A Framework for Salt/Nitrate Source Identification Studies

1. Introduction

At the April 22, 2011 Executive Committee Meeting, the Knowledge Gained Subcommittee presented a technical memorandum, dated April 15, 2011, to the Executive Committee outlining the framework for preparing salt/nitrate source identification studies. The Executive Committee approved the basic elements provided in the memorandum and directed the Knowledge Gained Subcommittee to complete a more detailed framework document. This document provides the more detailed framework for preparing regional-scale salt/nitrate source identification studies in the Central Valley, as requested by the Executive Committee.

Our recommendation is that salt/nitrate source identification studies be conducted in a phased manner to promote cost-effective and timely evaluations, and to provide an opportunity for on-going stakeholder input to data evaluations. We have developed a detailed approach for preparing "Initial Studies" consisting primarily of initial data gathering and simplified modeling to establish water budgets and salt/nitrate balances for each identified Study Area.[1] The Knowledge Gained Subcommittee also recommends that the Initial Studies include basic summary information about known contamination and impairment, recycled water and groundwater recharge projects, regulatory parameters, and local planning programs and monitoring pertaining to salt and nitrate within the Study Area. [2] Such basic information will be useful to Stakeholders for prioritizing Study Areas and evaluating the need and scope for subsequent "Follow-up Studies" needed to complete a comprehensive Salt and Nitrate Management Plan for the entire Central Valley.

[1] We use the term "Study Area" throughout the document to define planning areas within the Central Valley. At this point we have not attempted to define Study Areas beyond thinking of them as small enough to be effectively managed and modeled. The framework described herein is intended to guide regional-scale salt/nitrate source identification studies and is not necessarily applicable to source identification studies that would be accomplished on a facility- or municipal-scale basis, although much of this framework is scalable for those applications.

[2] Such information does not include detailed evaluations of the current management and policy issues in Study Areas. However, we recognize the value and need for such evaluations and recommend that they be completed simultaneously with, but separate from, the Initial Studies.

At this point, we have not developed a detailed approach for preparing subsequent "Follow-up Studies" because the specific scopes of such additional studies will depend on the Initial Study results and region-specific management and policy issues for the Study Area.

2. Technical Study Goals

The goals, or general statements of intent, of the salt/nitrate source identification studies are to provide data and information that can be used to:

- Prioritize Study Areas throughout the Central Valley;
- Understand the linkages between Study Areas;
- Prioritize potential salt/nitrate management practices;
- Develop Salt and Nutrient Management Plans required by the Recycled Water Policy;
- Identify and support appropriate beneficial use and water quality objective changes, and
- Support proposed Basin Plan amendments.

3. Technical Study Objectives

Technical objectives define the strategies or steps to attain the identified goals. To provide flexibility to the parties performing the studies, these objectives are general in nature. Steps for performing studies that comply with these objectives are described in later sections of this document.

The key technical objectives for an Initial Study are:

1. Develop a conceptual model for the Study Area including water budgets and salt/nitrate mass balances;
2. Characterize the movement of water and salt/nitrate into and out of neighboring Study Areas;
3. Develop water budgets and salt/nitrate mass balances that are complete and include an accounting of all components in sufficient detail to identify potential management strategies.
4. Quantify the rate of salt/nitrate accumulation or reduction in surface water and groundwater within a Study Area;
5. Analyze historical and projected salt /nitrate loading rates and concentrations for surface water and groundwater within the Study Area in cases where these loads can be quantified;
6. Provide the information needed to prioritize Study Areas; and
7. Identify and evaluate data gaps, data sensitivity, default assumptions, and data limitations for the Study Area.

