AUGUST 2021

CHAPTER 3: SUSTAINABLE MANAGEMENT CRITERIA

SISKIYOU COUNTY FLOOD CONTROL & WATER CONSERVATION DISTRICT

Shasta Valley Groundwater Sustainability Plan

PUBLIC DRAFT REPORT

SISKIYOU COUNTY FLOOD CONTROL AND WATER CONSERVATION DISTRICT GROUNDWATER SUSTAINABILITY AGENCY SHASTA VALLEY GROUNDWATER SUSTAINABILITY PLAN

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Contents

3.1 Introduction and Definition of Terms

This section defines sustainable groundwater management in the Basin through the description and quantification of sustainable management criteria (SMC) for each of the sustainability indicators and definition of the sustainability goal. Building on the Basin conditions described in Chapter 2, this section describes the processes and criteria used to define the undesirable results, measurable objectives, and minimum thresholds for each sustainability indicator.

The following terms, defined below, are used throughout this chapter.

Sustainability Goal: The overarching goal for the Basin with respect to managing groundwater conditions to ensure the absence of undesirable results.

Sustainability Indicators (SI): Six indicators, defined under SGMA: chronic lowering of groundwater levels, reduction of groundwater storage, seawater intrusion, degraded groundwater quality, land subsidence and depletions of interconnected surface water. These indicators describe groundwater-related conditions in the Basin and are used to determine occurrence of undesirable results. (23 CCR 354.28(b)(1)-(6).)

Sustainable Management Criteria (SMC): Minimum thresholds, measurable objectives, and undesirable results, consistent with the sustainability goal, that must be defined for each sustainability indicator.

Undesirable Results (UR): Conditions, defined under SGMA as:

> … one or more of the following effects caused by groundwater conditions occurring throughout the basin:
>
> - Chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply if continued over the planning and implementation horizon….
> - Significant and unreasonable reduction of groundwater storage.
> - Significant and unreasonable seawater intrusion.
> - Significant and unreasonable degraded water quality, including the migration of contaminant plumes that impair water supplies.
> - Significant and unreasonable land subsidence that substantially interferes with surface land uses.
> - Depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water.(Wat. Code § 10721(x)(1)-(6).)

Minimum Thresholds (MT): a quantitative value representative of groundwater conditions at a site (or sites), that, if exceeded, may cause an undesirable result. The term "maximum threshold" is the equivalent value for sustainable management criteria with a defined maximum limit (e.g., groundwater quality and stream depletion).

Measurable Objectives (MO): specific and quantifiable goals that are defined to reflect the desired groundwater conditions in the Basin and achieve the sustainability goal within 20 years. Measurable objectives are defined in relation to the six undesirable results and use the same metrics as minimum thresholds.

Interim Milestones: periodic goals (defined every five years, at minimum), that are used to measure progress toward measurable objectives and the sustainability goal.

Representative Monitoring Sites (RMP): for each sustainability indicator, a subset of the monitoring network, where minimum thresholds, measurable objectives and milestones are defined.

Project and Management Actions (PMAs): creation or modification of a physical structure / infrastructure (project) and creation of policies, procedures, or regulations (management actions) implemented to achieve Basin sustainability.

3.2 Sustainability Goal

The overall sustainability goal of groundwater management in the Basin is to maintain groundwater resources in ways that best support the continued and long-term health of the people, the environment, and the economy in Shasta Valley, for generations to come. This includes managing groundwater conditions for each of the applicable sustainability indicators in the Basin so that:

- Groundwater elevations and groundwater storage do not significantly decline below their historically measured range, protect the existing well infrastructure from outages, protect groundwater-dependent ecosystems, and avoid significant additional stream depletion due to groundwater pumping.
- Groundwater quality is suitable for the beneficial uses in the Basin and is not significantly or unreasonably degraded.
- Significant and unreasonable land subsidence is prevented in the Basin. Infrastructure and agricultural production in Shasta River Valley remain safe from permanent land subsidence.
- Groundwater will continue to provide river baseflow as interconnected surface water with no significant or unreasonable reduction in volume.

The GSA's groundwater management is efficiently and effectively integrated with other watershed and land use planning activities through collaborations and partnerships with local, state, and federal agencies, private landowners, and other organizations, to achieve the broader "watershed goal" of sufficient surface water and groundwater flows that sustain healthy ecosystem functions.

3.3 Monitoring Networks

The full monitoring network presented here will be used to continue to investigate hydrologic relationships within the Basin. A subset of the full monitoring network will be used to evaluate SMCs for individual sustainability indicators (SI) for the Basin and will be used to demonstrate the sustainability of the basin through 2042. Table 1 details all of the available information the GSA will be collecting during implementation to fill identified data gaps within the Basin.

Per 23 CCR Section 354.34, monitoring networks should be designed to:

- Demonstrate progress towards achieving measurable objectives described in the Plan
- Monitor impacts to the beneficial uses or users of groundwater
- Monitor changes in groundwater conditions relative to measurable objectives and minimum or maximum thresholds; and
- Quantify annual changes in water budget components.

Monitoring networks are required to have sufficient spatial density and temporal resolution to evaluate the effects and effectiveness of Plan implementation and represent seasonal, short-term, and long-term trends in groundwater conditions and related surface conditions. Short-term is considered here to be a time span of 1 to 5 years, and long-term is considered as 5–20 years. The spatial densities and frequency of data measurement are specific to monitoring objectives, the quantity to be measured, degree of groundwater use, and Basin conditions, among other factors. A description of the existing and planned spatial density and data collection frequency is included for each monitoring network. Detailed descriptions, assessments and plans for improvement of the monitoring network are provided for each sustainability indicator in the following sections. An overview of all wells included in the initial monitoring networks established for each sustainability indicator is provided in Table 1.

Identification and Evaluation of Potential Data Gaps

Per 23 CCR Section 351, data gaps are defined as, “a lack of information that significantly affects the understanding of the basin setting or evaluation of the efficacy of Plan implementation and could limit the ability to assess whether a basin is being sustainably managed”. A detailed discussion of potential data gaps, and strategies for resolving them, is included as Appendix Z. Data gaps are primarily addressed in this chapter through the ‘Assessment and Improvement of Monitoring Networks’, associated with each sustainability indicator in the Basin. Of particular focus for the monitoring networks are the adequacy of the number of sites, frequency of measurement, and spatial distribution in the Basin. In addition to the monitoring network-specific data gaps, information was identified that would be valuable to collect. This information is valuable to support increased understanding in the Basin setting, understanding of conditions in comparison to the sustainable management criteria, data to calibrate or update the model, and to monitor efficacy of PMAs. These additional monitoring or information requirements depend on future availability of funding and are not yet considered among the GSP Representative Monitoring Points (RMPs). They will be considered as potential RMPs and may eventually become part of the GSP network at the 5-year GSP update. The list includes:

- Spring discharge (either continuous or monthly)
- Continuous groundwater level measurements
- Additional stream gauges and monitoring of the Little Shasta River
- Additional wells near the main stem of the Shasta river and, as needed, near some of the main tributaries, to measure groundwater levels near the river (see Section 3.3.5) for use in model calibration, as part of ISW monitoring, and for measuring PMA efficacy.
- Pumping volumes and locations
- Additional biological data that would be useful for monitoring and evaluation of GDEs

A detailed discussion of these potential data gaps and suggested approach and monitoring prioritization can be found in Appendix 3-A.

Pumping Volume and Location Data Gap

Owners and/or operators of groundwater wells, meeting a certain criteria, are encouraged to report pumping volumes. The reporting of pumping volumes will establish baseline values as well as provide information for the Shasta Watershed Groundwater Model. The suggested criteria for wells that should report are:

- Pumps Operated above 500 gallons per minutes; or
- Pumps used for commercial purposes.

Reporting can be done one of three ways:

- A flow meter or totalizer will be installed and read on a monthly basis.
- Monthly electrical use from the pump can be reported in-lieu of pump volume.
- Monthly report of acres of irrigated land, irrigation method, and crop.

Where possible, all three types of data should be collected on one site. This would allow the comparison of the power meter and land use to the values from the totalizer and evaluate how close they come. This can then be used as a correction for other areas where only land use or power data are available.

Possible subsidies in installation of flow meters from future grants will be explored.

Monitoring Network to Fill Identified Data Gaps

To fill data gaps, data is being collected at new locations, with the potential for further expansion with additional funding. The current groundwater level network is shown in Figure 1. Continuous monitoring offers the best data coverage while periodic monitoring is generally completed twice a year (spring and fall). A subset of the monitoring wells is instrumented with continuous datalogger (temperature and water level measured every 15 minutes) with telemetry, while for the rest of the CASGEM wells, by-annual measurements have been collected. If funding allows, CASGEM wells will be monitored quarterly. Transects collect continuous data for interconnected surface water and the report with the details on location and instrumentation of the transect are provided in Appendix 3-X. Surface water monitoring includes spring discharge (monthly data are currently available, continuous are being evaluated), river flow, and river stage (Figure 2). Additional monitoring includes atmosphere, diversions, and lake storage (Figure 3). Additional details are included in Appendix 3-A.

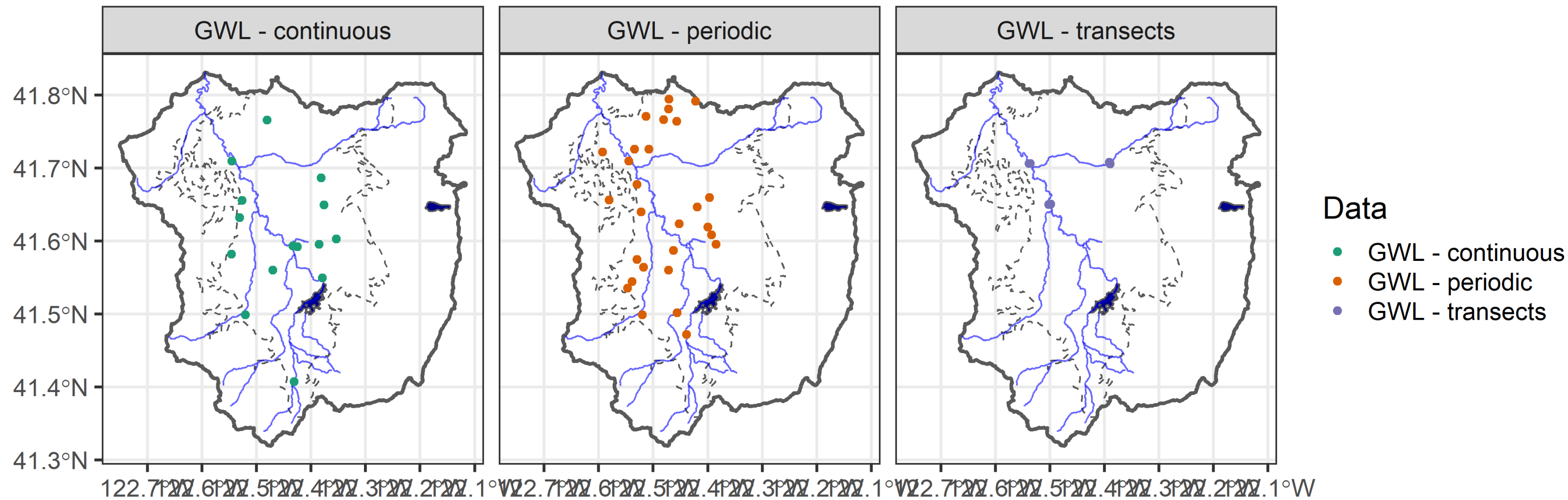

Figure 1: Current state of monitoring of groundwater in Shasta Valley. The solid black and dashed black line mark the border of the watershed and groundwater basin, respectively.

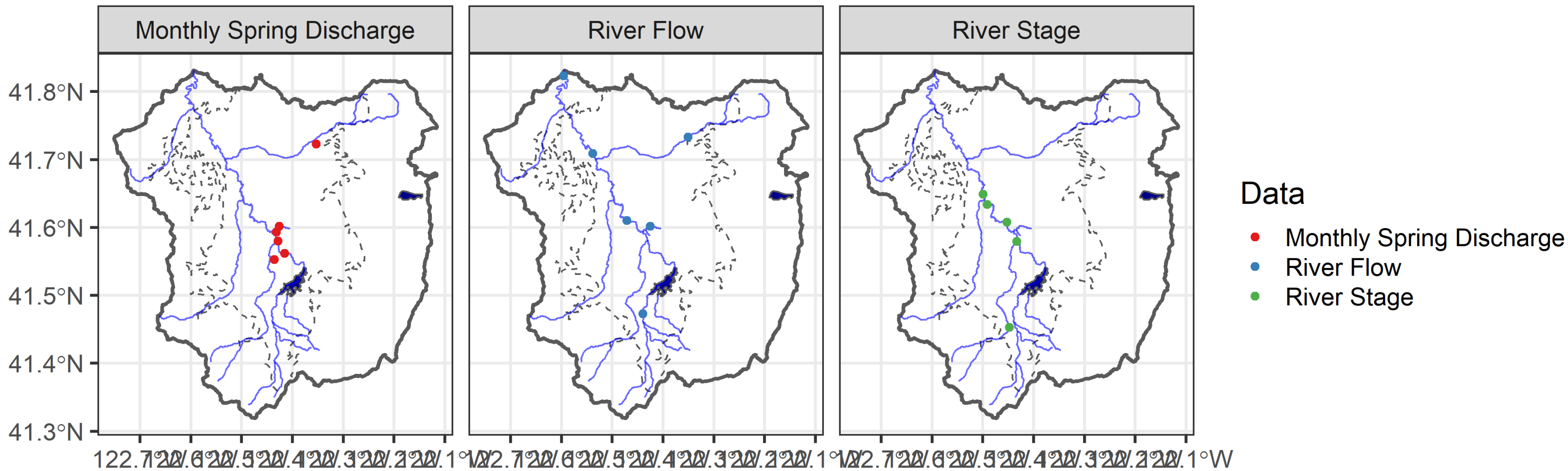

Figure 2: River and Spring Monitoring. The solid black and dashed black line mark the border of the watershed and the groundwater basin, respectively.

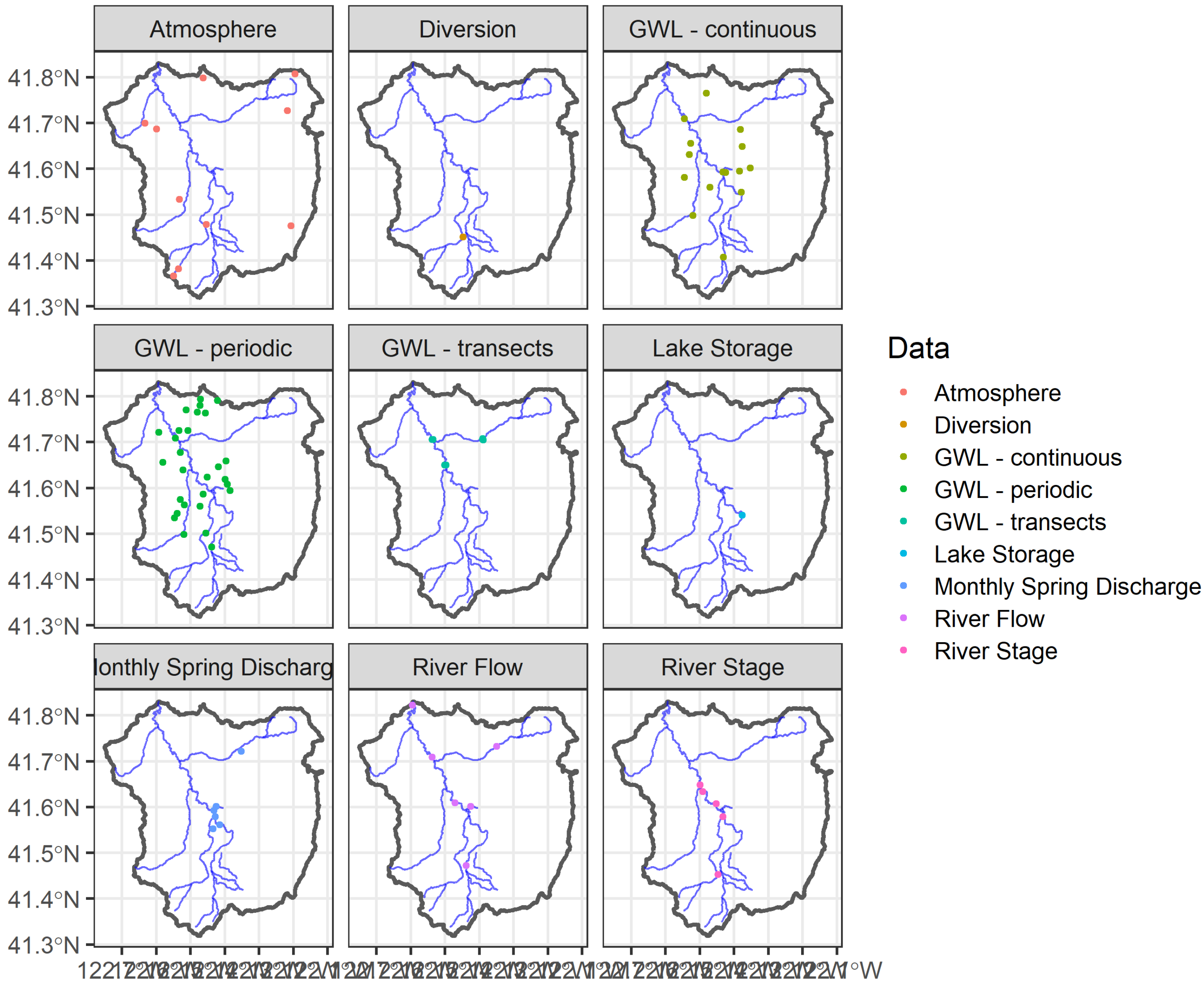

Figure 3: Atmosphere, Groundwater, and Surface Water Monitoring. The solid black and dashed black line mark the border of the watershed and the groundwater basin, respectively.

