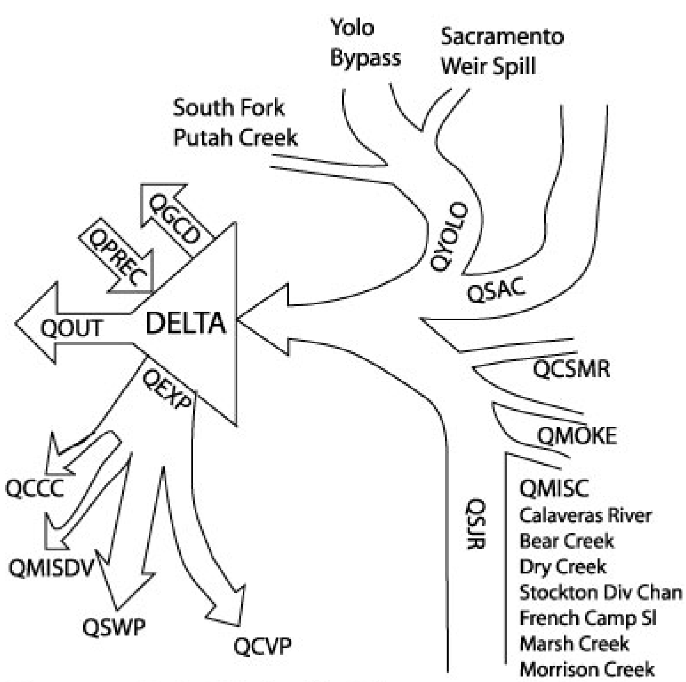
CHAPTER 5.0 NUTRIENT CONCENTRATIONS AND LOADS IN THE DELTA

This chapter is focused on evaluating the sources of nutrients to the Delta in a manner similar to that used for the tributaries in Chapter 4. The load calculations in Chapter 4 and this chapter can be thought of as an accounting process, where, using available data, we have identified the relative magnitudes of different nutrient sources in the Central Valley and Delta region. However, detailed nutrient characterization is only available at a limited spatial and temporal resolution. Until better data are available, therefore, loads of total nitrogen and phosphorus presented herein provide a useful measure of the relative importance of different sources. This information will be refined in future efforts to quantify sources and potential drinking water impacts based on additional data.

5.1 DELTA INFLOWS AND OUTFLOWS

Characterization of flows is central to estimating loads of constituents in moving water bodies. Daily water flows entering and exiting the Delta at various locations, shown in Figure 5-1, were obtained from the DAYFLOW model. DAYFLOW is a computer program developed in 1978 as an accounting tool for determining historical and current Delta hydrology at the boundaries. Inflows in all tributaries, outflows to the San Francisco Bay and diversion by the water supply intakes are represented in the model. However, DAYFLOW does not characterize internal flows in the channels of the Delta and cannot be used to understand the mixing processes of different tributary and internal sources of individual constituents. DAYFLOW output is used extensively in studies conducted by the Department of Water Resources (DWR), the Department of Fish and Game (DFG), and other agencies. Model output is available electronically at http://www.iep.ca.gov/dayflow/index.html.

Annual water supply diversions at the Banks Pumping Plant (SWP), Tracy Pumping Plant (CVP), Contra Costa Water District's Rock Slough and Old River pumping plants (CCC), and the North Bay Aqueduct's Barker Slough Pumping Plant (NBAQ) are shown in Figure 5-2. The naming conventions on this figure are consistent with the DAYFLOW model diversion names shown in Figure 5-1. Over 95% of the water diverted from the Delta is diverted at the Banks and Tracy pumping plants. The sum of water diversions from the Delta is shown as a percentage of annual flows from the major tributaries (Sacramento and San Joaquin Rivers) in Figure 5-3. Over the water years 1983-2004, the average amount of water diverted was 5.2 million acre feet, varying between 3.1 and 6.3 million acre feet. Compared to the variability of tributary flows into the Delta, the diversion volumes are relatively uniform. In dry years, such as the late 1980s and the early 1990s, diversions by the projects can be nearly 50% of Delta inflows. In more recent years, because of higher tributary inflows, the diversions have been a smaller fraction of the inflows, but even so, diversions of 30-40% are common.



LEGEND

QSJR	San Joaquin River flow
QMISC	Miscellaneous streamflow
QMOKE	Mokelumne River flow
QCSMR	Cosumnes River flow
QSAC	Sacramento River flow
QYOLO	Yolo Bypass flow
GGCD	Gross channel depletion
QPREC	Precipitation runoff
QOUT	Delta outflow
QEXP	Exports
QCCC	Contra Costa Water District Diversions at Rock Slough and Old River
QMISDV	Flooded island and island storage diversion
QSWP	State Water Project exports at Banks Pumping Plant
QCVP	Central Valley Project pumping at Tracy
QNBAQ	North Bay Aqueduct export

Note: In DAYFLOW equations, QMISDV replaced with QNBAQ. Updated figure not available.

Figure 5-1. Delta locations with daily flow data reported in the DAYFLOW model. (Figure reproduced from http://wwwiep.water.ca.gov/dayflow/documentation/fig2.jpg).

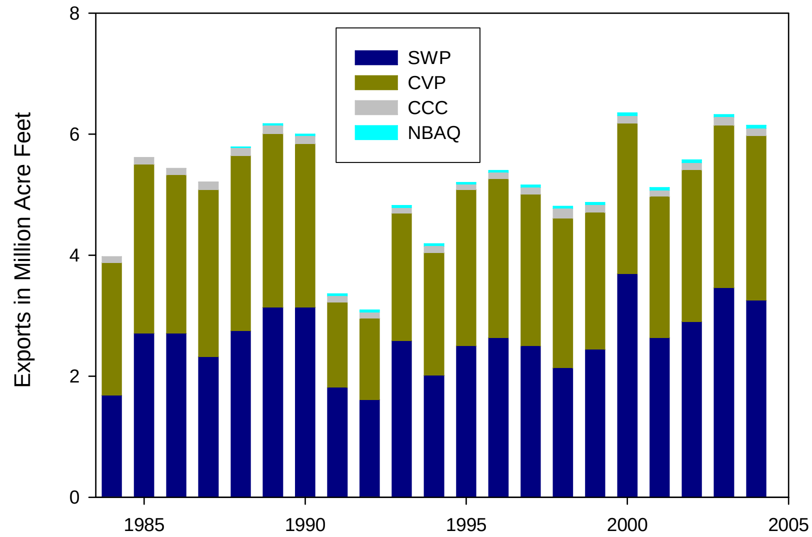


Figure 5-2. Annual water supply diversions (Banks Pumping Plant (SWP), Tracy Pumping Plant (CVP), Contra Costa Water District's Rock Slough and Old River pumping plants (CCC), and the North Bay Aqueduct's Barker Slough Pumping Plant (NBAQ) as reported in the DAYFLOW model.

