Section 5
Surveillance and Monitoring Program

5.1 Overview

CV-SALTS developed an SNMP for the entire area under the Central Valley Water Board's jurisdiction. Although broader in overall scope, the SNMP was also developed to meet requirements set forth in the State Recycled Water Policy, adopted in 2009 by the State Water Resources Control Board (State Water Board).[1] The Recycled Water Policy establishes the minimum requirements for the development of an SNMP for the Central Valley Region, including requirements to establish a monitoring program (**Figure 5-1**).[2]

Figure 5-1. Recycled Water Policy - SNMP Monitoring Requirements

- Section 6.b(3)(a) - A basin/sub-basin wide monitoring plan that includes an appropriate network of monitoring locations - adequate to provide a reasonable, cost-effective means of determining whether the concentrations of salt, nutrients, and other constituents of concern are consistent with applicable water quality objectives. Salts, nutrients, and other constituents of concern shall be monitored as follows:
  - (i) The monitoring plan must be designed to determine water quality in the basin, and must focus on basin water quality near water supply wells and areas proximate to large water recycling projects, particularly groundwater recharge projects. Also, monitoring locations shall, where appropriate, target groundwater and surface waters where groundwater has connectivity with adjacent surface waters.
  - (ii) The preferred approach to monitoring plan development is to collect samples from existing wells if feasible as long as the existing wells are located appropriately to determine water quality throughout the most critical areas of the basin.
  - (iii) The monitoring plan shall identify those stakeholders responsible for conducting, compiling, and reporting the monitoring data. The data shall be reported to the Regional Water Board at least every three years.
- Section 6.b(3)(b) - A provision for annual monitoring of Constituents of Emerging Concern (e.g., endocrine disrupters, personal care products or pharmaceuticals) (CECs) consistent with recommendations by CDPH [California Department of Public Health] and consistent with any actions by the State Water Board taken pursuant to paragraph 10(b) of this policy [the Drinking Water Policy].

In addition to the monitoring requirements established by the Recycled Water Policy, the Central Valley Water Board is required to include a monitoring and surveillance program when establishing an implementation program in the Basin Plans: "*The implementation program shall*

[1] State Water Resources Control Board Resolution No. 2009-0011, amended by Resolution No. 2013-0003 http://www.waterboards.ca.gov/board_decisions/adopted_orders/resolutions/2013/rs2013_0003_a.pdf

[2] The Recycled Water Policy includes provisions to monitor "salt, nutrients, other constituents of concern" and "Constituents of Emerging Concern (see Figure 5-1)." In accordance with the development of the SNMP, the Executive Committee decided to focus the SNMP monitoring and surveillance program on only salt and nitrate.

include, but not be limited to: …3. A description of surveillance to be undertaken to determine compliance with the objectives (Water Code Section 13242)."[3]

The sections below provide an overview of the Surveillance and Monitoring Program (SAMP) recommended for implementation as part of the SNMP (CDM Smith 2016b). This SAMP applies only to groundwater. CV-SALTS has not developed a comparable program for surface waters; instead, the Central Valley Water Board will rely on existing monitoring and assessment programs already established for surface waters in the region.

The SAMP established the framework for the groundwater surveillance and monitoring program required to support implementation of the SNMP. While this framework relied on the use of IAZs (see SNMP Section 3.1), this framework can be readily modified to other spatial areas, including a groundwater basin, subbasin, or management zone.[4]

The SAMP framework will be further developed while the Basin Plan amendment process is underway to incorporate the SNMP into the Basin Plans. The sections below describe the goals of the SAMP framework, summarize the general proposed approach for achieving these goals, and then identify steps to be implemented so that the required surveillance and monitoring program is ready for implementation when the planned Basin Plan amendments become effective.

5.2 Program Goals

The purpose of a surveillance and monitoring program is to provide the means for determining if the established implementation programs are achieving their goals. With regard to groundwater quality, the SNMP establishes goals to improve nitrate and salt conditions in groundwater (see Section 4.1). The SAMP framework is intended to provide a means to periodically assess salt and nitrate concentrations in groundwater on a Central Valley-wide basis to evaluate progress toward meeting those goals.