Network Enrollment and Expansion

With the exceptions of streamflow, land subsidence, and stream depletion due to groundwater pumping, monitoring is performed using wells. Some wells will be monitored for water level, some for water quality, some for both. Prior to enrolling wells into the GSA's monitoring network, wells will be evaluated, using the selection criteria listed below, to determine their suitability. The selection criteria for potential wells to be added to the monitoring network include the following:

- Well location
- Monitoring History
- Well Information
- Well Access

Well Location

The location and design of a well network is important to ensure adequate spatial distribution, coverage, and well density. Objectives for network design include sufficient coverage and density of wells to capture hydraulic gradients and overall groundwater in storage. Additionally, wells important for the measurement of groundwater level and groundwater quality must be included in areas within or adjacent to planned GSP projects and management actions and locally defined areas where existing operations are found to pose a significant risk of affecting groundwater levels or quality. Statistical methods will be used to aid in extrapolating measurements from a limited number of monitoring sites to groundwater conditions the entire Basin to measure compliance with the minimum or maximum thresholds set and to measure progress towards interim milestones.

Monitoring History

Wells with a long monitoring record provide valuable historical groundwater level or water quality data and enable the assessment of long-term trends. Such wells were preferentially selected for a network over wells with limited monitoring data.

Well Information

In addition to well location, information about the construction of the well, including the well depth and screened interval(s) is necessary to provide context for the measurement taken at the well, such as which water bearing formation is being sampled. Well information is critical for an effective well network, so the groundwater aquifer can be efficiently monitored. For wells that are candidates for being added to the well network, the GSA will continue to verify well information with well logging.

Well Access/Agency Support

To be a functional component of the monitoring network, the ability to gain access to the well to collect samples at the required frequency is critical.

Wells in existing monitoring programs, particularly for water quality, are located near populated areas, leaving sections of the remainder of the Basin without monitoring data. The planned additional wells for inclusion in a network are intended to provide data representative of different land uses, activities, and geologic units to improve upon the existing spatial coverage in the Basin. Any wells added to the monitoring network will be evaluated using the criteria listed above to ensure well suitability. A more detailed evaluation of the required spatial density and monitoring frequency of the individual sustainability indicator monitoring network(s) has been conducted to determine appropriate attributes so that the monitoring network is representative of Basin conditions and enables evaluations of seasonal, short-term, and long-term trends.

The monitoring networks will continue to be developed throughout GSP implementation. Individual sustainability indicator monitoring networks will be expanded throughout GSP implementation, as necessary, to address monitoring objectives and support any projects and management actions (PMAs). The RMPs currently included are the ones with a long enough period of data, spanning different year types, that allows to properly define SMCs. This explains why the wells instrumented with continuous data are not currently included as RMPs (Table 1): only few months of data have been collected for those wells and they will be included in the GSP network at the 5-years update. A similar approach applies to the monthly spring discharge measurements: as soon as a few years of data are available, they will included as RMPs. Expansion of individual sustainability indicator monitoring networks that rely on wells will involve identification of existing wells in the Basin that could be included in the monitoring network once evaluated, using the selection criteria, and approved for inclusion in the network. Evaluations of the monitoring network will be conducted at least every five years to determine whether additional wells are required to achieve sufficient spatial density, whether wells are representative of land uses in the Basin, and whether wells provide monitoring in key areas identified by stakeholders. If additional sites are required to ensure sufficient spatial density, then existing wells may be identified or new wells may be constructed at select locations, as required. The monitoring frequency and timing that enable evaluation of seasonal, short-term, and long-term trends will also be assessed throughout GSP implementation. Where it is necessary, the GSA will coordinate with existing programs to develop an agreement for data collection responsibilities, monitoring protocols, and data reporting and sharing. For existing monitoring programs implemented by agencies, monitoring would be conducted by agency program staff or their contractors. For water quality monitoring, samples will be analyzed at contracted analytical laboratories. To prevent bias associated with date of sample collection, all samples should be collected on approximately the same date (i.e., +/- 30 days of each other) each year.

Table 1: Preliminary list of all monitoring locations and data in Shasta Valley Groundwater Basin. Site will be added and removed based on review.

Site	Agency	Type	Frequency	SI Network	Primary SI
4700577-001	Big Springs Union Elementary School	Water Quality	Parameter dependent	Yes	Groundwater Quality
4700559-001	Butteville Union School	Water Quality	Parameter dependent	Yes	Groundwater Quality
4700557-001	Caltrans-Weed Rest Stop	Water Quality	Parameter dependent	Yes	Groundwater Quality
4700557-002	Caltrans-Weed Rest Stop	Water Quality	Parameter dependent	Yes	Groundwater Quality
27D002M	CASGEM	Groundwater Elevation	Bi-annual	Yes	Groundwater Elevation
42N05W08E001M	CASGEM	Groundwater Elevation	Bi-annual	No	–
42N05W20J001M	CASGEM	Groundwater Elevation	Bi-annual	No	–
43N05W07K001M	CASGEM	Groundwater Elevation	Bi-annual	No	–
43N05W19F002M	CASGEM	Groundwater Elevation	Bi-annual	Yes	Groundwater Elevation
43N06W15F003M	CASGEM	Groundwater Elevation	Bi-annual	No	–
43N06W22A001M	CASGEM	Groundwater Elevation	Bi-annual	No	–
43N06W33C001M	CASGEM	Groundwater Elevation	Bi-annual	Yes	Groundwater Elevation
44N05W14M002M	CASGEM	Groundwater Elevation	Bi-annual	Yes	Groundwater Elevation
44N05W21H001M	CASGEM	Groundwater Elevation	Bi-annual	No	–
44N05W32C002M	CASGEM	Groundwater Elevation	Bi-annual	Yes	Groundwater Elevation
44N05W34H001M	CASGEM	Groundwater Elevation	Bi-annual	No	–
44N06W10F001M	CASGEM	Groundwater Elevation	Bi-annual	No	–
44N06W18Q001M	CASGEM	Groundwater Elevation	Bi-annual	Yes	Groundwater Elevation
44N06W27B001M	CASGEM	Groundwater Elevation	Bi-annual	Yes	Groundwater Elevation

Table 1: Preliminary list of all monitoring locations and data in Shasta Valley Groundwater Basin. Site will be added and removed based on review. *(continued)*

Site	Agency	Type	Frequency	SI Network	Primary SI
45N05W07H002M	CASGEM	Groundwater Elevation	Bi-annual	Yes	Groundwater Elevation
45N06W10A001M	CASGEM	Groundwater Elevation	Bi-annual	No	–
45N06W26C002M	CASGEM	Groundwater Elevation	Bi-annual	No	–
45N06W30E001M	CASGEM	Groundwater Elevation	Bi-annual	No	–
46N05W31F001M	CASGEM	Groundwater Elevation	Bi-annual	No	–
46N05W33J001M	CASGEM	Groundwater Elevation	Bi-annual	Yes	Groundwater Elevation
SV03	CASGEM	Groundwater Elevation	Bi-annual	No	–
SV03A	CASGEM	Groundwater Elevation	Bi-annual	Yes	Groundwater Elevation
SV04	CASGEM	Groundwater Elevation	Bi-annual	No	–
4710011-003	City of Yreka	Water Quality	Parameter dependent	Yes	Groundwater Quality
4700626-001	Cove Mobile Villa	Water Quality	Parameter dependent	Yes	Groundwater Quality
4700591-002	Delphic Elementary School	Water Quality	Parameter dependent	Yes	Groundwater Quality
InSAR	DWR	Subsidence	Multi-year	Yes	Subsidence
SPU	DWR	Stream Flow	Continuous	No	–
SRE	DWR	Stream Flow	Continuous	No	–
4700582-001	Gazelle School	Water Quality	Parameter dependent	Yes	Groundwater Quality
4700523-003	Grenada Sanitary District	Water Quality	Parameter dependent	Yes	Groundwater Quality
SHA_01	GSA	Groundwater Elevation	Continuous	No	–
SHA_02	GSA	Groundwater Elevation	Continuous	No	–
SHA_03 / SV01	GSA	Groundwater Elevation	Continuous	No	–

Table 1: Preliminary list of all monitoring locations and data in Shasta Valley Groundwater Basin. Site will be added and removed based on review. *(continued)*

Site	Agency	Type	Frequency	SI Network	Primary SI
SHA_04 / SV02	GSA	Groundwater Elevation	Continuous	Yes	ISW
SHA_05	GSA	Groundwater Elevation	Continuous	No	–
SHA_06	GSA	Groundwater Elevation	Continuous	No	–
SHA_08	GSA	Groundwater Elevation	Continuous	No	–
SHA_09	GSA	Groundwater Elevation	Continuous	No	–
SHA_10	GSA	Groundwater Elevation	Continuous	No	–
SHA_11	GSA	Groundwater Elevation	Continuous	No	–
SHA_17	GSA	Groundwater Elevation	Continuous	No	–
SHA_172	GSA	Groundwater Elevation	Continuous	No	–
SHA_18	GSA	Groundwater Elevation	Continuous	No	–
SHA_24	GSA	Groundwater Elevation	Continuous	No	–
4700627-002	Juniper Creek Estates	Water Quality	Parameter dependent	Yes	Groundwater Quality
4710013-001	Lake Shastina C.S.D	Water Quality	Parameter dependent	Yes	Groundwater Quality
4710013-002	Lake Shastina C.S.D	Water Quality	Parameter dependent	Yes	Groundwater Quality
4710013-004	Lake Shastina C.S.D	Water Quality	Parameter dependent	Yes	Groundwater Quality
4700638-001	Oak Valley Acres P.O.A	Water Quality	Parameter dependent	Yes	Groundwater Quality
4700528-001	Siskiyou Co. Rolling Hills MWC	Water Quality	Parameter dependent	Yes	Groundwater Quality
Surface Water Diversions	SSWD	Flow	Periodic	Yes	ISW
Big Springs Creek	SVRCD	Spring Flow	Monthly	No	–
Clear Spring	SVRCD	Spring Flow	Monthly	No	–

Table 1: Preliminary list of all monitoring locations and data in Shasta Valley Groundwater Basin. Site will be added and removed based on review. *(continued)*

Site	Agency	Type	Frequency	SI Network	Primary SI
Evans Spring	SVRCD	Spring Flow	Monthly	No	–
Hole in the Ground Spring	SVRCD	Spring Flow	Monthly	No	–
Kettle Spring	SVRCD	Spring Flow	Monthly	No	–
Little Springs Creek	SVRCD	Spring Flow	Monthly	No	–
Transect 1	SVRCD	Groundwater Elevation	Continuous	No	–
Transect 2	SVRCD	Groundwater Elevation	Continuous	No	–
Transect 3	SVRCD	Groundwater Elevation	Continuous	No	–
SRM	USGS	Stream Flow	Continuous	Yes	ISW
SRY	USGS	Stream Flow	Continuous	No	–
4700663-001	WEED GOLF CLUB, INC.	Water Quality	Parameter dependent	Yes	Groundwater Quality

3.3.1 Groundwater Level Monitoring Network

The objective of the groundwater level monitoring network design is to capture sufficient spatial and temporal detail of groundwater level conditions to assess groundwater level changes over time, groundwater flow directions, and hydraulic gradients between aquifers and surface water features. The monitoring network is critical for the GSA to show compliance with SGMA and quantitively show the absence or improvement of undesirable results. The design of the monitoring network must enable adequate spatial coverage (distribution, density) to describe groundwater level conditions at a local and Basin-wide scale for all beneficial uses. Revisions to the monitoring network and schedule will be considered after review of the initial five years of monitoring data and as part of any future GSP updates. The groundwater level (GWL) monitoring network is a subset of wells presented in Table 1 that meets the DWR GSP reporting requirements.

3.3.1.1 Description of Monitoring Network

The groundwater level monitoring (GWL) network consist of 14 CASGEM and Volunteer CASGEM wells (Table 2) in the Basin. Four wells are located within the fractured basalt aquifer, 7 in the alluvial aquifer, and 3 in various other geologic material. The distribution of monitoring wells is shown in Figure 4. The currently designed network satisfies DWR requirements with respect to spatial distribution and can be expanded using recently installed new instruments that will be evaluated over the first 5 years of implementation.

Table 2: Groundwater level monitoring network.

CASGEM Site ID	Sample Schedule	Principal Formation	Well Depth (ft)	First Perforated Top (ft)	First Perforated Bottom (ft)	Second Perforated Top (ft)	Second Perforated Bottom (ft)	Likely geologic unit(s) in perforation interval	CASGEM WCR Number
22363	Twice Annual	Volcanics	340	300	330	–	–	Qv	101729
22370	Continuous	Volcanics	120	8	250	–	–	Qv	5586
22373	Twice Annual	Alluvium	317	60	238	–	–	Q, Qvs, SOd (Basement)	2081
22375	Twice Annual	Volcanics	95	8	90	–	–	Qv	133440
24045	Twice Annual	Alluvium	80	40	80	–	–	Q, Tv	78681
24067	Twice Annual	Alluvium	45	28	45	–	–	Q	54934
36753	Twice Annual	Other	79	40	69	–	–	Qvs	53277
36892	Twice Annual	Alluvium	200	22	200	–	–	Q, Tv	99808
36999	Twice Annual	Other	110	50	110	–	–	Qvs	129187
37001	Continuous	Alluvium	150	33	84	–	–	Q	112928
49002	Twice Annual	Alluvium	300	120	250	270	285	Q, Qvs	713302
49294	Twice Annual	Other	150	120	150	–	–	Qvs	563238
49295	Twice Annual	Alluvium	165	17	160	–	–	Q, Qvs	125419
50631	Twice Annual	Volcanics	102	17	102	–	–	Qv	127502

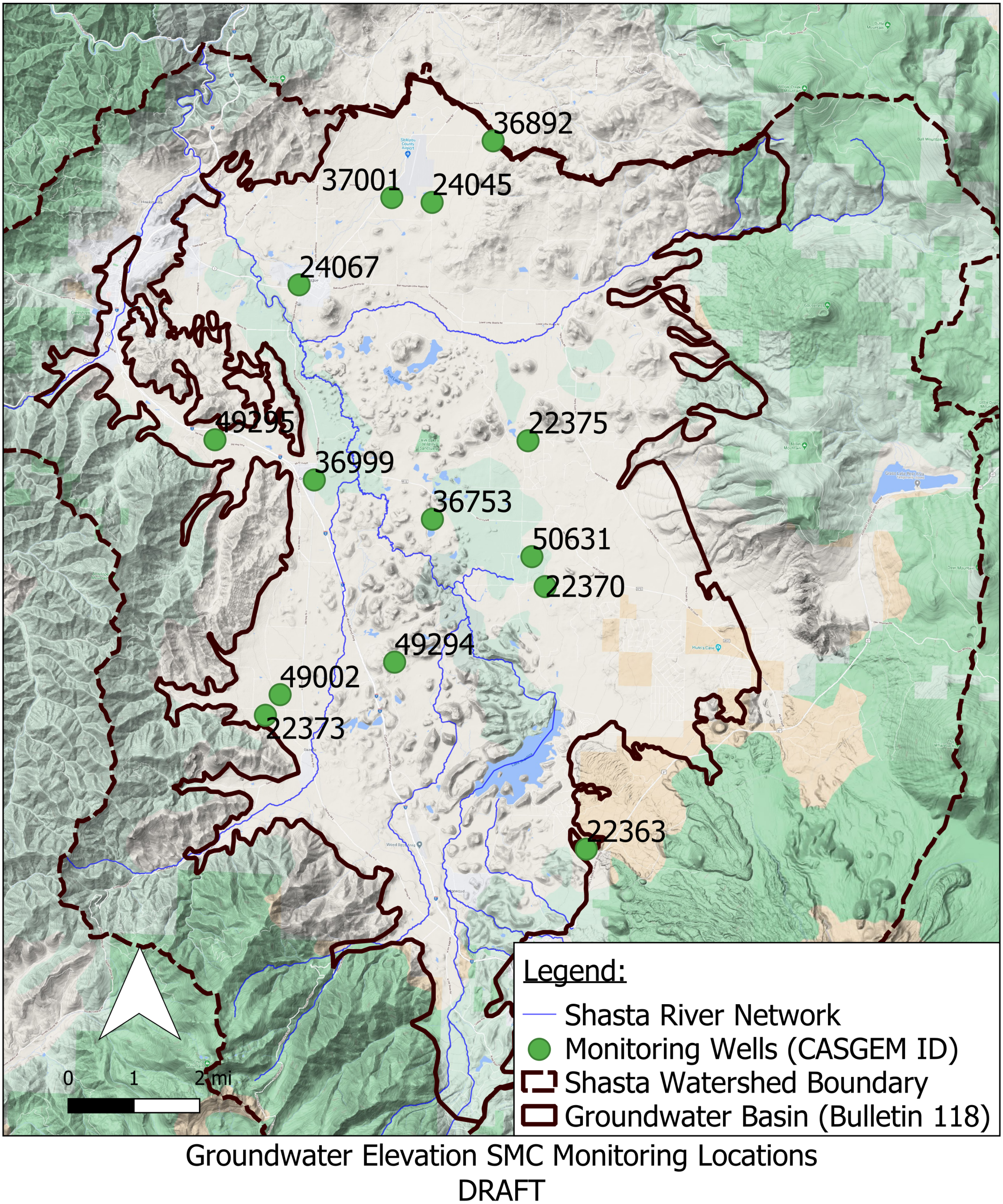

Figure 4: Groundwater Elevation monitoring wells.

