REVIEW OF THE GRASSLAND BYPASS CHANNEL PROJECT MONITORING PROGRAM
PART I: EXECUTIVE SUMMARY
PART II: REVIEW OF THE GBCP MONITORING PLAN AND QUALITY ASSURANCE PROJECT PLAN

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USGS REVIEW OF THE GRASSLAND BYPASS CHANNEL PROJECT MONITORING PROGRAM

Abstract

In early calendar year 1996, the U.S. Geological Survey (USGS) was contracted by the Bureau of Reclamation (BOR) to conduct a technical review of the *November 1995 Draft Proposed Compliance Monitoring Program for Use and Operation of the Grassland Bypass Channel Project* (formerly entitled *Use and Operation of the Grasslands Bypass to Remove Agricultural Drainage from the Grassland Water District Channels).* This review includes both the Monitoring Plan (MP) and the associated Quality Assurance Project Plan (QAPP) for the Grassland Bypass Channel Project (GBCP) area in the San Joaquin Valley, California. The results of the review presented in this report include conclusions, recommendations, and detailed comments to help improve the MP and QAPP in support of developing a long-term management strategy for irrigation drainage in the GBCP area which includes the San Joaquin River (SJR). A conceptual basis for the MP is also given in accordance with long-term scientific goals to understand the biogeochemical cycling of selenium in the environment. The main emphasis of the review is on water quality, flow, and sediment characterization. Biological monitoring and toxicity testing, although important for assessing the selenium cycle and mass balance inventory, are not reviewed in detail because of the involvement of the U.S. Fish and Wildlife Service (USFWS) and U.S. Environmental Protection Agency (USEPA) in these aspects of the MP.

Historically, subsurface drainage from the Grassland Drainage Service Area has been routed through wetland habitat channels, Mud Slough, and Salt Slough for eventual discharge into the SJR. With the initiation of the GBCP, drainage water will be removed from Salt Slough and many miles of wetland channels. It will be diverted to the San Luis Drain (SLD) and 6.6 miles of Mud Slough before being discharged to the SJR. Beneficial effects in the wetland channels and Salt Slough are expected from removal of drainage water and cessation of loading of selenium.

However, drainage will be more directly routed to Mud Slough through the SLD to the SJR without dilution by wetland flows and potential loss through bioaccumulation in sediment and biota (i.e., in-transit losses/load attenuation in wetland channels). As a requirement of the GBCP, historical loads to the SJR "will not worsen" with adoption of the project. Comprehensive monitoring of areas of potential benefit (Salt Slough and Grassland wetland channels) and possible degradation (SLD, Mud Slough, and SJR) will help determine impacts from the GBCP. Previous monitoring efforts may not have adequately addressed the non-conservative behavior of selenium; the partitioning of selenium in water, sediment, and biota; and spatial and temporal variations in flow and selenium concentrations.

Water-quality constituents-of-interest for the GBCP are selenium, salt, and boron. Sources of selenium, salt, and boron to the GBCP area include surface and subsurface agricultural drainage and ground-water seepage through weep valves in the SLD. Five internally defined systems within the GBCP area (i.e., the SLD, Mud Slough, the Grassland Water District wetland channels including Salt Slough, the San Joaquin River, and the Grassland Drainage Service Area sumps and drains) are designated for sampling consistency and comparative selenium inventories (input versus output).

The review resulted in 17 conclusions concerning MP adequacy and 28 recommendations concerning MP tasks to provide the data to meet environmental commitments and goals of the GBCP and objectives of the MP. However, revised goals of the GBCP and objectives for the MP cannot be met by compliance monitoring alone because of the need to also improve scientific understanding. Complementary studies, as presented in an appendix to the review, will integrate knowledge concerning selenium fluxes among water, sediment, and biota with mass-balances determinations. Two conclusions and nine recommendations are also given concerning the QAPP.

The major conclusions and recommendations that are fundamental to adequate flow measurement, water-quality monitoring, and sediment characterization for the GBCP include:

- A mass-balance-conceptual basis for the MP that includes the flux of selenium among water (dissolved), suspended matter, bed sediment, and biota;

- Accounting of all appropriate sources and sinks for the GBCP that may affect the selenium inventory. In this regard, two monitoring sites for a 28-mile reach of the SLD may be a minimum that may not be adequate to define the SLD system because of the number of complexities in the system (e.g., check structures and ground-water seepage);

- Recognition of flow conditions (static, pulsed, high, or low) as an important factor and common variable to assess by the MP because flow may have a controlling influence on selenium bioaccumulation, toxicity, and fluxes and transport of selenium (e.g. sediment movement) in the GBCP area and receiving waters including the SJR;

- Development of a water-quality baseline for the GBCP, including the SJR, to document and assess historical and current spatial and temporal variations in water quality and to provide the basis for determining changes in water quality as a result of the GBCP;

- Paired sampling sites with regard to water-quality and flow measurements to calculate and compare mass loadings between (among) sites;

- Additional sampling sites to provide adequate spatial coverage of the SJR with regard to flow measurements and water-quality and sediment sampling;

- Sampling-design-consistency among sites and samples that includes comparable flow measurements, water-quality parameters, sampling frequency, methodology, and documentation;

- Calendar-based (routine), management, and critical-period (event-driven) sampling frequencies;

- Periodic checks of representativeness of samples through depth- and width-integrated sampling (Equal Discharge Increment, EDI, or Equal Width Increment, EWI) and cross-sectional profiles of specific conductance;

- Collection of suspended matter to include two portions, inorganic particulate matter and organic floc, that may be dependent on differing physical properties including size;

- Monitoring of source drains and sumps to define a causal connection between drainage management and changes in water quality in relation to water-quality standards;

- Field filtration and preservation of samples to adequately define a dissolved selenium phase;

- Determination of dissolved solids on the basis of major-ion analyses and specific-conductance measurements;

- Accurate bed-sediment-quantity surveys and method to locate bed sediment sampling areas;

- Bed-sediment-chemical characterization as a source and/or sink that includes differentiation of areas of scour (oxidation) and deposition (reduction);

- A QAPP that adequately defines data-quality objectives for the GBCP MP and that describes the measurement, sampling, laboratory, and office methods used to ensure that the collection, review, analyses, and reporting of data meet those data-quality objectives;

- Recognition of interpretive guidelines for selenium exposure and risk assessment that are based, in part, on selenium speciation and partitioning; and

- Assessment of selenium and quantification of amounts and ranges of risk that account for: 1) ecological hazard created by the high mobility of the dissolved selenate species; and 2) bioassay toxicity created by the high toxicity of the dissolved organic selenide species (e.g., selenomethionine). In this regard, selenium speciation is recognized as a topic for complementary research.

PART I

USGS REVIEW OF THE GRASSLAND BYPASS CHANNEL PROJECT MONITORING PROGRAM

EXECUTIVE SUMMARY

Preface

This document (**Parts I and II**) provides the results of a U.S. Geological Survey (USGS) review of the Monitoring Plan (MP) and Quality Assurance Project Plan (QAPP) for the Grassland Bypass Channel Project (GBCP). The conclusions, recommendations, and detailed comments by the USGS are provided to improve the MP and QAPP in support of developing a long-term management strategy for irrigation drainage in the GBCP area. It is important that this strategy begin **now** rather than **later** and that it be based on data that are scientifically credible. The overall design of the MP should be formulated so that a defined baseline can be used to measure change, whether beneficial or adverse, and a clear cause and effect can be shown and understood from the data collected. In this regard, we present a conceptual basis for the GBCP MP, technical recommendations for monitoring, and proposals for investigations.

Part I, the *Executive Summary*, includes: (a) introduction, questions, tasks, and strategy for USGS's review of he GBCP MP; (b) the USGS's general conclusions and recommendations concerning the 1995 GBCP MP, the 1995 QAPP, and the role of complementary investigations; and (c) the revised environmental commitments and goals of the GBCP and revised objectives of the GBCP MP as developed by the Technical Advisory Committee (TAC) for the GBCP and supplemented by the USGS.

Part II, the *USGS Review of the Grassland Bypass Channel Project Monitoring Plan and Quality Assurance Project Plan*, includes: (a) a review of the 1995 GBCP MP and QAPP and detailed recommendations to modify the MP and QAPP; (b) the USGS's conceptual model (mass-balance approach) and corresponding monitoring tasks for quantifying selenium, salt, and boron for the GBCP area; (c) research investigation proposals that will complement the MP and contribute to a scientific basis for management of irrigation drainage specific to the San Luis Drain (SLD) and GBCP area; (d) a copy of *Surface Water Quality-Assurance Plan for the California District of the U.S. Geological Survey* that will be published as a USGS open-file report and will be part of the supporting documentation for flow monitoring for the GBCP QAPP; and (e) the USGS review of plans for initiation of monitoring for the GBCP.

Incorporation of the recommended modifications to the GBCP MP will be completed by the TAC and Oversight Committee (OC) for the GBCP. If areas of disagreement occur when the current TAC version of the MP is compared with that recommended by the USGS, either the modification will be incorporated or an explanation given as to why the suggestion is not being acted upon. An explanation of what recommendations were incorporated or why a recommendation was not incorporated will be presented to the OC. The OC will then either approve the MP or require modifications.

This document thus provides the basis for obtaining accurate monitoring data in support of developing a long-term management strategy for irrigation drainage. With this information, effective resolution of issues of concern can take place and correct choices can be made to implement an effective drainage management program while meeting the environmental commitments of the GBCP.

Introduction

In early calendar year 1996, the USGS was contracted by the Bureau of Reclamation (BOR) to conduct a technical review of the *November 1995 Draft Proposed Compliance Monitoring*

Program for Use and Operation of the Grasslands Bypass to Remove Agricultural Drainage from the Grassland Water District Channels (BOR, 1995a) and the associated *Quality Assurance Project Plan* (BOR, 1995b). The review questions, tasks, and strategy, and main conclusions and recommendations from this review are summarized here.

Questions

The main questions that the BOR requested the USGS to answer in its review are:

1. Whether results from the monitoring plan provide the information needed to adequately determine how well the environmental commitments are being met during project implementation; and
2. Whether results from the monitoring adequately measure the amount of selenium and other trace elements in the drainage released at the Drain's discharge point (Drain terminus at Mud Slough) in order to determine compliance with project load limits.

Tasks

The USGS agreed to review the GBCP MP and QAPP in a December 1995 memorandum to the BOR that stated the following tasks and information would be required:

- An assessment of the accuracy and precision of flow and chemistry data to set selenium and other (e.g. boron and dissolved solids) load limits for the GBCP. Flow and chemistry data will be needed for the sites and time periods used to calculate load limits. This assessment will help determine the percent error of load limits specified for the Project, and if violations of load limits (i.e., annual or monthly load exceedances of 20 percent) or annual load reductions of 5 percent can be determined reliably by the proposed compliance monitoring program.

- An assessment of the capability of physical and chemical components of the proposed compliance monitoring program to determine changes and trends in flow and water quality and whether or not adverse biological effects are occurring. In addition to the MP and the QAPP, retrieval of pertinent historical data will be needed to evaluate how well baseline conditions of flow and water quality are known. These data would include flow and chemistry for inflows, including agricultural drainage, to the Grasslands Water District, Mud Slough, Salt Slough, and the San Joaquin River from the Project area, and those data used as a basis for the Finding Of No Significant Impact (FONSI) and Supplemental Environmental Assessment (SEA). A field visit to proposed compliance sampling sites will be necessary to assess their acceptability for flow measurements and water-quality sampling.

- An assessment of the adequacy of the QAPP, including field, laboratory, and office methods regarding data acquisition, review, analysis, and reporting to meet data-quality objectives. Additional documentation is needed on sampling methods, including how samples are collected and processed and what equipment is used.

- Preparation of study proposals to obtain information that will provide a better understanding of flow and chemical conditions in the GBCP area, and that will refine our conceptual model of selenium cycling in water bodies receiving irrigation drainage in the San Joaquin Valley. These proposed studies will complement and integrate with compliance monitoring, and will provide data that will help the BOR make prudent policy and management decisions regarding the GBCP.

Strategy

The review was undertaken with the understanding that the MP and QAPP were drafts that would evolve over the review period as a result of revisions made by the TAC for the GBCP. One of the main revisions made by the TAC during the review period was substantial modifications to the goals and objectives of the GBCP and MP. These revised goals of the GBCP and objectives for the MP are included in this review document, and are the foundation for many of the recommendations made in this review. During TAC meetings, the USGS was asked to discuss our approaches and bring up our concerns about specific monitoring tasks. Our suggestions presented at TAC meetings are consistent with what is presented in this review and some recommendations have been incorporated in a revised monitoring plan being prepared by the TAC.

The following steps were taken to accomplish the review:

- A team of USGS scientists representing the relevant disciplines (surface-water hydrology, water quality, and quality assurance) was formed to conduct and coordinate the review.

- Relevant documents including the MP (BOR, 1995a), QAPP (BOR, 1995b), Finding of No Significant Impact (BOR, FONSI, 1991 and 1995c), Supplemental Environmental Assessment (BOR, SEA, 1990 and 1995c), Use Agreement (BOR, 1995d), and Consensus Letter (BOR, SL&DMWA, USEPA, and USFWS, 1995) were obtained and examined.

- Flow and chemistry data used to calculate load limits for the GBCP and needed to establish baseline flow and water-quality conditions as the basis for determining changes and trends in flow and water quality as a result of the Project were requested and evaluated.

- The review team participated in TAC meetings.

- Primary sampling sites were visited.

- The Central Valley Regional Water Quality Control Board (CVRWQCB) water-quality monitoring program for the GBCP area was reviewed and a letter stating our findings was prepared.

- A progress report was prepared so that the BOR, TAC, and others could provide feedback on review findings as the review was being conducted.

- A review document including conclusions and recommendations was prepared.

The focus of the review is on flow, water quality, and sediment characterization at the 14 primary sites described in the MP. Secondary sites were not considered unless they complemented primary sites and contributed to defining a mass balance or baseline of flow and water-quality conditions. Even though biota are important for assessing the mass-balance inventory and flux of selenium in the selenium cycle, review of the biological monitoring and toxicity testing was not done because of the detailed consideration given these monitoring tasks by USFWS and USEPA. The different parts of this document were written over the course of approximately nine months, but we have attempted to update this document as changes were made and the TAC process for the GBCP progressed.

Monitoring Conclusions

I. General conclusions regarding GBCP goals and Monitoring Plan objectives

- The MP and QAPP need to provide data to comply with and evaluate the environmental commitments in the Use Agreement, Consensus Letter, FONSI, and SEA, and to improve scientific understanding of processes that control fluxes of water and water-quality constituents of interest in the GBCP area.

- The revised goals of the GBCP and objectives for the MP developed by the TAC have much improved the MP in terms of ensuring that data are provided to comply with and evaluate environmental commitments and to improve scientific understanding of processes that control fluxes of water and water-quality constituents of interest in the GBCP area.

- Based on the environmental commitments and revised goals of the GBCP and the revised objectives of the MP, the MP is appropriately focused on selenium, salt, and boron.

II. General conclusions regarding Monitoring Plan design

- All primary sites are well located except sites D, E, and I.

- The original MP is not adequate because it does not account for all appropriate sources and sinks of selenium, salt, and boron within the GBCP area and because the sampling design does not adequately address temporal, width, and depth variability in chemical concentrations and loads.

- A revised MP would be adequate if a comprehensive mass-balance approach was adopted in order to help develop causal relations between source-load reductions and water-quality improvements. A mass-balance approach that accounts for all appropriate sources and sinks is described in the recommendations that follow, and in more detail in the attached document.

- A mass-balance approach or design for the MP is appropriate to inventory loads of a potentially non-conservative element, i.e., selenium. Monitoring selenium concentrations in bed sediment, suspended matter, and dissolved in water will help account for food-borne versus water-borne bioaccumulation of selenium in the food chain.

- Because of the number of complexities in the SLD system (e.g., check structures and ground-water seepage), two monitoring sites (A--input at Check 17 and B--output at Mud Slough), for a 28-mile reach of the SLD, should be thought of as a minimum and may not be adequate to define the system.

- A quarterly sampling of bed sediment for selenium at primary sites A, B, C, D, E and F as stated in the MP is a good initial choice for documenting changes in selenium concentrations in the SLD, Mud Slough, and Salt Slough as a result of the GBCP and for mass-balance determinations. However, this quarterly sampling should also include the San Joaquin River and Grassland wetland channel sites.

- Exact locations of quarterly sampling for bed sediment at sites A and B in the SLD inlet and outlet are problematic due to the absence of a platform to sample from at site A and the fact that site B is at a midpoint of a check, an area traditionally of little sediment accumulation.

- Initiation of the MP three months prior to the start of the GBCP as stated in the MP and as proposed in the section of the SEA entitled "Plan for Initial Operation, Filling, and Management of Releases from the SLD" is important to help provide data to define pre-project flow and water-quality conditions.

III. Conclusions regarding question 1 (page 8), i.e., adequacy of MP to determine how well environmental commitments are being met during project implementation

- Other than the commitment to meet selenium load compliance criteria (see Conclusions regarding question 2, below), the environmental commitments address potential benefits and/or impacts of the project on the Grasslands wetlands and channels (including Salt Slough), and the San Joaquin River. As described in more detail below, an assessment of the adequacy of the MP to meet all the environmental commitments of the GBCP cannot be done without an evaluation of baseline flow and water-quality conditions in Mud and Salt Sloughs, the San Joaquin River, and the Grassland channels in order to measure change, whether beneficial or adverse. Thus the MP should be considered preliminary until this evaluation is done.

- Establishing and documenting historical flow and water-quality baselines for the GBCP area are fundamental to the MP to meet the environmental commitments of the GBCP and the revised goals of the GBCP and objectives of the MP developed by the TAC. Historical, baseline water-quality and flow conditions have not been defined for Mud and Salt Sloughs, the San Joaquin River, and the Grassland wetland channels because all of the flow and water-quality data for these areas have not been documented, compiled, and evaluated or consolidated into one document. Thus, these data were not readily available and could not be evaluated as a part of this review.

- Baseline data are needed to determine if the 5 percent annual selenium load reduction goal for the GBCP can be measured. Data on the historical values for selenium, salinity, and boron and flow for Mud and Salt Sloughs were provided by the CVRWQCB. No conclusion can be made about the accuracy of historical selenium load calculations from these data because of limitations in: 1) the sampling record -- frequency of sampling in relation to spatial and temporal variation; 2) sampling methods -- grab, unfiltered, etc.; and 3) data documentation and reduction -- accuracy, precision, margin of error, etc.

- Because of limitations in defining historical baseline conditions in the GBCP area, assessment of the competency of the MP with regard to monitoring site locations, the timing of measurements and samples, variables to be monitored, and data-collection methods is necessarily constrained to general comments based on the revised goals of the GBCP and objectives of the MP and the recommended mass balance conceptual framework.

IV. Conclusions regarding question 2 (page 8), i.e., whether the MP will adequately measure selenium and other trace elements to determine compliance with project load limits

- Flow monitoring at site B is adequate and results from water-quality monitoring should adequately measure the amount of selenium and water quality constituents of interest at site B if more consistent sampling takes place that includes: Equal Discharge Increment (EDI) or Equal Width Increment (EWI) sampling; dissolved and suspended selenium determinations; and both field specific conductances and laboratory dissolved solids determinations to represent salt loads.

- Loads measured at the compliance point (site B) need to be related to upstream and downstream sources and sinks in order to elucidate processes controlling the transport and fate of selenium, salt, and boron.

Monitoring Recommendations

- Assessment of baseline water-quality and flow conditions in the San Joaquin River, Mud and Salt Sloughs, the Grassland wetland channels, and any other areas pertinent to the GBCP should be done by the TAC. The historical period of record used in setting load targets was 1986 to 1994. The assessment could be accomplished by a process that includes the following tasks:

  1) Decide on relevant flow characteristics and water-quality constituents that need to be assessed.
  2) Identify potential sources of information (e.g., BOR, CVRWQCB, USFWS, USGS, USEPA, DWR, and CDF&G) and request data.
  3) Assemble requested data into easily accessible computer compatible database(s) with sources and quantifying information (e.g., accuracy, precision) documented.
  4) Evaluate the sampling record and data to determine suitability for defining baseline flow and water-quality conditions for the areas of interest.
  5) Document data limitations (spatial and temporal coverage, appropriateness of sampling methods, limits on accuracy and precision, appropriateness for calculations of loads or determining mass balances).
  6) Develop a monitoring strategy that would complement the MP such that changes in flow and water quality in the GBCP area and receiving waters can be detected and explained.

- An interim (de facto) monitoring plan is provided because the recommended TAC process may not be completed before the scheduled initiation of the GBCP in June 1996.

- A conceptual model of mass balance of water and water-quality constituents of interest in the GBCP area that accounts for fluxes for these constituents is suggested as the scientific basis for the MP. For the GBCP, this model would include: sources of selenium, salt, and boron to the San Luis Drain (SLD) from surface and subsurface agricultural drainage and from ground-water weep valves in the SLD; fluxes of selenium, salt, and boron among water, sediment, and biota in GBCP waters and receiving waters; transport of selenium, salt, and boron in the SLD to receiving waters; and the fate and effect of selenium, salt, and boron in these receiving waters (fig. 1).

- Flow is an important factor (and common variable) to be assessed by the MP as it may have a controlling influence on bioaccumulation, toxicity, fluxes, and transport of selenium in the GBCP area and receiving waters.

- Where possible, continuous flow measurements are recommended for primary sites to account for flow variability and provide data needed for calculating loads and determining mass balances for water-quality constituents of interest.

- Paired sites (upstream and downstream) sampled at the same frequency using depth and width integrated sampling (EDIs or EWIs) methods are needed to accurately determine and compare concentrations and loads among sites.

- A consistent monitoring design is needed for all primary sites so that flow, concentration (dissolved and suspended), and loads can be compared among these sites. Additional flow measurements and water-quality sampling are appropriate at some sites (e.g., sites A and B) to meet GBCP goals and MP objectives related to load limits, but the monitoring design for these additional measurements and samples also should be consistent for such sites.

- The MP now consists of grab samples from banks, grab samples from the center of flow, and pumped samples by automatic samplers with sampling intakes located in the flow near the bank where the autosampler is located. Having several types of samples introduces variability into the sampling program that probably will make it more difficult to compare data among sites. If automatic samplers are used at primary sites A, B, and N to collect daily samples, weekly mid-depth centroid samples and SC profile, and periodic EWI or EDI samples will be needed to provide comparability with other primary sites and to check and document mixing conditions at sites A, B, and N. Thus, consistent sampling methods would be used at all primary sites for weekly and monthly sampling and the additional sampling at sites A, B, and N would be consistent among these sites and comparable to other primary sites.

- A cost-effective analysis of manual versus automatic sampling is suggested.

- Consistent field pretreatment and preservation techniques (i.e., filtering and acidification) are also necessary to accurately differentiate the dissolved from the suspended selenium loads. Separate samples to represent these fractions should be treated and preserved at the time of field collection rather than a "total" or "total recoverable" sample taken that is "split" or "treated" in the laboratory. Elimination of this variability in sample collection also improves consistency with regard to the issues of preservation (i.e., quenching of biological activity), sample digestion, bioavailability, and speciation.

- Some sites should be relocated or deleted. Adequate mixing of water from the SLD at site D on Mud Slough is questionable because the site is only about 100 yards downstream of the discharge of the SLD into Mud Slough. Backwater and out-of-channel flow conditions at site E make flow measurement and water-quality sampling difficult. Thus, site E is questionable for meeting the GBCP goals and MP objectives. Site I is in a large backwater (ponded) area where flow measurements are not possible. If water-quality information is desired at this site, then sampling methods used for impoundments would need to be used. The need for this site in relation to MP objectives is questionable. However, USFWS concerns for assessing potential biological impacts for impounded areas warrants continued support of biological monitoring by the USFWS. Thus, we recommend that site I be deleted from the MP for flow and water-quality assessment, be continued as a USFWS quarterly biological monitoring site, and be included as a complementary study to the MP if additional sites are needed for comparison.

