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Sustainably Managing Groundwater - Surface Water Interactions within the Santa Rosa Plain Basin

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This Master's Project

SUSTAINABLY MANAGING GROUNDWATER-SURFACE WATER INTERACTIONS WITHIN THE SANTA ROSA PLAIN BASIN

by

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Acronyms

CASGEM	California Statewide Groundwater Elevation Monitoring
CEQA	California Environmental Quality Act
CTM	Contaminant Transport Model
DWR	Department of Water Resources
EPA	Environmental Protection Agency
GDE	Groundwater Dependent Ecosystem
GIS	Geospatial Information System
GSA	Groundwater Sustainability Agency
GSFLOW	Groundwater-Surface Water Flow Model
GSP	Groundwater Sustainability Plan
HCM	Hydrologic Conceptual Model
IHM	Integrated Hydrologic Model
NDVI	Normalized Difference Vegetation Index
NDWI	Normalized Difference Water Index
SGMA	Sustainable Groundwater Management Act
SRPB	Santa Rosa Plain Basin
SWRCB	State Water Resource Control Board
USGS	United States Geological Survey

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Definitions

Cone of depression: The area around the borehole of a well where a cone shaped depression in the water table occurs due to the groundwater being pumped.

Confined aquifer: An aquifer that is confined by a rock layer that is impermeable.

Discharge: The removal of groundwater from the subsurface aquifer. There are both natural causes for discharge which occurs when groundwater interacts with surface water and human caused discharge from pumping.

Groundwater: The water found in the cracks and spaces between grains of soil, sand and rock. It is stored in geologic formations known as aquifers.

Groundwater Levels: The distance of the water table to the surface.

Groundwater Storage: The overall volume of water storage available within an aquifer.

Interconnected surface water: Surface water that is connected hydraulically at any point by a continuous saturated zone to the groundwater aquifer.

Overdraft: This occurs when the amount of groundwater discharged from an aquifer exceeds the amount that is recharged which can lead to the lowering of groundwater levels.

Phreatic zone: Also known as the zone of saturation, this is the area of the aquifer where all the pores and open spaces are filled with water.

Recharge: The addition of water from the surface into the subsurface aquifer.

Stakeholder: A person or group that has specific interest in or can be directly affected by groundwater regulation

Streambed Conductivity: Measure of the ability of the streambed to transmit water into the underlying groundwater subsurface.

Unconfined aquifer: An aquifer that has the water table as the upper boundary and is directly recharged from the surface.

Undesirable results: These six results are used by the Sustainable Groundwater Management Act to help determine if a basin is being managed sustainably. The basin must be managed in a way to avoid: land subsidence, lowering of the groundwater levels, decreasing of groundwater storage, depletion of interconnected surface waters, seawater intrusion and degradation of water quality.

Vadose zone: Also known as the unsaturated zone, this is the area that is between the surface of the ground and the phreatic zone.

Abstract

In this paper, I designed a strategy for implementation of sustainably managing groundwater-surface water interactions in the Santa Rosa Plain Basin in compliance with the requirements set forth by the Sustainable Groundwater Management Act of 2014. The research objectives for this analysis are: (1) to fully examine the requirements of the Sustainable Groundwater Management Act and the implications that implementation will have on the Santa Rosa Plain Basin, (2) to use technical data gathered regionally coupled with related policy design theory to analyze how groundwater and surface water interactions can be managed to meet the requirements set forth in this landmark bill, and (3) to make recommendations to overcome these challenges and aid in the implementation process. To fulfil the objectives of this research, I conducted a comprehensive literature review and synthesized the information gathered from these materials. Additionally, I participated in a mentoring program with two professionals that work directly with groundwater management for the Santa Rosa Plain Basin. I also attended multiple meetings conducted by the Groundwater Sustainability Agency for the Santa Rosa Plain Basin. Based on this assessment, I have been able to compile recommendations for minimum thresholds, triggers and methods for identifying potential monitoring locations to supplement the existing monitoring program. It is my hope that this document will provide guidance in developing a plan to sustainably management groundwater-surface interactions within the Santa Rosa Plain Basin.

1. Introduction

Humanity must manage groundwater resources sustainably to preserve this vital resource as it serves as a primary water supply source in many places around the world. Groundwater is the most valuable natural resource available on the planet and is the most extracted raw material in the world with estimated withdrawal rates currently at 982 km3/year (Environmental Protection, 2016). Only three percent of all of Earth's water sources is freshwater and approximately seventy percent of this freshwater is not available for use as it is frozen in glaciers and ice caps. The remaining ninety-seven percent of Earth's total water is found in the oceans and is too saline for consumption unless processed using extremely expensive desalination techniques. The USGS estimates that groundwater makes up ninety-nine percent of all the usable freshwater in the world (Perlman, 2008).

Dependence on groundwater is escalating as populations increase and climate change reduces the availability of other sources such as surface water. Humans mainly use groundwater for irrigation purposes and to supply drinking water to both urban and rural communities. The drinking water supply for half of the global population is provided by groundwater resources and more than forty percent of water used for agricultural purposes are from groundwater sources (Kiparsky et al., 2017). The Unites States depends on groundwater for about twenty-three percent of the overall freshwater usage per year (U.S. Geological Survey, 2018). The importance of sustainable groundwater management is increasing as the implications of global climate change are experienced firsthand. Groundwater resource managers are being faced with questions of how to overcome obstacles caused by ground water storage, streamflow reduction, potential loss of ground water-dependent ecosystems, land subsidence, saltwater intrusion, and impacts to ground water quality (USDS and Forest Service, 2007).

In the United States, water management laws have historically been state based and water related challenges have been resolved locally. Despite decades of dealing with water crises caused by extensive periods of drought, California was without a comprehensive groundwater management policy until recently. On September 16, 2014 when Governor Brown enacted the Sustainable Groundwater Management Act referred to as SGMA. Upon the signing of SGMA, Governor Brown affirmed the national trend by stating that "groundwater management in California is best accomplished locally" (Leginfo.legislature.ca.gov, 2018). This three-bill California legislative package was enacted after a 7-year long drought when the state relied on groundwater resources for approximately sixty percent of their freshwater needs.

The Sustainable Groundwater Management Act requires that local agencies who manage groundwater resources within all medium or high priority basins create Groundwater Sustainability Agencies by July 1, 2017. These GSAs must create and implement Groundwater Sustainability Plans by 2020 or 2022 and must achieve sustainability twenty years after the adoption of the GSP by avoiding six undesired outcomes described in SGMA. GSAs will need to analyze each of the six undesired outcomes to determine obstacles to achieving sustainability within their basin.

The Santa Rosa Plain Basin (SRPB) is located within Sonoma County, California and "is a distinctive, ecologically and economically important hydrologic area of Northern California" (Santa Rosa Plain Advisory Panel, 2014). Previous studies have demonstrated that between the years of 1976 and 2010 there has been an average overdraft of groundwater within the overall watershed of approximately 4% or 3,300-acre feet (Santa Rosa Plain Groundwater Management Program, 2014). In most ecosystems, groundwater is interconnected with surface water and long-term overdraft critically impacts groundwater levels and lead to the depletion of interconnected surface waters. The depletion of interconnected surface waters, which is defined as an undesired outcome under SGMA, is one of the most significant obstacles for the Santa Rosa Plain Basin in achieving sustainability goals.

The Sustainability Groundwater Management Acts states:

"The minimum threshold for depletions of interconnected surface water shall be the rate or volume of surface water depletions caused by groundwater use that has adverse impacts on beneficial uses of the surface water and may lead to undesirable results."

Since SGMA is a new statewide regulation, there is minimum precedence to set an example of how to structure the GSAs and GSPs.

2. Purpose and Objectives

In this paper, I examine how groundwater and surface water interactions can be managed to meet SGMA sustainability requirements for the Santa Rosa Plain Basin. Three objectives of my paper are (1) to fully examine the requirements of the Sustainable Groundwater Management Act and the implications that implementation will have on the Santa Rosa Plain Basin. I will also: (2) use technical data gathered regionally coupled with related policy design theory to analyze how groundwater and surface water interactions can be managed to meet the requirements set forth in this landmark bill as well as (3) make recommendations to overcome these challenges and aid in the implementation process.

3. Methods

3.1 Literature Review

To fulfil the objectives of this research, I conducted a literature review and synthesized the information gathered. Most of the resources for the research consisted of documents compiled by the government agencies required to assist in the implementation and enforcement of the law, including The Department of Water Resources, the State Water Resources Control Board and the Santa Rosa Plain Basin Groundwater Sustainability Agency. Other important resources were gathered from policy design theory organizations that developed procedures to assist GSAs in GSP development and implementation, such groups include: CalEPA, the federal EPA, The Union of Concerned Scientists and The Pacific Institute. Technical data were collected from studies conducted by the USGS to provide necessary statistics and information for basin characterization.

Additionally, I used a myriad of peer reviewed articles to provide supplementary data, research and policy design recommendations relevant to the topic. Lastly, I used three specific guides to assist in the structure development for this analysis:

- *A Quick Guide to the Developing Watershed Plans to Restore and Protect Our Waters*
- *Best Management Practices for Sustainable Management of Groundwater*
- *Groundwater Dependent Ecosystems under the Sustainable Groundwater Management Act*

In *A Quick Guide to the Developing Watershed Plans to Restore and Protect Our Waters,* the EPA recommends that resource managers use nine elements within six overarching steps to develop watershed plans. I have modified these elements and applied the EPA's recommended framework to create a guideline for resource managers to develop plans that meet the criteria for sustainably managing groundwater-surface water interactions within a basin.

The six steps include:

- Building Partnerships
- Characterizing the Basin
- Finalize Goals and Identify Solutions
- Design the Management Plan
- Implement the Management Plan
- Measure Progress and Adjust

These six steps will be used as a framework to answer the following questions:

How can groundwater and surface water interactions be managed to meet sustainability requirements for the Santa Rosa Plain Basin?

<u>Step One: Building Partnerships</u>

- Identify stakeholders within the SRPB
- Discuss the structure of collaboration between GSAs in adjacent basins
- Analyze the structure of the SRPB GSA
- Identify existing state or federal laws intersect with SGMA requirements for managing groundwater and surface water interconnections

<u>Step Two: Characterize the Basin</u>

- Analyze the physical characterization for the basin
- Analyze the groundwater use, budget and groundwater-surface water interactions within the SRPB
- Identify existing management plans and potential data gaps

Step Three: Finalize Goals and Identify Solutions

- Identify inputs, outputs and outcomes
- Analyze indicators and targets to recommend minimum thresholds and triggers

Step Four: Design the Management Plan

- Identify a potential plan outline and implementation schedule
- Identify components of a successful monitoring program
- Analyze current monitoring plan and recommended actions
- Characterize available technology and monitoring tools
- Analyze measurable objectives and milestones

Step Five: Implement the Management Plan

- Implement the plan
- Implement the monitoring plan and gather results

Step Six: Measure Progress and Adjust

- Determine success of the plan
- Modify plan as necessary
- Communicate results with stakeholders

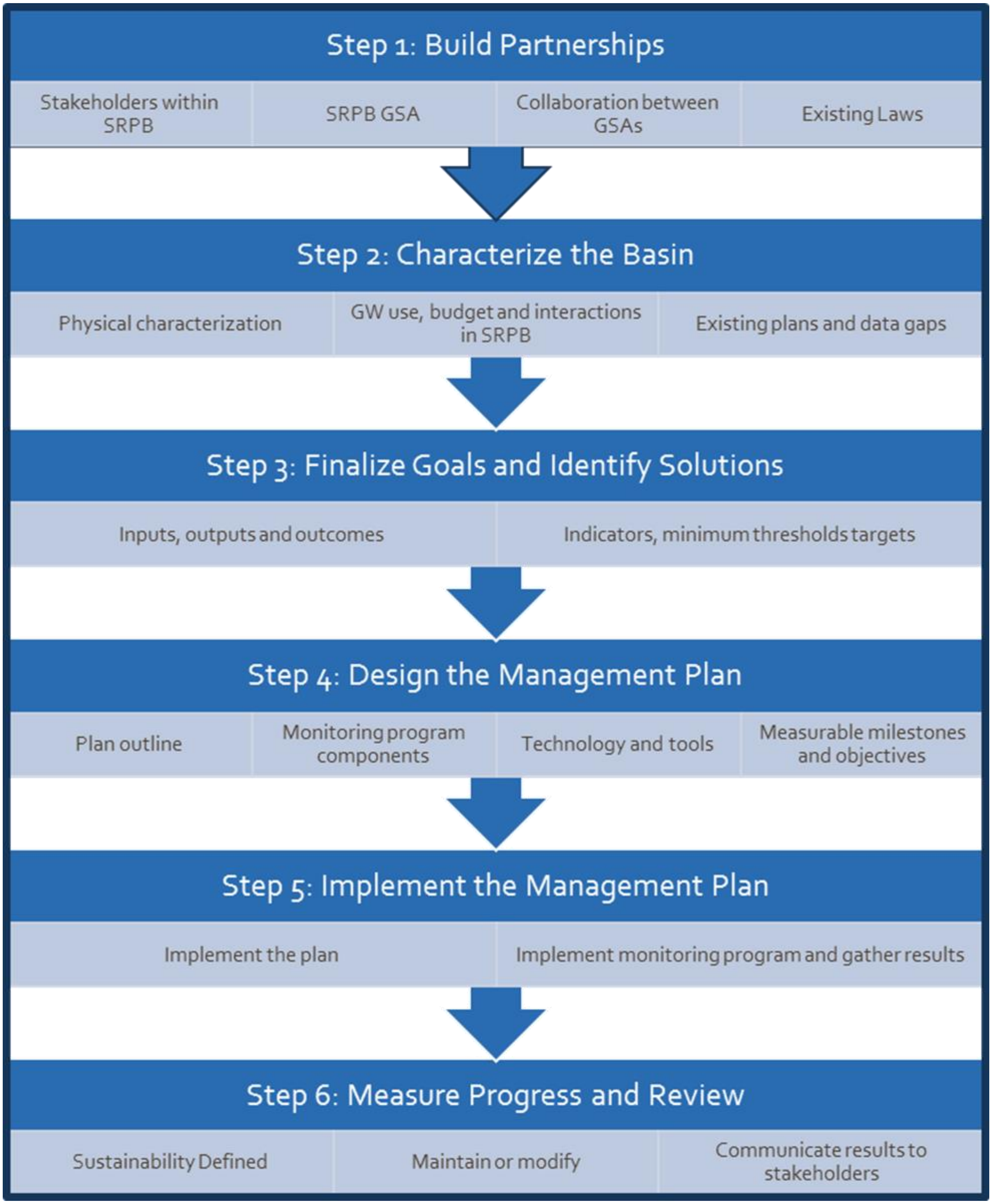

Figure 1 Recommended Steps for Sustainably Managing Groundwater-Surface Water Interactions within the Santa Rosa Plain Basin

3.2 Mentoring and Discussion

As an employee of the City of Santa Rosa, I was able to participate in a mentoring program with two of my colleagues that work directly with groundwater resources for the SRPB. One of my mentors, Jennifer Burke, is the Deputy Director of Water Resources and the representative for Santa Rosa on the Advisory Committee for the SRPB GSA. I also have been mentored by Colin Close, Senor Water Resources Planner for Santa Rosa Water. Mentoring from these individuals has provided me with an opportunity to learn about how the Sustainable Groundwater Management Act is being implemented within the Santa Rosa Plain Basin. This also allowed me to gain direct knowledge of the potential challenges in achieving the goal of sustainability and to ask questions as they arose.

3.3 GSA Meeting Attendance

The Board of Directors for the Santa Rosa Plain Basin Groundwater Sustainability Agency meets once a month and the Advisory Committee meets every other month and these meetings are often hosted at the City of Santa Rosa's Utility Field Office. I attended three of these meetings which enabled me to attend meetings and observe the process and discussion. An agenda and supplementary documents were made available for the audiences of the meetings. This information was pertinent to the basin and I used it for this analysis. Attending these meetings allowed me to gain insight into the current circumstances for the basin including potential challenges, stakeholder concerns and responses as well as next steps.

