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].

CV-SALTS prepared a surveillance and monitoring program (SAMP) report that may be used as a template for the establishment of a surveillance and monitoring program to support implementation of the SNMP once the Basin Plan amendment process is complete (CDM Smith 2016e). This effort only focused on addressing the requirements of Recycled Water Policy Section

[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.

6.b(3)(a) as related to salt and nitrate. Section 6.b(3)(b), which addresses CECs was not covered by the SAMP; instead, the Central Valley Water Board will rely on existing or new monitoring and assessment programs established for CECs the region.

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 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 SAMP report provides an example of the type of program that could be established.

The sections below provide an overview of the findings of the SAMP report developed to provide an example for development of a surveillance and monitoring program to assess the effectiveness of the SNMP. This effort relied on the use of IAZs (see SNMP Section 3.1), to develop the template; however, the approach can be readily modified to other default spatial areas, such as a groundwater basin, subbasin, or management zone.[4] The example SAMP is specific to groundwater. CV-SALTS has not developed a comparable example 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 actual surveillance and monitoring program that will be established to support SNMP implementation will be further developed while the Basin Plan amendment process is underway to incorporate the SNMP into the Basin Plans. To facilitate this effort, the sections below are provided to describe the goals for a surveillance and monitoring program to support SNMP implementation, summarize how the SAMP can serve as an example of such a program that can achieve these goals, and then identify steps still 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 to determine if the SNMP's programs are achieving their goals. With regard to groundwater quality, the SNMP establishes goals to improve nitrate and salt conditions (see Section 4.1). The SAMP report describes an approach that may be used to periodically assess salt and nitrate concentrations in these waters on a Central Valley-wide basis to evaluate progress toward meeting those goals. Ultimately, the selected approach is intended to rely on existing local, regional and subregional monitoring programs to the maximum extent practicable. To that end, **Figure 5-2** illustrates how such a surveillance and monitoring program can be developed that relies primarily on existing monitoring programs.

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[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).

The SAMP report recognizes that a surveillance and monitoring program to evaluate the effectiveness of SNMP implementation should be consistent with the two following key objectives: (a) utilize 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. To meet this objective:
    - Establish a program that provides the requisite data to inform management and regulatory decisions and implementation strategies. More specifically, the program is intended to provide the requisite data to be able to determine the effectiveness of SNMP measures being implemented on a groundwater basin/subbasin scale or other scales as appropriate. In this regard, data collection should focus only on the data needed to periodically assess AWQ and water quality trends and the need for program modifications.
    - Establish a program 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 (a) expanded to meet future data needs or (b) 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 practicable 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* (see Figure 5-2 for an illustration of how existing monitoring programs are intended to be incorporated into a surveillance and monitoring program).
    - Recognize that an effective surveillance and monitoring program does not require the same level of detail and intensity of monitoring throughout the Central Valley. The SAMP provides an example of how a well monitoring network may be established, e.g., the 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 occur every 5 years, using a moving 10-year average of well concentration data.

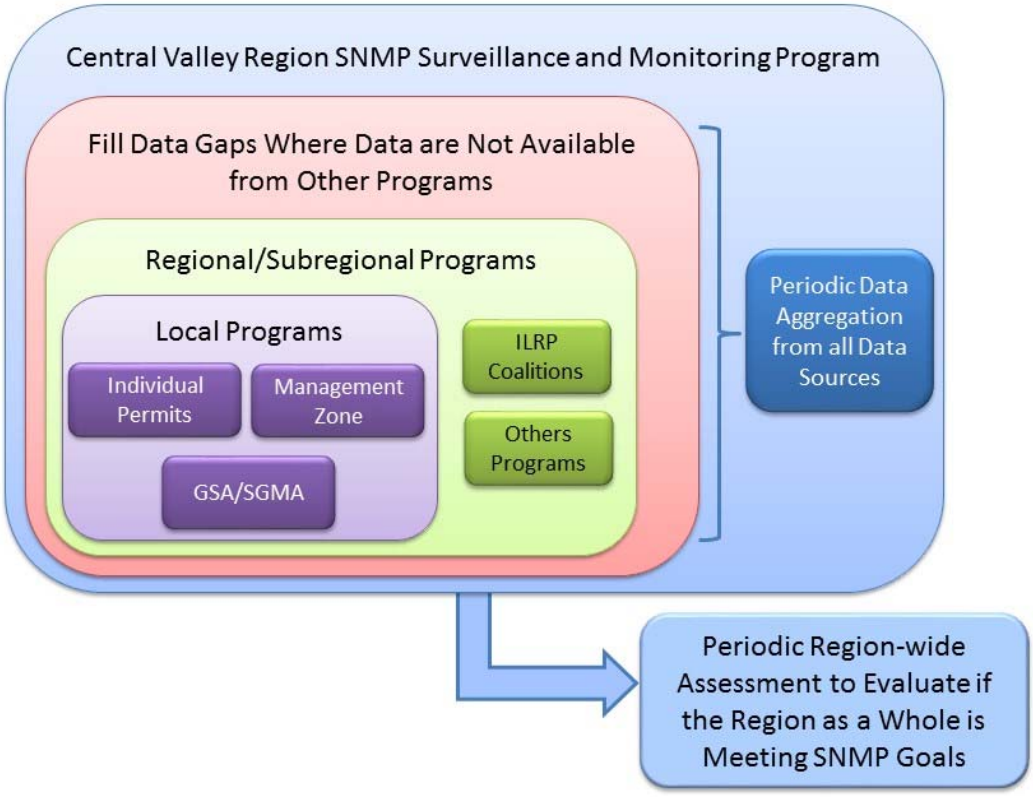

Figure 5-2. Illustration of SNMP Surveillance and Monitoring that Relies on Existing Monitoring Program Data

