CHAPTER 6.0
MAJOR FINDINGS AND RECOMMENDATIONS FOR FUTURE WORK

The development of the conceptual model in this report involved the synthesis of a large amount of data and information from published reports. The conceptual model can be used to direct future investigations to improve understanding of nutrient-related sources, impacts, and management. This chapter summarizes key findings and recommendations for future work.

6.1 MAJOR FINDINGS

Temporal and spatial patterns in nitrogen and phosphorus transport in the Central Valley are related to the flows in the rivers, which are highly variable, especially on an inter-annual basis. Tributary nutrient loads are substantially greater in the wet season than in the dry season. Tributary loads were also found to vary significantly between wet and dry years. Although the nutrient concentrations in the Sacramento River are lower than the concentrations in the San Joaquin River, the Sacramento River load to the Delta exceeds the San Joaquin River load by a factor of nearly two or greater for both nitrogen and phosphorus. Concentrations of nitrogen and phosphorus in San Joaquin River and in the Delta were fairly high, suggesting that these waters could be classified as eutrophic. The San Joaquin River exhibits many classic symptoms of eutrophication such as low dissolved oxygen levels in deeper waters that adversely affects many beneficial uses. Given the abundance of nutrients, primary productivity in the Delta is fairly low suggesting that factors other than nutrients are limiting, specifically light limitation caused by suspended solids. In the absence of other limiting factors, as might occur during transport of these waters in aqueducts, and storage in reservoirs, these high nutrient levels may express themselves as high levels of algal growth. Further, future changes in Delta conditions

that change these limiting conditions, such as increased clarity due to greater abundance of submersed plants, could cause the phytoplankton productivity to increase.

In evaluating the watershed nutrient loads, it was not possible to calculate export rates for each type of land use present in the Central Valley and Delta. A limited amount of nutrient data has been collected from watersheds with one particular type of land use. Most of the data available for this analysis were collected at locations that have mixed land uses. Export rates of nutrients (mass of nitrogen or phosphorus exported per unit area per year) were estimated for several land uses: urban land, agricultural land, wetlands, and background areas (including forests, shrubland, and rangeland) based on the limited data. The calculated total watershed exports are comparable to the stream loads at key locations (such as Sacramento River at Hood/Greene's Landing and San Joaquin River at Vernalis). There were considerable differences in the estimated loads derived from the two methods at locations where there were limited nutrient concentration data. Export rates, as currently approximated, could be improved through focused flow and concentration data collection in small, relatively homogenous watersheds.

Using watershed export rates, preliminary conclusions can be drawn about nutrient loads from different sources. Forest/rangeland loads for nitrogen may dominate the overall loads for the Sacramento Basin and agriculture loads for nitrogen may dominate in the overall loads for the San Joaquin Basin, particularly for wet years. Point source loads from wastewater discharge may contribute nearly half or more of overall nitrogen and phosphorus loads during dry years in both basins, and during wet years for phosphorus in the San Joaquin Basin.

At location in the Delta over the period 1980 to 2004, the average concentration of ammonia-N was two times higher in the Sacramento River than the San Joaquin River. For other nutrient species, average concentrations were higher in the San Joaquin River than the Sacramento River (up to a factor of ten higher for NO3+NO2-N). In general, average concentrations at the Banks Pumping Plant lie between average concentrations in the Sacramento and San Joaquin Rivers, except for ammonia-N and TKN, where average concentrations at Banks are lower than both Sacramento and San Joaquin River average concentrations.

The major source of in-Delta contribution of nutrients is from agricultural drainage on Delta islands. NO3-N is the only nutrient species data collected by MWQI from Delta agricultural drains; phosphorus loads are estimated using watershed export rates developed in Chapter 4. Current estimates show that annual loads of nutrients from the tributaries are substantially greater than the loads from in-Delta agricultural drainage. The nutrient export in water diversions is relatively uniform from year to year, particularly when compared with the tributary loads. In dry years, the exports of nitrogen and phosphorus in water diversions are similar in magnitude to their export to the Bay.

