Measurements

The following laboratory analytical procedures will be used in this project. Refer to EMD's QA Manual for instrumentation, corrective action, and sample holding time. As for sample disposal procedure, analyzed samples and standards used in analyses are disposed of according to EMD's Chemical Hygiene Plan.

In situ sampling procedures will follow the SWAMP QA Management Plan, Appendix D, "Field Collection of Water Samples."

Laboratory and field instrumentation/technology needed for analyses are the following:

Chemical Parameters
All water samples will be analyzed in EMD laboratory by the following analysis methods:

- Total suspended solids and Total dissolved solids will be determined by the glass fiber filtration technique as indicated by Standard Methods 2540D.

- Turbidity will be determined by Standard Methods 2130B.

- Chlorophyll-a will be determined by the spectrophotometric method as indicated by Standard Methods 10200H.

- Nutrients samples will be analyzed for Ammonia-N , Total Nitrogen, Nitrite (NO_2), Nitrate (NO_3), Organic Nitrogen, Total Phosphorus, and Ortho-Phosphorus. Ammonia-N will be analyzed by EPA method 350.1; Organic Nitrogen will be analyzed by EPA Method 351.2; Nitrite and Nitrate will be analyzed by EPA Method 300.0; and Total and Ortho-Phosphorus will be analyzed by Standard Methods 4500-P E. The digestion procedure for total phosphorus is described as follows:

    8.4.3.2 Add 1 ml 11N H2SO4 solution and 4 ml of freshly prepared 10% ammonium persulfate solution. Add water to the total volume of 50mL.

    8.4.3.3 Heat for 45 min. in the autoclave at a pressure of 98 to 137 kPa, using liquid cycle. Cool. Add a drop of phenolphthalein. Neutralize to a faint pink color with 5N NaOH. Carefully add 5 N H2SO4 to just discharge the color.

    8.4.3.4 Determine P using the ascorbic acid method.

Physical Parameters

- pH, conductivity, dissolved oxygen, and temperature will be measured using a YSI Sonde 6600 Environmental Monitoring Systems.

- Secchi Depth will be measured using a standard 8" diameter Secchi disc with alternating black and white quadrants according to SWAMP Quality Assurance Management Plan, Appendix E, "Field Data Measurements."

In the event that standard protocol was not followed, the respective laboratory unit supervisor or Field Team Coordinator will address the issue and will provide proper training as according to established standard operating procedures. Whenever there is an out-of-control event, investigation and correction efforts are to be initiated by all concerned personnel as outlined in Element 20 (Assessment & Response Actions) and documented by the QA officers.

Samples will always be analyzed within prescribed holding times. Laboratory turn-around times (TAT) for nutrients and conventional chemistry is approximately 30 days from the time of sample collection. This TAT includes the process of uploading the data into the WISARD database. The laboratory should notify the Field Team Coordinator if it anticipates a significant departure from this approximate TAT.

Data validation includes dated and signed entries by the analyst on the worksheets and logbooks for all samples and use of QC criteria to reject or accept specific data.

All analyses for this study adhere to Standard Methods for the Examination of Water and Wastewater 20th edition and EPA methods; therefore, no method validation is required for this study.

Table 7. Laboratory and Field Methods and Detection Limits

Parameter	Laboratory	Method	ML Limit	MDL Limit
Total Suspended Solids	EMD	SM 20th ed. 2540 D	N/A	2.0 mg/L
Total Dissolved Solids	EMD	SM 20th ed. 2540 D	N/A	28 mg/L
Organic Nitrogen	EMD	EPA 351.2	0.1 mg/L	0.1 mg/L
Ammonia-N	EMD	EPA 350.1	0.1 mg/L	0.05 mg/L
Nitrate/Nitrite	EMD	EPA 300.0	0.1 mg/L	0.02 mg/L
Total Nitrogen	EMD	Sum of NH3, NO3, NO2, and Organic-N.		
Ortho-Phosphorous	EMD	SM 20th ed 4500-P E	0.1 mg/L	0.05 mg/L
Total Phosphorous	EMD	SM 20th ed 4500-P E	0.1 mg/L	0.05 mg/L
Chlorophyll-*a*	EMD	SM 20th ed. 10200 H	10 ug/l-mg/m3	6 ug/l-mg/m3
Turbidity	EMD	SM 20th ed. 2130 B	1.5 NTU	0.3 NTU
pH	Field Monitoring By WPD staff	WPD YSI 6600 SONDE SOP	N/A	N/A
Conductivity	Field Monitoring By WPD staff	WPD YSI 6600 SONDE SOP	N/A	N/A
Dissolved Oxygen	Field Monitoring By WPD staff	WPD YSI 6600 SONDE SOP	N/A	N/A
Temperature	Field Monitoring By WPD staff	WPD YSI 6600 SONDE SOP	N/A	N/A
Secchi Depth	Field Monitoring By WPD staff	SWAMP QAMP Appendix E	N/A	N/A
Lake Depth	Field Monitoring By WPD staff	Staff Gauge Reading	N/A	N/A

*Standard Methods for the Examination of Water and Wastewater, 20th edition

In order to monitor the sampling process, the QA Officer will randomly observe sampling processes and compare the actual actions against the sampling SOP. Proper documentation of the field log sheet will ensure accuracy and consistency during sampling events. Field practices/procedures will be observed by QA Officer and compared to the sampling protocols (described in section 11) and the Monitoring Plan. Copies of all field log sheets will be filed with the COC forms for this particular project.

B.13.2 Laboratory Analysis

The laboratory will analyze the field blanks, samples, and QC samples (method blank, lab control sample, replicates or matrix spike/matrix spike duplicate) using the quality assurance/quality control programs and SOPs established by the EMD Laboratory. EMD Laboratory's quality assurance program has been reviewed by WPD's Quality Assurance Officer, and was found to contain the SWAMP required elements required for hardness, metals, nutrients, and bacterial analyses. The laboratory monitors data quality by performing internal QC checks. These checks are method-specific. The QC checks are used to ensure that the data were generated correctly and reliably. Laboratory control samples analyzed and calculated as percent recovery and spike results are used to measure accuracy or bias of a measurement. Control charts are used to monitor the system in its day-to-day operations. These charts not only indicate serious immediate problems, but can also act as early warning signs by indicating potential bad trends.

B.13.3 Procedures and Formulas for Calculating Data Quality Indicators

Accuracy of nutrient data will be assessed using standard reference solutions for the target analyte. The ratio (%) of the measured concentration to the known concentration will be compared to the criteria listed in "Measurement Quality Objectives for Laboratory Analyses". The standard reference solutions are not available for TSS, TDS, and Chlorophyll-a measurements. Therefore, accuracy formulas do not apply.

Precision of the TSS, TDS, and Chlorophyll-a data will be calculated by determining the relative percent difference (RPD) among laboratory replicates and/or among field duplicates, where:

$$RPD = | R_1 - R_2 | / \text{mean} (R_1, R_2)$$

Recovery is assessed by calculating the ratio (%) of the measured concentration of the target analyte in the matrix spike sample to its known (theoretical) concentration. This value is compared to criteria listed in "Measurement Quality Objectives for Laboratory Analyses".

Completeness is simply the number of acceptable data points divided by the number of samples analyzed for each type of analysis.

B.13.4 Out-of-Control Events and Action Plan

An out-of-control event is defined as any occurrence failing to meet pre-established quality assurance/quality control criteria. Whenever there is an out-of-control event, investigation and correction efforts are to be initiated by all concerned personnel as outlined in Element 20 (Assessment & Response Actions) and documented by the QA officers.

B.14 Instrument/Equipment Testing, Inspection and Maintenance

B.14.1 Field Sampling

Prior to each sampling event, field sampling equipment will be checked for proper operation. Field technicians will be responsible for preparing sampling kits that include field logs, COC forms, sample labels, sampling bottles, field equipment and tools. Equipment will be inspected for damage when first handed out and returned from use. The Field Team Coordinator will be responsible for implementing the field maintenance program. For this project, field equipment includes a sonde (YSI Sonde 6600), depth-integrated sampling device, compositing buckets, Secchi disk, which will be cleaned and examined prior to each sampling event. Maintenance will occur according to manufacturer's recommendations. The staff gauge will be cleaned and cleared of debris prior to each reading.

B.14.2 Analytical Laboratory

EMD evaluates, tests, and maintains its equipment and instruments in accordance with its QA Manual and SOP's, which include those specified by the manufacturer and those specified by the method. It ensures that equipment and instruments are calibrated and operated with the reliability required for quality results. When repairs are necessary, they are performed by either trained staff or trained service engineers through commercial service contracts. Information documenting the preventive maintenance and repairs performed on each analytical instrument is also maintained. Documentation may include date, findings, probable cause, name of person who performed the service and calibration or standardization procedures that were performed with acceptable results or that were within performance criteria.

B.14.3 List of Field/Laboratory Instruments that Require Periodic Maintenance:

1. Custom-made sampling device for depth integration (WPD - sample collection)
2. Filtration apparatus (EMD- TSS and TDS analysis)
3. Analytical Balance (EMD- TSS and TDS analysis)
4. Tissue Grinder (EMD- Chlorophyll-a analysis)
5. Clinical Centrifuge (EMD- Chlorophyll-a analysis)
6. Filtration Equipment (EMD- Chlorophyll-a analysis)

7. Lachat instrument (EMD- Nutrients analysis)
8. Hach Turbidimeter (EMD- Turbidity analysis)
9. YSI Sonde 6600 (pH, conductivity, DO probes)

B.14.4 Availability and Locations of Spare Parts

Spare Parts for WPD's field equipment are stored in WPD's instrument calibration/storage room. Spare Parts for EMD instruments are stored in EMD's instrument rooms.

B.14.5 Instrument Deficiency and Corrective Actions

Instrument deficiencies come from instrument malfunction and/or failure of internal QA/QC checks.

If failure is due to instrument malfunction, the instrument will not be used until repaired; precision and accuracy will be reassessed, and the analysis will be rerun. All attempts will be made to reanalyze all affected parts of the analysis so that in the end, the product is not affected by failure of QC requirements.

When an instrument fails QA/QC requirements, the problems will immediately be brought to the attention of the Laboratory Supervisor and QA Officer. Corrective measures to be taken will depend entirely on the type of analysis, the extent of the error, and whether the error is determinant or not. The corrective action to be taken can be determined by the Laboratory Supervisor, Technicians/Analysts, Project Manager, or QA Officer, or by all of them in conference, if necessary. However, final approval is the responsibility of the QA Officer and/or Project Manager. Documentation of the incident will include date, name of analyst, findings, probable cause and remedy, and subsequent calibration. Refer to EMD's QA Manual for more details on the laboratory stated procedures for handling corrective actions.

B.15 Instrument/Equipment Calibration and Frequency

B.15.1 Analytical Laboratory

EMD calibrates its instrumentation at a frequency that ensures the validity of the results. EMD maintains calibration practices as part of the method SOPs (attached). That is, all analytical systems/instruments are calibrated at the time of use, or as often as each method requires. Each instrument is calibrated within its dynamic linear range bracketing the concentration of the target analyte, and for spectrophotometers, within the optimum performance range. Some instruments may require final calibration at the end of a test analysis. Calibration processes should comply with method-specific requirements and must be documented.

B.15.2 Instruments Requiring Calibration

For TSS and TDS analysis, the analytical balance requires daily calibration prior to use along with performance checks before/after measurements. For nutrients analysis, calibration will be required for every 10 samples and the correlation coefficient (r) must be 0.995 or better for the calibration curve. If not, calibration must be repeated. For turbidity analysis, the Hach turbidimeter requires quarterly calibration or as needed. If daily secondary standard checks deviate by more than 10% of its original value, action will be taken and a reliable daily check will be restored.

The sonde used in field measurements will be calibrated according to manufacturer's specification immediately prior to departure into the field against known pH, electric conductivity (EC), and DO solutions.

B.15.3 Calibration Deficiencies

If instruments do not calibrate properly, calibration will be repeated. If problems persist, instrument will be serviced according to manufacturer's recommendations.

B.16 Inspection/Acceptance of Supplies and Consumables

All laboratory and field equipment and supplies will be inspected for quality assurance as they are received. All standards and reagents will be checked by comparing their reading with those generated by the current lot of standards. Standards must agree exactly. All standards will be recorded on standard logbook with name, concentration, quantity, and expiration date. All required QA/QC protocols will be followed to assure proper performance of supplies. Confirmation that sample bottles are laboratory-certified clean will be made when received. EMD section supervisors will be responsible for EMD laboratory supplies and consumables. WPD Field Team Coordinator will be responsible for WPD field supplies and consumables.

Laboratory and Field Critical Supplies and Consumables:

- Instrument calibration standards
- QC check standards
- Reagents and glassware
- De-ionized water
- Spare parts
- Sample containers

B.17 Non-Direct Measurements

There are no non-direct measurements in this project.

B.18 Data Management

Data management will be a collaborative effort involving field staff from the WPD, as well as laboratory staff from the EMD. WPD will record and maintain all field data collected during sampling events. For each sampling event, sonde measurements will be stored in the instrument's internal memory. Upon returning from the field, these data will be uploaded and stored as data files on WPD network. A field log sheet will be used to register all information during a particular sampling event, such as date, time, name of field personnel, sampling location, sample ID, name of sampling program, and visual inspection of the site, as well as additional comments that may be relevant to the project. All field data will be entered into an electronic database following each sampling event. EMD will record and log all samples that are analyzed at the laboratory, and all laboratory data will be entered into EMD's LIMS. Upon validation from each respective laboratory supervisor, EMD will upload the validated data into the BOS' WISARD. Likewise, WPD field staff will upload the required in-situ measurements and other pertinent field observations into WISARD. The WISARD database is maintained by the ICSD and is used extensively by the Bureau of Sanitation for legal reporting of data for various NPDES and TMDL monitoring programs. Custom report templates will be developed for the Machado Lake Nutrients TMDL Monitoring Program so that data are reported in a timely, consistent manner, with systems in place to maintain the integrity of the data. Data within WISARD can only be edited with administrative approval, and will have an access log showing activities and changes made to the file. WISARD files are stored on a secure server, and are backed up on a daily basis.

In addition, hard copies of the Field log sheets and laboratory results will be filed in project specific folders at WPD and EMD, respectively. All electronic data files, at WPD and EMD, are saved on a network drive and are backed-up in an archive. Records will be maintained for a minimum of five years after submission of the data to the Regional Board. However, it is the practice of the Bureau of Sanitation (including WPD and EMD) to maintain monitoring records indefinitely.

Tasks and checklists for data management are included in the Pollution Assessment Section SOP for Managing Data and EMD QA Manual.

GROUP C Elements: Assessment & Oversight

B.19 Assessments and Response Actions

All reviews will be made by the WPD QA Officer and may include the SWRCB QA Officer. WPD will conduct reviews of sampling and field monitoring procedures. Reviews will evaluate observed practices against those found in the SWAMP sampling SOP. The reviews of laboratory analytical procedures will evaluate observed method practices against EMD's SOPs and an audit of data from EMD quality assurance and quality control program. Assessments and response actions are necessary when field monitoring procedures are not followed as according to the established SWAMP sampling SOP. Corrective actions will be implemented immediately by WPD's QA Officer. For this project, sampling will occur biweekly following 60 days after the Lake Management Plan has been approved by the Regional Board. With each event, the QA Officer will conduct reviews of field procedures and make necessary adjustments before the next sampling event. The QA Officer will approve field log sheets as well as COC forms to ensure all required analyses are properly marked and legible. The QA Officer will report the results of the assessments to the Project Manager.

In an unlikely event that data quality does not meet the established standards such as calibration criteria, inadequate recordkeeping, improper storage or preservation of samples, proper corrective actions will take place according to the appropriate person responsible for the activity. Laboratory analysts should be able to recognize all unusual circumstances that will jeopardize the integrity of data quality and notify the laboratory supervisor to solve the problem. The laboratory supervisor should review all analytical and QC data for reasonableness, accuracy and clerical errors. When suspected data are present, the laboratory supervisor works with the analyst, as well as EMD Laboratory Quality Assurance Officer, to solve the problem and prevents the reporting of suspected data by stopping work on the analysis in question. After the source of error is determined and remedied, all suspected results are repeated. This will insure the highest quality assurance possible. Refer to the EMD QA Manual for additional details. The general guidelines for initiating a corrective action are as follows:

- Identify/define the problem.
- Assign responsibility for investigating the problem.
- Investigate and determine the causes.
- Develop corrective actions to eliminate the problem.
- Measure the effectiveness of the corrective action.

- Analyst, unit supervisor, laboratory manager, and Laboratory QA Officer meet to review and evaluate the process, if necessary.

- Document the process by filling out the Corrective Action Report Form.

B.20 Reports to Management

EMD is responsible for all laboratory QA/QC reports. This will be done according to their established protocol as specified in the EMD QA Manual, and will ensure that all laboratory data has been thoroughly assessed and reviewed prior to being uploaded into the WISARD database. Other QA/QC review will be performed by the Field Team Coordinator and the Project QA Officer. This review will assess field generated data, in addition to laboratory results. Specifically, this will involve examination of field blanks and duplicates.

Reports to management including frequency, approximate due dates, report writers, and report recipients are listed in Table 8.

Table 8. Reports to Management Due Dates

Type	Frequency	Projected Delivery Dates(s)	Person(s) Responsible for Report Preparation	Report Recipients
Internal progress report	Quarterly	By the 30th of the month following the quarter	Project QA Officer	Project Manager, Technical Leader
Compiled data set and summary	Annually	March 31st of each year	EMD Laboratory Manager	Project Manager, Technical Leader, Field Team Coordinator
Draft annual report	Annually	May 31th of each year	Technical Leader	Project Director, Laboratory Manger
Final annual report	Annually	June 30th of each year	Project Director, Laboratory Manger	RWQCB Executive Officer

Group D Elements: Data Validation & Usability

B.21 Data Review, Verification, and Validation

All field data and EMD data will be reviewed by the WPD QA Officer to determine if the data meet Data Quality Objectives (DQO) and Criteria cited in Section 7 and the quality assurance/quality control practices cited in Sections 14, 15, 16, and 17. EMD will review and validate analytical results prior to uploading to the WISARD database. WPD will review and validate all field observations and measurements prior to uploading to the WISARD database. The data will be available for examination and interpretation by the Technical Leader, Field Team Coordinator, Project QA Officer, and other persons with access to the WISARD database. Decisions to accept or reject or qualify data are made by the Project QA Officer and Laboratory QA Officer in consultation with the Field Team Coordinator.

All data will be separated into three categories based on DQO:

1. Data meeting all data quality objectives – Data Acceptable

2. Data failing to meet precision or recovery criteria – Data Re-assessed

3. Data failing to meet accuracy criteria – Data Rejected

Data falling in the first category is considered usable by the project. Data falling in the last category is considered not usable. Data falling in the second category will have all aspects assessed. If sufficient evidence is found supporting data quality for use in this project, the data will be moved to the first category, but will be flagged with a "J" as per EPA specifications.

Data meeting all data quality objectives, but with failures of quality assurance/quality control practices will be set aside until the impact of the failure on data quality is determined. Once determined, the data will be moved into either the first category or the last category.

