LAKE SAN MARCOS WATERSHED
SWRCB CLEANUP AND ABATEMENT FUND APPLICATION

NUTRIENT WORKPLAN
May 26, 2010

Lake San Marcos ("the Lake") is listed under CWA Section 303(d) as an impaired water body (called "San Marcos Lake" in the listing) due to impairments caused by:

- Ammonia as Nitrogen*,
- Nutrients, and
- Phosphorous*.

The Lake is an impoundment of San Marcos Creek ("the Creek") upstream of a concrete arched dam (the "Dam"). The Creek is also listed as an impaired water body for Phosphorous. This Workplan addresses only Lake San Marcos and nutrient sources from the contributing watershed upstream of the Dam.

The 303(d) listings include a schedule for development of TMDLs to address the impairments. A group of local stakeholders (the "Working Group") has been working over the past year to address these issues, and San Diego Regional Water Quality Control Board ("Water Board") staff has encouraged the stakeholders to proceed with a non-TMDL approach to address the listings. This Workplan is a product of the Working Group, and specifically meets the following Working Group goal:

> *"Develop a technically sound Workplan (including a Scope of Work and Budget) for a Cleanup and Abatement Fund application to address nutrient issues in Lake San Marcos and San Marcos Creek upstream of the Dam."*

Essential background documents that were used as references during the development of the Workplan include:

- Lake San Marcos CWA Section 303(d) Listings (2006) (Attachment A-1)
- RWQCB Executive Officer Summary Report, 4/8/2009, Revised 2/10/2010; Status Report: Lake San Marcos (Attachment A-2)
- Water Quality Management in Lake San Marcos: Analysis of Available Data, Final Report, Michael Anderson, 3 February 2010 (Attachment A-3)

Those documents are appended to this Workplan.

As indicated in both the Executive Officer's Summary Report and Dr. Anderson's report cited above, substantial gaps exist in knowledge and understanding of internal Lake processes, watershed sources of nutrients, and watershed hydrology. These gaps must be addressed before a meaningful or comprehensive plan for cleanup, abatement, and mitigation can be developed. This Workplan describes the necessary diagnostic and investigative research that is proposed, the need for comprehensive data analysis and interpretation, and the preparation of a feasibility study to facilitate and inform cleanup implementation planning.

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* Throughout this Workplan nitrogen is abbreviated as "N" and phosphorous is abbreviated as "P".

EXHIBIT A

As specified in the CAA fund application, the City of San Marcos will serve as lead agency for the proposed work. The following three phases of activity are proposed under this Workplan:

A. Monitoring and Research – this is the investigative/diagnostic phase of the Workplan. This phase will include multiple projects and studies involving data collection, targeted to address identified knowledge gaps.
B. Data Analysis and Interpretation – this phase is essential in order to make effective use of the results of the Monitoring and Research phase – for both individual investigative/diagnostic studies as well as to synthesize results across multiple studies. The results of the Data Analysis and Interpretation phase will be published in a separate report and submitted to the Water Board as a Workplan deliverable.
C. Feasibility Study and Cleanup Implementation Planning – based on the results of the Monitoring and Research and Data Analysis and Interpretation phases, a feasibility study will be performed, and a prioritized list of cleanup and abatement options will be developed. This will include measures aimed at reducing the primary causes of nutrient impairment in Lake San Marcos, with the goal of meeting applicable water quality standards, and may include actions designed to mitigate, abate, remediate or cleanup nutrient levels in the Lake. The work product from this phase will include a priority-ranked list of specific measures expected to result in demonstrable improvements in lake water quality.

The specific activities proposed under each of these phases are described in the Scope of Work, below.[1] The Workplan Schedule and estimated Budget follows the proposed Scope of Work.