- Three additional primary sites on the SJR are recommended: SJR at Lander Avenue, SJR at Patterson Bridge, and SJR at Vernalis. The SJR at Lander is listed as a secondary site in the MP and the SJR at Patterson is not included as a primary or secondary site in the MP. Consistent flow and water-quality data are needed for these two sites along with the three SJR sites included in the MP (sites G, H, and N) to determine changes in concentrations and loads of water-quality constituents of interest in the SJR as a result of the GBCP. SJR sites at Lander, at Patterson, and at Hills Ferry/Newman (site H) should be recognized in the MP as currently existing DWR or USGS flow-monitoring stations and these flow data should be added to the GBCP database. Accommodations should be made to measure flow at Fremont Ford (site G). The SJR at Vernalis also is not included in the MP. This site needs to be monitored in accordance with the environmental commitment in the Use Agreement that salt loads in the SJR are not to increase due to the GBCP. The Use Agreement specifies that this site be monitored for this purpose.

- Source load sites (sumps and drains in the Grasslands Drainage Service Area) also are recommended for monitoring to better determine sources of concentrations and loads of water-quality constituents of interest to the SLD and to assess effects of major changes in farming practices on these concentrations and loads in keeping with the environmental commitment of ensuring that progress continues toward long-term resolution of drainage management issues. We recommend that the drain sites be primary sites. Information for sump sites could be obtained from water and drainage district managers, and thus, might not need to be primary sites.

- Water-quality (dissolved and suspended phase) samples should be collected to account for variability (i.e., frequency distribution) in concentrations, loads, and mass balances of water-quality constituents of interest (i.e., selenium, salt, and boron). Characterization needs to be done on a routine (calendar) basis, during periods of flow management (e.g., pre-irrigation, irrigation, drainage release, wetland release), and during critical periods including during storm flows, drought, and excessive algal growth (i.e., stagnant water conditions).

- Without an evaluation of baseline flow and water-quality conditions, only interim (de facto) recommendations can be provided on the timing of collection of water-quality samples. A monthly frequency is recommended for dissolved and suspended inorganic matter at primary sites because this frequency allows year-around coverage that most likely will account for calendar-based changes in water quality. During managed flow conditions (e.g., irrigation season) weekly sampling (one of which would coincide with the monthly sampling schedule) is recommended to account for water-quality changes during such periods of expected greater variability in water quality. Storm flows might require more frequent sampling because of expected rapid changes in flow and water-quality conditions. Daily composites of hourly interval samples or, at least, a daily grab sample might be necessary.

- Samples of suspended inorganic and organic matter, for amount, selenium concentration, and boron concentration, should be collected weekly at primary sites A and B during the irrigation season and times when large quantities of sediment, algal clumps, and/or organic floc are present in the SLD. At other times, monthly sampling probably would be sufficient. These samples would allow a calculation of these components of load to the overall load of selenium and boron transported by the SLD and would be needed for mass-balance determinations for the SLD. A sample collected for suspended inorganic material would not necessarily contain a representative sample of algal blooms and related organic material because of differing physical properties including size considerations. Collection of samples for organic matter at primary sites in Mud and Salt Sloughs and the San Joaquin River is not possible until a suitable method of collection is developed for sloughs and streams.

- A more accurate method for measuring dissolved salt than specific conductance, and thus the preferred method, is the sum of the major cation (Ca, Mg, Na, K) and anion (HCO3, SO4, Cl) analyses (plus silica and boron, if ionized) on field filtered and/or preserved samples. If resource limitations will not allow these determinations, then a composite analysis for dissolved solids (DS) accompanied by field specific conductance (SC) measurements should be made. The DS and SC determinations should be made even if analyses for individual major ions are done. Water temperature measurements also should be made to allow a calculation of SC from electrical conductivity measurements and to help assess the biological productivity and toxicity of the waters sampled. Measurements of pH, sulfate, and carbonate hardness also are appropriate to help assess the biological activity and toxicity of the waters sampled.

- The quantity and quality of bed sediment need to be monitored to meet the revised GBCP goals and MP objectives including the mass-balance characterization of water and water-quality constituents of interest in the GBCP area and its receiving waters.

- Monitoring selenium concentrations in bed sediment, suspended matter, and dissolved in water will help account for food-borne versus water-borne bioaccumulation of selenium in the food chain.

- In addition to documentation of selenium loads in water, sediment, and biota, documentation of short- and long-term trends in boron loads in water, sediment, and biota should be part of the MP because of the sensitivity of plants to elevated boron levels. Environmental concerns extend to wetland channel ecosystems (e.g., potential diminishing vegetation and food chain viability) in addition to downstream irrigation water use.

- Selection of sampling sites in the SLD for bed-sediment monitoring should include consistent depositional areas at check structures and should be based on the recent inventory of bed sediment by Summers Engineering. Areas of accumulation and reducing conditions need to be differentiated from areas of scour and oxidation to accurately represent the mass of selenium residing in the SLD sediment at any one time. Because more evaluation of potential sampling sites is needed before sampling sites can be selected, we recommend that the TAC conduct the following activities:

1) Compare field observations to bed sediment inventory.
2) Determine areas of deposition and areas of scour.
3) Determine a method of accurately locating bed sediment sampling sites.
4) Select either a check reach or single point sampling site.
5) Determine bed sediment thickness.
6) Calculate the amount of bed sediment represented by a sample at a site.
7) Set check-by-check goals for sediment removal.
8) Determine if land use adjacent to individual checks is an important variable for sediment accumulation and hence management.

- Until the amount of spatial and temporal variability in selenium concentrations in the bed sediment of the SLD is better known and the aforesaid process for selection of sampling sites is done by the TAC, only interim (de facto) guidance on bed sediment sampling can be provided. This guidance is as follows:

1) Sample at depositional areas in a check and include three longitudinal points (downstream, middle, and upstream).
2) Obtain three samples across the check structure at each longitudinal point composited for three depths (0-3 cm, 3-8 cm, and composited whole core to bottom).
3) Sample quarterly at sites A and B.
4) Intensively sample depositional areas of >30 cm (i.e., approximately one foot) at four check reaches (reaches between checks 1-2, checks 10-11, checks 15-16, and checks 17-18) annually. The intensive sampling would include collecting a complete detailed core (top 2.5 cm, then every 5-cm interval) and analyzing each interval for selenium, organic carbon, boron, and grain size. Also obtain a composite sample from areas of

<30 cm (i.e., one foot) of sediment.

5) During critical periods (flood, drought, stagnant water conditions) sample as stated for annual intensive sampling, except that sampling sites would be sites A and B and selected check reaches depending on conditions during the critical period.

- Quarterly sampling of bed sediments at the recommended primary sites on the San Joaquin River and in the Grassland wetland channels also should be done. Because of the paucity of data on selenium concentrations in bed sediments in the San Joaquin River and Grassland wetland channels, a field visit with the California Department of Fish and Game (CDF&G) (who have done some sampling for selenium in bed sediment in the San Joaquin River) to assess sampling site locations in these areas is recommended.

- Depth and width integrated (Equal Discharge Increment, EDI or Equal Width Increment, EWI) and cross-sectional samples are suggested for water and suspended-material samples at primary sampling sites because these methods are best to represent the water quality of streams or canals. If EWI or EDI samples cannot be collected at all primary sites during all sampling times because of resource limitations or sampling site conditions, grab samples at mid-depth in the centroid of flow could be collected. In this case, cross-sectional profiles of SC and periodic EWI or EDI samples to check and document mixing characteristics at primary sampling sites should be done.

- Without some measure of how well the water is mixed at sampling sites, questions about how well a point (grab) sample represents the water quality at sampling sites cannot be answered. Thus, the data from such samples can be questioned as to how well they represent the water quality conditions at sampling sites. Cross-sectional profiles of SC can help characterize how well dissolved constituents are mixed (distributed horizontally and vertically in the water column) at sampling sites. These profiles could be fairly easily and inexpensively done at most primary sites where there are bridges or some platform across the water body to be sampled. Where needed, such platforms could be installed.

- Samples for the dissolved fraction of selenium should be filtered upon collection and acid preserved after filtration.

- In addition to selenium, suspended material should be analyzed for concentration instead of for Total Suspended Solids (TSS), which includes dissolved as well as suspended solids (i.e., filter and dry versus residue-on-evaporation). Partitioning of selenium between dissolved and suspended components of load cannot be determined from TSS analyses. Analysis of the suspended material for organic carbon, boron, and particle size is also recommended.

- A map showing primary sampling sites overlaid on the flow system and other important features of the GBCP area would help the reader visualize the MP.

Investigation Conclusions

- Speciation of selenium is an important factor to assess by the MP as it may have a controlling influence on bioaccumulation, toxicity, fluxes, and transport of selenium in the GBCP area and receiving waters.

- Revised goals of the GBCP and objectives for the MP related to selenium fluxes among water, sediment, and biota and mass-balance determinations cannot be met by compliance monitoring alone. Complementary studies are needed to integrate with compliance monitoring to determine such fluxes and mass balances, and the processes controlling them.

Investigation Recommendations

- Water samples for dissolved selenium should include the determination of total, oxidized, and reduced dissolved selenium species.

- Study Proposals are included in Appendix D that if implemented could help meet the revised GBCP goals and MP objectives related to selenium fluxes and mass-balance determinations.

Quality Assurance Conclusions

- The QAPP needs to be updated to be consistent with the MP. The QAPP refers to a 1993 version of the MP instead of the November 1995 draft that was provided for review.

- The USGS agrees with the findings of the thorough review of the QAPP provided by the U.S. Environmental Protection Agency in December 1995.

Quality Assurance Recommendations

- The QAPP needs to specify the lead agency for implementing and overseeing the operation of the MP and for maintaining the databases that result from the MP.

- The QAPP should focus on the water-quality constituents of interest as defined in the MP.

- The QAPP should contain information on how patterns of sediment erosion, deposition, and transport will be monitored and cite appropriate references to the methods used, or refer to this description in the MP.

- The QAPP or the MP should describe the rationale behind selection or exclusion of sampling sites (e.g., Salt Slough at Lander Avenue and the San Joaquin River at Vernalis). A schematic diagram of the flow system or map of the GBCP area showing this and the location of primary sampling sites would help the reader understand the relation of the flow system and map features to sampling sites.

- The QAPP should describe sampling methods and equipment and cite appropriate method documents, or refer to such description in the MP.

- The procedures described in the QAPP on the QC of field activities are not satisfactory. For example, the QAPP should include procedures to ensure and assess the accuracy and precision of water temperature and SC measurements (calibration and maintenance of meters) and sampling activities (e.g., equipment blanks, field blanks, replicate samples).

- The QAPP should describe how samples will be processed once collected. For example, will samples be filtered in the field and acidified for dissolved cations and trace elements?

- The QAPP needs to include methods for processing and analysis of samples for selenium at the South Dakota State University Laboratory.

- Office methods regarding the review, evaluation, analysis, and reporting of data to meet data-quality objectives is needed in the QAPP.

Environmental Commitments, Project Goals, and Monitoring Plan Objectives

The **Environmental Commitments** as listed in the FONSI of November 1995 (BOR, 1995c) are:

A. To ensure that progress continues toward long-term resolution of drainage management issues.

B. To ensure that there are no significant adverse effects to fish and wildlife, other environmental resources, or public health.

C. To ensure that the above listed Commitments are implemented and adhered to as part of the project.

The objectives of the monitoring program as stated in the MP of November 1995 (BOR, 1995a) are:

1) Provide information that will allow monthly and annual evaluation of constituent loads discharged to the San Joaquin River in order to allow comparisons to be made to the monthly and annual constituent load targets established for the project.
2) Measure contaminant concentrations in water, sediment, plants, and animals within the SLD, Mud Slough, and the San Joaquin River to enable assessment of the potential adverse effects of the project (to fish, wildlife, and people).
3) Measure contaminant concentrations in those sampling media within Salt Slough and Grassland channels to enable assessment of the beneficial effects of the project.
4) Assess toxicity of drainage water discharged to Mud Slough.
5) Ensure that sensitive species are not adversely affected by project-related activities.

The **goals** of the Grassland Bypass Channel Project as recommended by the TAC as of March 26, 1996 and **supplemented by the USGS are:**

First, the goal is to ensure that the implementation of the project meets with the commitments made as part of the Use Agreement, FONSI, Supplemental EA and consensus letter to the Regional Board.

Second, the goal of the project is to determine if long-term use of the drain is appropriate in part, by assessing the validity of the assumptions upon which approval of the short-term project was granted.

Third, the goal of the project is to implement and to assess the success of improved drainage management techniques and provide the information necessary to further improve management techniques as required.

***Fourth*, the goal of the project is to improve, where possible, the current scientific understanding of selenium fluxes among water, bed sediment, and biota and selenium transport and fate so as to provide the information necessary to reduce risk to the ecological system.**

***Fifth*, to establish pre-project (baseline) water-quality conditions in the GBCP area and San Joaquin River that can be used to assess changes in water quality as a result of the GBCP.**

The **objectives** of the Monitoring Plan for the Grassland Bypass Channel Project as recommended by the TAC as of March 26, 1996, and **supplemented by the USGS** are:

1) To assess compliance with those requirements of the Use Agreement, FONSI, and SEA which restrict use of the drain within certain parameters.

2) To assess changes in the physical, chemical, biological, ecological, and human health conditions from pre-project conditions in Mud Slough which are related to discharges from the SLD.

3) To assess changes in the physical, chemical, biological, ecological, and human health conditions from pre-project conditions to Salt Slough and Grassland channels which are related to the removal of agricultural drainage water from these water bodies.

4) To assess changes in the physical, chemical, biological, ecological, and human health conditions from pre-project conditions in the San Joaquin River which are related to the re-routing of agricultural drainage water from the Grassland wetland channels and Salt Slough to the SLD and Mud Slough.

5) To assess event-driven changes in sediment, water, and biotic selenium concentrations which are related to the project.

6) To assess transport of sediment and selenium within the SLD.

7) To assess selenium fluxes among water, bed sediment, and biota.

Relation of the MP to the revised Environmental Commitments, FONSI, SEA, Consensus Letter, and Use Agreement has been assessed mainly through the TAC and completion of tables for the revised monitoring plan which contain (1) general objective, specific objective, and monitoring task; (2) goal or commitment and document; and (3) hypotheses or assumptions and MP objectives.

PART II

USGS REVIEW OF GRASSLAND BYPASS CHANNEL PROJECT MONITORING PLAN AND QUALITY ASSURANCE PROJECT PLAN

Questions and Tasks

In a November 7, 1995 Memorandum to the U.S. Geological Survey (USGS), the Bureau of Reclamation (BOR) requested the USGS to conduct a technical review of the Grassland Bypass Channel Project (GBCP) Monitoring Plan (MP) and Quality Assurance Project Plan (QAPP). The main **questions** that the BOR requested the USGS to answer in its review are:

1) Whether results from the monitoring plan provide the information needed to adequately determine how well the environmental commitments are being met during project implementation; and

2) Whether results from the monitoring adequately measure the amount of selenium and other trace elements in the drainage at the Drain's discharge point (Drain terminus at Mud Slough) in order to determine compliance with project load limits.

To accomplish such a review the USGS, in a December 1, 1995 memorandum to the BOR, stated that the following **tasks and information** would be required:

- An assessment of the accuracy and precision of flow and chemistry data to set selenium and other (e.g., boron and dissolved solids) load limits for the GBCP. Flow and chemistry data will be needed for the sites and time periods used to calculate load limits. This assessment will help determine the percent error of load limits specified for the Project, and if violations of load limits (i.e., annual or monthly load exceedances of 20 percent) or annual load reductions of 5 percent can be determined reliably by the proposed compliance monitoring program.

- An assessment of the capability of the physical and chemical components of the proposed compliance monitoring program to determine changes and trends in flow and water quality and whether or not adverse biological effects are occurring. In addition to the MP and the QAPP, retrieval of pertinent historical data will be needed to evaluate how well baseline conditions of flow and water quality are known. These data would include flow and chemistry for inflows, including agricultural drainage, to the Grassland Water District, Mud Slough, Salt Slough, and the San Joaquin River from the Project area, and those data used as a basis for the Finding of No Significant Impact (FONSI) and Supplemental Environmental Assessment (SEA). A field visit to proposed compliance sampling sites will be necessary to assess their acceptability for flow measurements and water-quality sampling.

- An assessment of the adequacy of the QAPP, including field, laboratory, and office methods regarding data acquisition, review, analysis, and reporting to meet data-quality objectives. Additional documentation is needed on sampling methods, including how samples are collected and processed and what equipment is used.

- Preparation of study proposals to obtain information that will provide a better understanding of flow and chemical conditions in the GBCP area, and that will refine our conceptual model of selenium cycling in water bodies receiving irrigation drainage in the San Joaquin Valley. These proposed studies will complement and integrate with compliance monitoring, and will provide data that will help the BOR make prudent policy and management decisions regarding the GBCP.

The following steps were taken to accomplish the review:

- A team of USGS scientists representing the relevant disciplines (surface-water hydrology, water quality, and quality assurance) was formed to conduct and coordinate the review.

- Relevant documents including the MP (BOR, 1995a), QAPP (BOR, 1995b), Finding of No Significant Impact (BOR, FONSI, 1991 and 1995c), Supplemental Environmental Assessment (BOR, SEA, 1990 and 1995c), Use Agreement (BOR, 1995d), and Consensus Letter (BOR, SL&DMWA, USEPA, and USFWS, 1995) were obtained and examined.

- Flow and chemistry data used to calculate load limits for the GBCP and needed to establish baseline flow and water-quality conditions as the basis for determining changes and trends in flow and water quality as a result of the Project were requested and evaluated.

- The review team participated in TAC meetings.

- Primary sampling sites were visited.

- The Central Valley Regional Water Quality Control Board (CVRWQCB) water-quality monitoring program for the GBCP area was reviewed and a letter stating our findings was prepared.

- A progress report was prepared so that the BOR, TAC, and others could provide feedback on review findings as the review is being conducted.

- A review document including conclusions and recommendations was prepared.

The focus of the review is on flow, water quality, and sediment characterization at the 14 primary sites described in the MP. Secondary sites were not considered unless they complemented primary sites and contributed to defining a mass balance or baseline of flow and water-quality conditions. Even though biota are important for assessing the mass-balance inventory and flux of selenium in the selenium cycle, review of the biological monitoring and toxicity testing was not done because of the detailed consideration given these monitoring tasks by USFWS and USEPA. The different parts of this document were written over the course of approximately nine months, but we have attempted to update this document as changes were made and the TAC process for the GBCP progressed.

Environmental Commitments, Project Goals, and Monitoring Plan Objectives

Listed in **Appendix A** are commitments, goals and objectives used as guidelines in this review:

- The **Environmental Commitments** as given in the FONSI of November 1995 (BOR, 1995c);
- The **objectives** of the monitoring program as stated in the MP of November 1995 (BOR, 1995a);
- The **goals** of the GBCP as recommended by the TAC and **supplemented by the USGS** as of March 26, 1996;
- The **objectives** of the MP as recommended by the TAC and supplemented by the USGS as of March 26, 1996.

Philosophy

Our general philosophy regarding the review of the MP and the QAPP for the GBCP is that they need to provide data to comply with and evaluate the environmental commitments as stated in the Use Agreement, Consensus Letter to Central Valley Regional Control Board, Finding of No Significant Impact (FONSI), and Supplemental Environmental Assessment (SEA) of November 1995.

This philosophy is consistent with the subsequently revised goals for the GBCP and objectives for the MP developed by the TAC for the GBCP. These goals and objectives reflect the need for data to assess compliance with environmental commitments of the GBCP and to improve scientific understanding of processes affecting the mobilization, transport, fate and effects of selenium, salt, and boron in the GBCP area and receiving waters. The MP should be constructed such that the data collected can be used to assess compliance and improve understanding.

As a scientific agency that, among other work, designs monitoring programs and collects water-quality data nationwide, the USGS recommends a scientifically credible basis for the GBCP MP. The overall design of the MP should be formulated so that a clear cause and effect can be shown and understood from the data collected. Documents supporting and defining the GBCP should ensure linkages between the monitoring-plan tasks to the larger goals of compliance with environmental commitments and improved scientific understanding. This task has been partially completed through the revisions of MP objectives by the TAC. What remains to be defined is the scientific basis for the MP in order to comprehensively connect the different parts of the MP and to develop a consistency among samples and data collected. The fundamental processes that control the mobilization, transport, fate, and effects of selenium and salts have not been documented to the extent necessary as the basis for the design. Our recommendations in this regard are included in what follows.

Mass-Balance Basis for Monitoring Plan

The basis for any resource monitoring plan is a conceptual model of how the resource system operates. For water resources, a conceptual model of mass balances of water and water-quality constituents of interest is appropriate. For the GBCP the model includes: sources of selenium, salt, and boron to the San Luis Drain (SLD) from surface and subsurface agricultural drainage and from ground water through weep valves in the SLD; fluxes of selenium, salt, and boron among water, sediment, and biota in GBCP waters and receiving waters; transport of selenium, salt, and boron in the SLD to receiving waters; and the fate and effect of selenium, salt, and boron in these receiving waters (fig. 1). In accordance with such a model, the MP would include:

- Quantitatively representative samples of water, sediment, and biota to document the mass balance of selenium, salt, and boron within the GBCP system; and

- Differential sampling points (upstream and downstream) for the SLD, Mud and Salt Sloughs, the San Joaquin River (SJR), and the Grasslands Drainage Service Area (sumps and drains) to calculate and compare mass loadings between sampling sites.

Thus, for the example of the SLD inlet and outlet, the input versus export of selenium and salt could be calculated and compared. Discrepancies between the two chemical balances would elucidate the processes undergone by a **conservative element** (salt) and a potentially **non-conservative element** (selenium). In addition, the movement of selenium through different media (sediment, water, biota, etc.) would be monitored to calculate the fluxes (or partitioning coefficients) of selenium among the media. If changes occur and are measured, this inventory would establish the basis for differentiating the conservative versus non-conservative behavior of selenium.

Prediction of selenium's behavior based on various models, which include load attenuation, mass balance, and ecotoxicity, is a topic prevalent in recent literature. For example, Skorupa et al., (1996) recently reviewed the literature on ecotoxicity of selenium (5,500 entries). Models encompassing the larger biogeochemical cycle (Presser and Ohlendorf, 1987; Lemly, 1993; and Presser, 1994) include assessment of areas susceptible to irrigation-induced selenium contamination in the western United States (Presser et al., 1994 and Seiler and Skorupa, 1995). Although the models need further validation, the principles of bioaccumulation and bioconcentration of selenium are well established. Interpretive guidelines for selenium exposure and risk assessment are based in part on these models of selenium partitioning and speciation.

A model of load attenuation of selenium is described in both the 1991 FONSI and the 1995 SEA for the GBCP as applied to the Grassland (i.e., wetland areas of the North and South Grassland Water District and adjacent channels). Annual losses of selenium of up to 50 percent (SEA, fig. 3, page 23) occurred from the aquatic environment as the water traversed the Grassland wetland channels (i.e., "in-transit loss"). In terms of mass balance, the measured input to the Grassland wetland area was more than that exported at specific times. This loss has been translated into a loss of load. The amount of selenium lost from the drainage water traversing the Grassland wetland channels from water year (WY) 1986 to WY 1994 was 15,500 lbs of selenium with an annual maximum of 3,000 lbs (SEA, fig. 4, page 25). As stated in the SEA (page 30): "The assumed 50 percent reduction in selenium in-transit losses may be too high or too low; there is insufficient available data to make reliable estimates of this reduction". The SEA (page 29) states that: "This [further] research suggests that the model of selenium uptake as a function of channel length may not adequately explain selenium in-transit losses".