B.22 Verification and Validation Methods

Data verification and validation processes require all results to be visually inspected and recorded as checked by initials and dates. This also consists of evaluating the field log sheets and COCs for consistency. Data validation criteria are based upon the measurement quality objectives developed in the QAPP. Data validation includes a determination, where possible, of the reasons for any failure to meet method, procedural, or contractual requirements, and an evaluation of the impact of such failure on the overall data set. Data validation applies to activities in the field as well as in the analytical laboratory. All field data and final laboratory data will be reviewed by Project QA Officer and Project Manager to determine if the data meet quality assurance project plan objectives. Decisions to reject or qualify data are made by the Project QA Officer and Laboratory QA Officer in consultation with the Field Team Coordinator. All laboratory data generated by EMD will be reviewed by EMD section supervisors. EMD analysts should report unusual results to the section supervisor/laboratory manager. A second sample should be analyzed as soon as possible to verify the condition. Any issues will be noted. Reconciliation and correction will be done by a committee composed of Project QA Officer, Project Manager Technical Leader, and Laboratory's QA Officer and/or Laboratory Manager. Any corrections require a unanimous agreement that the correction is appropriate. Certification of the data will be made by the Project Director and Laboratory Manger when submitting the final annual report. See the list below for a data validation checklist. For further details on data validation procedures refer to the EMD QA Manual and the PAS SOP for Managing Data.

Calibration requirements as defined in the method:

- Documented traceability of instrument and spiking standards
- Documentation of methods used and QC applied
- Maintenance performed on instruments
- Documentation of sample preservation, transport, and storage
- Review of QC sample data

B.23 Reconciliation with User Requirements

Quarterly internal progress reports and the annual report will be automatically generated through standardized queries within the WISARD database. The data generated in these reports will be considered "validated"; however, at this point they are not considered "official" results. This designation only comes after the Project Direction and the Laboratory Manager have certified the results with their signatures on the Annual Report. Further review of the "validated" data will be conducted to assess the data in terms of its uncertainty with respect to the goals and objectives of this monitoring program—that is, assessing compliance with TMDL Load Allocations and attainment of numeric targets (refer to section 5.3 of this QAPP). This review process will be conducted by a team consisting of the Technical Leader, Project Manager, and Field Team Coordinator, in consultation with the Project QA Officer and Laboratory QA Officer. The review will involve comparing monitoring results with historical trends to identify anomalies and/or questionable data. As a general guideline, results that are greater than two (2) standard deviations away from historical mean values will be considered for further review. Monitoring data will also be reviewed in relation to field observations and other notes that may have been recorded by field staff when the samples were collected. In addition, information may also be acquired through other sources (e.g., RAP staff) if it pertains to the representativeness of the samples. Samples that were collected on days that concur with lake management activities or other events that may alter lake conditions, will be flagged for further review. The Field Team Coordinator will prepare a report of any "uncertain" results. This report will be provided to the Project QA officer for a final decision to be made on how to handle they results in question. Finally, a narrative statement, including any pertinent analysis or graphs, will be attached to the annual report, providing an explanation of how the questionable results were handled, and the reasoning behind the decisions that were made.

Data from this monitoring program will be reported in a manner consistent with existing TMDL and NPDES reporting programs. Data gathered from this program will be comparable in quality to SWAMP guidelines.

B.24 References

EMD Chemical Hygiene Plan

Attachment A to Resolution No.R08-006, Amendment to the Water Quality Control Plan for the Los Angeles Region (Basin Plan). May 1, 2008.

SWAMP Quality Assurance Management Plan, 2nd Ed., 2008, Appendix D, "Field Collection of Water Samples"

SWAMP Quality Assurance Management Plan, 2nd Ed., 2008, Appendix E, "Field Measurements Procedures

Appendix C
Lake Water Quality Model

C.1 Introduction

The purpose of the Lake Water Quality Model is to illustrate the long term projected concentrations of nutrients in Machado Lake after the installation of the proposed BMPs. The proposed BMPs that are included in the model are dredging, installation of an oxygenation system, supplemental water, and a recirculating treatment wetlands with alum treatment. The modeling effort involved establishing the following:

External Nutrient Loading to the Lake (Sections C.2 though C.3): To define current conditions and inflowing concentrations of nutrients to the lake, this step served to establish the appropriate data set to use as the dry weather baseflow and wet weather event mean concentration (EMC) to be input into Lake Water Quality Model.

Internal Nutrient Load (Sections C.4): To define internal nutrient loading in the lake, this step involved a sediment flux study and paleolimnological study that establish the current conditions and effects that various BMPs would have on the nutrient loading from the sediments to the water column. The model includes explicit simulation of sediment nutrient (N and P) dynamics and resulting summer flux release to the water column.

The model simulates the conditions within the lake as a function of internal nutrient loading as well as the external nutrient loading from urban runoff and the effect that the implementation of the proposed BMPs will have on nutrient concentrations in the lake.

In order to be able to directly simulate a range of rehabilitation alternatives at Machado Lake, it was decided to move away from published, "black box," modeling options, such as the USACE Bathtub model (Walker, 2004). The model needed to include the ability to be flexible with the model code to include explicit representation of features such as the link between daily wet weather runoff loads, settling and dry weather internal loads; monthly-varying supplemental water inflows; and the offline re-circulating wetlands. The fundamental equations used in the model, however, are based on simple and well-established mass and flow balances, various forms of which are used in nearly all water quality models and the widely-used empirical relationship between phytoplankton and nutrients adopted from the Bathtub model.

Like all models, this tool has limitations with respect to predictive ability. These limitations are due to the various simplifications and assumptions inherent in the fundamental equations and to the uncertainties associated with the model parameterization. Therefore, both a sensitivity analysis and an uncertainty analysis were performed, the process and results of which are presented in Sections C.6 and C.7, respectively.

C.2 Existing Runoff Water Quality Data

City of Los Angeles Monitoring Data

The City of Los Angeles Bureau of Sanitation (BOS) Watershed Protection Division (WPD) regularly collects runoff water quality monitoring data from three storm drain outfall locations, which include the Wilmington Drain above Lomita Boulevard, the Project 77 storm drain outfall on the west side of Machado Lake, and the Project 510-Line C storm drain outfall on the west side of Machado Lake. Additionally, BOS-WPD collects water quality data from four in-lake sampling locations. Sampling data summaries for storm drain and in-lake sampling are presented in this Section. The analytic data for nutrient species was used to calibrate the lake water quality model.

Currently available sample collection data range from June 2006 through September 2008 for in-lake samples and from June 2007 through September 2008 for storm drain outfall samples. Most water quality samples were collected during dry weather periods with low baseflow in the drains. However, there is also limited grab sampling data from the drains on five wet weather days or days immediately following wet weather events. The mean of all dry weather samples collected from each of the three storm drain outfall locations during this sampling period was calculated for each of the nutrient species in the pollutant load model. Table C-1 presents the minimum, average, and maximum concentrations of TSS, nutrient species, TDS, alkalinity, and hardness in dry and wet weather runoff. Table C-2 presents the average, minimum, and maximum values of parameters collected using field instruments.

Table C-1
Machado Lake Storm Drain Outfall Analytic Water Quality Monitoring Data 2006-2008

Constituent	Units	Dry Weather			Wet Weather		
		Minimum	Average	Maximum	Minimum	Average	Maximum
TSS	mg/l	0.5	12	181	7	96	311
Total P	mg/l	0.03	0.6	4.66	0.13	0.6	1.99
Total N	mg/l	1.29	2.7	18.42	1.77	2.8	5.71
Organic N	mg/l	0.42	1.6	15.4	0.76	1.1	2.3
Ammonia-N	mg/l	0.03	0.3	1.44	0.14	0.5	0.86
(Nitrate+Nitrite)-N	mg/l	0.41	5	2.12	0.87	1.1	2.91
TDS	mg/l	456	820	1,760	36	260	620
Alkalinity	mg/l	58	130	238	14	56	108
Hardness	mg/l	134	360	1,000	15.1	120	264

Table C-2
Machado Lake Storm Drain Outfall Field Collected Monitoring Data 2006-2008

Parameter	Units	Minimum	Average	Maximum
Temperature	Deg C	9.24	18.04	23.60
Conductivity	mS/cm	0.61	1.27	2.52
DO	mg/l	2.17	8.47	14.27
pH	SU	7.53	8.09	9.09
Turbidity	NTU	-2.90	6.93	131.20
TDS	mg/l	0.30	8.30	28.50
Chl-a	ug/l	9.24	18.04	23.60

Available in-lake water quality samples range from June 2006 through September 2008, and occurs at the four locations shown in Figure C-1 (ML 1 to ML-4). WPD regularly monitors ML-1 and ML-2 and has intermittently monitored ML-3 and ML-4.

Most in-lake water quality samples were collected during dry weather periods with low baseflow in the drains. No samples were collected during wet weather; however, a few samples were collected one or two days after wet weather events. Table C-3 presents the statistics of all samples collected from each of the in-lake sampling locations during this sampling period for several of the nutrient species, chl-*a*, DO, and Secchi depth.

The TMDL reports that the most distinct water quality problem affecting the lake is eutrophication, which is a result of increased nutrient loading. Phosphorus and nitrogen are recognized as key nutrients responsible for the eutrophication of Machado Lake, and Secchi depth is an additional indicator of eutrophication. The sampling data presented in Table C-3, identify that the lake is eutrophic to hypereutrophic based on a tropic status, or degree of eutrophication, as related to both Secchi depth and total phosphorus. Secchi depths less than 2 meters (m) are indicative of eutrophic lakes (Horne 1994); sampling data range from 0.17 m to 0.91 m, with mean values presented in the table and an overall average of 0.35 m. Based on EPA nutrient guidelines, hypereutrophic lakes exceed 0.10 mg/L total phosphorus; however these guidelines were based on lakes that may not be in geographic areas similar to Machado Lake. Sample results for total phosphorus range from 0.19 mg/L to 1.38 mg/L, with mean values presented in the table and an overall average of 0.8 mg/L.

Additional wet weather sampling was performed for the City (CDM & Parsons 2010) during seven wet weather days from October 2009 through January 2010. Two samples were taken at each location for each rain event. A summary of the average at each of the three sampling locations is presented in Table C-4.

Table C-4
Machado Lake Wet Weather Sampling (2009 –2010 Wet Season)

Location	Total P (mg/L)	Dissolved Orthophosphate as P (mg/L)	Total N (mg/L)	Ammonia as N (mg/L)	Nitrate + Nitrite (mg/L)	Suspended Solids (mg/L)
Wilmington Drain	0.83	0.31	4.77	1.12	1.05	102.05
Project 77	0.82	0.53	5.77	1.26	1.5	104.27
Machado Lake Dam	0.53	0.28	1.48	2.82	0.33	101.49

Notes:
Samples were taken during the 2009-2010 wet season as part of a State Coastal Conservancy Grant for the City of Los Angeles. Seven rain events were sampled, with generally two samples taken per rain event per location. Sampling locations include Wilmington Drain south of PCH, at the Project 77 drain, at the Machado Lake dam.

Figure C-1
Machado Lake Sampling Locations

Table C-3
Summary of Machado Lake Sampling Data

		NH3-N (mg/L)	Inorganic-N (mg/L)	Total-N (mg/L)	Total-P (mg/L)	Ortho-P (mg/L)	CRG Corrected Chl-a (ug/L)	Dissolved Oxygen (mg/L) Surface (<0.5m)	Dissolved Oxygen (mg/L) Mid-Depth (0.5m<1.0 m)	Dissolved Oxygen (mg/L) Bottom (1.0m<1.5m)	Secchi Depth (m)
ML-1 (in-Lake)	**Mean**	**0.05**	**0.08**	**1.84**	**0.81**	**0.65**	**69.69**	**5.81**	**5.17**	**5.39**	**0.35**
	Median	0.03	0.03	1.87	0.84	0.68	62.06	5.70	4.90	4.85	0.33
	St. Dev	0.08	0.14	0.72	0.21	0.29	42.26	2.26	2.32	4.06	0.10
	Minimum	0.03	0.03	0.30	0.31	0.13	3.41	2.82	1.81	0.98	0.20
	Maximum	0.53	0.68	3.79	1.38	2.60	220.72	17.07	16.68	16.53	0.64
	95th Percentile	0.13	0.47	3.30	1.12	0.89	141.87	8.68	8.39	12.15	0.55
ML-2 (in-lake)	**Mean**	**0.06**	**0.08**	**1.81**	**0.79**	**0.65**	**66.28**	**5.66**	**4.96**	**4.84**	**0.36**
	Median	0.03	0.03	1.78	0.80	0.66	66.22	5.44	5.15	4.57	0.32
	St. Dev	0.08	0.15	0.68	0.19	0.23	34.24	1.75	1.82	1.97	0.12
	Minimum	0.03	0.03	0.30	0.33	0.20	5.70	2.58	1.26	1.07	0.22
	Maximum	0.58	0.70	4.62	1.31	2.00	172.61	11.84	11.88	11.85	0.75
	95th Percentile	0.20	0.45	2.74	1.07	0.93	124.31	8.72	7.45	7.71	0.61
ML-3 (in-lake)	**Mean**	**0.03**	**0.03**	**1.81**	**0.81**	**0.69**	**83.59**	**4.93**	**4.37**	**4.52**	**0.34**
	Median	0.03	0.03	1.80	0.81	0.69	73.38	4.71	4.24	4.43	0.32
	St. Dev	0.01	0.03	0.52	0.16	0.25	52.15	1.63	1.84	2.53	0.12
	Minimum	0.03	0.03	0.30	0.52	0.33	37.51	1.42	0.89	0.46	0.17
	Maximum	0.09	0.19	3.30	1.22	2.10	337.71	10.38	10.36	10.29	0.91
	95th Percentile	0.05	0.08	2.50	1.05	0.87	156.30	7.25	7.28	7.69	0.55
ML-4 (in-lake)	**Mean**	**0.03**	**0.03**	**1.61**	**0.80**	**0.67**	**70.84**	**5.58**	**4.95**	**3.92**	**0.33**
	Median	0.03	0.03	1.70	0.80	0.68	61.26	5.58	5.13	3.88	0.33
	St. Dev	0.02	0.02	0.48	0.15	0.24	31.58	1.80	1.71	1.82	0.07
	Minimum	0.03	0.03	0.30	0.47	0.33	30.88	1.12	1.08	1.01	0.21
	Maximum	0.11	0.14	2.80	1.10	1.90	165.54	10.06	9.14	6.86	0.56
	95th Percentile	0.04	0.09	2.50	1.02	0.91	144.11	8.69	7.49	6.81	0.47
Overall Average		0.04	0.06	1.77	0.80	0.67	72.60	5.50	4.86	4.67	0.35

LACDPW Monitoring (1987-1995)

LACDPW collected water quality samples at several locations within the Dominguez Watershed from 1987 through 1995. One sampling location was in the Machado Lake subwatershed, located in Wilmington Drain upstream of the Pacific Coast Highway (PCH). These data are presented in the Dominguez Watershed Management Master Plan and below in Table C-5. It is assumed that this data was collected during wet weather events but that is not stated in the Master Plan.

Table C-5
Summary of LADPW Water Quality Data Collected in Wilmington Drain above PCH

Pollutant	Units	Sample Results[1]		
		Minimum	Average	Maximum
TSS	mg/l	13	225.2	1,143
Total P	mg/l	0.08	0.3	1.3
Ammonia-N	mg/l	0	1.0	15
(Nitrate+Nitrite)-N	mg/l	0	1.1	10.83
Total Copper	ug/l	0	28.3	100
Dissolved Copper	ug/l	0	9.9	140
Total Lead	ug/l	0	33.5	260
Dissolved Lead	ug/l	0	12.1	290
Bacterial Indicators				
Total Coliform	MPN	930	38,197	790,000
Fecal Coliform	MPN	33	8,336	160,000
Enterococcus	MPN	20	5,023	50,000

Notes:
1. Average concentrations presented in Table 2.3-24 Summary of historic water quality data for the Dominguez Watershed, in the Dominguez Watershed Management Master Plan

Los Angeles County and other Regional Monitoring Data

From 1994 through 2000 the Los Angeles County Department of Public Works (LACDPW) collected water quality monitoring data from a variety of sites throughout Los Angeles County. Two of the stations were located within the Dominguez Watershed. The purpose of this water quality and land use monitoring was to evaluate possible effects of land use on water quality, to evaluate the relative importance of land use as a pollutant source, and to provide data to develop pollutant loading event mean concentration (EMC) data. Using these land use based EMCs, the projected pollutant load from the Machado Lake watershed was estimated. This process is summarized in Section C.3.

C.3 Existing Pollutant Load Estimates Using County of Los Angeles EMC Database

A runoff pollutant load model was used to estimate the generation of pollutants and expected constituent concentrations resulting from both dry weather baseflow and wet weather stormwater runoff within the Wilmington Drain and Machado Lake watersheds, and the results of this modeling effort are the inputs into the Lake Water Quality Model that estimates current in-lake conditions and future, post-BMP conditions. The model accounts for the pollutants coming from upstream subwatersheds both those tributary to Wilmington Drain and those that discharge directly to the lake or the riparian areas within the park upstream of the lake and to pollutant loads from the subwatersheds that discharge to the Freshwater Marsh below Machado Lake. Two pollutant load estimates were developed, one for dry weather baseflow and one for wet weather flows, both of which utilized the same subwatershed delineation.

The Machado Lake and Wilmington Drain watersheds were divided into 18 subwatersheds for pollutant load modeling, as shown in Figure C-2. The area of each subwatershed is presented in Table C-6. Thirteen of the subwatersheds (totaling approximately 14,156 acres) are ultimately tributary to Machado Lake, while the other five (totaling approximately 1,337 acres) are tributary to the Freshwater Marsh downstream of Machado Lake. Of the eleven subwatersheds tributary to Machado Lake, six discharge to Wilmington Drain, which itself discharges through the upper Riparian Woodland to Machado Lake. Ultimately, all runoff that flows out of Machado Lake and the Freshwater Marsh discharges to a slip of the Los Angeles Harbor. Figure C-3 shows the areal breakdown for these four overall subwatershed areas (Wilmington Drain, Riparian Woodland, Machado Lake, and Freshwater Marsh).