4. Background

General Groundwater Concepts

Freshwater that percolates from the surface through the open spaces of soil, sand and rock found in the vadose zone enters aquifers within the phreatic zone and becomes groundwater. The vadose zone, also known as the unsaturated zone, exists between the ground surface and the water table while the phreatic, or saturated zone, is found beneath the water table. Unconfined and confined aquifers can occur within the phreatic zone to store groundwater.

Confined aquifers have layers of impermeable rock that prevents water from the vadose zone from seeping from the surface directly into the aquifer. Alternatively, unconfined aquifers have a connection between the surface and the water table and are not obstructed by these impermeable layers. The defining physical characteristics of unconfined aquifers allow for increased recharge potential Groundwater can be recharged by both natural or artificial methods. Natural recharge occurs from either freshwater that percolates through the vadose zone or from water that is gained from surface water interactions. The most common methods of artificial recharge are unintended seepage from constructed ponds or injection wells which use high pressure pumps to inject water into aquifers. As with recharge, groundwater can be discharged from both natural and artificial means. The most common natural method of groundwater discharge is losing water through interconnected surface water streambeds. The most common artificial method for groundwater discharge is extraction for human use.

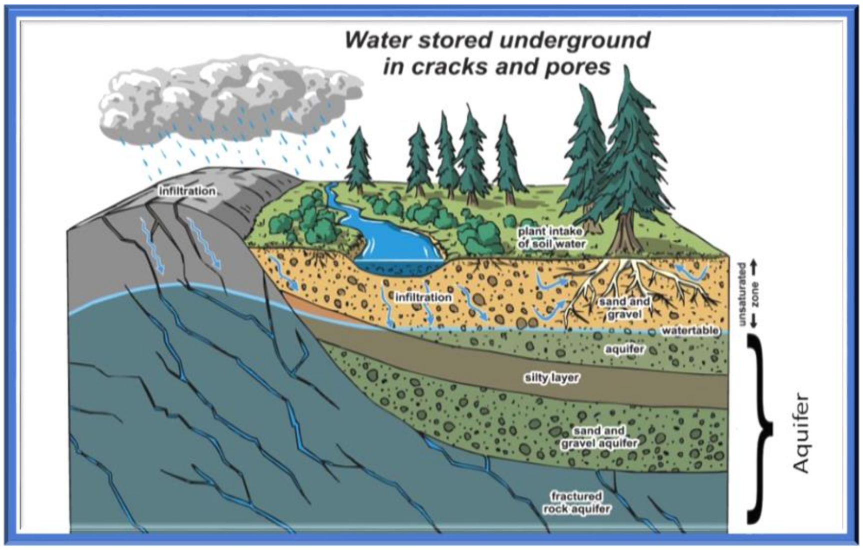

Figure 2 Groundwater Recharge (Gado, 2018)

4.1 Groundwater in California

California experiences a Mediterranean climate with wet, cool winters and hot, dry summers. This climate has varying annual precipitation and periods of extended drought. During these dry periods, California relies heavily on groundwater as a resource especially when surface water is limited. Under normal conditions, groundwater can supply as much as 38 percent of the water supply for the state. This can increase to as much as 60 percent during times of drought (UC Davis, 2014). Many rural and urban cities rely on groundwater for their drinking water supply; some even rely entirely on groundwater as a drinking water source. More than any other state, California relies on groundwater and overdrafts as much as 1.4 million-acre feet per year (Little Hoover Commission, 2010). California was the last State in the nation to adopt a statewide system for groundwater regulation despite its great reliance on groundwater. (Leahy, 2018).

Historically, California water law has viewed groundwater as separate from surface water. SGMA is California's first statewide groundwater regulation and—the first law to require that GSAs consider the impacts that groundwater pumping has on water supply, surface water and beneficial users. Interconnected surface water is defined by SGMA as "surface water that is hydraulically connected at any point by a continuous saturated zone to the underlying aquifer and the overlying surface water is not completely depleted" (Berkeley Law, 2018).

Unfortunately, very little data exists to about the connectivity between groundwater and surface water systems since they were previously viewed as separate systems.

4.2 Understanding the Relationship between Groundwater and Surface Water Interactions

Groundwater and surface water systems frequently interact in one of three ways: gaining, losing or a combination of both. These types of interactions are defined by whether surface water systems gain water from groundwater sources, lose water to groundwater sources or a combination of both gaining and losing. The relationship that develops between these systems is largely dependent on the elevation of the water table relative to the elevation of a surface water body such as a stream (Berkeley Law, 2018).

If the groundwater elevation is higher than the elevation of the stream surface, then groundwater will flow into the surface water system. Alternatively, if the stream surface is higher elevation than the groundwater elevation then the stream will lose water to the groundwater system. Gaining streams can be dependent on groundwater systems to help support streamflow especially during dry weather conditions while losing streams can be an essential source of groundwater recharge. Streams can both gain and lose water along its course their length or if there are changes over time in hydrology, underlying geology, local climate or streamflow conditions (Santa Rosa Plain Groundwater Sustainability Agency, 2018). If the interaction between the surface water and groundwater systems are disrupted for an extended period, then the two systems can become disconnected. A disconnected stream is generally separated from the groundwater system by an unsaturated zone; however, disconnected streams can still lose water to the groundwater system through seepage into the unsaturated zone.

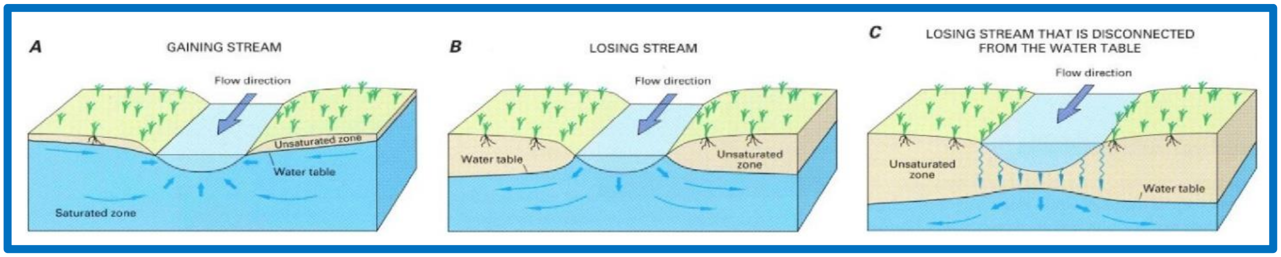

Figure 3 Examples of Groundwater-Surface Water Interactions (SRPB GSA, 2018)

5. Sustainably Managing Surface Water and Groundwater Interactions

5.1 Sustainable Groundwater Management Act

Overdraft caused by groundwater pumping results in surface water depletion for seventy-five percent of California's rivers and streams (The Nature Conservancy, 2016). Surface water provides much needed replenishment of groundwater resources and habitat for groundwater dependent ecosystems. Groundwater dependent ecosystems are defined by SGMA as ecological communities of species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface. Groundwater managers must abide by the requirements set forth in SGMA to ensure that the groundwater-surface water interactions are managed sustainably within the Santa Rosa Plain Basin to protect groundwater dependent ecosystems as well as groundwater and surface water resources. The Sustainable Groundwater Management Act (SGMA) was signed into law on September 16, 2014 by Governor Jerry Brown. SGMA is a bundle of three separate bills that provide the framework for statewide groundwater management- SB 1168, AB 1739 and SB 1319. These combined bills mandate local agencies to adopt sustainability management plans that implement required statewide standards to protect groundwater levels and storage, groundwater quality, and surface water-groundwater interactions (League of California Cities, 2014). Sustainable groundwater management as defined by SGMA is the 50-year planning for the management and use of groundwater without causing undesirable results" (Kiparsky et al., 2017). SGMA outlines six undesirable results that must be avoided to achieve sustainable groundwater management. In addition, SMGA established specific requirements for notifying and engaging tribal communities and stakeholders. The baseline for

SGMA is January 1, 2015—this means that GSAs are not required to address impacts on groundwater surface water interactions that occurred prior to this date. They will still need to abide by intersecting laws related to these impacts.

Table 1 SGMA Requirement Deadlines (Aquilogic Inc., 2014)

Jan 2015	• **Basin prioritization:** DWR assigned each basin a level of very low, low, medium or high priority based on CASGEM data.
Nov 2015	• **Basins in critical condition of overdraft:** DWR identified which basins should have expedited timelines due to experiencing critical overdraft conditions.
Jan 2016	• **Basin boundary regulations:** DWR adopted regulations for basin boundary adjustments.
June 2016	• **GSP regulations and alternatives to GSPs:** DWR adopted regulated structure for groundwater sustainability plans and coordinations agreements for groundwater sustainability agencies.
Dec 2016	• **Water available for groundwater replacement:** Completed and reported study to determine how much water is available for replenishment.
Jan 2017	• **Bulletin 118 interim update and best management practices:** DWR had the responsibility to update Bulletin 118 and prepare a list of best managment practices.
2020	• **Review GSPs and complete comprehensive update for Bulletin 118:** DWR must review the submitted GSPs every five years. The agency must also complete a comprehensive update for Bulletin 118.

Senate Bill 1168 (2014): Introduced by Fran Pavley, this bill applies the California Constitution requirements that states that "any use of water must be both reasonable and beneficial" (Wilson, 2011) to groundwater by directing that "groundwater resources be managed sustainably for long-term reliability and multiple economic, social, and environmental benefits for current and future beneficial uses" (State of California, 2014). Senate bill 1168 requires that all basins deemed as medium or high priority relative to critical overdraft conditions by the California Statewide Groundwater Elevation Monitoring Program (CASGEM) are managed by a Groundwater Sustainability Plan (GSP) by January 31, 2020. Basins that have a medium or high prioritization without being impacted by overdraft conditions must be managed by a GSP by January 31, 2022. This bill doesn't apply to basins that are adjudicated and managed by courts or that have been given very low or low prioritization by CASGEM. If a basin has produced a voluntary GSP then the plan must be updated to meet the requirements of SB 1168. Local agencies are required to form groundwater sustainability agencies no later than June 30, 2017. The local agency that is managing the basin can petition to be the groundwater sustainability agency (GSA) or collaborate with regional agencies to form a GSA which will develop and implement the GSP. The GSP has a 20-year implementation horizon (Association of California Water Agencies, 2014) with the potential for an agency to apply for two five-year extensions if the agency is progressing toward sustainability. Senate Bill 1168 grants the GSAs authority to require that groundwater extraction facilities register and use meters to measure extraction which can be used to establish limitations. Under this bill, GSAs also can conduct inspections of groundwater extraction facilities.

Figure 4 Relationship Between Agencies and Stakeholders (California State Water Resources Control Board, 2016)

Assembly Bill 1739 (2014): Roger Dickinson introduced Assembly Bill 1739 which required the DWR to review the proposed GSPs to ensure that they meet the requirements set forth in SB 1168 and complete multiple tasks based on the timeline below.

Additionally, AB 1739 would allow the State Water Control Board to designate a basin as a probationary basin (State of California, 2014) and to develop an interim GSP on behalf of the basin if it is determined that the local agency has not remedied a deficiency (State of California, 2014) that influenced the original determination. If it is determined that a basin be classified as probationary, then the local agency would concede management authority to the state.

Senate Bill 1319 (2014): Senate Bill 1319 is another bill introduced by Fran Pavley that requires local agencies to adopt and implement a groundwater management plans (State of California, 2014). The plan must contain specific components that meet state defined sustainability objectives tailored for the basin within the SGMA timeframe. As dictated by this bill, a managing agency would only be able to seek state funding for groundwater projects if an acceptable plan is established and approved.

Table 2 Responsible Agencies for SGMA (East Bay Municipal Utility District, 2018)

Deadline	Action	Responsible Agency
1/1/2015	Prioritize Basins using CASGEM	DWR
1/1/2016	Develop emergency regulations for basin boundary revisions	DWR
6/1/2016	Develop emergnecy regulations for evaluating GSPs	DWR
12/31/2016	Estimate water available from groundwater replenshment	DWR
1/1/2017	Develop best management practices for sustainability	DWR
1/1/2017	Submit alternative to GSP	GSA
6/30/2017	Deadline for GSA Formation	GSA
6/30/2017	SWRCB can put basins on type 1 probation	SWRCB
7/1/2017	Outside management areas must report extraction data	GSA
1/1/2018	Develop interim GSPs for basins on type 1 probation	SWRCB
1/31/2020	High and medium priority basins with critical overdraft managed	GSA
1/31/2020	SWRCB can put basins on type 2 or 3 probation	SWRCB
7/31/2020	Develop interim GSPs for basins on type 2 probation	SWRCB
1/31/2021	Develop interim GSPs for basins on type 3 probation	SWRCB
1/31/2022	SWRCB can put basins on type 4 or 5 probation	SWRCB
1/31/2022	Develop interim GSPs for basins on type 4 or 5 probation	SWRCB
1/31/2022	Evaluate all GSPs submitted by 1/31/2020	DWR
1/31/2022	All high and medium priority basins managed	GSA
1/31/2024	Evaluate all GSPs submitted by 1/31/2022	DWR
1/31/2025	SWRCB can put basins on type 6 probation	SWRCB
1/31/2025	Develop interim GSPs for basins on type 6 probation	SWRCB
1/31/2040	Basins managed by 1/31/20 achieve sustainability	GSA
1/31/2042	Basins managed by 1/31/22 achieve sustainability	GSA
1/31/2045	Basins managed by 1/31/20 with one extension achieve sustainability	GSA
1/31/2047	Basins managed by 1/31/22 with one extension achieve sustainability	GSA
1/31/2050	Basins managed by 1/31/20 with two extensions achieve sustainability	GSA
1/31/2052	Basins managed by 1/31/22 with two extensions achieve sustainability	GSA

<u>State Water Resources Control Board:</u> The SWRCB is the enforcement agency that is authorized to intervene if the local agency that manages a basin does not comply with the SGMA requirements. Basins that were not represented by a GSA by July 1, 2017 were considered unmanaged areas. Failure to form a GSA or to develop and implement a sufficient sustainability plan warrant a probationary designation for the basin which triggers intervention of the state on behalf of the basin. If a basin is designated as probationary, the SWRCB is authorized to directly manage the groundwater extractions in the basin. Anyone that extracts groundwater from an unmanaged area or probationary basin is required to file an annual groundwater extraction report (Department of Water Resources, 2016) and pay the associated administrative fees.

Local agencies that do not comply will have an opportunity to rectify the probationary designation; however, if they do not comply— the SWRCB has the authority to develop an interim sustainability plan for the basin. This plan must include corrective actions, a timeline for the basin to be deemed sustainable, and a monitoring plan to ensure corrective actions are working (Department of Water Resources, 2016).