The failure to account for the "in-transit loss" of selenium could be due to several factors including errors introduced by making temporal and spatial extrapolations of discrete measurements of flow and concentration to calculate loads, or a failure to document accurately the partitioning of selenium among the different media (water, sediment, and biota). Failure to adequately document the partitioning of selenium delayed recognition of the full scope of ecotoxicity at Kesterson National Wildlife Refuge (KNWR) (Presser and Barnes, 1985; Presser and Ohlendorf, 1987). Studies at KNWR demonstrated that selenium "lost" from solution in the ponds (compare the concentrations of selenium and sodium in SLD input water to their concentrations in KNWR pond 12) could enter the food chain through uptake by biota, and that organic processes were probably more effective in removing selenium than were inorganic processes. The GBCP in its original inception was in response to protecting the Grassland from a fate similar to that which occurred at KNWR and to improve the efficiency of delivery of wetland supplies that do not exceed two parts per billion (ppb) selenium (California State Water Resources Control Board, 1985). According to the mass balance for KNWR for the years 1981 to 1985 (BOR, 1986, *Kesterson Program EIS*), the selenium input was 22,700 lbs; of that, 5,300 lbs were estimated to have remained in the sediments of the SLD and 17,400 lbs were distributed in the water, sediment, and biota of Kesterson Reservoir. This estimate is comparable to the 15,500 lbs of selenium "in-transit losses" for the Grassland wetland area. Potential mechanisms responsible for load attenuation are listed in the SEA and FONSI and include: sedimentation, bioaccumulation, diversions, and volatilization.

The same potential for "load attenuation" exists for the SLD, Mud Slough, and the San Joaquin River. Because load attenuation has been inadequately documented and the processes controlling load attenuation are poorly understood in the GBCP area, a mass-balance approach to the MP should be invoked to accurately account for selenium, salt, and boron in the GBCP system (e.g., SLD, fig. 1). Although not all the ramifications of selenium cycling are known, a mass-balance approach would contribute to establishing limits of bioaccumulation of selenium in relation to such important variables as flow and speciation [i.e., a measure of the chemical and/or biological capacity to oxidize (solubilize), reduce (precipitate), or incorporate (seleno-amino acids) selenium]. Bioconcentration of water-borne dissolved selenium and bioaccumulation (possibly biomagnification) of food-borne particulate selenium are important to quantify in relation to potential toxicity. Such information is necessary for designing management strategies to optimize selenium, salt, and boron concentrations and loads in the GBCP to comply with environmental commitments that adequately protect the environment.

Flow and Speciation as Determinants of Variability

The ultimate question of selenium transfer may center around static systems (evaporation ponds) and flowing systems (streams). Selenium is known to bioaccumulate very efficiently in terminal sink evaporation ponds (KNWR and Tulare Lake Basin). Flushing flows, either natural or managed, in some wetland areas (Grassland versus KNWR) were thought to mitigate some potential effects of selenium loading. The "flip-flop" system was essentially instigated as an interim measure to supply clean water to the Grassland wetlands after the ecological disaster at KNWR, and to ensure selenium did not enter duck club and wildlife habitat ponds. With this flow management technique, drainage water was alternated with fresh water flows in the same delivery canals (flushing time approximately 24 hours) under a relatively constant flow regime in order to efficiently deliver wetland water supplies.

With the initiation of the GBCP, drainage water will be removed from Salt Slough and the Grassland wetland channels and diverted to the SLD and 6.6 miles of Mud Slough. Therefore, opportunities for depuration (or mobilization) and accumulation probably will change in the drainage, supply, and receiving water channels. Beneficial effects are expected from removal of drainage water and consequent loading of selenium. However, drainage will be more directly routed to Mud Slough through the SLD without dilution by wetland flows and potential loss through bioaccumulation in sediment and biota (i.e., in-transit losses). Changes in dispersion plume chemistry could take place where the drainage water flows into Mud Slough and the San Joaquin River even though the load due to the GBCP might not increase over historical loads. Comprehensive monitoring of areas of potential benefit (Salt Slough and Grassland channels) and possible degradation (SLD and SJR) would help determine impacts from the GBCP.

The chemical and biological processes occurring as a function of the physical processes imposed by the operation and management practices of the GBCP are also of importance. Biological processes involving selenium are more efficient than chemical processes resulting in a high rate of selenium uptake in biologically active systems (Oremland et al., 1989). While it is true that biologically active systems are kinetically faster, chemical exchange among selenium species (selenate, selenite, elemental selenium, and organic and inorganic selenide) also takes place. Thus, the overall uptake rate potentially encompasses many reservoirs of selenium (e.g., dissolved versus particulate; selenate versus selenite) in which high rates of exchange between pools may take place making for an efficient transfer among water, sediment, and biota. Whether a system is dominated by biological or chemical processes may be a function of flow. Therefore, flow may be both a driving force and a controlling variable. As such, it is a uniting (common) consideration for water-quality monitoring and a controlling variable for sediment movement, oxidation/reduction conditions, and bioaccumulation. Thus, flow management is of primary importance with regard to fluxes, transport, and mass balances of selenium, salt, and boron in the GBCP and receiving waters. To this end, a management strategy could be developed whereby flow is slow enough so sediment movement does not occur but fast enough so selenium bioaccumulation will not take place.

Operational questions related to flow and selenium mobilization are: (1) How to manage the selenium inventory (flux into and out of water and sediment) of the SLD and thus bioavailability to biota; and (2) How to define the overall toxicity to receiving waters. The optimization of relevant variables will result in:

- Optimal input versus export (i.e., maximize input without harm to the environment).

- Optimal flow so that the flow is slow enough to not cause sediment movement (downstream effect) but fast enough to minimize bioaccumulation (in-stream effect).

- Optimal rate of (re)mobilization from sediment to water (or water to sediment) to avoid toxicity to biota.

- Optimal environmental partitioning in a selenium cycle or ecosystem (i.e., maximize input without harm to the environment).

In order to successfully manage selenium in the SLD, speciation also should be measured: (1) to define the events driving changes in the inventory of selenium in the SLD that determine overall toxicity; and (2) to define potential mitigating circumstances of load reduction. These considerations lead to two types of assessment for selenium for which amounts and ranges of risk need to be quantified:

- ecological hazard created by the high mobility of the dissolved selenate species;

- bioassay toxicity created by the high toxicity of the dissolved organic selenide species (e.g., selenomethionine).

Concerning defining protection of the environment Skorupa et al., 1996, state that, generally if selenium loading (i.e., environmental, dietary, or tissue concentrations of selenium) equals or exceeds 10X normal background, then overt negative consequences for populations of fish and wildlife are likely. Specifically they state: "An important factor confounding interpretation of field data for water-borne selenium is the differential partitioning of selenium mass loads between the water column and other compartments of an aquatic ecosystem. Partitioning ratios can be strongly influenced by the overall biotic productivity of a water body. In highly productive waters, less dissolved selenium is left in the water column even though food-chain exposure of fish and wildlife may be substantive. **Therefore, low water-borne selenium concentrations can indicate low mass loading (low risk) or high biotic uptake (high risk)**". As a case in point of how the speciation of water-borne selenium, as reflected in irrigation-water selenium (selenate) and oil-refinery selenium (selenite), can substantially affect the potential for bioaccumulation in fish and wildlife tissues, oil-refinery wastewater containing 10-30 ppb selenium has been determined to have the same ecological bioaccumulative power as irrigation wastewater containing 330 ppb selenium. Both sources of water, upon impoundment in marshes, produced water boatmen (a species of aquatic insect) averaging about 20 ppm Se (i.e., 10X normal or effect range) and black-necked stilt eggs averaging about 25 ppm Se (10X normal).

Flow and Water Quality

Need for Baseline Data

The MP needs to provide data adequate to comply with or evaluate the Environmental Commitments in the Use Agreement, Consensus Letter, FONSI, and SEA for the GBCP. Non-degradation of water quality in the San Joaquin River as a result of the GBCP and improvement in water quality in the wetland areas of the Grassland Water District and Salt Slough are stated frequently in these documents. Thus, establishing and documenting a water-quality baseline in the

GBCP area and receiving waters seems fundamental to a MP and QAPP designed to assess the effect of this project.

The load targets contained in the Consensus Letter on which compliance will be based and fees assessed were developed through a negotiation process. Loads measured as part of the GBCP monitoring program will be compared to these monthly and annual load targets. Accurate measurement of these loads is crucial to the competency of the MP. At least a 5 percent annual load reduction is expected as a result of the GBCP. Thus the adequacy of the MP partly depends on whether or not baseline conditions are defined and therefore change, adverse or beneficial, can be measured accurately.

Mud and Salt Sloughs are tributaries to the 130-mile reach of the San Joaquin River (SJR) that has been designated as a water-quality-impaired segment of the SJR. The monthly load targets in the Consensus Letter were negotiated from a nine-year average of historical loads (1986 to 1994) from Mud and Salt Sloughs or a calculated load from a Total Maximum Monthly Load (TMML) model, whichever was higher. The TMML model was developed by the CVRWQCB for the SJR at Crows Landing as part of USEPA's general Total Maximum Daily Load (TMDL) remedial approach to water bodies that do not meet water-quality standards (CVRWQCB, 1994, *TMML Model for the SJR*). The annual negotiated load maintains the status quo of 6,600 lbs of selenium for the interim two years of the project in which "water quality in the SJR will not worsen", (Consensus Letter, page 2). However, the promulgated standards for the SJR based on water-quality objectives have neither been achieved nor enforced during the period since 1985, when selenium became a concern, until present. The negotiated annual load is 4,002 to 5,437 lbs higher, depending on water-year type, than that required as an allowance calculated by using the TMDL model based on a 5 ppb selenium water-quality standard. Assumptions used in the models to derive these loads include: 4-day average; exceedance frequency of one violation in three years; and tenth percentile flow or derived monthly equivalent of 4-day low flow, whichever is greater (EDF, 1994; CVRWQCB, 1994). At least a 5 percent reduction per year is a goal for the remaining three years of the five year project (Consensus Letter, page 2). A 20 percent exceedance of the annual load cap would terminate the Use Agreement if there are no extenuating circumstances (Use Agreement, page 16). During this time Waste Discharge Requirements (WDRs) will be established by the CVRWQCB. If a longer term project is negotiated, an EIS or EIR would be needed.

Thus, the data available historically prior to the GBCP, the data collected for the initial start-up of the project (see Appendix E), and the data collected during the interim two-year project itself are crucial to assessing the success of the project. Assessment of changes in water quality for the GBCP and receiving waters is dependent on defining and documenting water-quality conditions prior to the GBCP.

The implicit compliance point for the GBCP is the SJR. The explicit compliance point for the MP is SLD discharge point or drain terminus at Mud Slough. This "end-of-the-drain" was designated because this is the last point of control for the Grassland Basin Drainers and the last point to measure selenium solely derived from the Grassland Drainage Service Area (GDSA). However, use of this compliance point will not include several sources of selenium traditionally included in the SJR load measured at Crows Landing. These include the background wetland load (e.g., Salt Slough) and the selenium load from the "upper" SJR.

Although the compliance point of the GBCP is the SLD's discharge point (SLD terminus at Mud Slough), load reductions are implicitly tied to the SJR. Questions remain therefore, (1) as to the relation of load targets to concentration-based/water-quality standards for the historical compliance point for water quality at the SJR at Crows Landing; (2) as to the effect on allowable loads of the use of a model based on the non-conservative behavior of selenium (i.e., a mass-loading model which takes into account bioaccumulation and selenium partitioning in water, sediment, and biota) rather than one based on dilution only (conservative behavior of selenium); and (3) as to the protective nature of the load targets derived from models that consider a violation rate based on a 5 ppb water-quality objective given the USFWS's recommendation of a 2 ppb ecological risk guideline for selenium in water (Henderson, et al., 1995).

Concerning question #2 above, some confusion has arisen over the terms **mass loading** and **assimilative capacity** when used in reference to the TMDL (EDF, 1994) or TMML (CVRWQCB, 1994) models for the SJR. These models address the complexities of flow and the derivation of loads in relation to "applicable" violation rates of water-quality regulations based on concentration. The models fail to include the complexities of chemistry and biology as applied to selenium. For a conservative element (e.g., salt), in the most basic sense, total mass loading is entirely carried in the water phase. The rules of dilution apply and the behavior of the element is completely defined on the basis of dilution. The SJR load models are in reference only to dilution and therefore the assimilative capacity is based only on dilution. For a non-conservative element like selenium however, the total mass of selenium may reside in water, sediment, and biota because of the bioaccumulative nature of selenium. Selenium is partitioned in water, sediment, and biota. Assimilative capacity defined for selenium would therefore be different than that derived for a conservative element (e.g., salt) as in the TMDL or TMML for the SJR. Allowable loads based on the non-conservative behavior of selenium would need to be determined using a mass-balance approach and recognizing the historical loading of selenium as part of the total mass loadings.

As stated in the SEA (page 30) regarding these questions: "The consequence of a reduction in selenium in-transit losses to a number greater than the 50 percent could result in a small increase in the concentration of selenium at Crows Landing compliance point. This field study [GBCP MP] should help better understand these processes." Concerning the assimilative capacity of the SJR, the Environmental Defense Fund in *Plowing New Ground, Using Economic Incentives to Control Water Pollution from Agriculture* (1994), states: "The regional load allocation derived in this study[1] is based on a direct conversion of a water concentration standard. In the future, load allowances (or mass emissions limits) may be derived independent of water concentration standards, based on the capacity of an ecosystem to safely absorb pollutants as measured in sediments or plant and animal tissues. If so, the method for deriving the TMDL will be different,

[1]This study refers to the dilution capacity or Total Maximum Daily Load (TMDL) model for the SJR.

but implementation issues will be much the same as in the case discussed here." (page 25).

Availability of Baseline Data

Baseline Data for Mud and Salt Sloughs

Data on the historical values for selenium, boron, salinity, and flow for the period 1986 through 1994 from Mud Slough (site D) and Salt Slough (site F) were provided by the Central Valley Regional Water Quality Control Board (CVRWQCB) to the USGS. These data were provided in a spreadsheet format. Comments and findings from our review of these data are summarized below.

The conversion factor used to convert TDS to EC varied from 0.656 to 0.675. The source of this variation should be cited, and if this is an estimate, perhaps using 0.6 or 0.7 consistently would be appropriate.

The primary objective in reviewing the historical selenium and flow data was to evaluate the procedure used to calculate the historical selenium load for Mud and Salt Sloughs. This evaluation was done by examining the values for total selenium and flow in the spreadsheet, attempting to verify them against their primary source, and reviewing the formula used to calculate load. No attempt was made to validate the TMML model (CVRWQCB, 1994, *A TMML Model for the SJR*) of which the analysis of Mud and Salt Sloughs are a part.

Monthly acre-feet totals for discharge were checked for several years for Mud Slough (at footbridge below terminus of SLD near Gustine) and Salt Slough (at Lander Avenue--HWY 165--near Stevinson). It was found that the streamflow data in the spreadsheet(s) used by the CVRWQCB are from the USGS ADAPS database and data published in USGS annual reports of water resources data for California (USGS, 1985-1994, *Water Resources Data for California,* *Water Years 1985 through 1994, Southern Central Valley and the Great Basin from Walker River to Truckee River, Volume 3, Water-Data Report, CA-85-3 to CA-94-3;* Shelton and Miller, 1988 and 1991, *Water-Quality Data, San Joaquin Valley, California, USGS Open-File Reports 88-479 and 91-74*). The data presented in the CVRWQCB spreadsheet were not annotated as to quality of streamflow data (e.g. estimated, affected by variable backwater etc.) nor accuracy [excellent (data within 5 percent of true value), good (within 10 percent), fair (within 15 percent), or poor (> 15 percent)], although this annotation is provided in USGS water-data reports. See section "Assessment of Monitoring Site Location" for further discussion of backwater problems from the SJR that affect Mud Slough and Salt Slough flow measurements on pages 53-56 and pages 59-60, respectively.

A comparison of total selenium in the spreadsheet(s) to a data retrieval from the USGS database is shown in the **following table**. All data from sources other than the USGS appear to have no unusual high or low outliers, and seem to compare well in terms of magnitude; however, no comparisons were made between these data and their sources.

Mud Slough	Salt Slough
1986 25 of 62 total Se values were from USGS samples (40 percent) All others appear to have normal variation and are of the same order of magnitude. Three samples differ from the USGS database: 10-10-85 2 vs 3.5 10-24-85 1 vs 9.5 04-03-86 17 vs 4.7	1986 25 of 57 samples (44 percent) from USGS. All USGS database values agree with what is in spreadsheet.
1987 24 of 50, (40 percent) USGS, as above. One sample differs 12 vs 15	1987 24 of 50 (40 percent) USGS

Mud Slough	Salt Slough
1988 24 of 71 (34 percent), as above, one USGS sample not included, 08-21-88 26	1988 24 of 70 (34 percent) USGS
1989-1993 apparently NO USGS sample data available	1989-1993 apparently NO USGS sample data available
1994 USGS samples available, not used	1994 USGS samples available, not used. USGS values compare well with what is in table.

The appropriateness of the data analysis techniques used to calculate monthly and annual selenium loads from the assembled record was then assessed as to whether the calculated loads represented the actual loads, i.e., how well the sampling record reflected the flow and concentration distribution. The four or five selenium concentration measurements taken per month by the CVRWQCB were correlated to a daily flow for each day selenium was sampled. From these data, a "**flow-weighted selenium concentration**" (FWSC) was derived and thus the relation of selenium concentration to flow was determined. This **FWSC** was then applied to the monthly acre-feet totals in order to calculate monthly and annual loads. How well the **FWSC** calculation procedure actually represents how selenium concentrations change with discharge (i.e., seasonal range and distribution frequency) in the Grassland Drainage Service Area is not known. Derivation of selenium load as a function of discharge in this manner may only be appropriate if flow is relatively constant.

The largest potential weakness of this data-analysis method is that it uses only a small portion of the discharge data - i.e., about 13 percent (4 of 30) of the data on mean daily discharges - to represent the variability of flow in the load calculation. It is possible that the calculation of selenium load can be greatly improved by incorporating all of the selenium and flow data into a load estimation model that quantifies the relation between selenium concentration and flow. It is further suggested that such a model should incorporate the relation between selenium and electrical conductivity (EC), as well as expected patterns in Se/EC and Se/flow relations that may result from seasonal and management-based changes in the source of flow in Mud and Salt Sloughs. These considerations have been discussed with staff at the CVRWQCB, and they indicated that such an analysis is appropriate. A report will be issued to further document historical data for Mud and Salt Sloughs and the SJR by the CVRWQCB staff (personal communication, Les Grober).

Because of limitations in defining the historical baseline conditions in the GBCP area, no conclusive statement can be made concerning the accuracy of calculated selenium loads reported in the spreadsheet used to set selenium load limits for the GBCP. The limitations of the historical data set used to develop load targets is a necessary part of the documentation for the GBCP. Reliability of past and future data collection needs to be documented in order to successfully define the relations of flow and salinity, flow and selenium, and eventually salinity and selenium (i.e., real time management) for the GBCP system. Causal relations between drainage management and water quality need to be determined because of the developing nature of drainage-management techniques (e.g., drainage re-use, withholding of effluent releases in regulating reservoirs, efficient pumping rates from collector sumps, etc.). Further statements concerning the relation of data quality and sampling frequency to determine variability are given in sections "Conceptual Design for Monitoring" (page 45) and "Assessment of Timing of Flow and Water-Quality Monitoring" (page 66).

Baseline Data for San Joaquin River and Grassland Channels

Water-quality and flow data for the San Joaquin River, the Grassland channels, and water-quality data other than selenium for Mud and Salt Sloughs have not been documented, compiled, and evaluated or consolidated into one document, and are hence, not readily available. Thus, baseline water-quality and flow conditions for these areas have not been defined.

Given this situation, our review is limited to determining the capability of the MP to assess compliance with the selenium load limit as discharged from the SLD compliance point for the project (question #2 from the BOR). Without baseline flow and water-quality data for the SJR and Grassland channels, changes in the water quality in these areas as a result of the GBCP (question #1 from BOR) as specified in the FONSI, SEA, Consensus Letter and Use Agreement cannot be determined. In summary, we conclude that an assessment of the adequacy of the MP to meet all of the environmental commitments listed cannot be done because historical data are not available and have not been documented or compiled.

Conceptual Design for Monitoring

USGS recommendations for sampling are based on: 1) underlying scientific principles of selenium biogeochemistry (including conceptual models) and hydrology; and 2) a consideration of variability of sampling media to determine sampling frequency. The basis for determining frequency of sampling is usually through an analysis of the historical record or baseline data.

In order to determine frequency of sampling, variability must first be characterized. If a historical record or data from an initial pre-project phase of monitoring is not available to assess increments of change, then initial sampling frequency must be more intensive and comprehensive to define that variability. Such a sampling frequency will allow the establishment of a scientifically based frequency. This high frequency sampling after an initial data gathering period may be downsized as determined by measurement of inherent variability.

Because baseline flow and water-quality conditions and intrinsic variability have not been determined for much of the GBCP area and receiving waters, the USGS recommends that the TAC decide on a process for compiling, documenting, evaluating, and analyzing historical flow and water-quality data for the San Joaquin River, Mud and Salts Sloughs, Grassland channels, and any other areas (e.g., page 52, SLD and pages 64-66, sumps and drains) pertinent to the GBCP. The process would include the following tasks:

1) Decide on relevant flow characteristics and water-quality constituents that need to be assessed.
2) Identify potential sources of information (e.g., BOR, CVRWQCB, USFWS, USGS, USEPA, DWR, and CDF&G) and request data.
3) Assemble requested data into easily accessible computer compatible database(s) with sources and qualifying information (e.g., accuracy, precision) documented.
4) Evaluate the sampling record and data to determine suitability for defining baseline flow and water-quality conditions for the areas of interest.
5) Document data limitations (spatial and temporal coverage, appropriateness of sampling methods, limits on accuracy and precision, appropriateness for calculations of loads or determining mass balances).
6) Develop a monitoring strategy that would complement the MP such that changes in flow and water quality in the GBCP area and receiving waters can be detected and explained.

An interim (de facto) monitoring plan is given below because the process described above is not likely to be completed until after the scheduled initiation of the GBCP (scheduled to start in August 1996). Thus, the MP should be considered preliminary. Without a determination of baseline conditions and intrinsic variability, assessment of the competency of and guidance on improvement of the MP are necessarily constrained to the general comments that follow.

For water quality, two phases need to be considered: dissolved and suspended. Accurate dissolved and suspended concentrations are necessary to calculate an accurate mass balance. The suspended phase includes inorganic sediment and organic particulate matter (e.g., living and dead algae). Along with bed sediment, these phases will address to some degree food-borne particulate selenium (bioaccumulation and possibly biomagnification) versus water-borne dissolved selenium (bioconcentration) in the food chain. The collection of dissolved selenium would further facilitate the comparison of the GBCP database derived from the MP to that of the National Irrigation Water Quality Program (NIWQP) database that encompasses 29 areas susceptible to irrigation drainage problems across the western United States (Presser et al., 1994). Conclusions derived from the NIWQP database then could be applied to the data collected as part of the GBCP.

Both accurate water-quality concentrations and flow measurements are necessary in order to calculate accurate loads of selenium, boron, and salt. Both temporal and spatial variations must be taken into account in order to collect representative samples. Flow is an integral part of load, as flow multiplied by concentration equals load. In terms of mass balance, flow is also a crucial variable to measure in order to relate changes in inventories to seasonal management practices and thus, further define conservative behavior versus non-conservative behavior of chemical ions.

Optimization of flow for both maximization of selenium input and protection of the environment (i.e., bioaccumulation) may be possible. Chemical speciation of selenium, in part, determines the effectiveness of biological processes that are known collectively as bioaccumulation. Operationally defined dissolved reduced selenium (organic selenide and selenite) and oxidized selenium (selenate) can be determined. Operationally defined oxidized and reduced particulate species are more difficult to determine and may be less important to distinguish for the GBCP. Therefore, to adequately characterize selenium's behavior under the varying conditions imposed by the GBCP, not only does the concentration of dissolved selenium need to be determined, but also the dissolved selenium species need to be taken into account.