3.3.1.2 Assessment and Improvement of Monitoring Network

The 14 wells provide good coverage of the central part of the Basin, with data gaps on the Basin edges such as near Weed, Yreka, Lake Shastina, Little Shasta River and Pluto's Cave. Specific projects and management actions (PMAs) are outlined to address including additional groundwater monitoring wells into the GSP monitoring network.

Spatial coverage criteria

DWR's guidance on monitoring networks (DWR 2016) recommends a range of well densities to adequately monitor groundwater resources, with a minimum of 0.2 wells and a maximum of 10 wells per 100 sq mi (259 sq km). Because the Basin covers approximately 82 sq mi (212 sq km), these recommendations would translate directly into a range from 1 to 10 RMP wells, evenly spaced in the Basin. A total of 14 wells are included in the groundwater level monitoring network, exceeding the minimum well density set by DWR guidance.

Measurement schedule

The water elevation in RMP wells will be measured, at a minimum, twice per year to capture the fall low and spring high water levels. Two wells in the network have continuous data and provide higher resolution water elevation measurements. Additional frequency of measurement, to quarterly or monthly, may be conducted to better enable determination of seasonal trends.

3.3.1.3 Monitoring Protocols for Data Collection and Monitoring

Groundwater level data collection may be conducted remotely via telemetry equipment or with an in-person field crew. Appendix 3-B provides the monitoring protocols for groundwater level data collection. Establishment of these protocols will ensure that data collected for groundwater levels are accurate, representative, reproducible, and contain all required information. All groundwater level data collection in support of this GSP is required to follow the established protocols for consistency throughout the Basin and over time. These monitoring protocols will be updated as necessary and will be re-evaluated every five years.

3.3.2 Groundwater Storage Monitoring Network

This GSP will adopt groundwater levels as a proxy for groundwater storage. The groundwater level network described in Section 3.3.1. will also serve as the groundwater storage network. The network currently provides reasonable coverage of the major water-bearing formations in the Basin and will provide reasonable estimates of groundwater storage. The network also includes municipal, agricultural, and municipal wells of shallow to deep depths. Expansion of the network to close data gaps will benefit the characterization of both the groundwater level and storage sustainability indicators.

Historic groundwater storage changes are computed with the SWGM numerical model. Throughout the implementation period of this Plan, updates the model provide updated time series of groundwater storage changes at least every five years.

To obtain groundwater storage changes for the most recent, non-simulated period, SWGM is used to establish a linear regression equation of year-specific spring-to-spring Basin groundwater storage change, ΔSTORAGE, as a function of the year-specific average model-simulated groundwater level change, ΔWL, at the RMP locations of the groundwater level network:

$$\Delta STORAGE = intersect + slope * \Delta WL$$

where "intersect" and "slope" are parameters of the linear regression equation, obtained from statistical analysis of ΔSTORAGE and ΔWL during the simulation period. The regression analysis is performed using the specific, actual monitoring locations available each year for spring-to-spring water level change observations. The "intersect" and "slope" parameters in the above equation can be updated when new, updated, or re-calibrated versions of the model become available, or when individual RMPs in the water level monitoring network are added or removed.

The above equation is then used to annually compute groundwater storage change using the actually measured average change in groundwater levels within the Basin's groundwater level monitoring network. The resulting estimate of annual groundwater storage change (in units of thousand-acre-feet, positive or negative) is then summed with previous year's estimates and combined with the simulated groundwater storage change timeline for the historic period.

This regression-based method allows for computation of groundwater storage change from measured groundwater level monitoring for the years between the end of the model simulation period (to be updated at least every five years) and the current reporting year (currently 2021). As the model is updated in the future, regression-based estimates of groundwater storage change for a given year (e.g., for 2021) may be replaced with the model-simulated groundwater storage changes for the same year.

In summary, the combination of simulated groundwater storage change in model and regression-estimated groundwater storage changes for the post-simulation period provides a time series of cumulative groundwater storage change for the entire period from 1991 to present time (where "present time" is the most recent year in the GSP implementation).

3.3.3 Groundwater Quality Monitoring Network

3.3.3.1 Description of Monitoring Network

The objective of the groundwater quality monitoring network design is to capture sufficient spatial and temporal detail to measure groundwater conditions and assess groundwater quality changes over time. The monitoring network is critical for the GSA to show compliance with SGMA and quantitatively show that groundwater conditions are maintained below maximum thresholds. The monitoring network is used to identify when maximum thresholds are exceeded, when trends indicate a path towards undesirable results, or when undesirable results occur. The network data will provide a continuous water quality record for future assessments of groundwater quality.

Existing wells used for monitoring groundwater quality in the Basin include public water supply wells and monitoring wells, which are shown in Figure 5. Initially, the groundwater quality monitoring network is based on wells that are regularly sampled as part of existing monitoring programs for the constituents for which SMCs are set: nitrate and specific conductivity (Table 3). The well depths and well screens of wells outside the network are not well defined and sampled water bearing formation cannot be confirmed. The existing network will therefore be augmented with well logging of those additional wells. The locations of the existing wells in the proposed well network are shown in Figure 5, with details in Table 3. Initial monitoring schedules are shown in Table 3.

The design of the monitoring network must enable adequate spatial coverage (distribution, density) to describe groundwater quality conditions at a local and Basin-wide scale for all beneficial uses. Future revisions to the monitoring network and schedule will be considered after review of the initial 5-years of observation data and during any future GSP updates. Additional wells may be added throughout GSP implementation in response to changes in land use, project implementation, or with new water quality concerns.

Prior to enrolling wells into the GSA monitoring network, wells will be evaluated, using the selection criteria listed in Section 3.3. Wells in existing monitoring programs are located near populated areas, leaving much of the remainder of the Basin without monitoring data. The planned additional wells are intended to gather groundwater quality data representative of different land uses and activities and geologic units and to improve upon the existing spatial coverage in the Basin. Current data gaps include no domestic and agricultural wells. Any wells added to the monitoring network will be evaluated using the criteria listed above to ensure well suitability. A more detailed evaluation of the required spatial density and monitoring frequency of the monitoring network will be conducted to determine appropriate attributes so that the monitoring network is representative of Basin conditions and enables evaluations of seasonal, short-term (1-5 years) and long-term (5-10 year) trends.

Table 3: Existing and planned elements of the groundwater quality monitoring network.

Name of Network	Well Name	Agency	Nitrate Frequency	Specific Conductivity Frequency
Municipal	4710011-003	City of Yreka	Annually	9 years
Municipal	4700528-001	Siskiyou Co. Rolling Hills MWC	Annually	9 years
Municipal	4700627-002	Juniper Creek Estates	Annually	3 years
Municipal	4700638-001	Oak Valley Acres P.O.A	Annually	3 years
Municipal	4700626-001	Cove Mobile Villa	Annually	9 years
Municipal	4700591-002	Delphic Elementary School	Annually	–
Municipal	4700577-001	Big Springs Union Elementary School	Quarterly	–
Municipal	4710013-001	Lake Shastina C.S.D	Annually	9 years
Municipal	4710013-002	Lake Shastina C.S.D	Annually	9 years
Municipal	4710013-004	Lake Shastina C.S.D	Annually	9 years
Municipal	4700582-001	Gazelle School	Annually	–
Municipal	4700557-001	Caltrans-Weed Rest Stop (north bound)	Annually	–
Municipal	4700557-002	Caltrans-Weed Rest Stop (north bound)	Annually	–
Municipal	4700559-001	Butteville Union School	Quarterly	–
Municipal	4700663-001	WEED GOLF CLUB, INC.	Annually	–
Municipal	4700523-003	Grenada Sanitary District	Annually	9 years

3.3.3.2 Assessment and Improvement of Monitoring Network

As the existing monitoring network has limited spatial coverage and is not representative of all land uses in the Basin, an expansion of the network is required to adequately characterize and monitor groundwater quality in the Basin. Funding has been made available through the NCRWQCB for sample analysis and results of this sampling will be used to help inform the monitoring network expansion. Additionally, increasing temporal resolution to quarterly is necessary to enable evaluation of seasonal trends. Specifically the expansion of specific conductivity should increased beyond the requirements in current water quality plans. An assessment and expansion of the monitoring net-

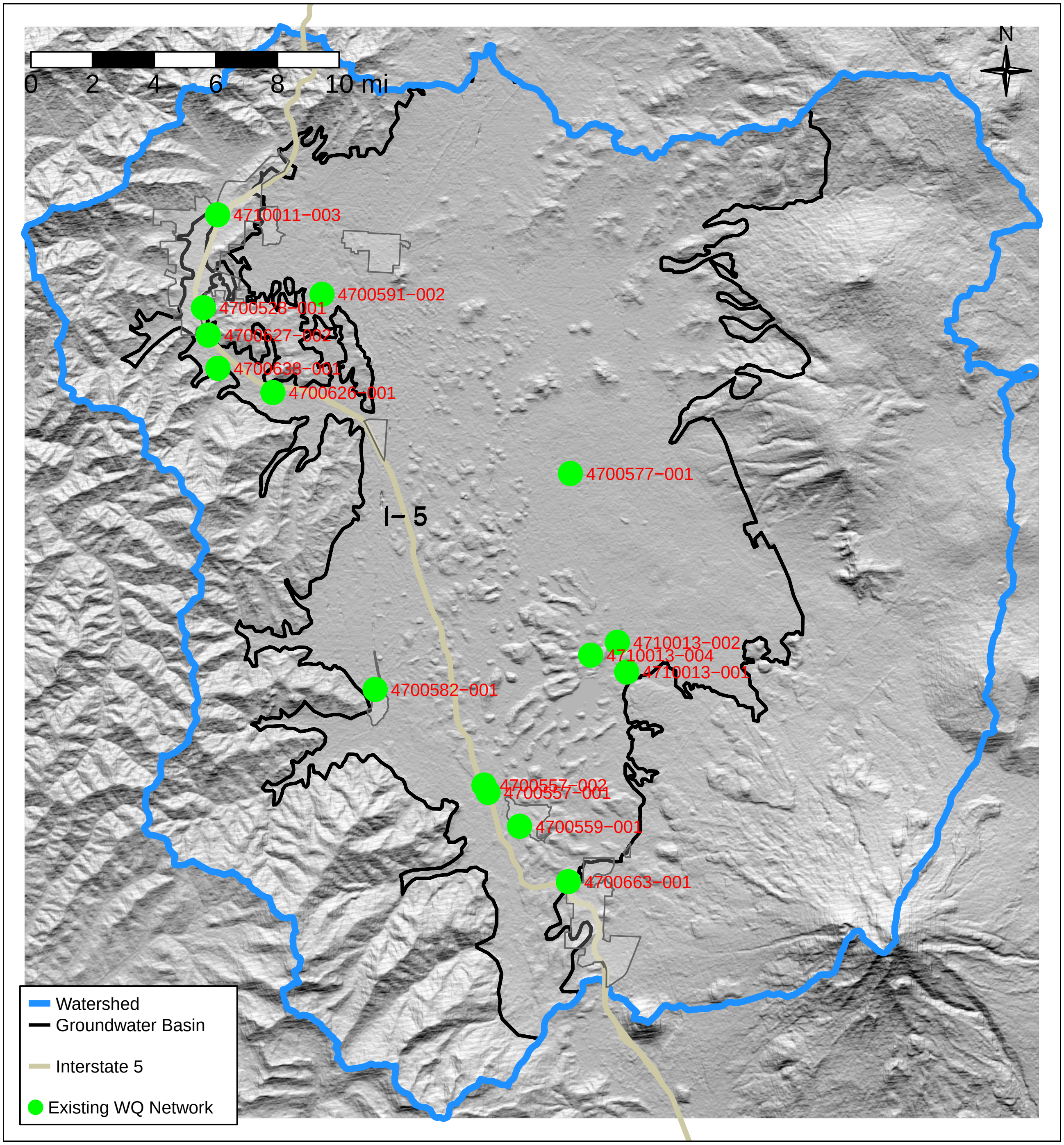

Figure 5: Water Quality Monitoring Network.

work is planned within the first five years of GSP implementation. An expanded monitoring network will occur through a combination of adding suitable existing wells and construction of new wells. Further evaluations of the monitoring network will be conducted on a five-year basis, particularly with regard to the sufficiency of the monitoring network in meeting the monitoring objectives and demonstrating the sustainability of the Basin with respect to water quality. The monitoring network may be modified or expanded based on an evaluation of the data collected or future changes in land use, or as new information becomes available.

An evaluation of the monitoring network, for both spatial density and monitoring frequency suitability will be included in the design of the monitoring network, as discussed in Section 3.3.4.1. Data gaps have been identified, particularly in spatial coverage, well information and representation of all land and beneficial uses in the Basin. Temporal data gaps have been identified as intra-annual data is required to evaluate seasonal trends. These data gaps will be resolved through addition of suitable existing wells, and construction of new wells. The location and number of these wells will be informed by the evaluation completed as part of the monitoring network design, resulting from the process outlined in Section 3.3.4.1.

In the North Coast Hydrologic Region, dairy operators are required to monitor and report groundwater data to the NCRWQCB, making them good candidates for network expansion. Annual groundwater monitoring of nitrate was first required in 2012 as a part of Waste Discharge Requirements for Dairies (Order No. R1-2012-0002). Order No. R1-2019-0001 extends the monitoring program but increases sampling frequency to every three years after the year 2022.

The 2020 NCRWQCB report "North Coast Hydrologic Region Salt and Nutrient Management Planning Groundwater Basin Evaluation and Prioritization" further emphasizes the needed partnership between the GSA and NCRWQCB. The report discusses the need for expanded groundwater monitoring through monitoring and reporting programs (MRPs) in Waste Discharge Requirements (WDRs) and Waivers. Additionally, Regional Water Board staff are assessing a Basin Plan amendment for a Groundwater Protection Strategy with new regulatory options or strategies (NCRWQCB 2020).

3.3.3.3 Monitoring Protocols for Data Collection and Monitoring

Sample collection will follow the USGS National Field Manual for the Collection of Water Quality Data (Wilde, 2005) and Standard Methods for the Examination of Water and Wastewater (Rice et al., 2012), as applicable, in addition to the general sampling protocols listed in Appendix 3-B.

3.3.4 Depletion of Interconnected Surface Water Monitoring Network

3.3.4.1 Description of Monitoring Network

The GSP Regulations provide that the monitoring network for Depletions of Interconnected Surface Water should include "[m]onitor[ing] surface water and groundwater where interconnected surface water conditions exist, to characterize spatial and temporal exchanges between surface water and groundwater and to calibrate and apply the tools and methods necessary to calculate depletions of surface water caused by groundwater extractions. (23 CCR 354.34(c)(6).)

The monitoring of interconnected surface water (ISW) will be conducted to establish two objectives. The first objective of the ISW monitoring network is to evaluate groundwater contributions to the Shasta River during the irrigation season. The second objective is to monitor shallow groundwater for protection of vegetative GDE's, as identified in Chapter 2. The monitoring network will use surface water gaging stations, measured surface water diversions, and groundwater elevations to assess sustainability. Section 3.4.3 provides background and justification on site location and methodology.