The development of the SAMP framework focused on addressing two key programmatic objectives: (a) Implement a statistically-representative approach for evaluating ambient water quality (AWQ) and water quality trends across the Central Valley; and (b) establish a cost-effective program that relies on existing monitoring programs and data collection efforts to the maximum extent possible. Following is a more detailed discussion of each objective:

- Develop a monitoring program that will allow for statistically-representative AWQ determinations and trend analyses. Specifically,
    - Focus on the data necessary for the determination of AWQ, the need for programmatic updates of AWQ, and trend analyses. The goal of SAMP is value-added monitoring to provide the requisite data to inform management and regulatory decisions and implementation strategies. More specifically, the SAMP is intended to provide the

[3] SRSJR Basin Plan, p. IV-1.00; the TLB Basin Plan includes similar language on p. IV-1.

[4] Early work by CV-SALTS relied on the use of Initial Analysis Zones (IAZs) as the basis for characterizing salt, nitrate and water balance in the Central Valley (see SNMP Section 3.2). CV-SALTS later modified its approach to characterizing water quality and the SNMP presents its recommendations based on the use of groundwater basins/subbasins as its foundation (see SNMP Section 3.3).

requisite data to be able to determine the effectiveness of SNMP measures being implemented on a groundwater basin/subbasin or other subarea.

- Establish a SAMP that is robust and dense enough, both spatially and temporally, to make the AWQ determinations in a complex geographic, hydrologic, and hydrogeological environment.
- Collect ancillary data required to estimate volume-weighted ambient groundwater quality, including groundwater elevations.
- Incorporate monitoring stations associated with planned recycled water projects, including indirect potable reuse projects, to the extent that this information is available.
- Establish a dynamic monitoring network that can be expanded to meet future data needs or reduced based on findings from periodic data analyses that show less monitoring coverage is warranted.

- Develop a cost-effective monitoring program. To meet this objective:
  - Utilize existing and proposed monitoring programs and existing and proposed local monitoring wells to the maximum extent possible in order to be cost-effective and consistent. As will be discussed below this means incorporating other monitoring programs, including but not limited to, the *Irrigated Lands Regulatory Program (ILRP) trend monitoring, the Groundwater Ambient Monitoring and Assessment (GAMA) shallow domestic well monitoring program,* the *Central Valley Dairy Representative Monitoring Program, routine Title 22 sampling program, and Waste Discharge Requirements (WDR) sampling programs*.
  - Recognize that the SAMP does not require the same level of detail and intensity of monitoring throughout the Central Valley. The SNMP well network density in each area was chosen to produce an acceptable level of uncertainty, given the data variability and the spatial distribution of existing groundwater wells. In other words, fewer wells may be acceptable for areas where the spatial distribution of TDS and nitrate in groundwater is relatively small.
  - Assess groundwater quality only as frequently as necessary to meet the objective of the program. Regional groundwater quality changes typically occur over a number of years; therefore, the SAMP recommends that the recomputation of ambient TDS and nitrate will occur every 5 years, using a moving 10-year average of wells in the SAMP network for each groundwater basin/subbasin or other subarea evaluated. Trends in AWQ will be assessed the same scales as AWQ.

5.3 SAMP Framework

As described above, the SAMP established the framework for the groundwater surveillance and monitoring program to support implementation of the SNMP (CDM Smith 2016b). The basic framework for this program is summarized below. CDM Smith (2016b) provides additional details regarding each element.

5.3.1 CV-SALTS Database

The SAMP was developed using the most recent version of the CV-SALTS database (Luhdorff & Scalmanini and LWA 2014). The database was screened to remove duplicate water quality data results and wells where the most recent data were collected before 2003. The resulting database included 8,712 wells screened in the deep zone and 7,285 wells screened in the shallow zone.[5]

5.3.2 Defining a Monitoring Network

Defining the SAMP monitoring well network involved selecting a subset of wells from the SAMP database representative of each IAZ and hence capable of serving as the basis for nitrate or TDS monitoring at the IAZ scale. The larger set of wells in the SAMP database is generally unequally distributed spatially across the IAZs, often containing both well clusters and areas without well coverage. It is therefore important that the method used to select wells for inclusion in the monitoring network incorporates the ability to simultaneously de-cluster and maximize coverage across the IAZ. This was accomplished by using an equal-area and regularly-shaped (square in this case) grid cell method.