The dissolved inorganic species of selenate and selenite are biotransformed into organic species (e.g., selenomethionine) after uptake by primary producers such as algae. The initial step of selenium uptake from water to primary producer (i.e., bioconcentration) is the step of greatest bioconcentration. As described in the review by Skorupa et al., 1996 (see also section "Flow and Speciation as Determinants of Variability", pages 36-39), speciation of water-borne selenium strongly influences how much loading is required to cause dangerous concentrations of selenium in the aquatic food chain, but the water-borne starting point (selenate or selenite) does not appear to influence the unit toxicity of biotransformed (food-chain-incorporated) selenium (USFWS, 1990; Besser, et. al., 1993). However, aquatic food chain selenium has a toxicity profile similar to selenomethionine. Skorupa et al., 1996, considers dietary intake of selenium the most sensitive exposure pathway to higher trophic levels, e.g., fish and wildlife. It is generally hypothesized in a re-evaluation of the marine biogeochemistry of selenium, that the dissolved organic selenide maximum coincides with primary productivity maximum and particulate selenium may be found primarily in the -2 oxidation state (Cutter and Bruland, 1984). Therefore, water-borne selenium (dissolved) and food-borne selenium (particulate) are both exposure pathways for biota in aquatic systems. This duality results in a two-fold approach to selenium assessment of toxicity and protection of the environment in which speciation is a consideration.

In addition to adequate characterization of the dissolved component, to ensure the complete analysis of the biological cycle in reference to the overall cycle of selenium, it is important to sample and analyze both suspended inorganic and organic particulate material including floating algal clumps or mats as a transport mechanism for selenium. A sample collected for suspended inorganic material would not necessarily contain a representative sample of algal blooms and related organic material because of differing physical properties, most likely size. Amount of suspended material and selenium concentration should be determined. Boron concentration and organic carbon content is also important to determine for the overall considerations of selenium and boron transport in sediment and plants.

Sampling for suspended organic material is not referred to in the MP. The members of the TAC discussed collecting samples to document algal blooms if low-flow or stagnant conditions occurred in the SLD. Movement downstream of algae and organic floc composed of senescent or dead algae that are elevated in selenium and resuspended from bed sediment by microbial, chemical, or physical processes would not be accounted for in the MP without a mass-balance approach. These data could help interpret results of the toxicity testing recommended by USEPA and to be performed by Block Environmental. Algal samples are to be grown in the consulting laboratory using water from the SLD for several days. Growth and amount of selenium uptake is to be measured. Collecting samples of floating algal colonies and organic floc in the SLD under field conditions would introduce an "in situ" component to augment the laboratory experiments on selenium uptake. Frequent sampling should occur during times of algal blooms brought on by slow-flowing water due to management decisions so that the effect of such conditions on selenium transport can be documented.

Assessment of Monitoring-Site Locations

Proper location of monitoring sites is important to ensure that the goals of the GBCP and objectives of a water-quality monitoring program are met. Site locations in the MP were evaluated based on the revised goals of the GBCP and objectives for the MP developed by the TAC (Appendix A) and our assessment of their suitability for determining mass balances and changes in flow and water quality as a result of the GBCP. According to the November 1995 Draft MP, 14 primary sites and 29 secondary sites have been designated. The focus of this review is on the primary sites. Secondary sites are not considered unless they complement primary sites and contribute to defining a mass balance or baseline of flow and water-quality conditions.

To avoid redundancy and keep costs affordable, the MP is composed of on-going or planned monitoring efforts by several agencies (e.g., BOR, CVRWQCB, USFWS, USGS, CDF&G). Thus, in the evaluation that follows, the primary agencies responsible for a site or group of sites are provided. The overall sampling design is given below, including the recommendation that flow and water quality be measured at paired sites in five designated sampling site systems. These five internally-defined systems within the GBCP area (i.e., the SLD, Mud Slough, the Grassland Water District wetland channels including Salt Slough, the SJR, the Grassland Drainage Service Area sumps and drains) are designated for sampling consistency and comparative selenium inventories (input versus output). Thus, the designated paired primary sampling sites will facilitate the calculation of a mass balance for each system. As requested by the USGS of the BOR early in this review, a map(s) showing sampling site locations (including drainage service area and GBCP area) and a schematic diagram of the flow system in relation to the sampling sites is needed to elucidate the MP.

San Luis Drain and Mud Slough Sites

1)SLD upstream site A (below inlet structure at check 19, at check 17) and downstream site B (above outlet structure at terminus, at check 1).

The **SLD** at check 17 is primary site A, which is downstream of the inflow structure for the GBCP at check 19. The SLD discharge point into Mud Slough is primary site B and is a compliance point for the GBCP. These two locations are key for determining a mass balance for the SLD and for detecting and explaining changes and trends in flow and water quality in the SLD. Flow measurements and water-quality sampling need to be done in a consistent way at both sites so that flow, concentrations, and loads can be compared.

Changes in concentrations and loads of water-quality constituents of interest between these sites can indicate uptake or release processes within the SLD. An accounting of the main sources and sinks for these constituents in the SLD is needed to help determine what processes are controlling uptake and release. The main sources and sinks of selenium in the SLD are thought to be: irrigation drainage (subsurface and surface) from the Grassland Drainage Service Area; ground-water seepage into the SLD from "weep" valves and cracks in the SLD; irrigation and wetland supply water; bed sediment in the SLD; aquatic biota in water and sediment of the SLD; and suspended sediment and organic particulate matter in the SLD.

An assessment of comparability of existing data with data collected for the MP is needed for evaluating the degree to which changes and trends can be expected to be detected and explained. The SLD terminus and check 10 are listed as CVRWQCB water quality stations in *Agricultural Drainage Contribution to Water Quality in the Grassland Area of Western Merced County, California* for WY 1993 but not WY 1994 (CVRWQCB, 1995a and b). However, data are not listed in the report. Therefore, no systematic water-quality data collection was available for baseline considerations for the SLD as a surface water evaporator and/or a ground-water seepage collector since its closure in 1986.

"Weep" valves are estimated to be present every 10-12 feet either as a single row traversing the center of the SLD or two rows, one down each side of the SLD (personal comm., Mike Delamore, BOR). If 28 miles of the SLD are re-opened then 10,000 to 20,000 valves could be involved in hydrologic equilibration with the surrounding ground water. This feature of the SLD adds a second source water (local ground water) to that of subsurface drainage from the Grassland Water District whose characteristics and effects must be accounted for in the MP.

Check structures between sites A and B control water flow and effect sediment transport and deposition. These check structures that exist approximately each mile of the SLD (checks 1 through 19 encompass the 28 miles to be re-opened) to manage flow, act as separate entities in regard to hydrological, biological, and chemical activity. Thus, the effect of these structures on flow and water-quality changes between sites A and B needs to be assessed to help determine mass balance in the SLD. Specifically, the effects of both intervening check structures between the SLD inlet (check 19) and site A (check 17) and a build up of sediment at check 18 need to be taken into account when evaluating data collected at site A. Thus, because of the number of complexities in the SLD system (e.g., check structures and ground-water seepage), two monitoring sites (A--input at Check 17 and B--output at Mud Slough), for a 28-mile reach of the SLD, should be thought of as a minimum and may not be adequate to define the system.

Flow at site A will be measured by a weir. This structure has not been constructed yet, so it was not possible to evaluate the proposed weir. The site was visited, but the channel will be changed and a new weir installed. If the weir is well designed and correctly installed, it may provide good to excellent records. In the low-slope environment of the Grasslands, backwater and partial or whole submergence of the weir is possible. That possibility will need to be carefully evaluated and documented. Once the weir is installed, a survey of the as-built conditions should be made. Following this, a theoretical sharp-crested weir computation should be made and reviewed. The computation will allow development of a stage-discharge relation, or rating. The rating should be verified by current meter measurements throughout the range in stage and adjusted as required. No noticeable arrangements have been made to record water depths at the weir, but BOR has stated it will be by staff gage. As a further development of the OC meeting on September 3, 1996, it was agreed to install a recorder at site A in order to provide continuous flow data at the SLD inlet site.

All of the discharge measurements should be considered provisional until calibration is checked following the period of measurement. This comment pertains to all of the indirect methods for measuring flow. Provisions will have to be made to maintain the database containing the discharge measurements and to incorporate the calibration procedure into the project QAPP. The integrity of the discharge measurements in the database will have to be safeguarded by maintaining a record of all corrections made to the data.

Site B appears ideal for Ultra-sonic Velocity Measurement (UVM) of flow. The cross section has a uniform shape, with footbridges installed to facilitate operation, maintenance, and measurement of the current meter. If the system is correctly installed, maintained, and calibrated, the daily value record should be good to excellent. The UVM should be calibrated by making a series of current meter measurements (using a calibrated meter) with no fewer than 25 vertical sections each, with each vertical having at least 40 seconds of observation. The measurements should be made for the entire range of discharge. Once the UVM is calibrated, regular measurements at least each quarter should be made to verify the calibration.

2)Mud Slough (upstream site C, immediate downstream site D, and downstream revised site E) with consideration for backwater site I.

Mud Slough sites include four primary sites inclusive of approximately 6.6 miles. Site C is upstream of the SLD discharge. Sites D and TAC-revised site E are downstream of the SLD discharge. These three primary sites are CVRWQCB water-quality stations. Site I is a seasonal backwater (ponded) tributary of Mud Slough. Even though site I is a recent addition in regards to backwater documentation, backwater effects from the SJR have historically affected Mud Slough flow and flow measurements (see discussion on the reliability of the Mud Slough gage, pages 41-44 and pages 54-56).

Along with SJR sites, Mud Slough sites C and D are essential for determining the effect of discharges from the SLD on receiving waters. Mud Slough and Salt Slough have traditionally been considered together in the CVRWQCB historical databases due to the overall drainage system evaluation. Historical Mud and Salt Slough water-quality data including annual calculated loads are reported by the CVRWQCB in annual water-quality reports entitled *Agricultural Drainage Contribution to Water Quality in the Grassland Area of Western Merced County, California* (CVRWQCB, 1990a, 1991a, 1992a, 1993, 1995a, and b). Historical Mud and Salt Sloughs selenium concentration and flow data are available but have not been documented as to source and margin of error. A report will be issued to further document historical data for Mud and Salt Sloughs and the SJR by the CVRWQCB staff (personal communication, Les Grober). The CVRWQCB has provided USGS staff with a data disk containing the flow and selenium data used to calculate selenium loads from Mud and Salt Sloughs (see section "Availability of Baseline Data, Baseline Data for Mud and Salt Sloughs", pages 43-46).

Site C (Mud Slough approximately 600 yards upstream of SLD discharge) should be paired with site D to account for changes in flow, concentrations, and loads as a result of discharge from the SLD. Thus, flow measurements and water-quality sampling at these sites should be the same. The MP should be revised in this regard. For instance, the MP does not include flow measurements at site C.

Two further sources of discharge exist in the area just below the SLD discharge into Mud Slough (i.e., above site D) beside the contribution of upstream Mud Slough measured at site C. The sources are: (1) ground-water seepage from Kesterson Reservoir that hampered recent construction at the SLD terminus; and (2) a flow-through wetland discharge pipe on the north-east side of the SLD and Kesterson Reservoir installed as part of the continuing program of wildlife refuge management in this area. These two additional sources to Mud Slough could further complicate the interpretation of water-quality and flow conditions at site D in Mud Slough (i.e., below the SLD discharge). The USFWS has observed effects potentially attributed to the ground-water discharge from Kesterson Reservoir in the form of a significantly decreased invertebrate population and diminished vegetation as compared to previous sampling (USFWS, *Memo to GBCP file*, June 1996).

Site D (Mud Slough at footbridge approximately 400 ft below terminus of SLD near Gustine) is only about 100 yards downstream of the discharge of the SLD into Mud Slough. This seems too close to provide adequate mixing of the SLD discharge into Mud Slough. Thus, if a well-mixed site is desirable, we recommend that a site farther downstream, but upstream of the backwater conditions at site I, be considered.

The existing gage at Mud Slough at site D is operated and maintained by personnel of the USGS. Previous flow records for Mud Slough at the footbridge below the terminus of the SLD near Gustine are available (USGS station #11262900, USGS, 1985-1995, *Water Resources Data for California, Water Years 1985 through 1995, Southern Central Valley and the Great Basin from Walker River to Truckee River, Volume 3, USGS Water-Data Report, CA-85-3 to CA-95-3).* Standard methods of stream gaging as detailed in Meyer (1996) and Rantz et al., (1982) are used in the operation of site D on Mud Slough, as well as all of the sites operated by the USGS in the vicinity of the GBCP (Salt Slough and the San Joaquin River at Crows Landing). The Mud Slough site is prone to "backwater" effects because the stream has a very low gradient and is close to the confluence with the San Joaquin River. Backwater conditions occur when flow on the San Joaquin River is sufficiently high to increase the water level (increase the gage height) at Mud Slough, thereby reducing the gradient between Mud Slough and the San Joaquin River. Under these conditions, stream velocities are very low and highly variable in time, making accurate measurement extremely difficult.

The Mud Slough gage at site D should provide a 'good'[2] record during periods of moderate flow on the San Joaquin River, but will have "poor" accuracy when affected by backwater. By increasing the number of current meter measurements during backwater conditions the accuracy of the daily values will be increased, but the improvement cannot be accurately determined. Discharge measurements made during backwater conditions with mean velocity less than 0.25 feet

[2]"Excellent" means that about 95 percent of the daily discharges are within 5 percent of the true value; "good" within 10 percent, and "fair" within 15 percent. Records that are >15 percent are considered "poor".

per second (fps) are by definition "poor" (Sauer and Meyer, 1994). If the mean velocity is less than 0.20 fps, the measurement uncertainty cannot be calculated, but is greater than 15 percent. Because the backwater condition adversely affects stream gage height and measurements are "poor", the daily discharge values are considered to be estimates rather than measured flow.

As an example of the backwater problem, Mud Slough at site D was mostly in backwater for the period April 10 through July 17, 1995. Of the 12 measurements made during this period, 4 had mean velocities so low that uncertainty could not be computed (i.e., the velocity was outside the limits of the meter). The other eight had 7 to 10 percent uncertainty. Because backwater affects gage height, and is variable, the stage-discharge relation was unreliable. Therefore, calculated discharge for this period should be considered estimates rather than measured values.

The relation between one or two San Joaquin River gages and the Mud Slough gage stages should be determined. By identifying the stage on the San Joaquin River that initiates backwater at Mud Slough, the periods when more detailed measurements are necessary may be determined.

When backwater conditions are not present on the San Joaquin River, fewer measurements could be made with little reduction in accuracy.

Flow record quality at site D on Mud Slough will also be adversely impacted during periods of very low flow (< 3 cubic feet per second {cfs}). Under these conditions, record quality will be poor, with >15 percent uncertainty.

Streamflow records at site D on Mud Slough were estimated due to lost or faulty records about 6 percent of the time in the period 1990-94. All estimated records are "poor", with > 15 percent uncertainty. The amount of lost records are a function of the physical conditions at the site. Extra time, effort, and money are required to reduce the loss, or it will have to be accepted.

Site E (Mud Slough at HWY 140 bridge) will require special arrangements to measure flow and collect water-quality samples at times when flows are not confined to the channel. At these times, backwater and multiple flow lines may occur at this site. Out-of-channel flow conditions are common at this site during the fall-spring rainfall period. Only estimates of flow and water quality are possible at this site during such conditions. Thus, during such conditions, site E is questionable for meeting revised MP objectives concerning monitoring for impacts to Mud Slough. As suggested at the TAC, six intensive measurement periods per year overseen by USGS stream-gaging personnel may be an effective interim measure for which the Grassland Basin Drainers are willing to provide funds.

Site I is in a large backwater (ponded) area where flow measurements are not possible and would have little meaning. If water-quality information is desired at this site, sampling methods used for impoundments (lakes and reservoirs) would need to be used. The need for this site in relation to MP objectives including mass-balance understanding is questionable but it may be important for assessing potential biological impacts for impounded areas. An assessment of biological impacts for impounded areas would require a special study involving more than one site. Such a study is beyond the scope of the MP, but could be done to complement the MP. Thus, we recommend deleting site I for flow and water-quality assessment from the MP. The USFWS considers specific need of site I to assess biological impacts and has collected quarterly samples for biological monitoring in recent years (Henderson et al., 1995, *Assessing Selenium Contamination in Two San Joaquin Valley, California Sloughs, An Update of Monitoring for Interim Re-Use of the San Luis Drain,* USFWS, Sacramento, CA). Thus, this site should be retained by the USFWS for biological monitoring.

Wetlands and Salt Slough Sites

3) Grassland wetlands and Salt Slough [upstream sites J (Camp 13 Canal), K (Agatha Canal), L (San Luis Canal), and M (Sante Fe Canal); downstream Salt Slough site F].

Grassland wetland sites include upstream sites J (Camp 13 Canal), K (Agatha Canal), L (San Luis Canal), and M (Sante Fe Canal) and downstream site F (Salt Slough). Agatha Canal (site K) and Camp 13 Slough (Site J) previously contained alternating drainage water and wetland supply water under the flip-flop method of management. They are now primary sites used to assess the effect of continuous wetland supply water provided as part of the GBCP (i.e., beneficial impacts). Monitoring these sites will also ensure no agricultural drainage enters the Grassland wetlands. Two supply canals, the San Luis Canal (site L) and Santa Fe Canal (site M), are also primary sites that are included to define the effects of supply sources. Thus, all these sites are needed to meet the revised goals of the GBCP and objectives for the MP regarding documentation of improvements in environmental conditions in the Grassland wetland channels.

These four Grassland wetland sites are listed as either inflows or outflows in CVRWQCB's annual water-quality report *Agricultural Drainage Contribution to Water Quality in the Grassland Area of Western Merced County, California* (CVRWQCB, 1990a, 1991a, 1992a, 1993, 1995a, and b). These data are generally not documented as to source nor associated with flow data. Thus, calculation of error and loads is not possible from the historical data provided.

Salt Slough at Lander Avenue (HWY 165) near Stevinson is primary downstream Site F. This is a key site for assessing potential beneficial changes in flow and water quality as a result of the GBCP (i.e., drainage water removal), determining the loads of water-quality constituents of interest to the San Joaquin River from Salt Slough, and for calculating the mass loadings between the wetland canals and this site.

Flow measurements and water-quality sampling should be the same at wetland channel and Salt Slough sites. The MP should be revised in this regard. For instance, flow measurements are not shown for wetland sites, but are needed for calculation of loads to Salt Slough from these wetland canals and for determining a mass balance in the wetland area between influent supply water and wetland discharge.

The gage at Salt Slough site F will be operated and maintained by personnel of the USGS according to standard methods of stream gaging (Meyer, 1996, and Rantz et al., 1982). Previous flow records for Salt Slough at Lander Avenue (HWY 165) near Stevinson are available. (USGS station #1126110; USGS, 1985-1994, *Water Resources Data for California, Water Years 1985 through 1994, Southern Central Valley and the Great Basin from Walker River to Truckee River, Volume 3, USGS Water-Data Report, CA-85-3 to CA-94-3).* Conditions at this site are subject to backwater conditions as discussed above for Mud Slough. The Salt Slough gage should provide a "good" record during periods of low to moderate flow on the San Joaquin River, but will have "poor"accuracy when affected by backwater. Increasing the number of current meter measurements during backwater conditions will increase the accuracy of the daily values, but the improvement cannot be accurately determined. Daily discharge values calculated during periods of backwater should be considered to be estimates rather than measured flow. As for Mud Slough site D, an evaluation for the relation between backwater conditions at Salt Slough and gage height at nearby sites on the San Joaquin River can help determine when more detailed flow measurements will be necessary at Salt Slough.

San Joaquin River Sites

4) Historically relevant monitoring sites for the **San Joaquin River** from south (upstream of Mud and Salt Sloughs) to north (Vernalis, Use Agreement salinity station) are:

San Joaquin River [upstream secondary site at Lander/HWY 165/Stevinson); downstream site G (Fremont Ford), site H (Hills Ferry/Newman), and site N (Crows Landing, downstream of Merced River)], with consideration for SJR sites at Patterson Bridge and at Vernalis.

a) **SJR at Lander Avenue (HWY 165) near Stevinson** is listed as a secondary site in the MP. It is upstream of Mud and Salt Sloughs. The station is a Department of Water Resources (DWR) gaging station, and both a CVRWQCB (CVRWQCB, 1988, 1989, 1990b, 1991b, 1992b, and 1995c, *Water Quality of the Lower San Joaquin River: Lander Avenue to*

Vernalis, Water Years 1986 to 1994) and USGS (USGS station #11260815, USGS, 1985-1995, *Water Resources Data for California, Water Years 1985 through 1995, Southern Central Valley and the Great Basin from Walker River to Truckee River, Volume 3, USGS Water-Data Report, CA-85-3 to CA-95-3*) water-quality site. The USGS period of record is 1985 to 1995. This reach is referred to as the "dry reach" because most of the water in the SJR from Friant Dam is diverted upstream of this site. Historical loads for this reach of the SJR would be needed for calculating the total load to the SJR (e.g., at Crows Landing). Although Mud and Salt Sloughs are reported to account for an average of 86 percent of the selenium load to the SJR for WY 1986 to 1994 (CVRWQCB, 1995c, *Water Quality of the Lower San Joaquin River: Lander Avenue to Vernalis, October, 1992, to September, 1994, WY 1993 and 1994*) the remaining 14 percent to the load at Crows Landing has not been directly assigned to this upper portion of the SJR.

The SJR at Lander should be acknowledged as a DWR continuous flow monitoring station to be used for calculating loads upstream of Mud and Salt Sloughs and added as a primary site.

b) **SJR at Fremont Ford** is primary site G. It is a CVRWQCB (CVRWQCB, 1988, 1989, 1990b, 1991b, 1992b, and 1995c, *Water Quality of the Lower San Joaquin River: Lander Avenue to Vernalis, Water Years 1986 to 1994*), DWR, and BOR water-quality site. Flow was measured by DWR at least from 1970 to September 1982, but only recently by USGS (1986 through 1989) (USGS station #11261500, USGS, 1985-1995, *Water Resources Data for California, Water Years 1985 through 1995, Southern Central Valley and the Great Basin from Walker River to Truckee River, Volume 3, USGS Water-Data Report, CA-85-3 to CA-95-3*). If load calculations are made, comparisons could be made to historical data to determine change.

No flow gage exists now at site G (DWR personal communication, August 1996), but since site G is a primary site, consideration should be given to measurement of flow in order to calculate loads at this downstream station below the SLD but above the confluence with the Merced River.

c) **SJR upstream of the Merced River** is primary station H. This site is named SJR at Hills Ferry Road as a CVRWQCB water-quality monitoring site (CVRWQCB, 1988, 1989, 1990b, 1991b, 1992b, and 1995c, *Water Quality of the Lower San Joaquin River: Lander Avenue to Vernalis, Water Years 1986 to 1994*). It is downstream of Mud Slough and approximately 6 miles upstream of Crows Landing. This station is a USGS flow station (SJR at Newman, USGS station #11274000; USGS, 1985-1995, *Water Resources Data for California, Water Years 1985 through 1995, Southern Central Valley and the Great Basin from Walker River to Truckee River, Volume 3, USGS Water-Data Report, CA-85-3 to CA-95-3).*

Primary site H should be acknowledged as a USGS daily mean flow station to be used for calculating loads.

d) **SJR at Crows Landing** is primary site N. It is approximately 22 river miles downstream of the tributaries of Mud and Salt Sloughs and below the confluence with the Merced River. The Merced River is the main dilution water for the effluent-driven (i.e., agricultural drainage) upper reach of the SJR. This site previously has not been a USGS flow-monitoring station. Although a CVRWQCB water-quality site (CVRWQCB, 1988, 1989, 1990b, 1991b, 1992b, and 1995c, *Water Quality of the Lower San Joaquin River: Lander Avenue to Vernalis, Water Years 1986 to 1994*), flow data was only collected at this station for the period 1941 to 1971 by DWR. Because only three years (1970-1972) of flow data for the Crows Landing site is available for the period under consideration (CVRWQCB, 1994, *A TMML Model for the SJR*), much of the development of the TMML was done by comparing flow at Newman (above) and Patterson (below) and calculating a flow at Crows Landing. Traditionally this site has been difficult to obtain reliable flow measurements because of the configuration of the river. A new water-quality monitoring platform has been installed by the USGS and BOR (1995) to ensure measurement of a mixed sample and it will be the monitoring site for this project. The DWR gage house remains at the bridge at Crows Landing Road. This site or the reach of the SJR "from the mouth of the Merced River to Vernalis" is a critical compliance point on the SJR with a USEPA promulgated water-quality standard of 5 ppb Se (four-day average not to be exceeded more than once every three years) and of 12 ppb (one-hour average concentration not to be exceeded more than once every three years on average).