Table C-6
Subwatershed Characteristics

Subwatershed	Area (acres)	Percent Impervious (%)	Tributary to
College	116	55	Below Lake
D24010	158	49	Riparian Woodland above lake
Figueroa Drain	707	54	Below Lake
Golf	75	20	Lake
P2533	67	48	Below Lake
D7223	436	32	Below Lake
P6545	71	74	Riparian Woodland Above Lake
P9481	11	35	Below Lake
P36466	37	84	Lake
KMHRP West	33	22	Lake
Project 1104B[2]	3,224	57	Wilmington Drain
Wilmington Channel	84	35	Wilmington Drain
WD Project 510	753	62	Wilmington Drain
Project 2	311	60	Wilmington Drain
Project 9827[3]	4,554	47	Wilmington Drain
Walteria[1]	3,170	60	Wilmington Drain
Project 77	1,604	46	Lake
Project 510 Line C	81	37	Lake
Summary			
Tributary to Wilmington Drain	12,097		
Tributary to Lake Including Wilmington Drain	14,156		
Tributary Below Lake	1,337		
TOTAL	15,493		

Notes:
1. Walteria Lake adds an additional 26 acres to this subwatershed. The lake is not included in the pollutant load model.
2. Includes subwatershed Project 8101 Project 509, Project 1201
3. Included Project 1104

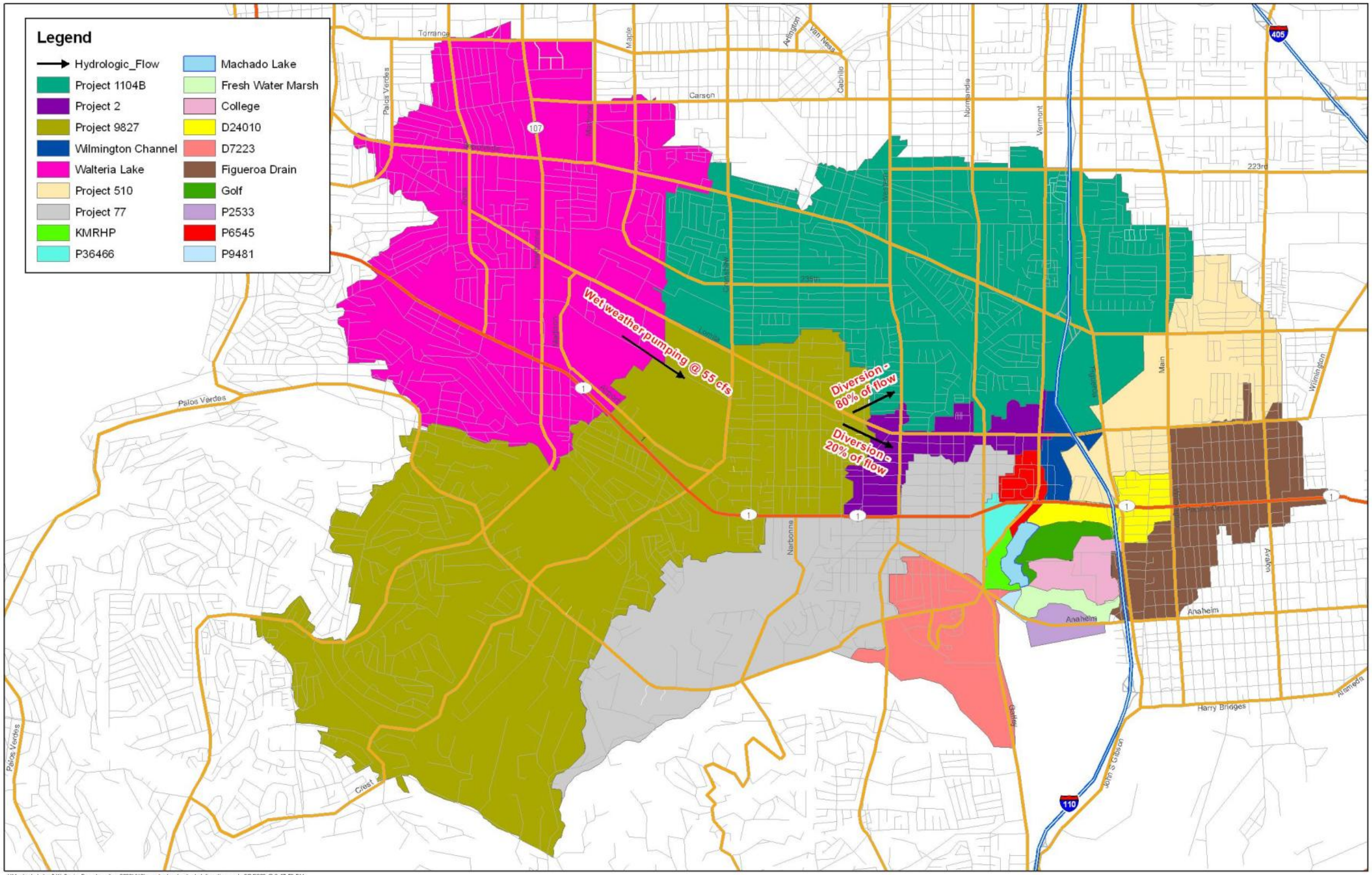


Figure C-2
Machado Lake and Wilmington Drain Subwatershed Delineation

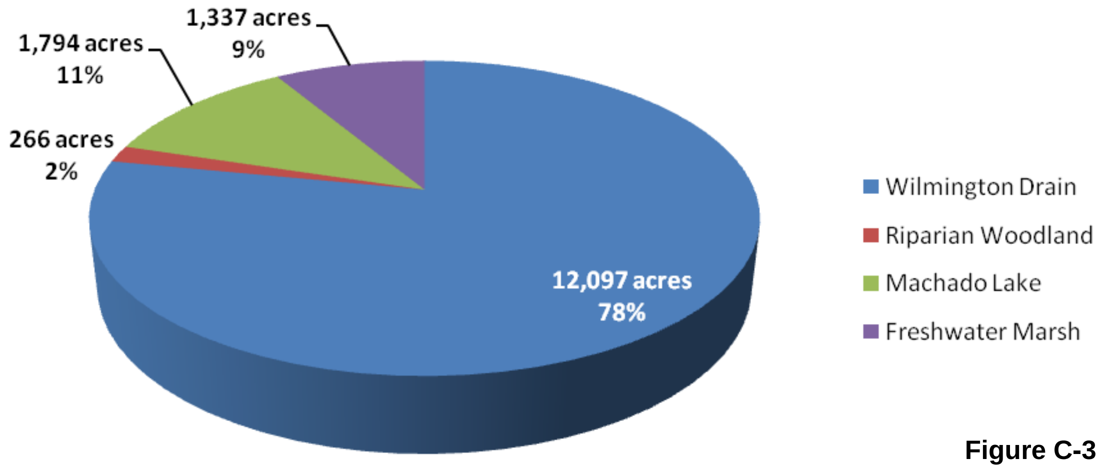


Figure C-3
Project Area Breakdown

C.3.1 Wet Weather Flow and Pollutant Load Reduction Modeling

In general, the wet weather pollutant load model calculated wet weather pollutant loads by (1) estimating runoff coefficients to convert rainfall data into runoff volumes, (2) estimating pollutant loads using runoff volumes and pollutant event mean concentrations (EMCs). The pollutant loading model is based on four main equations which determine the runoff coefficient, the annual runoff, the annual pollutant loadings, and the resulting average annual pollutant concentrations. For purposes of this model, the term pollutant refers to any physical or chemical constituent that exists naturally or is anthropogenically deposited within a watershed that can be mobilized by rainfall and transported by runoff. Pollutants have the potential for causing adverse effects on the receiving water environment because of concentrations in the water or as result of physical or biological accumulation.

The model methodology has been adapted from an empirical method that has been referred to by others as the Simple Method (Schueler 1987). The Simple Method is an empirical approach developed for estimating pollutant export from urban development sites. The model was developed to provide a simple yet effective method for predicting runoff volumes, pollutant loads, and resulting pollutant concentrations from proposed project areas.

The model, developed in spreadsheet format, utilized available stormwater monitoring and rainfall data, watershed drainage, and land use information derived for hydrologic analysis, to predict runoff volumes. The model is capable of estimating changes in runoff volumes, pollutant loads, and resulting pollutant concentrations that may occur as a result of property development or redevelopment. The model does not incorporate individual storm event hydraulics or hydrology of the project site, which would be more appropriate for hydrology/hydraulic design and requires additional data and more sophisticated modeling. Model calculations are deterministic in that only a single average value is obtained from a set of inputs without an estimation of the potential variation in stormwater loads or concentrations.

This type of model was selected because it allows for the incorporation of the treatment benefits expected from the implementation of structural BMPs.

C.3.1.1 Source Data

Source data, including land use, rainfall and estimated runoff, are presented below.

Land Use

Land use categories include: education, high density single family residential, light industrial, mixed residential, multi-family residential, retail/commercial, transportation, and vacant. Table C-7 shows the land use breakdown by subwatershed and Figure C-4 presents the overall landuse breakdown for all subwatersheds.

Table C-7
Land Use Breakdown by Subwatershed in Acres

Subwatershed	Education	HDSFR[1]	Light Industrial	Mixed Residential	MFR[2]	Retail / Commercial	Transportation	Vacant
College	76	0	0	16	0	0	2	21
D24010	0	70	6	3	9	24	14	30
Figueroa Drain	74	431	12	49	46	76	17	2
Golf	2	0	0	55	1	0	0	17
P2533	0	0	37	18	0	0	0	12
D7223	0	86	9	20	50	44	6	220
P6545	3	0	6	10	39	11	0	1
P9481	0	0	3	8	0	0	0	1
P36466	0	0	0	2	0	35	0	0
KMHRP West	0	0	0	33	0	0	0	0
Project 1104B	113	1,804	465	80	328	319	56	59
Wilmington Channel	0	0	4	17	10	10	6	38
Project 510	14	286	203	56	108	71	14	2
Project 2	13	118	20	29	67	51	3	10
Project 9827	132	2,007	203	600	233	578	199	602
Walteria[3]	141	1,476	197	55	290	771	89	151
Project 77	31	623	153	371	155	119	13	139
Project 510 Line C	1	22	4	10	9	7	1	27
Summary								
Tributary to Wilmington Drain	413	5,690	1,092	836	1,037	1,800	366	862
Tributary to Lake Including Wilmington Drain	451	6,406	1,262	1,321	1,249	1,997	394	1,076
Tributary Below Lake	151	517	62	111	97	120	25	256
Total	602	6,923	1,324	1,433	1,345	2,117	419	1,331

Notes:
1: HDSFR – high density single family residential
2: MFR – Multi-family residential
3: There are no EMCs for open water. Therefore, Walteria Lake is not included in the pollutant load model.

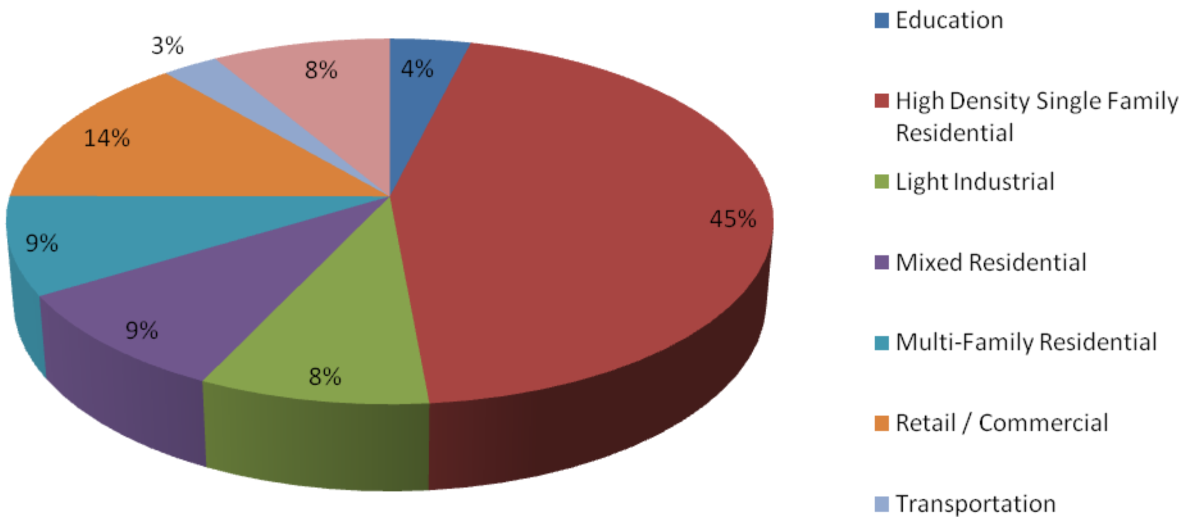


Figure C-4
Land Use Breakdown

Annual Rainfall Data
A long-term average annual rainfall value of 12.6 inches was used to estimate the rainfall anticipated in the Wilmington Drain/Machado Lake watersheds. This value is based on a 31 year record collected at the Long Beach National Climatic Data Center Station rain gage CA5085 (1976 through 2007).

Runoff Estimation
The wet-weather pollutant loading spreadsheet model estimates annual average runoff volumes based on a simple relationship between annual rainfall, annual runoff and pollutant concentrations. The model uses the following formula to determine runoff volume:

$$Q_i = (R_i) \times (I) \times (A_i) \times (CF_1) \qquad \text{Eqn. 1}$$

Where:

Qi	=	*annual runoff volume (ft3) from land use area i*
I	=	*annual average rainfall depth (inches)*
Ai	=	*land use area i (acres)*
Ri	=	*runoff coefficient of land use area i*
CF1	=	*conversion factor to convert from in-acres to acre-feet*

Model results express runoff in acre-feet per year (AFY). The runoff coefficient, Ri, is a unit-less value that is a function of the imperviousness of land use area, i, and is approximated in the model by the following equation (Federal Highway Administration 1990):

$$Ri = 0.007 \times (\%\ \text{imperviousness of } Ai) + 0.1 \qquad \text{Eqn. 2}$$

The percent impervious factors (Table C-8) were derived from an area-based weighted average of the impervious factors of all land uses that make up each land use category. Using Equations 1 and 2, annual wet weather runoff was estimated for each subwatershed on a land use basis (Table C-9). Figure C-5 graphically presents the modeled annual runoff volume from each subwatershed.

Table C-8
Percent Impervious Factors per Land Use

	Education	HRSFR	Light Industrial	Mixed Residential	MFR	Retail / Commercial	Transportation	Vacant
Impervious Factors	77	42	75	22	85	88	91	2

Notes:
1: HDSFR – high density single family residential
2: MFR – Multi-family residential

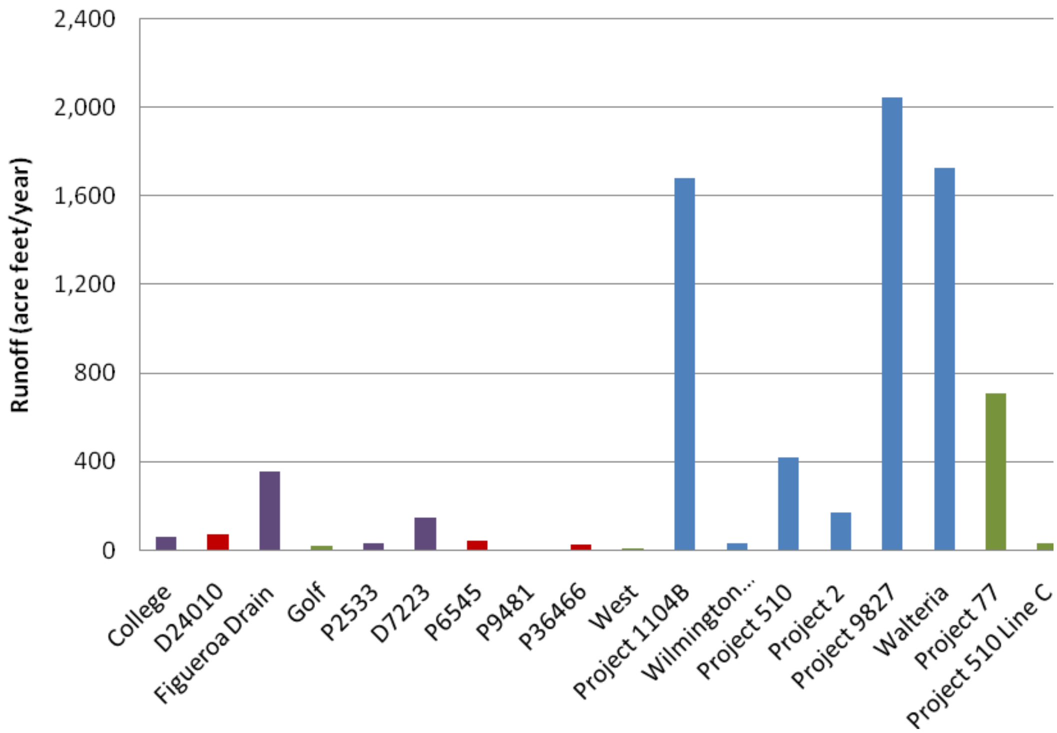


Figure C-5
Annual Runoff per Subwatershed

Table C-9
Annual Wet Weather Runoff Estimation per Subwatershed

Subwatershed	Education (AFY)	HDSFR[1] (AFY)	Light Industrial (AFY)	Mixed Residential (AFY)	MFR[2] (AFY)	Retail / Commercial (AFY)	Transportation (AFY)	Vacant (AFY)	Total (AFY)
College	51	0	0	4	0	0	2	3	60
D24010	0	29	4	1	6	18	11	3	74
Figueroa Drain	50	178	8	13	34	57	13	0	353
Golf	1	0	0	15	0	0	0	2	19
P2533	0	0	25	5	0	0	0	1	31
D2773	0	36	6	5	37	33	5	26	148
P6545	2	0	4	3	29	8	0	0	46
P9481	0	0	2	2	0	0	0	0	4
P36466	0	0	0	1	0	26	0	0	27
KMHRP West	0	0	0	9	0	0	0	0	9
Project 1104B	76	746	306	22	240	241	43	7	1,681
Wilmington Channel	0	0	3	4	8	7	4	4	31
Project 510	9	118	134	15	79	54	11	0	420
Project 2	9	49	13	8	49	39	2	1	170
Project 9827	88	830	134	162	171	436	154	70	2,045
Walteria	94	611	130	15	213	581	69	18	1,730
Project 77	21	258	101	100	113	90	10	16	709
Project 510 Line C	0	9	3	3	6	6	1	3	31
Summary									
Tributary to Wilmington Drain	276	2,354	720	226	760	1,357	283	100	6,076
Tributary to Lake Including Wilmington Drain	301	2,650	832	356	916	1,505	305	125	6,991
Tributary Below Lake	101	214	41	30	71	91	19	30	595
Total	402	2,864	872	386	986	1,596	324	155	7,586

Notes:
1. HDSFR – high density single family residential
2. MFR – Multi-family residential

C.3.1.2 Wet Weather Loadings and Concentrations Estimation

Land use-based pollutant loads and concentrations derived from a review of data from Los Angeles County's 1994-2000 monitoring data (LACDPW 2006), considered the most extensive, locally-derived data for a variety of land use types, which is also used in the pollutant load model maintained by BOS, were considered to determine if these values would be appropriate to use as an estimate of the runoff loads from the Machado Lake watershed. This section summarizes the data available from the Los Angeles County's monitoring program, and a comparison to the Machado Lake water quality data is presented in Section C.3.1.3.

The water quality parameters selected for modeling were based on the following pollutants provided that a scientifically sufficient amount of data is available from the Los Angeles County's monitoring program:

- Typical pollutants found in urban stormwater from the various land uses existing in the Machado Lake and Wilmington Drain subwatersheds,
- Pollutants listed on the 303(d) list for Machado Lake and Wilmington Drain, or
- Pollutants for which TMDLs have been completed.