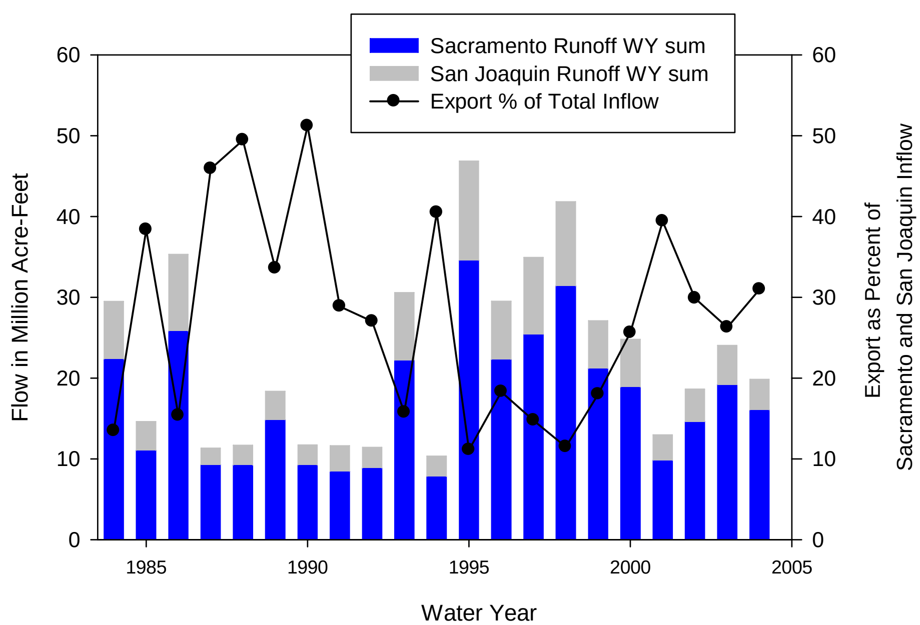


Figure 5-3. The sum of project diversions as a percentage of annual flows from the major tributaries (Sacramento and San Joaquin Rivers) to the Delta.

5.2 Patterns in Nutrient Concentrations

The ratio of NO3+NO2-N plus ammonia-N to TN at three key Delta locations (Banks Pumping Plant, Sacramento River at Hood/Greene's Landing, and the San Joaquin River at Vernalis) is illustrated in Figure 5-4. The median value is similar across the three locations, from about 0.6 to 0.7. The ratio of orthophosphate-P to TP at the three locations is illustrated in Figure 5-5. The median and range is similar at Banks Pumping Plant and Sacramento at Hood/Greene's Landing (approximately 0.6 to 0.65), but slightly lower at the San Joaquin River at Vernalis (approximately 0.5).

Figure 5-6 presents scatterplots of TN and TP concentrations at the three Delta locations where simultaneous measurements were available. Also shown on these plots is the 7:1 ratio line, which denotes the Redfield ratio. As discussed in Chapter 2, if total nitrogen in the water is more than 7 times the total phosphorus, then phosphorus will be in low supply and limit algal growth. If the nitrogen is less than 7 times the phosphorus, then nitrogen will be limiting. These plots show significant scatter with data points on both sides of this line. However, there are more data points to the right of the line (phosphorus limiting) for Banks Pumping Plant and San Joaquin River at Vernalis, and more data points to the left of the line (nitrogen limiting) for Sacramento River at Hood/Greene's Landing.

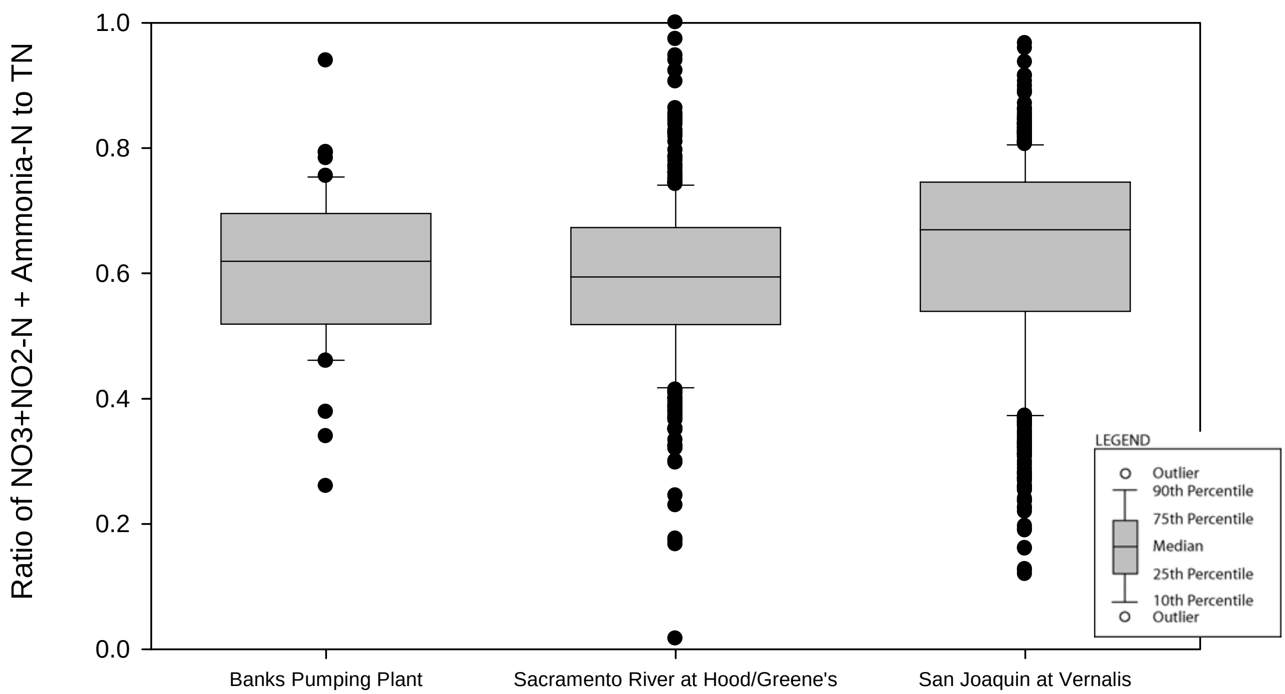


Figure 5-4. Ratio of NO3+NO2-N + ammonia-N to TN at key Delta locations.