5.3 SAMP Approach

As described above, the SAMP established a template for how a groundwater surveillance and monitoring program could be developed to support implementation of the SNMP. The SAMP only provides an example. The actual surveillance and monitoring program will be developed during the development of Basin Plan amendments to support SNMP implementation. To provide guidance in development of the final surveillance and monitoring program, the following sections are provided to summarize key elements considered in the SAMP example (see CDM Smith [2016e] for additional information 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 Consulting Engineers and Larry Walker Associates 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 example 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 (or other areas such as a groundwater basin/subbasin or management zone). For the SAMP example, 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] 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. For the purposes of the surveillance and monitoring network the selection of wells for incorporation into the program should be based on the use of upper and lower zones.

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, for the SAMP example the number of wells to include in the monitoring network depended on selecting a set of grid cell sizes that results in a practical and consistent margin of error across all IAZs (to the extent possible given the data contained in the 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 example 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 (Note: The 15 percent uncertainty value was selected for the purposes of developing the example SAMP network; this uncertainty value can be modified as appropriate to meet the objectives of the surveillance and monitoring program).

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 example SAMP well network include the following:[6]

[6] Note that the algorithm used for the SAMP example is generally an automated approach for selecting wells based on select criteria. In some cases, it is known that selected wells are already being sampled under existing monitoring

- 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 criteria, 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 only provides an example for the establishment of a groundwater surveillance and monitoring program to evaluate progress towards achieving the management goals of the SNMP. Implementation of this program will require collaboration by Central Valley Region stakeholders to complete a number of steps. **Table 5-1** summarizes these steps, which are recommended for implementation during development of the Basin Plan amendments to implement the SNMP. The outcome will be a monitoring program that is ready for implementation.

programs (e.g., community water system wells); for other selected wells, it is expected that they are currently being sampled under existing programs given the relatively recent nitrate and/or TDS data in the database. Ultimately, the goal of the well selection process is to select as many wells as possible that are already being sampled by existing programs to minimize the cost of implementation of a surveillance and monitoring program to support SNMP implementation.

Table 5-1. Minimum Recommended Next Steps in Development of Surveillance and Monitoring Program to Support SNMP Implementation

Step	Description
1	**Identify Existing and Planned Monitoring Programs.** To the extent possible, the surveillance and monitoring program will utilize existing monitoring programs and existing monitoring stations in order to be cost-effective and consistent. During the development of the surveillance and monitoring program, existing monitoring programs that can provide the data needed for this program will be identified and evaluated for incorporation into the program, including the ILRP trend monitoring, the GAMA shallow domestic well monitoring program, the Central Valley Dairy Representative Monitoring Program, routine Title 22 sampling program, WDR sampling programs, and other programs as identified (e.g., see Figure 5-2). In the future, wells included in the original program could be modified based on new information, local knowledge or establishment of new or updated monitoring programs. For example, when developing a Management Zone Implementation Plan for a management zone, the Plan must include a monitoring component. It is anticipated that when these monitoring programs are developed, this activity would be coordinated with the surveillance and monitoring program to minimize any duplication of sampling. In addition, when new monitoring program requirements are established at the regional or state level, e.g., in response to implementation of SGMA, such efforts should be closely aligned with the goals of this surveillance and monitoring program.
2	**Final Selection of Monitoring Wells for Inclusion in the Program.** Stakeholders implementing the SNMP surveillance and monitoring program will work collectively to establish a well network that meets the goals and objectives of the program, as described in this chapter. This effort will consider existing monitoring programs to the maximum extent practicable and where spatial gaps exist in the Region, determine how to best address data collection needs in those areas. Ultimately, the outcome of this effort is to minimize duplication of effort and select only the minimum number of wells needed to meet program goals and objectives so that the surveillance and monitoring program is as cost effective as possible.
3	**Sampling and Analysis Plan (SAP) and Quality Assurance Project Plan (QAPP)**. Because the surveillance and monitoring program will rely on existing data collection efforts to the maximum extent practicable, the program should establish a common SAP and QAPP to ensure that data collection efforts are consistent across the Central Valley Region. The SAP and QAPP should be consistent with state data collection requirements. Specifically: • 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. • 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 include data reporting protocols, including requirements to upload data to the program's selected database, e.g., GeoTracker GAMA database.
4	**Health and Safety Plan (HASP).** Similar to the SAP and QAPP, a HASP should be developed for program consistency. 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, describe decontamination procedures for personnel and equipment, establish site emergency procedures, prevent of heat stress, minimize slip trip and fall hazards, and promote safe driving. Where appropriate, HASPs developed for existing programs can be compiled into one repository.

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 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 quality. Accordingly, it is anticipated that the first water quality assessment under the SNMP surveillance and monitoring program would begin five years after the effective date of the planned 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 uploaded into a database, e.g., GeoTracker GAMA Database. As illustrated in Figure 5-2, these data would be uploaded as part of existing monitoring program activities. 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.

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