Groundwater Levels as Proxy for Stream Depletion Monitoring – not suitable

Water levels are not a suitable proxy for surface water depletion in the Shasta Valley, although they have been proposed in other groundwater basins (e.g., SCMCGA 2019). This is because in the Shasta Valley system (1) groundwater levels are affected by many factors including, but not limited to groundwater use, and (2) the typical variability induced by seasonal climate, recharge, and pumping changes is greater than the change in head that would correspond to a significant change in outflow to the stream system. In other words, the head data currently available are too noisy to be useful for assessing stream depletion due to groundwater pumping or stream depletion reversal due to specific projects and management actions (PMAs).

The hypothetical numbers of change in depth presented in Figure 6 show values that are much smaller than the typical transient variations induced by pumping wells and seasonal climate variability in water levels measured in monitoring wells near the river (see Chapter 2). Additionally, water levels near the stream - and more so away from the stream - are influenced by factors other than groundwater, including proximity to tributaries and their recharge history, proximity to wells and their pumping history, irrigation methods and agricultural return flows in nearby fields, and aquifer heterogeneity.

However, the GSP recognizes that groundwater levels are fundamentally linked with groundwater-stream flux rates, and these measurements can be useful when judiciously used in combination with the SWGM. In addition, use of observing long-term trends in the hydraulic gradient between the aquifer and stream has been suggested as a tool to comply with SGMA requirements for depletion of interconnected surface water (Hall et al., 2018). While groundwater levels as a proxy for stream depletion monitoring are by themselves not suitable for the Basin, these measurements will be collected and used to assess long-term trends in water level gradients and to avoid long-term, Basin scale water level declines (see Sections 3.3.1 and 3.4.1). These data, among many others, will also be used to calibrate and improve SWGM. The refined and calibrated version of SWGM over the next 5 years will be able to account for and processes a much wider range of relevant land use, hydrologic, and geologic data that would not be reflected in water level data alone. Using more appropriate, comprehensive information, including measured water level dynamics, SWGM will be used to compute water level changes due to PMAs and to estimate stream depletion reversal occurring specifically due to PMAs in ways that cannot be achieved with water level measurements alone (see below).

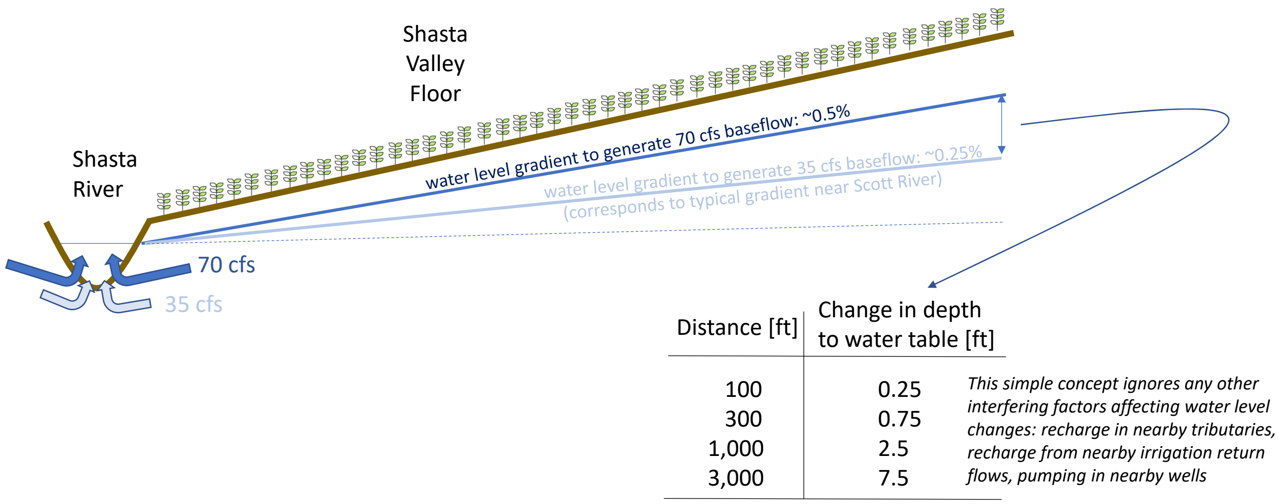

Figure 6: Current state of monitoring of groundwater in Shasta Valley. The solid black and dashed black line mark the border of the watershed and groundwater basin, respectively.

Streamflow as Proxy for Stream Depletion Monitoring – not suitable

Direct measurement of streamflow at the Yreka gauge or any other gauge is also not a suitable proxy for surface water depletion in the Shasta Valley because it is affected by several factors other than groundwater use. The Yreka gauge provides an overall water balance of the region because it is near the outlet of the basin. During the summer baseflow season, stream gauges along the main stem of the Shasta river can provide a direct measure of the total groundwater contribution from the Shasta River Valley Basin to the stream (see approach for ISW Minimum Thresholds). That groundwater contribution to streamflow is a function of groundwater use for pumping, of winter and spring recharge from precipitation and irrigation on the valley floor, of winter and spring recharge from tributaries on the upper alluvial fans, of mountain front recharge, and of surface water diversions (Chapter 2.2.3.3.). It is a function of both, their total amounts and the temporal dynamics of these amounts (pumping, recharge, diversions, etc.).

Quantifying Stream Depletion Using a baseflow measurement approach (preliminary approach for the first 5-years of implementation)

To overcome the issue of using groundwater levels as proxy or streamflow as proxy, a baseflow approach has been developed where stream flows are measured upstream and downstream and diversions are measured in between, and any differences between these flows can be attributed to contributions from groundwater. The goal is to use this approach for the first 5 years of implementation, collect more data, and at the GSP update provide a stream depletion approach based on more reliable results produced by the further calibrated SWGM.

The interconnected surface water (ISW) monitoring network includes two surface water gaging locations, measured surface water diversions, and one groundwater elevation. A table of monitoring sites for ISW is provided as Table 4 and Figure 7.

These are the Shasta River near Montague (SRM) maintained by the USGS and the Instream Flow Releases from Dwinnell Reservoir/Shasta River Dam No. 60 (F21396). Both stations record and store data at 15 minute intervals. The monitoring network will also include surface water diversions manually measured by the Scott and Shasta Watermaster District (SSWD). These measurements are done bi-monthly throughout the irrigation season.

Table 4: Monitoring locations for monitoring interconnected surface water.

Monitoring Location	Monitoring Type	Agency	Measurement Frequency
Shasta River near Montague (SRM)	Stream Gage	USGS	Continuous
Instream Flow Releases (DFB)	Stream Gage	MWCD	Continuous
Diversions	Manual	SSWD	Bi-monthly
SV02	Groundwater Elevation	GSA	Continuous

3.3.4.2 Assessment and Improvement of Monitoring Network

Inclusion of additional stream gaging stations, including Shasta River near Yreka (SRY), Shasta River at Grenada Pump Plant (SPU), Water Wheel, and Parks Creek are expected to be part of the 2027 ISW monitoring network (Table 5). These sites are not included in the current monitoring network due to insufficient historical data. If sufficient funding is available for monitoring at these sites, they will be added to the monitoring network and SMCs set.

The ISW monitoring network currently has the Little Shasta River as a data gap. Ongoing work by SWRCB and UCD Watershed Sciences in evaluating the interconnection of groundwater and surface water in the area are expected to inform the work of the GSP. Monitoring of the upper Little Shasta River watershed using the water balance method is expected to be implemented during the 2032 GSP update.

Table 5: Future monitoring locations for monitoring interconnected surface water, dependent on funding.

Monitoring Location	Monitoring Type	Agency
Shasta River near Yreka (SRY)	Stream Gage	NA
Shasta River at Grenada Pump Plant (SPU)	Stream Gage	NA
Big Spring Creek (Water Wheel)	Stream Gage	NA
Parks Creek	Stream Gage	NA

3.3.4.3 Monitoring Protocols for Data Collection and Monitoring

Monitoring will be done during the irrigation season after Parks Creek and Little Shasta River have no flow from snowmelt or rain. This will be established by visually confirming there is no flow in mid-Parks Creek or in the lower Little Shasta River (Figure 7). Typically monitoring will begin in July and extend through the irrigation season into September. Stream gages SRM and Instream Flows (F21396) are connected via a telemetry network and available online for inclusion into the data management system. Estimates of surface water diversions from SSWD will be submitted to the County when finalized based on SSWD internal reporting requirements. Surface diversions will be entered into the County data management system and calculations for the groundwater contributions will be done within the data management system.

Groundwater elevation data is collected continuously. A minimum sampling of bi-annual will be conducted to verify levels. Water levels for evaluating ISW will be conducted in accordance with sampling protocols outlined in Section 3.3.1.3 - Monitoring Protocols for Data Collection and Monitoring of Groundwater Elevation Data.

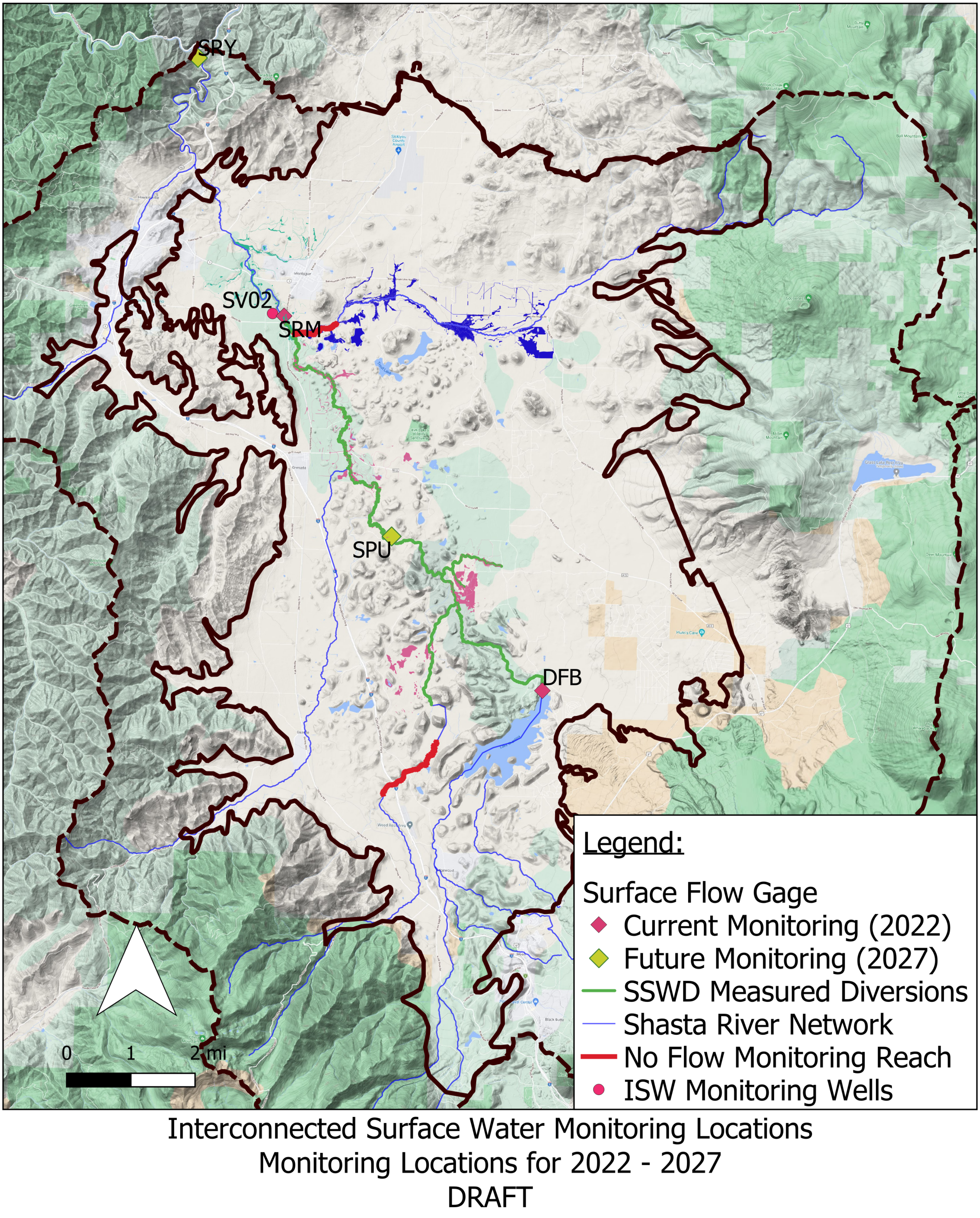

Figure 7: ISW monitoring gages and wells for the current GSP implementation in 2022 and the planned expansion in 2027.

3.3.5 Subsidence Monitoring Network

3.3.5.1 Description of Monitoring Network

Interferometric Synthetic Aperture Radar (InSAR) is a satellite-based remote sensing technique that measures vertical ground surface displacement changes at high degrees of measurement resolution and spatial detail. The Department of Water Resources provides vertical displacement estimates derived from InSAR data collected by the European Space Agency Sentinal-1A satellite and processed under contract by TRE ALTAMIRA Inc. The InSAR dataset has spatial coverage for much of the Basin and consists of two data forms: point data and a Geographic Information System (GIS) raster, which is point data interpolated into a continuous image or map. The point data are the observed average vertical displacements within a 328 by 328 feet (100 meter) area. The InSAR data covers the majority of the Basin as point data and entirely as an interpreted raster dataset. The dataset provides good temporal coverage for the Shasta Valley Basin with annual rasters (beginning and ending on each month of the coverage year from 2015 to 2019), cumulative rasters, and monthly time series data for each point data location. These temporal frequencies are adequate for understanding short-term, seasonal, and long-term trends in land subsidence.

Representative Monitoring

The DWR / TRE ALTAMIRA InSAR data will be used to monitor subsidence in Shasta Valley. There are no explicitly identified representative subsidence sites because the satellite data consists of thousands of points. Figure 43 (Chapter 2) shows the coverage of the subsidence monitoring network, which will monitor potential surface deformation trends related to subsidence. Data from the subsidence monitoring network will be reviewed annually. The subsidence monitoring network allows sufficient monitoring both spatially and temporally to adequately assess that the measurable objective is being met.

3.3.5.2 Assessment and Improvement of Monitoring Network

It is currently sufficient for the monitoring network to be based on InSAR data from DWR / TRE ALTAMIRA, which adequately resolves land subsidence estimates in the Basin spatially and temporally. However, data gaps exist in the subsidence network, including the lack of data prior to 2015 and no Continuous Global Positioning System (CGPS) stations to ground-truth the satellite data. The DWR/TRE ALTAMIRA InSAR dataset is the only subsidence dataset currently available for the Basin and only has data extending back to 2015. Historical subsidence data prior to 2015 is currently unavailable. Compared to satellite data, CGPS stations offer greater accuracy and higher frequency and provide a ground-truth check on satellite data. However, there are no CGPS or useful borehole extensometer stations located within or near the Basin boundary. The single borehole strainmeter in the basin (UNAVCO station #B039) does not record vertical strain or displacement, only horizontal, is not useful for recording inelastic subsidence signal (Figure 43; Chapter 2). The strainmeter is also on the very edge of the basin boundary on a foundation of andesite and serpentinite with minimal sediment overburden, also effectively invalidating this station as a monitoring location for groundwater basin subsidence monitoring. There are no other strainmeters or extensometers located within the basin boundary or close enough to be relevant.

Due to little current evidence of subsidence since 2015, see Section 2.2.2.4, no future CGPS or additional borehole extensometer stations are proposed for the Basin at this time. If subsidence becomes a concern in the future, then installation of CGPS stations and/or borehole extensometers can be proposed. The subsidence monitoring network will be used to determine if and where future CGPS or ground-based elevation surveys would be installed. In addition, if subsidence anomalies are detected in the subsidence monitoring network, ground truthing, elevation surveying, and GPS studies may need to be conducted.

3.3.5.3 Monitoring Protocols for Data Collection and Monitoring

The subsidence monitoring network currently depends on data provided by DWR through the TRE ALTAMIRA InSAR Subsidence Dataset. Appendix 3A describes the data collection and monitoring completed by DWR contractors to develop the dataset. The GSA will monitor all subsidence data annually. If any additional data become available, they will be evaluated and incorporated into the GSP implementation. If the annual subsidence rate is greater than minimum threshold, further study will be needed.

3.4 Sustainable Management Criteria

3.4.1 Groundwater Elevation

Groundwater elevations in the Basin have generally been high enough to satisfy demand for agricultural and other users. Groundwater elevation minimum thresholds will be determined based on recorded historic lows as measured by the CASGEM monitoring network. The compliance point for GWL monitoring will be conducted in the Fall. CASGEM measurements have historically been recorded in October.