The parameters selected for modeling include total suspended solids (TSS), total phosphorus (Total P), dissolved phosphorus, total nitrogen (Total N), organic nitrogen, ammonia-nitrogen, nitrate + nitrite as nitrogen, total copper (Cu), dissolved Cu, total lead (Pb), and dissolved Pb. The data set does not include trash and debris, as that data was developed separately under the Trash TMDL. Table C-10 presents the EMCs on a land use basis for the selected parameters modeled.

Table C-10
LACDPW Event Mean Concentrations

Pollutant	Units	Education	HDSFR[1]	Light Industrial	Mixed Residential	MFR[2]	Retail / Commer-cial	Transpor-tation	Vacant
TSS	mg/l	103.02	104.65	229.37	69.06	46.35	67.40	75.35	164.68
Total P	mg/l	0.31	0.39	0.44	0.26	0.19	0.41	0.44	0.11
Dissolved P	mg/l	0.27	0.29	0.28	0.20	0.16	0.30	0.36	0.06
Total N	mg/l	2.34	3.94	4.02	3.52	3.68	4.09	2.65	1.97
Organic N	mg/l	1.36	2.44	2.59	2.12	1.48	2.46	1.58	0.73
Ammonia-N	mg/l	0.26	0.36	0.48	0.58	0.38	0.91	0.23	0.08
(NO_2+NO_3)-N	mg/l	0.71	1.13	0.95	0.81	1.82	0.71	0.84	1.16
Total Cu	ug/l	21.49	15.30	31.04	17.33	12.23	34.77	51.86	9.12
Dissolved Cu	ug/l	12.80	8.44	20.22	11.52	6.75	14.60	32.68	0.0[3]
Total Pb	ug/l	4.53	9.59	14.87	8.70	5.13	11.53	9.08	0.0[3]
Dissolved Pb	ug/l	0.0[3]	0.0[3]	0.0[3]	0.0[3]	0.0[3]	0.0[3]	0.0[3]	0.0[3]
Total Zn	ug/l	123.69	80.35	565.60	184.85	134.88	238.53	279.45	0.00
Dissolved Zn	ug/l	65.97	39.11	460.19	125.83	75.36	164.12	203.89	0.00

Notes:
1: HDSFR – high density single family residential
2: MFR – Multi-family residential
3: Not enough data above the detection limit, considered statistically invalid by LA County, therefore 0.00 was adopted.

The land use EMC for each pollutant in conjunction with the runoff volumes from each land use area were used to estimate the average annual load to the receiving waterbodies in the project area. The following equation was utilized in the model:

$$L_{Dj} = \sum_{i=1}^{n_{LU}} L_i = \sum_{i=1}^{n_{LU}} (EMC_i) \times (Q_i) \times (CF_2) \qquad \text{Eqn.3}$$

Where:

LDj	=	*total average annual load (lbs) from subwatershed j*
Li	=	*load (lbs) from land use area i*
EMCi	=	*event mean concentration (mg/L) from land use area i*
Qi	=	*runoff volume (ft3) from land use area i*
CF2	=	*conversion factor to convert mg/L to lbs/ft3*
nLU	=	*total number of different land use areas in subwatershed j*

To estimate the annual average storm event pollutant concentrations to receiving waters, the total annual load calculated above is simply divided by the total runoff volume, or symbolically as:

$$C_{Dj} = \frac{L_{Dj}}{\left(\sum_{i=1}^{n_{LU}} Q_i \right) \times CF_2} \qquad \text{Eqn.4}$$

Where:

CDj	=	*total annual average concentration (mg/L) from subwatershed j*
LDj	=	*total average annual load (lbs) from subwatershed j*
Qi	=	*total annual runoff volume (ft3) from land use area i*
nLU	=	*total number of different land use areas in subwatershed j*
CF2	=	*conversion factor to convert mg/L to lbs/ft3*

C.3.2 Selection of Baseline Pollutant Load EMCs

The pollutant loading model simultaneously calculates loads and concentrations for each of the constituents of concern. Table C-11 presents the average annual wet weather pollutant load from each subwatershed and Table C-12 presents the total annual average pollutant concentrations. The average water quality concentrations calculated by the wet weather model using the LACDPW EMC data was compared with the wet weather sampling data presented in Section C.2. Table C-13 presents a summary of these data sets.

This following is a summary of the comparison:

- In general, analytical results from the sampling programs are of a similar order of magnitude as the values derived using the area-wide EMC data in the pollutant load model.
- Total phosphorous estimated by the pollutant load model (Column D) is somewhat lower compared to the average of the three data sets (Column E).
- Total nitrogen estimated by the pollutant load model (Column D) is slightly higher compared to the average of the three data sets (Column E).

Since the data set for the measured wet weather monitored data (columns A, B and C) is representative of current conditions, it was used to calibrate the lake water quality model. However, it was determined that the pollutant load model results (Column D) would be used in the Lake Water Quality Model to represent future conditions since the area-wide EMC data set used in the pollutant load model is considered more representative of long-term wet weather nutrient concentrations. Also, due to the upstream BMPs, including public education and outreach the future runoff to the lake is expected to have relatively lower total nitrogen and total phosphorus values.

Table C-11
Wet Weather Average Annual Pollutant Loads

Subwatershed	TSS (lbs)	Total P (lbs)	Dissolved P (lbs)	Total N (lbs)	Organic N (lbs)	Ammonia-N (lbs)	(Nitrate+Nitrite)-N (lbs)	Total Cu (lbs)	Dissolved Cu (lbs)	Total Pb (lbs)	Dissolved Pb (lbs)	Total Zn (lbs)	Dissolved Zn (lbs)
College	16591	49	42	392	227	45	120	3	2	1	0	21	12
D24010	19083	74	56	731	431	95	206	5	3	2	0	36	24
Figueroa Drain	89496	344	263	3504	2075	424	1004	20	11	8	0	134	82
Golf	4156	13	10	168	98	26	44	1	1	0	0	8	6
P2533	16944	33	22	324	205	40	79	2	2	1	0	40	33
D7223	38130	118	87	1409	753	181	476	8	4	3	0	58	38
P6545	8725	33	25	466	224	62	180	2	1	1	0	24	16
P9481	1648	4	3	42	26	6	10	0	0	0	0	4	3
P36466	4951	30	22	300	34	66	53	3	0	1	0	17	12
KMHRP West	1688	6	5	86	52	14	20	0	0	0	0	5	3
Project 1104B	515139	1673	1227	17455	10304	2085	5065	99	55	45	0	948	664
Wilmington Channel	7613	25	19	283	150	40	92	2	1	1	0	17	12
Project 510	144579	416	298	4400	2576	541	1283	27	15	12	0	314	233
Project 2	40300	151	114	1740	963	232	545	10	5	4	0	83	55
Project 9827	539326	2000	1496	20494	12128	2667	5699	129	69	52	0	961	642
Walteria	439311	1733	1291	17871	10482	2563	4827	115	58	46	0	880	591
Project 77	201068	654	484	7244	4213	904	2126	39	22	18	0	377	261
Project 510 Line C	8340	26	20	304	170	39	96	2	0	0	0	14	10
Summary													
Tributary to Wilmington Drain	1686268	5998	4445	62242	36602	8129	17511	381	203	159	0	3202	2196
Tributary to Lake Including Wilmington Drain	1934279	6835	5066	71541	41969	9335	20237	434	230	181	0	3665	2515
Tributary Below Lake	162809	548	416	5671	3286	696	1689	34	18	13	0	257	167
Total	2088748	7357	5462	76908	45085	9992	21830	466	248	195	0	3940	2695

Table C-12
Wet Weather Average Annual Pollutant Concentrations

	TSS (mg/l)	Total P (mg/l)	Dissolved P (mg/l)	Total N (mg/l)	Organic N (mg/l)	Ammonia-N (mg/l)	(Nitrate+ Nitrite)-N (mg/l)	Total Cu (ug/l)	Dissolved Cu (ug/l)	Total Pb (mg/l)	Dissolved Pb (ug/l)	Total Zn (ug/l)	Dissolved Zn (ug/l)
Subwatersheds tributary to Wilmington Drain	102.05	0.36	0.27	3.77	2.22	0.49	1.06	23.09	12.30	9.64	0.00	193.79	132.93
Subwatersheds tributary directly to Lake	101.75	0.36	0.27	3.76	2.21	0.49	1.06	22.68	12.10	9.53	0.00	192.82	132.32
Subwatersheds tributary Below Lake	101.75	0.36	0.27	3.76	2.21	0.49	1.06	20.98	11.23	8.32	0.00	158.97	103.41
Total Watershed	100.56	0.34	0.26	3.50	2.03	0.43	1.04	22.67	12.04	9.47	0.00	191.00	130.63

Table C-13
Comparison of Actual and Theoretical Wet Weather Pollutant Load Concentrations

Pollutant	Units	Sample Results			(Column D) Pollutant Load Model-Derived Concentrations[4]	(Column E) Average of Columns A-C
		(Column A) LA BOS 2006-2008[1]	(Column B) LACDWP 1987-1995[2]	(Column C) CDM & Parsons 2009-2010[3]		
Total P	mg/L	0.62	0.3	0.82	0.36	0.58
Dissolved P	mg/L	NA[5]	NA	0.42	0.27	0.42
Total N	mg/L	2.76	NA	5.27	3.77	4.02
Organic N	mg/L	1.14	NA	NA	2.22	1.14
Ammonia-N	mg/L	0.52	1.0	1.19	0.49	0.90

Notes:
1 See Tables C-1. Total P, dissolved-P, all nitrogen species, and TSS data are average concentrations of these constituents sampled at Wilmington Drain above Lomita Boulevard, Project 77, and Project 510 Line C under wet weather conditions. Data provided by WPD on December 1, 2008.
2 See Table C-5. Average concentrations presented in Table 2.3-24. Summary of historic water quality data for the Dominguez Watershed, in the Dominguez Watershed Management Master Plan.
3 See Table C-3. Average concentrations of storm drain samples at Wilmington Drain and Project 77 outfall under wet weather conditions.
4 Using the City of Los Angeles pollutant load model that is based on LA County derived land use based event mean concentrations (EMCs), the land use in the Machado Lake watershed and historical rainfall. Does not account for possible load removed from Walteria Lake subwatershed, which usually retains stormwater after rain events. This practice could remove 50-60% of TSS and up to 40% of metals from the fraction of flow that is detained/retained. Walteria Lake is 25% of the tributary area to Machado Lake, so this would translate to loads to Machado Lake potentially being on the order of 10-15 percent lower than predicted.
5 NA – not analyzed

C.3.3 Dry Weather Flow and Pollutant Load Modeling

Dry weather flow from urban subwatersheds is not a function of storm-driven hydrology, but rather of typical water usage patterns such as sprinkler over-irrigation, car washing, and a variety of other activities that result in drainage from the landscape to the storm drain.

As part of the water quality monitoring program, BOS has been monitoring the flow at three storm drain outfalls: Wilmington Drain above Lomita Boulevard, Project 510 – Line C, and Project 77. Based on this data set (through September 2008), a design value of 0.23 cfs (19 gal/acre/day) was selected for average dry weather flow for Wilmington Drain, 0.08 cfs (32 gal/acre/day) was selected for average dry weather flow for the Project 77 storm drain outfall, and 0.03 cfs (239 gal/acre/day) was selected for average dry weather flow for Project 510 Line C subwatershed. These design values were assumed to represent the average flow measured over the monitoring period. Dry weather flow from upstream subwatersheds is in the flow from Project 1104B, such that loading derived for Project 1104B is representative of all three subwatersheds. No separate flow monitoring was conducted or is reported in the data set to indicate whether there was any indication of dry weather flow coming from the Project 2 storm drain. As a result of LACSD recently initiating the JWPCP Bixby Marshland project, it is anticipated that there may be little to no consistent dry weather flow coming from Wilmington Drain, Project 1104B in the future. During a recent site tour of the JWPCP wetlands project (May 4, 2009) and a field visit to the Wilmington Drain project site above Lomita no flow was observed in the concrete or soft bottom channel.

Observations made by BOS staff indicate that there may be some dry weather flow entering Wilmington Drain from Project 2 storm drain which has not previously been measured or reported, with a single field estimate of potentially 0.7 cfs. Additional observations and more accurate flow measurements over a number of months would be required to confirm the range of flow that may still enter Wilmington Drain channel at Lomita. For the purpose of the model, the 0.23 cfs value was used. During the field visit on May 4, 2009, water was observed in the channel downstream of Lomita Boulevard although it could not be determined whether there was any measurable flow. Ponded water was also observed in the Project 510 storm drain (top picture in Figure C-6). Because there was no observed flow coming down the drain, it is assumed that this standing water is residual runoff from a previous rain event or part of the backwater that forms behind the berm at PCH.

Figure C-6
Project 510 Outlet and Weir Downstream of PCH

Although water was observed in the channel, surface flow from Wilmington Drain to the Riparian Woodland was not observed over the weir downstream of PCH (bottom picture in Figure C-6). In fact, there was significant freeboard above the water surface, suggesting that losses to evaporation, evapotranspiration and/or infiltration in the drain upstream of the weir may exceed any continuous dry weather flow that may be entering Wilmington Drain upstream. Therefore, dry weather surface flow from Project 2 and /or Project 510, if flow exists, may not reach Machado Lake. However, aquatic vegetation was observed downstream of the weir, indicating that there may be subsurface connection between Wilmington Drain and Machado Lake during the dry season, by way of the Riparian Woodland. Pollutants in dry weather runoff would be treated by natural processes in the Riparian Woodland before reaching Machado Lake. Likewise, dry weather flow was not observed or recorded at any of the other storm drains tributary to Machado Lake other than to two noted above.

Available water quality data for key parameters in dry weather urban runoff were reviewed for the Wilmington Drain/Machado Lake watershed area and other urban watersheds in the City, as well as other local areas to establish typical composite design values for key constituents in dry weather runoff from urban watersheds (Table C-14). In general, much less consistent and statistically valid dry weather urban runoff water quality data is available compared to wet weather runoff data. Total P and Ortho-P, all nitrogen species and TSS data were derived from LA City BOS WPD sampling program data. Metals data were taken from the City of LA status and trends program for Ballona Creek as representing a reasonably similar urban watershed dominated with urban runoff. No distinction was made for different land uses as there is insufficient data for dry weather urban runoff from landuse specific areas to develop landuse specific water quality data.

Table C-14
Monitored Dry Weather Pollutant Concentrations

Pollutant	Units	Concentration
TSS	mg/l	11.9
Total P	mg/l	0.61
Dissolved P	mg/l	NA[1]
Ortho P	mg/l	0.48
Total N	mg/l	2.69
Organic N	mg/l	1.6
Ammonia-N	mg/l	0.34
(Nitrate+Nitrite)-N	mg/l	0.75
Total Cu	ug/l	18.50
Dissolved Cu	ug/l	12.00
Total Pb	ug/l	7.50
Dissolved Pb	ug/l	6.20

Sources: Total P and Ortho-P, all nitrogen species and TSS data were derived from LA City BOS WPD sampling program data. Metals data were taken from the City of LA status and trends program for Ballona Creek.

Notes:
1. NA – not analyzed

Based on these data and assumptions, dry weather pollutant loads were calculated based on the previously available BOS flow data separately for both Wilmington Drain and Machado Lake and are presented in Table C-15.

Table C-15
Dry Weather Average Annual Pollutant Load

Subwatershed	TSS (lbs)	Total P (lbs)	Dissolved P (lbs)	Total N (lbs)	Organic N (lbs)	Ammonia -N (lbs)	(Nitrate+ Nitrite)-N (lbs)	Total Cu (lbs)	Dissolved Cu (lbs)	Total Pb (lbs)	Dissolved Pb (lbs)
Subwatersheds tributary to Wilmington Drain	9629	278	0	1228	730	155	342	8	5	3	3
Subwatersheds tributary directly to Machado Lake[1]	4586	133	0	585	348	74	163	4	3	2	1

Notes:
1. Subwatersheds tributary lake only includes Project 77 and Project 510 Line C. It is unknown whether dry weather flow from Wilmington Drain actually reaches the lake.

C.4 Lake Water Quality Model

The Lake Water Quality Model, which is a numerical model, was constructed to simulate water quality in Machado Lake after the implementation of the selected BMPs (which include dredging, oxygenation, supplemental water delivery, offline treatment wetland, and alum injection at the treatment wetland).

The model was developed to evaluate the complex dynamics within the lake. For example, phosphorus and nitrogen are introduced to the lake in two ways:

- **External Loading:** Phosphorus and nitrogen are introduced to the lake though urban runoff, as described in Section C.3, when the runoff transports nutrients and other contaminants to the lake. There is also a small steady baseflow delivery of nutrients to the lake from the watershed throughout the year.

- **Internal Loading:** Under certain conditions, phosphorus and nitrogen are released from the nutrient-rich sediments on the bottom of the lake to the water column. When oxygen is depleted at the sediment/water interface anoxic conditions occur and these releases are exacerbated. When oxygen levels are sufficiently high (i.e., greater than 2.0 milligrams per liter [mg/L]), more of the phosphorus and nitrogen remain bound to the sediment.

In order to simulate the naturally occurring current in-lake conditions, and the future in-lake conditions after implementation of the selected BMPs, the Machado Lake water quality model was developed to explicitly simulate both types of lake nutrient loading, and the internal dynamic response to these loadings including algal growth. Further details of the model are provided below. This section describes the development of the model based on current conditions, while Sections C.5 describes the projected conditions in the lake post-BMP implementation. Model sensitivity and uncertainty analyses are provided in Sections C.6 and C.7, respectively.

C.4.1 Development of the Model

The lake water column is simulated as a fully mixed system, also termed a "continuously stirred tank reactor," or CSTR. This assumption is known to approximate lake dynamics for small, shallow lakes, such as Machado Lake, where mixing (e.g., diffusion, wind turbulence) dominate over advection. Lake volumes are assumed steady on a daily basis (outflow = inflow) but can be varied monthly to account for summer losses (e.g., evapo-transpiration, ET). The model targets the key parameters of this eutrophic lake: phytoplankton (as chl-a), phosphorus (P), and nitrogen (N). The model was constructed in Microsoft Excel to allow for easy adaptation of code to address various potential rehabilitation options and alternatives.

A conceptual depiction of the model mechanics is provided in Figure C-7. The model simulates total phosphorus and total nitrogen on a daily timestep. Particulate and dissolved fractions are estimated based on user-input constant particulate fractions. Simulated external sources of phosphorus and nitrogen include: wet weather runoff, dry weather baseflow, and supplemental "make-up" water pumped into the lake by the County during summer months. Other potential external sources of nutrients, including wildlife and atmospheric deposition of nitrogen, are deemed insignificant for this study.

Internal processes included in the model are: N and P settling (particulate fractions only), first-order assimilation of N and P (dissolved fractions only), and internal loading of dissolved N and P from the sediments to the water column. Dissolved nutrient removal (uptake) from the water column, parameterized by k_d, is included as an inflow load to the particulate nutrient pool. In other words, this process is a transformation of nutrient forms (from dissolved to particulate), rather than a complete removal of dissolved nutrients. This captures the dynamic of phytoplankton uptake, which is believed to be driving water column nutrient assimilation during the summer, and also facilitates the coupling between water column and sediment layer calculations. The importance of this phenomenon to the lake nutrient cycle is supported by historical measured in-lake particulate fractions of both N and P.