The new gage at the San Joaquin River at Crows Landing will be operated and maintained by personnel of the USGS according to standard methods of stream gaging (Meyer, 1996, and Rantz et al.,1982). The Crows Landing gaging station should, when fully operational, produce "good" daily value records. There is also the possibility of verifying the discharge at this site by combining the discharge of two upstream gages. The site requires boat discharge measurements that should result in a "good" flow record.

e) **SJR at Patterson Bridge** near Patterson is approximately 6 miles below the Crows Landing site and is not a GBCP primary monitoring station even though data are available. This site is a DWR gaging station with flow data gathered since 1938. It is also a USGS water-quality station since 1989 and continuing through 1995 (USGS station #11274570, USGS, 1985-1995, *Water Resources Data for California, Water Years 1985 through 1995, Southern Central Valley and the Great Basin from Walker River to Truckee River, Volume 3, USGS Water-Data Report, CA-85-3 to CA-95-3*). As stated by the CVRWQCB, "good data set is available", but these data have not been compiled. This site has received less attention because it is not a compliance point. The CVRQWCB is planning to evaluate historical selenium, salt, and boron loads because data from this site were used in development of the TMML.

The SJR at Patterson Bridge should be acknowledged as a DWR gaging station and this flow data should be used to calculate loads.

We recommend that the five aforesaid SJR sites be primary sites that have the same flow measurements and water-quality sampling design because they are needed to determine changes in concentrations and loads of water-quality constituents of interest in the SJR as a result of the GBCP. They also are needed to determine a mass balance for the SJR in the vicinity of the GBCP.

g) **SJR near Vernalis** is approximately 15 miles downstream of Patterson station and a total of approximately 60 miles downstream from Sack Dam, the furthest upstream site considered in the "lower reach of the SJR". This station is a USGS gaging station (USGS station #11303500, USGS, 1985-1995, *Water Resources Data for California, Water Years 1985 through 1995, Southern Central Valley and the Great Basin from Walker River to Truckee River, Volume 3, USGS Water-Data Report, CA-85-3 to CA-95-3*). Although not listed in the MP as a primary or secondary site, this site is to be "monitored and analyzed on a monthly basis" as stated in the Use Agreement (page 6) because salt loads are not to increase due to the GBCP. Data is available, but not compiled. Calculated loads for selenium, salt, and boron are available because this is a compliance point for downstream water users and federal and state water contractors for salt loads, i.e., salinity. Calculated annual load values are available in CVRWQCB's annual reports *Water Quality of the Lower San Joaquin River: Lander Avenue to Vernalis*, although these reports contain no details of source nor accuracy of calculations (CVRWQCB, 1988, 1989, 1990b, 1991b, 1992b, and 1995c).

We recommend this site be included as a primary site in the MP because of the necessity of calculating salt loads in accordance with the Use Agreement and to better understand long-term loading of selenium, salt, and boron to the SJR.

Source Load Sites

5) Primary agricultural subsurface **sumps** (upstream) and agricultural **drains** (downstream) as source inflows to the SLD from the GDSA at the check 19 inlet structure.

Primary agricultural subsurface **sumps** that collect and discharge subsurface agricultural drainage are not included in the MP. An estimate of source drainage is needed to assess effects of major changes to farming practices in order to meet the Environmental Commitment to "ensure that progress continues toward long-term resolution of drainage-management issues" (SEA, page 4). Documenting and understanding load reduction is crucial to the success of the GBCP. A 47-80 percent load reduction is needed in the **Grassland Drainage Service Area** (DSA) to meet water-quality standards in the future (CVRWQCB, 1996, *Staff Report for Control of Agricultural Subsurface Drainage Discharges in Draft Amendments to the Water Quality Control Plan for the Sacramento and San Joaquin River Basins*).

The relation of source loads to compliance loads may be illustrative of selenium's conservative or non-conservative behavior. For example, the loads measured from the DSA, Mud and Salt Sloughs, and the San Joaquin River at Crows Landing are different (CVRWQCB, 1995c, *Water Quality of the Lower San Joaquin River: Lander Avenue to Vernalis, October 1992 to September 1994, Water Years 1993 and 1994*). Further: "Water quality in Mud Slough, Salt Slough, and the San Joaquin River upstream of the Merced River does not improve in response to pollution load reduction", (page 9, CVRWQCB, 1995d, *Staff Report on Beneficial Uses Designations and Water-Quality Criteria to be Used for the Regulation of Agricultural Subsurface Drainage Discharges in the San Joaquin Basin*). A recent evaluation of various actions that might reduce drainage stated the limitations of existing data on source sumps (i.e., "the use of a single value to represent selenium tile drainage concentrations is based on lack of data, rather than a reflection of actual conditions", CVRWQCB, 1996, page 156). Limitations also exist in source data for estimation of an overall drainage reduction in terms of subsurface tile drainage, tail water that may include recycled tile drainage water, and surface drainage (Appendix B, CVRWQCB, 1995e, *Staff Report on the Water Quality Objectives and Implementation Plan to be Used for the Regulation of Agricultural Subsurface Drainage Discharges in the San Joaquin River Basin;* and Appendix 3, CVRWQCB, 1996, *Staff Report for Control of Agricultural Subsurface Drainage Discharges in Draft Amendments to the Water Quality Control Plan for the Sacramento and San Joaquin River Basins*). Because of the lack of causal connections between source-load reductions and water-quality improvements, we recommend that source sumps be included as an integral part of the MP.

Due to resource limitations however, we recommend that the sump sites not necessarily be designated as primary sites. Rather historical (e.g., annual reports of sumps prepared by the

CVRWQCB, Grassland Water District, and DWR) and future data should be tabulated and documented as to source and margins of error and included as part of the monitoring program data given to the Oversight and Technical Advisory Committees. An attempt should be made to document discharge (flow) from these sumps during subsequent collections. Water and drainage district managers should submit their data used to estimate loads in order to determine effects from changes in management techniques. This type of data is annually available as part of the Drainage Operation Plans (DOP) and/or Best Management Practices (BMP) documentation required by the CVRWQCB as part of its Basin Plan Amendments for Water Quality Control for the San Joaquin River Basin.

As discussed by the TAC, six agricultural **drains** will discharge into the SLD inlet at check 19. These drainage outlets from the Grassland drainage entities are listed as routine monitoring sites for internal drainage management and are secondary sites in the GBCP. These drains as reported by the CVRWQCB in 1995 include: Main (Firebaugh) Drain; Panoche Drain; Hamburg Drain; Charleston Drain; Almond Drive Drain; Rice Drain; Boundary Drain. The six drain sites referred to by the Drainers as discharging into the newly constructed SLD inlet at check 19 are depicted on a *Location Map* provided by Summers Engineering that shows the following connections: from the Panoche Drain: from Firebaugh, Broadview, Widren, and Camp 13; and from Pacheco and Charleston (i.e., from seven draining entities). The six (or seven) drain sites should be included as primary monitoring sites as suggested by both the USGS and USEPA. These sites should be correctly documented as to location and number in the MP; listed both as primary sites and as sites routinely monitored as part of the Grassland Basin (Grassland Water Task Force data and CVRWQCB, 1990a, 1991a, 1992a, 1993, 1995a, and b); and the historical and on-going water-quality and flow data compiled and included as part of the GBCP database.

Assessment of the Timing of Flow and Water-Quality Monitoring

As stated previously, without an assessment of historical conditions to establish and determine intrinsic variability, only interim (de facto) recommendations can be provided of a general nature.

Better founded and more specific recommendations can be expected from the suggested TAC assessment of historical data.

The timing of flow measurements and water-quality (dissolved and suspended phase) samples is important to ensure that sufficient data are collected to meet the goals of the GBCP and objectives of the MP including the determination of mass balances and changes in concentrations and loads of water-quality constituents in the GBCP area and receiving waters. Where possible, continuous flow measurements are recommended for primary sites to account for flow variability and provide data needed for calculating loads and determining mass balances for water-quality constituents of interest. As stated previously, continuous flow measurement is not possible at sites E and I because of ponded, backwater, or other unsuitable channel or flow conditions.

Water-quality samples should be collected to account for variability in concentrations, loads and mass balances of water-quality constituents of interest (primarily selenium, salt, and boron). Characterization needs to be done on a routine (calendar) and a management and critical-periods basis. Management periods would include pre-irrigation, irrigation, drainage release, and wetland release. Critical periods would include flood (high flow), drought, and stagnation resulting in algal blooms.

A monthly sampling frequency is recommended for routine monitoring of dissolved and suspended inorganic matter at primary sites because this frequency allows year-around coverage that most likely will account for changes in water quality not associated with management or critical periods. During the irrigation season (April-September) weekly sampling (one of which would coincide with the monthly sampling schedule) is recommended to account for water-quality changes during this period of expected greater variability in water quality because of changes in water application quantities to crops, which affects salt leaching of soil. Weekly sampling also is recommended for other periods (e.g., pre-irrigation, drainage release, wetland release, and stagnation resulting in algal blooms).

Floods (high flows) are a special case that might require more frequent sampling to account for the variability in water quality during these flow conditions. Inflows of flood water into the SLD and other conveyances in the GBCP could scour channels and resuspend bed sediment, thus increasing loads and changing mass balances. Composite samples collected at frequent (e.g., hourly) intervals on a daily basis are recommended for such events (Horowitz, 1995). If composite samples cannot be collected (e.g., because no automatic sampler is available at a site), then at least a daily grab sample should be collected.

Suspended organic matter should be collected weekly at sites A and B during the irrigation season and other times when large quantities of algal clumps and/or organic floc are present in the SLD. At other times, monthly sampling probably would be sufficient. These samples would allow a calculation of this component of load to the overall load of selenium and boron transported by the SLD and would be needed for mass-balance determinations in the SLD. Collection of such samples at primary sites in Mud and Salt Sloughs and the San Joaquin River is not possible until a suitable method of collection for suspended organic matter is developed for sloughs and streams (i.e., natural channels).

Because site B is the primary selenium load compliance point for the GBCP, daily water samples for selenium are needed there to adequately characterize monthly and seasonal loads of selenium in the SLD that are discharged to Mud Slough. In order to compare concentrations and loads of selenium between sites A and B and to obtain a valid mass balance in the SLD, the sampling frequency at site A should be the same as site B. Thus, daily water samples for selenium should be collected at site A. Because site N (SJR at Crows Landing) is the compliance point for the SJR and is the site upon which TMML load caps were calculated, this site also should be sampled daily for selenium in water.

In summary, the main differences between our recommendations and what is described in the MP regarding temporal design are:

1) Continuous flow measurements at all primary sites except where backwater, channel, or flow conditions prohibit such measurements.
2) Monthly water-quality samples for routine monitoring.
3) Daily water samples for selenium at site A.
4) Weekly monitoring samples for management or critical periods, except for floods.
5) Daily water quality during floods (high flow).

Our recommendation would result in more consistency in flow measurements and water-quality sampling than described in the MP, and thus could better meet the revised goals of the GBCP and objectives for the MP.

Assessment of Water-Quality Variables to Monitor

Based on the goals and objectives of the MP, which are derived from the environmental commitments in the Use Agreement, Consensus Letter, FONSI, and SEA, the main variables to monitor in water, suspended matter, and bed sediment are selenium, salt, and boron. The MP is appropriately focused on these variables. To provide compatibility among selenium, salt, and boron analyses and facilitate mass-balance calculations the following recommendations are made.

Salt or Dissolved Solid Load and Boron

The preferred method for determination of dissolved salt is the sum of major cations and anions on EWI or EDI water samples that are field filtered and preserved (also see section "Assessment of Samplings and Analytical Methods", pages 84-93). These analyses would include: Na, K, Ca, Mg, sulfate, chloride, and bicarbonate (plus silica and boron, if ionized). Carbonate hardness, sulfate, and pH also are important to monitor because they affect the biological toxicity of contaminants.

If resources are limited, both field electrical conductance (EC) and laboratory dissolved solids could be measured instead of analyzing major ions individually. Whether or not EC and dissolved solids are substituted for analyses of major ions, field electrical conductivity on EWI or EDI water samples should be measured and an analysis for dissolved solids should be made. The meter should be calibrated against known standards and corrected for temperature to obtain specific conductance (SC) data. Water temperature measurements also should be made to help assess the biological productivity and toxicity of the waters sampled. If continuous EC measuring equipment is available at a site, the meter should be calibrated often and calibration documentation made available with the data. Applied factors for conversion to milligrams per liter (mg/L) of dissolved solids should be documented. Laboratory dissolved solids on EWI or EDI water samples that are field filtered should be measured. These values should be compared to SC values as a check on calculated versus measured mg/L dissolved solids.

Boron as a water-quality constituent of interest is important from a management standpoint because of the sensitivity of plants to elevated boron levels (USEPA irrigation water criterion of 750 ppb boron for long-term irrigation of boron-sensitive crops, USEPA, 1986). Excessively high concentrations of boron (>50,000 ppb) can occur in drainage water depending on factors that include geologic sources (Presser and Barnes, 1985; Fujii et al., 1995). Boron levels may correlate to dissolved solids (salt), but the relation may be affected by such variables as drainage reuse and opportunities for uptake and evaporative deposition. Boron concentrations may be limiting concentrations in regards to drainage management depending on whether adopted project water-quality objectives are greater than that promulgated by USEPA (CVRWQCB as proposed in 1995: 2,000 ppb monthly mean and 5,800 ppb maximum). Concerns may thus extend to downstream water-use, to wetland channel ecosystems, and diminishing vegetation. Therefore, documentation of short- and long-term trends in dissolved boron concentrations should be part of the MP.

Selenium

Water-borne or total dissolved selenium on water samples that are field filtered and preserved should be measured. In addition to total dissolved selenium (which includes selenate, selenite, and organic selenide), the following determinations should be made for speciation of selenium: oxidized dissolved selenium (operationally defined as selenate) and reduced dissolved selenium (operationally defined as selenite and organic selenide). Total dissolved selenium can be measured on a digested, filtered, acidified water sample using hydride generation atomic absorption spectrophotometry (AAS). Reduced dissolved selenium can be measured on an undigested, filtered, acidified water sample using hydride generation AAS. Oxidized dissolved selenium would then be calculated as the difference between the two measurements (Presser and Barnes, 1984).

Selenium concentrations in suspended matter (inorganic and organic) should also be determined so that this component of selenium load can be calculated for transport and mass-balance assessments.

Total or total recoverable selenium may be measured if regulation necessitates. Collection of a "whole" water sample dedicated to total selenium should be taken (i.e., the entire volume of sample collected should be analyzed) due to the difficulties encountered in removing a "representative" aliquot of a homogenized sample for selenium analysis (see additional discussion on pages 84-93 and 94-95).

Bed Sediment

Baseline Conditions

San Luis Drain

Bioaccumulation was a mechanism operating in the SLD during its use to convey subsurface drainage water to KNWR because elevated levels of selenium in the SLD sediment cannot be explained by primary or secondary source material (T.S. Presser, USGS, 1995, *Memo to TAC Committee on Re-use of the SLD*; BOR, 1995e, *Final Report Task Group on Initial Use and Operation of the SLD, Appendix 1, Environmental Effect Levels).* Hence, the SLD acted as a biological reactor (or treatment process) during the period of its initial use whereby selenium was removed from the drainage water and accumulated in bed sediment and biota as agricultural wastewater flowed in the SLD.

In general, sediments and rooted plants facilitate establishment of a substantive food chain that increases primary productivity by at least an order of magnitude and therefore, selenium accumulation. This, in turn, greatly increases risk to biota. The San Joaquin Valley Drainage Program (SJVDP) (Moore et al.,1990) concluded that benthos represented the most contaminated biomass in the food chain thereby adding considerably to risk as compared to that provided only by an aquatic environment.

A continuing history of the processes occurring in the SLD is provided in the chemical characteristics of the bed sediment residing in the SLD. These processes include those occurring during its initial operation in which subsurface agricultural drainage water was flowing from 1981 to 1986; its closure in which it acted as an evaporator and seepage collector from 1987 to 1994; and its use during flooding in WY 1995 in which it acted as a conduit for flood and drainage water. Analyzing bed-sediment of the SLD may elucidate controls on selenium partitioning and flux occurring in the sediment phase.

The SLD check structures (control structures located approximately at 1-mile intervals for flow management consisting of, in part, removable boards to regulate flow incrementally) present unique sampling opportunities in regards to sediment collection. Figures 2 and 3 shows the sediment distribution in the SLD reach between checks 10 and 11 and the reach between checks 15 and 16 as measured in September 1994 (data from BOR, 1995e, *Final Report, Task Group on Initial Use and Operation of the SLD*). Distribution is similar within the reaches, showing sediment accumulation at both the downstream and upstream ends. Less sediment is distributed in the center of each reach sampled.

The inventories of the SLD sediments per reach have been recently provided by Summers Engineering as part of the TAC process (2/27/96) and by the San Luis and Delta-Mendota Water Authority (August 1995). Sampling of consistent depositional areas within accurately specified reaches of the SLD is important to determine a complete mass balance including the amount of selenium in bed sediment. Obtaining representative selenium concentrations will be difficult based on the spatial variability indicated by the sampling record (figs. 2, 3, and 4). Areas of accumulation and reducing conditions need to be differentiated from areas of scour and oxidation to accurately represent the mass of selenium residing in the SLD sediment at any one time.

Sloughs, Wetland Channels, and San Joaquin River

Documentation of selenium concentrations in bed sediment of the Grassland wetland channels, Salt Slough and the SJR will help determine accumulation or loss of selenium among these sites, and hence, a mass balance of selenium. These data will also help identify variables (e.g., flow) and processes involved in the accumulation (e.g., sedimentation, bioaccumulation, etc.) or loss (e.g., diversions, volatilization, etc.).

Approximately 70,000 lbs of selenium has been discharged to the SJR from Mud Slough, Salt Slough, and the "upper" reach of the SJR during 1986 to 1994 from the Grassland Basin as measured at the SJR at Crows Landing [summation of data from CVRWQCB annual reports *Water Quality of the Lower San Joaquin River: Lander Avenue to Vernalis and Agricultural Drainage Contribution to Water Quality in the Grassland Area of Western Merced County, California WY 1986 to WY 1994* (CVRWQCB, 1988, 1989, 1990a and b, 1991a and b, 1992a and b, 1993, 1995a, b, and c)]. As previously stated, an additional 15,500 lbs was "lost" through "in-transit" losses in the Grassland wetland channels from WY 1986 through WY 1994 (SEA, fig. 4). Effects in bed sediment from this loading have not been documented. Potential mechanisms that could currently affect bed-sediment selenium concentrations of the Grassland wetland channels, Salt Slough, and the SJR include: (1) "load attenuation" through bioaccumulation of selenium from water into bed sediment; (2) chemical adsorption/precipitation of selenium into sediment; (3) diffusion of selenium into reducing sediment; (4) deposition of sediment containing selenium in areas of reduced flow velocity; (5) depuration of bed-sediment selenium loads to the water column through oxidation or diffusion resulting from freshwater flushing or changes in dispersion plume geometry and chemistry; and (6) scour of bed sediment resulting in suspension and transport of selenium downstream.

A mobilization or depuration mechanism was hypothesized to be operating during the emergency discharge of the SLD in WY 1995 due to flooding (i.e., high-flow conditions). During this time the SLD acted as a conduit for flood water into the San Joaquin River which included runoff from the Coast Range that was expected to contain elevated selenium concentrations. Approximately 1,746 lbs of selenium were discharged to the SJR during that flood event mainly from the SLD, Mud Slough, and Salt Slough. However, an additional spike of 120 ppb Se was seen in the SLD during that flood event with a downstream concentration of 33 ppb in Mud Slough. Sources of this additional selenium include: 1) upper watershed streamflow/runoff; 2) subsurface drainage; or 3) mobilization from sediments. Mobilization of selenium from the sediments triggered by mechanical stirring in the SLD was thought the most probable mechanism (testimony at CVRWQCB public hearing, Fresno, CA, May 26, 1996).

The effect of flow regime changes may also be seen in the recent selenium concentrations measured in bottom sediments in Mud Slough, Salt Slough, and the Agatha Canal. In the 14-month study of Agatha Canal, a canal operated under the flip-flop system, no consistent loss nor build-up of selenium was seen in sediments and vegetation (SEA, page 29). However, this conclusion was not based on a mass-balance determination. Sediment values in Mud and Salt Sloughs and East Big Lake, all of which have been exposed to drainage water and wetland supply water on an alternating schedule (flip-flop system), show low levels of selenium. These values, on average, are below the concern level (4 ppm Se) and in the "no effect zone" (< 2 ppm Se)

(Henderson et al., 1995, *Assessing Selenium Contamination in Two San Joaquin Valley, California Sloughs, An Update of Monitoring for Interim Re-use of the San Luis Drain*, USFWS, Sacramento, CA). In general, natural sloughs and channels would be exposed to greater thorough-flow from surrounding ground-water systems than those of concrete-lined channels. According to the USFWS, a sediment sample from East Big Lake had a concentration of selenium 2X or 3X higher than at Mud and Salt Sloughs. Factors to be considered as potentially responsible for the enrichment of selenium at this site may be flow and also that the site is a depositional area with consistent layering of fine-grained organic sediment and more reducing sediment conditions.

However, based on USFWS data from a biota standpoint, selenium in fish during 1992 and 1993 in Mud and Salt Sloughs had elevated concentrations of selenium (Henderson et al., 1995, *Assessing Selenium Contamination in Two San Joaquin Valley, California Sloughs, An Update of Monitoring for Interim Re-use of the San Luis Drain*, USFWS, Sacramento, CA). In Mud Slough 77 percent of the fish samples were in the level of concern zone and 85 percent of the fish samples from Salt Slough were in the level of concern range. USFWS's overall concern for the GBCP is that Mud Slough selenium concentrations do not move into the red zone (toxicity threshold exceeded) and Salt Slough selenium concentrations return to background levels (no effect zone). These USFWS levels of concern (zones and ranges) were approved by the SLD Re-Use Technical Advisory and Oversight Committees as *Recommended Ecological Risk Guidelines Based Upon Selenium Residues* (Henderson et al., 1995, *Assessing Selenium Contamination in Two San Joaquin Valley, California Sloughs, An Update of Monitoring for Interim Re-Use of the San Luis Drain*, USFWS, Sacramento, CA) to be used in evaluating impacts of the GBCP.

Conceptual Basis for Monitoring

The overall questions concerning selenium in the SLD are related to downstream movement, risk assessment to biota, and creation of a hazardous waste. The juxtaposition of an oxidizing, alkaline water or *source* (agricultural drainage water) and a reduced bed sediment or *sink* (accumulated bed sediment) occurs within the SLD. This association has been shown on a wetland scale to lead to a repetitive cycling in water, sediment, and biota of a net mass of selenium (or other trace elements), thus making selenium continually available for biological assimilation (Presser et al., 1995; Fujii et al., 1995). In such environments, oxidation/reduction boundaries, to some extent, lead to a partitioning of selenium in soluble and particulate forms and hence mobilization or accumulation in water, sediment, and biota.