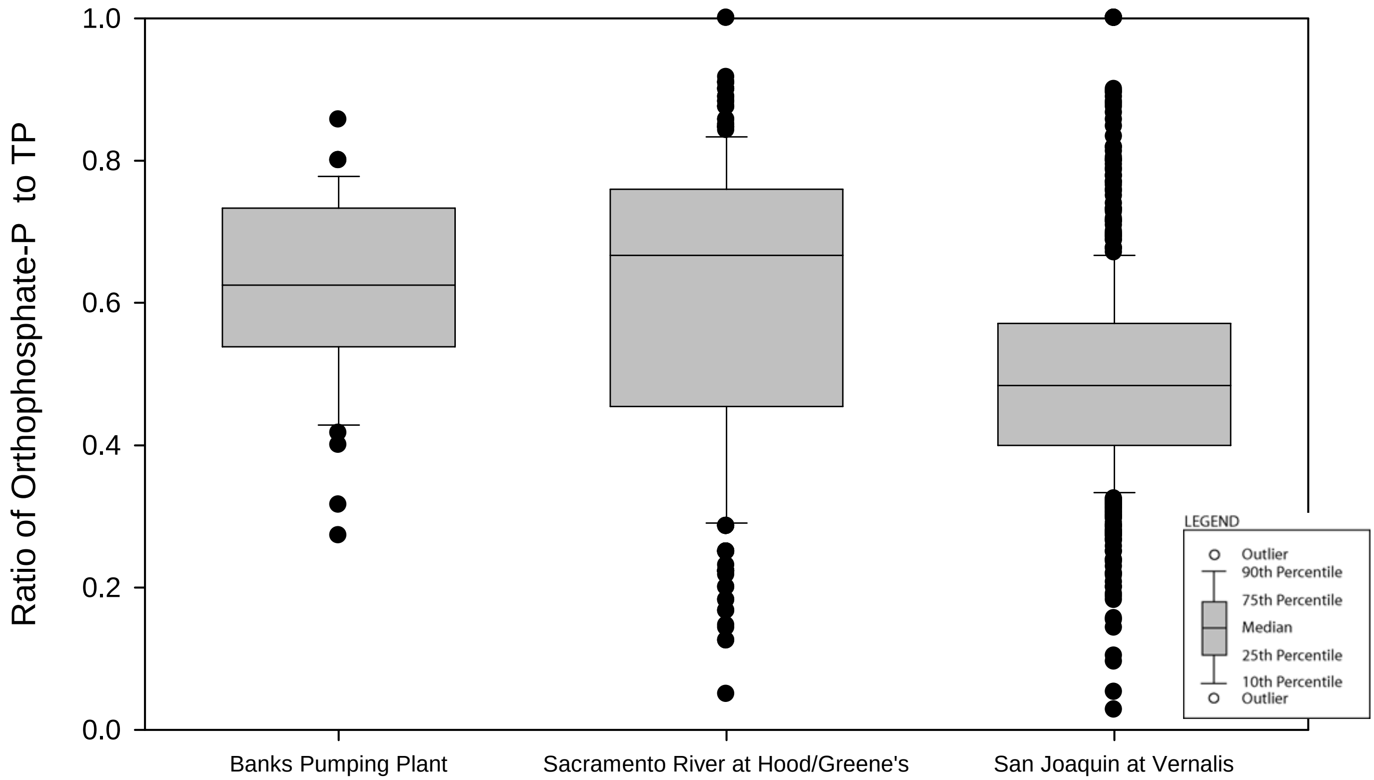


Figure 5-5. Ratio of orthophosphate-P to TP at key Delta locations.

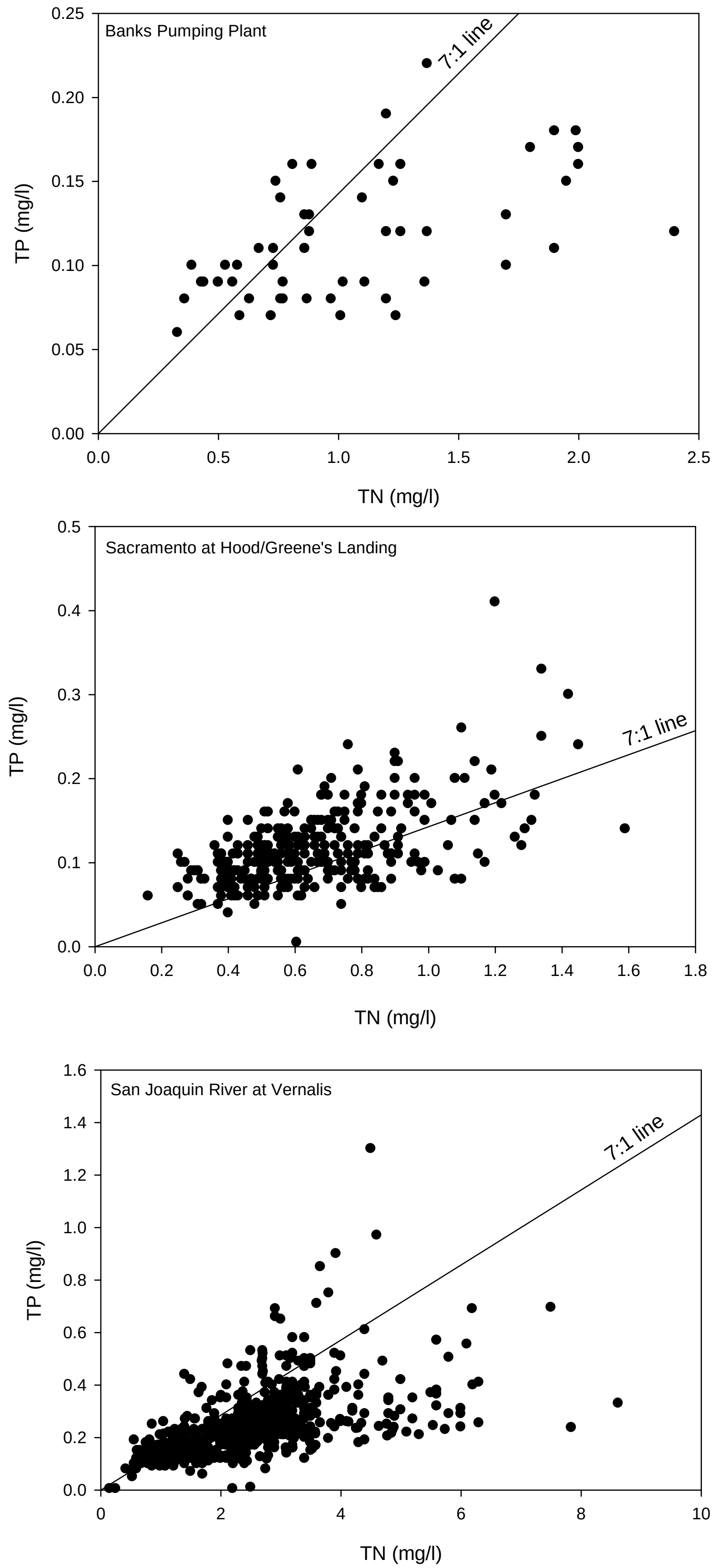


Figure 5-6. TN and TP concentrations at key Delta locations.

Some of the longest records of nutrient concentrations exist at the Sacramento River at Greene's Landing/Hood, San Joaquin River at Vernalis, and the Banks Pumping Plant. The two river locations are important because they constitute the majority of the flow into the Delta, and the Banks Pumping Plant is the largest water diversion from the Delta. Average concentrations at these locations are presented in Table 5-1. Figures 5-7 and 5-8 present concentrations of nitrogen species and phosphorus species, respectively, at these locations from 1980 to 2004. Several observations result:

- The average concentration of ammonia-N is about two times higher in the Sacramento River than the San Joaquin River. NO3+NO2-N and TN concentrations are substantially higher in the San Joaquin River (average data are ten times and four times higher, respectively).

- Average concentrations at Banks Pumping Plant lie between San Joaquin River concentrations and Sacramento River concentrations for TN and NO3+NO2-N, while for ammonia-N and TKN, average concentrations at Banks Pumping Plant are lower than both Sacramento and San Joaquin River concentrations.

- Average concentrations of TKN are slightly higher in the San Joaquin River than in the Sacramento River or at Banks Pumping Plant.

- Average concentrations of orthophosphate-P and TP are approximately two times higher in the San Joaquin River than in the Sacramento River or at Banks Pumping Plant.

Table 5-1.
Average nutrient concentrations at key Delta Locations.