SCOPE OF WORK

A. Monitoring and Research

1) Determine Modeling Approach
This task will involve creation of a conceptual model for the watershed, and selection of a surface water hydrology model, groundwater hydrology model, and water quality model (or modules for the hydrology models). Note that the model selection will be done in a comprehensive way to ensure that the models can be effectively integrated. Upon model selection and review of existing data, the conceptual model will be updated and additional data needed to run each model will be specified. [The models also will be used to predict improvements in Lake nutrient levels based on evaluations of various alternatives and scenarios for cleanup/mitigation/remediation; see Task C.] This task includes the following steps:

a) Develop Conceptual Model
A conceptual model will be created to illustrate the key sources, sinks, transport pathways, and transformational processes of nutrients within the watershed. The conceptual model will be used to help identify the areas where significant data gaps exist, as well as guide the selection and development of the surface water and groundwater models.

[1] Phases A and B are referred to as the Diagnostic Phase and Feasibility and Cleanup Implementation and Planning Phase in the CAA Application.

b) Surface Water (Hydrological) Model Selection
A surface water model will be developed as a tool for understanding the hydrology of the watershed, including providing a means of evaluating seasonal and annual variations in the water budget. This initial task will involve the following steps:

- Select model
- Contract with modeling consultant
- Refine conceptual model
- Assess data gaps; Specify needed data

The modeling consultant will review the known conditions and existing data within the watershed, help refine the conceptual model, and then specify the additional data that will be needed for model input, calibration, and verification.

c) Groundwater (Hydraulic) Model Selection
A groundwater model will be used as a tool for understanding the sources and volumes of groundwater contributing to the water budget of Lake San Marcos, and the pathways groundwater takes to reach the lake: directly through subsurface flow, via infiltration into storm sewers, by pumping from groundwater dewatering wells, or by contributing to base flow in the creek. This initial task will involve the following steps:

- Select model
- Contract with modeling consultant
- Refine conceptual model
- Assess data gaps; Specify needed data

The modeling consultant will review the known conditions and existing data within the watershed, help refine the conceptual model, and then specify the additional data that will be needed for model input, calibration, and verification.

d) Water Quality Model/Module Selection
A water quality model will be used as a tool for understanding the concentrations and loadings of nutrients from the various sources contributing to nutrient levels in the Lake, including in-lake processes and seasonal and annual variations. It is anticipated that the water quality modeling can be accomplished by adding the appropriate components or modules to the surface water hydrology and groundwater models. This initial task will involve the following steps:

- Select model(s)/module(s)
- Contract with modeling consultant (may be same as selected for hydrological/hydraulic models above)
- Refine conceptual model
- Assess data gaps; Specify needed data

The modeling consultant will review the known conditions and existing data within the watershed, help refine the conceptual model, and then specify the additional data that will be needed for model input, calibration, and verification.

For subtasks 1b, 1c, and 1d, the existing/historical data will be compiled and evaluated as part of the data gap analysis. This analysis will identify data collection targets and monitoring frequencies that will be supportive of the statistical data requirements of the modeling efforts, with due consideration of budgeting constraints and established protocols, to help ensure scientifically valid and statistically verifiable outcomes for the various studies described in this Workplan.

2) Understand Water Budget
The rate at which water flows into the Lake from various sources is a key determinant of nutrient loadings, and both water flow rates and Lake water levels are key factors in understanding the fate and transport of nutrients affecting the Lake. Therefore, it is critical to understand the differential rates of water movement through the various pathways into and out of the Lake. Sources of inflow include urban and agricultural irrigation, stormwater runoff (urban, agricultural and open space), groundwater inflows (surface and subsurface), direct precipitation, and dewatering. Outflows (losses) include loss to groundwater, evaporation, dewatering/diversion, and flows over or through the Dam. A key issue involves the relative contribution of groundwater to the Lake volume under both dry and wet season conditions. This includes the following steps:

a) Quantify Surface Inflows/Outflows
Based on the data gap analysis from Task 1, field measurements will be made to quantify specific types of surface inflows to the lake, as well as outflows. This will involve field collection of flow data at representative locations within the watershed. In addition to quantifying standard rainfall/runoff and dry weather inflows, including precipitation and evaporation, the effects of the operation of the Dam (including issues relating to impoundment and bypass) and the exercise of riparian, overlying, and appropriative water rights (including issues relating to dewatering) will be quantified.