Oxidizing or reducing conditions in SLD sediment are dependent on penetration of oxygen from the water column into the bed sediment. The net flux of organic matter is dependent on biological activity and the balance between primary producers (algae) and primary consumers (bacteria) in the bed sediment. For selenium, biological reactions have proven to be much faster and utilize selenium more efficiently than chemical reactions (Oremland et al., 1989). Thus biologically active layers in the bed sediment are sites of selenium transport or deposition.

Luoma et al., (1992) identified a surficial bottom layer of 0 to 3 cm as being important as an indictor of toxicity and in defining selenium toxicity standards for ecosystems. This layer includes: 1) benthic microalgae and microbial biomass; and 2) non-living organic materials associated with fine-grained surficial sediment. The authors define 1.0 to 1.5 ppm selenium for particulates as a limit in this layer for protection of aquatic life based on their measurement of 22 percent (elemental selenium) to 86 percent (particulate organo-selenium) being bioavailable. Even though biota may exhibit a preference for a particular selenium species, a high-exchange rate and cycling of selenium species between reservoirs (pools) including water, sediment, and biota, therefore makes all selenium species potentially available. Amounts of suspended sediments transported downstream also may be of importance to define ecosystem protection. Luoma et al., (1992) conclude that "selenium clearly requires a protective criterion based upon particulate concentrations or food web transfer". In the "Ecological Assessment Guidelines" by the SFBRWQCB, (1993) both a suspended material guideline of 0.7 ppm organic selenium and a bed sediment guideline of 1.5 ppm selenium are considered.

Samples collected at the bed-sediment/water interfaces may be good indicators of oxidation/reduction processes at this boundary. A general pattern of decreased concentration of selenium in the top bed-sediment layer in the SLD as compared to the middle and bottom layers (fig. 4) as defined by the 9/94 bed-sediment survey is opposite of traditional theory. This phenomenon may be due to oxidation taking place at the bed-sediment/water interface and hence mobilization of selenium into the water column and/or diffusion of selenium into subsurface reducing bed sediment. Another hypothesis is that more elevated biota were trapped in the bed sediments sometime in prior history when drainage water was flowing. The relation of organic carbon to selenium (BOR, 1995e, *Final Report Task Group on Initial Use and Operation of the SLD*) unfortunately does not elucidate this route of selenium transfer further (correlation coefficient of -0.04). A second source of water (e.g., surrounding ground water infiltrating into the bottom of the SLD through weep valves provided for canal equilibration) may be a complicating factor that lessens the effect of the other mechanisms. However, further elucidation of the relation between selenium and organic carbon might be possible by continuing to include organic carbon analyses of bed sediment in the MP.

These considerations lead to specific questions of (a) bioavailability and thus speciation or form of selenium present in solid and aqueous phases; (b) evaluation of the total mass of selenium and variability within that mass; and (c) flux of selenium at interfaces and partitioning between phases. The rate of biological processes (biological activity) are dependent to some degree on flow conditions. No flow (stagnation), low flow (accumulation in bed sediment), or high flow (bed-sediment re-suspension) of drainage water over accumulated bed sediment may be determinants in transport of both sediment and selenium. Thus, predictions of transport based on a conservative-element-dilution model may show greater, or at other times less, variation when applied to variable flow, biologically active systems (e.g., evaporation ponds versus streams or rivers). Also, an assumption of steady-state conditions may not be applicable to natural systems that are subject to seasonal and intermittent management-induced variations. A mass-balance sampling design, when accompanied by a sampling protocol that takes into account flow variations, can account for changes in natural and management-induced biological activity. In conclusion, bed-sediment sampling should be done in a mass-balance context for the SLD. All relevant phases of selenium transport should be included.

Assessment of Bed-Sediment Monitoring

San Luis Drain

The sediments accumulated in the SLD have been classified as a "designated waste" for regulatory purposes (BOR, 1986, *Kesterson Program EIS*). Removal of accumulated sediments in the SLD was recommended as part of the GBCP as originally conceived by the San Joaquin Valley Drainage Program (SJVDP, 1990), but was never carried out. Therefore, sediments in the SLD are to be managed. An estimated 55,788 cubic yards of sediment have accumulated in the 28-mile section of the SLD to be re-opened [San Luis and Delta Mendota Water Authority, (SLDMWA), 1996].

In terms of mass balance, the SLD bed sediments may either accumulate selenium from the drainage water or depurate selenium into the water. If 44 ppm selenium is the average concentration of selenium in the accumulated bed sediment (T.S. Presser, 1995, *USGS Memo to TAC Committee on Re-use of the SLD*), BOR, 1995e, *Final Report Task Group on Initial Use and Operation of the SLD, Appendix 1, Environmental Effect Levels;* then approximately 4,600 lbs of selenium is currently contained in the SLD bed sediments.

Concentrations of selenium in bed sediment in the SLD (figs. 2, 3, and 4) through recent surveys (BOR, 1995e, *Final Report, Task Group on Initial Use and Operation of the San Luis Drain*) have been shown to vary greatly between checks (e.g., checks 1-2, 10-11, 15-16, 27-28) and within a check structure (upstream, middle, downstream of checks 10-11 and 15-16). Within the check, selenium concentrations vary with depth, longitudinally, and latitudinally (fig. 4). Although percent recoveries are within acceptable precision, replicate sampling shows up to a 100 percent relative percent difference. According to a statistical power analysis performed by the

USFWS and presented at the TAC, to detect a 25 percent change in selenium concentration in bed sediment in check 10 given the variability in the concentration, 138 samples would be needed. It was concluded that the sampling schedule used in the initial start-up monitoring plan (check 1-2, check 10-11, check 15-16, check 27-28 for the previously considered 34 miles of the SLD to be reopened) would only show gross differences. To implement a sampling plan to define a smaller increment of change may be cost prohibitive. The variability of organic carbon analyses among and within checks (fig. 5) as mentioned previously, is also great and not readily interpretable.

Distribution of boron in SLD bed sediment is shown in figure 6 for sampling surveys completed in 1993 and 1994. The significance of these highly-elevated levels of boron (up to 150 ppm boron) occurring in SLD sediment when compared to a geometric mean concentration for soils in the western United States (23 ppm boron) and the dominant form of boron for transport has not been considered previously in documentation of the SLD.

As also discussed by the TAC, one of the goals of bed-sediment monitoring is to make timely management decisions. The SLDMWA would remove bed sediment if it impeded flow in individual checks. The BOR wishes to know when the bed-sediment selenium concentrations are approaching the California hazardous waste level (100 ppm, wet weight) so they know when to remove bed sediment in particular reaches. The suggested trigger was 80 ppm, wet weight. Bed sediment in the SLD has reached 62 ppm, wet weight and 146 ppm dry weight (no percent moisture given) in recent samplings. In addition to the California hazardous waste criterion, the USDOI National Irrigation Water Quality Program has suggested 4 ppm selenium, dry weight, as a guideline for concern in bed sediment.

As stated by the CVRWQCB, compositing the whole core sample would address the issue of sampling to determine a hazardous waste. However, as suggested by the USGS to the TAC, a detailed incremental sampling of bed-sediment layers (at 5 cm increments of an entire core) would elucidate the processes occurring within the SLD bed sediment that includes mobilization and oxidation/reduction over the longer term. The question of variability and how to sample to detect and determine a rate of change applicable to compliance with environmental commitments o the GBCP is unresolved by the TAC.

Sampling sites selection should be based on the recent inventory provided by Summers Engineering (Feb. 1996) and by the SLDMWA (1995). Previous selection of sites was based on periodic sampling by the BOR at check reaches 1-2 and 10-11. Additional sampling at check reaches 15-16 and 27-28 took place because of previously considered drainage inlet structures planned for the GBCP. Recent revision by the TAC has resulted in additional sampling sites at: 1) in-between the inlet structure at check 19 and the flow and water-quality station at check 17; and 2) at check 18 where a large amount of bed sediment has accumulated that might impede flow. An additional number of check reaches should be sampled in order that check-by-check goals could be set in regards to sediment removal and environmental commitments. Bed-sediment sampling site locations should be re-thought based on the recent inventory of the SLD in order to obtain cores of > 1 foot (approximately 30 cm) to elucidate the processes occurring in the SLD that include mobilization and oxidation/reduction over the longer term. The amount of bed sediment (cubic yards) represented by each sample should be calculated.

We recommend that the TAC conduct an assessment of bed-sediment sampling-site locations based on the following:

1) compare field observations to bed-sediment inventory
2) determine areas of deposition and areas of scour
3) determine a method of accurately locating bed-sediment sampling sites (as discussed by TAC)
4) select either a check reach or a single point sampling site
5) determine bed-sediment thickness
6) calculate the amount of bed sediment represented by a sample at a site
7) determine check-by-check goals for sediment removal
8) determine if land-use adjacent to individual checks is an important variable for sediment

accumulation and hence management

It is further noted that collection of a bed-sediment sample at sites A and B in the SLD may be problematic. Site A is at check structure 17, a probable area of downstream deposition. However, sampling may be difficult because no bridge has been constructed to provide a sampling platform for centroid sampling. Sampling from a raft may be difficult because of the installation of flow and water-quality monitoring equipment. Therefore, a designated sampling location should be selected at this site in order to provide a consistent sampling record. Site B is located at the midpoint of the terminus reach of the SLD. A bridge has been constructed to provide a stable platform for flow and water-quality monitoring equipment. This area, however, is predicted not to be an area of deposition based on its position midway between a check structure (e.g., see figs. 2 and 3). Sampling further downstream may be affected by the flow dispersion structure constructed at the outlet from the SLD. Therefore, the exact location for bed-sediment sampling at site B in order to obtain a representative quarterly sample needs to be determined.

Until the amount of intrinsic variability is better assessed and the aforesaid process for selection of sampling sites is done by the TAC, final guidance on bed-sediment sampling cannot be provided. However, interim (de facto) guidance is needed because the MP will need to start with the initiation of the GBCP in August 1996. The following recommendations are based on suggested revisions to the MP made by the TAC in February 1996:

1) Sampling locations at a site:

   Three sampling locations longitudinally along a check reach: downstream, middle, and upstream;

   Three samples across individual checks composited for 3 depths: 0-3 cm, 3-8 cm, and composited whole core to bottom;

2) Sampling frequency:

Routine quarterly sampling at primary sites A and B.

Annual intensive sampling

3) Sampling site locations and variables to monitor:

On a quarterly basis, samples should be collected as recommended by the TAC.

On an annual basis, samples should be collected at four check reaches (reaches between checks 1-2, checks 10-11, checks 15-16, checks 17-18) and two single-point sites (terminus and check 18) to correspond with one of the routine quarterly samplings at sites A and B. [total sampling locations = 14; total number of samples = 42; amount of sediment represented per sample: 1,328 cubic yards of sediment (55,788 cubic yards of sediment from the terminus to check 19].

The samples should be analyzed for selenium, organic carbon, boron, and grain size.

On an annual basis, within a check to be monitored, samples should be collected in known areas of deposition of > 30 cm (i.e., approximately one foot) of sediment. A complete detailed core (undisturbed top 2.5 cm; then each 5-cm interval) should be collected and analyzed for selenium, organic carbon, boron, and grain size. The core intervals should be documented as much as possible through detailed examination and logging procedures performed on site at the time of sampling.

Areas of < 30 cm (i.e., one foot) deposition in the middle of the check reach or in areas of scour, should also be sampled because of the elevated concentrations documented in recent bed-sediment surveys (e.g., 48 ppm and 63 ppm Se) in these areas. In areas of < 30 cm deposition, composited cores should be taken and analyzed for selenium, organic carbon, and grain size.

4) Critical period sampling: To document the effect of a flood, drought, stagnation resulting in algal blooms, etc, the sampling protocol is the same as for the annual intensive sampling. Sampling site locations would be primary sites A and B and on a reasonable number of depositional sites based on location of event inputs and outputs.

Sloughs, Wetland Channels, and San Joaquin River

As stated under "Sediment Monitoring" in the November 1995 Draft MP by the BOR (page 32), bed-sediment samples have been collected quarterly by BOR for selenium and boron analyses at primary Mud Slough stations C, D, E, and I and Salt Slough. However, table 2 notes only bed-sediment sampling by the USFWS since 1992 at stations C, D, and F, quarterly and Station I, annually. These data should be correctly documented and compiled for background assessment.

No background bed-sediment samples are noted for the SJR in table 2 of the November 1995 Draft MP. As discussed at the TAC meetings, the CDF&G have sites for bed-sediment collection in the SJR. These data should be documented and compiled. BOR/LBNL is concluding a 14-month study of the Agatha Canal system during which, according to table 2, bed-sediment samples were collected. Both of these sets of data should be documented and compiled.

Currently recommended in the November 1995 Draft MP by the BOR is one bed-sediment sample per quarter at slough sites C, D, E, and F, with no San Joaquin River or wetland sites sampled. The slough sites are important to sample to document changes in selenium and boron concentrations as a result of the GBCP and for mass-balance determinations. The same is true for recommended SJR and wetland sites (see "Assessment of Monitoring Site Locations" pages 59 and 60-64). Thus, quarterly sampling of bed sediment also should be done at these sites.

However, long-term trends in the Mud Slough, Salt Slough, Grassland wetland channels, and the SJR, may be difficult to assess due to changing channel geometry and mixing patterns during high and low flows. Short-term bed-sediment sampling is dependent on flow variables (e.g.,volume and duration), especially in the San Joaquin River. The relation between flow and selenium concentrations in bed sediments needs to be determined. Bed-sediment sampling could also be done in conjunction with invertebrate sampling. Thus, we recommend a field site visit to assess sampling site locations in cooperation with the CDF&G who have been funded for a continuing study of biota and sediments in Mud Slough, Salt Slough, and the San Joaquin River.

Assessment of Sampling and Analytical Methods

Correct sampling procedures need to be used to obtain representative samples of all media affected by the GBCP: water, sediment, and biota. Of particular concern are the short- and long-term spatial (especially cross channel) and temporal variations in the distribution and concentration of suspended sediment and associated trace elements that commonly occur in fluvial systems (Horowitz, 1995). For the GBCP, one of the questions to be answered is the importance of selenium transport through water (dissolved) and inorganic and organic particulate material (i.e., is the majority of selenium in the water or particulate fraction under certain conditions). Therefore, adequate samples must be collected in order to calculate the distribution of selenium between dissolved and particulate material. Consistent field collection methods and methods of sample preparation, preservation, and digestion through filtering and addition of acids are needed to obtain representative and reproducible samples. To meet the goals of the GBCP and objectives of the MP of compliance and understanding, further consideration needs to be given to the determination of total, total recoverable, dissolved, and particulate selenium (see discussions below in sections "Water Quality" and "Bioavailability").

Horowitz (1995) describes concerns about sample collection and analysis in order to accurately calculate fluxes of trace elements from water and suspended sediment samples. His conclusions include the importance of: (1) quantifying dissolved and suspended sediment-associated concentrations to identify sources of trace elements; (2) characterizing the collection site (i.e., type of sampler, time of sampling, and horizontal and vertical location of sample collection); and (3) directly analyzing suspended-sediment material to improve accuracy and reproducibility in flux calculations. Direct analysis involves separation of particulate matter from water through decantation, filtration, or centrifugation rather than calculation of the particulate concentration through analysis of total and dissolved concentrations (i.e., total minus dissolved).

USGS has identified several additional operational concerns associated with quantifying the dissolved and particulate fractions of a water-quality sample. These include: (1) determining dissolved and sediment-associated proportions and fluxes of trace elements through a methodology which relies on removing a subset of a sample collected for a "total" determination (Skougstad et al., 1979; Horowitz, 1995), especially at levels near the analysis detection limits (see recommendation below concerning digestion of the entire volume of sample collected); and (2) assuming that "true solution" concentrations for trace elements are represented by measured dissolved concentrations obtained by filtration (e.g. 0.45 or 0.1 micron membrane filters, tangential/sequential filtering, plate and capsules filters) (Horowitz et al., 1994; 1996a and b). Dissolved concentrations need to represent "true solution" concentrations for use in mass balance calculations and models (Luoma et al., 1992) and solution-mineral-equilibrium programs for water-rock interactions (Kharaka, 1988). Analytical errors associated with these sample preparation methodologies may not necessarily be of the same magnitude as errors associated with variations in sample collection methodologies. Recent USGS protocols have included systematic sample collection and preparation to improve reproducibility for large monitoring efforts (e.g., USGS National Water Quality Assessment Program and USDOI National Irrigation Water Quality Program).

General reference USGS Open-File Reports concerning sampling and analytical methodology in addition to those by Horowitz et al. (1995 and 1996) are: Edwards and Glysson (1988); Sylvester et al., (1990); Ward and Harr, (1990); Horowitz et al., (1994); Averett and Schroder, (1994); and Shelton, (1994). Detailed USGS laboratory methodology is given in Skougstad et al., (1979) and USEPA (1983 and 1991).

Data collection methods for water quality were also reviewed as part of a request from the CVRWQCB to the USGS (letter undated but received 1/31/96; conference call 3/5/96; field trip 3/8/96). The USGS discussed with the CVRWQCB its monitoring program as part of the GBCP MP and specifically was asked to assess whether sites and protocols were satisfactory. Theory and recommendations for improvement of field-collection and analytical methods are given in what follows, especially in regards to the need of comparability in the final data analysis.

Water Quality

Depth-integrated/cross-sectional samples [Equal-Width-Increment (EWI) or Equal-Discharge-Increment (EDI)] are suggested for water and suspended-matter samples at primary sites because they are best to represent the water quality of streams or canals. If EWI or EDI samples cannot be collected at all primary sites during all sampling because of resource limitations, or sampling-site conditions, we recommend collecting grab samples at mid-depth in the centroid of flow with depth integrated and cross-sectional profiles of SC and periodic EWI or EDI samples to check and document mixing characteristics at primary sampling sites.

More consistency in sampling methodology is suggested. The MP now consists of grab samples from banks, grab samples from the center of flow, and pumped samples by automatic samplers with sampling intakes located in the flow near the bank where the auto sampler is located. Having several types of samples collected introduces variability into the sampling program that probably will make it more difficult to compare data among sites. Sample treatment or preparation also varies between "total" and lab filtered (see further discussions on sampling methodology and bioavailability on pages 71 and 94-95).

Automatic samplers could be used at sites A, B, and N, where daily samples are collected. This might be more cost effective than manual sampling that requires a person to collect a sample each day. However, manual sampling by the aforesaid method would provide more consistency in the MP. Thus, a cost-effectiveness analyses of manual versus automatic sampling is suggested. If automatic samplers are used to collect daily samples, weekly mid-depth, centroid samples and SC profiles, and periodic EWI or EDI samples will be needed to provide comparability with other primary sites and to check and document mixing conditions at A, B, and N. Thus, consistent sampling methods would be used at all primary sites for weekly and monthly sampling and compliance sites would have additional sampling to meet compliance goals of the GBCP and objectives of the MP. Data from all primary sites can be compared because the same methods are used at all sites for weekly and monthly sampling. In addition, data for compliance goals and objectives can be compared among compliance sites because additional samplings at these sites are done in a consistent way.

Cross-sectional and vertical measurements of SC can help characterize how well dissolved constituents are mixed (distributed horizontally and vertically in the water column) at sampling sites. Cross-sectional and vertical SC measurements could be fairly easily and inexpensively done at most sites where there are bridges or some other platform across the waterbody to be sampled. The San Joaquin River site at Crows Landing is an exception because of the narrow road way making it unsafe to work off the bridge. Despite indications that the flow might be well mixed in the SLD because of dispersion structures upstream being constructed for the GBCP, confirmation of mixing is needed at SLD sampling sites. At sampling site A (inflow to SLD), constructing a platform with a railing over the SLD like the one at sampling site B (SLD discharge) would allow easy access for making cross-sectional and vertical measurements of SC at the time of water-sample collection. A two-person sampling crew is recommended. One person could collect the water sample while the other is performing the SC profile.

Without some measure of how well the water is mixed at sampling sites, questions about how well a point (grab) sample represents the water quality at sampling sites cannot be answered. Thus, data from such samples can be questioned as to how well they represent water-quality conditions at sampling sites.

Suspended sediment (SS, suspended inorganic matter) should be analyzed for concentration (i.e., settle, decant, and dry) and for selenium concentration on a total digest of the sediment sample. Particle size analysis and organic carbon analyses (i.e., organic matter incorporated in sediment), and boron analyses also should be performed. The SS analysis is recommended over the Total Suspended Solids (TSS) or residue-upon-evaporation which also includes dissolved solids. In the case of the SLD, salts are elevated and suspended sediment is to be kept to a minimum through management practices, thus, use of the TSS measurement may introduce unnecessary error and concern.

Samples of suspended organic matter can be collected with a phytoplankton net, but further collecting devices may be needed to collect all applicable size fractions of suspended organic matter (e.g., attached vegetation). The samples should be washed and concentrated and a selenium concentration obtained on a total digest of the sample. These samples also should be analyzed for organic carbon and boron.

Defining the dissolved selenium phase in addition to determining the partitioning and fluxes in organic and inorganic particulate matter (from direct analysis of separated suspended matter) is important in the GBCP area as previously recommended. Samples should be filtered upon collection and acid preserved after filtration to represent the dissolved phase accurately. Total or total recoverable selenium may be measured if regulation necessitates. Defining the relation between total/total recoverable and dissolved concentrations of selenium still needs to be done under the variable physical, chemical, and biological conditions of the GBCP to address the needs of both regulation and understanding as outlined in the goals of the GBCP and objectives of the MP. Further considerations concerning the determination of total, total recoverable, and dissolved selenium are given below.

USEPA (1992) states in its *Interim Guidance on Interpretation and Implementation of Aquatic Life Criteria for Metals* that the simplest approach is to measure total recoverable metals in ambient waters, and to compare such measurements to national or state-wide criteria. USEPA recognizes four general types of sample preparation addressing the measurement of total (unfiltered) versus dissolved (filtered) concentrations: (1) total--dissolved plus completely digested particulate material; (2) total recoverable--dissolved plus readily soluble particulate material (< 95 percent of total material); (3) acid soluble--dissolved plus readily soluble particulate material excluding the remaining insoluble material that is separated by filtration before analysis (< 95 percent of total material); and (4) dissolved--material that passes through a 0.45 micron membrane filter. For various reasons, USEPA has recently removed the acid soluble determination from consideration when comparing measured metals to bioavailable metals (USEPA, 1992).

Because the total or total recoverable value is, by definition, equal to or higher than the dissolved value, a higher level of protection is thought to be achieved than that afforded by dissolved criteria. The USFWS preference for unfiltered samples is based on the criterion that unfiltered samples yield measures of selenium that have greater statistical value for predicting levels of biotic tissue bioaccumulation (and thus biotic risk), than filtered samples (Joe Skorupa, personal communication). However, this type of sampling (unfiltered, total or total recoverable) does not address understanding all aspects of the chemical and biological equilibrium of highly bio-reactive elements such as selenium. The USFWS has had success in using the operationally defined total recoverable selenium value, rather than the more absolute dissolved and total values, as an accurate indictor of biotic interfacing in static systems (i.e., evaporation ponds) (Skorupa and Ohlendorf, 1991). Under certain conditions, the protection level may be the same whether a 2 ppb unfiltered criterion is advocated (as by USFWS, Henderson et al., 1995 and Skorupa and Ohlendorf, 1991) or a 1 ppb filtered criterion is advocated (as by a USEPA commissioned study, Peterson and Nebeker, 1992). Recognition of such complexity, especially in regards to sampling for selenium, is becoming increasingly important as levels for aquatic protection are lowered and defined on more sophisticated chemical and biological bases (e.g. partitioning, mass balance, bioaccumulation rate or potential, food web transfer).