Table 3 Deadlines that Initiate State Intervention (California State Water Resources Control Board, 2016)

Date	Event
July 2017	Entire basin is not covered by GSA(s) or Alternative
Feb. 2020	Basin is in critical overdraft and there is no plan or DWR fails plan
Feb. 2022	No plan or DWR fails plan and basin is in long-term overdraft
Feb. 2025	DWR fails plan and basin has significant surface water depletions

5.2 Groundwater Sustainability Plans

Groundwater Sustainability Agencies are required under California Water Code Section 10727.2(b)(2) to develop, implement and manage Groundwater Sustainability Plans. The plan, which must be developed by 2020 or 2022 depending on basin prioritization, will include a vision of future land and water use that preserves groundwater quantity and quality for each community (Union of Concerned Scientists, 2018). The plan is required to include a physical description of the basin and measurable objectives to achieve sustainability in the 20-year timeframe in the basin (Water Foundation Education, 2014). Each GSA is authorized to define sustainability as it relates to their basin; however, this definition cannot threaten other basins' ability to achieve their sustainability goals (Union of Concerned Scientists, 2018). The plan must include a plan area and description. According to California Water Code (Water Code) §10727.2(b)(4), the plan must include the following criteria: groundwater elevation data, groundwater extraction data, surface water supply, total water use, change in groundwater storage, water budget and sustainable yield. The plan must also include sustainability goals with measurable objectives that lays out a path for avoiding the six undesirable results. Projects and management actions that GSA plans utilize to achieve its goals must be outlined within the GSP. Lastly, the plan must also include a monitoring plan to measure the process of the objectives. Although measurable objectives are required to be included in the GSP, the law does not define the objectives or how they should be evaluated over time (Christian-Smith, J. et al., 2015) The legislation allows the local agency to define this criterion specific to the basin if the objectives avoid the six undesirable results specified in SGMA. The GSA will be permitted to establish a basin specific water budget and monitoring system if the plan is working towards sustainability goals. The GSA must file a notice of intent with DWR prior to the development of the plan. After development, the GSA must notify the public and allow a comment period of 90 days prior to adoption. Once adopted, the plan must be submitted to DWR for evaluation and approval. GSAs will have to submit annual reports documenting their progress to the DWR.

5.3 Six Undesired Results

The Sustainable Groundwater Management Act details six undesired outcomes that all plans must work to avoid significant and unreasonable effects of within each basin: lowered Groundwater Levels, reduction of Groundwater Storage, seawater Intrusion, water Quality Degradation, land Subsidence and the depletion of interconnected Streams.

Lowered Groundwater Levels: Depletion of groundwater levels is the root cause of the other undesired results. This can lead to the lowering of the groundwater table which would increase the chances that well owners will need to drill new, deeper wells. Deeper wells are costlier as they often need to use pumps to lift the water to the surface. Deeper wells impact more shallow wells by drying them up which can be either caused by lowered groundwater levels and larger cones of depression.

Reduction of Groundwater Storage: During times of drought, California relies on groundwater for approximately 60% of the needed water supply. If there is less groundwater being stored, then there will be less to use during years of drought.

Seawater Intrusion: Seawater is denser than fresh water due to the dissolved salts which increases the weight. Freshwater floats on top of seawater in the water table since it is less dense. When fresh groundwater is depleted, the seawater rises to the surface of the water table contaminating water supply used for drinking and agricultural purposes.

Water Quality Degradation: Groundwater overdraft can impact water quality due to the exchange of fluids and solutes that take place during the process. Other factors that can contribute to the degradation of water quality for a basin is the "natural geology and local aquifer conditions, human activities related to land use and well construction and operation" (California Water Science Center, 2017).

Land Subsidence: Land subsidence can be caused by the chronic overdraft of groundwater within a basin and this loss of land is often irreversible (Union of Concerned Scientists, 2018). The abrupt sinking of the land causes costly destruction to both subsurface and surface infrastructures.

Depletion of Interconnected Streams: Surface water and groundwater commonly interact and rely on each other. Depending on the elevation difference between the surface water and groundwater—lakes and streams can lose water to the groundwater table, gain water from the table or do a combination of both types of interactions. This undesirable result is the greatest obstacle for the Santa Rosa Plain Basin and requires the development and implementation of a management plan to achieve sustainability goals.

Sustainability Indicators	Lowering GW Levels	Reduction of Storage	Seawater Intrusion	Degraded Quality	Land Subsidence	Surface Water Depletion
Metric(s) Defined in GSP Regulations	• Groundwater Elevation	• Total Volume	• Chloride concentration isocontour	• Migration of Plumes • Number of supply wells • Volume • Location of isocontour	• Rate and Extent of Land Subsidence	• Volume or rate of surface water depletion

Figure 5. Six Undesired Results (California State Water Resources Control Board, 2016)

6. Developing and Implementing a Management Plan

The following guideline has been prepared using the EPA's recommended six steps to develop watershed plans as a framework. This guideline, based on the Santa Rosa Plain Basin, is intended to provide resource managers a pathway to achieving the goal of sustainably managing groundwater and surface water interactions while meeting the requirements set forth in SGMA.

6.1 Step One: Building Partnerships

The enactment of SGMA has created an opportunity for GSAs to resolve the longstanding conflict between groundwater users and surface water users. GSAs must navigate the conflicting interests of stakeholders by developing a GSP that meets the various needs of all users without sacrificing the goal of sustainability. Building partnerships with stakeholders early in the decision-making process will reduce conflict and establish support for the program. SGMA requires that the GSA maintains communicate with all partners and stakeholders in timely, straight forward and consistent manner (Department of Water Resources, 2018). SGMA also requires that a list of stakeholders be prepared and submitted to the DWR. This list of stakeholders must be notified before the GSA is formed, before the GSP is adopted or amended and before fees are imposed or increased. For stakeholder engagement to be successful, the GSA will need to develop a communication plan that educates water users about the requirements of SGMA and the different roles that agencies will play in the implementation, regulation and enforcement of the law. According to *Collaborating for Success: Stakeholder Engagement for Sustainable Groundwater Management Act Implementation*, the following components are essential to any successful communication plan:

- Purpose of plan
- Project and communication schedule
- Stakeholder engagement opportunities
- Communication tools and information materials

The California Water Code Sec. 10723.2 requires that GSAs consider these users as stakeholders and engage them regularly:

- Holders of overlying groundwater rights, including agricultural users and domestic well owners
- Municipal well operators
- Public water systems
- Local land-use planning agencies
- Environmental users of groundwater
- Surface water users (when there is a connection between surface and groundwater bodies)
- The federal government
- California Native American Tribes
- Disadvantaged communities (including but not limited to those served by private domestic wells or state small systems)
- Entities monitoring and reporting groundwater elevations

Figure 6 SGMA Stakeholder Engagement Requirements (California Water Code Sec. 10723.2, 2014)

6.1.1 Stakeholders for the Santa Rosa Plain Basin

The Santa Rosa Plain Basin GSA has contracted with a consultation organization, Raftelis Financial Consultants, Inc., to identify stakeholders for the basin and to estimate usage. Ultimately, this data is being used to generate recommendations for rates and/or fees to facilitate in the fiscal solvency of the GSA; however, this data is also useful for the initial documentation of stakeholders for the basin. Raftelis Financial Consultants, Inc. determined that the groundwater uses for the basin are: agricultural, municipal, rural residential, urban residential, small water service providers and golf courses.

It is estimated that these stakeholders use approximately 22,517-acre feet of groundwater per year. This does not take into consideration groundwater dependent ecosystems or environmental specific groundwater interests. Including environmental interests and GDEs as stakeholders is essential for the sustainable management of groundwater and surface water interactions. Additionally, SGMA requires the "lawful, collaborative, and thorough evaluation of all areas of a basin" (Scott, 2015)

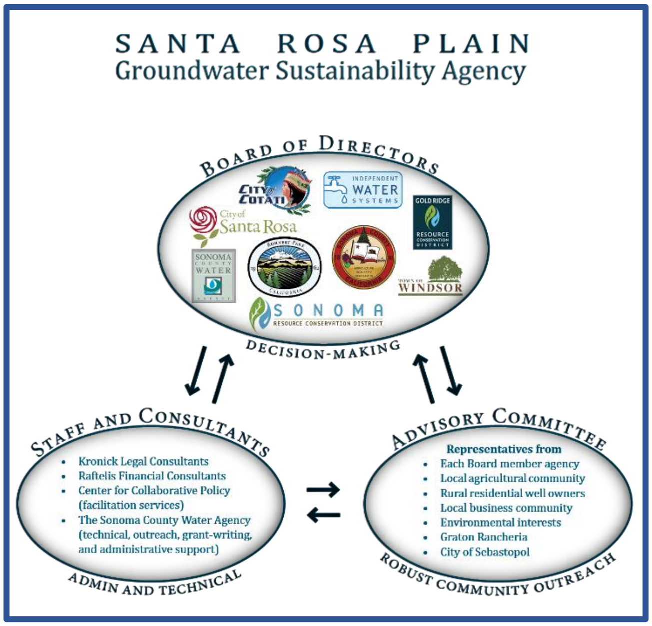

Figure 7 Structure for SRPB GSA (SRPB GSA, 2018)

which makes it critical that GSAs consider the needs of local Tribal interests as well. GSAs will also need to access tribal lands to obtain data to inform the development of the GSP.

6.1.2 Santa Rosa Plain Basin GSA

The first action that SGMA required local agencies to fulfil was the creation of one or more GSAs for each basin. This action was required to be completed by June 30, 2017. Any agency that didn't complete this action by the deadline was designated a probationary basin by the SWRCB. The GSA is the primary agency responsible for achieving groundwater sustainability (Water Foundation Education, 2014) and required to develop and implement a groundwater sustainability plan if managing a basin that was characterized as medium or high priority. The guidelines by which DWR will evaluate the GSPs were adopted on June 1, 2016. If the basin is experiencing critical conditions of overdraft, the deadline for GSP development is June 1, 2020; otherwise, the deadline is June 1, 2022. All neighboring GSAs must coordinate GSP efforts since each region will influence groundwater availability due to the mobile nature of groundwater. The structure of the GSA will impact their ability to develop an understanding of their physical groundwater system; set objectives; develop, implement, gain support for, and enforce policies; and adapt to changes as they arise (Kiparsky et al., 2017).

Initiated in 2017, the Santa Rosa Plain Basin GSA is comprised of three branches of membership: the Board of Directors, the Advisory Committee and Technical staff and consultants. The Board of Directors includes representatives from member agencies and independent water suppliers. The Advisory Committee consists of stakeholders with "diverse perspectives on beneficial groundwater use" (Santa Rosa Plain Basin GSA, 2018) which includes representatives from agriculture, the environmental community, local business, rural residential and public water districts. These participating agencies entered into a Joint Exercise of Powers Agreement which details the requirements for membership, initial funding, voting rights and other governance issues. Currently, the City of Sebastopol and the Graton Rancheria Tribe have elected not to have representation on the Board of Directors; however, both have appointed representatives in the Advisory Committee.

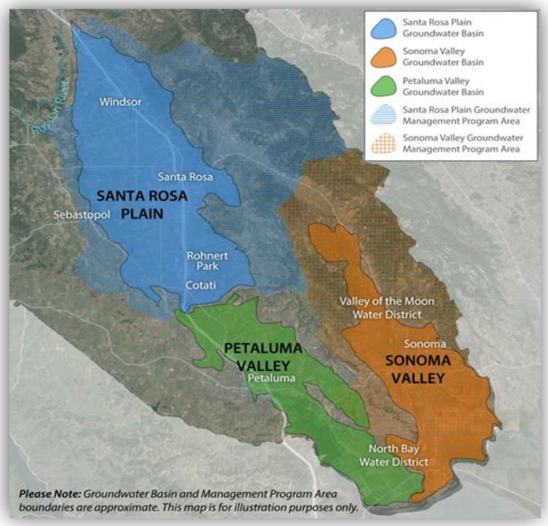

Figure 8 SRPB Boundary (SRPB GSA, 2018)

6.1.3 Collaboration Between Local GSAs

Groundwater is not a static resource—it travels between basins through underground conduits. This mobility makes it necessary for neighboring GSAs to communicate with each other to make more informed decisions for this shared resource. Additionally, charaterization data from neighboring GSAs provide a more indepth look at the hydrology of the area as a whole.

The Santa Rosa Plain Basin has two primary neighboring Basins: Sonoma Valley and Petaluma Valley. The project summary for the Santa Rosa Plain Basin specifies that “development of the GSP will be closely coordinated with neighboring GSAs in Petaluma and Sonoma Valleys” (Department of Water Resources, 2018) to share resources to “maximize efficiencies, including shared templates and methodologies for certain GSP components, outreach resources, grant opportunities, and the development of data management system tools and technologies” (California Department of Water Resources, 2018). In addition to collaborating with neighboring basins, GSAs need build partnerships with both state and federal agencies by being familiar with existing laws that intersect with SGMA in regard to groundwater and surface water interactions. According to the GSP project summary submitted to the Dept. of Water Resources, the process by which the sharing of resources will be facilitated by is fourfold: (1) each of the local agencies with land use responsibilities in the Basin are either members of the GSA and are represented on the GSA Board or serve on the GSA Advisory Committee; (2) several members of the Santa Rosa Plain GSA (County of Sonoma, Sonoma County Water Agency, and Sonoma Resource Conservation District) are also members and represented on the Boards of the two neighboring GSAs in Petaluma and Sonoma Valleys; (3) the Sonoma County Water Agency is providing technical, grant management and outreach services to all three GSAs in

Sonoma County through service agreements; and (4) administrators from each of three GSAs meet regularly with Water Agency staff to coordinate activities.

6.1.4 Existing State or Federal Laws Regarding Groundwater and Surface Water Interactions that Intersect with SGMA

To successfully implement the Sustainable Groundwater Management Act, GSAs must understand intersecting law, such as "relevant environmental laws and regulations, and instream flow requirements within the basin" (Berkeley Law, 2018) and how these laws relate to SGMA. This understanding could mitigate potential legal opposition to their groundwater sustainability plans and assist in the development of successful management strategies. The relevant intersecting laws are as follows:

Reasonable Use Doctrine: The Reasonable Use Doctrine states that "each owner has the right to make use of any water, provided that the use is reasonable in relation to the use of other riparian landowners" (US Legal, 2016). Groundwater use is also subjected to the authority of the Reasonable Use Doctrine. The State Resources Control Board has the authority to define reasonable use and "would do well to look at serious overdraft situations" (Brian, 2015) and use their authority to prohibit situations that increase the impacts of critical overdraft.

Figure 9. Laws that Intersect with SGMA (Berkeley Law, 2018)

Water Rights: Groundwater rights do not change with the implementation of SGMA. These rights will continue to be regulated by the Water Code 10720.5 of the California Constitution; however, as water budgets are created, and sustainable yields identified—user's withdrawals may be reduced to "bring a basin into balance" (Miliband, 2015) in order to achieve sustainability goals.

Regulatory Takings: There are three types of rights within a basin as defined by the California Supreme Court: overlier, appropriative and prescriptive. Water rights are considered to be property rights in California except the owners of these rights "hold no right to private ownership" (Green, 2016); however as stated by the Fifth Amendment of the U.S. Constitution “private property [shall not] be taken for public use, without just compensation” (Center for Progressive Reform, 2018). If a “pumping limit disproportionately forces a property owner to bear a burden that should be shared by the public” (Green, 2016) that owner may be able to levy a successful taking claim against the GSA and their sustainability plan.

Public Trust Doctrine: The Common Law Doctrine of the Public Trust secures the “public's right to use California's waterways for navigation, fishing, boating, natural habitat protection and other water-oriented activities” (State of California, 2015). The implications of these intersecting laws are illustrated in the recent case law: Environmental Law Foundation et al. v. State Water Resources Control Board. This case law determined that the public trust doctrine applies to groundwater resources and the permitting of extraction that impacts navigable water ways.

Endangered Species Act: Groundwater dependent ecosystems are communities of animal and plant life that depend on groundwater to meet either all or a portion of their water supply. Many of these species are considered endangered as defined by either the federal or state level Endangered Species Act. Groundwater dependent ecosystems are defined as beneficial users of groundwater and are required under SGMA to be considered during the development and implementation of GSPs (The Nature Conservancy, 2016).

California Environmental Quality Act: The development of groundwater sustainability plans is exempt from meeting CEQA requirements. However, implementation of the plan is subjected to the requirements of CEQA which includes the analyzing and mitigating potential negative impacts on interconnected surface waters (Berkeley Law, 2018).

Clean Water Act: The Clean Water Act directly relates to SGMA in such that it protects the interconnected surface waters of the U.S. which directly intersects with one of the undesired results defined in SGMA. The Clean Water Act also sets water quality standards which are addressed within SGMA.