Constituent	Sacramento at Hood/Greene's Landing	San Joaquin at Vernalis	Banks Pumping Plant
NO3+NO2-N (mg/l)	0.14	1.5	0.61
Ammonia-N (mg/l)	0.23	0.10	0.064
TKN (mg/l)	0.50	0.85	0.44
TN (mg/l)	0.64	2.5	1.1
Orthophosphate-P (mg/l)	0.070	0.12	0.071
TP (mg/l)	0.12	0.25	0.12

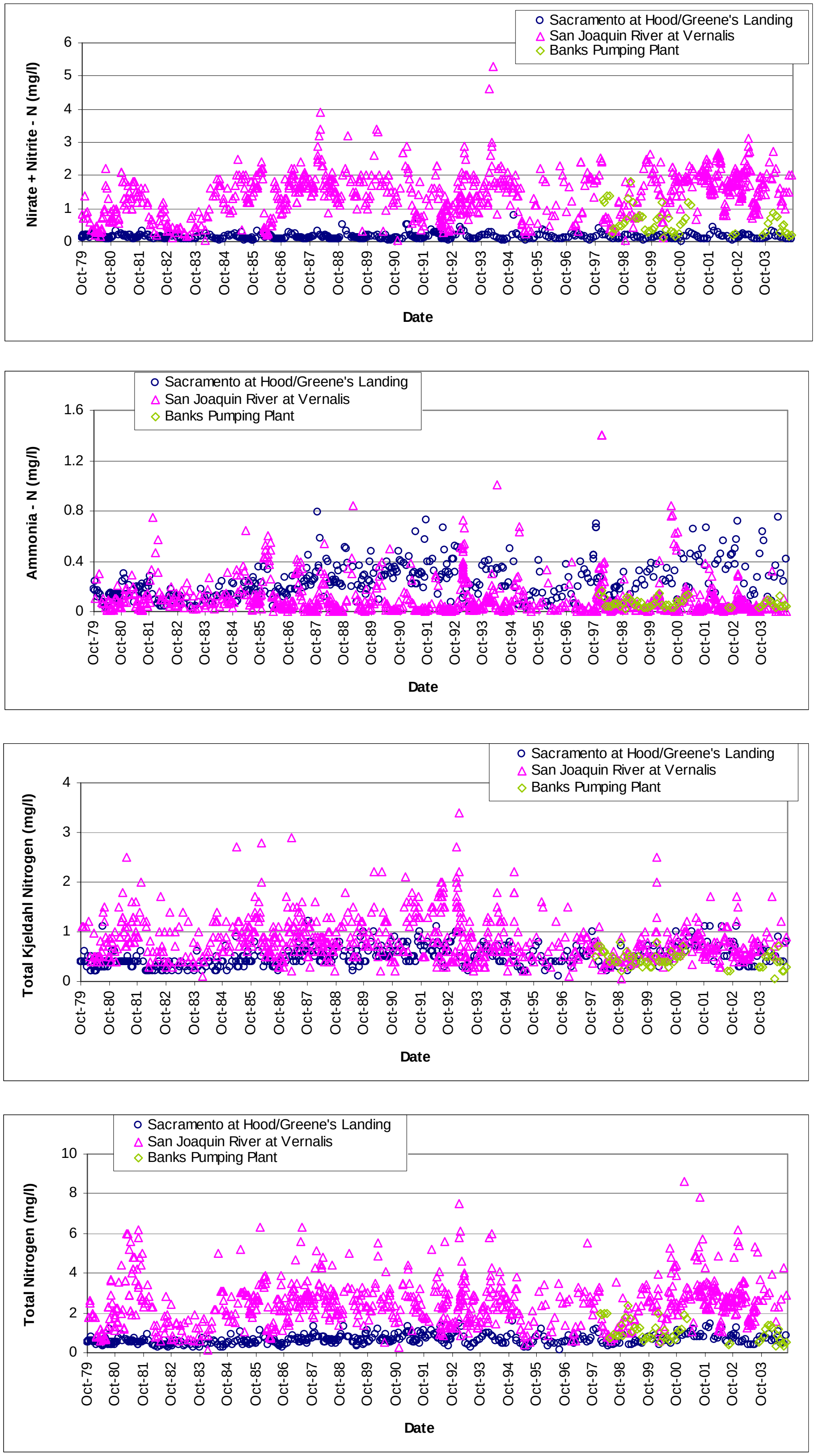
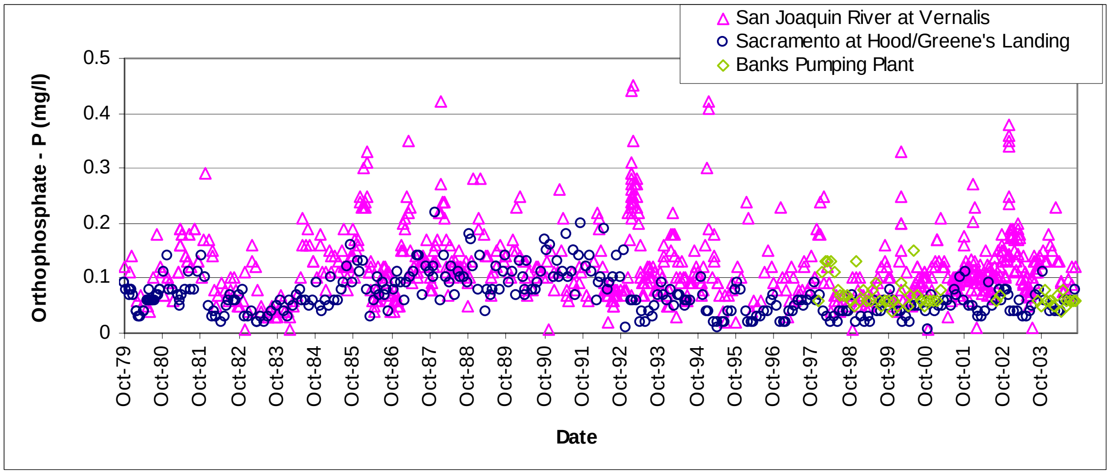


Figure 5-7. Nitrogen species concentrations at Sacramento River (Hood), San Joaquin River (Vernalis), and Banks Pumping Plant.



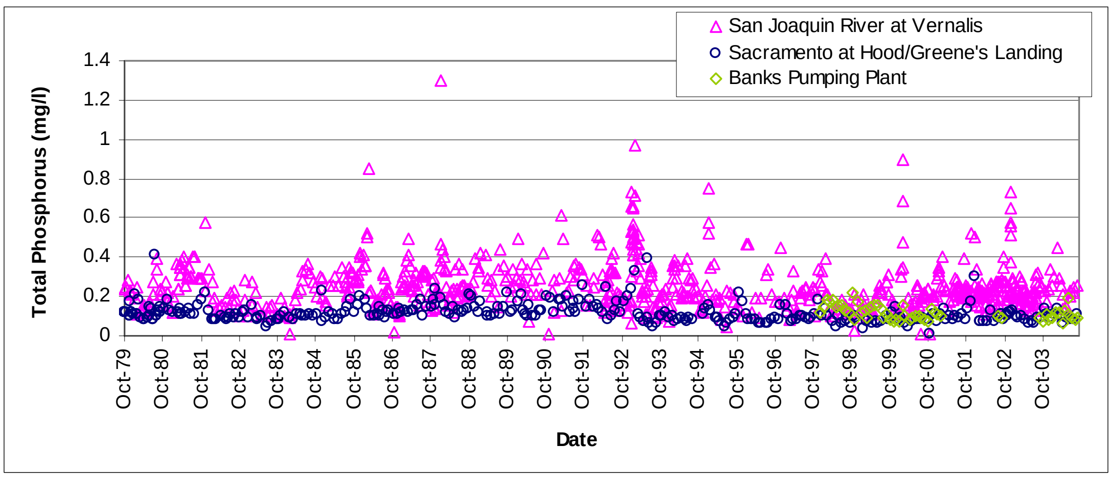


Figure 5-8. Phosphorus species concentrations at Sacramento River (Hood), San Joaquin River (Vernalis), and Banks Pumping Plant.