The determination of total or total recoverable selenium should be based on a "whole water sample" rather than on an aliquot taken from a collected sample (Skougstad et al., 1979; Horowitz, 1995). If a "whole water sample" is digested for a selenium or metals analysis, meaning the entire volume of a collected sample is carried throughout the process of digestion, the competency of the sample will have been preserved and the analysis will accurately represent the total constituents in the sample. However, if a subset of the collected sample is removed for digestion and analysis, then difficulties are encountered inherent in removing a homogenous aliquot from a non-homogenous mixture, especially at concentrations near the detection limits for water and solids.

Addition of acid to an unfiltered sample in the field as a sample preservation method, rather than keeping the sample chilled (USGS maximum holding time, eight days), adds another variable. The rate at which a steady state concentration is achieved between the water and the particulate phases is not known. The acid preservation is not rigorous enough to completely solubilize selenium or metals, yet sufficient to cause partial de-sorption of selenium and metals from particulate material. Thus, the distribution between the dissolved and particulate phase has changed. The sample neither represents the dissolved phase nor the particulate phase with assurance (i.e., total minus dissolved equals particulate, for flux calculations) because of variable contact time between the added acid and the particulate material. On the other hand, biological activity in unfiltered, unacidified samples may also change partitioning between dissolved and particulate.

Digestion procedures for selenium and metals analysis in the laboratory also involve addition of acids and heating. We recommend documenting acid conditions, heating time, percent recoveries, etc., in the QAPP for laboratory methods.

Filtering and acidification of a water-quality samples (through 0.45 micron membrane filter paper; < 2 pH) immediately after collection in the field quenches biological and chemical processes (e.g., sorption, dissolution, microbial metabolism, etc.) that could alter the quantity of selenium and metals dissolved in the sample. In general, problems of comparability and repeatability in water-quality databases occurred prior to establishment of standardized preparation and filtering protocols (Horowitz et al., 1994; Horowitz, 1996; and other citations). Specifically, numerous problems of reproducibility of selenium analyses in water samples of both the Kesterson Reservoir ponds and SLD agricultural water occurred during 1983 to 1985 (e.g., BOR, USGS, and USFWS databases). These problems stemmed from complications present in the sample at the time of collection including: (1) amounts of inorganic and organic particulate matter (Moore et al., 1990; Fujii, 1988); (2) the presence of more than one species of selenium (Presser and Barnes, 1984 and 1985); and (3) the magnitude of the selenium concentration of the sediment or organic matter present in the water (see discussion, page 86). For example, dissolved samples (n = 45) from Kesterson Reservoir gave an aggregate geometric mean waterborne selenium concentration of 78 ppb. Total recoverable samples (n =104) gave an aggregate geometric mean total recoverable selenium of 154 ppb (Moore, 1990). These data showed: (1) the importance of both the dissolved and particulate phase in the transport of selenium; and (2) the magnitude of potential error if a heterogeneous sample is not treated properly.

The large differences in selenium concentrations between dissolved and total recoverable samples may be partially due to the elevated biological productivity of the Kesterson ponds, a terminal pond system subjected to low flow conditions. Stream and river samples collected under relatively high flowing conditions, have shown less variation in selenium concentrations between dissolved and total recoverable samples (Hill and Gilliom, 1993). Differences in selenium concentrations between flowing input waters [e.g. SLD to Kesterson ponds (Presser and Barnes 1984 and 1985) and MD-1 to Tulare ponds (Fujii, 1988)] and the relatively stagnant ponds themselves, add to the complexities of interpreting total versus dissolved selenium data in regards to salt and selenium inventories (i.e., selenium load attenuation or "loss").

Flow (static, low flow, or high flow) may be an important variable in determining heterogeneity and biological productivity of the sample. According to Skorupa et al., (1996) concerning the effects of partitioning of selenium in water and in the organic and inorganic particulate matter of the sample, low water-borne selenium concentrations can indicate either low mass loading (low risk) or high biotic uptake/productivity, (high risk). The effect of flow regime should also be included when making this assessment. Since flow is variable at the GBCP primary sites, some sites at different times are more affected by the considerations of heterogeneity and productivity. Thus standard preservation techniques, especially during critical-period (event-driven) sampling, are important for consistent results (e.g., partitioning/filtering is important for samples collected in low-flow environments).

More recent selenium databases (1986 to 1993 NIWQP database) comparing filtered (dissolved) water samples to those collected for total-contaminant levels, may demonstrate a similar importance of sample preservation and analysis procedures especially at low levels of selenium (Seiler, in press). Discrepancies in selenium concentrations between these two types of samples occur for samples containing < 10 ppb selenium. Selenium concentrations in this range: (1) may result from either low mass loading (low risk) or high biotic uptake (high risk) (Skorupa et al., 1996); (2) encompass the biological guidelines recommended for selenium exposure and risk assessment for total recoverable for the GBCP (< 2 ppb, Henderson et al., 1995) and dissolved selenium (< 1 ppb, Peterson and Nebeker, 1992); (3) encompass the federal and state selenium standards for protection of aquatic life (2 to 10 ppb, CVRWQCB, 1996b); (4) are difficult to use to quantify sediment-associated trace element concentrations and calculate fluxes (i.e., whole water determinations of dissolved and suspended material) (Horowitz, 1995); and (5) may represent an unsaturated particulate phase. Accurately defining selenium at these low levels is important. However, it may be difficult to apply water-quality standards and biological-effect levels with certainty to measured contaminant at these levels in waters without prescribed sample preparation and preservation techniques. Previous success in reproducibility of total recoverable selenium values may be due to sampling of static, non-flowing systems.

An example of the bias that can result if sample filtration and acidification are not carried out correctly is provided by the proportion of selenium in SLD sediment and water that may occur during a sampling period (e.g., 1995 flood conditions). If the average selenium concentration in

SLD bed sediment is 44 ppm (Presser, 1995, *Memo to TAC Committee on Re-Use of the SLD*) and the dissolved selenium concentration is low (< 10 ppb), then suspension of only 100 mg of sediment in each liter of sample will give a concentration of 4.4 ppb selenium due to the sediment (assuming that the 100 milligrams is totally digested with the sample aliquot removed for analysis). This suspended sediment concentration was likely exceeded during flood conditions because SLD bed sediment contained up to 146 ppm selenium. Most routine monitoring based on "totals" is aimed toward the case where the dissolved selenium concentration is elevated (> 10 ppb) compared to that in sediment (1-2 ppm), i.e., selenium in water makes up a higher proportion of the total concentration compared to selenium in sediment.

Bed Sediment

In regards to bed sediment sampling methods, our considerations and recommendations are:

1) The BOR bed sediment sampler is limited to retrieving a sample of sediment only up to 24.5 cm or 10 inches in length. Therefore, another type of sampling device is needed to retrieve core samples greater than 24.5 cm (e.g., see Shelton and Capel, 1994). The USGS has recently successfully used a 3-inch diameter plexiglas tube to retrieve bed sediment samples.

2) Bed-sediment samples are collected by wading or use of an inflatable raft where the SLD is not wadable. Careful sampling of the top layer of sediment is crucial and thus disturbance should be kept to a minimum.

3) Determination of bed sediment is enhanced by analysis of particle size. Clay, silt, and sand and their subsets can be differentiated. The <63 micron (fine particle) fraction usually contains higher trace element concentrations than the >63 micron fraction, but the coarser material is also an important contributor to overall suspended sediment trace element transport (Horowitz, 1995).

Bioavailability

In regards to bioavailability, our sampling method recommendations are:

1) USEPA (1983 and 1991) has historically recognized four methods of sample preparation for metals analysis that lead to measurement of dissolved, total, total recoverable, and acid soluble **and some of these considerations are applicable to selenium.** Recently USEPA (1992) has considered these methods in their relation to determining bioavailability of metals (also see #3 below). The four methods differ in the amount of particulate quantified. A further caution is applied to dissolved in that quantification may depend on pore size of filter (0.45 or 0.1 micron) or tangential/sequential filtering resulting in inclusion or exclusion of colloid size material. The final three categories differ in the amount of acid and/or heat used in a digestion to solubilize an element. USEPA is recommending that the *acid soluble* procedure be discontinued for various reasons including that it only adds complexity to the issue of bioavailability. In general, the total recoverable and acid soluble procedure use a dilute acid for digestion and the determination thus represents less than the total amount (defined as < 95 percent) present in the sample. To obtain a total measurement, a rigorous acid digestion is needed to solubilize all particulate material (i.e., no residue present).

2) Added to these complexities in **sampling procedures** is a species-dependent **analytical procedure,** which also involves acid digestion necessary for a total dissolved selenium analysis. Selenium species exhibit different sensitivities in certain analytical techniques (e.g., those related to hydride generation atomic absorption spectrophotometry). The supposed limitation of these techniques however, has the potential for selective determination of different dissolved oxidation states of selenium. Therefore, the conditions of the digestion can result in the quantification of operationally defined reduced dissolved selenium (selenide plus selenite), oxidized dissolved selenium (selenate), and total dissolved selenium (Presser and Barnes, 1984). Failure to digest the sample correctly can result in up to 98 percent of total dissolved selenium not being measured.

3) USEPA (1992) considers the correlation between metals that are measured by different protocols (i.e., dissolved, total, total recoverable, acid soluble) and amounts of metals that are identified as biologically available (e.g., dependent on speciation), a principle issue in determining aquatic life criteria. A *water-effect* ratio is used to obtain a site-specific concentration value that is reflective of bioavailability, i.e., the toxicity of various metal species and the transformations that may ensue from effluent to receiving water. USEPA concludes that this ratio is still difficult to define, and therefore, the relation between measured concentrations and toxicity is not precise. Further discussion by USEPA includes the following generalizations: Particulate metal is generally expected to have less bioavailability than dissolved metal. In most, but not all toxicity tests underlying the criteria, the percentage of metal in the particulate is fairly low. Aquatic life criteria in ambient waters may be implemented either as total recoverable metal or dissolved metal. Pollution effluent limits are generally expressed as total recoverable metal. Toxicity testing, however, has shown dissolved measurements to be better than total recoverable measurements as predictors of toxicity. Therefore, potential concerns remain with both approaches, especially when the dissolved concentration is a small percentage of the particulate concentration. A dissolved criteria is difficult to apply to effluents because there is no assurance that effluent particulate metal would not dissolve after discharge.

A site-specific study has not been done for the GBCP to determine bioavailability as suggested in USEPA protocols. A mass balance sampling design will help document toxicity limits to help define bioavailability in the GBCP area.

REFERENCES

Averett, R.C. and Schroder, L.J., 1994, A guide to the design of surface-water-quality studies, USGS Open-File Report 93-105, 39 p.

Besser, J.M., Canfield, T.J., and LaPoint, T.W., 1993, Bioaccumulation of organic and inorganic selenium in a laboratory food chain: Environ. Toxicol. Chem., v. 12, p. 57-72.

Bureau of Reclamation, 1986, Final environmental impact statement, Kesterson Program, Volume II, Sacramento, CA, Chapters 1-6.

Bureau of Reclamation, 1990, Supplement to Environmental Assessment, Proposed Use Agreement allowing use of the San Luis Drain for conveyance of agricultural drainage waters through the Grassland Water District and adjacent Grassland Areas: Mid-Pacific Region, Sacramento, CA, 18 p. and appendixes.

Bureau of Reclamation, 1991, Finding of No Significant Impact, Proposed Use Agreement allowing use of the San Luis Drain for conveyance of agricultural drainage waters through the Grassland Water District and adjacent Grassland Areas: Mid-Pacific Region, Sacramento, CA, 6 p.

Bureau of Reclamation, 1995a, November 1995 Draft proposed compliance monitoring program for use and operation of the Grassland Bypass to remove agricultural drainage waters from the Grassland Water District and adjacent Grassland channels: Mid-Pacific Region, Sacramento, CA, 73 p.

Bureau of Reclamation, 1995b, Draft quality assurance project plan [for the] monitoring program for use of the San Luis Drain to convey agricultural drainage water through the Grassland Water District and adjacent Grassland Channels, Mid-Pacific Region, Sacramento, CA, 32 p. and appendixes.

Bureau of Reclamation, 1995c, Finding of No Significant Impact and Supplement Environmental Assessment, Grassland Bypass Channel Project, Interim use of a portion of the San Luis Drain for conveyance of drainage water through the Grassland Water District and adjacent Grassland Areas: Mid-Pacific Region, Sacramento, CA, 36 p. and appendixes.

Bureau of Reclamation, 1995d, Agreement for use of the San Luis Drain,: Mid-Pacific Region, Sacramento, CA, 24 p. and appendixes.

Bureau of Reclamation, 1995e, Final report, task group on initial use and operation of the SLD, 1995, Appendix 1, Environmental Effect Levels: Sacramento, CA, 8 p. and appendixes.

Bureau of Reclamation, San Luis and Delta Mendota Water Authority, U.S. Environmental Protection Agency, and U.S. Fish and Wildlife Service, 1995, Consensus Letter to California Central Valley Regional Water Quality Control Board: Sacramento, CA, 8 p.

California State Water Resources Control Board, 1985, In the matter of the petition of Robert James Clause for review of inaction of CA Regional Water Quality Control Board, Central Valley Region: SWRCB Order no. WQ 85-1, File no. A-354, Sacramento, CA.

Central Valley Regional Water Quality Control Board, 1988, Water quality of the lower San Joaquin River: Lander Avenue to Vernalis, October 1985 to September 1988: Sacramento, CA 17 p. and appendixes.

Central Valley Regional Water Quality Control Board, 1989, Water quality of the lower San Joaquin River: Lander Avenue to Mossdale Bridge, October 1987 to September 1988: Sacramento, CA, 22 p. and appendixes.

Central Valley Regional Water Quality Control Board, 1990a, Agricultural drainage contribution to water quality in the Grassland Area of western Merced County, California: October 1988 to September 1989: Sacramento, CA, 46 p.

Central Valley Regional Water Quality Control Board, 1990b, Water quality of the lower San Joaquin River: Lander Avenue to Vernalis, October 1988 to September 1989: Sacramento, CA, 30 p. and appendixes.

Central Valley Regional Water Quality Control Board, 1991a, Agricultural drainage contribution to water quality in the Grassland Area of western Merced County, California: October 1989 to September 1990: Sacramento, CA, 48 p.

Central Valley Regional Water Quality Control Board, 1991b, Water quality of the lower San Joaquin River: Lander Avenue to Vernalis, October 1989 to September 1990: Sacramento, CA, 31 p. and appendixes.

Central Valley Regional Water Quality Control Board, 1992a, Agricultural drainage contribution to water quality in the Grassland Area of western Merced County, California: October 1990 to September 1991: Sacramento, CA, 47 p.

Central Valley Regional Water Quality Control Board, 1992b, Water quality of the lower San Joaquin River: Lander Avenue to Vernalis, October 1990 to September 1991: Sacramento, CA, 39 p.

Central Valley Regional Water Quality Control Board, 1993, Agricultural drainage contribution to water quality in the Grassland Area of western Merced County, California: October 1991 to September 1992: Sacramento, CA, 47 p.

Central Valley Regional Water Quality Control Board, 1994, A total maximum monthly load model for the San Joaquin River: Sacramento, CA, 86 p.

Central Valley Regional Water Quality Control Board, 1995a, Agricultural drainage contribution to water quality in the Grassland Area of western Merced County, California: October 1992 to September 1993: Sacramento, CA, 52 p.

Central Valley Regional Water Quality Control Board, 1995b, Agricultural drainage contribution to water quality in the Grassland Area of western Merced County, California: October 1993 to September 1994: Sacramento, CA, 58 p.

Central Valley Regional Water Quality Control Board, 1995c, Water quality of the lower San Joaquin River: Lander Avenue to Vernalis, October 1992 to September 1994: Sacramento, CA, 55 p.

Central Valley Regional Water Quality Control Board, 1995d, Staff report on beneficial uses designations and water-quality criteria to be used for the regulation of agricultural subsurface drainage discharges in the San Joaquin Basin: Sacramento, CA, 38 p.

Central Valley Regional Water Quality Control Board, 1995e, Staff report on the water-quality objectives and implementation plan to be used for the regulation of agricultural subsurface drainage discharges in the San Joaquin River Basin, Appendix B, 9 p.

Horowitz, A.J., 1995, The use of suspended sediment and associated trace elements in water quality studies: International Association of Hydrological Sciences Special Publication no. 4, Wallingford, Oxfordshire, 58 p.

Horowitz, A.J., Demas, C.R., Fitzgerald, K.K., Miller, T.L., and Rickert, D.A., 1994, USGS protocol for the collection and processing of surface-water samples for the subsequent determination of inorganic constituents in filtered water: USGS Open-File Report 94-539, 57 p.

Horowitz, A.J., Lum, K.R., Garbarino, J.R., Hall, G.E., and Demas, C.R., 1996a, Problems associated with using filtration to define dissolved trace-element concentrations in natural water samples: Environmental Science and Technology, v.30, no. 3, p. 954-963.

Horowitz, A.J., Lum, K.R., Garbarino, J.R., Hall, G.E., Lemieux, Claire, and Demas, C.R., 1996b, The effect of membrane filtration on dissolved trace-element concentrations: Water, Air, and Soil Pollution, v. 90, p. 281-294.

Kharaka, Y.K., Gunter, W.D., Aggarwal, P.K., Perkins, E.H., and DeBraal, J.D., 1988, SOLMNEQ: Solution mineral equilibrium computations: USGS Computer Contribution WRD-73-002, 82 p.

Lemly, A.D., 1993, Subsurface agricultural irrigation drainage: The need for regulation: Regulatory Toxicology and Pharmacology, v. 17, p. 157-180.

Luoma, S.N., Johns, C., Fisher, N., Steinberg, N.A., Oremland, R.S., and Reinfelder, J.R., 1992, Determination of selenium bioavailability to a benthic bivalve from particulate and solute pathways: Environmental Science and Technology, v. 26, p. 485-491.

Central Valley Regional Water Quality Control Board, 1996, Staff report on control of agricultural subsurface drainage discharges *in* Draft Amendments to the Water Quality Control Plan for the Sacramento and San Joaquin River Basins: Sacramento, CA, 192 p.

Cutter, G.A. and Bruland, K.W., 1984, The marine biogeochemistry of selenium: a re-evaluation: Limnol. Oceanogr., v. 29, no. 6, p. 1179-1192.

Edwards, T.K. and Glysson, D.G., 1988, Field methods for measurement of fluvial sediment: USGS, Open-File Report 86-531, 118 p.

Environmental Defense Fund, 1994, Plowing new ground, using economic incentives to control water pollution from agriculture: 136 p.

Fujii, Roger, 1988, Water-quality and sediment-chemistry data of drain water and evaporation ponds from Tulare Lake Drainage District, Kings County, California, March 1985 to March 1986, USGS Open-File Report 87-700, p. 19.

Fujii, Roger and Swain, W.C., 1995, Areal distribution of selected trace elements, salinity, and major ions in shallow ground water, Tulare Basin, southern San Joaquin Valley, CA: USGS Water-Resources Investigations Report 95-4048, 67 p.

Henderson, J.D., Maurer, T.C., and Schwarzbach, S.E., 1995, Assessing selenium contamination in two San Joaquin Valley, California sloughs, an update of monitoring for interim re-use of the San Luis Drain: USFWS, Sacramento, CA, 19 p.

Hill, B.R. and Gilliom, R.J., 1993, Streamflow, dissolved solids, suspended sediment, and trace elements, San Joaquin River, California, June 1985-September 1988: USGS Water-Resources Investigations Report 93-4085, 21 p.

Meyer, R.W., 1996, (In review) Surface water quality assurance plan for the California District of the U.S. Geological Survey Open-File Report 96-xxx.

Moore, and others, 1990, Fish and wildlife resources and agricultural drainage in the San Joaquin Valley, California, two volumes: San Joaquin Valley Drainage Program, Sacramento CA, Volumes I and II.

Oremland, R.S. and others, 1989, Selenate reduction to elemental selenium by anaerobic bacteria in sediments and culture: biogeochemical significance of a novel, sulfate-independent respiration, Applied and Environmental Microbiology, v. 55, no. 9, p. 2333-2343.

Peterson, J.A. and A.V., Nebeker, 1992, Estimation of waterborne selenium concentrations that are toxicity thresholds for wildlife: Archives of Environmental Contaminant Toxicology, V. 23, p. 154-162.

Presser, T.S., USGS memorandum to Technical Advisory Committee on re-use of the SLD, 1995: Menlo Park, CA, 6 p.

Presser, T.S. and Barnes, I., 1984, Selenium concentrations in waters tributary to and in the vicinity of the Kesterson National Wildlife Refuge, Fresno and Merced Counties, California: Water Resources Investigations Report 84-4122, 26 p.

Presser, T.S. and Barnes, I, 1985, Dissolved constituents including selenium in the vicinity of the Kesterson National Wildlife Refuge and the west Grassland, Fresno and Merced Counties, California: Water Resources Investigations Report 85-4220, 73 p.

Presser, T.S. and Ohlendorf, H.M., 1987, Biogeochemical cycling of selenium in the San Joaquin Valley, California, USA: Environmental Management, v. 11, p. 805-821.

Presser, T.S., 1994, "The Kesterson effect": Environmental Management, v. 18, no. 3, p. 437-454.

Presser, T.S., Sylvester, M.A., and Low, W.H., 1994, Bioaccumulation of selenium from natural geologic sources in the western United States and its potential consequences: Environmental Management, v. 18, no. 3, p. 423-436.

Presser, T.S., Swain, W.C., and Fujii, Roger, 1995, Surface water/ground-water linkages in relation to trace element and salinity distribution, Tulare Basin, Southern San Joaquin Valley, CA [abs.]: American Geophysical Union Proceedings, 1995 Fall Meeting, Dec. 11-15, San Francisco, CA, page F241.

Rantz, S.E., and others, 1982, Measurements and computation of streamflow, volumes 1 and 2: U.S. Geological Survey Water-Supply Paper 2175, 631 p.

San Francisco Bay Regional Water Quality Control Board, 1993, Derivation of site-specific water-quality criteria of selenium in San Francisco Bay: Oakland, CA, p. 37.

San Joaquin Valley Drainage Program, 1990, A management plan for agricultural subsurface drainage and related problems on the westside San Joaquin Valley: Sacramento, CA, p. 183.

San Luis and Delta-Mendota Water Authority, 1995, Sediment survey: San Luis Drain: Tracy, CA, 4 pages and appendixes.

Sauer, V.B. and Meyer, R.W., 1992, Determination of errors in individual discharge measurements: U.S. Geological Survey Open-File Report 92-144, 21 p.

Seiler, R.L. and Skorupa, J.P., 1995, Identification of areas at risk for selenium contamination in the western United States: *Water Resources at Risk,* American Institute of Hydrology, p. LL 85-94.

Shelton, L.R., 1994, Field guide for collecting and processing stream-water samples for the National Water-Quality Assessment Program, USGS Open-File Report 94-455, 42 p.

Shelton, L.R. and Capel, P.D., 1994, Guidelines for collecting and processing samples of stream bed sediment for analysis of trace elements and organic contaminants for the National Water-Quality Assessment Program: Open-File Report 94-458, 20 p.

Shelton, L.R. and Miller L.K., 1988, Water-quality data, San Joaquin Valley, California, March 1985 to March 1987: USGS Open-File Report 88-479, 210 p.

Shelton, L.R. and Miller L.K., 1991, Water-quality data, San Joaquin Valley, California, April 1987 to September 1988: USGS Open-File Report 91-74, 189 p.

Skorupa, J.P. and Ohlendorf, H.M.., 1991, Contaminants in drainage water and avain risk thresholds: *in* A. Dinar and D. Zilberman (eds), The Economics and Management of Water and Drainage in Agriculture, Kluwer Academic Publishers, Boston, MA, p. 345-368.

Skorupa, J.P., Morman, S.P., and Sefchick-Edwards, 1996, Guidelines for interpreting selenium exposures of biota associated with nonmarine aquatic habitats: USFWS, Sacramento, CA, 74 p.