Both k_d (first order removal rate constant for water column) and v_s (particulate fraction settling rate) are allowed to vary seasonally. This is to capture the seasonal dynamics of phytoplankton in the lake. Uptake is believed to be highest during the summer months, while net settling rates are believed to be lower during the summer when live phytoplankton, rather than sediments, dominates the particulate nutrient pool.

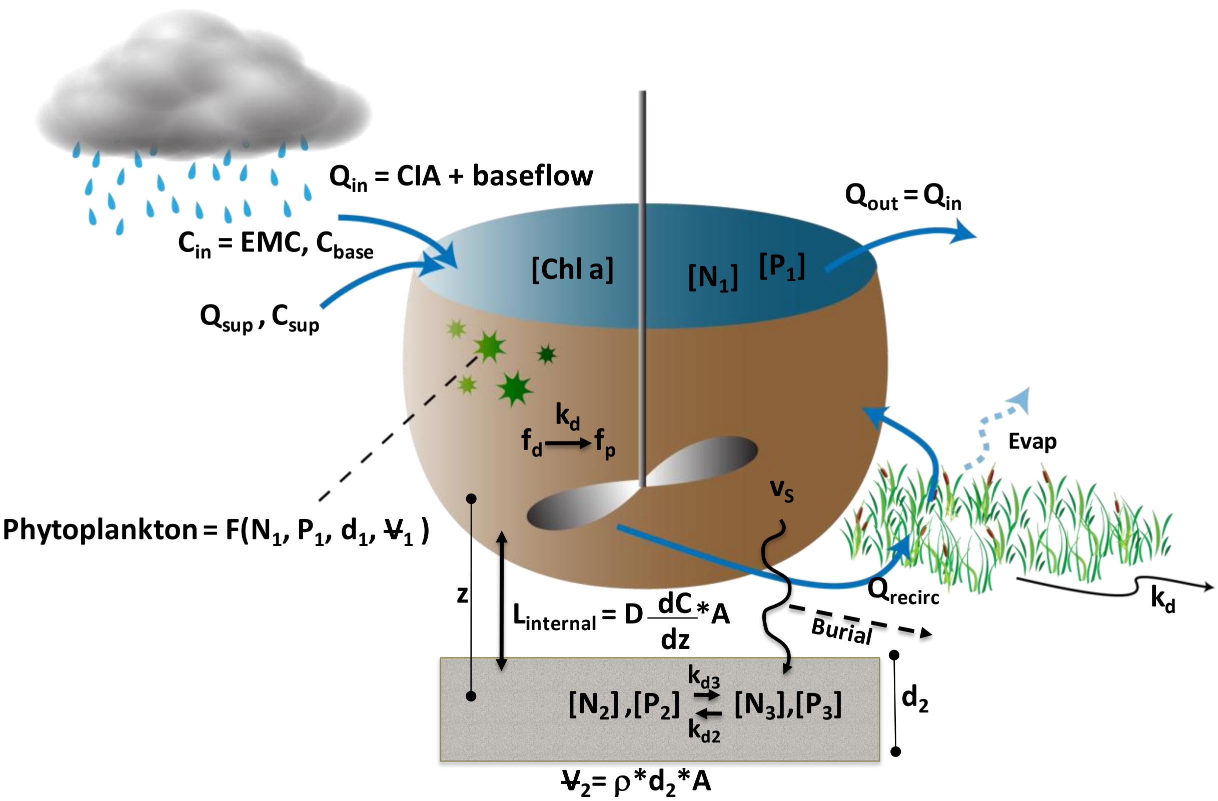


Figure C-7
Machado Lake Water Quality Model

Internal loads of N and P, released by the sediments back to the water column, are calculated with a separate module. For these calculations, a second vertical layer was added to the fully mixed water column to represent surface, biologically-active, sediments (Figure C-7). The size of this layer is defined by a user-specified depth (d) and porosity (ρ). Both sediment-bound and porewater nutrient concentrations are calculated within this layer based on standard formulations found in the literature [e.g. Cerco & Cole 1993; Pollman 2000]. Sediment-bound nutrients are replenished via settling of particulate fraction nutrients in the water column. Movement from the sediment-bound nutrient pool to the porewater pool occurs via a first order lumped mineralization/desorption rate. Movement in the opposite direction (porewater to sediments) occurs via a first order adsorption rate. Both rates are variable depending on the oxic state of the sediments. Transport of nutrients from the sediment porewater to the lake water column, and at times vice versa, is calculated following a standard Fickian diffusion formulation.

A module for simulating the impacts of off-channel wetlands on lake water quality was constructed to allow for direct simulation of this management option. A user-specified flow rate moves water and nutrient load from the lake and through a wetland, where nutrient removal and ET occur, and then back to the lake. Return flows and loads from the wetland are lagged according to the wetland retention time. Retention time is calculated in the model as a function of user-specified recirculation flow rate, wetland area, and wetland flow depth. Other wetland module parameters are: first order removal rate constants for N and P, ET rate, ET transpiration fraction, and start and ending months for wetland recirculation.

The model mass balance equation for water column nutrient concentrations is as follows:

$$\frac{dM}{dt} = Q_{ww}EMC + Q_{base}C_{base} + Q_{sup}C_{sup} + L_{internal} - Q_{out}C_{tot} - v_sC_pA - k_dC_d - Q_{wetland}C_{tot} + Q'_{wetland}C_{wetland}$$

Eqn. 1

Where:

M	=	*total mass of nutrient in lake*
	=	$V * C_{tot}$
V	=	*lake volume*
C_{tot}	=	*lake total nutrient concentration (TP or TN)*
Q_{ww}	=	*wet weather runoff flow rate*
	=	CIA_W *(Rational Method)*
C	=	*watershed runoff coefficient*
I	=	*daily rainfall*
A_W	=	*watershed area*
EMC	=	*event mean concentration (TP or TN)*
Q_{base}	=	*steady baseflow rate*
C_{base}	=	*baseflow concentration*
Q_{sup}	=	*supplemental water inflow rate*
C_{sup}	=	*supplemental water concentration*
$L_{internal}$	=	*internal loading from sediments (see below)*
f_L	=	*monthly distribution factor for internal loading*
f_b	=	*burial fraction*
$Load_{settled}$	=	*calculated total settled mass of nutrient (by water year)*
Q_{out}	=	*lake outflow*
	=	*lake inflow – wetland losses*
	=	$Q_{ww} + Q_{base} + Q_{sup} + I*A - (Q_{wetland} - Q'_{wetland})$
A	=	*lake surface area*
v_s	=	*particulate nutrient settling velocity*
C_p	=	*lake particulate nutrient concentration*
	=	f_p*C_{tot}
f_p	=	*particulate fraction*

k_d = *first order removal rate for dissolved nutrients*
C_d = *lake dissolved nutrient concentration*
= $(1 - f_p) * C_{tot}$
$Q_{wetland}$ = *wetland recirculation outflow rate*
$Q'_{wetland}$ = *wetland recirculation inflow rate; and*
$C_{wetland}$ = *nutrient concentration for flow leaving wetland.*

For the coupled recirculating wetland module, a plug-flow (no mixing) mass balance equation is applied as follows:

$$M_{out} = M_{in} - R_{uptake} - R_{trans} \quad \text{Eqn. 2}$$

Where:
M_{out} = *mass flux of nutrient leaving the wetland*
= $Q'_{wetland} * C_{wetland}$
M_{in} = *mass flux of nutrient entering wetland at a previous timestep (lagged according to calculated retention time)*
= $Q_{wetland}(t - t_r) * C_{tot}(t - t_r)$
T_r = *wetland retention time*
R_{uptake} = *loss of nutrient mass via first-order removal*
= $0.5*[C_{tot}(t - t_r) + C_{wetland}]*v_r*A_{wetland}$
v_r = *wetland first-order uptake velocity*
Awetland = *area of wetland*
R_{trans} = *dissolved nutrient loss via plant transpiration*
= $0.5*[f_p*C_{tot}(t - t_r) + f_p*C_{wetland}]* \alpha*ET*A_{wetland}$
α = *fraction of ET that is macrophyte transpiration*
ET = *evapotranspiration rate.*

Within the sediment layer, the following sediment nutrient dynamics are simulated:

- Lumped nutrient mineralization (of organic particulate nutrients) and desorption (of sediment-bound nutrients)
- Nutrient adsorption (from pore water to sediments)

Note that the model requires both oxic and anoxic rate constants for defining these two processes, where the extent of surface sediment anoxia (by percentage of lake bottom) is specified on a monthly basis by the user.

The exchange of dissolved nutrients between surface sediment pore water and the water column (i.e., the internal nutrient flux) is calculated according to Fickian diffusion as a function of the gradient between porewater and water column nutrient concentrations and parameterized by a user-specified diffusion coefficient (D). Particulate and sediment-bound nutrients are transported from the lake water column to the sediment layer via one-way settling with a fraction of this load unavailable for subsequent release per a user-specified "burial fraction."

The governing equations for the sediment module can be written as:

$$\frac{dC_2}{dt} = D(C_{1d} - C_2)\frac{A\rho}{z * V_2} + k_{d2}C_3\frac{M_{sed}}{V_2}\rho - k_{d3}C_2 \quad (3)$$

$$\frac{dC_3}{dt} = -k_{d2}C_3 + k_{d3}C_2\frac{1000}{V_2M_{sed}} + v_sC_{1p}(1 - burialFrac)\frac{1000}{v_1zM_{sed}} \quad (4)$$

Where:

C_{1d} = *water column dissolved nutrient concentration (g m^{-3})*

C_2 = *porewater dissolved nutrient concentration (g m^{-3})*

A = *area of lake sediments (m^2)*

z = *vertical mixing length (m)*

V_1 = *water column volume (m^3)*

V_2 = *sediment layer porewater volume (d * A * ρ, m^3)*

ρ = *sediment layer porosity*

k_{d2} = lumped first order mineralization/desorption rate constant (d^{-1}) (different values for oxic vs. anoxic conditions)

C_3 = sediment nutrient concentration (mg g^{-1})

M_{sed} = total dry mass of sediments in active layer (calculated as function of particle density and ρ ,g)

k_{d3} = 1st order adsorption rate constant (d^{-1}) (different values for oxic vs. anoxic conditions)

v_s = water column settling velocity (m d^{-1})

C_{1p} = water column particulate nutrient concentration (g m^3)

burialFrac = burial fraction of settled particulate nutrient.

Equations 3 and 4 are solved numerically in the model, simultaneous to Equations 1 and 2, with the internal nutrient load term ($L_{internal}$) calculated for each timestep according to a Fickian diffusion formulation:

$$L_{internal} = \frac{dM}{dt} = D(C_2 - C_1)\frac{A}{z}\rho \qquad (5)$$

Seasonal and monthly steady-state water column phytoplankton concentrations, as chl-a, are estimated in the model as a function of mean nutrient concentrations, lake flushing rates, lake depth, and non-algal turbidity. The model uses the following empirical equation, developed for the U.S. Army Corps of Engineers' Bathtub model (Walker, 2004):

$$B = \frac{KBx}{(1 + bBxG)(1 + Ga)} \qquad (6)$$

Where:

B	=	*lake mean phytoplankton as chl-a concentration (ug/l)*
K	=	*model calibration factor (unitless)*
Bx	=	*nutrient-potential chl-a concentration (ug/l)*
	=	$Xpn^{1.33} / 4.31$
Xpn	=	*lake composite nutrient concentration (ug/l)*
	=	*[P-2 + ((N-150)/12)-2]-0.5*
B	=	*algal light extinction coefficient* (m^{-1})
G	=	*kinetic factor*
	=	*Zmix(0.14 + 0.0039*Fs)*
Zmix	=	*mean depth of lake (m)*
Fs	=	*lake summer flushing rate* ($year^{-1}$)
	=	*(inflow + precip – ET)/V*
A	=	*non-algal turbidity (m-1)*
	=	*1/S – b*B*
S	=	*lake mean secchi depth (m).*

Equation (6) is solved for B as a function of monthly and seasonal (summer) predicted TP and TN concentrations (described above).

C.4.2 Model Calibration

C.4.2.1 Calibration of Sediment Nutrient Flux Module

A simplified model was developed to simulate the dynamics of the sediment core incubation studies conducted in 2009 for the City of Los Angeles (See Section C.4). The objective was to quantify the sediment flux parameters, to be used in the lake model described above (k_{d2} and k_{d3}), for both oxic and anoxic sediment conditions based on the experimental data. The simple 2-layer incubation chamber model is depicted in Figure C-8. The numerical formulation of the model closely follows that of the sediment flux module of the lake model described above. A major difference, however, is that the water column of the incubation chamber model is essentially stagnant (no flushing flows) and is only impacted by the diffusive exchanges with the sediment (assuming no internal water column dynamics). Additionally, the sediment nutrient concentrations (C_3) are assumed to be steady in the chamber model. This assumption is believed to be appropriate for the timescales of the incubation studies.

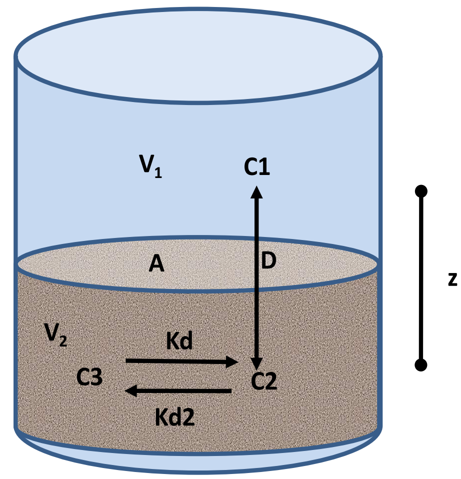


Figure C-8
Incubation Chamber Model

The governing equations for this model are therefore:

$$\frac{dC_1}{dt} = D(C_2 - C_1)\frac{A\rho}{z * V_1} \qquad (7)$$

$$\frac{dC_2}{dt} = D(C_{1d} - C_2)\frac{A\rho}{z * V_2} + k_{d2}C_3\frac{M_{sed}}{V_2}\rho - k_{d3}C_2 \qquad (8)$$

C_3 = constant (9)

These equations are solved numerically for C_1 and C_2. For each incubation, Microsoft Excel's "Solver" add-in program was used to calibrate k_{d2} and k_{d3} values to best match the reported water column concentration versus time profiles. Solver's nonlinear optimization code was used to minimize the sum of squares error of modeled versus measured concentration data, by varying oxic and anoxic k_{d2} and k_{d3} values. Each of the incubations involved both an oxic period and an anoxic period and therefore allowed for the determination of both types of rate constants for each incubation. A value of 10^{-4} cm^2 s^{-1} was assumed for the diffusion coefficient (D) (high end of molecular diffusion, per Chapra 1998) for all incubations. Oxic and anoxic calibrated rate constants were then averaged across all of the incubations to arrive at the final values used in the lake model (described below). Example incubation calibration profiles are provided in Figure C-9. Results of the rate constant parameterization are summarized in Table C-15.

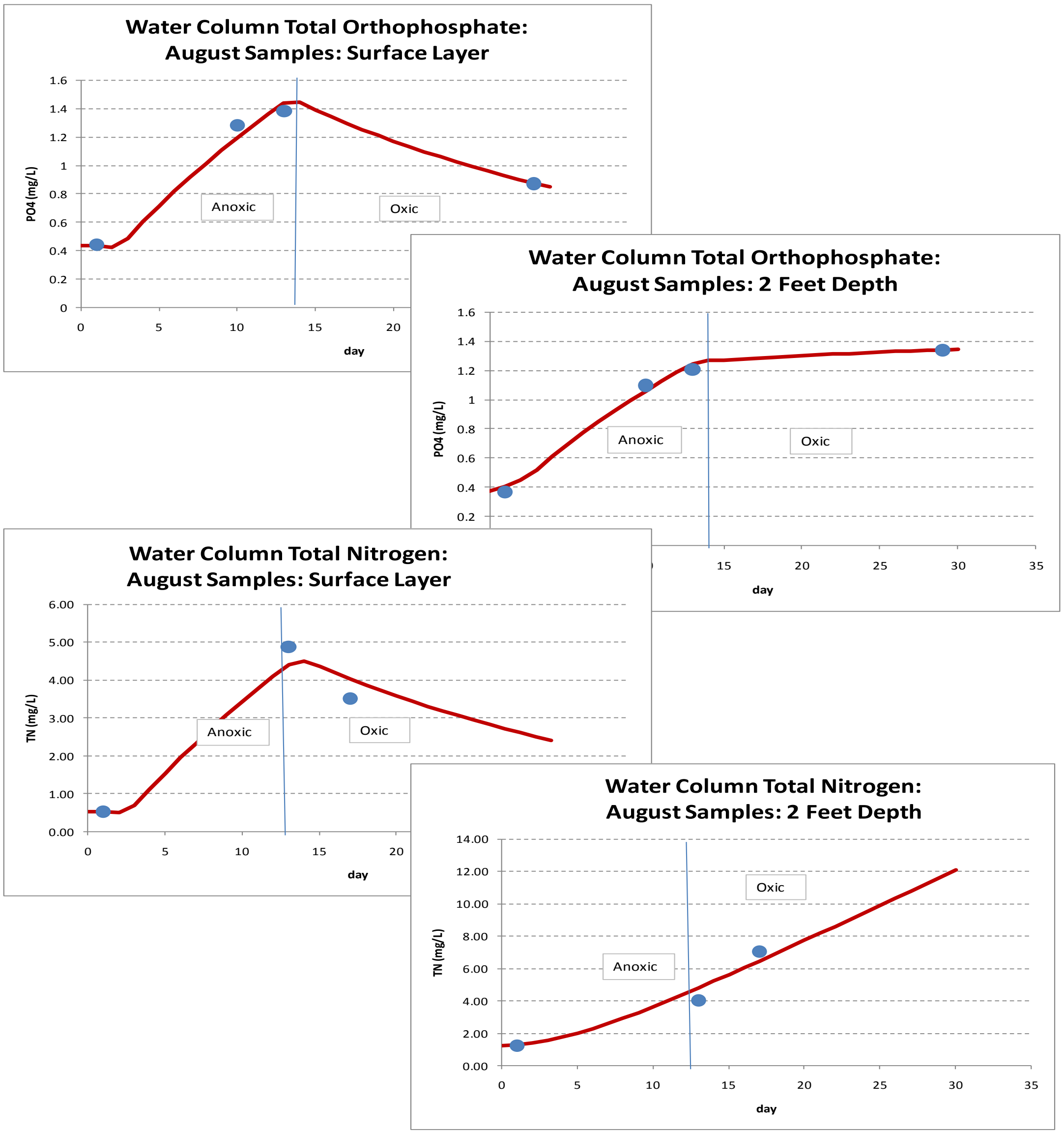


Figure C-9
Example Incubation Model Calibration Results: Modeled vs. Measured
(red lines = model predictions, blue dots = measured data)