5.3 Nutrient Loads

To account for the various inflows and outflows of nutrients in the Delta, the inputs from tributary and in-Delta sources and the exports to San Francisco Bay and water supply diversions were quantified. The tributary inputs and the exports to the Bay were estimated in Chapter 4. This chapter describes the approach used to estimate nutrients exported in the water supply diversions and loads generated within the Delta.

5.3.1 Export in Water Supply Diversions

Nutrient concentration data from the four major water supply diversions in the Delta are paired with flow rates to estimate the exported nutrient loads. Loads are calculated in the same manner as described in Chapter 4 for the stream loads, using monthly average concentration and flow data. Nutrient concentration data was obtained from the MWQI program through the internet at http://wdl.water.ca.gov/wq-gst/. TN data are obtained by summing NO3+NO2-N and TKN. The monthly average nutrient concentrations for the water supply diversions, along with the data count, are shown in Figure 5-9. These concentrations were used to estimate monthly loads of nitrogen and phosphorus using DAYFLOW flow data. Phosphorus data were not available for the Tracy Pumping Plant (CVP).

The annual nitrogen and phosphorus exports over the water years 1984-2004 are shown in Figure 5-10. The annual average phosphorus load for the Tracy Pumping Plant (CVP) was scaled from the nitrogen load by using the same ratio of nitrogen load at Tracy to the nitrogen load at Banks (SWP) to calculate the phosphorus load at Tracy. Because the flow volumes in the exports are relatively uniform, the estimated annual loads vary over a fairly narrow range, from 4,500 to 8,500 tons/year for nitrogen and 600 to 850 tons/year for phosphorus.

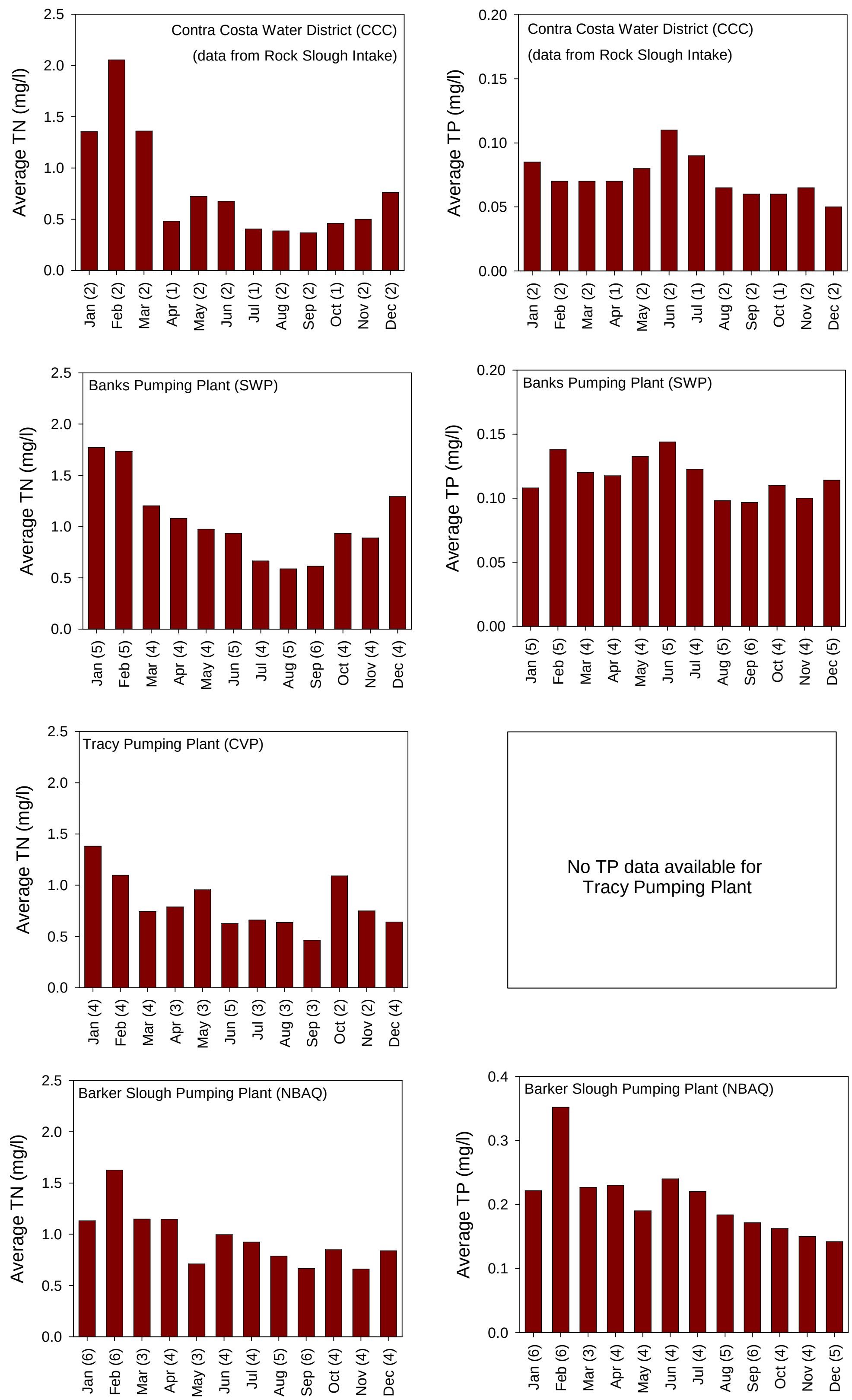
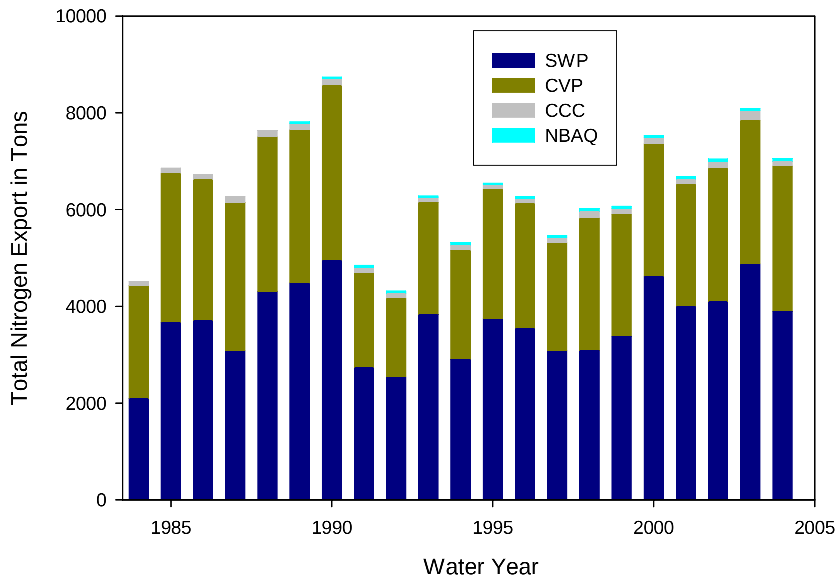


Figure 5-9. Nutrient concentrations at water supply diversions. The number of data points is shown after each month.