3.4.1.1 Undesirable Results

Chronic lowering of groundwater levels is considered significant and unreasonable when a significant number of private, agricultural, industrial, or municipal production wells can no longer pump enough groundwater to supply beneficial uses. SGMA defines undesirable results related to groundwater levels as chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply if continued over the planning and implementation horizon. The lowering of water levels during a period of drought is not the same as (i.e., does not constitute) "chronic" lowering of groundwater levels if extractions and groundwater recharge are managed as necessary to ensure that reductions in groundwater levels or storage during a period of drought are offset by increases in groundwater levels or storage during other periods.

Potential impacts and the extent to which they are considered significant and unreasonable were determined by the GSA with input by technical advisors and members of the public. During development of the GSP, potential undesirable results identified include:

- Excessive number of domestic, public, or agricultural wells going dry.
- Excessive reduction in the pumping capacity of existing wells.
- Excessive increase in pumping costs due to greater lift.
- Excessive need for deeper well installations or lowering of pumps.
- Excessive financial burden to local agricultural interests.
- Adverse impacts to environmental uses and users, including interconnected surface water and groundwater-dependent ecosystems (GDEs).

Undesirable results are defined quantitatively for the groundwater level sustainability indicator as any water level measurement that goes below the Management Trigger for two consecutive years within the Basin.

Effects on Beneficial Uses and Users

Undesirable results would prevent an unknown number of private, agricultural, industrial, or municipal production wells from supplying groundwater to meet their water demands. Some wells may even go dry temporarily. Chronic well outages are not expected in Shasta Valley due to the lack of long-term overdraft. Temporary well outages may initially affect the shallowest wells, which tend to be located in the valley bottom and in some locations, tend to be domestic wells.

The following provides greater detail regarding the potential impact of declining groundwater levels on several major classes of beneficial users:

- **Municipal Drinking Water Users** – Undesirable results due to declining groundwater levels can adversely affect current and projected municipal users, causing increased costs for potable water supplies.
- **Rural and/or Agricultural Residential Drinking Water Users** – Falling groundwater levels can cause shallow domestic and stock wells to go dry, which may require well owners to drill deeper wells. Additionally, the lowering of the water table may lead to decreased groundwater quality drinking water wells.
- **Agricultural Users** – Excessive lowering groundwater levels could necessitate changes in irrigation practices and crops grown and could cause adverse effects to property values and the regional economy.
- **Environmental Uses** – Lowered groundwater levels may result in significant and unreasonable reduction of groundwater flow toward streams and groundwater dependent ecosystems. This would adversely affect their ecological habitats and resident species. This would adversely affect ecosystem functions related to baseflow and stream temperature, as well as resident species.

3.4.1.2 Information and Methodology Used to Establish Minimum Thresholds and Measurable Objectives

Historic data from CASGEM wells located in the Basin were used to develop the specific SMCs for each well. Each CASGEM well in Table 6. Depth to water is used as the measurement for each well. Fall Range refers to the maximum and minimum of measurements collected at each well in the months Sept-Nov. The Measurable Objective (MO) is set as the 75th percentile of the fall measurement range - i.e., the measurement at which 25% of groundwater elevation measurements fall below it. The Action Trigger (AT) is set at the historic low groundwater elevation measurement. The Minimum Threshold (MT) is set at the historic low plus a buffer. The buffer is either 10% of the historic low, or 10 feet, whichever is smaller. As the water table becomes more shallow, ie. closer to the land surface, the buffer will continue to decrease. This allows for near-stream well monitoring to operate at a smaller range due to the impact GWL drawdowns can have on streamflow and stream leakage. There are currently no state, federal, or local standards that relate to this sustainability indicator in the Basin.

3.4.1.3 GWL SMCs

A summary of the SMCs for each well is shown on Table 6. Figure 8 shows an example of the ‘thermometer’ for GWL levels. Figure 9 shows an example hydrograph for development of GWL

SMCs.

Table 6: SMC values for GWL.

Station ID	Well Depth (ft bgs)	Fall Low (ft bgs)	Fall High (ft bgs)	MT (ft bgs)	AT (ft bgs)	MO (ft bgs)
22363	340	245.7	229.2	255.7	245.7	243.8
22370	120	156.5	121.0	166.5	156.5	144.1
22373	317	71.9	36.4	79.1	71.9	61.0
22375	95	59.8	52.5	65.8	59.8	56.5
24045	80	27.9	15.1	30.7	27.9	22.3
24067	45	7.9	5.1	8.7	7.9	6.8
36753	79	66.4	40.4	73.0	66.4	51.3
36892	200	41.1	25.5	45.2	41.1	34.4
36999	110	20.2	11.7	22.2	20.2	17.4
37001	150	48.5	6.4	53.4	48.5	24.2
49002	300	80.1	70.4	88.1	80.1	76.0
49294	150	12.1	9.8	13.3	12.1	10.0
49295	165	30.3	6.7	33.3	30.3	27.1
50631	102	62.7	42.8	69.0	62.7	47.3

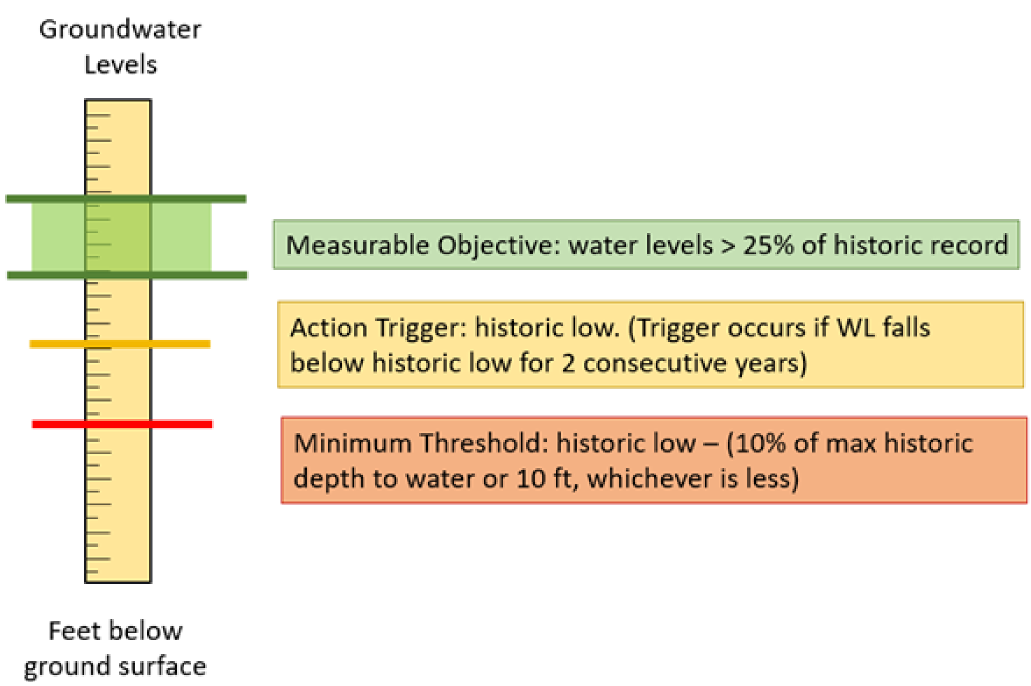

Figure 8: Example thermometer for evaluating GWL SMCs.

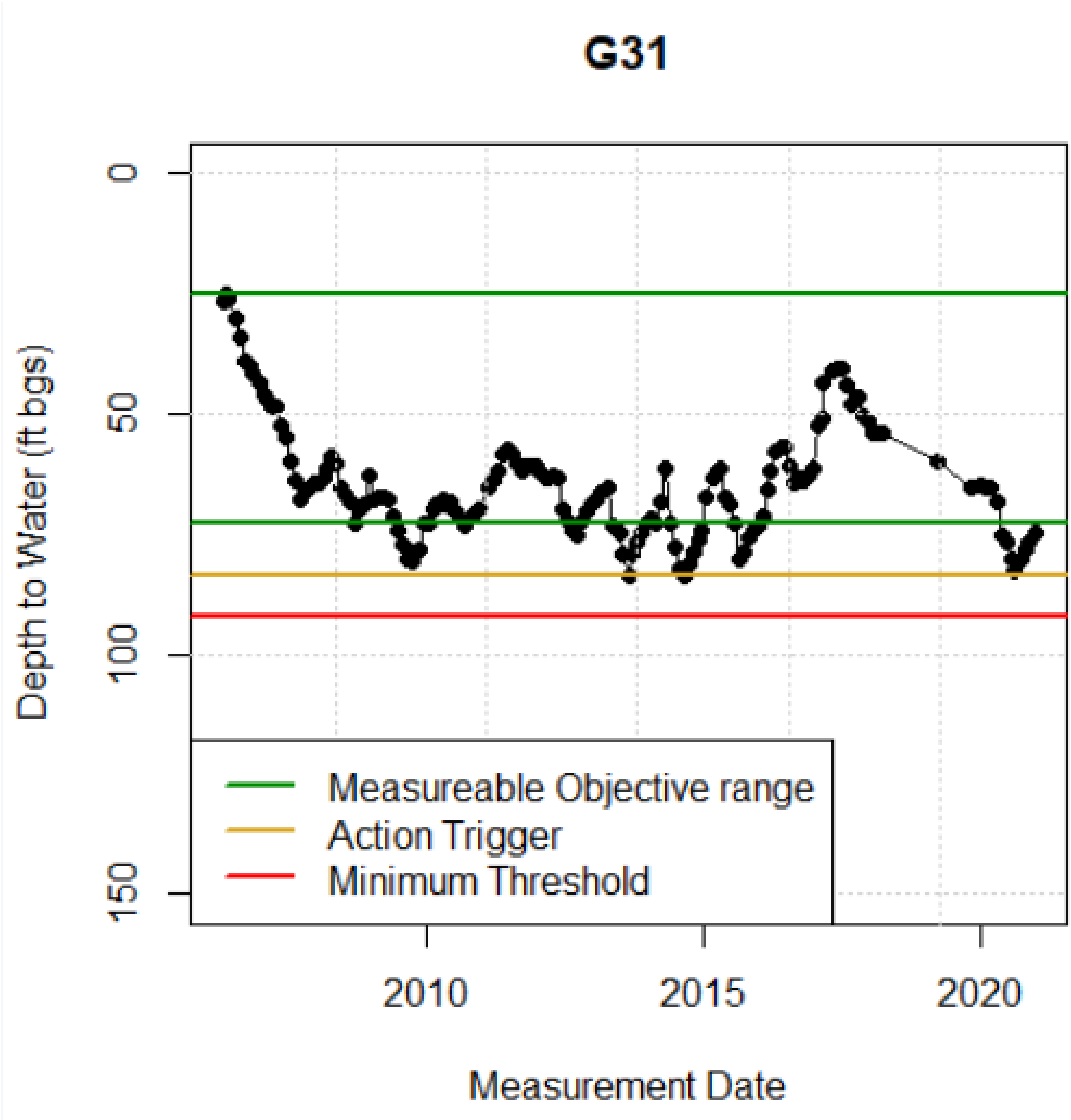

Figure 9: Example of Shasta Valley hydrograph for SMC development.

3.4.1.4 Relationship to Other Sustainability Indicators

Minimum thresholds are selected to avoid undesirable results for other sustainability indicators. Groundwater levels is an important influence on the groundwater storage, depletion of interconnected surface waters, water quality, subsidence, and impacts on groundwater-dependent ecosystems. The relationship between groundwater level minimum thresholds and minimum thresholds for other sustainability indicators are discussed below.

- **Groundwater Storage** – Groundwater levels are closely tied to groundwater storage, with high groundwater levels related to high groundwater storage. The undesirable result for groundwater storage is measured and thus defined as the occurrence of an undesirable result for groundwater elevations.
- **Depletion of Interconnected Surface Waters** - Currently ISW minimum thresholds are based on measured groundwater contributions to a hydraulically connected area of the stream network. Continued data collections will help determine the connection of near stream wells and groundwater contributions. Section 3.3.3.2 provides information on how groundwater levels will be incorporated into ISW in future updates.
- **Seawater Intrusion** - This sustainability indicator is not applicable in this Basin.
- **Groundwater Quality** - A significant and unreasonable condition for degraded water quality is exceeding drinking water standards for COCs in supply wells due to projects and management actions proposed in the GSP. Groundwater quality could potentially be affected by projects and management action-induced changes in groundwater elevations and gradients. These changes could potentially cause poor quality groundwater to flow towards supply wells that would not have otherwise been impacted.
- **Subsidence** - Subsidence has not historically been a problem in Shasta Valley. The groundwater level SMC will ensure that there is no onset of subsidence in the future. The minimum threshold for water level is sufficiently close to historic water levels that, under the hydrogeologic conditions prevalent in Shasta Valley, no significant subsidence can occur due to lowering of water levels within the limits set by the minimum threshold.

3.4.2 Groundwater Storage

Groundwater levels is the proxy for groundwater storage and the sustainability management criteria (SMCs) are identical (Section 3.4.1). According to the United States Geologic Survey, estimates of groundwater storage rely on groundwater level data and sufficiently accurate knowledge of hydrogeologic properties of the aquifer. Direct measurements of groundwater levels can be used to estimate changes in groundwater storage (USGS 2021). As groundwater levels fall or rise, the volume of groundwater storage changes accordingly, where unacceptable groundwater decline indicates unacceptable storage loss. The hydrogeologic model outlined in Chapter 2 provides the needed hydrogeologic properties of the aquifer.

Protecting against chronic lowering of groundwater levels will directly protect against the chronic reduction of groundwater storage as the lowering of groundwater levels would directly lead to the reduction of groundwater storage. The reduction of groundwater storage is a volume of groundwater that can be withdrawn from a basin or management area, based on measurements from multiple representative monitoring sites, without leading to undesirable results. There are currently no other state, federal, or local standards that relate to this sustainability indicator in the Basin.

An undesirable result from the reduction of groundwater in storage occurs when reduction of groundwater in storage interferes with beneficial uses of groundwater in the Basin. Since groundwater levels are being used as a proxy, the undesirable result for this sustainability indicator occurs when groundwater levels drop to chronically low levels, as defined by the undesirable result for the chronic lowering of groundwater levels. This should avoid significant and unreasonable changes to groundwater storage, including long-term reduction in groundwater storage or interference with the other sustainability indicators. Possible causes of undesirable reductions in groundwater storage are increases in well density or groundwater extraction or increases in frequency or duration of drought conditions.

The minimum threshold for groundwater storage for this GSP is the minimum threshold for groundwater levels. Information used to establish minimum thresholds and measurable objectives for groundwater levels can be found in Section 3.4.1. Since groundwater storage is defined in terms of water level, Section 3.4.1.5 for the water level indicator equally applies to define the relationship of the groundwater storage SMC to other sustainability indicators.

The measurable objective for groundwater storage is the measurable objective for groundwater levels, as detailed in Section 3.4.1.6. The path to achieve measurable objectives and interim milestones for the reduction in groundwater storage sustainability indicator are the same measurable objectives and interim milestones as for the chronic lowering of groundwater levels sustainability indicator detailed in Section 3.4.1.7.

3.4.3 Depletion of Interconnected Surface Water

3.4.3.1 Undesirable Results

Undesirable Results in the Context of Interconnected Surface Water

As described in Section 2, groundwater throughout the Basin is interconnected with the Shasta River stream network including its tributaries. As also described in Section 2, the Shasta River stream network is ecologically stressed due, in part, to periodically insufficient baseflow conditions during the summer and fall. Summer baseflow levels are, in part, related to groundwater levels and storage which determine the net groundwater contributions to streamflow. Excessive stream temperatures are also related to earlier completion of the snowmelt/spring flow recession, and due to later onset of the fall flush flow from the first significant precipitation event of the season. These adverse conditions primarily impact two species of native anadromous fish, coho and Chinook salmon. Adverse conditions have occurred primarily since the 1970s, exacerbated by the large frequency of dry years that have occurred over the past 20 years. There exists no long-term trend in streamflow minima, but the frequency of low precipitation years has been higher over the past 20 years than in the second part of the 20th century. Ecosystem stresses in the Shasta River stream network also include geomorphic conditions unrelated to flow (channel straightening and incision, sediment deposition).

The undesirable result that is relevant to SGMA is the stream depletion that can be attributed to groundwater pumping to the degree it leads to significant and unreasonable impacts on beneficial uses of surface water. SGMA also requires that the design of the SMC is consistent with existing water rights and regulations (23 CCR § 354.28(b)(5)). With respect to the interconnected surface water SMC in the Basin, relevant rights and regulations include (Cantor 2018): Porter-Cologne Water Quality Control Act (NCRWQCB Basin Plan and TMDL), and Endangered Species Act (ESA). These programs are described in Chapter 2 and briefly summarized here as they relate to the SMC development.