__Porter-Cologne Water Quality Control Act:__ This act is the primary law that mandates water quality regulation in California. This act provides a framework for SGMA water quality standards which is relevant to groundwater-surface water interactions, including through effects on streamflow volume and temperature.

6.1.5 Identifying Issues of Concern and Developing Preliminary Goals

Once the stakeholders for the basin have been recognized and communication established—it is important that the stakeholders assist in identifying the critical issues of concern and overall goals for the basin. In terms of the groundwater-surface water interactions for the Santa Rosa Plain Basin, the overarching goal is to manage these interactions sustainably. A direct measurement of the success of this goal is not exceeding the established minimum threshold for groundwater or surface water depletion. An indirect measurement of the success of this threshold is examining the health of groundwater dependent ecosystems. It is important to set a baseline standard for groundwater and surface water levels as well as GDE health. Baseline standards provide a foundation for a successful management plan.

Preliminary goals for sustainably managing groundwater- surface water interactions in the Santa Rosa Plain Basin include:

- Define baseline standards
- Establish a monitoring system
- Set minimum thresholds
- Maintain fiscal solvency for the GSA
- Develop an educational component
- Identify milestones to measure success
- Identify and resolve data gaps
- Implement a successful management plan
- Reduced withdrawals
- Increased recharge

6.2 Step Two: Regional Basin Characterization

The characteristics of the basin provide the foundation for developing and implementing a strategy for sustainably managing groundwater-surface water interactions within the basin. It is important to gather data regarding the: physical and natural features, land use and population, groundwater use and budget, existing plans and management strategies, existing data and monitoring programs, data gaps and beneficial users and uses. This information can be used to create a data inventory for the basin to facilitate in the development of monitoring programs and identification of locations vulnerable to surface water loss due to interactions with groundwater.

6.2.1 Santa Rosa Plain Basin Characterization

The Santa Rosa Plain is located within Sonoma County in Northern California. This hydrologically important area is comprised of the cities of Windsor, Sebastopol, Santa Rosa, Rohnert Park, Cotati and unincorporated areas of Sonoma County which accounts for roughly half the population of Sonoma County.

The cities within this Basin rely heavily on the water resources of the Basin as a source of drinking water as well as other urban, agricultural, economic and environmental uses. This resource is expected to be increasingly stressed as changes in the future to water use, land use, population growth and climate change (Santa Rosa Plain Basin Groundwater Sustainability Agency, 2014) continue to impact the 78,720-acre Basin.

Boundary: The SRPB is approximately 22 miles long with a varying width of between 6 and 9miles. Located in the inland area of the North Coast Ranges and is bound by various series of hills and mountains. The boundary of the Santa Rosa Plain Basin is defined in the north by a series of low hills called the Mayacamas Mountains (Sonoma County Water Agency, 2010) to the south that form a drainage divide that separates the Santa Rosa Valley from the Petaluma Valley basin (State of California, 2003). The Basin is bordered by the Russian River floodplain and the Mendocino Range to the west and the Sonoma Mountains to the east.

Figure 10. SRPB Boundary (SRPB GSA, 2018)

Hydrogeology: The Santa Rosa Plain Basin has two groundwater sub-basins which vary from depths of 4,500 ft to 10,000 ft. The two sub-basins include four primary geologic units in the Santa Rosa Plain Basin which groundwater flows through to form the primary aquifers (Santa Rosa Plain Basin

Groundwater Sustainability Agency, 2014) for the region: the Wilson Grove Formation, the Petaluma Formation, the Sonoma Volcanics and the Glen Ellen Formation. The Wilson Grove Formation contains sandstone that extends beneath the basin from the western upland hills. The Petaluma Formation consists of shale and sandstone and extends beneath the basin from series if low hills in the south. The Sonoma Volcanics consists of a thick sequence of lava flows (Basin Conditions) that ranges along the Sonoma Mountains to the east of the basin. All these formations produce and store variable amounts of water for the basin through stream channels filled with alluvial sands and gravels (Santa Rosa Plain Basin Groundwater Sustainability Agency, 2014).

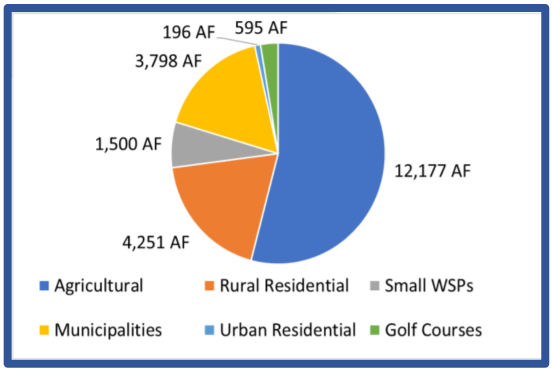

Figure 11. SRPB Water Use per Beneficial User (Raftelis Financial Consultants, Inc., 2018)

Climate: The Santa Rosa Plain Basin is located in the North Coast Ranges and has a Mediterranean climate with approximately ninety percent of the annual precipitation occurring in the winter months and periods of dryness in the summer. The precipitation, which is typically due to atmospheric rivers, occurs between October and April. The average annual rainfall for the SRPB for the last 100 years is approximately thirty-one inches; however, periods of lower than average rainfall per year are becoming increasingly common for the area.

Current Groundwater Use and Budget: The consultation group hired by the SRPB GSA, Raftelis Financial Consultants, Inc., estimates that 22,517-acre feet of groundwater is used in the basin per year. This water use estimation is approximately four thousand less than the estimate of 26,428-acre feet put forth by the Department of Water Resources. This usage is divided among the approximately 6,000 wells (Kovner, 2017) owned by the recognized groundwater users for the area—the totals of which can be seen in figure 11 above. These totals do not take environmental needs such as groundwater dependent ecosystems and habitats into account. Natural discharge, which includes groundwater lost to surface water, evapotranspiration and groundwater lost to boundary outflow also contributes to the annual use of groundwater sources. Previous studies have demonstrated that between the years of 1976 and 2010 there has been an average overdraft of groundwater within the overall watershed of approximately 4% or 3,300-acre feet (Santa Rosa Plain Groundwater Management Program, 2014). This reduction raises concerns about impacts to groundwater dependent ecosystems and habitats due to the loss support that groundwater provides for surface water.

<u>Groundwater-Surface Water Interactions in the Santa Rosa Plain Basin:</u> In addition to elevation, subsurface geology and streambed conductivity play an integral role in groundwater-surface water interactions. Both the vertical and horizontal hydraulic conductivity, also known as the coefficient of permeability, of a streambed is a variable used in determining the hydraulic connection between a stream and adjoining groundwater aquifers (Chen, 2000). Hydraulic conductivity is higher midstream and lower along the streambanks which means that midstream surface-waters have a higher probability of interacting with sub-surface groundwater aquifers. Monitoring groundwater-surface water interactions within the basin can help the GSA design a more comprehensive management plan.

According to the *Santa Rosa Plain Watershed Groundwater Management Plan*, the locations with the highest values of conductivity, or the highest potential for groundwater-surface water interactions, within the Santa Rosa Plain Basin occurs in the Mark West and Santa Rosa Creeks, in a section of the Laguna de Santa Rosa and in some of the smaller creeks at the eastern boundaries of the SRP (Santa Rosa Plain Basin Advisory Panel, 2014) (Figures 12 and 13). The Santa Rosa Creek is classified as both a gaining and losing stream. The Santa Rosa Creek is primarily a gaining stream just east of the Rodgers Creek fault zone and becomes a losing stream just west of the Rodgers Creek fault zone, and then becomes a gaining stream again several miles to the west (Santa Rosa Plain Basin Advisory Panel, 2014).

Using data gathered from the groundwater and surface-water flow model (GSFLOW), the *Simulation of Groundwater and Surface-Water Resources of the Santa Rosa Plain Watershed, Sonoma County, California*, determined that the main point of surface-water outflow from the SRPW is where Mark West Creek exits the watershed. There are nine other documented surface-water outflow locations within the watershed. Within the Santa Rosa Plain Basin, the lowest values of conductivity for interactions have been found in Windsor, Santa Rosa and Cotati; however, according to the *Santa Rosa Plain Watershed Groundwater Management Plan*, the overall trend for the watershed is that more surface water is lost to groundwater than is gained by groundwater flowing into streams.

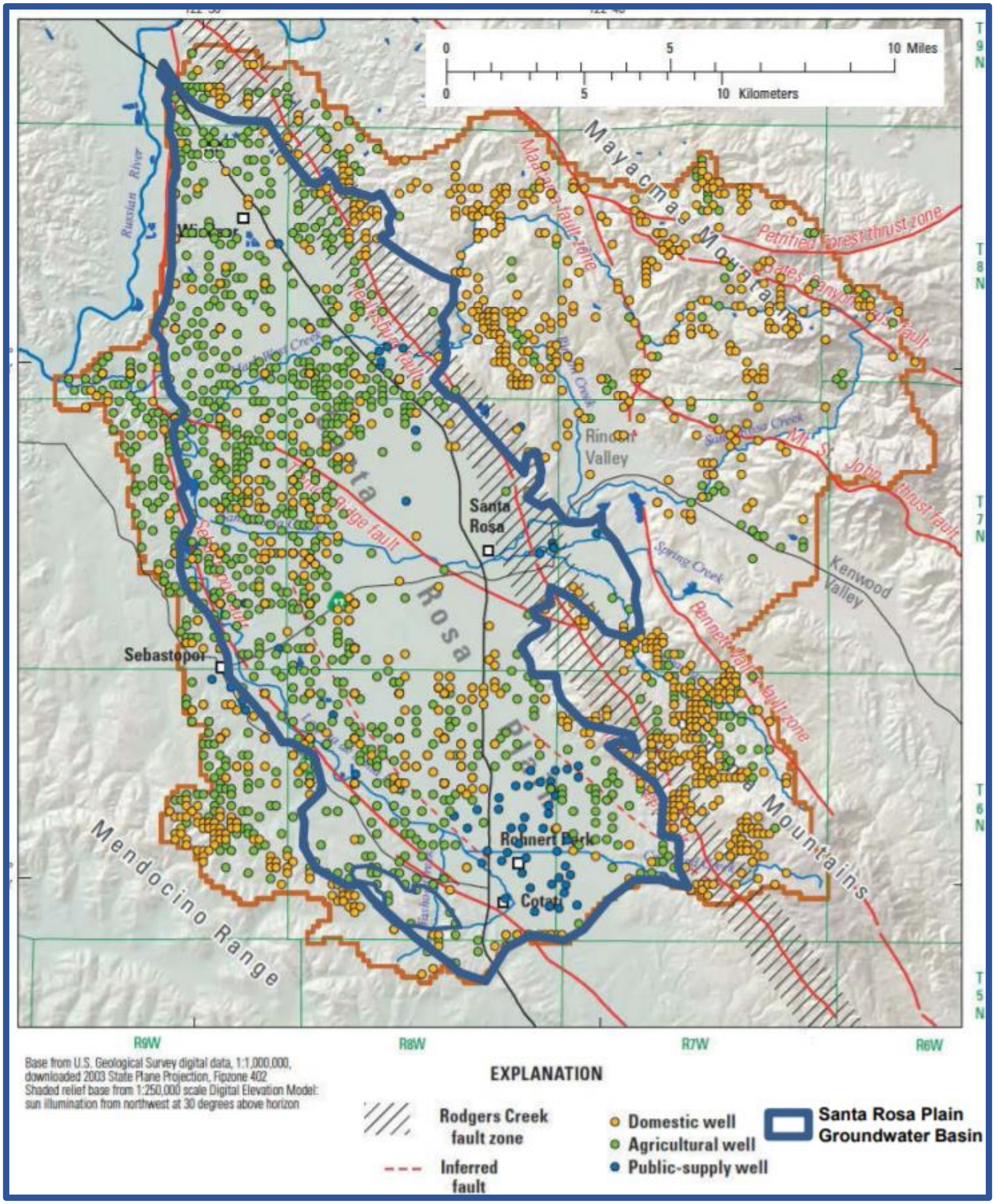

Figure 12. Known wells within the SRPB (USGS 2014).

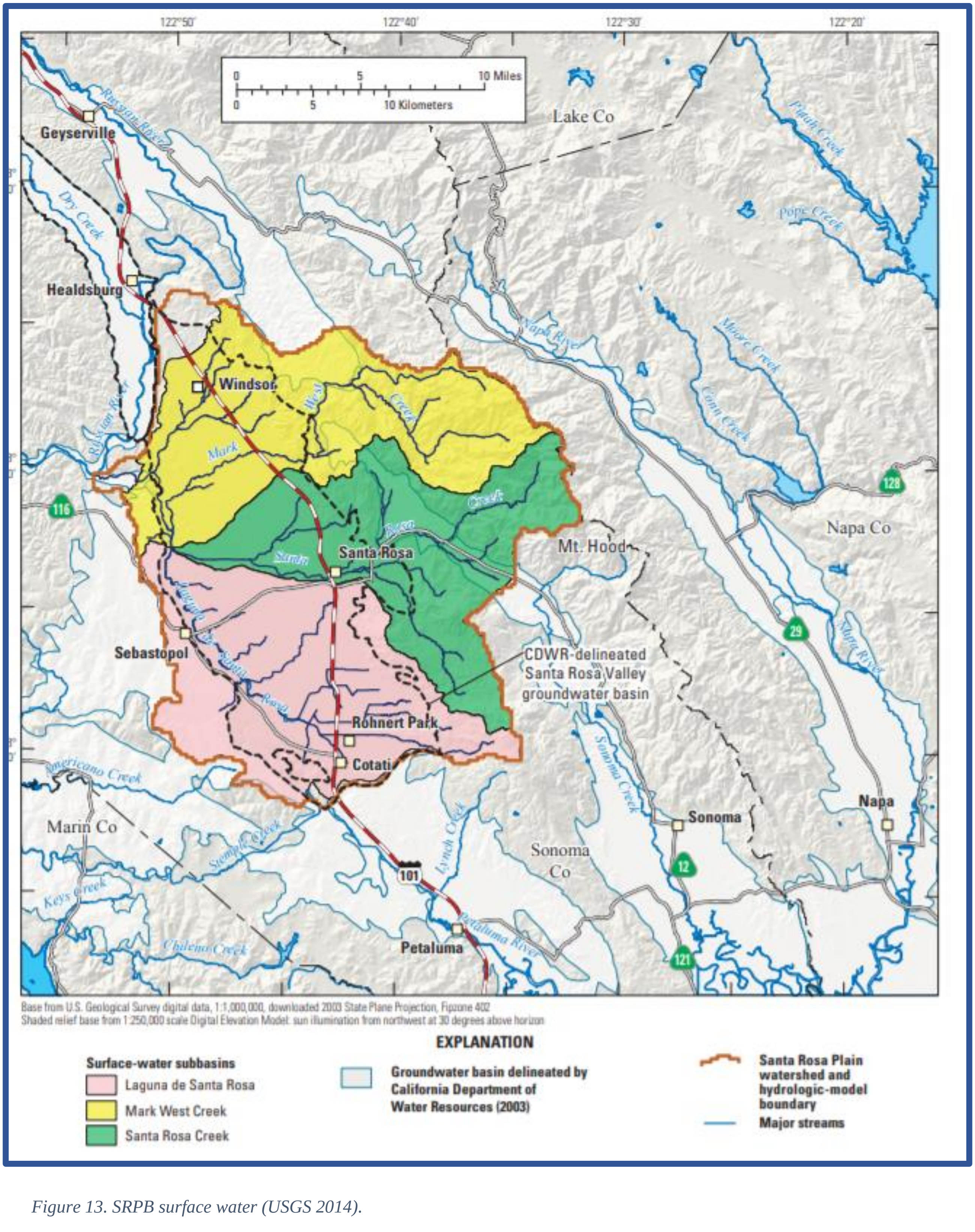

Figure 13. SRPB surface water (USGS 2014).