Table C-15
Calibration Results: Incubation Chamber Sediment Nutrient Rate Constants

	k_{d2} anoxic	k_{d2} oxic	k_{d3} anoxic	k_{d3} oxic
PO_4 Mean (d^{-1})	0.011	0.002	1.121	1.121
PO_4 Std Dev (d^{-1})	0.003	0.002	0.243	0.243
TIN Mean (d^{-1})	0.093	0.028	0.50	0.93
TIN Std Dev (d^{-1})	0.044	0.039	0.38	0.14

C.4.2.2 Calibration of Water Column Module

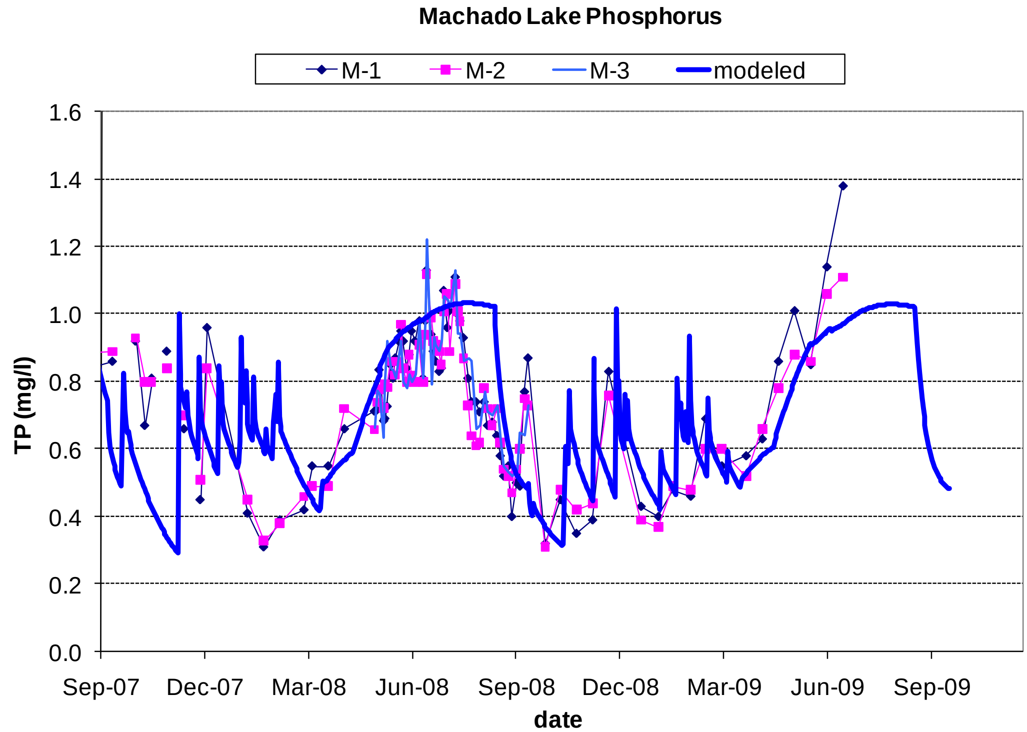
The mean values for k_{d2} and k_{d3} obtained from the chamber experiment analysis described above, for both anoxic and oxic conditions, were input directly into the lake model described in Section C.5.1. The lake model was then calibrated to measured lake water column N, P, and chlorophyll-a concentrations. The following parameters were calibrated as part of this task:

- k_d (water column dissolved nutrient uptake rate constant, for both N and P)
- burialFrac (burial fraction of settled particulate nutrient, for both N and P)
- v_s (particulate nutrient settling velocities) and settling seasonality factors (for both N and P)
- monthly weighting factors for oxic vs. anoxic k_{d2} and k_{d3} values (roughly representing anoxic levels in lake)
- ρ (surface sediment layer porosity)
- K (chlorophyll-a empirical model calibration factor, recommended range of 0 - 1)

These parameters were adjusted, within expected ranges, to achieve satisfactory model predictions of the following calibration targets, based on 2007-10 measured data (with listings of the primary calibration parameters for each target):

- Lake water column N and P concentrations (all of above calibration parameters)
- Lake water column mean summer chlorophyll-a concentrations (K)
- Lake water column mean N and P particulate fraction (k_d)
- Sediment mean N and P concentrations and achieving equilibrium of sediment N and P concentrations (v_s, burialFrac, ρ)
- Approximate range of measured N and P sediment flux rates from incubation chamber experiments (v_s, burialFrac, ρ)
- Approximate Redfield ratio (algae nutrient stochiometric ratio, 7:1) for ratio of k_d(N) to k_d(P) (k_d)

Results of the lake model nutrient calibration are provided in Figures C-10 and C-11. Satisfactory simulations of the seasonal trends and magnitudes of both measured N and P lake water column concentrations (a) and surface sediment concentrations (b) were achieved. A close calibration with respect to mean summer phytoplankton (chlorophyll-a) concentrations was also achieved (Table C-16). Final model parameter values are summarized in Table C-17.



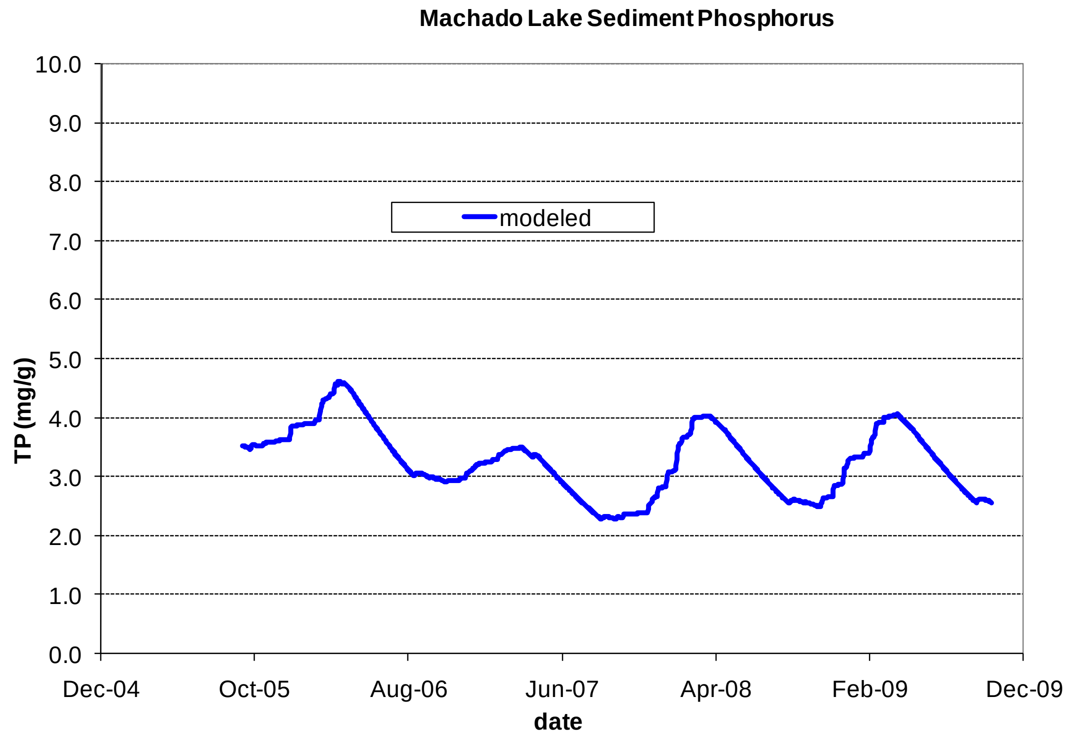
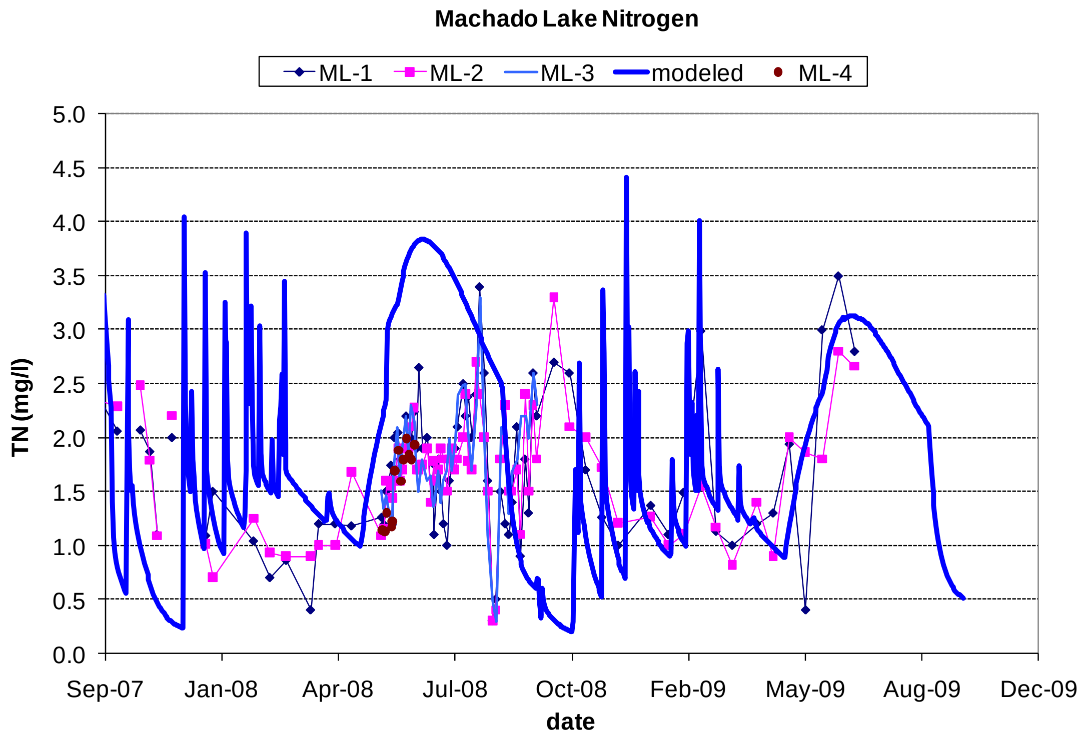


Figure C-10
Machado Lake Water Quality Calibration: Phosphorus



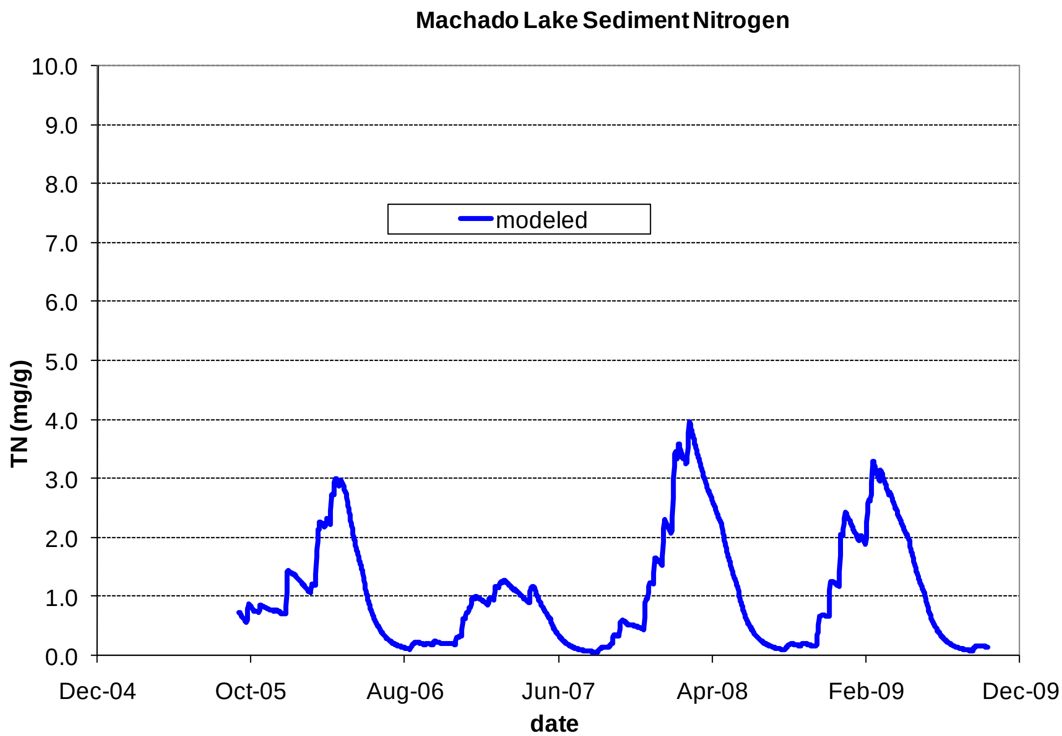


Figure C-11
Machado Lake Water Quality Calibration: Nitrogen

Table C-16
Lake Model Calibration Summary: Mean Summer Chlorophyll-a

	Measured (μg/L)	Modeled (μg/L)
2007	55	47
2008	72	73

Table C-17
Model Calibration Parameters (e.g. existing conditions)

Parameter	Value	Units	Source
Watershed:			
drainage area (A_W)	**57.5**	km^2	Lai (2008), updated CDM calculations
% impervious	62	%	Lai (2008)
runoff coefficient (C)	**0.47**	unitless	calculated, updated CDM calculations
baseflow (Q_{base})	0.1	cfs	observed (CDM 2009)
daily rainfall (I)	0 – 2.5	in/d	measured (Long Beach Station)
Lake:			
total capacity	154,000	m^3	lake bathymetric data (CDM & Parsons 2009)
monthly volume (V)	114,000 – 154,000	m^3	anecdotal evidence, Lai (2008)
mean summer depth (d)	0.84	m	Lai (2008)
surface area (A)	117,000	m^2	lake bathymetric data (2008)
Phosphorus:			
baseflow concentration (C_{base}) (wet season)	0.44	mg/L	measured[1]
baseflow concentration (C_{base}) (dry season)	0.75	mg/L	measured[1]
event mean concentration (EMC)	0.86	mg/L	measured[1]
fraction particulate (f_p) of inflow	0.2	unitless	measured[1]
fraction particulate (f_p) of lake concentration	0.3	unitless	modeled (measured[1] in-lake f_p = 0.2)
settling velocity (v_s)	**2**	m/d	calibrated
first order removal rate constant (k_d)	**0.03**	d^{-1}	calibrated
burial fraction (f_b)	0.1	unitless	calibrated
internal loading rate (dry season)	**9 - 16**	$mg/m^2/d$	modeled (note: Horne incubation experiments mean = 12 - 16)
Nitrogen:			
baseflow concentration (C_{base}) (wet season)	2.26	mg/L	measured[1]
baseflow concentration (C_{base}) (dry season)	2.61	mg/L	measured[1]
event mean concentration (EMC)	3.45	mg/L	measured[1]
fraction particulate (f_p) of inflow	0.5	unitless	measured[1]
fraction particulate (f_p) of lake concentration	0.5	unitless	calculated (measured[1] in-lake $f_p \leq 0.9$)
settling velocity (v_s)	2	m/d	calibration
first order removal rate constant (k_d)	**0.14**	d^{-1}	calibration
burial fraction (f_b)	**0.5**	unitless	calibration
internal loading rate (dry season)	**10 – 113**	$mg/m^2/d$	calculated (note: Horne incubation experiments mean = 61)

Table C-17
Model Calibration Parameters (e.g. existing conditions)

Parameter	Value	Units	Source
Supplemental Water:			
inflow rate (Q_{sup})	0.33	cfs	independent estimate[3]
TP concentration (C_{sup})	0.05	mg/L	Measured[4]
TN concentration (C_{sup})	0.6	mg/L	Measured[4]
start month	June	-	Measured[4]
end month	October	-	Measured[4]
Phytoplankton:			
calibration factor (K)	0.65	unitless	calibrated (recommended range = 0 – 1)
algal light extinction coefficient (b)	0.025	m^{-1}	model default (Walker, 2004)
secchi depth (S)	0.31	m	measured[1]
Sediment Nutrient Dynamics:			
vertical diffusion coefficient (D)	**10^{-4}**	$cm^2\ d^{-1}$	Chapra, 1998
surface sediment porosity (ρ)	**0.9**	unitless	Pollman (2000)
vertical mixing length (z)	**0.4**	m	set to ½ of mean lake depth
depth of active layer (d_2)	**0.02, 0.03 (P, N)**	m	Horne (pers. comm.)
N mineralization rate (kd_2) (oxic, anoxic)	**0.03, 0.09**	d^{-1}	independent chamber model calibration
P mineralization rate (kd_2) (oxic, anoxic)	**0.001, 0.008**	d^{-1}	independent chamber model calibration
N adsorption rate (kd_3) (oxic, anoxic)	**0.9, 0.5**	d^{-1}	independent chamber model calibration
P adsorption rate (kd_3) (oxic, anoxic)	**1, 1**	d^{-1}	independent chamber model calibration
N monthly anoxia weighting factors (Jan, Feb, Mar,…)	**0,0,0,0,0.3,0.9, 1,1,1,0.4,0,0**	unitless	calibrated
P monthly anoxia weighting factors (Jan, Feb, Mar,…)	**0,0,0.7,0.8,0.9,1, 1,0.7,0.4,0,0,0**	unitless	calibrated

[1] = combined City of L.A. BOs Data and CDM/Parsons in-lake or stormwater data collected 2006 – 2010 in support of the Machado Lake Ecosystem Rehabilitation and Wilmington Drain Multiuse Proposition O projects. See Table C-13.;

[2] = Based on land use based LA County EMC data, load determined by the pollutant load model.
[3] = CDM water balance calculations;
[4] = MWD and LADWP 2008 Water Quality Reports for Diemer, Jensen, and Weymouth Filtration

Final revised model parameter values are summarized in Table 3. Italicized and bold font indicates values that have changed since the original model calibration (CDM & Parsons 2009).

C.5 Water Quality Modeling of Options

In-lake rehabilitation options presented in this section will be implemented at Machado Lake. The following in-lake rehabilitation options that can be modeled are included in the project.

- **Supplemental water** (low-nutrient) to maintain lake levels during the dry season.
- **Dredging** - Removal of lakebed and lake edge sediment via hydraulic dredging.

- Construction of an **off-line treatment wetland** that recirculates lake water to further reduce nutrients within the lake and improve water quality.
- **Phosphorus removal** system at the off-line treatment wetlands
- One-time whole lake **alum** treatment after dredging of the lake.
- An **oxygenation system** to provide ample oxygenation at the sediment-water interface.

Key assumptions and model construction details for predictive modeling of lake rehabilitation options are provided below. For all modeled options, the simulation start year was set at October 2007, and the 2008 water year precipitation pattern was repeated annually into the future for a 14-year total simulation period.

As stated in Section C.3.1.3, wet weather runoff N and P concentrations were maintained at regional (LA County) mean levels. Following are the selected BMPs that are included in the Machado Lake Rehabilitation Project that were included in the model.