Potential Causes of Undesirable Results

Causes of the overall low flow challenges in the Shasta River stream system include consumptive use of surface water and groundwater and climate variability (which must be accounted for in the GSP). Some consumptive uses of groundwater may have a more immediate impact on streamflow than others; for example, a well that begins pumping groundwater 66 ft (20 m) from the river bank may cause stream depletion hours or days later, while a well that begins pumping two miles (3 km) west of the river bank may not influence streamflow for months or even a year. Possible causes of undesirable results include increasing frequency or duration of drought conditions, increased groundwater extraction, and continued surface water diversions. Changes in pumping distribution and volume may occur due to unforeseen rural, residential, agricultural, and urban growth that depend on groundwater as a water supply. Climate change or an extended drought can lead to reduced snowpack, rainfall reductions, prolonged periods of lowered groundwater levels, and reduced recharge. It may also lead to reduced recharge in surrounding uplands, lowering groundwater inflow to the Basin

The depletion of interconnected surface water is considered significant and unreasonable when there is a significant impact to environmental and agricultural uses of surface water in the Basin.

Potential impacts and the extent to which they are considered significant and unreasonable include:

- Inadequate flows to support riparian health and ecosystems.
- Diminished agricultural surface water diversions, beyond typical reductions for any given water year type.

Because the surface flow of the Shasta River, which is sustained by ISW, is currently inadequate in many years to meet the needs of both the environment and agriculture, a sustained reduction in ISW would constitute an undesirable result.

Under the California Water Action Plan the State Water Resources Control Board is tasked with developing instream flow recommendations based on recommendations developed by the California Department of Fish and Wildlife to allow for sufficient flows for salmonid species within the Shasta River. The development of CDFW flow standards are considered part of the Aspirational Watershed Goal detailed in Section 3.2.

Effects of Undesirable Results on Beneficial Uses and Users

- **Agricultural Land Uses and Users** - depletions of interconnected surface water due to groundwater pumping can reduce the surface flow available to downstream diverters.
- **Domestic and Municipal Water Uses and Users** - depletions of interconnected surface water can negatively affect municipalities that use surface water as a drinking water source.

None of the PMAs considered in the GSP development process would change operations for domestic water users pumping less than 2 AFY (2,467 m3/year), as these are *de minimis* groundwater users who are not regulated under SGMA. Similarly, none of the PMAs prioritized in the GSP development process would negatively affect municipal water users.

- **Recreation** - depletions of interconnected surface water can affect the ability of users to partake in recreational activities on surface water bodies in the Basin.

- **Environmental Land Uses and Land Users** - depletions of interconnected surface water may negatively affect the following: near-stream habitats for plant and animal species; instream ecosystems, including habitat necessary for reproduction, development, and migration of fish and other aquatic organisms; terrestrial ecosystems reliant on surface water; and wildlife that rely on surface waters as a food or water source. Additionally, low flow conditions can result in increased stream temperature that can be inhospitable to aquatic organisms, including anadromous fish. Low streamflow can also lead to increased concentrations of nutrients which can result in eutrophication.

3.4.3.2 Information and Methodology Used to Establish Minimum Thresholds and Measurable Objectives

Groundwater contributions during the irrigation season

The GSA will not be using a numerical groundwater-surface water model to evaluate ISW at this time. A temporary approach based on baseflow calculation will be used. The analytical calculation used to determine Depletion of Interconnected Surface Water adequately provides information on the location, quantity, and timing of the identified ISW. The system and identified reaches for ISW monitoring are known to have no surface water inputs during the months of July through September. This allows for direct measurements of groundwater contributions.

Minimum thresholds for ISW related to GDEs and instream flows are based on a water balance approach for lower Parks Creek and Shasta River from Dwinnell Reservoir to the SRM gage. Groundwater contributions to river flows are estimated with a simplified surface water balance.

Technical studies produced in 2016 and 2017 (SVRCD 2017; SVRCD 2018) provide detailed water balance measurements for both inflows and diversions on the mainstem of the Shasta River. Reports provided by the SSWD for WYs 2018, 2019, and 2020 were provided to quantify diversion flows from the water balance segment of interest. Instream flow releases are estimated at 1.5 CFS for WY 2019 and 2020, information from MWCD will be incorporated to accurately reflect true daily instream flow releases. Riparian diversions from the segment of interest is estimated at 20 CFS throughout the growing season. Based on conversations with SSWD staff (personal communications, 2021) riparian diverters do not continuously divert flow, estimates are set at approximately 2/3 of total riparian diversion rights. The remaining diversions were measured by the SSWD on the dates show on Table 7 and summarized on Figure 10. Values of flows from gaging stations are aggregated to mean daily flows of the days of interest. The water balance equation for groundwater contributions during late irrigation season is:

$$Baseflow_{contributions} = SRM - Instream + Diversions$$

Where:

$Baseflow_{contributions}$ is groundwater contributions to baseflow during irrigation season;

SRM is flow out of the USGS maintained SRM gage;

$Instream$ is instream flow releases out of Dwinnell Reservoir;

$Diversions$ are the sum of estimate riparian right holders and measured SSWD diverters.

The equation can be generalize to:

$$Baseflow_{contributions} = Outflow_{reach} - Inflow_{reach} + Diverions_{reach}$$

Where:

$Outflow_{reach}$ is flow leaving a stream reach of interest;

$Inflow_{reach}$ is flow entering a stream reach of interest, may be summed if tributary flow is present;

$Diverions_{reach}$ are the sum of consumptive diversions in the reach of interest.

There are multiple sources of uncertainty in the water balance measurements. Accuracy of stream gages can have up to 10% error in continuous measurements, though uncertainty is likely less with the USGS support in maintaining accurate flow monitoring. Riparian diverters are not measured. Best estimates are, and will continue to be, used to quantify riparian right holders. Water diversions measured by SSWD also operate on variable speed pumps and typically on an 'as needed' schedule. Measured diversions are only applicable to time of measurement, this methodology assumes the diversion rate holds steady throughout the day. No estimates of an energy balance on stream flow is implied with this methodology. Estimates from 2016 through 2020 show groundwater contributions range from 88 to 176 CFS, the evaporative losses and water uptake of riparian plants for ET are not accounted for. While this reach, as a whole, is a gaining stream, this is not proof that no areas in this reach may be losing.

The water balance approach will only be considered valid while surface water uses do not change. If significant changes to near river water use or application change, this approach and quantification of SMCs will need to be adjusted accordingly.

Table 7: Data used in estimating groundwater contributions during August and September for quantification of ISW SMCs.

Date	SRM Gage (CFS)	Instream Releases (CFS)	Total Diversions (CFS)	Groundwater Contributions (CFS)
8/24/2016	49.0	1.3	89.6	137.3
9/1/2016	55.0	1.2	103.3	157.1
9/19/2016	74.0	1.2	91.6	164.4
8/24/2017	64.5	1.2	99.3	162.6
9/6/2017	69.1	1.5	102.3	169.9
9/21/2017	78.3	1.6*	98.9	175.6
8/2/2018	29.2	4.7	84.0	108.5
8/16/2018	34.2	0.9	79.7	113.0
8/23/2018	42.6	2.9	71.6	111.3
8/27/2018	42.2	3	71.4	110.6
9/10/2018	19.8	2.9	76.6	93.5
9/18/2018	53.7	1.1	86.6	139.2
8/7/2019	31.0	1.5*	103.4	132.9
8/16/2019	50.7	1.5*	94.9	144.1
8/28/2019	46.9	1.5*	81.4	126.8
9/13/2019	48.9	1.5*	96.2	143.6
9/16/2019	72.4	1.5*	87.6	158.5

Table 7: Data used in estimating groundwater contributions during August and September for quantification of ISW SMCs. *(continued)*

Date	SRM Gage (CFS)	Instream Releases (CFS)	Total Diversions (CFS)	Groundwater Contributions (CFS)
8/6/2020	22.3	1.5*	67.4	88.2
8/25/2020	23.6	1.5*	73.1	95.2
9/9/2020	24.5	1.5*	77.7	100.7
9/24/2020	32.9	1.5*	70.7	102.1
9/30/2020	57.3	1.5*	70.5	126.3

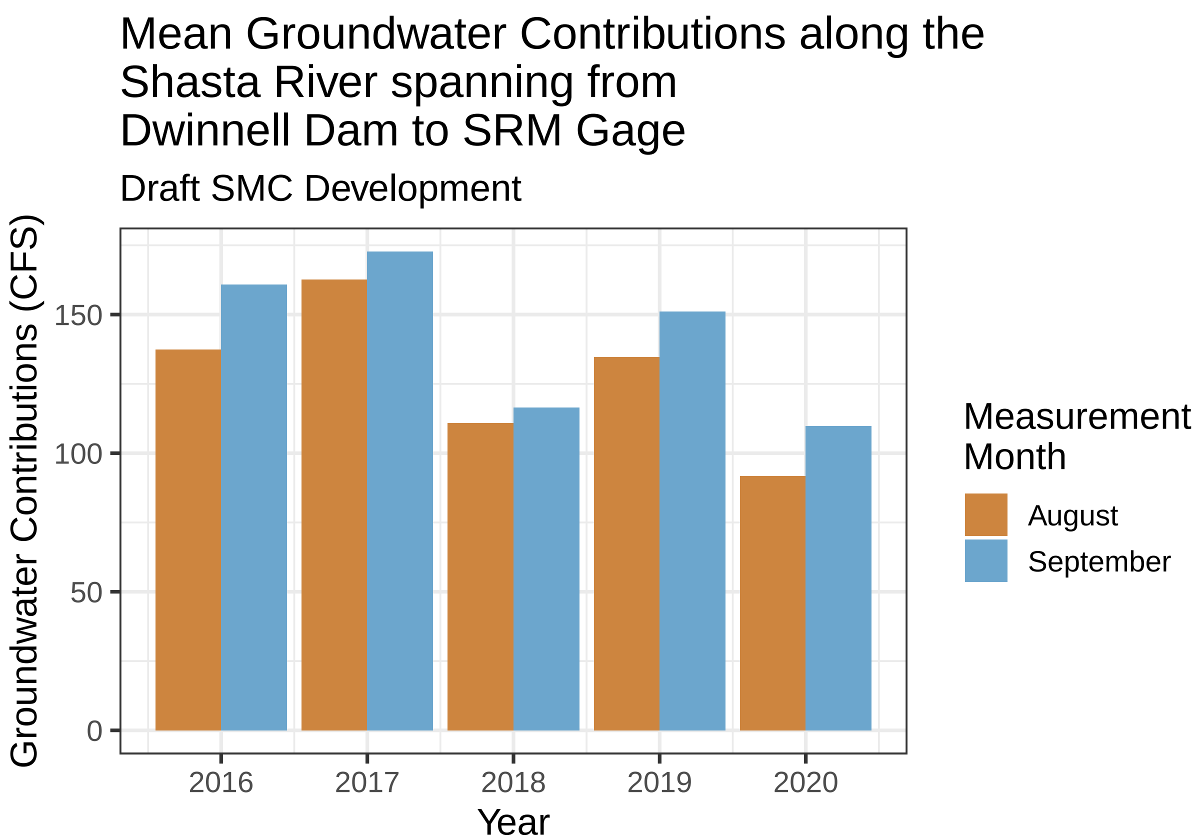

Figure 10: Mean groundwater contributions for 2016 through 2020. Data used in establishing minimum thresholds and measurable objectives.

Water Levels for Vegetative GDEs

Mapped GDEs in northern section of the Valley (Figure 49 in Chapter 2) will be monitored by groundwater elevations in the vicinity. GDE monitoring is best served by continuous monitoring wells within the GDE, but this type of data has been already highlighted as a data gap in the Basin. Water levels in well SV02 are monitored continuously and is currently the best candidate for monitoring groundwater levels for GDEs in the vicinity. Well SV02 is outside any GDE but near enough to monitor groundwater levels. In Section 2.2.2.7, GDEs are identified through historical groundwater levels so nearby monitoring wells should also remain within historical levels. Though SMCs for GDEs are not required by SGMA, the minimum thresholds for SV02 will be set to protect beneficial users such as GDEs and set at the Fall minimum (add graph of water levels). Further data collection based on other continuous well monitoring near critical GDEs and satellite images to evaluate twice per year the health of GDEs will be included in the management actions for future monitoring.

3.4.3.3 Minimum Threshold

Groundwater contributions during the irrigation season (April 1-October 1)

Based on the limited 5-year history of measurements for the groundwater contributions SMC, a preliminary Minimum Threshold will be set at 100 CFS of average monthly groundwater contributions. Updated MTs will be developed as additional years of data are collected. It is expected that MTs will be developed for different water year types, ie. Critical, Dry, Normal, Above Normal, and Wet.

Trigger measurements will be set at 15 CFS higher than the MT. If the trigger is exceeded for two consecutive non-dry years, additional investigations will be conducted.

Water Levels for Vegetative GDEs

Based on the 7 year history of data recorded in the CASGEM system for SV02, the MT for SV02 will be set at 31 feet below ground surface for the Fall measurement.

3.4.3.4 Measurable Objective

A summary of MT, Trigger, and MO can be found on Table 8

Groundwater contributions during the irrigation season (April 1 to October 1)

Measurable objective for groundwater contributions during irrigation season will be set at 145 CFS. Updated MO are expected as additional years of data of different water year types are experienced.

Water Levels for Vegetative GDEs

Due to the proximity to the Shasta River to the northeast, approximately 1,000 feet, and the northwest, approximately 2,700 feet, the MO for water levels in this well are constrained.

It is assumed the proximity to the Shasta River, approximately 1,000 feet and 2,700 feet to the northeast and northwest, respectively, provide a large degree of control over the groundwater elevation in the well. The MO will be set to 30 feet below ground surface.

Table 8: Summary of SMC values for ISW.

Measurement Point	Minimum Threshold	Trigger	Measurable Objective
Baseflow	100 CFS (+/- 20%)	115 CFS	145 CFS
SV02	31’ bgs	–	30’ bgs

3.4.3.5 Relationship to Other Sustainability Indicators

Minimum thresholds for depletion of interconnected surface water are set to measure the direct contribution of groundwater to the surface water system. The magnitude of the contribution should be correlated to groundwater level sustainability indicators upgradient of the identified contributing area. Due to the complexity of the geologic and hydrogeologic system, additional investigations are required to establish any specific correlations between groundwater levels and interconnected surface water. Specific planned monitoring and investigations are documented in Chapter 4 Project and Management Actions.

3.4.3.6 Expected approach modification at the 5-years GSP update

Quantifying Streamflow Depletion due to Groundwater Pumping with the integrated hydrological model

The Shasta Watershed Groundwater Model (SWGM) model remains the best available tool to evaluate surface water depletion conditions in the Basin and to quantify the amount of depletion attributable to groundwater use. However, to use the model to set SMC for depletion of ISW, the GSA needs to fill critical data gaps such as continuous groundwater level measurements along the monitoring transects and streamflow and spring measurements.

At the 5-year update, the approach to calculate ISW SMC will be reevaluated. Depletion of ISW will be calculated using a combination of measured and modeled. Measured information includes high-frequency groundwater level measurements at monitoring network wells, streamflow measurement at assigned gages, spring monitoring and available surface water diversion data. The integrated hydrological model will be updated based on the measured data and re-calibrated to sufficiently match the streamflow and groundwater elevation measurements for the recently collected data. The calibrated model will quantify changes in stream depletion due to pumping by comparing stream depletion of the “business-as-usual” scenario and stream depletion of the no-pumping scenario. The business-as-usual scenario is the simulation of the current conditions using best available data and methods and includes existing and implemented PMAs. The no-pumping scenario is a replicate of the business- as-usual scenario with two primary differences: 1) all pumping from the Basin is removed from the simulation, and, 2) no PMAs are included in the simulation.

This is designed to be an adaptive management process that evolves as new knowledge is gained. A detailed description of the relationship between the numerous data collection efforts and the process of updating the integrated hydrological model is provided in the following subsections. The approach expected at the 5-years update may also be a combination of the currently proposed baseflow approach and the stream depletion calculation based on model results. The model-based approach is the approach currently suggested for Scott Valley, where the model has been implemented for many years and can rely on extensive data for calibration and evaluation.