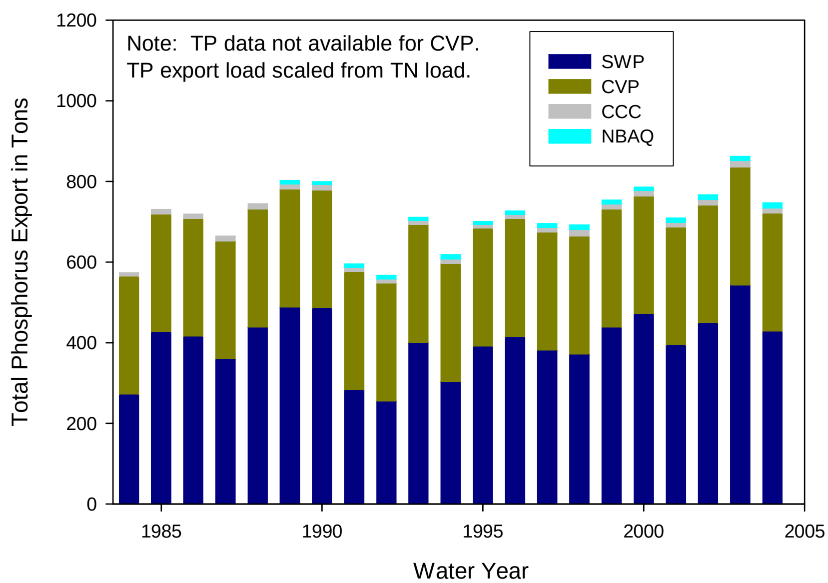


Figure 5-10. Annual nitrogen and phosphorus exports over water years 1984-2004.

5.3.2 NUTRIENT SOURCES INTERNAL TO THE DELTA

Export from agriculture on Delta Islands is the major source of nutrients internal to the Delta. Contributions from Delta agriculture were estimated using agricultural drain concentration data and total flow approximations from the Delta Island Consumptive Use (DICU) computer model. NO3-N data is the only nutrient species from Delta agricultural drains collected by MWQI, as shown in Figure 5-11. As shown in Figure 5-12, there is little variability by month. The Delta agricultural drainage concentrations for NO3-N are similar to the TN concentration values from agricultural drainage from the Sacramento River watershed (Colusa Basin Drain; monthly averages from 0.8 to 1.6 mg/l) but much lower than the concentration values from agricultural drainage from the San Joaquin River watershed (Mud Slough; monthly averages from 4 to 14 mg/l) discussed in Chapter 4.

The DICU model was developed to estimate the diversions and return flows of Delta waters into agricultural land on Delta islands. The model is calibrated from a detailed hydrologic study on Twitchell Island conducted in 1960. DICU estimates of flow for each month were coupled with mean monthly NO3-N concentration data observed at all island drains from Figure 5-12, to estimate the load of NO3-N from Delta agricultural drainage. The average annual load is estimated to be 1800 tons/year. This load estimate should be considered as a lower bound value because it uses NO3-N data instead of TN data. As shown in Figure 5-13, the highest loads of NO3-N occur in the wet winter months (January and February) that correspond with a peak in calculated discharge from the islands. Flows are also elevated in June through July, although these are associated with lower concentrations. Existing information does not allow consideration of year-to-year variability.

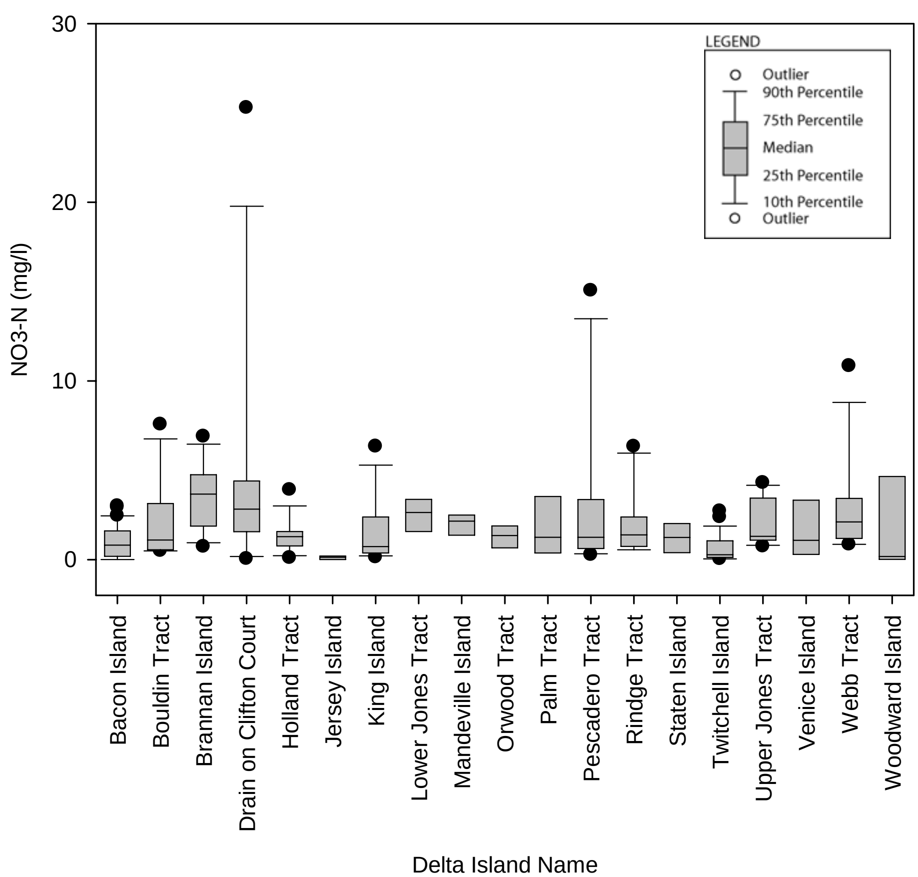


Figure 5-11. NO3-N concentrations in Delta agricultural drainage.

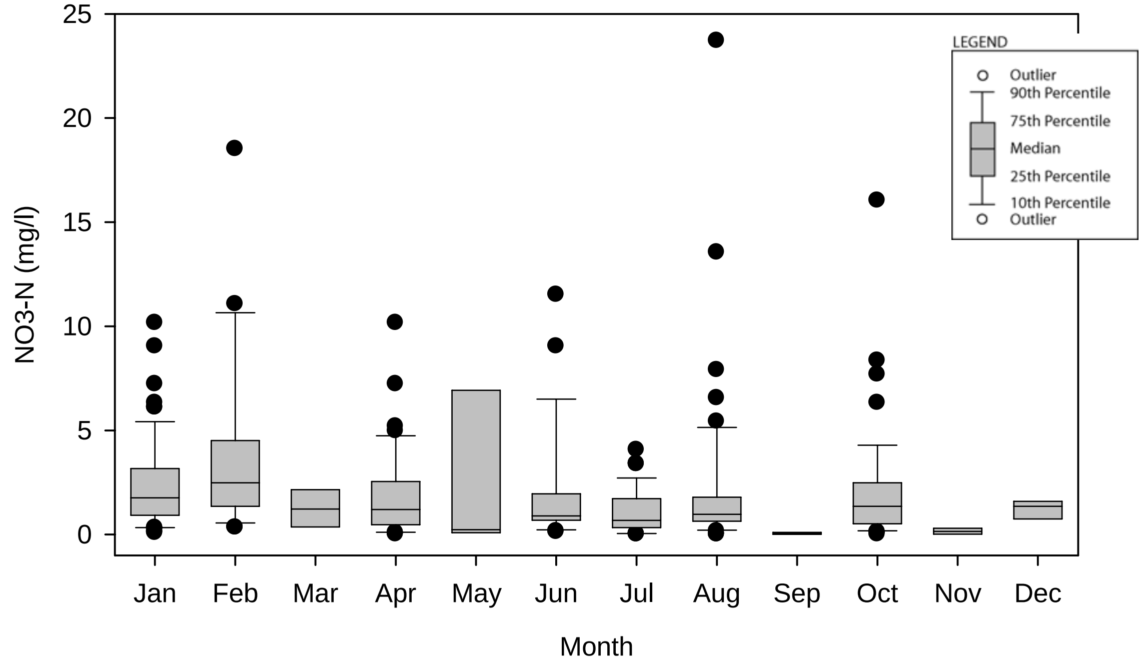


Figure 5-12. Seasonal variation in Delta agricultural drainage NO3-N concentrations.