The equal-area and regularly-shaped grid cell method was selected for defining the SAMP monitoring network because it focused on the actual data available and therefore minimized potential bias resulting from estimation across areas lacking well coverage. Square grid cells of various sizes were included for possible selection, ranging from 1 square mile (1-mile x 1-mile) to 16 square miles (4-mile x 4-mile). Selecting the most appropriate grid cell size for each IAZ was a function of the number of populated grid cells (number of grid cells containing at least one well) and the resulting variability in nitrate or TDS concentrations for the grid cell size and wells selected. This was accomplished using a method that incorporated both random well selection and sample power analysis.

5.3.3 Power Analyses

Power analysis involves determining the sample size required to obtain a statistical result within a specified level of confidence, and thus one that effectively satisfies project-defined or representative objectives. It incorporates a cost / benefit analysis from the standpoint that results can be used to inform and assist with defining overall project goals. With regard to the SAMP development, power analyses were used in conjunction with bootstrap resampling to examine changes in uncertainty (levels of confidence) inherent in selecting various grid cell sizes.

5.3.4 Grid Cell Size Selection

The power analyses results were evaluated in order to select appropriate grid cell sizes for each IAZ. Theoretically, as the grid cell size decreases, the number of populated grid cells increases and the variability (margin of error) decreases. Therefore, the number of wells to include in the monitoring network depends on selecting a set of grid cell sizes that results in a practical and

[5] Initial CV-SALTS water quality evaluations classified wells vertically as shallow or deep (see SNMP Section 3.2 for discussion of these zones). The SAMP was developed based on these initial classifications. Later, CV-SALTS commissioned work that resulted in a change in how wells are vertically classified. The new classification defines upper, lower and production zones (see SNMP Section 3.3 for discussion of these zones). While in principle shallow is similar to upper and deep is similar to lower, these terms are not equivalent. As discussed in Section 5.4, it is recommended that the SAMP be updated to reflect the new terminology.

consistent margin of error across all IAZs (to the extent possible given the data contained in the SAMP database, the spatial distribution of wells with TDS and nitrate data, and the variability of the data).

The grid cell size and therefore the number of wells in the SAMP network was selected to be the largest grid size where the percentage of the upper margin of error was less than 15 percent. Grid cell sizes were chosen for TDS and nitrate in the deep zone. Because the wells used in the SAMP would be the same for nitrate and TDS, the smaller grid cell size (TDS or nitrate) to achieve an uncertainty of 15 percent or less was selected.

TDS and nitrate concentrations in the shallow zone showed greater variability spatially than in the deep zone, and the pool of available monitoring wells for selection had less areal coverage across the IAZ than the deep zone. Hence, to meet the 15 percent uncertainty threshold it was typically necessary to rely on smaller grid cell sizes – often as small as the one-square mile grid size. The intent was to meet the 15 percent uncertainty threshold using available wells only. Many grid cells did not contain existing wells – or wells that met the data criteria described in Section 5.3.5 – and hence, as noted below, after completing the well selection process using *available wells*, the overall average density of selected shallow wells in the Central Valley Region was one well sampled for every 15 square miles.

5.3.5 Algorithm for Monitoring Well Selection

Using the power analyses, the grid cell sizes were chosen to provide a sufficient well density to characterize ambient groundwater quality to within about a 15 percent margin of error using the existing wells within each IAZ. In the SAMP algorithm, one existing well was selected to be representative of the water quality for the entire grid. Criteria used to select recommended wells for inclusion in the SAMP network include the following:

- The SAMP monitoring networks are based on overlaying the grid cell network over the array of existing wells.
- Only wells with nitrate and/or TDS data between 2003 and 2014 were selected for this analysis.
- Wells with an active status were preferentially selected over wells with inactive status.
- Community water system wells were preferentially selected for urban land use areas, because these wells are a part of other water quality monitoring programs. No other preferences for other land uses was used in the selection of wells.