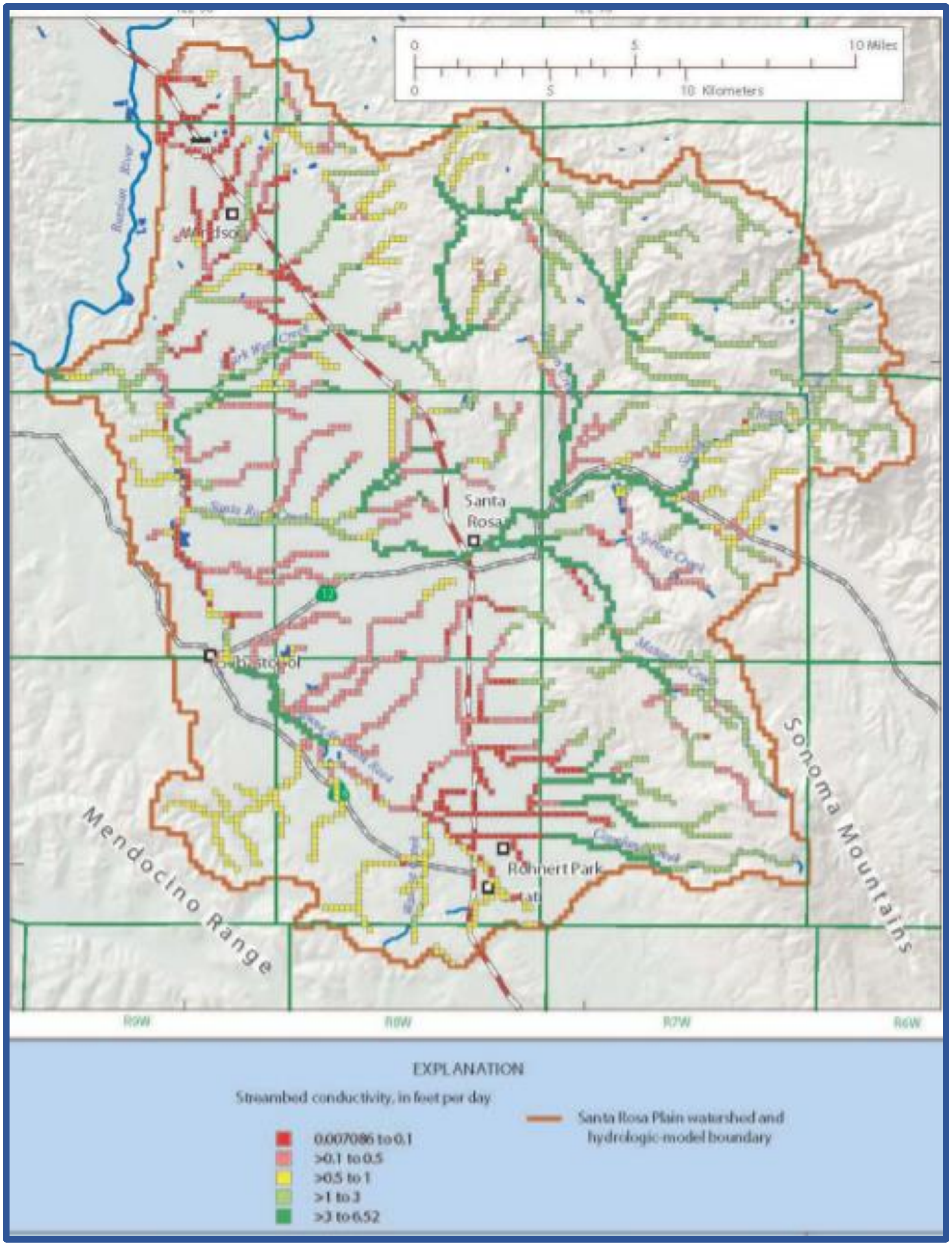

Figure 14 SRPB Streambed Conductivity Ratings (USGS, 2014)

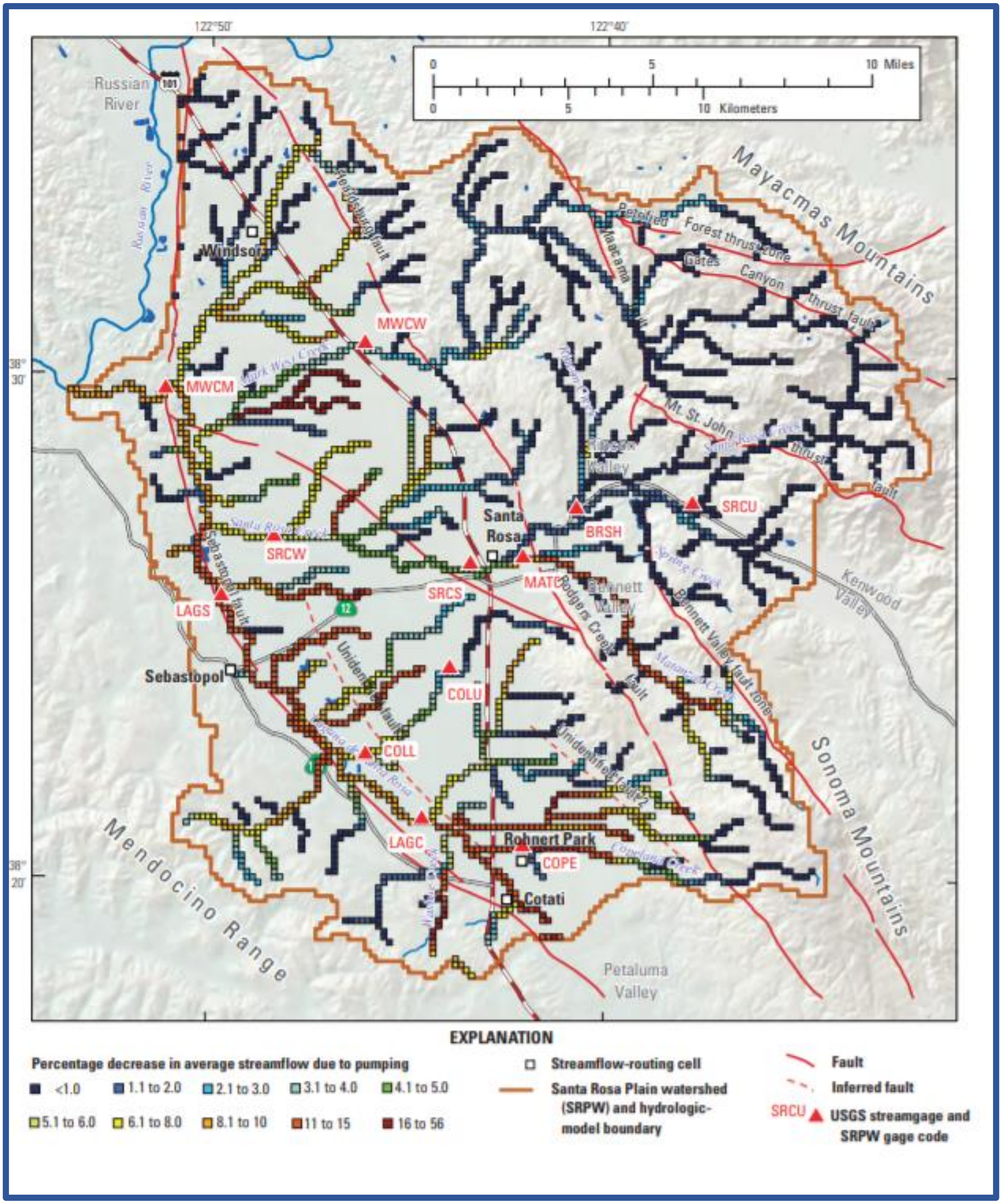

Figure 15 Percentage Decrease in Average Streamflow due to Pumping (USGS, 2014)

Land-Use and Population: In 2010, the population for the watershed had increased to 373,000 residents which was a five percent increase from the population in 2000. Most of the population– approximately 249,000 people, is concentrated in the urban areas while the remaining 124,000 people reside in the unincorporated rural areas. The population has continued to increase over the last eight years—especially in the five urban areas of the basin which has seen an increase of approximately 16, 648 people.

Most of the developed land-use data for the Santa Rosa Plain Basin is focused on the watershed which is larger than the defined basin area for SGMA. Historically, the land-use for the watershed has been primarily agricultural; however, land-use trends have changed to meet the needs of a growing population. The Santa Rosa Plain GSA uses the 2012 land use survey to determine that the land use for the basin is primarily urban, residential, commercial, industrial, native vegetation or water and agriculture. Industrial land use accounts for thirty-six percent of use while native vegetation and water account for thirty-five percent and agriculture accounts for twenty-six percent. Land use changes have resulted in a decrease in the native vegetation or water category and an increase in urban, residential, commercial and industrial. These changes have included converting crop and pasture land and upland forests to urban land uses, and increasingly converting grassland to vineyards (Santa Rosa Plain Basin Advisory Panel). The increased number of impervious surfaces that accompany urbanization increases incidents of run-off and directly impacts groundwater recharge by reducing direct infiltration to and evatranspiration, from the soil zone (U.S. Geological Survey, 2013).

Table 4 2017-2018 Santa Rosa Plain Basin Population by City (California Department of Finance, 2018)

2017-2018 City Population Percent Change Rankings			
California Cities Ranked by the 2017-2018 Percent Change in Population			
City	1/2017 Total Population	1/2018 Total Population	Percent Change
Cotati	7,453	7,716	3.5%
Rohnert Park	42,490	43,598	2.6%
Sebastopol	7,624	7,786	2.1%
Windsor	27,492	28,060	2.1%
Santa Rosa	178,064	178,488	0.2%
total	263,123	265,648	

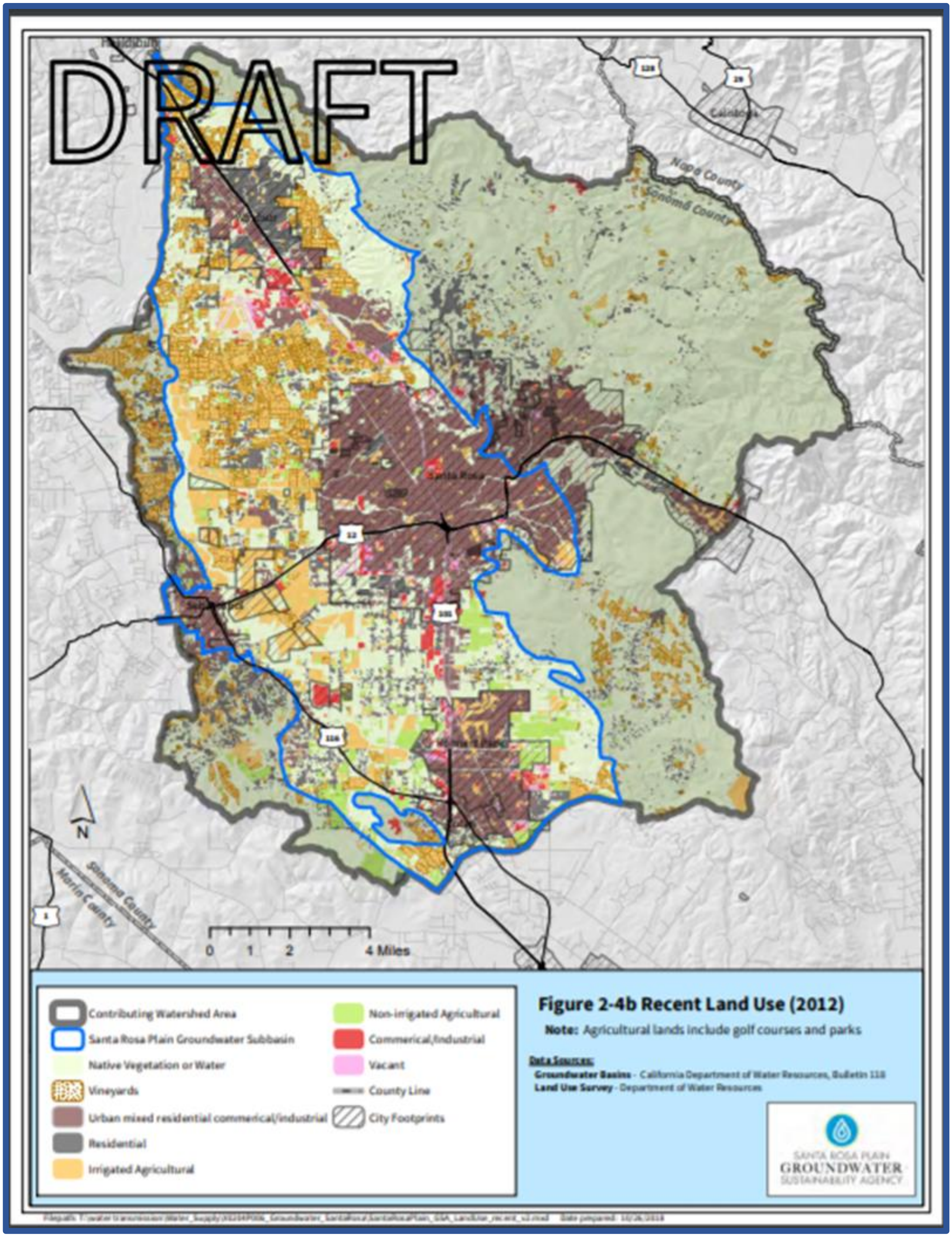

Figure 16 Recent Land Use for the SRPB (SRPB GSA, 2018)

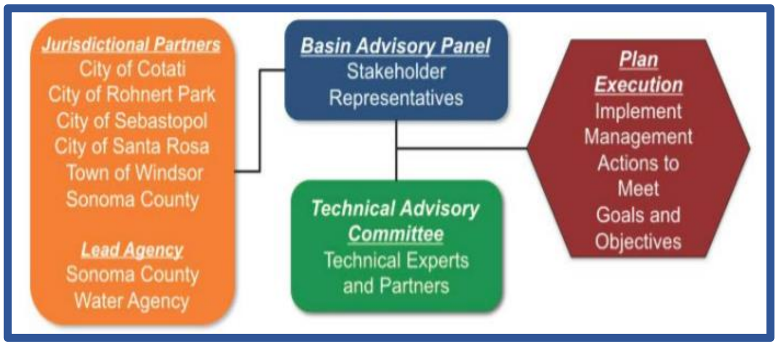

Figure 17 Structure for Santa Rosa Plain Basin Groundwater Management Plan (SRPB Advisory Panel, 2014)

Existing Plans and Data: The Santa Rosa Plain Basin Advisory Panel through a collaborative and cooperative effort (Santa Rosa Plain Basin Advisory Panel, 2014) developed a voluntary Groundwater Management Plan in December 2012. This panel consists of thirty members which includes a variety of stakeholders who live and work in the Santa Rosa Plain Watershed (Santa Rosa Plain Basin Advisory Panel, 2014). The Advisory Panel identified a management strategy that focused on seven components to facilitate the goal of sustainability: stakeholder involvement, monitoring and modeling, groundwater protection, increased conservation and efficiency, increased groundwater recharge, and increased water recycling.

This plan provides support for planning efforts within the Plan Area which are conducted by various local, state and federal agencies, as well as individual organizations and stakeholder groups (Santa Rosa Plain Basin Advisory Panel, 2014) which includes both regulatory and non-regulatory activities such as: water supply planning, water conservation, water reuse, storm water management, well permitting, water quality programs, monitoring and land use planning.