Follow-up Studies may be needed for a Study Area based upon stakeholder review of Initial Study results and the region-specific management and policy issues for the Study Area. Technical objectives for a Follow-up Studies may include:

1. Delineate the lateral and vertical extents of regions within a Study Area where beneficial uses are being or have been impaired by salt/nitrate accumulation, or are vulnerable to such impairment;
2. Determine current and legacy salt/nitrate sources that are causing or have caused beneficial use impairment and establish the salt/nitrate load contribution of each source;
3. Assess the fate and transport of salt and nitrate, including surface water mixing and preferential migration pathways (e.g., presence or absence of low permeability strata, proximity of irrigation or potable supply wells),
4. Ensure compliance with the salt and nutrient management plan requirements of the Recycled Water Policy, and
5. Characterize temporal variations in salt/nitrate loads that may influence implementation of management practices, such as the Real Time Management Program of discharges to the San Joaquin River.

4. Technical Study Approach

Studies should be conducted in a phased approach to promote cost-effective evaluations and provide an opportunity for stakeholder input at intermediate points in the technical study process.

Initial Studies should be completed for all Study Areas. They should consist of the initial data gathering and simplified modeling to establish water budgets and salt/nitrate balances and the collection of additional basic summary information about known contamination and impairment, recycled water and groundwater recharge projects, regulatory parameters, and local planning programs and monitoring pertaining to salt and nitrate within the Study Area.

INITIAL STUDIES

Step 1: The first step in an Initial Study is a clear delineation of the Study Area and a description of Study Area characteristics. All studies should employ a clearly defined Study Area, with horizontal and vertical boundaries that are consistently used as the frame of reference for all subsequent evaluations. Boundaries may include a combination of natural hydrological boundaries (watersheds and groundwater basins), water supply and wastewater infrastructure, locations of existing salty/nitrate regulatory endpoints, land use, data availability, coverage and format, and political boundaries such as water districts, agricultural coalitions, and Integrated Regional Water Management (IRMW) planning areas. Wherever possible, Study Areas should be defined by natural boundaries because use of political boundaries will complicate and increase the cost and amount of time it takes to develop water budgets

and salt/nitrate mass balances. Study area characteristics should include climate, physiography, geology, hydrology, and hydrogeology. We recommend using GIS to delineate Study Areas and Study Area features to promote consistency between Study Areas, but equivalent geo-referenced data are acceptable.

Step 2: The second step in an Initial Study is the development of water budgets.[3] A water budget is the characterization and accounting of inputs (water sources), outputs (water sinks), and changes in water volume (e.g., groundwater elevation changes) for a defined Study Area. Examples of water sources and sinks are provided in the attached Salt/Nitrate Balance Study Evaluation Checklist (Table 1). The study also may need to identify constraints to the water budget as applicable[4] (e.g. permit terms, environmental regulations, risk management). *The development of accurate water budgets is the foundation of the salt/nitrate mass balances.*

Step 3: The third step in an Initial Study is the development of salt/nitrate loads and mass balances. All salt/nitrate sources, sinks, and concentrators are identified with appropriate quantitative, location, and associated land use data. Examples of salt/nitrate sources, sinks, and concentrators are provided in the attached Salt/Nitrate Balance Study Evaluation Checklist (Table 1). This information is used in conjunction with the water budgets to estimate salt/nitrate loads and to complete accompanying mass balances. Salt/nitrate loads being discharged to a particular water body are estimated by multiplying the flow volume of each discharge by its total dissolved solids (TDS) (or other measurement of salt concentration) and nitrate concentrations. As with the water budgets, the data and assumptions relied upon to conduct the salt/nitrate mass balances must be clearly identified.

Step 4: The fourth step in an Initial Study is to synthesize and create visualizations of water budget and salt/nitrate mass balance information. Data visualization should be done in consideration of salt/nitrate issues and regulatory endpoints so that stakeholders can determine if the studies are sufficient to accomplish the goals of the study (i.e., the goals established in Section 2 of this document such as establish surface water and groundwater beneficial uses, prioritize Study Areas, understand the linkages between Study Areas, prioritize potential salt/nitrate management practices, identify and support appropriate beneficial use and water quality objective changes, and develop regional Salt and Nutrient Management Plans that act together to protect or restore surface water and groundwater beneficial uses ultimately adopted in the Basin Plan).

