Selenium in the Delta-Mendota Canal
1987 - 2001

U.S. Bureau of Reclamation Staff Report
April 2002

I. Introduction

Staff of the U.S. Bureau of Reclamation (Reclamation) have analyzed water quality in the Delta-Mendota Canal (DMC) focusing on selenium concentrations and loads between 1987 through 2001. Analyses were made on the DMC at Check 13 (O'Neill Forebay), six Closed Drain sumps near Firebaugh, and DMC at Check 21 (Bass Avenue). Selenium concentrations and flow records were used to estimate selenium loads. Electrical meter readings were used to determine flows from the closed drain sumps.

Objectives of the review are as follows:

1. quantify the base loads of selenium at the O'Neill Forebay (Check 13),

2. quantify the selenium loads discharged from the Closed Drain sumps into the DMC, and

3. quantify the selenium loads going from the terminus of the DMC (Check 21) into the Mendota Pool.

II. Background

The purpose of the DMC and related facilities is to provide Central Valley Project (CVP) water to the water-deficient San Joaquin Valley. The DMC extends 70 miles from the Sacramento-San Joaquin Delta to the O'Neill Forebay and then 46 miles to the Mendota Pool on the San Joaquin River. It provides water for agricultural lands and wildlife refuges en route and replaces San Joaquin River flows in the Mendota Pool. The DMC also transports CVP water to the O'Neill Forebay for delivery to the San Luis Unit.

Reclamation completed the DMC in July 1951. The maximum capacity of the canal is 4,600 cubic feet per second (cfs) at the Tracy Headworks and 3,200 cfs at Check 21, its terminus at Mendota. It is lined with concrete to Milepost 98.64. The remaining 18 miles of the canal to Mendota are earth-lined (Reclamation 1992).

In October 1951, local interests objected to the earth lining. They were concerned that seepage from the canal might raise groundwater levels beneath adjacent lands, and that it might act as a dike, impeding subsurface cross-drainage, and cause groundwater to accumulate on the up-slope side.

In response to the demands of landowners and without the benefit of technical data or study, a decision was made in 1951 to construct a system of Closed Drains parallel to the canal on the up-slope side (Reclamation 1953). The Closed Drains were constructed between Mileposts 99 and 110 through areas that had groundwater within 10 feet of the ground surface. The Closed Drains discharge into ten sump pits from which the accumulated water is removed with electric pumps. Water from the sumps is discharged into the DMC through six drainage inlet structures (Reclamation 1971).

Figure 1 shows the DMC and the location of the six closed drain inlet structures.

The San Luis & Delta-Mendota Water Authority (Authority) has operated the DMC for Reclamation since 1992. An Authority ditch-rider checks the sump operations on a daily basis. Flows are calculated based on the electricity drawn by each sump pump and the information is consolidated by Reclamation each month.

Water samples from the six closed drain inlet structures are tested by Reclamation in accordance with the Monitoring and Reporting Program Order Number SJR027 (revised 1994) issued by the California Regional Water Quality Control Board (see Appendix A). Reclamation collects samples from the DMC upstream and downstream from the sumps during the first week of each month. Samples of water from each Closed Drain sump are analyzed twice a year. The Closed Drain monitoring program is further described in Appendix B and C. A typical Closed Drain Sump is shown below.

In addition to the six Closed Drain sumps, there are 98 Check Drains between Checks 13 and 21 that allow high flows (any flow with an elevation higher than the water level in the canal) to enter the DMC. The Check Drains prevent overtopping of the up slope embankment with surface water. There are also hundreds of pressure relief valves in the bottom of the concrete-lined sections to prevent buckling the bottom or caving in the sides of the canal (Reclamation, December 1985).

The pressure relief valves only allow groundwater into the canal when water in the DMC is lower than the elevation of surrounding aquifer. The 50 year old concrete lining of the canal is damaged in several areas; groundwater also enters the canal though cracks and open joints in the concrete. Flows through the Check Drains, relief valves, and cracks are not measured by Reclamation or the Authority.