This plan details eighteen best management strategies to achieve sustainable groundwater management. This includes an agency made up of a balanced group of stakeholders to locally manage and protect groundwater resources through non-regulatory measures to support all beneficial uses, including human, agriculture, and ecosystems, in an environmentally sound, economical, and equitable manner for present and future generations (Santa Rosa Plain Basin Advisory Panel, 2014). These efforts have provided a foundation for the Groundwater Sustainability Plan for the basin; however, despite focusing on recharge, monitoring, conservation and groundwater protection it doesn't fully meet the GSP requirements set forth in SGMA. The discrepancies between the voluntary plan and the requirements for the SGMA plan will be discussed in the data gaps section of this assessment.

In addition to the groundwater management plan, in 2013 the USGS—in collaboration with the Sonoma County Water Agency and the cities of Cotati, Rohnert Park, Santa Rosa and Sebastopol, the town of Windsor, the County of Sonoma, and the California American Water Company completed a hydrologic study based on a groundwater-surface water flow models for the area that was presented in two reports that vary in scope. The purpose of this study was to develop a tool to aid in the management process of the local groundwater system. This study was based on results of a computer model that was developed for the area. The model, known as GSFLOW, uses data collected from surface water stream flow and groundwater flows as a tool to simulate different future water supply scenarios, as land uses and climate conditions change, to improve water supply planning and management (U.S. Geological Survey, 2013).

The first report, *Hydrologic and Geochemical Characterization of the Santa Rosa Plain Watershed, Sonoma County, California* details the hydrogeological and geochemistry of the Santa Rosa Plain, describes the conceptual groundwater-surface water flow model and discusses possible management strategies for the basin. The study confirmed that rainfall percolation and infiltration from surface water accounted for over ninety percent of groundwater recharge which was approximately 73,000-acre feet per year for the whole watershed. The trends indicated that surface water for the basin loses water to groundwater aquifers more often than gaining water from the aquifers. The results discussed in this report demonstrated trends of an estimated an overall annual overdraft of 3,300-acre feet for the basin which have caused groundwater levels and storage to decline over time affecting both well viability and flows to groundwater dependent ecosystems.

The second report, *Simulation of Groundwater and Surface-Water Resources of the Santa Rosa Plain Watershed, Sonoma County, California* provides supplemental data regarding the design of the GSFLOW hydrologic model such as the construction of the model and calibration used for the study, the results of the simulation as well as the projections from four climate change scenarios. The results of the simulation determined that approximately 189,000-acre feet of surface water is lost annually to groundwater recharge to compensate for overdraft caused by pumping.

The four climate change scenarios were based on two global climate models and two projected greenhouse gas models. These models were simulated for the years 2011-99 based on pumping estimates for the basin then used to project the long-term effects of climate change on surface water availability. The results indicated an overall increased need for groundwater pumping due to higher temperatures and a drier climate which would result in a decrease in groundwater levels and ultimately a reduction in surface water.

Existing Data Gaps: There is a significant need for additional data to inform the strategy design for the sustainable management of groundwater-surface water interactions in the Santa Rosa Plain Basin. The Santa Rosa Plain Basin Groundwater Sustainability Agency created the following table to illustrate the existing data gaps from the current management plan which need to be included to achieve SGMA compliance:

Table 5 Existing Groundwater Management Plan and Additional SGMA Requirements Needed (SRPB GSA, 2018)

GSP Component	Information available from existing SRP-GMP or studies	Additional GSP Requirements
Description of Plan Area - 354.8	Description of existing water resource management programs, jurisdictional boundaries, land use elements from general plans.	Well density maps, discussion of relationship between land use plans and GSP and how existing plans may affect ability to achieve sustainable groundwater management over 50-year planning horizon, description of how existing programs may limit operational flexibility in the Basin, summary of the well permitting process.
Hydro-geologic Conceptual Model - 354.14	Summary of Hydro-geologic Conceptual Model, description of principal aquifers and aquitards, general water quality, principal uses of each aquifer, 2 scaled cross-sections.	Description and assessment of boundaries, data gaps and uncertainty analysis, delineation of recharge and discharge areas
Groundwater Conditions - 354.16	Description of groundwater elevation trends over time, groundwater elevation hydrographs and contour maps, groundwater quality data.	Annual and cumulative change in groundwater storage based on groundwater-level changes, description and map of known groundwater contamination sites and plumes, rates and map of land subsidence, as applicable, identification of interconnected surface waters and groundwater dependent ecosystems and estimates on timing and quantity of stream depletions.
Water Budget - 354.18	Summary of historical and current Water Budget from GSFLOW model for Santa Rosa Plain Watershed.	Processing of output from existing model to define current, historical and projected groundwater budgets for Bulletin 118 Basin. Estimate of sustainable yield (based on development of Sustainable Management Criteria). Conduct Uncertainty Analysis. Future simulations incorporating 50 years of historical climate data, population projections, and climate change. Quantitative evaluation of availability or reliability of historical surface water supplies by source and water year type.
Management Areas - 354.20	Consider use of sub-areas defined in existing SRP- GMP	Describe reason for creation of management areas (if any), rationale for selecting different thresholds and objectives and how they will not impact sustainability of entire Basin

The study conducted by the USGS recognized additional needs for data in the region. There is a lack of water level and water quality data which impedes the calibration efforts for groundwater flow models. The most significant gap causes pumping data for the basin to be estimated due to the lack of data regarding urban, rural and agricultural usage. The only pumping that is reported is municipal which only accounts for fifteen percent of the total usage. There is a need for identifying the location of wells and for monitoring the usage for wells that are not considered de minimis users. The Santa Rosa Plain Basin Groundwater Sustainability Agency must work to identify potential data gaps in the implemented monitoring program. Data gaps in the monitoring network will compromise the quality of the management plan and limit goal success. The number of strategically placed monitoring stations must be increased to minimize monitoring data gaps. The Department of Water Resources recommends following this flowchart to identify and address data gaps:

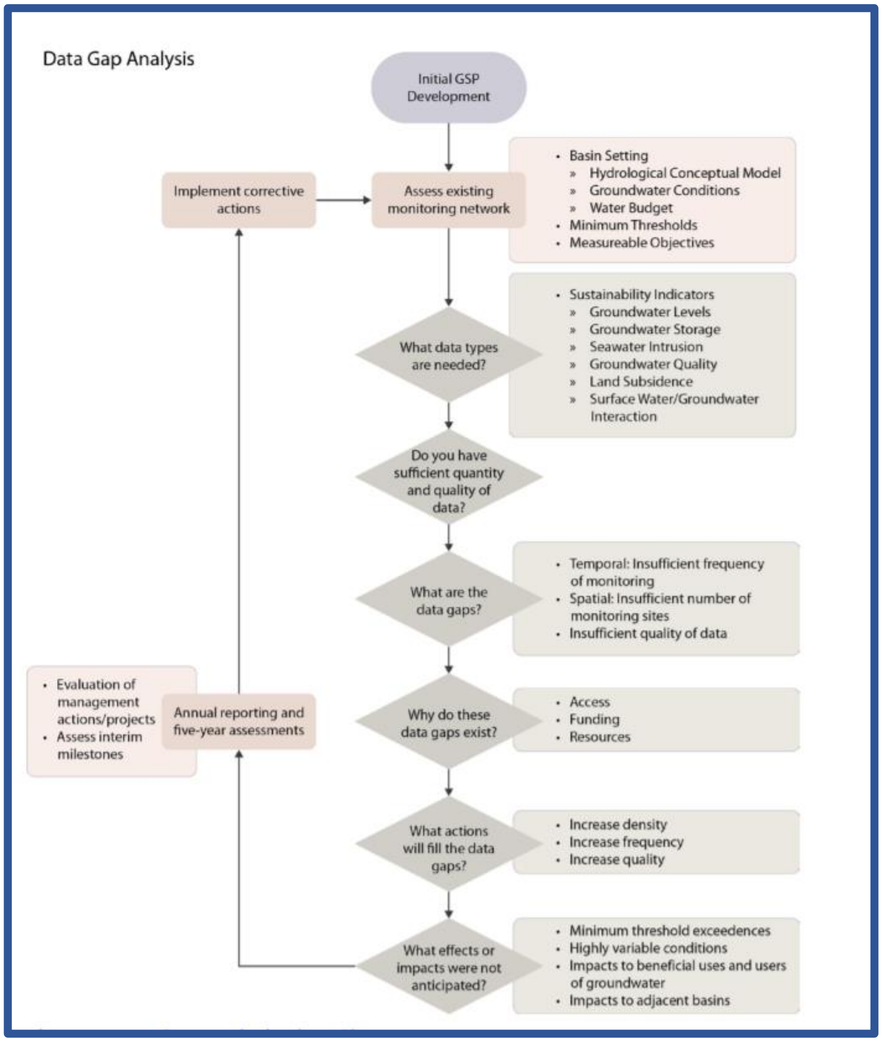

Figure 18 Data Gap Analysis Flow (California Department of Water Resources, 2016)

6.3 Step Three: Finalizing Goals and Identifying Solutions

In this step, resource managers will need to refine goals, develop objectives and set measurable targets and indicators to achieve the preliminary goals described in step one. It is important to define goal inputs, outputs, and outcomes. The inputs consist of all groundwater and surface water data for the basin in a stakeholder engagement process. These inputs provide the foundation of the management plan and define the developed outputs: minimum thresholds, milestones to measure success, monitoring schedule, and educational programs. The outcomes from this process is the overall achievement of the preliminary goals: determined baseline standards, established monitoring system, minimum thresholds set, fiscal solvency for the GSA, developed educational component, milestones to measure success identified, data gaps resolved, reduced withdrawals, increased recharge and a successful management plan implemented.

Current goals for the Santa Rosa Plain Basin Groundwater Sustainability Agency are: completion of the groundwater sustainability plan and completing a rate and fee study conducted by Raftelis Financial Consultants, Incorporated. The rate and fee study will assist in the goal of financial solvency and will provide an opportunity to register locations of wells within the basin.

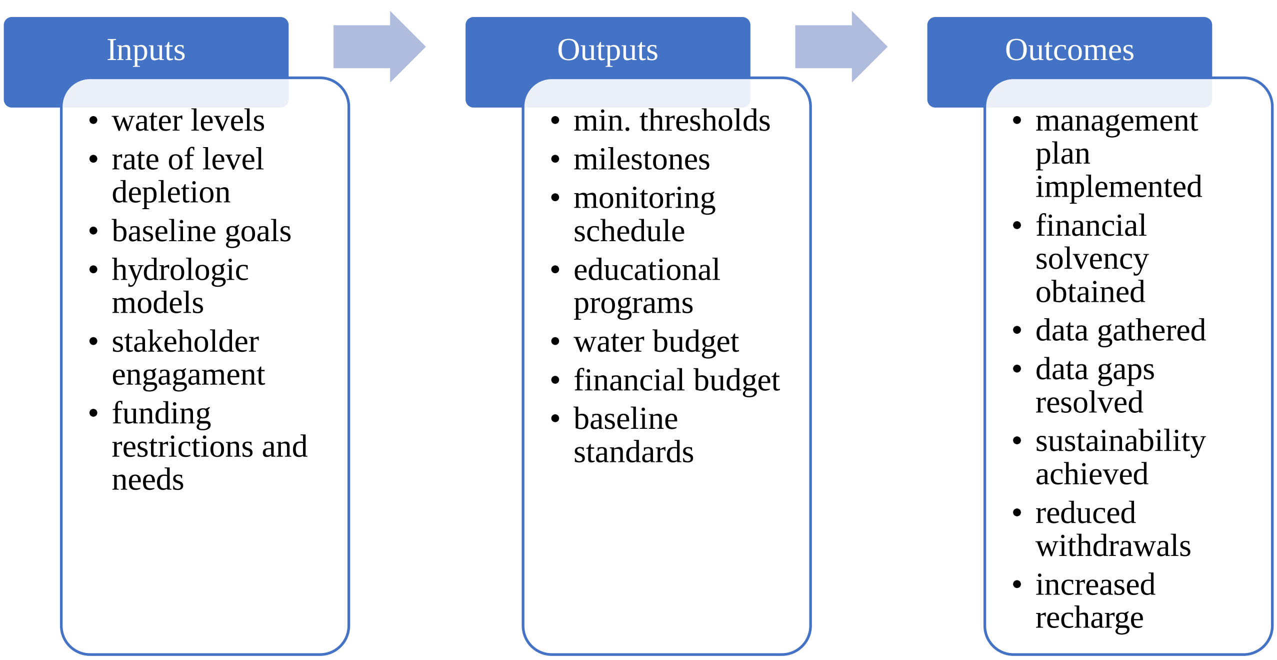

Figure 19 Inputs, Outputs and Outcomes

6.3.1 Developing Indicators and Targets

The Department of Water Resources defines the metric to measure sustainably managed groundwater and surface interactions as the volume or rate of surface water depletion. To establish a recommended threshold for the rate of depletion of surface water levels—it helps to consider the health of groundwater dependent ecosystems. Lowering of groundwater levels may result in area reductions of surface water for these ecosystems which impacts the plant and animal species that live there. These changes can be identified by conducting assessments of both the hydrological and biological data available for the basin; however, baseline conditions must be established prior to conducting these assessments. This step will likely have been completed in step two: basin characterization.

Establishing Baseline Conditions: The groundwater sustainability plan requirements set forth by SGMA specifies that a baseline condition is established by using historical information to project future conditions for hydrology, water demand and availability of surface water and to evaluate options for the sustainable management of the resources for the basin. (The Nature Conservancy, 2016). There are multiple baselines that need to be established to achieve the goal of sustainable management. These include standards for groundwater and surface water levels as well as baseline conditions for GDEs. Maintaining these baselines provide a measurement of goal success. As mentioned previously, GSAs are not responsible for mitigating impacts to groundwater-surface water interactions that occurred prior to January 1, 2015; however, the Department of Water Resources recommends that GSAs use data gathered for the ten-year period between 2005-2015 to determine a baseline for the basin (Department of Water Resources, 2016). This span of data collected from the GSFLOW hydrologic model can be used to establish baseline minimum thresholds for groundwater and surface water depletion for the basin. Refined goals for maintaining these thresholds for both groundwater and surface water levels include actions to reduce groundwater withdrawals and to increase groundwater recharge.

6.3.2 Hydrological Data

Hydrological data includes the quantifiable measurements of groundwater levels, surface water depth and variability in discharge volume and rates. Monitoring conducted using the GSFLOW hydrologic model provides most of this needed information; however, continued monitoring is recommended.

The type of hydrological data needed is dependent on the type of groundwater dependent ecosystem being assessed. The Nature Conservancy created table 6 to advise as to which indicator works best for each GDE type.

Table 6 Sustainability Indicators per GDE Type (The Nature Conservancy, 2018)

		HYDROLOGIC DATA		
CORRESPONDING SUSTAINABILITY INDICATOR‡		**Groundwater Elevations** in the principal aquifer connected to each GDE. Dataset should capture seasonal highs and lows.	Any **Groundwater Quality** trends for water quality indicators to address known water quality issues.	**Interconnected Surface Water** (i.e., surface water discharge, surface water head, and baseflow contribution). Date/location of where intermittent or ephemeral streams/rivers cease to flow, temporal changes in conditions due to variations in stream discharge and regional groundwater extraction.
GDE TYPE	SEEP OR SPRING	**Groundwater Elevations**—depth to water.	**Water Chemistry**—depends on site, soil, and geology. Some indicators may include temperature, total dissolved solutes, stable isotopes. Site-specific requirements (e.g., total maximum daily load (TMDL); applicable local, state, and federal water quality standards) may apply.	**Groundwater Discharge**—variability (seasonal or annual) of discharge. **Groundwater Elevations**—depth to water.
GDE TYPE	WETLAND OR LAKE	**Groundwater Elevations**—depth to water.	**Water Chemistry**—depends on site, soil, geology, water budget, surface water source (if applicable), plant species composition; thus, no general indicator suggested. Nutrients (nitrate), total dissolved solids (TDSs), chloride, dissolved oxygen. Site-specific requirements (e.g., TMDLs; applicable local, state, and federal water quality standards) may apply.	**Groundwater Discharge**—continued presence of groundwater discharge or saturated soils throughout the growing season. **Groundwater Elevations**—depth to water.
GDE TYPE	TERRESTRIAL VEGETATION	**Groundwater Elevations**—fluctuation in depth to water.	**Water Chemistry**—depends on site, soils and geology, water budget, plant species composition; thus, no general indicator suggested. Site-specific requirements (e.g., TMDLs, local/state/federal water quality standards applicable) may apply.	**Groundwater Elevations**—depth to water.
GDE TYPE	RIVER, STREAM, OR ESTUARY	**Groundwater Elevations**—fluctuation in depth to water.	**Temperature**—maximum seven-day average of daily maximum (7DADM) surface water temperature. **Water Chemistry**—Nutrients (nitrate), TDSs, chloride, dissolved oxygen. Site-specific requirements (e.g., TMDLs, applicable local, state, and federal water quality standards) may apply.	**Surface Water Flow**—number of zero-flow days, trends in annual mean low flow, number and severity of flow-related fish migration passage impediments (if applicable), number of days and timing of sand bar breaching (if applicable). **Temperature**—maximum 7DADM surface water temperature. **Groundwater Discharge**—location and extent of gaining and losing reaches. **Groundwater Elevations**—depth to water.