In grid cells with no active wells that meet the first criterion, then an inactive well was assigned to that grid cell.

The algorithm for well selection was implemented using ESRI's ArcGIS ModelBuilder, which is a "visual programming language for building geoprocessing workflows." The SAMP well selection workflow was programmed into ModelBuilder and then ModelBuilder was run to select the wells in the SAMP monitoring network (shallow and deep).

Based on the SAMP algorithm, two monitoring well networks were established – one for the shallow zone and one for the deep zone. Of the 8,712 wells in the CV-SALTS database for the deep zone, 2,315 were selected by the SAMP algorithm, or approximately 27 percent of the available wells. Likewise, for the shallow zone, 1,461 of 7,285 wells (20 percent) were selected by the SAMP algorithm. This translates to a well density of about one SAMP well per 9.7 square miles in the deep zone and one well per 15 square miles for the shallow zone.

5.4 Recommended Next Steps to Finalize the SNMP Surveillance and Monitoring Program

The SAMP (CDM Smith 2016b) only provides the framework for the establishment of a groundwater surveillance and monitoring program to evaluate progress towards achieving the management goals of the SNMP. As with any surveillance and monitoring program, implementation of this program will require completion of a number of steps. **Table 5-1** summarizes these recommended steps. It is recommended that these steps be implemented during development of the Basin Plan amendments to support implementation of the SNMP. The outcome will be a monitoring program that is ready for implementation.

5.5 Surveillance and Monitoring Program Implementation

It is anticipated that implementation of the Surveillance and Monitoring Program will occur soon after adoption of planned Basin Plan amendments. This program will implement data collection efforts as needed per the final selected wells in the program (see Table 5-1, Step 2) according to the program SAP, QAPP and HASP.

Regional groundwater quality changes typically occur over a number of years; as such, the water quality assessment period needs to be sufficiently long to capture meaningful changes in water. Accordingly, consistent with the SAMP (CDM Smith 2016b), the first water quality assessment under this surveillance and monitoring program will begin five years after the effective date of the Basin Plan amendments.

During the five-year period prior to the initiation of the water quality assessment, the results of samples collected from wells included in the surveillance and monitoring program will have been routinely uploaded into the GeoTracker GAMA Database. The assessment will use recorded groundwater elevation and water quality data to assess ambient water quality and trends for nitrate and TDS in the upper and lower zones in each groundwater basin/subbasin. The specific analyses completed and how these findings are reported will be as described in the SAP and QAPP.

Table 5-1. Recommended Next Steps in Surveillance and Monitoring Program Implementation