Skougstad, M.W., Fishman, M.J., Friedman, L.C., Erdmann, D.E., and Duncan, S.S., 1979, Methods for the determination of inorganic substances in water and fluvial sediments: Techniques of Water-Resources Investigations of the USGS, Chapter A1, Book 5, 626 p.

Sylvester, M.A., Kister, L.R., and Garret, W.B., 1990, Guidelines for the collection, treatment, and analysis of water samples: USGS Western Region Field Manual (for USGS internal use only), 1990, 144 p.

U.S. Environmental Protection Agency, 1983, Methods for chemical analysis of water and wastes: Environment Monitoring and Support Laboratory, EPA-600/4-79-020.

U.S. Environmental Protection Agency, 1986, Quality criteria for water: Washington, D.C., 453 p.

U.S. Environmental Protection Agency, 1991, Methods for the determination of metals in environmental samples: Environmental Monitoring and Support Laboratory, EPA-600/4-91-010.

U.S. Environmental Protection Agency, 1992, Interim guidance on interpretation and implementation of aquatic life criteria for metals: Washington, D.C., p. 24.

U.S. Fish and Wildlife Service, 1990, Agricultural irrigation drainwater studies. Final report to the San Joaquin Valley Drainage Program. National Fisheries Contaminant Research Center, U.S. Fish and Wildlife Service, Columbia, MO.

U.S. Geological Survey, 1985 through 1994, Water resources data for California, water years 1985 through 1994, southern Central Valley and the Great Basin from Walker River to Truckee River, v. 3. USGS Water-Data Report, CA-85-3 to CA-94-3, USGS, Sacramento, CA.

Ward, J.R. and Harr, C.A., 1990, Methods for collection and processing of surface-water and bed-material samples for physical and chemical analyses: USGS, Open-File Report 90-140, 71 p.

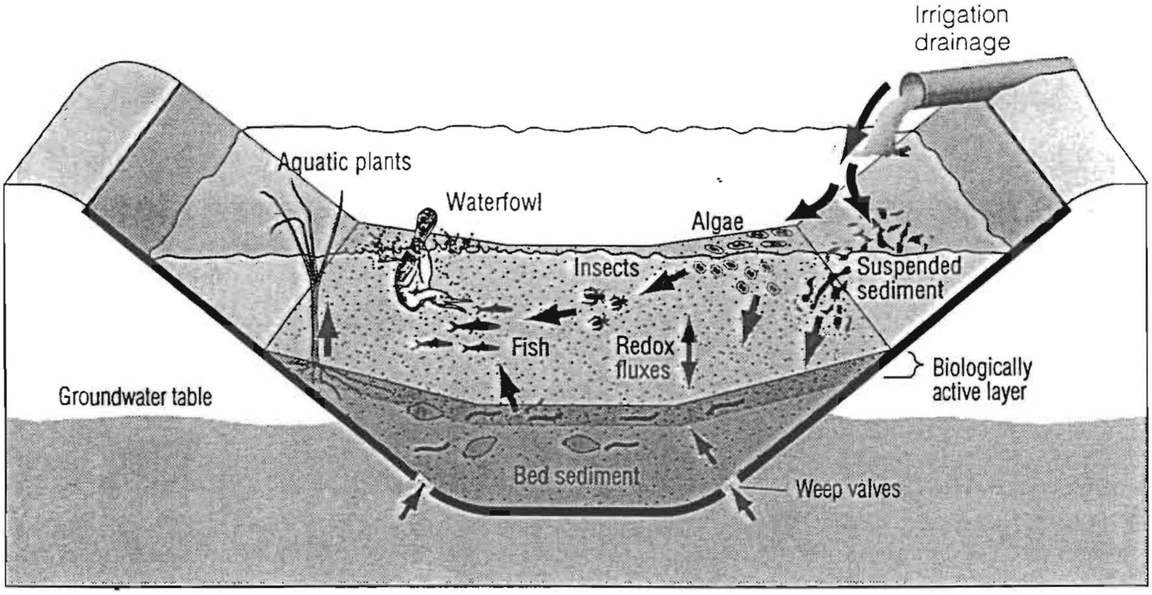

Figure 1. Conceptual model of mass balance of selenium in the San Luis Drain as part of the Grassland Bypass Channel Project (adapted from *Presser, 1994, Env. Mgm. 18 (#3): 437-454*).

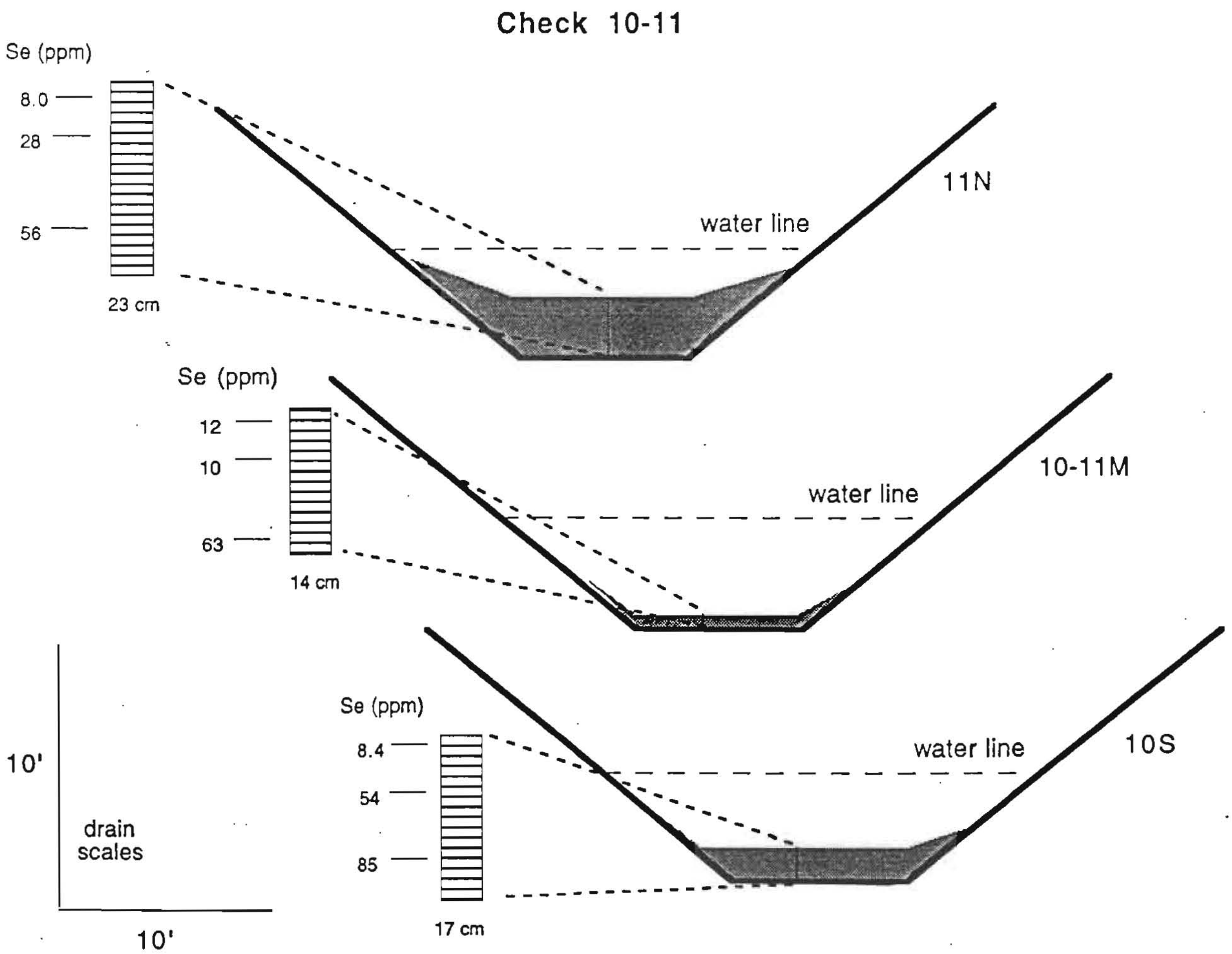

Figure 2. Variations in thickness and Se concentration within San Luis Drain sediment check 10 to 11 (sediment thickness is shown by shading).

Check 15-16

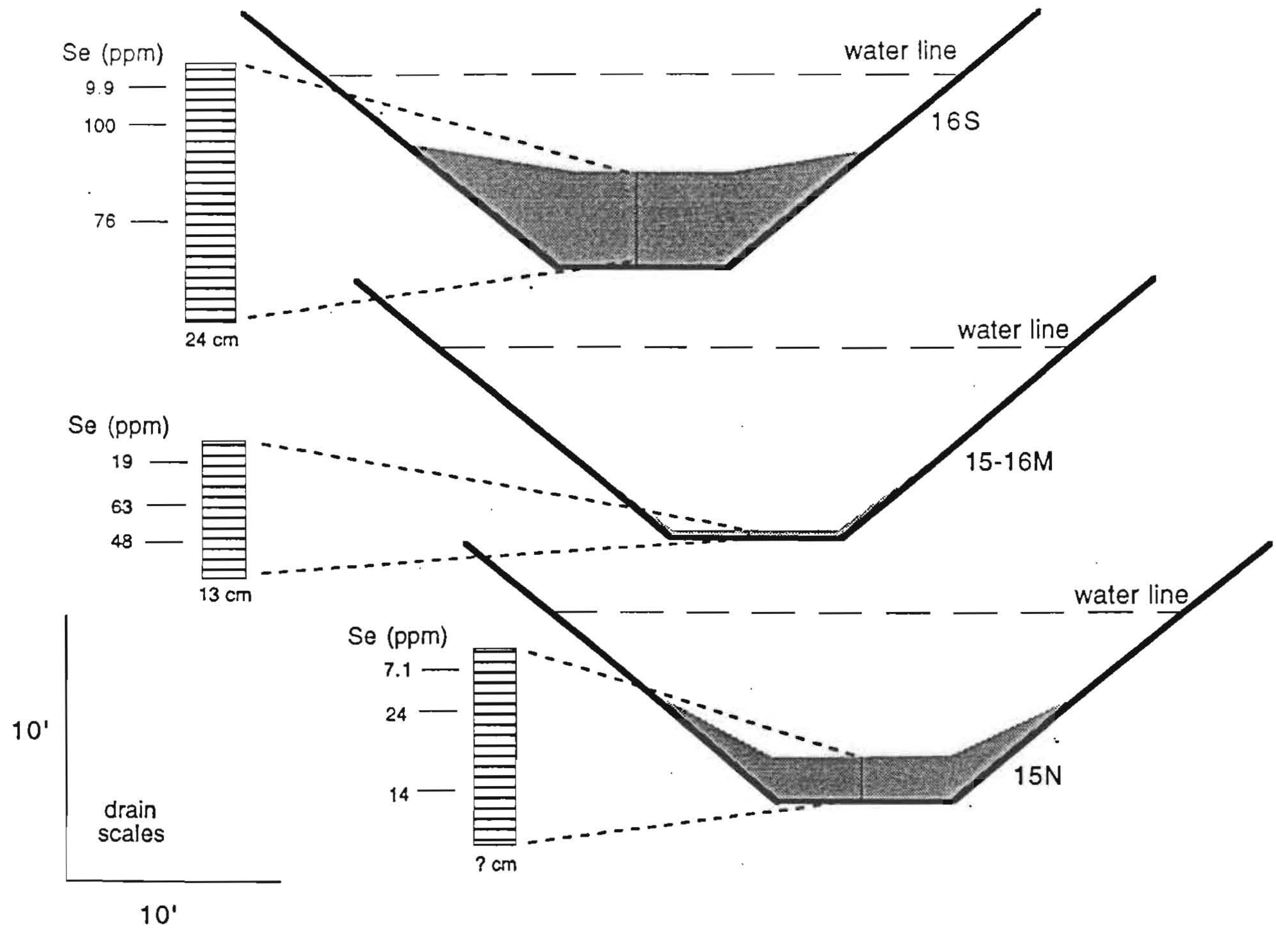

Figure 3. Variations in thickness and Se concentration within San Luis Drain sediment check 15 to 16 (sediment thickness is shown by shading).

San Luis Drain Sediment 9/94

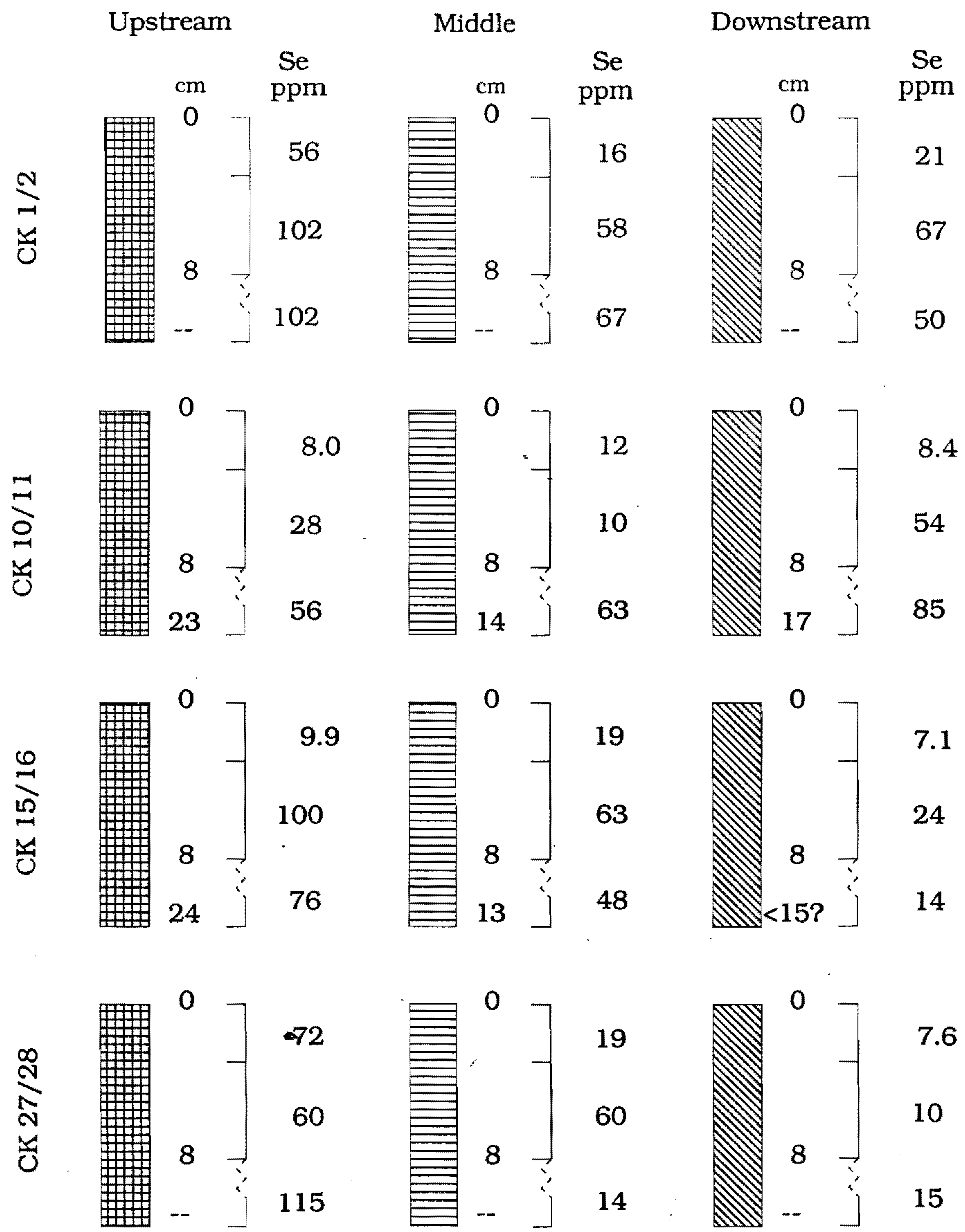

Figure 4. Variations in Se concentration in San Luis Drain sediment within checks 1/2, 10/11, 15/16, and 27/28.

San Luis Drain Sediment 9/94

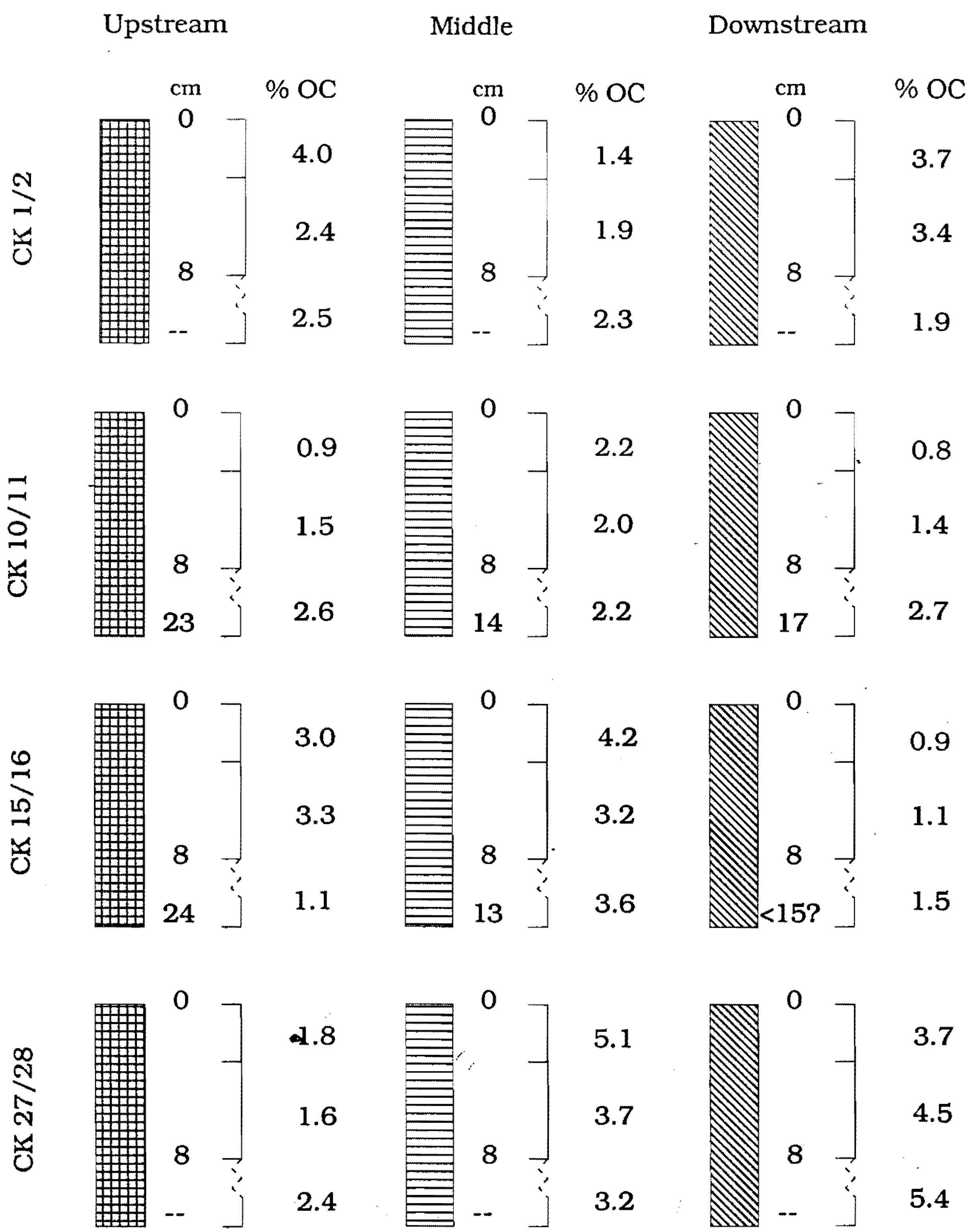

Figure 5. Variations in organic carbon concentration in San Luis Drain sediment within checks 1/2, 10/11, 15/16, and 27/28.

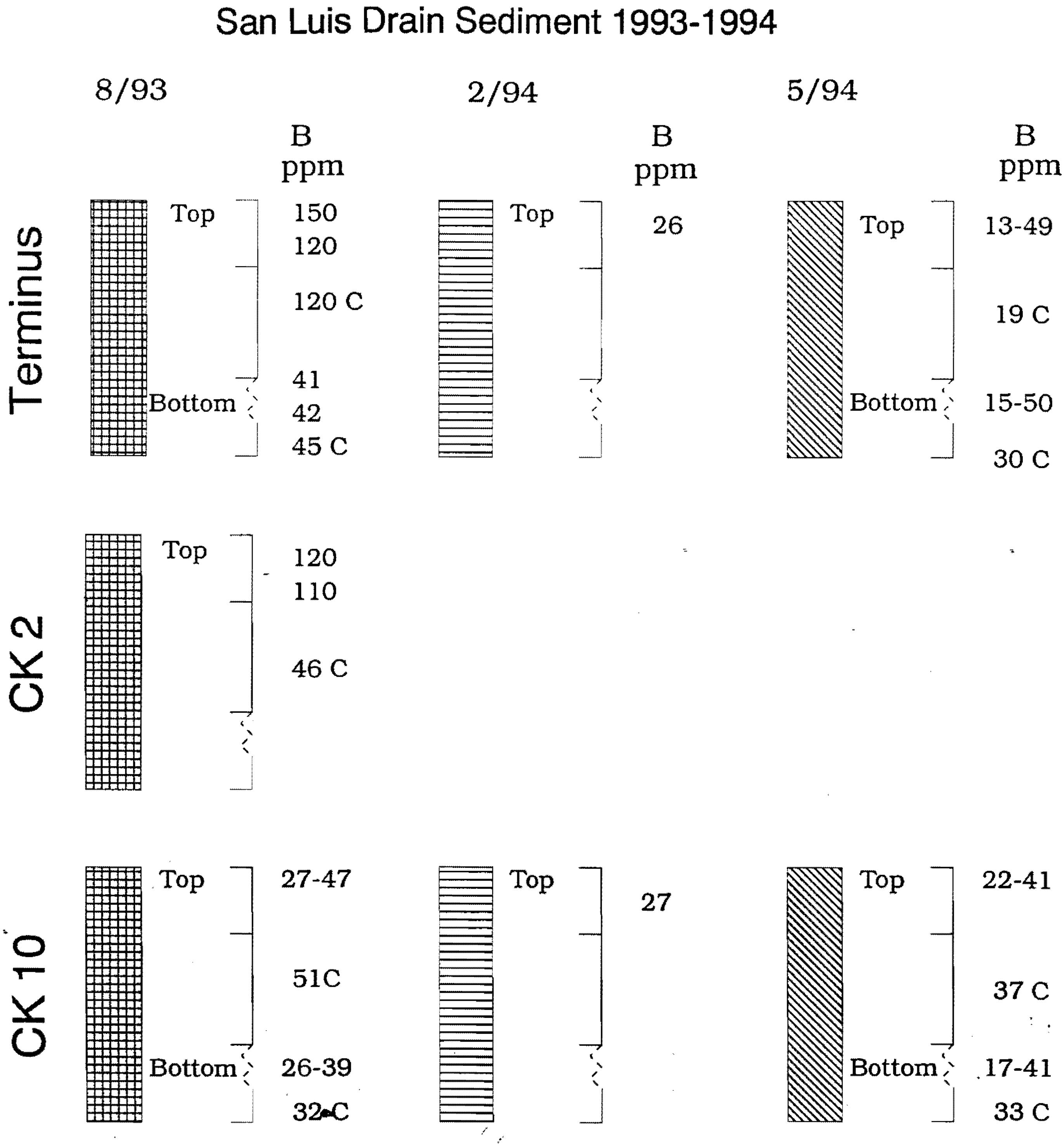

Figure 6. Variations in boron concentrations in San Luis Drain Sediment within the terminus, check 2, and check 10 (C = composite).