Current data for each GDE in question must be collected and compared to the established baseline to determine how vulnerable the area is to impacts of groundwater depletion. This comparison informs the GSA if the GDE is susceptible to experiencing significant or unreasonable changes in groundwater conditions.

Table 7 Susceptibility Ranges (The Nature Conservancy, 2018)

Low Susceptibility	Data for the current groundwater conditions fall within the baseline range and no future changes in these conditions are likely to cause the hydrologic data to fall outside the baseline range.
Mild Susceptibility	Data for the current groundwater conditions fall within the baseline range but future changes in these conditions are likely to cause it to fall outside the baseline range.
High Susceptibility	Data for the current groundwater conditions fall outside the baseline range.

6.3.3 Biological Data

Biological data includes, information regarding vegetation rooting depth, habitat assessment for groundwater dependent species, water and land measurements based on photography, remote sensing indices and biological surveys, examines how the health of the GDE is responding to current groundwater conditions and can potentially provide an early warning of health impacts to the GDE. These ecosystems are dependent on interconnected surface water for their survival and groundwater conditions has a range of complex impacts to the overall health of the ecosystem and assessing biological data is essential in determining these impacts.

Vegetation Rooting Depth: Root depth of groundwater dependent vegetation provides necessary evidence in determining if the ecosystem is impacted by depleted groundwater resources. Each type of vegetation has a measurable root length average which sets a minimum threshold for groundwater levels. For example, if a specific groundwater dependent plant has historically grown in the area and is known to have a maximum root length of fifteen feet then this species of plant will begin to exhibit signs of impact: reduced growth, reduced reproduction and increased mortality— if the groundwater levels exceed fifteen feet below the surface. Root depth data should be established locally since there are regional differences that can have varying effects on root length. Studies need to be conducted within the Santa Rosa Plain Basin to determine the maximum root length of the groundwater dependent vegetative species with the shortest expected root length. This information is critical in determining the minimum threshold for this criterion. Figure 20 is a flow chart of the range of changes in plant physiology, ecophysiology and ecology that is associated with various durations of water stress (Eamus et al. 2016).

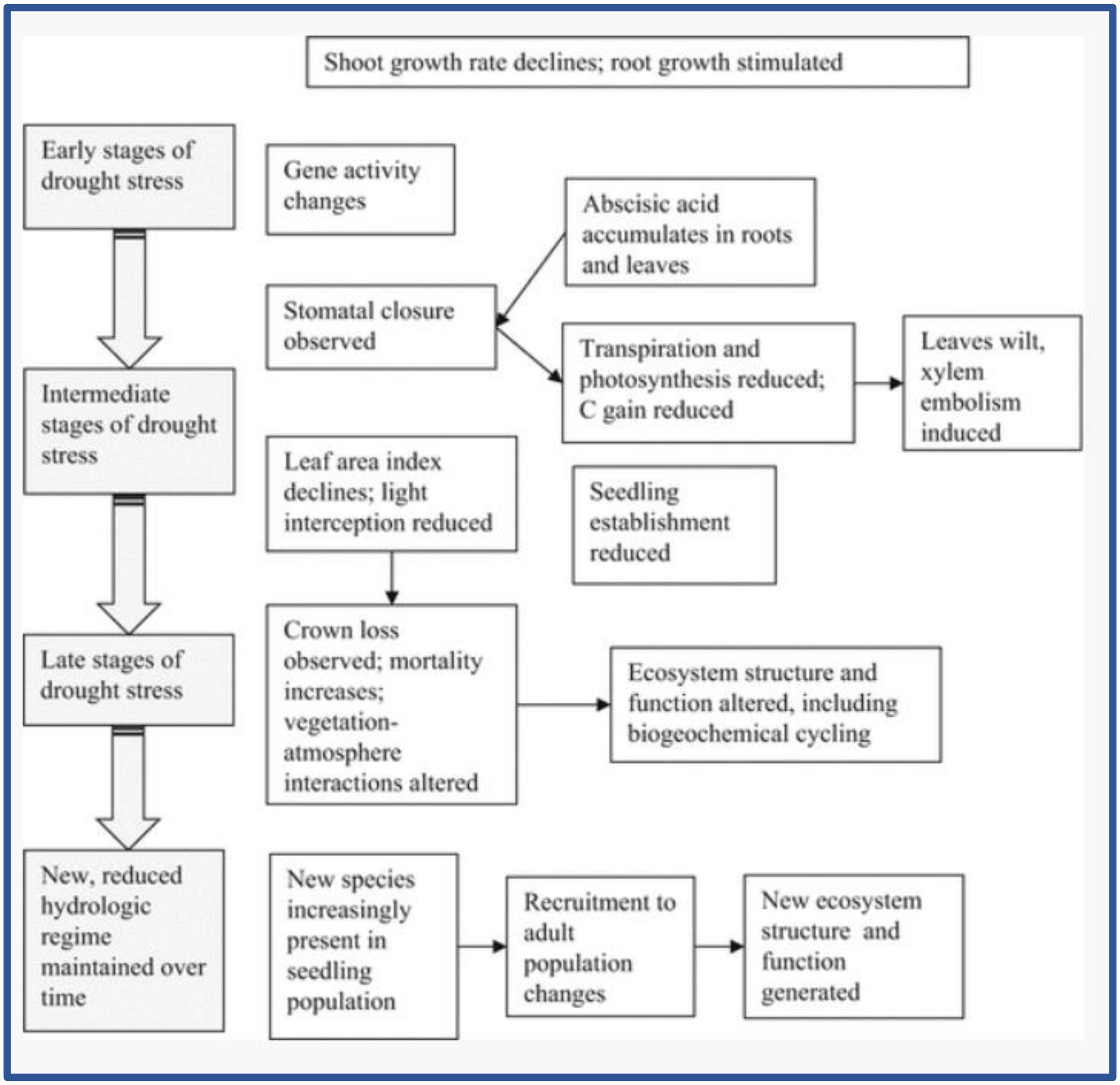

Figure 20 Changes in Plant Physiology, Ecophysiology and Ecology due to Drought Stress (Eamus D., Fu B., Springer A.E., Stevens L.E., 2016)

<u>Habitat Assessment of Groundwater Dependent Species:</u> Monitoring groundwater dependent species provides needed information regarding the cause and effect relationship between groundwater conditions and groundwater dependent ecosystems (The Nature Conservancy, 2016). The Santa Rosa Plain Basin is home to many endangered, threatened and/or rare species. Studies need to be conducted in the Santa Rosa Plain Basin to determine the minimum threshold of ecological function to maintain the survival if these species. For example, the SRPB is home to three anadromous salmonid species: Chinook salmon, steelhead and Coho salmon. The Nature Conservancy recommends that the annual mean low flow for anadromous fish not fall less than thirty cubic feet per second. This is a measurement of minimum threshold for these species.

<u>Photography Based Measurements:</u> Changes to the size or extent of interconnected surface water or groundwater dependent ecosystems can be detected using photography of the area over a period. Images from over the years can be visually compared and when coupled with technology, such as GIS, measurements of the land or water area can be recorded and compared as well. An indicator that can be established using photography coupled with GIS is a reduction to the area of surface water at discharge points or the width of the bodies of surface water may become narrower or experience longer dry periods.

<u>Remote Sensing Indices:</u> Detection of GDE locations, groundwater resources and changes in the rates or patterns of vegetative growth or the moisture levels in plants can be detected using remote sensing indices. These methods include the use of infrared sensing and aerial thermal imaging to detect inundation, vegetation, slope, aspect and other GDE attributes to develop indices that provide a strategy to assess vegetation structure and moisture, vegetation function and viability within an area (Eamus et al., 2016). Remote sensing technology is also a viable technology to detect groundwater levels and locations where groundwater and surface water interact. Specific indices will be discussed more thoroughly in the tools and technology section of this analysis.

6.3.4 Recommended Thresholds and Triggers

GSAs for each basin are required to set thresholds for groundwater-surface water interactions that avoid the significant and unreasonable depletion of interconnected surface waters. Local control for establishing thresholds is critical to the achievement of sustainable management due to the regional variances between basins. GSAs will need to set thresholds that do not exceed existing standards, involve stakeholders and do not violate the thresholds of neighboring basins (Christian-Smith et al. 2015). Juliet Christian-Smith and Kristyn Abhold (2015) recommend, in *Measuring What Matters Setting Measurable Objectives to Achieve Sustainable Groundwater Management in California*, the following framework for setting thresholds:

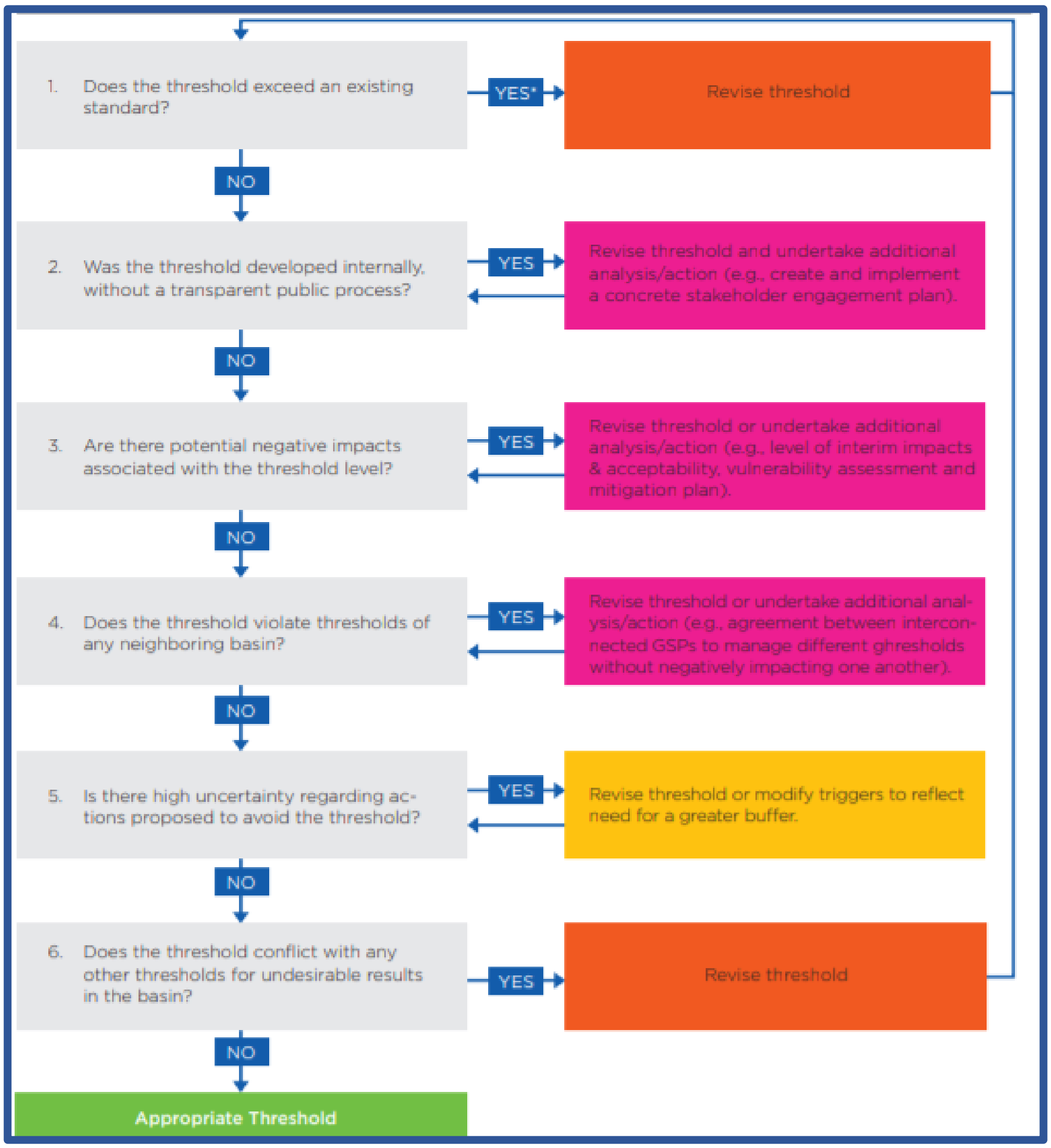

Figure 21 Setting Measurable Minimum Thresholds (Christian-Smith and Abhold, 2015)

The following table summarizes four recommended thresholds and indicators that have been synthesized from the hydrologic and biological data discussed in step three:

Table 8. Recommended Minimum Thresholds

Minimum Threshold	***Indicator***	***Types of Measurement***
Not to exceed 0.05m/year for surface water level depletion (Christian-Smith et al. 2015)	Surface water levels will no longer support GDEs due to chronic lowering of groundwater levels.	Surface water Level Monitoring Program
Preserve the following proportions of annual discharge from the Santa Rosa Plain Basin to maintain base flow of interconnected surface waters: • At least 87% for very dry years • At least 80% for dry years • At least 70% for normal to wet years (Northern Territory Government 2016)	Decline in width of rivers, streams or wetlands or decrease in overall area of surface water at discharge points.	Photography Coupled with Geospatial Technology
Groundwater levels not to decline below 10 cm which is the maximum root length of the groundwater dependent vegetative species with the shortest expected root length	Reduction in vegetative growth and decrease of moisture in plants	Remote Sensing (NDVI & NDWI)
Annual mean low flow not to decrease less than 30 cubic feet per second (The Nature Conservancy 2018)	Habitat loss for groundwater dependent species such as anadromous fish.	Species Specific Biological Assessment

In addition to minimum thresholds, it is also important for the GSA to establish triggers to avoid potential emergency scenarios related to overdraft since implementation of sustainable management actions can be timely (Christian-Smith et al., 2015). Sacramento Central Groundwater Authority has established the potential trigger points for groundwater-surface water interactions—the trigger points are as follows: (1) Monitoring losses of river water to groundwater shows a five percent increase over the current loss rate based on the total flow in the river and (2) Monitoring of losses of river water to groundwater shows a twenty-five percent increase over the current loss rate based on the total flow of the river.

6.4 Step Four: Design a Management Plan

A successful groundwater management plan for groundwater-surface interactions is an essential requirement for SGMA and beneficial in maximizing the availability and reliability of the water supply of both resources. Groundwater and surface water vary in availability, quality and management needs (California Department of Water Resources, 2016); however, GSAs must design plans to simultaneously manage both resources efficiently and sustainably. The key components of a successful management plan are the implementation schedule, milestones to track implementation, criteria to measure success, a monitoring program, financial solvency and an educational program for ongoing stakeholder involvement. A proposed outline for a GSP is shown in Figure 22.