Adaptive Sustainable Management Criteria Approach for Depletion of Interconnected Surface Waters due to Existing Data Gaps

As explained in the previous section, the lack of historical and high-frequency groundwater elevation data in the Basin, spatial gaps in streamflow and spring measurements, and uncertainty in the historical and current data regarding surface water diversions and groundwater does not allow the development of a reliable estimate of stream depletion due to pumping. Acknowledging these uncertainties and existing data gaps, the GSA finds it inappropriate to define the intercon- nected surface water SMC at this stage using modelled results of stream depletion. Instead, the GSA proposes an adaptive approach that would help improve the SMC setting in the future using newly collected data while addressing

SGMA requirements and avoiding undesirable results throughout the implementation period. This adaptive approach uses the 5-year assessment periods as an opportunity to adapt the SMC. The implementable SMC will be set ideally at the first, or ultimately the second 5-year assessment period and must be followed for the rest of the implementation period. The adaptive approach can be summarized as follows:

$$SMC_{MT,MO} = \begin{cases} 1 & \text{if sufficient data is gathered} : f(\text{calculated stream depletion}) \\ 0 & \text{otherwise} : f(\text{preliminary baseflow at RMPs}) \end{cases}$$

The GSA will use the baseflow approach in the first 5 years of the implementation. The GSA will gather data and information during this period to improve its understanding of the surface water and groundwater interaction, cover existing data gaps, and re-calibrate and improve its integrated hydrological model. Upon gathering sufficient data and information, the GSA may proceed to the revision of the SMC for the depletion of ISWs to be based on the volume or rate of depletion of surface water due to groundwater pumping at monitoring transect locations using measured data and model estimation, with an approach similar to what is currently suggested in the Scott Valley GSP.

Assessment and Improvement of the Monitoring Network Assessing and Improving Related Monitoring Network

As discussed above, the identified data gaps include high-frequency groundwater level measurements, streamflow and spring measurements, surface water diversion and groundwater pumping information. If the need is identified, the RMPsnetwork will be expanded by adding new wells, springs and stream gages.

Assessing and Improving the integrated hydrological model

The integrated hydrological model, as a monitoring instrument for surface water depletion due to groundwater pumping, will be assessed and updated every 5 years, utilizing the data and knowledge used for the original/previous model development update plus any additional monitoring data collected since the last model update. New data to be considered in the assessment and update of the model can be grouped into three general categories:

- *Validation and re-calibration data ("target" data)*: These include independently-collected field data, typically collected on a daily, monthly, or seasonal basis. These data are also produced by the model as outputs, which include groundwater levels and streamflows within the Basin and the upper watershed. They are commonly used as calibration tar- gets during model (re-)calibration. In other words, model simulation results will be compared with measured data to adjust model parameters (within the limits of the conceptual model) to increase the precision of simulated results including groundwater levels, streamflow rates, etc.
- *Conceptual model data*: hydrologic and hydrogeologic conditions (concept and "input" data). These are the model input data used to parameterize or conceptually design the model. Examples of these data include precipitation data, hydrogeologic data obtained from well logs and aquifer characterization tests (such the one suggested in Chapter 4, under Project and Management Actions), and research insights obtained from projects to further understand the hydrogeology of the Basin.

- *Data about implementation of projects and management actions ("PMA" data)*: These are (monitoring) data collected specifically to characterize the implementation of PMAs to inform the GSA, stakeholders, and the design of future model scenario updates. The specific data to be collected depend on each PMA and are described in Chapter 4.

These newly collected data will be used by the model in three ways:

1. Precipitation and streamflow data measured at weather stations and stream gages will be used to extend the simulation time horizon of the model without any adjustments to parameters, boundary conditions, or scenarios included in the original time horizon of the model. This is a relatively inexpensive model application that allows for updated comparison of simulated water level and streamflow predictions against measured data under baseline and (existing) scenario conditions through the most current time period for which data are available. This type of model application is anticipated to occur at least once every five years concurrently with the 5-year assessments, or possibly annually.
2. In addition to (1), data about PMA implementation will be used to update the model to include new, actual PMA implementation data on the correct timeline. This provides a model update that appropriately represents recent changes in PMA implementation and a more consistent evaluation of simulated versus measured water level and streamflow data. This type of model application is anticipated to occur at least once every five years concurrently with the 5-year assessments.
3. In addition to (1) and (2), conceptual model data are used to update model parameters and model boundary conditions unrelated to PMAs to improve the conceptual model underlying the integrated hydrological model based on newly measured data and information. This will typically (but not automatically) require a re-calibration of the model against measured target data. After the re-calibration, all scenarios of interest will be updated using the re-calibrated model to allow for consistent comparison of streamflow. This type of model application is anticipated to occur at least every ten years.

The above protocol ensures tight integration between monitoring programs, PMAs implementation, and the integrated hydrological model. It provides the most accurate estimation not only of streamflow depletion, but also of associated information about water level dynamics, streamflow dynamics and their spatial, seasonal, interannual, and water-year-type-dependent behavior. Examples of future field monitoring data used to assess and improve the model are listed below:

- Validation and re-calibration data ("target" data):
  - Groundwater levels from the groundwater elevation monitoring network.
  - Daily streamflows measured at the existing and newly installed stream gages.
  - Data documenting dates and locations of dry sections in the stream network.
- Hydrologic and hydrogeologic conditions (concept and "input" data):
  - Precipitation data from existing climate stations.
  - Potential ET data computed from existing climate stations.
  - Daily streamflows measured at locations near tributary streamflows to Ukiah Valley.
  - Pump test data that contain information about hydrogeologic properties in the vicinity of a well.
  - Geologic information obtained from the new well drilling logs.
  - Data collected in conjunction with research and pilot projects characterizing hydrologic and hydrogeologic conditions in the Basin.

3.4.4 Degraded Groundwater Quality

Groundwater quality in the Basin is generally well-suited for the municipal, domestic, agricultural, and other existing and potential beneficial uses designated for groundwater in the Water Quality Control Plan for the North Coast Region (Basin Plan). Existing groundwater quality concerns within the Basin are identified in Section 2.2.2.3 and the corresponding water quality figures and detailed water quality assessment are included in Appendix C. In Section 2.2.2.3, constituents that are identified as groundwater quality concerns include arsenic, benzene, boron, iron, manganese, nitrate, pH, and specific conductivity. Sustainability management criteria (SMCs) are defined for a select group of constituents: nitrate and specific conductivity. Benzene is already being monitored and managed by the Regional Board through the Leaking Underground Storage Tank (LUST) program. Arsenic, boron, iron, manganese, and pH are naturally occurring and as such, SMCs are not defined.

Groundwater quality monitoring in the Basin in support of the GSP will rely on the monitoring network described in Section 3.3.4.1. Groundwater quality samples will be collected and analyzed in accordance with the monitoring protocols outlined in Section 3.3.4.3. The monitoring network will use information from existing programs in the Basin that already monitor for the constituents of concern, and programs where constituents could be added as part of routine monitoring efforts in support of the GSP. New wells will be incorporated into the network as necessary to fill data gaps. Because water quality degradation is typically associated with increasing rather than decreasing concentration of constituents, the GSA has decided to not use the term “minimum threshold” in the context of water quality, but instead use the term “maximum threshold”. The use of the term maximum threshold for the water quality SMC in this GSP is equivalent to the use of the term minimum threshold in other sustainability management criteria or in the SGMA regulations.

Surface water is not always available in some areas of the Basin and does not satisfy all agricultural, domestic, and municipal water needs. Groundwater has an important role for those beneficial users of water in certain locations in the valley. Groundwater is also an important component of streamflow and its water quality benefits groundwater-dependent ecosystems (GDEs) and instream environmental resources. These beneficial uses, among others, are protected by the NCRWQCB through the water quality objectives adopted in the Basin Plan. The Basin Plan defines the existing beneficial uses of groundwater in the Basin: Municipal and Domestic Supply (MUN), Agricultural Supply (AGR), Native American Culture (CUL), and Industrial Service Supply (IND). Potential beneficial uses include Aquaculture (AQUA) and Industrial Process Supply (PRO).

Federal and state standards for water quality, water quality objectives defined in the Basin Plan and the management of known and suspected contaminated sites within the Basin will continue to be managed by the relevant agency. The role of the GSA is to provide additional local oversight of groundwater quality, collaborate with appropriate parties to implement water quality projects and actions, and to evaluate and monitor, as needed, water quality effects of projects and actions implemented to meet the requirements of other sustainability management criteria.

Sustainable management of groundwater quality includes maintenance of water quality within regulatory and programmatic limits (Section 2.2.2.3) while executing GSP projects and actions. To achieve this goal, the GSA will coordinate with the regulatory agencies that are currently authorized to maintain and improve groundwater quality within the Basin. This includes informing the Regional Board of any issues that arise and working with the Regional Board to rectify the problem. All future projects and management actions implemented by the GSA will be evaluated and designed to avoid causing undesirable groundwater quality outcomes. Historic and current groundwater quality monitoring data and reporting efforts have been used to establish and document conditions in the Basin, as discussed in Section 2.2.2.3. These conditions provide a baseline to compare with future groundwater quality and identify any changes observed due to GSP implementation.

3.4.4.1 Undesirable Results

Significant and unreasonable degradation of groundwater quality is the degradation of water quality that would impair beneficial uses of groundwater within the Basin or result in failure to comply with groundwater regulatory thresholds. Degraded groundwater quality is considered an undesirable result if concentrations of COCs exceed defined maximum thresholds or if a significant trend of groundwater quality degradation is observed for the identified COCs. Groundwater quality changes that occur independent of SGMA activities do not constitute an undesirable result. Based on the State's 1968 Antidegradation Policy , water quality degradation that is not consistent with the provisions of Resolution No. 68-16 is degradation that is determined to be significant and unreasonable. NCRWQCB and the State Water Board are the two entities that determine if water quality degradation is inconsistent with Resolution No. 68-16.

For purposes of quantifying and evaluating the occurrence on an undesirable result, the concentration data are aggregated by statistical analysis to obtain spatial distributions and temporal trends. Specifically, statistical analysis is performed to determine the ten-year linear trend in concentration at each well. The linear ten-year trend is expressed unitless as percent relative concentration change per year. From the cumulative distribution of all ten-year trends observed across the monitoring network, the 75th percentile, $trend75_{10year}$, is obtained. Similarly, the moving two-year average concentrations are computed at each well, and from their cumulative distribution the 75th percentile, $conc75_{2year}$, is obtained. Concentrations are expressed in their respective concentration units (ug/L, mg/L, or micromhos). For purposes of this GSP, a "water quality value" is defined by combining the measures of trend and concentration.

$$\text{Water quality value} = Maximum[(+15\% – trend75_{10year}), (conc75_{2year} – MT)]$$

The undesirable result is quantitatively defined as:

$$\text{Water quality value} > 0$$

This quantitative measure assures that water quality remains constant and does not increase by more than 15% per year, on average over ten years, in more than 25% of wells in the monitoring network. It also assures that water quality does not exceed maximum thresholds for concentration, MT, in more than 25% of wells in the monitoring network.

Potential Causes of Undesirable Results

Future GSA activities with potential to affect water quality may include changes in location and magnitude of basin pumping, declining groundwater levels and groundwater recharge projects. Altering the location or rate of groundwater pumping could change the direction of groundwater flow which may result in a change in the overall direction in which existing or future contaminant plumes move thus potentially compromising ongoing remediation efforts. Similarly, recharge activities could alter hydraulic gradients and result in the downward movement of contaminants into groundwater or move groundwater contaminant plumes towards supply wells.

Land use activities that may lead to undesirable groundwater quality include industrial contamination, pesticides, sewage, animal waste, and other wastewaters, and natural causes. Fertilizers and other agricultural activities can elevate analytes such as nitrate and specific conductivity. Wastewater, such as sewage from septic tanks and animal waste, can elevate nitrate and specific conductivity. The GSA cannot control and is not responsible for natural causes of groundwater contamination. Natural causes (e.g., local volcanic geology and soils) can elevate analytes such as arsenic, boron, iron, manganese, pH, and specific conductivity. For further detail, see Section 2.2.2.3.

Groundwater quality degradation associated with known sources will be primarily managed by the entity currently overseeing these sites, the NCRWQCB. In the Basin, existing leaks from underground storage tanks (USTs) are currently being managed, and though additional degradation is not anticipated from known sources, new leaks may cause undesirable results due to constituents that, depending on the contents of an UST, may include petroleum hydrocarbons, solvents, or other contaminants.

Agricultural activities in the Basin are dominated by pasture, grain and hay, and alfalfa. Alfalfa and pasture production have low risk for fertilizer-associated nitrate leaching into the groundwater (Harter et al., 2017). Grain production is rotated with alfalfa production usually for one year after seven years of alfalfa production. Grain production also does not pose a significant nitrate-leaching risk. Animal farming, a common source of nitrate pollution in large, confined animal farming operations, is also present in the valley, but not at stocking densities of major concern (Harter et al., 2017).

Effects on Beneficial Uses and Users

Concerns over potential or actual non-attainment of the beneficial uses designated for groundwater in the Basin are and will continue to be related to certain constituents measured at elevated or increasing concentrations, and the potential local or regional effects that degraded water quality have on such beneficial uses.

The following provides greater detail regarding the potential impact of poor groundwater quality on several major classes of beneficial users:

- **Municipal Drinking Water Users** – Under California law, agencies that provide drinking water are required to routinely sample groundwater from their wells and compare the results to state and federal drinking water standards for individual chemicals. Groundwater quality that does not meet state drinking water standards may render the water unusable or may cause increased costs for treatment. For municipal suppliers, impacted wells may potentially be taken offline until a solution is found, depending on the configuration of the municipal system in question. Where this temporary solution is feasible, it will add stress to and decrease the reliability of the overall system.

- **Rural and/or Agricultural Residential Drinking Water Users** - Residential structures not located within the service areas of the local municipal water agency will typically have private domestic groundwater wells. Such wells may not be monitored routinely and groundwater quality from those wells may be unknown unless the landowner has initiated testing and shared the data with other entities. Degraded water quality in such wells can lead to rural residential use of groundwater that does not meet potable water standards and results in the need for installation of new or modified domestic wells and/or well-head treatment that will provide groundwater of acceptable quality.

- Agricultural Users – Irrigation water quality is an important factor in crop production and has a variable impact on agriculture due to different crop sensitivities. Impacts from poor water quality may include declines in crop yields, crop damage, changes in crops that can be grown in an area, and other effects.
- **Environmental Uses** – Poor quality groundwater may result in migration of contaminants which could impact groundwater dependent ecosystems or instream environments, and their resident species, to which groundwater contributes.

3.4.4.2 Maximum Thresholds

Maximum thresholds for groundwater quality in the Basin were defined using existing groundwater quality data, beneficial uses of groundwater in the basin, existing regulations, including water quality objectives under the Basin Plan, Title 22 Primary MCLs, and Secondary MCLs, and consultation with the GSA advisory committee and stakeholders (see Section 2.2.2.3.). Resulting from this process, SMCs were developed for two constituents of concern in the Basin: nitrate, and specific conductivity. Although benzene is identified as a potential constituent of concern in Section 2.2.2.3, no SMC is defined for the constituent as current benzene data is associated with leaking underground storage tanks (LUST) where the source is known, and monitoring and remediation are in progress. These sites will be taken into consideration with projects and management actions undertaken by the GSA, as applicable. Arsenic, boron, iron, manganese, and pH do not have an SMC because they are naturally occurring.

The selected maximum thresholds for the concentration of each of the two constituents of concern and their associated regulatory thresholds are shown in Table 9.

Table 9: Constituents of concern and the associated maximum thresholds. Maximum thresholds also include a 15 percent average increase per year over ten years in no more than 25 percent of wells, and no more than 25 percent of wells exceeding the maximum threshold for concentration listed here.

Constituent	Maximum Threshold	Regulatory Threshold	Units
Nitrate as Nitrogen	5 trigger only	10 (Title 22)	mg/L
Nitrate as Nitrogen	9 trigger only	10 (Title 22)	mg/L
Nitrate as Nitrogen	10 MT	10 (Title 22)	mg/L
Specific Conductivity	500 trigger only	500 (50% of Basin Plan Upper Limit)	micromhos
Specific Conductivity	800 trigger only	800 (90% of Basin Plan Upper Limit)	micromhos
Specific Conductivity	900 MT	900 (Title 22)	micromhos

Triggers

The GSA will use concentrations of the identified constituents of concern as triggers for preventive action, in order to proactively avoid the occurrence of undesirable results. Trigger values and associated definitions for specific conductivity are the values and definitions listed in the Basin Plan. The Basin Plan specifies two upper limits for specific conductivity, a 50% upper limit, or 50 percentile value of the monthly means for a calendar year and a 90% upper limit or 90 percentile values for a calendar year. The triggers provided in Table 9 for nitrate correspond to half and 90% of the Title 22 MCL.

Method for Quantitative Measurement of Maximum Thresholds

Groundwater quality will be measured in representative monitoring wells as discussed in Section 3.3.4.1. Statistical evaluation of groundwater quality data obtained from available water quality data obtained from the monitoring network will be performed and evaluated using a water quality value using the equation above. The maximum threshold for concentration values are shown in Table 9 and Figure 11. Figure 11 shows example “thermometers” for each of the identified constituents of concern in Shasta Valley Groundwater Basin with the associated maximum thresholds, range of measurable objectives, and triggers.