b) Calibrate and Validate Surface Water Model
The flow measurements will be used as input to the surface water hydrology model. The model will be calibrated and validated, and run to illustrate the range of seasonal and annual (e.g., wet vs. dry years) conditions.

c) Quantify Groundwater Inflows/Outflows
Evaluate groundwater elevation contours (if available) to assess hydraulic gradient, review available hydraulic parameters (hydraulic conductivity and storativity) from the local aquifers, and assess likely discharges to derive a local groundwater budget – inflow (recharge sources), outflow (e.g., pumping) and storage.

This will be validated against a macro water budget obtained by calculation from estimated surface flows and evaporation.

d) Differentiate Groundwater Sources
Once the relative proportion of groundwater contributing to the lake water budget has been estimated, it will be necessary to determine the proportional origin of that groundwater; i.e., to distinguish between "natural" groundwater derived from local aquifers or percolation of precipitation through the soil, vs. irrigation water derived from surface sources that infiltrates through the soil and migrates to the lake. This will be done by attempting to establish "signatures" or "fingerprints" for the various groundwater and surface water sources, using standard water quality parameters such as Total Dissolved Solids (TDS) or conductivity, as well as stable isotopes of oxygen and hydrogen. TDS and conductivity are easily measured in the field or lab using standard field equipment. Stable isotope

analyses also can be performed in commercial laboratories using standard procedures. Groundwater samples are analyzed using EPA Test Method CF-IRMS for oxygen isotope ratios and EPA Test Method DI-IRMS for hydrogen isotope ratios. Stable isotopes of oxygen (delta oxygen-18 d^{18}O) and hydrogen (delta deuterium dD) are presented as ratios in parts per thousand (commonly expressed "permil" and indicated by ‰) relative to Vienna Standard Mean Ocean Water (VSMOW).

e) Calibrate and Validate Groundwater Model
Available hydraulic and other data will be used as input to the groundwater model. The model will be calibrated and validated, and run to illustrate the range of seasonal and annual (e.g., wet vs. dry years) conditions.

3) Understand Nutrient Budget
It is necessary to quantify concentrations and loadings of nutrients in inflows to the Lake, within the Lake (water column, sediments, and flora), and in discharges from the Lake. Nutrient sources likely include urban and agricultural irrigation, stormwater runoff (urban, agricultural and open space), groundwater inflows (surface and subsurface), dewatering discharges, and direct inputs from wildlife. Losses may include biological uptake, sedimentation within the lake, loss to groundwater, dewatering/diversion, and flows over or through the dam. Seasonal and annual variation in relative concentrations and loadings from various sources may be substantial. This includes the following steps (internal Lake processes are covered under Task 5):

a) Quantify Nutrient Concentrations in Surface Inflows/Outflows
Based on the data gap analysis from Task 1, monitoring will be performed to quantify N and P concentrations in specific types of surface inflows to the lake, as well as outflows. In addition to quantifying nutrient concentrations in runoff and dry weather inflows, the effects of the operation of the Dam (including issues relating to impoundment and bypass) and the exercise of riparian, overlying, and appropriative water rights (including issues relating to dewatering) on Lake nutrient levels will be quantified.
This will involve collection and analysis of samples for concentration data at representative locations within the watershed. Samples will be analyzed for the standard set of field parameters (temperature, dissolved oxygen, pH, conductivity, and possibly turbidity), and analyzed by a certified laboratory for total suspended solids, total dissolved solids, total and dissolved organic carbon, biochemical oxygen demand, hardness, silica, chlorophyll a, and major anions, in addition to the various forms of N and P (including Total N, Total P, Total Dissolved N, Total Dissolved P, Nitrate+Nitrite, Ammonium, and Soluble Reactive P). This work will be coordinated to the extent feasible with the flow monitoring performed under Task 2a.