- Current Management Practices:
  - Current use of potable make-up water during dry season
  - No parameter changes from calibration simulation (Table C-17)
- Option 1 – Supplemental Water:
  - Increased use of recycled water to maintain full lake levels throughout dry season
  - Recycled water TP = 0.10 mg/L, TN = 2.0 mg/L
- Option 2 – Dredging:
  - Post- dredged mean lake depth = 2.4 meters (8 feet)
  - Post-dredged max lake volume = 250,000 m^3
  - Post-dredged lake surface area = 129,000 m^2
  - Clean sediments at start of simulation (TP = TN = 0 mg/kg)
- Option 3 – Re-circulating Wetlands:
  - Q_{recirc} = 1 cfs
  - Wetland area = 4 acres
  - Wetland uptake velocities = 10, 99 m/yr for TP and TN, respectively
  - Operation period = April through September
- Option 4 – Oxygenation System:
  - Oxic rates of sediment nutrient dynamics assumed throughout year for both N and P (anoxic weighting factors = 0)
- Option 5 – Phosphorus removal:
  - **One-time whole lake alum treatment**: TP burial fraction = 1.0 (100 percent entrainment of settled P)
  - **Phosphorus removal systems at treatment wetlands**: treating Q_{recirc} = 1 cfs.

- Phosphorus removal system to reduce TP concentration to 0.01 mg/L for portion of flow treated
- Operation period = year round

- Wet weather runoff and baseflow from the responsible jurisdictions assumed to be treated to meet the TMDL:

  - Wet weather nutrient event mean concentration (EMCs) reduced to TMDL targets of 1.0 mg/L TN and 0.1 mg/L TP for the portion of the flow that is not City of Los Angeles. City of Los Angeles is 13 percent of the total watershed; therefore it is assumed that the 87 percent of the wet weather runoff and baseflow to the lake will have concentrations of TN and TP that meet these TMDL targets. Note that for the City's portion of the watershed, the EMC was maintained at 0.36 mg/L TP and 3.77 mg/L TN.

The results of the model runs are presented in Tables C-18, C-19 and C-20. Table C-18 presents the 2014 (year 1), 2018 (year 5) and 2024 (year 10) monthly concentrations of TP, TN and chlorophyll-*a* assuming that only the in-lake BMPs are installed. Table C-19 presents the 2014 (year 1), 2018 (year 5) and 2024 (year 10) monthly concentrations of TP, TN and chlorophyll-*a* assuming the in-lake BMPs are installed in addition to the other responsible jurisdictions meeting their WLAs. Table C-20 presents the 2014 (year 1) and 2024 (year 10) summer average concentrations of TP, TN and chlorophyll-*a* for both scenarios (only in-lake BMPs installed compared to in-lake BMPs plus other responsible jurisdictions meeting the TMDL WLAs).

Table C-18
Modeled Monthly Nutrient Concentrations After Implementation of only the In-Lake BMPs

	Monthly mean[1, 2, 3] 2014			**Monthly mean[1, 2, 3] 2018**			**Monthly mean[1, 2, 3] 2024**		
Month	**TP (mg/L)**	**TN (mg/L)**	**Chl-*a* (ug/L)**	**TP (mg/L)**	**TN (mg/L)**	**Chl-*a* (ug/L)**	**TP (mg/L)**	**TN (mg/L)**	**Chl-*a* (ug/L)**
April	0.13	0.58	9	0.15	0.60	9	0.16	0.63	10
May	0.12	0.90	13	0.14	0.84	12	0.15	0.75	11
June	0.17	1.73	23	0.19	1.76	24	0.21	1.81	25
July	0.14	1.62	22	0.17	1.65	23	0.19	1.69	24
Aug	0.13	1.48	20	0.15	1.51	21	0.17	1.54	22
Sept	0.08	0.88	12	0.10	1.14	16	0.12	0.90	14
Oct	0.13	0.74	-	0.13	0.70	-	0.12	0.64	-
Nov	0.11	0.34	-	0.12	0.27	-	0.14	0.32	-
Dec	0.24	1.33	-	0.24	1.36	-	0.23	1.25	-
Jan	0.26	1.72	-	0.25	1.52	-	0.25	1.37	-
Feb	0.26	1.61	-	0.26	1.63	-	0.27	1.70	-
March	0.20	0.94	-	0.22	1.15	-	0.24	1.32	-

Note:
1 Assumes that BMPs are installed by 2013. 2014 is therefore 1 year post BMP installation, 2018 is 5 years post BMP installation, and 2024 is 10 years after BMP installation.
2 Summer months are the worst case with respect to sustained elevated nutrient concentrations and phytoplankton growth. However, increases in nutrient concentrations can occur during the winter months due to large spikes in loading from rain events. These become more pronounced in the model as summer internal loads are addressed with dredging. Additionally

the model assumes that the wetlands only operate during the summer.

[3] The model does not simulate winter phytoplankton. The empirical formulation is intended for summer mean concentration. It is assumed that winter phytoplankton is not the concern due to lower temperatures and sunlight.

Table C-19
Modeled Monthly Nutrient Concentrations Based on In-Lake BMPs and Assuming Other Jurisdictions Meeting TMDL WLAs

	Monthly mean[1, 2, 3] 2014			Monthly mean[1, 2, 3] 2018			Monthly mean[1, 2, 3] 2024		
Month	**TP (mg/L)**	**TN (mg/L)**	**Chl-*a* (ug/L)**	**TP (mg/L)**	**TN (mg/L)**	**Chl-*a* (ug/L)**	**TP (mg/L)**	**TN (mg/L)**	**Chl-*a* (ug/L)**
April	0.13	0.58	9	0.07	0.25	2	0.07	0.25	2
May	0.12	0.90	13	0.07	0.39	4	0.07	0.35	3
June	0.17	1.73	23	0.09	0.76	11	0.09	0.76	11
July	0.14	1.62	22	0.09	0.78	12	0.09	0.78	12
Aug	0.13	1.48	20	0.09	0.78	12	0.09	0.78	12
Sept	0.08	0.88	12	0.07	0.50	6	0.07	0.49	6
Oct	0.13	0.74	-	0.07	0.34	-	0.05	0.27	-
Nov	0.11	0.34	-	0.06	0.14	-	0.06	0.13	-
Dec	0.24	1.33	-	0.09	0.50	-	0.09	0.46	-
Jan	0.26	1.72	-	0.10	0.59	-	0.10	0.50	-
Feb	0.26	1.61	-	0.10	0.60	-	0.10	0.62	-
March	0.20	0.94	-	0.09	0.39	-	0.09	0.47	-

Note:
[1] Assumes that BMPs are installed by 2013. 2014 is therefore 1 year post BMP installation, and 2018 is 5 years post BMP installation, and 2024 is 10 years after BMP installation. It is assumed that the other responsible jurisdictions, which account for 87 percent of the tributary drainage area, are in compliance with their WLA starting in 2018.
[2] Summer months are considered the worst case with respect to sustained elevated nutrient concentrations and phytoplankton growth. However, increases in nutrient concentrations can occur during the winter months due to large spikes in loading from rain events. These become more pronounced in the model as summer internal loads are addressed with dredging. Additionally the model assumes that the wetlands only operate during the summer.
[3] The model does not simulate winter phytoplankton. The empirical formulation is intended for summer mean concentration. It is assumed that winter phytoplankton is not the concern due to lower temperatures and sunlight.

Table C-20
Model Results

	2014 (Year 1) Summer Mean			2024 (Year 10) Summer Mean		
	P (mg/L)	**N (mg/L)**	**chl a (µg/L)**	**P (mg/L)**	**N (mg/L)**	**chl a (µg/L)**
Current Conditions	0.96	2.3	69	0.88	2.3	70
Post BMP Implementation[1]:	0.12	1.19	17	0.16	1.22	19
Post BMP Implementation *Plus* other responsible jurisdictions in compliance with the TMDL	0.12	1.19	17	0.08	0.57	8
TMDL Numeric Targets	*0.1*	*1*	*20*	*0.1*	*1*	*20*

Notes:
1 – BMPs include supplemental water, dredging, recirculating treatment wetland, oxygenation, and phosphorus treatment at the treatment wetland and a one-time whole lake alum treatment immediately after dredging.
2 – It is assumed that the other responsible jurisdictions throughout the watershed not participating in this LWQMP (e.g. all upstream responsible jurisdictions except the City of Los Angeles) will treat their wet weather and baseflow runoff prior to it entering Machado Lake.

As shown in Tables C-18 through C-20, in order to meet the TMDL numeric limits (equal to the WLA and LA) the upstream responsible jurisdictions will need to meet the WLAs for their portion of the watershed in order for Machado Lake to be in compliance with the TMDL requirements.

C.6 Sensitivity Analysis

In order to assess model sensitivity to individual model input parameters, a "jack-knifing" procedure was employed. The term "jack-knifing" commonly refers to the process of varying individual model parameters, in isolation and within reasonable ranges, to assess model sensitivity. Through this process, jack-knifing also provides an initial level of uncertainty quantification. Model sensitivity for this exercise is defined as the changes in the key output variables of mean summer P, N, and Chl-a due to input parameter perturbations. Model input parameters and their perturbations are summarized in Table C-21. The baseline input parameter set corresponds to the "Post BMP Implementation Plus …" scenario described above (Table 20).

Results of this analysis (output sensitivities) are summarized in Table C-22 and Figure C-12. All results presented correspond to year 1 of the simulation. Percent changes in the three output variables are defined as:

$$\%change = \frac{(X_{high} - X_{low})}{X_{baseline}}$$

Where X = P, N, or Chl-a concentrations, "high" refers to the high end of the input perturbation range, "low" refers to the low end of the input perturbation range, and "baseline" refers to the baseline model output (provided in the table). Perturbation number indices in Figure C-12 refer to the order of parameters presented in Table C-21, with all high end perturbations first (#s 1 – 20) and all low end perturbations second (#s 21 – 39). In general the analysis shows moderate to low model sensitivity (within $\pm$ 25%) to the majority of input parameters. More importantly, for the specific application of the model presented in this document, none of the perturbations resulted in excursions above the TMDL targets for any of the three output variables.

One of the highest ranking parameters, with respect to sensitivity of chlorophyll-a model predictions, is the assumed lake mean depth following dredging (d). This result highlights the importance of achieving a certain depth in the lake through dredging that has been discussed above. However, since this is a controllable parameter (a construction target), this sensitivity is not truly a measure of model uncertainty. The model also shows significant sensitivity to parameters associated with sediment nutrient (particularly nitrogen) releases. These include N burial fraction, $K_{dsed, N}$, D_{sed}, ρ, and d_{sed}. This result is not surprising, as the importance of summer sediment nutrient fluxes has been well-documented. Fortunately, the existing model parameterization is well-supported by two calibration exercises using measured historical data and an independent focused study on lake nutrient fluxes. Therefore, the uncertainty associated with the existing parameterization has been minimized to the extent possible. It is recommended that future studies continue to focus on this component of the lake nutrient cycle, particularly in the post-dredging system. Finally, the model shows significant sensitivity to the assumed nitrogen first order removal rate constant in the water column (kd, N) and the nitrogen uptake velocity in the re-circulating wetland (Kw, N). The former is parameterized based on a rigorous calibration exercise. However, the biological nutrient cycling simulated in any model is always a source of uncertainty, particularly when simulating a water body after major rehabilitation efforts. Therefore, future studies and monitoring of the post-BMP system is recommended to support future parameterization of this variable. With respect to the latter, this component of the model is essentially un-calibrated, and, given the quantified sensitivity, should be highlighted as a limitation of the current model. Future studies and modeling may be warranted to lend confidence to the recirculating wetland module in the model.

Table C-21
Summary of Jack-Knife Sensitivity Analysis Input Parameters: Machado Lake Water Quality Model

Parameter	Description	Units	Baseline Value	High End	Low End	Rationale for Range
C_{net}	watershed runoff coefficient	unitless	0.47	0.71	0.24	± 50%
d	mean lake depth (full)	m	2.44	3	1.5	engineering judgment
V	lake volume (full)	$x1000\ m^3$	250	300	200	engineering judgment
Q_{base}	baseflow	cfs	0.1	0.7	0	range of observed values
v_s, P	particulate P settling velocity	$m\ d^{-1}$	2	3	0.1	recommended range (e.g. Chapra 1998)
v_s, N	particulate N settling velocity	$m\ d^{-1}$	2	3	0.1	recommended range (e.g. Chapra 1998)
kd, P	dissolved P uptake rate constant	d^{-1}	0.03	0.3	0.003	± 1 order of magnitude
kd, N	dissolved N uptake rate constant	d^{-1}	0.14	0.9	0.014	sensible range, - 1 order of magnitude
burialFrac, P	burial fraction for settled P	unitless	1	1	0.05	sensible range
burialFrac, N	burial fraction for settled N	unitless	0.5	0.9	0.05	sensible range
D_{sed}	vertical diffusion coefficient at sediment interface	$m^2\ d^{-1}$	3.9e-3	3.9e-2	3.9e-4	± 1 order of magnitude
Kd sed, P, oxic	lumped mineralization/desorption rate constant for sediment P under oxic conditions[1]	d^{-1}	0.001	0.006	0	measured (incubations) range
Kd sed, N, oxic	lumped mineralization/desorption rate constant for sediment N under oxic conditions[1]	d^{-1}	0.03	0.08	0	measured (incubations) range
Kd_2 sed, P, oxic	adsorption rate constant for sediment P under oxic conditions[1]	d^{-1}	1	1	0.7	measured (incubations) range
Kd_2 sed, N, oxic	adsorption rate constant for sediment N under oxic conditions[1]	d^{-1}	0.9	1	0.7	measured (incubations) range
ρ	sediment porosity	unitless	0.9	0.95	0.5	± 50%
d_{sed}	depth of active sediment layer	m	0.02 – 0.03	0.1	0.01	engineering judgment
Kw, P	re-circulating wetlands + adsorptive treatment outflow P	$mg\ l^{-1}$	0.05[2]	0.1	0.01	engineering judgement

Table C-21
Summary of Jack-Knife Sensitivity Analysis Input Parameters: Machado Lake Water Quality Model

Parameter	Description	Units	Baseline Value	High End	Low End	Rationale for Range
Kw, N	re-circulating wetlands uptake velocity for N	$m\ d^{-1}$	0.27	2.7	0.027	± 1 order of magnitude
anoxFrac	assumed summer sediment anoxia fraction	unitless	0[1]	0.5	0	engineering judgment
C_3 init, P	post-dredging initial sediment P concentration	$mg\ g^{-1}$	0	3.5	0	high end set at existing (pre-dredging) mean value
C_3 init, N	post-dredging initial sediment N concentration	$mg\ g^{-1}$	0	0.7	0	high end set at existing (pre-dredging) mean value

[1] = Note that only oxic conditions are assumed as part of the baseline model scenario due to planned aeration
[2] = Assumed baseline parameter value given planned annual alum addition to wetlands + adsorptive treatment

Table C-22
Summary of Jack-Knife Sensitivity Analysis Results: Machado Lake Water Quality Model

baseline values: Chl-a = 8 µg/L, TP = 0.07 mg/L, TN = 0.6 mg/L										
Rank	**Parameter**	**Chl-a^H^**	**TP^H^**	**TN^H^**	**Chl-a^L^**	**TP^L^**	**TN^L^**	**%Var Chl-a**	**%Var TP**	**%Var TN**
1	burialFrac, N	6	0.07	0.5	10	0.07	0.8	-54%	0%	-49%
2	d	7	0.07	0.6	11	0.07	0.7	-53%	3%	-13%
3	D_{sed}	9	0.06	0.8	6	0.07	0.5	43%	-22%	47%
4	d_{sed}	7	0.07	0.5	10	0.07	0.7	-43%	-1%	-39%
5	kd, N	7	0.07	0.5	11	0.07	0.8	-42%	0%	-42%
6	Kw, N	7	0.07	0.5	10	0.07	0.7	-35%	0%	-33%
7	C_{net}	9	0.08	0.7	6	0.06	0.5	35%	22%	28%
8	ρ	9	0.07	0.7	7	0.07	0.5	29%	0%	24%
9	v_s, N	8	0.07	0.6	10	0.07	0.7	-29%	0%	-28%
10	Q_{base}	10	0.09	0.7	8	0.07	0.6	25%	29%	21%
11	Kd sed, N, oxic	7	0.07	0.5	5	0.07	0.4	21%	0%	16%
12	kd, P	7	0.05	0.6	9	0.09	0.6	-15%	-53%	0%
13	Kd_2 sed, N, oxic	8	0.07	0.6	9	0.07	0.7	-15%	0%	-14%
14	wetlands outflow conc, P	9	0.09	0.6	8	0.06	0.6	9%	38%	0%
15	V	8	0.07	0.6	8	0.07	0.6	-6%	2%	-8%
16	v_s, P	8	0.07	0.6	9	0.09	0.6	-6%	-33%	0%
17	C_3 init, P	9	0.09	0.6	-	-	-	5%	29%	0%
18	C_3 init, N	8	0.07	0.6	-	-	-	2%	0%	2%
19	burialFrac, P	-	-	-	8	0.08	0.6	-1%	-6%	0%
20	sed anoxic fraction	8	0.07	0.6	-	-	-	1%	0%	1%
21	Kd sed, P, oxic	8	0.07	0.6	8	0.07	0.6	0%	1%	0%
22	Kd_2 sed, P, oxic	-	-	-	8	0.07	0.6	0%	0%	0%

[H] = high end of input range
[L] = low end of input range

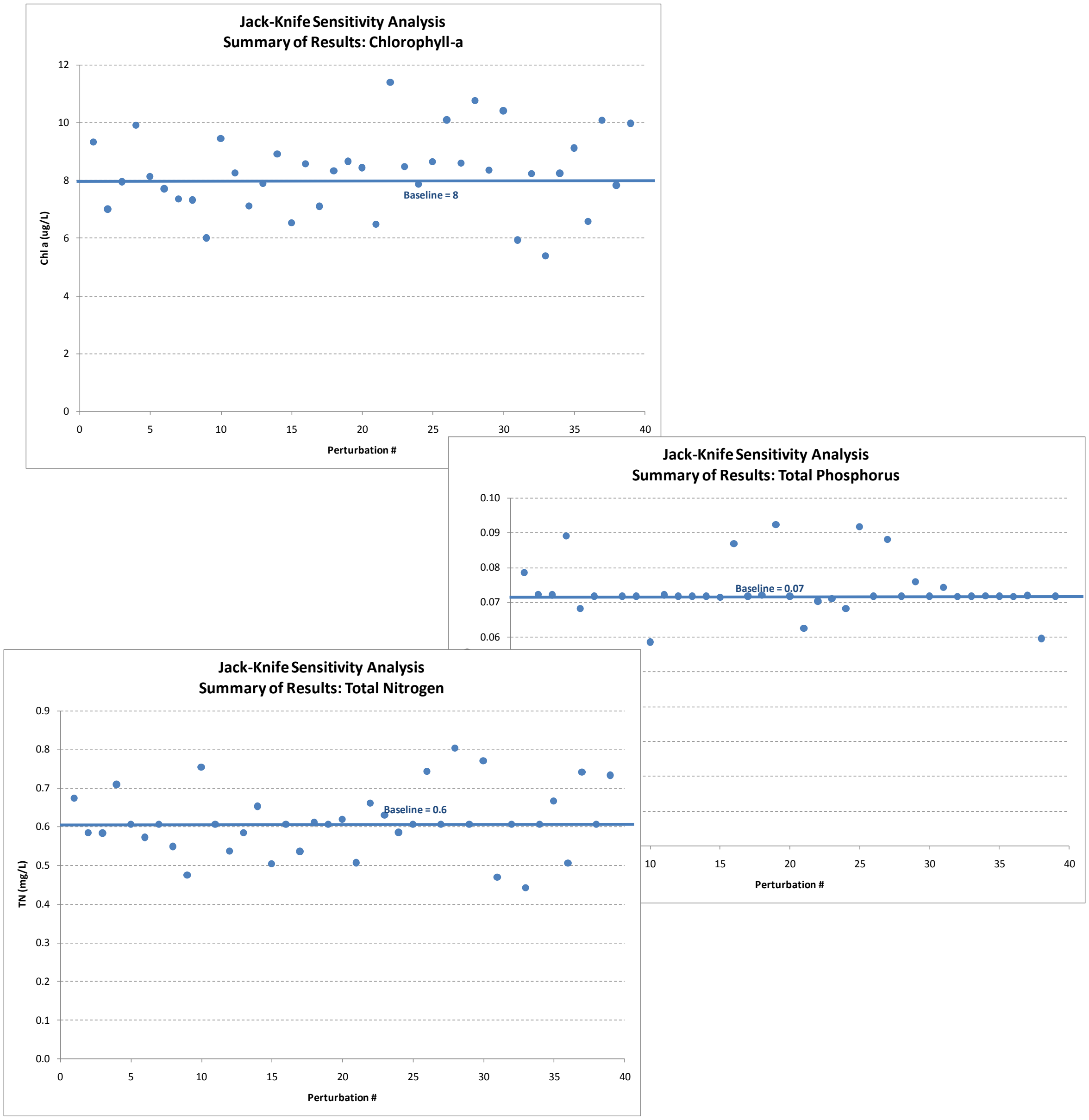


Figure C-12
Jack-Knife Sensitivity Analysis Results: Machado Lake Water Quality Model

C.7 Uncertainty Analysis

The jack-knife analysis described above provides useful information on model sensitivities to individual parameters and also provides initial steps in quantifying model prediction uncertainty. As demonstrated and discussed above, a moderate level of uncertainty in model predictions can be attributed to model parameterization, although this is lessened by the fact that the parameterization is supported by measured data, model calibration efforts, and sound engineering judgment and experience. However, an additional source of significant uncertainty in the model predictions is that associated with input parameters that we know to be "naturally" variable. In this model, such parameters are generally linked to weather and hydrology, both of which introduce elements of randomness and unpredictability. To address this category of uncertainty, a stochastic version of the Machado Lake Water Quality model was developed.