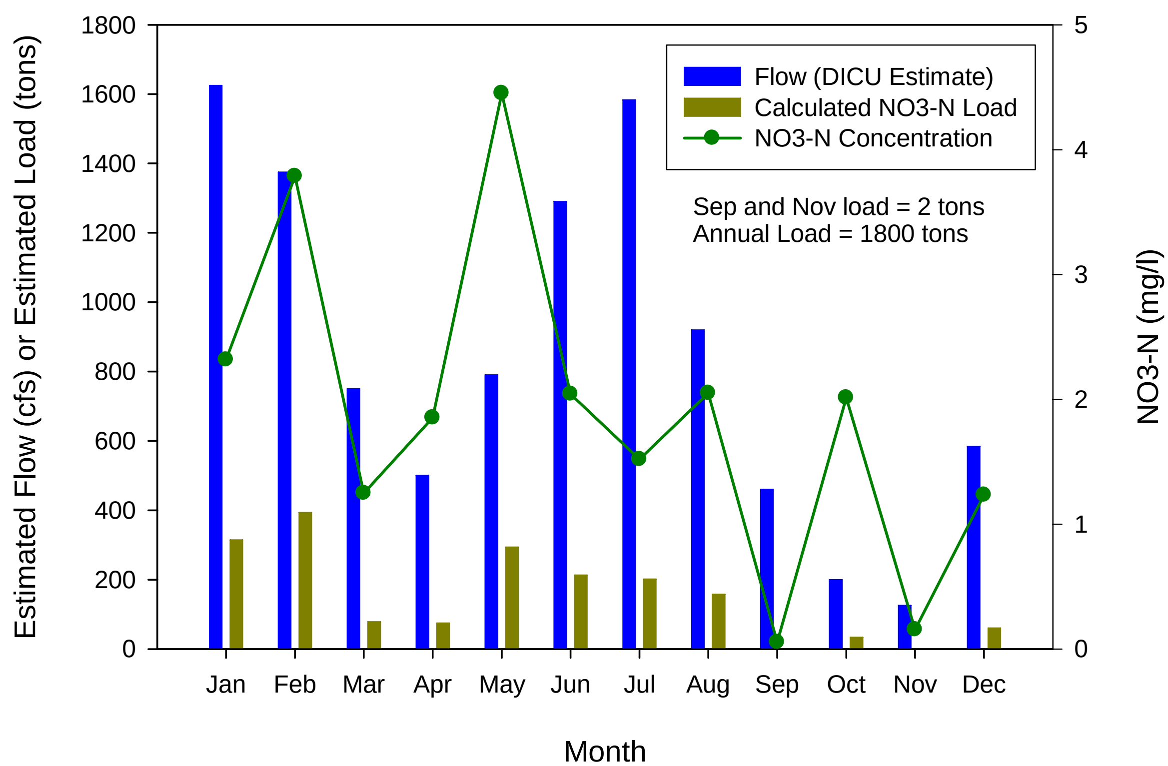


Figure 5-13. DICU estimates of flow for each month coupled with mean monthly concentration data observed at all island drains from Figure 5-12, used to estimate the contribution of NO3-N from agriculture on Delta islands.

Due to the lack of phosphorus data from Delta agricultural drainage, phosphorus export rates for agriculture were used to estimate the phosphorus load. An export rate of 0.030 tons/km^2, calculated by averaging the Sacramento Basin value (0.042 tons/km^2) and San Joaquin Basin value (0.017 tons/km^2) was used. Note that these are composite values for all years, and thus are between the numbers presented for wet and dry years separately in Table 4-7. The total area of the Delta (700,000 acres) was multiplied by the fraction devoted to agriculture (2/3) to obtain the agricultural acreage on the Delta Islands of 466,700 acres or 1,890 km^2 (DWR, 1995). The export rate multiplied by the agricultural area gives a total annual phosphorus load of 56 tons. Due to the uncertainty inherent in this estimate, separate values for wet and dry years were not calculated.

5.3.3 Summary of Nutrient Loads in the Delta

Figures 5-14 and 5-15 present annual averages of the tributary loads estimated in Chapter 4 and the in-Delta loads estimated in this chapter for nitrogen and phosphorus, respectively. The tributary loads were presented in Tables 4-10 through 4-13, and represent outflow loads (calculated using in-stream flow and concentration data) where available. The loads denoted 'Delta Watersheds' are the sum of watershed loads from sub-watersheds 20 and 21 (from the 'Sum of Watershed Loads' column in Tables 4-10 through 4-13). In-delta loads of both nitrogen and phosphorus are a small portion of total tributary loads during both wet and dry years. The nutrient export in water diversions is relatively uniform from year to year, particularly when compared with the tributary loads. In dry years, the export of nitrogen and phosphorus in water diversions is similar in magnitude to their export to the Bay.

Figure 5-14 shows that during both wet and dry years the load of nitrogen to the Delta (tributaries and in-Delta agriculture) exceeds the exports from the Delta (to the Bay and the water diversions) by approximately 7,000 tons. Figure 5-15 shows that during both wet and dry years the load of phosphorus to the Delta (tributaries and in-Delta agriculture) exceeds the exports from the Delta (to the Bay and the water diversions) by approximately 1,000 tons. These are not precise numbers due to the uncertainty in the load estimates; however, some of this nitrogen and phosphorus is likely taken up as a food source by Delta organisms.