6.2 RECOMMENDATIONS FOR FUTURE WORK

This section focuses on the uncertainties associated with the quantitative information presented in preceding chapters, and identifies key data gaps that should be addressed in future work, primarily through targeted monitoring. A summary of the uncertainty associated with the quantitative information presented in Chapters 3, 4, and 5 is shown in Table 6-1. Uncertainties and recommendations for nutrients largely follow those presented for organic carbon in Tetra Tech, 2006.

Table 6-1.
Relative levels of uncertainty and importance of sources identified in the Conceptual Model.

Source	Level of Uncertainty	Importance
Tributary Loads		
Sacramento Basin		
Sacramento R. at Bend Bridge	**Medium**	Medium
Butte Cr.	High	Low
Sacramento R. at Colusa	**Medium**	Medium
Yuba R.	**Medium**	Medium
Bear R.	Medium	Low
Feather R.	High	Medium
American R.	Medium	Medium
Sacramento R. at Hood/Greene's Landing	Low	High
Cache Cr.	**Medium**	Low
Putah Cr.	High	Low
San Joaquin Basin		
San Joaquin R. at Sack Dam	High	Low
Chowchilla R.	High	Low
Bear Cr.	High	Low
Merced R.	**Medium**	Medium
San Joaquin R. at Newman	Medium	Medium
Tuolumne R.	Medium	Medium
Stanislaus R.	Medium	Medium
San Joaquin R. at Vernalis	Low	High
Delta		
Cosumnes R.	Medium	Low
Mokelumne R.	Medium	Low
Delta North	High	Medium
Delta South	High	Medium
In-Delta Sources		
Delta Island Agricultural Drainage	High	High
Export Rates		
Agricultural Land	High	High
Urban Runoff	**Medium**	High
Background Areas	High	High
Wetlands	**High**	High
Other		
Point Source Discharges	**Medium**	High
Reservoirs	High	Medium

Note: The Level of Uncertainty or Importance is bolded where different from organic carbon data (Tetra Tech, 2006).

6.2.1 TRIBUTARY LOADS

Uncertainty and Importance

The number of water quality samples and the length of the flow data record were used to assign the rankings of low, medium, and high uncertainty associated with each of the subwatersheds listed in Table 6-1. The loads in the Sacramento River at Hood/Greenes Landing and the San Joaquin River at Vernalis are well characterized due to many years of data collection. In general, the loads of nutrients in the other subwatersheds that discharge to the Sacramento and San Joaquin rivers are not as well characterized. It is interesting to note that compared to organic carbon data availability, some uncertainty levels went from high to medium due to *more* data at these locations for nutrients.

Recommendations

There are substantial data that were not used in this study because the concentration data were collected at locations for which there are no flow data or because the database did not contain latitude and longitude information. The Workgroup should review all of the data that have been collected for each of the subwatersheds and determine the key locations that require additional monitoring. In addition, it is recommended that for future monitoring programs and future versions of the database, a consistent set of nutrient names is used. In the version of the database used for this study, 22 different variations of nutrient species names were present for the six constituents reported in this document.

Finer resolution of the sub-watershed delineation may be necessary to enhance understanding of load sources. For example, finer resolution on the Sacramento River between Colusa and the Delta would facilitate understanding of the importance of the agricultural and urban loading in this area.

6.2.2 DELTA AGRICULTURAL DRAINAGE

Uncertainty and Importance

Drainage volumes are currently estimated with the DICU model. NO3-N data is the only nutrient species from Delta agricultural drains collected by MWQI. It is important to have an accurate estimate of the phosphorus concentrations, total nitrogen concentrations, and drainage volumes before management options can be considered.

Recommendations

USGS is currently monitoring drainage volumes on Twitchell Island and MWQI is conducting a study of drainage volumes on Staten Island. These measured drainage

volumes should be compared to estimates from the DICU model to assess how accurately the model predicts drainage volumes. Then decisions can be made on the importance of obtaining additional drainage volume data. Phosphorus data should be collected in Delta agricultural drains so that phosphorus loads can be more accurately estimated.