[3] More than one water budget may need to be developed to capture variability in water volumes and management strategies attributable to different hydrologic conditions (e.g., wet, above normal, below normal, dry, and critical water year classifications, dry vs. rainy seasons). For surface water evaluations, we recommend a minimum of a monthly temporal scale for water budgets and salt/nitrate mass balances. For groundwater evaluations, we recommend an annual, or if justified, a longer temporal scale for water budgets and salt/nitrate balances.

[4] It is critical to identify the water that may be consumed in the Study Area and that which must be allowed to pass through or remain in place.

The Knowledge Gained Subcommittee recommends that data be presented in a consistent manner and that minimum data visualization requirements be developed by CV SALTS such that results of studies from different Study Areas can be compared and integrated into a valley-wide conceptual model. Examples of recommended data visualization are water budget diagrams, mass balance diagrams, bar charts, pie charts, histograms and time series graphs. For consistency, we recommend that such data visualizations use the following units:

- Loading rates: tons/day, tons/month, or tons/yr (depending on temporal scale of interest)
- Concentrations: mg/L
- Flowrates: acre-ft/day, acre-ft/month, or acre-ft/yr (depending on temporal scale of interest)

The salt/nitrate source identification studies should be essentially the "common language" between regional Salt and Nitrate Management Plans, so as to allow for some surety that regional management practices will be coordinated and not acting at cross-purposes to one another.

Step 5: The fifth step in an Initial Study is the collection of the additional basic information needed to prioritize Study Areas, identify Study Areas that will require Follow-up Studies, and feed into the comprehensive salt and nitrate management plan for the entire Central Valley. This additional information should include identification and descriptions of known contamination/impairment in the Study Area , recycled water and groundwater recharge projects in the Study Area, regulatory parameters, and local planning programs and monitoring pertaining to salt and nitrate within the Study Area.

FOLLOW-UP STUDIES

The nature and complexity of Follow-up Studies will vary depending on the situation. Additional investigations or computer modeling may be needed to refine water budgets, more accurately characterize temporal salt/nitrate concentration trends, evaluate salt/nitrate fate and transport, or help prioritize management practices needed to meet regulatory endpoints (e.g., attainment of water quality objectives in local and downstream water bodies).

Follow-up Studies may include the following:

- Modeling to develop more refined water budgets, salt/nitrate mass balances, and for other complex analytical needs;
- Evaluation of surface water bodies carrying the largest loads and regions within groundwater basins with the highest salt/nitrate concentrations;
- Evaluation of drivers of surface water and groundwater supply management and of land cover decisions in the Study Area;
- Evaluation of land cover at current development level and at estimated build out (or through end of existing general plan coverage);
- Evaluation of current best management practices in the region; and

- Evaluation of current monitoring gaps and funding/schedule to fill.

DATA COMPLETENESS AND ACCURACY

All data relied upon to conduct the studies should be clearly documented.

The reliability of the water budgets and salt/nitrate mass balances largely depends upon data completeness and accuracy. Data completeness and accuracy varies broadly throughout the Central Valley. Incomplete or conflicting data should be described, and actions taken to address such problems (e.g., using other assumptions supported by references needed to develop salt/nitrate loads and mass balances) should be documented.

Data that has undergone quality assurance/quality control review should be used preferentially to conduct salt/nitrate source identification studies. Other data should be used only after they are reviewed for obvious quality issues, and such data should be clearly documented as being of lower quality. Sensitivity analyses should be conducted to determine whether data variability affects water budgets and salt/nitrate mass balances.