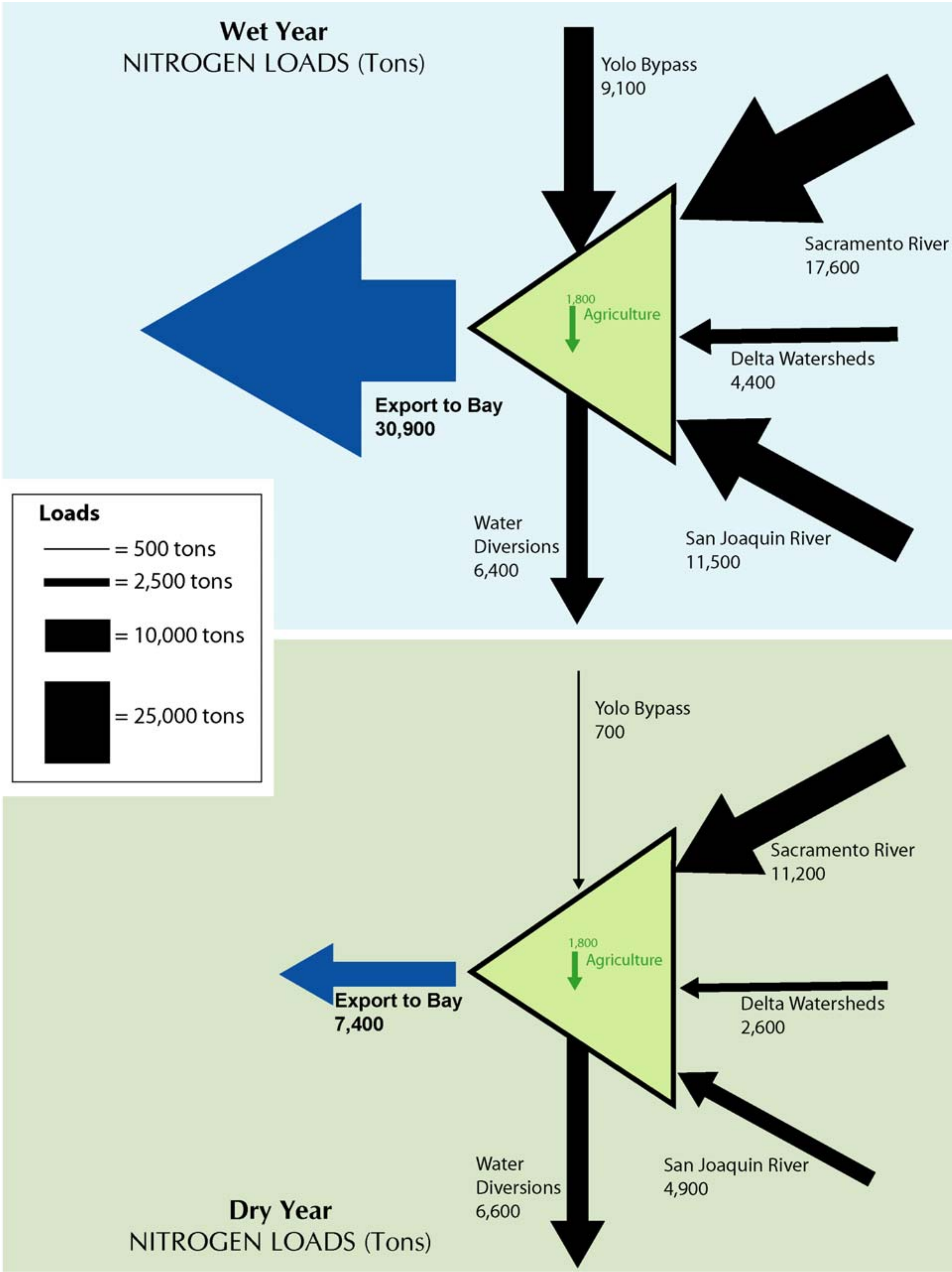


Figure 5-14. Nitrogen tributary loads calculated in Chapter 4, along with the internal loads estimated in Chapter 5.

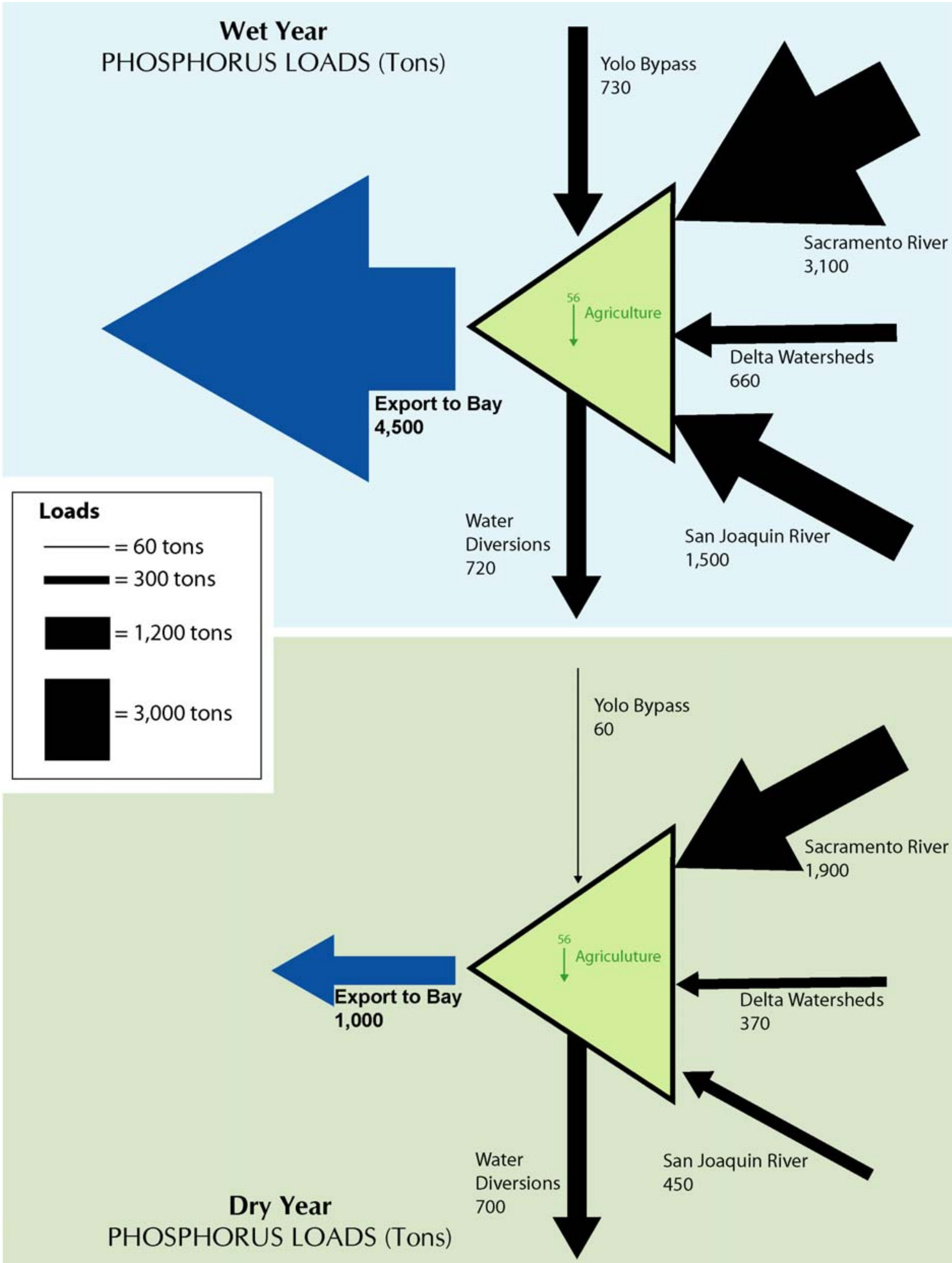


Figure 5-15. Phosphorus tributary loads calculated in Chapter 4, along with the internal loads estimated in Chapter 5. Note that the scale is different in this figure for phosphorus loads than the scale in the previous figure for nitrogen loads.

5.4 MAJOR FINDINGS

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 Delta island agricultural drainage. NO3-N is the only nutrient species data collected by MWQI from Delta agricultural drains. Estimates from this study show that annual loads of nutrients from the tributaries are substantially greater than the loads from in-Delta agricultural drainage. As previously shown in Chapter 4, Sacramento River nutrient loads to the Delta are larger than San Joaquin River nutrient loads, especially in dry years.

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.