In 1986, the staff of the Agricultural Unit of the Central Valley Regional Water Quality Control Board investigated the check drains of the Delta-Mendota Canal as potential sources of selenium to this canal and the Mendota Pool. Of the 93 drains observed, 20 were discharging to the Delta-Mendota Canal and five showed signs recent signs of having discharged. These 25 check drains showed strong possibilities of receiving agricultural flows by virtue of being connected to field drainage systems and being located at the low point of field(s) in production.(CVRWQCB, October 1987).

III. Results

DMC at O'Neill Forebay (Check 13)

Flows

Daily flows on the DMC at Check 13 (Milepost 70) were developed indirectly by using the measured flow at the Tracy Headworks less measured flow going into O'Neill Forebay, plus measured flow coming out of O'Neill Forebay. The derived daily flow values represent the maximum volume of water that flowed past the check; any deletions for deliveries out of the DMC from the Headworks to O'Neill were not made. Table 1 is a list of the derived daily flows between 1992 and 2001. Figure 2 shows the mean daily flow of water that passed Check 13 between 1992 and 2001, and periods of de-watering for maintenance.

Concentrations

Reclamation collected 96 monthly samples[1] of water from the DMC at Check 13 from January 1994 through December 2001. Table 2, column 2, lists the selenium concentrations of these samples. Note that 76 of these samples were less than the minimum detection level (MDL)[2].

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[1]Depth-integrated samples collected at intervals across the canal prism

[2]Note: From January 1994 through August 1998, the MDL was 1 µg/L. From September 1998 to present, the MDL was 0.4 µg/L.

Loads

Daily load values were computed using the concentration[3] (Table 2, column 3) and the associated flow on the sample date (from Table 1). The resulting loads are shown in Table 2, column 4. The average load from the 96 observations were 4.5 pounds per day, or approximately 1,644 pounds per year[4].

The estimated loads at this location are not considered precise due to:

- limited selenium sampling frequency (monthly)
- wide variation in measured selenium concentrations
- most results were less than the MDL, and
- wide range in derived daily flows ranging between 0 to over 4,400 cfs.

Closed Drain Sumps

Discharges / Flows

Daily discharge values for each Closed Drain sump were determined indirectly from electrical usage by each pump. Seasonal conversion factors were used to derive the discharge in cubic feet per second. Table 3 shows the computed discharge values for each sump for March 1987 through December 2001. Prior flow data is not available.

Selenium concentrations

Reclamation collected 594 water samples from the six Closed Drain sumps from March 1987 through December 2001. Monthly measurements were made from March 1987 through September 1994. Twice a year sampling, April and October, was initiated in 1995. Table 4 is a summary of selenium measurements in each sump.

Loads

On Table 5A, selenium loads were calculated for the samples collected from March 1987 to December 2001. Analysis of these loads provide the following information:

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[3]When the MDL was reported by the laboratory, half of that value was used for computing loads.

[4]4.5 pounds per day * 365.25 days per year

Observations:	107
Mean:	1.7 pounds per day
Standard deviation:	0.9 pounds per day
Tests for normality:	both the skewness and kurtosis values indicate that the 107 observations did not come from a normal distribution

The amount of selenium produced from the Closed Drain sumps for any one day ranged from 0.0 to 6.4 pounds. Using the overall average of 1.7 pounds per day, the annual loading of selenium into the DMC from the sumps would be 621 pounds.

The individual load values are shown in Tables 5B and 5C. Table 5B shows the loads sorted by month and year. On Table 5C, the load values are sorted from the lowest to the highest and displayed as a frequency diagram. Statistical tests for normality indicate that two observations, 5.72 (April 30, 1987) and 6.45 (October 2, 1996), could be considered outliers.

DMC at Check 21 (Bass Avenue)

Flows

Daily flows in the DMC are listed in Table 6. Figure 3 shows the mean daily flow of water that passed Check 21 between 1992 and 2001, and periods when the DMC was emptied for maintenance.

Concentrations

Reclamation has collected water quality samples from the DMC at Bass Avenue each month since January 1999. Table 7, column 2, lists the concentrations of 36 samples. The selenium concentrations tend to increase with low DMC flows (December and January) and during March and April. Only four samples had a concentration of selenium less than the MDL of 0.4 µg/L.