b) Quantify Atmospheric Deposition of Nutrients
Monitoring will be performed to quantify N and P concentrations in atmospheric deposition within the watershed. This will involve collection and analysis of samples of bulk dry and wet deposition at representative locations within the watershed during both dry season and wet season.

c) Calibrate and Validate Surface Water Quality Model
The available nutrient concentration data will be used as input to the surface water quality model/module. The model will be calibrated and validated, and run to illustrate the range of seasonal and annual (e.g., wet vs. dry years) conditions.

d) Quantify Nutrient Concentrations in Groundwater Inflows/Outflows
Based on the data gap analysis from Task 1, monitoring will be performed to quantify N and P concentrations in specific types of groundwater inflows to the lake, as well as outflows. This will involve collection and analysis of samples for concentration data at representative locations within the watershed. For irrigated lands that drain to the lake, the irrigation source water also will be tested. Samples will be analyzed for the standard set of field parameters (temperature, dissolved oxygen, pH, conductivity, and possibly turbidity), and analyzed by a certified laboratory for total suspended solids, total dissolved solids, total and dissolved organic carbon, biochemical oxygen demand, hardness, silica, chlorophyll a, and major anions, in addition to the various forms of N and P. The newly-acquired data will be combined with existing/historical data to create a more comprehensive picture of groundwater quality.

e) Calibrate and Validate Groundwater Quality Model/Module
The available nutrient concentration data will be used as input to the groundwater quality model/module. The model will be calibrated and validated, and run to illustrate the range of seasonal and annual (e.g., wet vs. dry years) conditions.

4) Calculate External Nutrient Loadings
The results of Tasks 2 and 3 will be evaluated to create a picture of nutrient loadings to the Lake from the various external sources, and the fate of those nutrients once discharged to the Lake, including quantification of any outflows. This will include quantification of seasonal and annual variations (depending upon type of water year).

5) Understand In-Lake Processes
The two processes most critical to the nutrient impairment of the Lake are the build-up of sediment behind the Dam and thermal stratification of the Lake.

Dams provide a physical barrier that blocks the downstream movement of sediment and associated constituents, and they also slow the water flow, enhancing the sedimentation process. In Lake San Marcos, as in other lakes formed by a dam across a creek, sediment builds up on the Lake bottom over the years – in the case of Lake San Marcos this process has been ongoing for several decades. Various forms of N and P are among the constituents contained within the sediment build-up.

In thermally-stratified lakes, the lake is separated vertically into three distinct strata:

- the epilimnion, or upper layer, where temperature and dissolved oxygen are relatively high,
- the thermocline, an area of rapidly declining temperature and dissolved oxygen, and
- the hypolimnion, or lower layer, where temperature and dissolved oxygen are relatively low.

The hypolimnion has very little exposure to air or photosynthetic activity, and therefore tends to be very low in dissolved oxygen, and may even be anoxic. As there is nominally little vertical mixing in stratified lakes, constituents tend to become trapped in the lower level of the lake (the hypolimnion), below the thermocline, and the water may be anoxic. Exchange of pollutants between water column and sediment is limited to this zone during periods of thermal stratification. As the upper layer of water cools with the onset of winter, the stratification may break down, and the lake can mix rapidly in a process known as turnover. If turnover occurs, pollutants trapped within the hypolimnion and the sediments can be mixed throughout the lake. Dr. Anderson's report confirms that the lake is thermally stratified, but he was not able to conclude whether turnover occurs.