Assumptions will need to be made in cases where no data exist. All assumptions should be clearly identified and, whenever, possible, supported by references. **The Knowledge Gained Subcommittee recommends that CV SALTS develop a set of approved default assumptions for use when data are not available. Sensitivity analyses can be used to determine whether default assumptions are appropriate, or whether additional data collection or studies are needed.**

5. Suggested Initial Study Outline

A suggested general outline for Initial Study report, along with a brief description of each report section, is provided below. In addition, the attached Salt/Nitrate Balance Study Evaluation Checklist (Table 1) provides much more detail and should be reviewed and used in conjunction with the outline below. Recommended outline for Initial Study reports:

- Description of the Study and Physical Description of Regions: This section should include an overview of the study goals and objectives, the constituents addressed in the study, and any stakeholders participating in study. In addition, both written and graphical descriptions should be provided of regional, watershed, and groundwater basin boundaries; areal extent of the region; climate, water sources, hydrology, geology, hydrogeology, and land use of the region.

- Data: This section should identify data sources, discuss data quality, limitations and sensitivity, and describe any assumptions used and the basis for those assumptions..

- Water Budgets: Regions should develop one or more water budgets that characterize the water dynamics and use of the region, at spatial and temporal scales that are appropriate for salt/nitrate management. This section should include a conceptual model of the budgets; discuss factors influencing the budgets; identify and quantify the significant surface and groundwater sources entering and pathways leaving the region; and should develop and discuss the water balances. All assumptions upon which the water budgets were based should be clearly identified, and the bases for the assumptions should be explained and, where possible, supported by references.

- Salt/Nitrate Loads and Mass Balances: Regions should develop salt/nitrate loads and mass balances that correspond to each water budget developed. This section should identify all significant salt/nitrate sources and sinks; quantify salt/nitrate loads associated with each source and sink; prioritize sources to surface water and groundwater, and estimate the rate of salt/nitrate accumulation or loss and project groundwater TDS/nitrate concentrations into the future. Representative TDS/nitrate concentrations used to calculate salt/nitrate loads should be identified. All assumptions upon which the mass balances were based should be clearly identified, and the bases for the assumptions should be explained and, where possible, supported by references. Data gaps and recommended areas of further study, if needed, should be discussed.

- Additional Basic information: For each Study Area, additional basic information should be collected that will be needed for the overall CV-SALTS effort. This additional information should include a summary of:

  - Known contamination/impairment in the Study Area – this information could be obtained from individuals, organizations, or agencies familiar with water quality issues in the Study Area (e.g. County Environmental Health Departments, Integrated Regional Water Management Groups, water purveyors. water users)
  - Recycled water and groundwater recharge projects in effect or planned in the Study Area
  - Regulatory requirements, beneficial uses, local planning objectives, and existing management programs and strategies pertaining to salt and nitrate loads and concentrations within the Study Area, and
  - Surface water and groundwater monitoring programs collecting flow, groundwater level, and salt and nitrate-related water quality data.

Salt/Nitrate Balance Study Evaluation Checklist

				Pilot Study	Turlock Study
1	**Description of the Study and Physical Description of Study Area**				
	Identifies Stakeholders Participating in the Study			●	○
	Identifies Goals and Objectives of the Study			●	●
	Physical Description of Study Area				
		Describes physical boundaries of the Study Area		●	●
		Describes the rationale for the physical boundaries		●	●
		Applies physical boundaries to water, salt, and nitrate balances		●	●
		Provides the areal extent (acreage) of the Study Area		●	●
		Identifies watershed boundaries within and near the Study Area		●	○
		Identifies groundwater subbasin boundaries within and near the Study Area		●	●
		Identifies hydrologic areas (surface and groundwater) tributary to and from the Study Area		●	⊙
		Describes Study Area geology		●	●
		Describes Study Area hydrogeology		●	●
		Describes current Study Area land use		●	●
		Describes the Study Area climate		⊙	○
		Identifies Study Area water sources		●	●
		Are GIS shapefiles and data sources available for the following:			
			Physical boundaries of Study Area	●	○
			Boundaries of watershed(s)	●	○
			Boundaries of groundwater subbasin(s)	●	○
			Surface water bodies	●	○
			Land use	●	○
2	**Data**				
		Presents and references all flow data used for the study		⊙	●
		Presents and references all salt data used for the study		●	●
		Presents and references all nitrate data used for the study		●	●
		Evaluates and discusses data sensitivity		●	⊙
		Identifies and quantifies data limitations, including accessibility and availability in useful format		●	⊙
3	**Water Budget(s)**				
		Provides a conceptual model of the water budget(s)		⊙	●
		Identifies and describes the water uses associated with various land uses		⊙	⊙
		Defines and discusses an appropriate physical scale based on available data		●	●
		Defines and discusses an appropriate temporal scale based on available data		⊙	○
		Develops water budget(s) for dry, wet, and average conditions		○	○
		Identifies and discusses the applicability of the following factors in the water budget:			
			assumed water usage used for different land use categories	⊙	●
			hydrology	⊙	○
			residence time factors	⊙	○
			regulatory demands	○	○
			habitat considerations	○	○
			flood control	○	○
			water supply variability	⊙	○
		Identifes and discusses the applicability of the following elements in the water budget(s):			
			imported surface water	⊙	●
			precipitation	⊙	●
			land application of wastewater	⊙	●
			wastewater discharges to surface water	⊙	●
			residential irrigation	⊙	●