Loads

Daily loads were computed on Table 7 using flow and daily concentration. The average load from the 36 observations was 7.2 pounds per day, or approximately 2,630 pounds per year.

IV. Analysis and Comparison of Daily / Annual Loads

An assessment of selenium loads in the DMC was made by comparing values at Check 13 (O'Neill Forebay), the six Closed Drain Sumps, and Check 21 (Bass Avenue). This procedure provided an estimate of the change in selenium loadings from O'Neill to Bass Avenue along with the contribution from the sumps. The averages of all available data provided the following information:

	Data Table	Number of Samples	Pounds per Day	Pounds per Year	Percent of Check 21
Check 21 Bass Avenue	7	36	7.2	2,630	
Check 13 O'Neill	2	96	4.5	1,644	63%
Closed Drain Sumps	5A	105	1.7	621	24%
Other sources			0.9	365	14%

Based on the available data, the six Closed Drain sumps contribute about 24 percent of the load of selenium in CVP water that passed Check 21 into the Mendota Pool. About 63 percent of the selenium load in water passing Check 21 was the base load in the water at Check 13. The difference, about 14 percent of the load, comes from other sources of contamination between Check 13 and 21.

A comparison of data for the same period of time (1999 through 2001) shows similar results:

	Data Table	Number of Samples	Pounds per Day	Pounds per Year	Percent of Check 21
Check 21 Bass Avenue	7	36	7.2	2,630	
Check 13 O'Neill	2	36	3.9	1,424	54%
Closed Drain Sumps	5A	7	2.1	767	29%
Other sources			0.9	439	17%

Figure 4 is a comparison of average selenium concentrations along the DMC between 1999 and 2001. The locations of Checks 13 and 21 are shown in relation to the six Closed Drain sumps and 98 check drains listed on the DMC Structures list. Note the increase in selenium concentration between O'Neill and the farm bridge at MP 100.85, possibly due to inflows from other sources located upstream of the six Closed Drain sumps.

V. Conclusions

The CVP delivers more than 700,000 acre-feet of water per year through the DMC to the Mendota Pool for farms and wildlife refuges. Based on Reclamation data, about 2,600 pounds of selenium annually is contained in water delivered to the Mendota Pool.

The base load of selenium in CVP water at DMC Check 13 is approximately 1,600 pounds, based on 96 samples collected by Reclamation between January 1994 and December 2001. This represents about 63 percent of the load discharged into the Mendota Pool.

The only measured sources of selenium between O'Neill and Bass Avenue are the six Closed

Drain sumps located near Firebaugh. Reclamation data indicates that the sumps contribute less than 2 pounds per day of selenium, or about 600 pounds annually. The sumps contribute less than one-third of the 2,600 pound load of selenium discharged annually into the Mendota Pool in CVP water.

The remaining 400 pounds of the selenium in CVP water delivered to the Mendota Pool is contamination from other sources (Check Drains, pressure relief valves, and cracks in the concrete lining) between DMC Checks 13 and 21. These flows are unregulated and are not monitored.

Eliminating the water from the six Closed Drain sumps from the DMC may reduce the average annual load of selenium discharged into the Mendota Pool to less than 2,000 pounds per year. It will be very difficult to close the Check Drains. The accumulation of surface and subsurface water will threaten the structural integrity of the canal embankment and will harm adjacent farmland. Routine maintenance will eventually seal most of the cracks in the concrete lining.

VI. Recommendations

More frequent samples are needed to determine daily loads of selenium being discharged from the DMC into the Mendota Pool. In Summer 2002, Reclamation will collect daily samples of CVP water at DMC Headworks, Checks 13 and 21, and from the CCID Main Canal at Bass Avenue.

The daily samples will help identify changes in selenium concentrations in the canal and better estimate loads delivered to the Mendota Pool. This data will compliment the CVRWQCB's weekly monitoring of Grassland Wetland Supply Channels and the Compliance Monitoring Program for the Grassland Bypass Project. The revised monitoring program is described in Appendix C.

Monitoring the Closed Drain Sumps shall continue with biannual sampling in accordance with SJR027 (Appendix A). Reclamation will continue to collect samples of DMC water upstream and downstream of the sumps each month, and twice yearly samples of each Closed Drain sump.