The following monitoring programs and studies are proposed to provide needed information regarding in-lake processes:

a) Depth Profiling
It is essential to understand stratification within the lake as it changes seasonally, and particularly important to know whether turnover occurs. This will be determined with a vertical series of measurements (depth profiling) of key water quality parameters* (temperature, dissolved oxygen, pH, conductivity, and turbidity) throughout the water column at two selected locations within the lake: in deeper water near the dam, and at a midway point (corresponding to Dr. Anderson's sites 1 and 2).
*These parameters all can be field-measured using standard field equipment. Depth profiles will be field-measured as described above during the quarterly field monitoring described in Task A.5.e below. In addition, automated data sondes (*in situ* monitoring devices) will be installed in place to automatically record these parameters at three specific depths (near surface, mid-depth and near-bottom) at two locations: the deep-water and mid-lake sites identified in Dr. Anderson's report as sites 1 and 2, respectively.

b) Determine Depth and Volume of Accumulated Sediment
It is important to determine how much sediment has accumulated within the lake, as the sediments represent a substantial potential source of nutrients, particularly in the event of lake turnover. This will be assessed through comparisons of historical vs. contemporary bathymetry. A field survey employing multi-beam survey equipment will be performed to determine the current, detailed bathymetry of the lake; the results of this survey will be stored in computerized format (auto-CAD or GIS shape files) and compared to as-built drawings from the original construction of the dam, also in computerized format.

c) Contributions from Shallow Sediments
In shallow areas of the lake stratification typically does not occur, and sediments that accumulate in those areas are subject to mixing into the water column by wind turbulence, storm flows, or physical disturbance from human activities such as use of watercraft. An attempt will be made to assess the extent to which these activities release nutrients from the sediments of shallow areas.

d) Sediment Chemistry
Sediment samples will be collected from approximately 20 sites throughout the lake, including the side "fingers". Samples will be collected from the upper layer of sediment and analyzed by a certified laboratory for a suite of standard

sediment properties, including % solids, grain size distribution, total and dissolved organic carbon, biochemical oxygen demand, pH, hardness, silica, sulfides and sulfites, in addition to the various forms of N and P.
Three sediment cores also will be collected if feasible in the deepest area of the lake, near the dam, with analysis of discrete core sections by a certified laboratory for the list of parameters given above.

e) Water Chemistry
Water quality monitoring will be performed at several locations throughout the lake, with sufficient numbers of samples to characterize seasonal differences, including wet weather vs. dry weather. This will include at a minimum quarterly sampling during dry weather (all four seasons), plus three storm events (early, middle and late wet season). Samples will be collected within one foot of the lake surface. For sites located in areas where the depth exceeds 10 feet, additional samples will be collected from a depth of one-half the estimated water depth. Samples will be analyzed for the standard set of field parameters (temperature, dissolved oxygen, pH, conductivity, and possibly turbidity), and analyzed by a certified laboratory for total suspended solids, total dissolved solids, total and dissolved organic carbon, biochemical oxygen demand, hardness, silica, chlorophyll a, and major anions, in addition to the various forms of N and P (including Total N, Total P, Total Dissolved N, Total Dissolved P, Nitrate+Nitrite, Ammonium, and Soluble Reactive P).

f) Other Water Quality Measurements
Secchi depth measurements will be collected at representative locations in the Lake on an ongoing basis as an indication of Lake water transparency/clarity, along with Lake level measurements, and near-surface measurements of dissolved oxygen and temperature. This task may be performed by trained citizen volunteers, with professional QA/QC oversight, in accordance with SWAMP protocols.

g) Biological Measurements
Several studies will be conducted to assess the biological conditions of the Lake, including:

- Biomass – collection and analysis of phytoplankton and zooplankton, with taxonomic identification of algal community to understand current conditions. Three samples will be collected from a late-summer algal bloom and analyzed taxonomically.
- Lake flora – survey several key locations within the Lake to assess relative amounts of periphyton (attached algae), emergent macrophytes (aquatic plants), and riparian canopy cover.
- Fish and wildlife study – population structure and composition will be assessed using standard ecological assessment techniques.
- Food Web/Trophic Study – based on results of preceding studies.