Salt/Nitrate Balance Study Evaluation Checklist

				Pilot Study	Turlock Study
3	**Water Budget(s) (continued)**				
			irrigation subsurface drainage	◉	●
			agricultural runoff	◉	●
			stormwater runoff	○	●
			groundwater extraction	◉	●
			groundwater recharge	◉	●
			groundwater seepage to surface water	◉	●
			groundwater inflow from outside the Study Area	◉	●
			groundwater outflow from the Study Area	◉	●
			surface water inflow from outside the Study Area	◉	○
			surface water outflow from the Study Area	◉	○
			infiltration	◉	●
			evaporation	◉	◉
			evapotranspitration	◉	●
		Defines terminologies used in the water budget(s)		◉	●
		Provides a written explanation of the water budget(s)		◉	●
		Identifies data gaps in the water budget(s) and recommends areas for further study		◉	●
		Provides a graphical representation of the water budget(s)		○	●
		--Graphic identifies and quantifies all significant sources of inflow to the Study Area		○	●
		--Graphic identifies and quantifies all water leaving the study area		○	●
4	**Salt Balance(s)**				
		Provides a conceptual model of salt movement from sources to sinks in the Study Area		●	●
		Develops salt balance(s) for dry, wet, and average conditions		◉	○
		Identifies and discusses the applicability of the following sources and sinks in the salt balance(s):			
			imported surface water	●	●
			agricultural runoff	◉	●
			irrigation subsurface drainage	●	●
			soil amendments	●	●
			fertilizer	●	○
			CAFOs (e.g., dairies)	●	●
			industries (e.g., food processors, wineries)	◉	●
			food and other products exported from the Study Area	◉	●
			land application of wastewater		
			-- CAFOs	●	●
			-- municipalities	●	●
			-- food processors and other industries	●	●
			wastewater discharges to surface water		
			-- municipalities	●	●
			-- food processors and other industries	●	●
			residential irrigation	●	●
			septic tank systems	●	●
			stormwater runoff	◉	●
			water transfers	●	○
			groundwater extraction	●	●
			groundwater recharge	●	●
			groundwater seepage to surface water	●	●
			groundwater inflow from outside the Study Area	◉	●
			groundwater outflow from the Study Area	◉	●
			surface water inflow from outside the Study Area	●	●