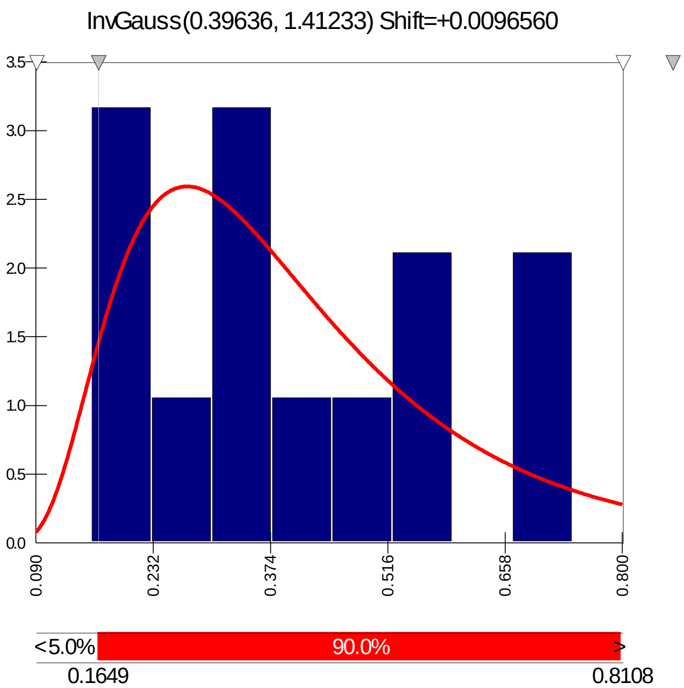
The stochastic version of the Machado Lake Water Quality model was constructed using the @RISK software (*Palisade Corporation*), an add-in to Excel (*Microsoft)*. In this version of the model, selected model parameters were allowed to vary stochastically during model simulation, rather than assumed constant. Probability distribution functions (PDFs) were fit to available data for each stochastic variable. These PDFs describe the expected variability of each stochastic variable using continuous functions. The stochastic variables used in this modeling exercise, and their associated PDFs, are summarized in Table C-23 and Figures C-13 and C-14. For each stochastic model simulation, the PDFs were randomly and simultaneously sampled 1000 times, with the result of each iteration recorded. The final results (N, P, and Chl-a concentrations) are presented as cumulative probability distribution function (CDF) across a range of values, rather than as single concentrations. This type of output provides valuable insight into the risk of concentration target exceedances and the level of uncertainty associated with each output parameter due to natural random variability.

Table C-23
Summary of Stochastic Model Inputs

Parameter	Fitted PDF	Mean Value	Supporting Rationale
baseflow, Q_{base} (cfs)	Uniform (min = 0, max = 0.7)	0.35	limited observations[1]
City winter baseflow conc., P (mg/L)[2]	Inverse Gaussian (mean = 0.40, λ = 1.41, Shift =0.0097)[4]	0.41	measured data[3]
City summer baseflow conc., P (mg/L)[2]	Inverse Gaussian (mean = 1.43, λ = 22.4, Shift =-0.65)[4]	0.78	measured data[3]
City wet weather EMC, P (mg/L)[2]	Triangular (min = 0.5, mean = 0.86, max =1.3)	0.75	measured data[3]
City winter baseflow conc., N (mg/L)[2]	Extreme Value (a = 1.96, b = 0.49)[5]	2.3	measured data[3]
City summer baseflow conc., N (mg/L)[2]	Extreme Value (a = 2.41, b = 0.51)[5]	2.7	measured data[3]
City wet weather EMC, N (mg/L)[2]	Triangular (min = 1.6, mean = 3.5, max =6.5)	2.5	measured data[3]
supplemental water conc., P (mg/L)	Normal (mean = 0.07, std dev = 0.035, truncated at 0.01 and 0.15)	0.07	anticipated range for recycled water[4]
supplemental water conc., N (mg/L)	Normal (mean = 2.1, std dev = 0.5, truncated at 1.7 and 2.9)	2.1	anticipated range for recycled water[6]
supplemental water summer inflow rates (AFM)	Uniform (Apr: 6-25, May: 9-29, Jun: 11-30, Jul: 15-35, Aug: 15-35, Sep: 10-29, Oct: 6-26)	Apr = 15.5, May = 19, Jun = 20.5, Jul = 25, Aug = 25, Sep = 19.5, Oct = 16	independent water balance calculations of make-up water requirements
Precipitation water year	Uniform (1978 – 2008)	1993	full period of available precipitation data

[1] = see CDM Technical Memorandum, May 2009, "Supplemental Information on Machado Lake Alternatives"
[2] = non-City drainage N and P concentrations held constant at TMDL targets;
[3] = combined City of L.A. and Regional Water Quality Control Board in-lake or stormwater data collected 2006 – 2010 in support of the Machado Lake Ecosystem Rehabilitation and Wilmington Drain Multiuse Proposition O projects;
[4] = for Inverse Guassian distribution, variance = $mean^3/\lambda$
[5] = for Extreme Value distribution, mean = a + 0.577b. variance = $\pi^2 b^2/6$
[6] = see Appendix L of CDM Preliminary Design Report, 2009.

A) Winter



B) Summer

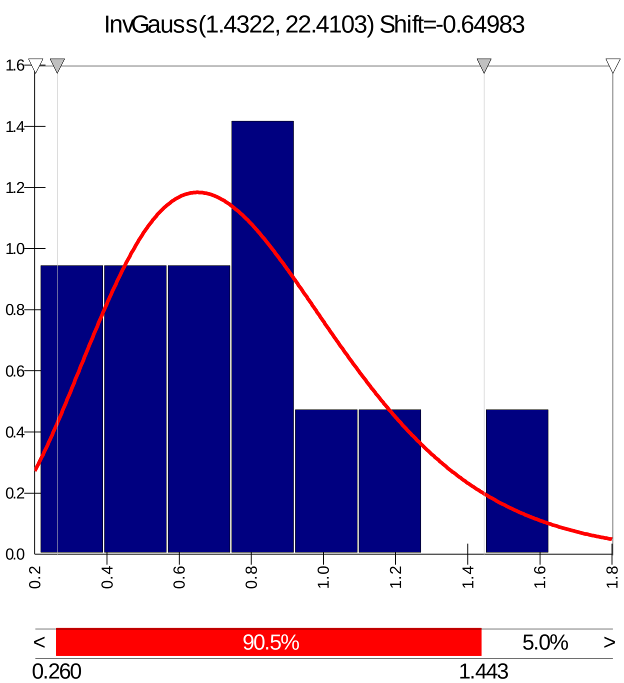
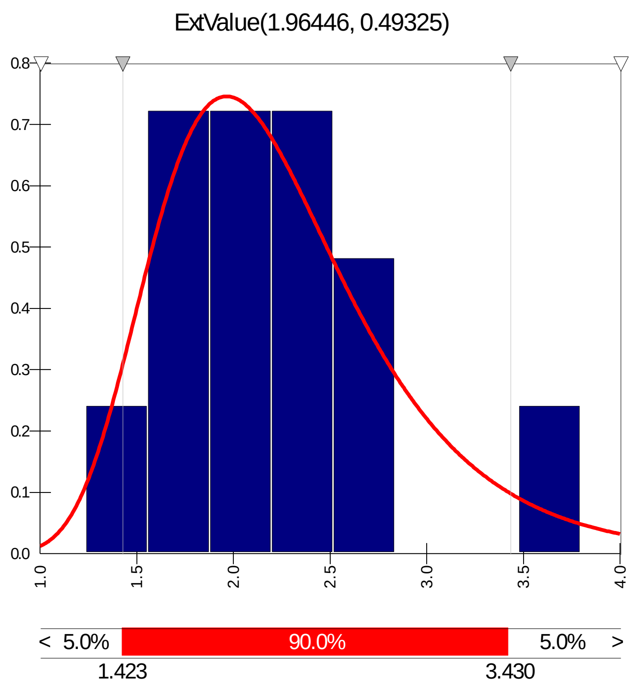


Figure C-13
@RISK PDF Fitting Analysis: Baseflow TP (blue histogram = measured data, red line = fitted PDF)

A) Winter



B) Summer

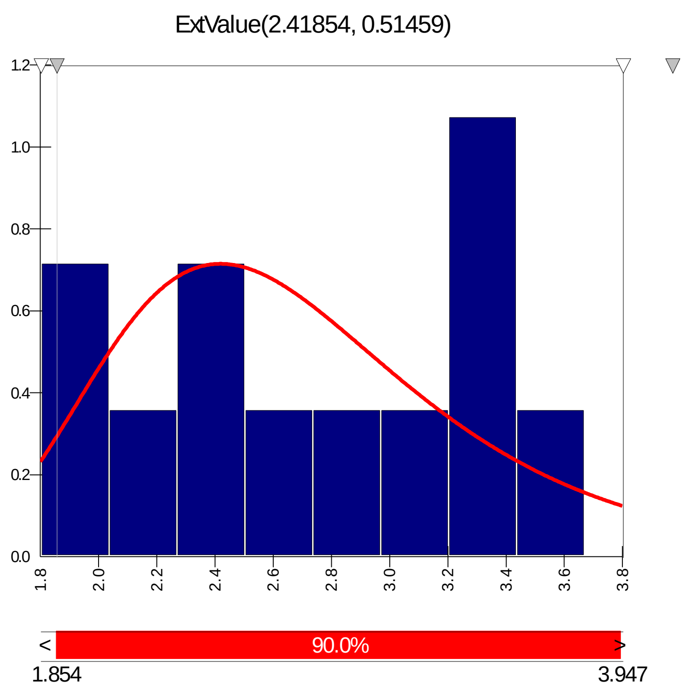
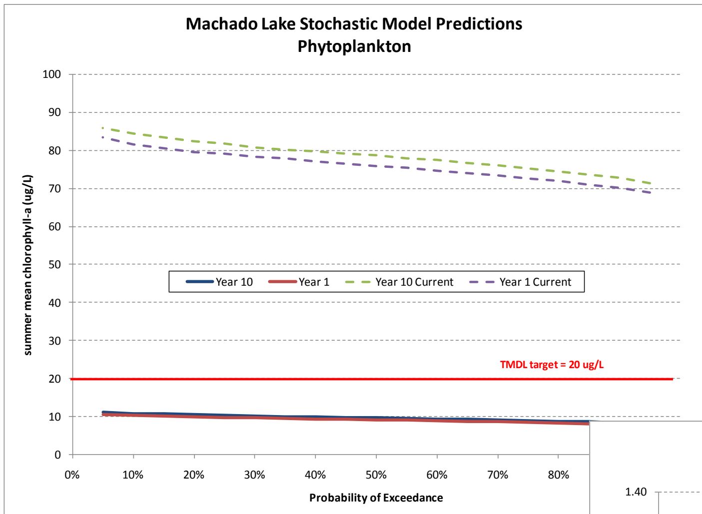
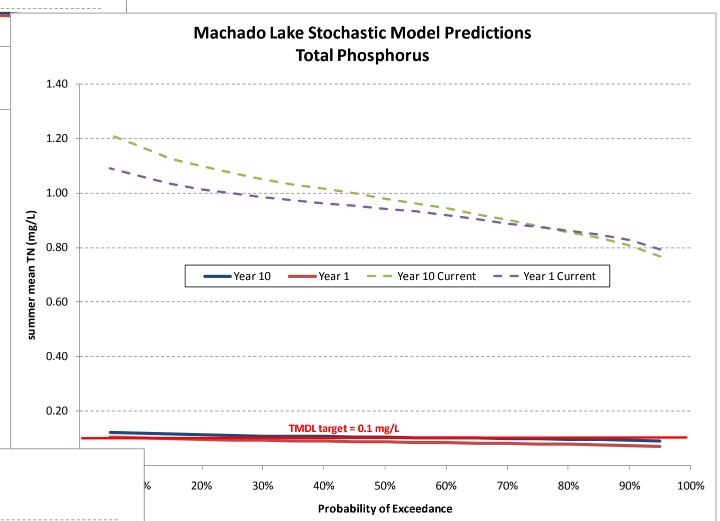


Figure C-14
@RISK PDF Fitting Analysis: Baseflow TN (blue histogram = measured data, red line = fitted PDF)

Stochastic modeling results are presented in Figure C-15. For reference, both the TMDL targets and results for the current lake system (pre-BMP) are provided. All of the calculated output curves for the baseline (post-BMP) system are relatively flat, indicating limited sensitivity to the inflow concentration and flow variability modeled here. It is also noteworthy that both the N and chl-a output curves lie fully below the TMDL targets, while the P curve extends slightly above the target only at approximately the 40% exceedance level. We can conclude from these results that, given the assumed effectiveness of in-lake and watershed mitigation efforts, the risk of exceeding TMDL targets as a result of randomness in weather and inflow concentration patterns is low.





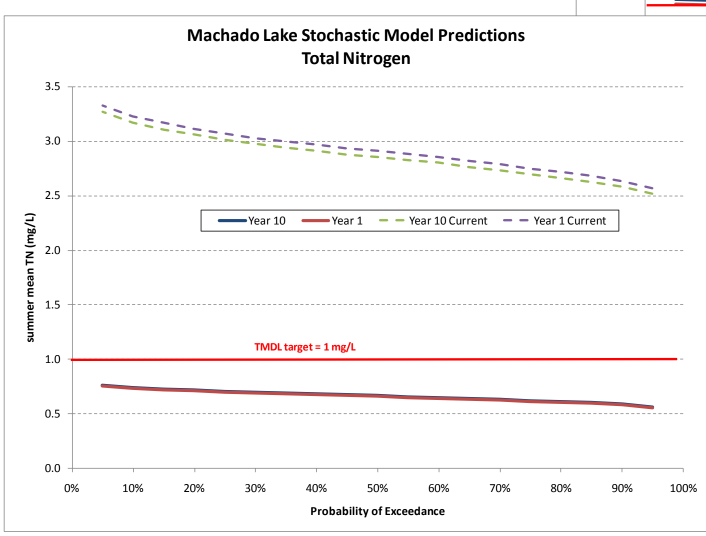


Figure C-15
Stochastic Modeling Results

C.8 Comparison of Lake Rehabilitation Modeling to the Regional Board's Bathtub Model

The modeling results presented in this Lake Rehabilitation model differ significantly, in some areas, from those presented as part of the Regional Board's 2008 Bathtub Model developed for the TMDL (TMDL model). This is not uncommon as models become more refined and new data become available. The differences seen here are primarily associated with relative magnitudes of lake external vs. internal loads. In the TMDL model, quantified watershed external loads were significantly lower than those quantified in this study. For internal loads, the relative differences are reversed (higher in the TMDL model, lower in this Lake Rehabilitation model). These differences can be attributed to the following points:

1) This Lake Rehabilitation model represents a major improvement to the TMDL model with respect to defensibility, predictive power, and comprehensiveness. Consequently, large strides have been achieved in the accuracy of model predictions. The Lake Rehabilitation model includes mechanistic simulations of sediment nutrient dynamics and supplemental water additions, and also includes separation of baseflow vs. runoff loading and seasonal variability in input parameters, while predicting lake water quality on a daily timestep. The TMDL model was based on lumped parameters and calculated on an annual and seasonal basis only. The TMDL model appears to have been calibrated using annual mean concentrations and therefore lacked incorporation of seasonal dynamics. The calibration of the Lake Rehabilitation model is based on a 2 year daily timestep simulation compared to a 2 year timeseries dataset of measured concentrations. It is also strongly supported by an independent laboratory empirical study of sediment nutrient fluxes and subsequent sediment flux parameter calibration.

2) The TMDL model used a 5 year average precipitation of 10.6" for calculating runoff N and P loads to the lake. The Lake Rehabilitation model reported mass balance is based on the 2008 calibration year, when precipitation was approximately 30% higher (13.2").

3) The internal nutrient loading rates assumed for the TMDL model are unusually high. They are partly based on a sediment nutrient flux study that is inconsistent with the sediment nutrient flux study conducted as part of the Lake Rehabilitation model development. The sediment nutrient flux study results used in the TMDL model resulted in flux rates that are of much larger magnitude than typically expected for this type of lake. Furthermore, the TMDL model made the incorrect assumption that these measured summer daily rates are realized by the lake continually throughout the lake. It is known that these rates vary significantly by season and are generally only significantly positive during the summer months, when external loads are low, temperatures higher, and sediment oxygen levels low. This was a significant inconsistency in the TMDL

model compared to the Lake Rehabilitation model. The flux rates in the Lake Rehabilitation model are directly supported by the empirical study performed by Dr. Horne using site-specific lake sediments. In contrast to the high rates reported in the TMDL model, these rates are very much in line with rates reported in the literature. Further, the lake model calibration was able to quantify the seasonality in the rates based on observed dynamic lake concentration profiles.

C.9 References

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