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Appendix A. Monitoring and Reporting Program SJR027 for Subsurface Drainage Discharges to the Delta-Mendota Canal (revised 26 October 1994)

Appendix B. History of Firebaugh Drain Inlet Monitoring Program

The six Firebaugh drainage inlets were added to the San Luis Unit service area monitoring program in May 1985. In addition to the six drainage inlets, several sites within the DMC, including one just upstream of the first sump and a second downstream of the last sump, were added to the monthly sampling effort. When the DMC sampling began, nearly 20 chemical and physical parameters were measured each month, including selenium, boron, molybdenum, and a suite of heavy metals. On a voluntary basis, Reclamation routinely submitted the data to the Central Valley Regional Water Quality Control Board (CVRWQCB).

The 1987 CVRWQCB Order Number SJR027 converted Reclamation's voluntary DMC monitoring program to one driven by a board order. The CVRWQCB felt that, given the concentrations of trace elements found in the Firebaugh drainage inlets during 1986 and the potential uses of the DMC water, a formal monitoring program was necessary. The requirements of the order actually resulted in a reduction of Reclamation's sampling effort in the DMC. Both the number of parameters and sites as well as the frequency of monitoring the remaining parameters were decreased. The only parameters required by the CVRWQCB to continue on a monthly basis were selenium, boron, EC, and flow. The few remaining heavy metals, chromium, mercury, molybdenum, and nickel, were only required to be sampled on a semiannual basis.

Following more than seven years of DMC monitoring under SJR027, Reclamation submitted a request to the CVRWQCB to modify the monitoring program by reducing the scope of effort. The primary changes in the modified program was a reduction in the frequency of monitoring of the Firebaugh drainage inlets from monthly to semiannually (April and October), with the exception of flow which was to continue on a monthly basis. The other significant change was that both chromium and nickel were dropped from the program altogether. The CVRWQCB formally adopted the changes in the program on October 26, 1994.

Prepared by John Fields, Bureau of Reclamation

Appendix C. Delta-Mendota Canal and Agricultural Drain Sumps
2002 Selenium Monitoring Program

Reclamation has been monitoring the southern reach of the Delta-Mendota Canal (DMC) at four bridge sites located at Russell Avenue (MP-97.68), farm bridge (MP-100.85), Washoe Avenue (MP-110.12), and Bass Avenue (MP-116.48), the Main Canal at Bass Avenue, and the Outside Canal at Bass Avenue since January 1999. An equal-width-depth-integrated water sample is collected during the first week of each month at these sites. Physical tests are measured on site to record the specific conductance, pH, and turbidity of the DMC water at the time of collection, and selenium samples are sent to Olson Laboratory which is located on the campus of South Dakota State University. Flow measurements at checks 13 and 21 are recorded by the San Luis & Delta-Mendota Water Authority and provided to Reclamation. Also monitored are six tile drain sumps that were built in concert with the construction of the DMC and are located between the farm bridge and Washoe Avenue. The sumps are identified by Reclamation as A&B (MP-100.91), C (MP-102.86), D&E (MP-104.19), F&G (MP-105.60), H&I (MP-107.24), and K (MP-109.50), and water samples are collected in April and October for specific conductance, selenium, and various heavy metals. Since the sump pumps are rated for electrical consumption and flow rates, the amount of electricity used by each pump to discharge subsurface agricultural drainage into the DMC is recorded and used to calculate the volume of water pumped each month.

Reclamation will expand the DMC water quality monitoring program this summer (2002) and begin measuring selenium, boron, and specific conductance daily at four sites. Automated samplers will be installed at MP-3.50 (near Tracy Headworks), MP-70.01 (Check 13 O'Neill Forebay), MP-116.48 (Check 21 Bass Ave), and on the CCID Main Canal at Bass Avenue. The sampling equipment will be programed to collect a fixed volume of water 8 to 12 times a day and composite these sub-samples. Daily flow in the DMC at Checks 13 and 21 will also be recorded. The daily measurements will provide the data necessary to calculate total daily loads of selenium, boron, and specific conductance discharged from the DMC to the Mendota Pool.

Prepared by John Fields, Bureau of Reclamation