6) Protocols, Documentation and QA/QC
All monitoring programs and research studies funded under this application will be performed according to SWAMP-approved protocols, or USEPA-approved or USGS-approved protocols in the absence of applicable SWAMP protocols. Sample collection

and analytical protocols and quality assurance/quality control (QA/QC) procedures will be documented in a Quality Assurance Project Plan (QAPP) following SWAMP format. All monitoring programs and studies will prepare a Monitoring Plan for approval by the Grant Manager prior to commencing work. All monitoring sites will be geo-located using standard GPS techniques.

B. Data Analysis and Interpretation

Data Analysis and Interpretation is essential in order to make effective use of the monitoring and research results – for both individual projects as well as to synthesize results across multiple projects.

Key analytical assessments for this Workplan include the following:

- Lake water quantity inputs: groundwater vs. surface water sources, including seasonal and annual variation
- Relative proportions of different sources of groundwater, including seasonal and annual variation
- Relative loadings of N and P from various external sources to Lake, including seasonal and annual variation
- The effects of lake level management and dam operations on water budget and in-lake nutrient levels
- Amount of accumulated sediment in Lake; historical decrease in Lake water storage volume
- Amounts of N and P in Lake sediment reservoir
- Seasonal patterns in Lake thermal stratification; estimated frequency of Lake turnover
- Relative importance of external vs. in-Lake sources of N and P
- Historical patterns in Lake sediment chemistry based on core samples
- Estimated quality of sediment that would be released from the Lake if water is released from the lower Dam outlet (based on core sample results)
- Biological condition of Lake, effects of current nutrient conditions on biota, and effects of fish and wildlife on current nutrient levels

The results of the data analysis and interpretation phase will be published in a separate report and submitted to the Water Board as a Workplan deliverable.

C. Feasibility Study and Cleanup Implementation Planning

Using the results of the various monitoring and research studies described in this Workplan, and based on the analytical and interpretive work described in Task B above, an assessment will be made of the cleanup measures most likely to produce measurable reductions in nutrient loadings to the Lake and/or mitigation of in-Lake nutrient concentrations.

A feasibility study will be performed to evaluate and rank the most promising measures. The surface water and groundwater models will be run to evaluate various alternatives and scenarios for cleanup/mitigation/remediation, including activities related to dam operations and lake management. This task will involve an evaluation and ranking of alternative measures, with an assessment of cost relative to amount of loading reduced or in-Lake concentration improvement expected.

The product of this task will be a prioritized list of cleanup and abatement options. This will include measures aimed at reducing the primary causes of nutrient impairment in Lake San Marcos, with the goal of meeting applicable water quality standards, and may include actions designed to mitigate, abate, remediate or cleanup nutrient levels in the Lake. The work product will include a priority-ranked list of specific measures expected to result in demonstrable improvements in Lake water quality.

SCHEDULE

Task	Scope Items	Timing
A	Monitoring and Research	(months from start)
1	*Determine Modeling Approach*	3
2	*Understand Water Budget*	15
3	*Understand Nutrient Budget*	15
4	*Calculate External Nutrient Loadings*	15
5	*Understand In-Lake Processes*	18
B	Data Analysis and Interpretation	21
C	Feasibility Study/Cleanup Implementation Planning	24
	QAPP and Monitoring Plan (SWAMP-Compat.)	4

BUDGET ESTIMATE

Task	Scope Items	Costs
A	Monitoring and Research	
1	*Determine Modeling Approach*	$59,500
2	*Understand Water Budget*	$200,000
3	*Understand Nutrient Budget*	$190,000
4	*Calculate External Nutrient Loadings*	$15,000
5	*Understand In-Lake Processes*	$333,849
B	Data Analysis and Interpretation	$70,000
C	Feasibility Study/Cleanup Implementation Planning	$50,000
	QAPP and Monitoring Plan (SWAMP-Compat.)	$24,000
	Project Management/Administration	$47,117
	TOTAL:	$989,466