Step	Description
1	**Convert IAZs to Groundwater Basins/Subbasins and Modify Shallow/Deep Zones to Upper/Lower Zones** – The original assessment of groundwater conditions in the Central Valley was IAZ based (see SNMP Section 3.1); later CV-SALTS modified its approach to use DWR groundwater basins/subbasins as the foundation for groundwater management under the SNMP. In addition, the designation of shallow and deep zones was modified to upper and lower zones. The revised SAMP would utilize these new definitions of upper and lower zones.
2	**Final Selection of Monitoring Wells.** Stakeholders implementing the SNMP surveillance and monitoring program will work collectively to verify that the wells selected as part of the SAMP development process exist (see CDM Smith 2016b) and that they are the most appropriate wells to include in the program, based on existing monitoring programs and local hydrogeological and water quality knowledge. (See also, the next step, below.) The intent of this evaluation is to ensure that data already being collected by existing monitoring programs are utilized to the maximum extent practicable. Wells that are locally-verified and selected for incorporation into the program will fall into one of three categories. These categories and the data handling approach are described as follows: • **Category 1 – Wells Routinely Sampled and Reported**. For wells in Category 1, database queries will be designed to extract the requisite data from the centralized database (GeoTracker GAMA or equivalent). These data will undergo data quality assurance/quality control (QA/QC) protocols for evaluating data quality prior to the uploading of data to the recommended SAMP database, in order to ensure that only data of sufficient quality are used in the statistical analyses. • **Category 2 - Wells Are Sampled, but Are Not Reported**. A determination of the appropriate stakeholder will need to be made concerning Category 2. Once identified, the stakeholder sampling the Category 2 well can either initiate the upload and incorporation of the well into GeoTracker GAMA, or they can report the data to the SAMP database. The data exchange will utilize an electronic data deliverable (EDD) request form for each of the identified Category 2 data sources. These data will be QA/QC'd using the same protocols as Category 1 wells. • **Category 3 - Wells in the CV-SALTS Database (sampled at least once during the period from 2003 to 2014), but Are Not Routinely Sampled**. Category 3 wells are not currently routinely monitored. It is assumed that up to 50 percent of these wells will need to be physically verified in the field. Incorporation of these wells will require completion of the following steps: - Develop appropriate documentation: Sampling and Analysis Plan (SAP), Quality Assurance Project Plan (QAPP) and Health and Safety Plan (HASP). - Contact the well owner and obtain written permission to sample the well once every five years, at a minimum. - Samples will be collected by a CV-SALTS representative per the SAP and QAPP; samples will be analyzed using a State-Water Board certified laboratory - Laboratory will generate a program-specific EDD, which will be submitted to GeoTracker GAMA as the data are generated.

Table 5-1. Recommended Next Steps in Surveillance and Monitoring Program Implementation

Step	Description
3	**Existing and Planned Monitoring Programs and Local Knowledge.** To the extent possible, the SAMP will utilize existing monitoring programs and existing monitoring stations in order to be cost-effective and consistent. During the on-going SAMP implementation, other monitoring programs that are being carried out – or will be in the future – will be identified and evaluated, including the ILRP trend monitoring, the GAMA shallow domestic well monitoring program, the Central Valley Dairy Representative Monitoring Program, routine Title 22 sampling program, and WDR sampling programs. These monitoring programs, or portions of the monitoring programs, may be incorporated into the SAMP. With regards to the use of local knowledge, it is anticipated that in some areas stakeholders will establish management zones as the pathway to comply with the SNMP. When developing a Management Zone Implementation Plan for a management zone, which must incorporate a monitoring component, it is anticipated that the SAMP, as applied to that area, would be evaluated and possibly modified to be consistent with the monitoring needs for the management zone. This step is intended to minimize duplication of effort and allow consideration of local factors including local knowledge of hydrogeology (including recharge areas and surface water and groundwater interconnections), historical and future land and water resource uses, existing monitoring programs (including refinement of existing local/regional programs in response to the Sustainable Groundwater Management Act), and consideration of disadvantaged communities.
4	**Sampling and Analysis Plan**. A SAP will be developed that is consistent with state data collection requirements. The SAP will include sections that describe the background, data quality objectives, sampling rationale, request for analyses, field methods and procedures, sample containers, preservatives, packaging, investigation-derived waste, sample documentation, chain-of-custody, and shipment.
5	**Quality Assurance Project Plan**. A QAPP will be developed that is consistent with state quality assurance requirements. The QAPP includes data quality objectives, criteria for measurement data, documentation and records, certification and training, sample handling and chain-of-custody, quality control, instrument/equipment testing, inspection, and maintenance requirements, assessment and oversight, and data validation and usability. The QAPP will including data reporting protocols, including requirements to upload data to the GeoTracker GAMA database.
6	**Health and Safety Plan.** The HASP will include a description of the known hazards and evaluations of the risks associated with program, a list of key personnel and alternates responsible for site safety, response operations, and protection of public health, description of levels of protection to be worn by personnel in work area, establishment of procedures to control site access, description of decontamination procedures for personnel and equipment, establishment of site emergency procedures, prevention of heat stress, slip trip and fall hazards, and driving safely.