Salt/Nitrate Balance Study Evaluation Checklist

				Pilot Study	Turlock Study
4	**Salt Balance(s) (continued)**				
			surface water outflow from the Study Area	●	●
			mineral dissolution	●	●
			atmospheric deposition and scour	●	●
			upwelling of saline groundwater	○	●
		Defines terminologies used in the salt balance(s)		◎	●
		Identifies, quantifies, and prioritizes salt sources to groundwater largest to smallest		●	●
		Identifies, quantifies, and prioritizes salt sources to surface water largest to smallest		●	●
		Provides concentrations and flow rates for each source		◎	◎
		Provides loading rates for each source			
			lbs	●	○
			tons	○	●
			per day	●	○
			per month	○	○
			per year	◎	●
			per acre	◎	○
			per Study Area	○	●
		Identifies and quantifies salt sinks		●	●
		Provides loading rates to each sink		●	●
		Provides a written explanation of the salt balance(s)		◎	●
		Provides a graphical representation of the salt balance(s)		◎	●
		--Graphic identifies and quantifies all significant salt sinks out of the Study Area		●	●
		Identifies data gaps in the salt balance and recommends areas for further study		●	◎
		Quantifies the rate of salt accumulation or reduction in the Study Area assuming current conditions		●	●
		Projects salinity concentrations into the future assuming current conditions		◎	●
5	**Nitrate Balance(s)**				
		Provides a conceptual model of nitrate movement from sources to sinks in the Study Area		●	○
		Develops nitrate balance(s) for dry, wet, and average conditions		◎	○
		Identifies and discusses the applicability of the following sources and sinks in the nitrate balance(s):			
			imported surface water	●	○
			agricultural runoff	◎	○
			irrigation subsurface drainage	●	○
			soil amendments	●	○
			fertilizer	●	○
			CAFOs (e.g., dairies)	●	○
			industries (e.g., food processors, wineries)	◎	○
			food and other products exported from the Study Area	◎	○
			land application of wastewater		
			-- dairies and other CAFOs	●	○
			-- municipalities	●	○
			-- food processors and other industries	◎	○
			wastewater discharges to surface water		
			-- municipalities	◎	○
			-- food processors and other industries	◎	○
			residential irrigation	●	○
			septic tank systems	●	○
			stormwater runoff	◎	○
			water transfers	●	○
			groundwater extraction	●	○

Salt/Nitrate Balance Study Evaluation Checklist

				Pilot Study	Turlock Study
5	**Nitrate Balance(s) (continued)**				
			groundwater recharge	●	○
			groundwater seepage to surface water	●	○
			groundwater inflow from outside the Study Area	◘	○
			groundwater outflow from the Study Area	○	○
			surface water inflow from outside the Study Area	●	○
			surface water outflow from the Study Area	●	○
			atmospheric deposition and scour	●	○
			naturally occuring nitrate in groundwater	●	○
			plant uptake and nutrient cycle	●	○
			reaction decay	●	○
			gaseous loss, volatilization	○	○
		Defines terminologies used in the nitrate balance(s)		◘	○
		Identifies transformation of nitrate precurors into nitrates by discharge type		○	○
		Identifies, quantifies, and prioritizes nitrate sources to groundwater largest to smallest		●	○
		Identifies, quantifies, and prioritizes nitrate sources to surface water largest to smallest		●	○
		Provides concentrations and flow rates for each source and pre-cursor		◘	○
		Provides loading rates for each source and pre-cursor			
			lbs	●	○
			tons	○	○
			per day	●	○
			per month	○	○
			per year	◘	○
			per acre	◘	○
			per Study Area	◘	○
		Identifies and quantifies nitrate and precursor sinks		◘	○
		Provides loading rates to each sink		●	○
		Includes nitrogen losses in analysis		◘	○
		Provides a written explanation of the nitrate balance(s)		◘	○
		Provides a graphical representation of the nitrate balance(s)		◘	○
		--Graphic identifies and quantifies all significant nitrate sources into the Study Area		●	○
		--Graphic identifies and quantifies all significant nitrate sinks out of the Study Area		●	○
		Identifies data gaps in the nitrate balance and recommends areas for further study		●	○
		Quantifies the rate of nitrate accumulation or reduction in the Study Area assuming current conditions		●	○
		Projects nitrate concentrations into the future assuming current conditions		◘	○

LEGEND:

- ● Study adequately addresses issue
- ◘ Study partially addesses issue
- ○ Study does not address issue