3.4.4.3 Measurable Objectives

Measurable objectives are defined under SGMA as described above in Section 3.1. Within the Basin, the measurable objectives for water quality are established to provide an indication of desired water quality at levels that are sufficiently protective of beneficial uses and users. Measurable objectives are defined on a well-specific basis, with consideration for historical water quality data.

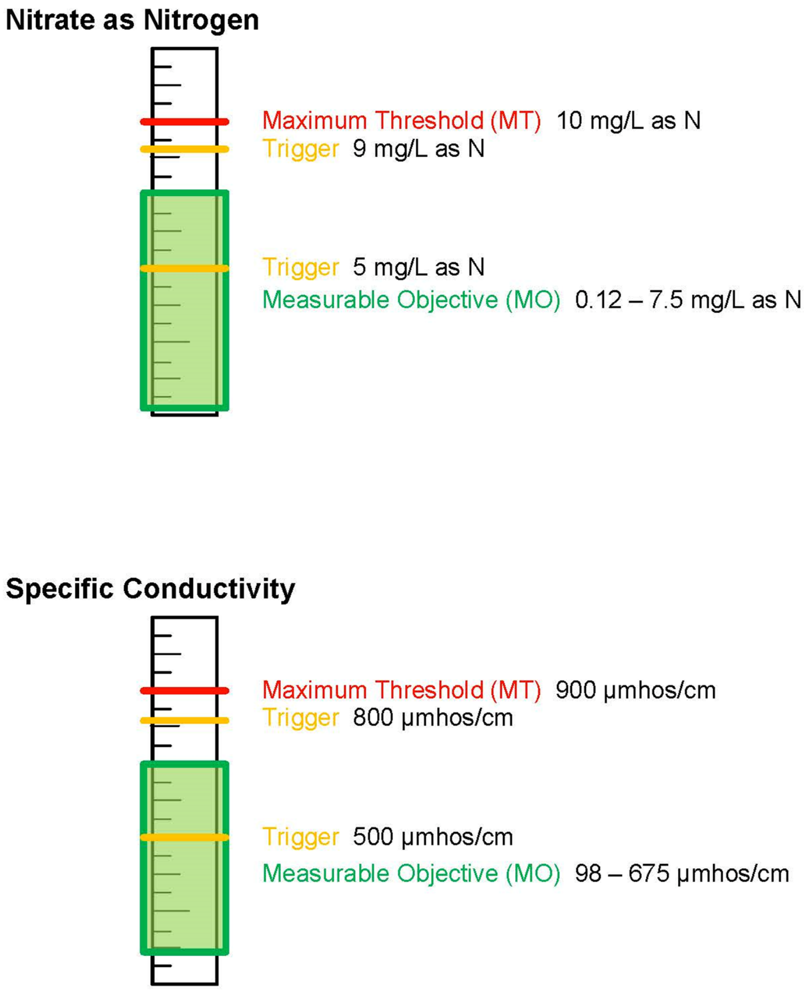

Figure 11: Example Shasta Valley Measurable Objectives of Nitrate and Specific Conductivity. Measurable objectives are specific to each well in the monitoring network.

Description of Measurable Objectives

The groundwater quality measurable objective for wells within the GSA's monitoring network, where the concentrations of constituents of concern historically have been below the maximum thresholds for water quality in recent years, is to continue to maintain concentrations at or below the current range, as measured by long-term trends. The measurable objective is defined using the identified consituents of concern, nitrate and specific conductivity.

Specifically, for these COCs, the measurable objective is to maintain groundwater quality at a minimum of 90% of wells monitored for water quality within the range of the water quality levels measured over the past 30 years (1990-2020). In addition, no significant increasing long-term trends should be observed in levels of constituents of concern.

3.4.4.4 Path to Achieve Measurable Objectives

The GSA will support the protection of groundwater quality by monitoring groundwater quality conditions and coordinating with other regulatory agencies that work to maintain and improve the groundwater quality in the Basin. All future projects and management actions implemented by the GSA will comply with State and Federal water quality standards and Basin Plan water quality objectives and will be designed to maintain groundwater quality for all uses and users and avoid causing unreasonable groundwater quality degradation. The GSA will review and analyze groundwater monitoring data as part of GSP implementation in order to evaluate any changes in groundwater quality resulting from groundwater pumping or recharge projects in the Basin. The need for additional studies on groundwater quality will be assessed throughout GSP implementation. The GSA may identify knowledge requirements, seek funding, and help to implement additional studies.

Using monitoring data collected as part of project implementation, the GSA will develop information (e.g., time-series plots of water quality constituents) to demonstrate that projects and management actions are operating to maintain or improve groundwater quality conditions in the Basin and to avoid unreasonable groundwater quality degradation. Should the concentration of a constituent of interest increase to its maximum threshold (or a trigger value below that objective specifically designated by the GSA) as the result of GSA project implementation, the GSA will implement measures to address this occurrence. This process is illustrated in Figure 12.

If a degraded water quality trigger is exceeded, the GSA will investigate the cause and source and implement management actions as appropriate. Where the cause is known, projects and management actions with stakeholder education and outreach will be implemented. Examples of possible GSA actions include notification and outreach with impacted stakeholders, alternative placement of groundwater recharge projects, and coordination with the appropriate water quality regulation agency. Projects and management actions are presented in further detail in Chapter 4.

The impacts of high nitrate and specific conductivity in groundwater is discussed in Section 2.2.2.3. Exceedances of nitrate, and specific conductivity will be referred to the NCRWQCB. Where the cause of an exceedance is unknown, the GSA may choose to conduct additional or more frequent monitoring.

Interim Milestones

As existing groundwater quality data indicate that groundwater in the Basin generally meets applicable state and federal water quality standards, the objective is to maintain existing groundwater quality. Interim milestones are therefore set equivalent to the measurable objectives with the goal of maintaining water quality within the historical range of values.

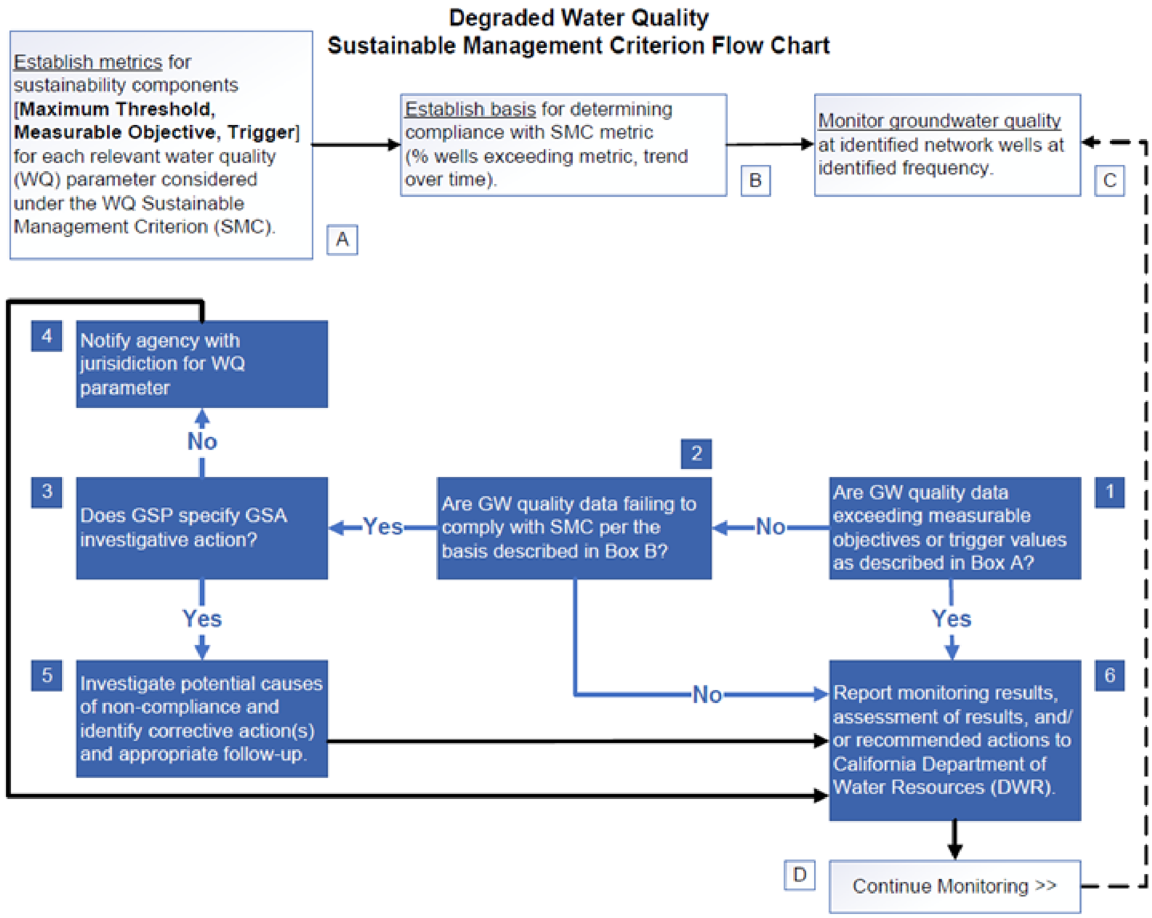

Figure 12: Degraded water quality sustainable management criteria flow chart. The flow chart depicts the high-level decision making that goes into developing sustainable management criteria (SMC), monitoring to determine if criteria are met, and actions to be taken based on monitoring results.

3.4.4.5 Information and Methodology Used to Establish Maximum Thresholds and Measurable Objectives

The constituents for which SMC were considered were specifically selected due to measured exceedances in the past 30 years, known groundwater contamination at LUST sites, and/or stakeholder input and prevalence as a groundwater contaminant in California. A detailed discussion of the concerns associated with elevated levels of each constituent of interest is described in Section 2.2.2.3. As the constituents of concern were identified using current and historical groundwater quality data, this list may be reevaluated during future GSP updates. In establishing maximum thresholds for groundwater quality, the following information was considered:

- Feedback about water quality concerns from stakeholders.
- An assessment of available historical and current groundwater quality data from production and monitoring wells in the Basin.

- An assessment of historical compliance with Federal and state drinking water quality standards and water quality objectives.
- An assessment of trends in groundwater quality at selected wells with adequate data to perform the assessment.
- Information regarding sources, control options and regulatory jurisdiction pertaining to constituents of concern.
- Input from stakeholders resulting from the consideration of the above information in the form of recommendations regarding maximum thresholds and associated management actions.

The historical and current groundwater quality data used in the effort to establish groundwater quality maximum thresholds are discussed in Section 2.2.2.3. Based on a review of these data, applicable water quality regulations, Basin water quality needs, and information from stakeholders, the GSA reached a determination that the state drinking water standards (MCLs and WQOs) are appropriate to define maximum thresholds for groundwater quality. These maximum thresholds are summarized in Table 9, as noted above. The established maximum thresholds for groundwater quality protect and maintain groundwater quality for existing or potential beneficial uses and users. For most analytes, the maximum thresholds align with the state standards listed in Title 22.

New constituents of concern may be added with changing conditions and as new information becomes available.

3.4.4.6 Relationship to Other Sustainability Indicators

Groundwater quality cannot typically be used to predict responses of other sustainability indicators. However, groundwater quality may be affected by groundwater levels and reductions in groundwater storage. In addition, certain implementation actions may be limited by the need to achieve minimum thresholds for other sustainability indicators. * Groundwater Levels – Declining water levels can potentially lead to increased concentrations of constituents of concern in groundwater and may alter the existing hydraulic gradient and result in movement of contaminated groundwater plumes. Changes in water levels may also mobilize contaminants that may be present in unsaturated soils. The maximum thresholds established for groundwater quality may influence groundwater level minimum thresholds by affecting the location or number of projects, such as groundwater recharge, in order to avoid degradation of groundwater quality.

- **Groundwater Storage** – Groundwater quality that is at or near maximum thresholds is not likely to influence pumping.
- **Depletion of Interconnected surface waters** – Groundwater quality that is at or near maximum thresholds may affect stream water quality.
- **Seawater Intrusion** – This sustainability indicator is not applicable in this Basin.
- **Subsidence** – This sustainability indicator is not affected by groundwater quality.

3.4.5 Subsidence

3.4.5.1 Undesirable Results

An undesirable result occurs when subsidence substantially interferes with beneficial uses of groundwater and land uses. Subsidence occurs as a result of compaction of fine-grained aquifer materials (i.e., clay) due to the overdraft of groundwater. Undesirable results would occur when substantial interference with land use occurs, including significant damage to critical infrastructure such as canals, pipes, or other water conveyance facilities, including flooding agricultural practices. As there has not been any historical documentation of subsidence in the Basin and the aquifer materials are unlikely to present such a risk, it is reasonable to declare that measurable land subsidence caused by the chronic lowering of groundwater levels occurring in the Basin would be considered an unreasonable result. This is quantified as pumping induced subsidence greater than the minimum threshold of 0.1 ft (0.03 m) in any single year, essentially zero subsidence accounting for measurement error. This relies on the fact that the point measurement error of vertical surface displacement measured by InSAR is +/- 0.1 ft (0.03 m), which is explained in more detail in Section 2.2.2.4 and in Appendix E.

Effects of Undesirable Results on Beneficial Uses and Users

Subsidence can result in substantial interference with land use including significant damage to critical infrastructure such as canals, pipes, or other water conveyance facilities, as well as breaking of building foundations and tilting of structures. Other effects include flooding of land, including residential and commercial properties, and negative impacts on agricultural operations. Subsidence is closely linked with declining groundwater levels and a decline in groundwater levels can trigger land subsidence.

3.4.5.2 Minimum Thresholds

The minimum threshold for land subsidence in the Basin is set at no more than 0.1 ft (0.03 m) in any single year, resulting in no long-term permanent subsidence. This is set at the same magnitude of estimated error in the InSAR data (+/- 0.1 ft (0.03 m)), which is currently the only tool available for measuring basin-wide land subsidence consistently each year in the Basin.

The minimum thresholds selected for land subsidence for the Basin area were selected as a preventative measure to ensure the maintenance of current ground surface elevations and as an added safety measure for potential future impacts not currently present in the Basin and nearby groundwater Basins. This avoids significant and unreasonable rates of land subsidence in the Basin, which are those that would lead to a permanent subsidence of land surface elevations that would impact infrastructure and agricultural production in Shasta Valley and neighboring groundwater Basins. There are currently no other state, federal, or local standards that relate to this sustainability indicator in the Basin.

3.4.5.3 Measurable Objectives

Measurable objectives are defined under SGMA as described above in Section 3.1. Within the Basin, the measurable objective for subsidence is established to protect beneficial uses and users.

The guiding measurable objective of this GSP for land subsidence in the Basin is the maintenance of current ground surface elevations. This measurable objective avoids significant and unreasonable rates of land subsidence in the Basin, which are those that lead to a permanent subsidence of land surface elevations that impact infrastructure and agricultural production.

Land subsidence risk in Shasta Valley is considered low because there is no historical record of subsidence in the Basin and the local geology is composed of alluvial aquifer and volcanic materials that are not susceptible to inelastic subsidence due to groundwater overdraft (see Section 2.2.2.4). Recent InSAR data show no significant subsidence occurring during the period of mid-June 2015 to mid-September 2019 (see Figure 35).

Land subsidence in the Basin is expected to be managed through the implementation period via the sustainable management of groundwater pumping through the groundwater level measurable objectives, minimum thresholds, and interim milestones. The margin of safety for the subsidence measurable objective was established by setting a measurable objective to maintain current land surface elevations and opting to monitor subsidence throughout the GSP implementation period. This is a reasonable margin of safety based on the past and current aquifer conditions (see Section 2.2.2.4).

3.4.5.4 Path to Achieve Measurable Objectives

Land subsidence in the Basin will be quantitatively measured by use of InSAR data (DWR-funded TRE ALTAMIRA or other similar data products). If there are areas of concern for inelastic subsidence in the Basin (i.e., exceedance of minimal thresholds) observed in the InSAR data, then ground-truthing studies could be conducted to determine if the signal is potentially related to changes in land use or agricultural practices, or from groundwater extraction. If subsidence is determined to result from groundwater extraction, then ground-based elevation surveys might be needed to monitor the situation more closely. At each interim milestone, subsidence data will be reviewed for yearly and five-year subsidence rates to assess continued compliance with the minimum threshold.

3.4.5.5 Relationship to Other Sustainability Indicators

Managing groundwater pumping and avoiding the undesirable result of chronic lowering of groundwater levels will reduce the risk of land subsidence. Additionally, land subsidence directly causes a reduction in groundwater storage.

List of Appendices

Appendix 3-A Data Gap Assessment

Appendix 3-B Monitoring and Measurement Protocols

Appendix 3-C Water Level Sustainability Management Criteria (In progress)

Appendix 3-D Interconnected Surface Water Sustainability Management Criteria (In progress)

References

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