6.2.3 EXPORT RATES

There is an extensive amount of nutrient concentration data collected in the major streams in the Central Valley. These data can be used to compute export rates from mixed land uses. However, for distinguishing sources, it is important to estimate the contribution of specific land uses. To meet this objective, focus should be placed on studying small indicator watersheds or specific sources.

Agriculture

Uncertainty and Importance

Over 5,460,000 acres (20%) of the Central Valley watershed is used for agricultural production. There are currently limited data on the loads of nutrients discharged from agricultural land in the tributary watersheds. The data from the Colusa Basin Drain in the Sacramento Basin is representative of loads from rice fields. Information is needed on other types of agricultural in the Sacramento Basin, such as orchards and row crops. Mud Slough, which receives drainage from agricultural lands, was used to estimate agricultural loads in the San Joaquin Basin due to lack of other available data. Due to different sources of water and different methods for management of drainage in the San Joaquin Basin, the loads of nutrients from agricultural operations may differ by crop type, and loads on the west side of the San Joaquin Basin may differ from those on the east side of the Basin.

Recommendations

The Workgroup should obtain data collected by the agricultural waiver monitoring programs and from the Regional Board agricultural monitoring to determine if nutrient loads from agricultural lands can be adequately estimated or if more focused monitoring is needed. In addition, USGS recently started a project to estimate contaminant loads from a small agricultural watershed, Willow Slough. This study should be tracked, and, when the results are available, they should be used to refine the estimate of agricultural loads.

Urban Runoff

Uncertainty and Importance

The export rate for urban runoff was estimated from seven years of data (USGS NWIS: 1996-98; 2001-04) from a single developed watershed, Arcade Creek. Additional data on urban runoff loads are needed to refine the load estimates presented in this report.

Recommendations

MWQI is completing a seven year study on loads from a rapidly urbanizing watershed in Sacramento and Placer counties. The Workgroup should review the MWQI study results and compare the export rate with the one calculated from Arcade Creek. In addition, the Workgroup should work with the City and County of Sacramento and the City of Stockton to determine if loads can be calculated from the data collected as part of their NPDES storm water permit programs.

6.2.4 POINT SOURCE LOADS

Wastewater Treatment Plants

Uncertainty and Importance

Nutrient and flow data were available for most wastewater treatment plants in the Central Valley and Delta, however per capita flow data was only available for three plants (Sacramento Regional Wastewater Treatment Plant, Davis and Vacaville).

Recommendations

Loads could be better characterized with per capita flow data for all wastewater dischargers. In addition, nutrient data should be further analyzed by treatment process type. This would help to determine if nutrient loads are related to treatment processes and to improve the estimates of nutrient loads from wastewater treatment plants.

Fish Hatcheries

Uncertainty and Importance

Fish hatcheries are permitted to discharge up to 352 MGD (average dry weather flow of 256 MGD) into Central Valley waters. There are currently no data in the project database on nutrient concentrations in fish hatchery waste, however literature data is

likely available. The importance of this source is currently unknown and should be investigated.

Recommendations

The Workgroup should collect nutrient data from several fish hatcheries during the next year or two. These data will be useful in determining if fish hatcheries are a source of nutrients that should be included in refined conceptual models.

6.2.5 RESERVOIRS

Uncertainty and Importance

There are reservoirs on most of the rivers in the Central Valley watershed but there are currently limited data on the concentrations of nutrients released from the reservoirs.

Recommendations

The Workgroup should gather any additional data that are available on concentrations of nutrients in reservoir releases. If sufficient data are not available, additional data should be collected on the major rivers immediately downstream from reservoirs.

6.2.6 OTHER RECOMMENDATIONS

The Delta Simulation Model (DSM2) was used to simulate dissolved oxygen (DO) in the Delta as part of the technical studies for the In-Delta Storage Project Feasibility Study (DWR, 2004). As part of the DO modeling, the nutrient cycle is simulated. Published results, however, relate only to DO. It is recommended that the workgroup work with DSM2 developers to obtain nitrogen and phosphorus specific model simulation results.