Introduction

A. Groundwater Sustainability Plan Purpose
B. Sustainability Goal
C. Groundwater Sustainability Agency Information
D. Groundwater Sustainability Plan Elements

Hydrological Conceptual Model

A. Current and Historical Groundwater Conditions
B. Water Budget
C. Management Area

Sustainable Management Criteria

A. Sustainability Goal
B. Measurable Objectives
C. Minimum Threshold
D. Undesirable Results
E. Monitoring Network

Projects and Actions to Achieve Goal

Groundwater Sustainability Plan Implementation

Figure 22 Proposed Groundwater Sustainability Plan Outline (California Department of Water Resources, 2016)

Implementation Schedule: The SRPB GSA has developed an implementation schedule for the basin that is in alignment with SGMA timeline requirements.

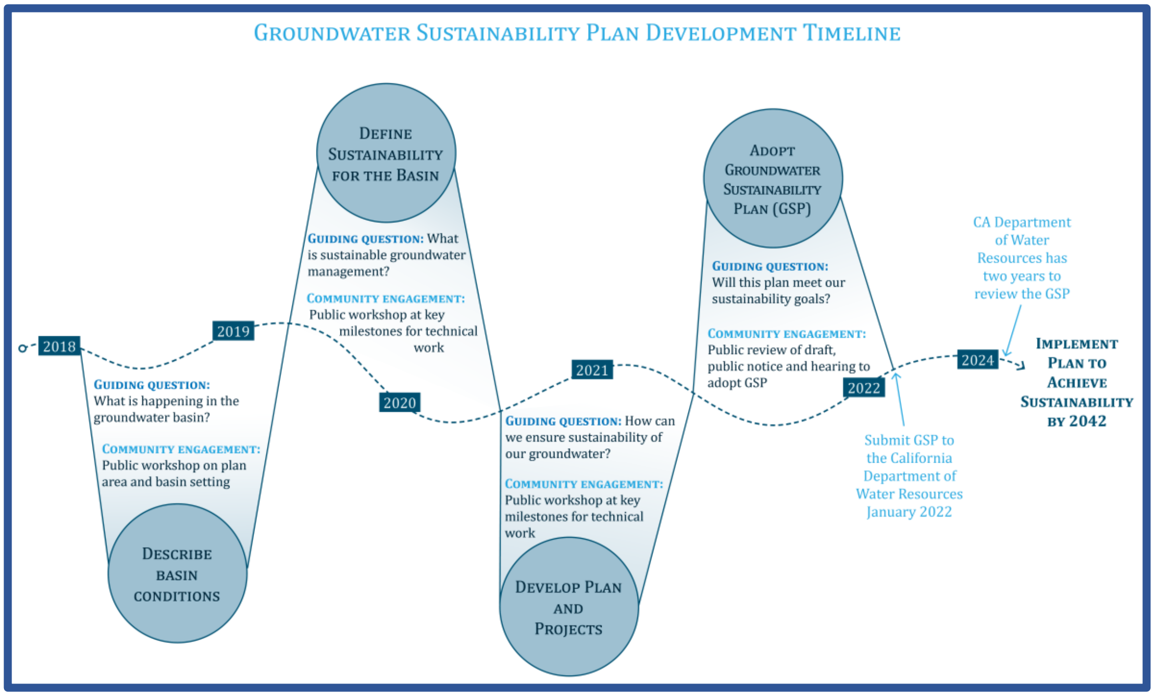

Figure 23 Groundwater Sustainability Plan Development Timeline (SRPB GSA, 2018)

6.4.1 Monitoring Program

Monitoring programs provide foundational insight into the complex system of groundwater-surface water interactions and can provide the interface for data necessary to design a success management plan. Monitoring groundwater-surface water interactions requires the use of technology and tools, primarily modeling methods, to analyze basin conditions, project changes to flow rates or water levels and estimate depletions caused by groundwater extraction. Monitoring is based on various codes of modeling—each with unique methods, software and approaches (California department of Water Resources, 2016). There are various classifications for model codes: conceptual, mathematical (analytical and numerical), integrated hydrologic models, coupled groundwater and surface water models and contaminant transport models. In addition to model-based monitoring approaches— there are emerging tools to monitor the interactions of groundwater and surface water. Some of these methods include approaches based in electrical, thermal or remote sensing technology.

The Nature Conservancy recommends using a series of shallow monitoring wells located with stream gages and positioned perpendicular to the stream to monitor groundwater levels and surface water interactions within groundwater dependent ecosystems. This method is non-invasive for the GDE and can monitor multiple layers of the aquifer to better understand the connectivity of the surface water and groundwater. Metrics that can be used to monitor the interactions are: temperature, pH, electrical conductivity, dissolved oxygen, nutrients, and salinity.

The Santa Rosa Plain Basin has an existing voluntary monitoring plan developed through a management plan:

Table 9 Existing Monitoring Plan for SRPB (SRPB Advisory Panel, 2014)

Parameter Monitored	**Program**
Groundwater Levels (variable monitoring frequency)	CASGEM - 36 private water wells, dedicated monitoring wells and inactive municipal supply wells DWR – 27 private wells PRMD - 10 public supply wells
Groundwater Quality (varied sampling)	
Specific Conductance	DWR – private wells
General Minerals	DWR – private wells
Drinking Water Title 22 Analytes	Public & private water supply wells
Land Surface Subsidence	3 Plate Boundary GPS Stations
Surface Water	12 Streamflow Gauging Stations
Rainfall Monitoring	15 Weather Stations

Under this current monitoring plan, the interactions between groundwater and surface water is not regularly monitored. There are currently twelve active and two inactive streamflow gages and the streamflow records range from two to twelve years (Figure 24) for the SR Basin. There is a significant need to modify this monitoring plan as it lacks data to estimate the amount of water moving through and discharging into the Russian River.

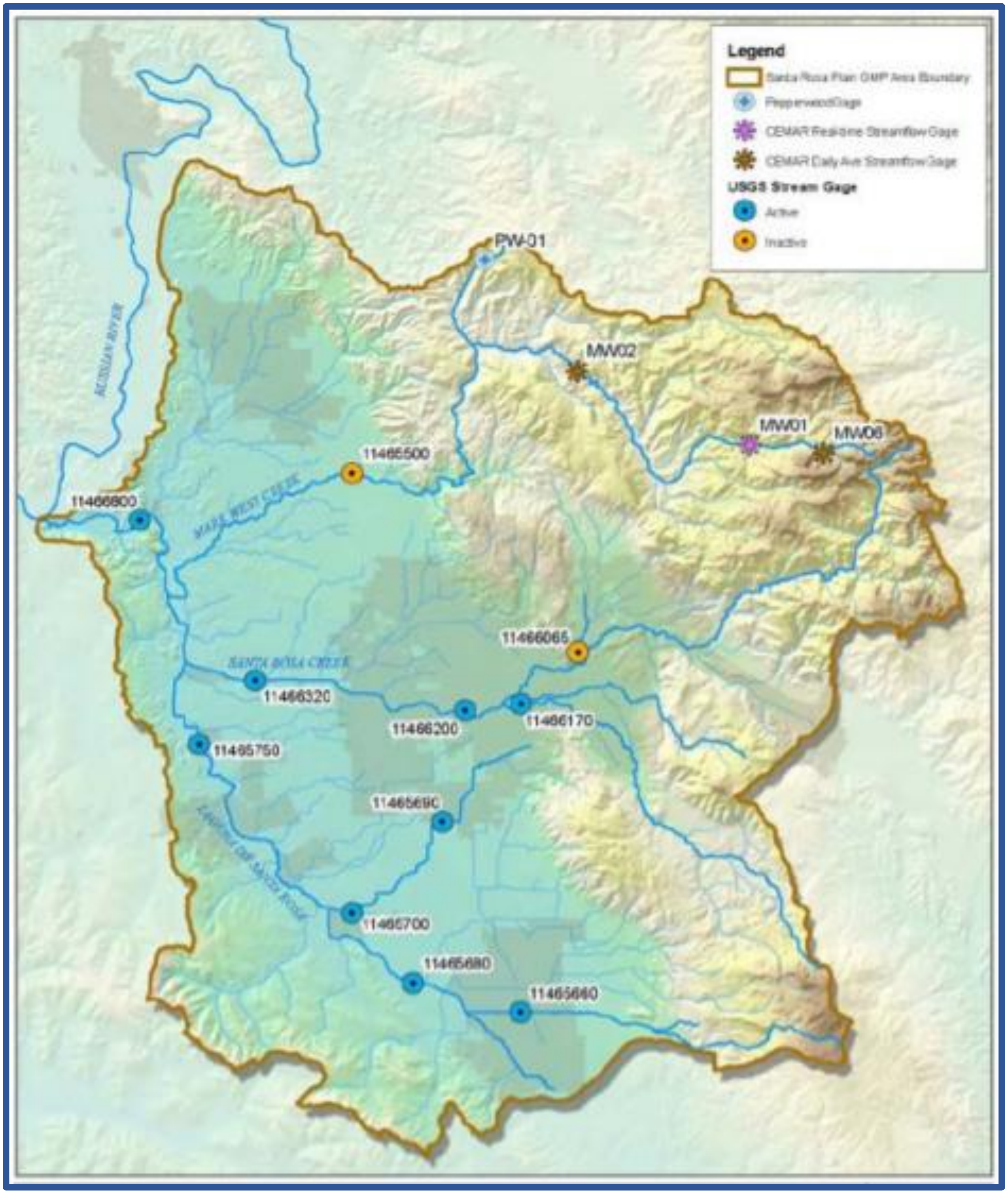

Figure 24. SRPB Streamflow Gauges (SRPB GSA, 2018)

6.4.2 Monitoring Plan Recommended Actions

Recommended actions for improving the scope of the current groundwater-surface water monitoring plan have been compiled in the table below:

Table 10 Recommended Actions for Monitoring Plan Update (SRPB Advisory Panel, 2014)

1	• Continue to compile available stream gauge data and information on tributary flows in the plan area.
2	• Determine current surface water quality sampling being conducted in the plan area.
3	• Analyze existing stream gauges and install new gauges in the plan area as needed
4	• Install new shallow monitoring wells along major watercourses to further assess surface water and groundwater interactions.
5	• Conduct seepage runs along major watercourses to further assess surface water and groundwater interactions. Correlate groundwater level data from wells in the vicinity of stream gauges to further establish connectivity of the creek water and groundwater.
6	• Conduct stable isotope study to understand surface water-groundwater flow. Analyze existing samples and samples for isotopic and other natural or anthropogenic tracers to evaluate surface water and groundwater interactions.

In addition to these six recommended actions from the existing monitoring plan, it would be beneficial for the updated monitoring plan to consider the streambed conductivity ratings established in *Simulation of Groundwater and Surface-Water Resources of the Santa Rosa Plain Watershed, Sonoma County, California*. These ratings determine locations of higher probability for groundwater-surface water interactions which is critical for finalizing viable monitoring locations.

6.4.3 Technology and Tools for Monitoring

Hydraulic Conceptual Model (HCM): Every GSP must include a hydraulic conceptual model that includes graphical representations of the basin based on known characteristics to facilitate in the understanding of the groundwater flow system for the basin (California Department of Water Resources, 2016). The HCM is the first step in developing a mathematical model but differs from a mathematical model in that it does not analyze quantities of water flow or levels but instead provides (1) an understanding of the general physical characteristics related to regional hydrology, land use, geology and geologic structure, water quality, principal aquifers, and principal aquitards of the basin setting, (2) provide the context to develop water budgets, mathematical (analytical or numerical) models, and monitoring networks and (3) provides tools for stakeholder outreach and communication (California Department of Water Resources, 2016).

Mathematical Model (Analytical or Numeric): Mathematical models provide quantitative estimates of water budget components by using either an equation or series of equations to simulate groundwater flow within the basin (California Department of Water Resources, 2016). There are two types of mathematical models: analytical and numerical. Analytical models are useful for analyzing an individual component of the groundwater system such as pumping, groundwater storage, groundwater quality, seawater intrusion, land subsidence and surface water interactions; however, this model is not useful for analyzing potential interactions between components. Alternatively, numerical modeling is used to analyze groundwater flow and transport to evaluate changes to the groundwater system. Basins, such as the Santa Rosa Plain Basin, that have significant groundwater-surface water interactions will have to use numerical models to demonstrate that the GSP will be success at avoiding the depletion of surface water due to interactions.

Integrated Hydrologic Model (IHM): Integrated hydrological models are essential in understanding the groundwater-surface water interactions for the basin. Using this technology allows GSAs to simulate streamflow interconnectedness to the groundwater system while analyzing how surface processes, such as irrigation deliveries and stream diversions, interact with surface flows and groundwater heads (California Department of Water Resources, 2016). IHMs fulfill two functions: (1) when using a specific code-they provide more consistency and reduce variability and uncertainty in models and (2) allows less commonly measured data, such as recharge to the water table or groundwater pumping, to be tied to data that is more commonly measured, such as evapotranspiration and surface water diversion (Moran, 2016).

<u>Coupled Groundwater-Surface Water Model:</u> Coupled groundwater-surface water models use separate models for both groundwater and surface water systems then use the output from one of the models are the solution for the other model to solve the groundwater flow equation. This is the type of model that is used in the study that was conducted by the USGS for the Santa Rosa Plain Basin that resulted in the two reports: *Hydrologic and Geochemical Characterization of the Santa Rosa Plain Watershed, Sonoma County,* and the *Simulation of Groundwater and Surface-Water Resources of the Santa Rosa Plain Watershed, Sonoma County, California.*

<u>Contaminate Transport Model (CTM):</u> Contaminate transport models simulate the transport of contaminants through subservice groundwater systems. CTM can fulfil several functions such as: simulating changes in contamination concentration from sources or sinks or simulating the movement of contamination by advection, dispersion and diffusion (Moran, 2016). CTMs can make projections regarding the concentration of chemical constituents based on changes in contaminate sources or sinks or remediation factors.

<u>Normalized Difference Vegetation Index (NDVI):</u> NDVI is a remote sensing technology that can detect the concentration of live green vegetation within an area. Green vegetation concentrations are an indicator for locations of groundwater dependent ecosystems. The NDVI assigns a score of between -1 and 1 depending on the concentration of green vegetation in a location and with continued monitoring these scores can change over time. A value of zero is assigned to bodies of water while values ranged between -0.1 to 0.1 are assigned to barren land. An increase in NDVI values over time indicate an increase of vegetative growth over time while a decrease in NDVI values indicate a decrease in vegetative growth over time. Decreases in NDVI values can result from impacts to GDE health due to depletion of surface water due to overdraft of groundwater resources (The Nature Conservancy, 2016).

__Normalized Difference Water Index (NDWI):__ NDWI is a remote sensing technology that can detect the moisture level in plants. Values for the NDWI range between 0-1 and can shift over time with continued monitoring of an area. Ranges that decrease over time indicate lower vegetation canopy moisture because of high drought stress while increases in NDWI values indicate higher canopy vegetation and lower drought stress (The Nature Conservancy, 2016).

__Handheld Thermal Imaging Photography:__ Temperature differences can be analyzed to identify and quantify groundwater interactions with surface water and may indicate locations where groundwater discharges to the surface (U.S. Geological Survey, and Office of Groundwater, 2016). Thermal imaging cameras are used to image bodies of surface water to locate thermal anomalies at a scale of centimeters to tens of meters. In addition to indicating locations of groundwater discharge—this technology helps to characterize the basin's hydrogeological conditions as well as identify potential locations for sampling and monitoring.

6.4.4 Measurable Objectives and Interim Milestones

It is important that measurable objectives are quantitative, clear, adaptable and account for uncertainty (Christian-Smith et al., 2015). Measurable objectives are required by SGMA to: (1) measure progress, (2) to provide a framework to successful avoid or remedy the six undesirable results, and (3) to define sustainable yield for the basin. It is essential that the developed baseline conditions for the basin are used to guide the development of the interim milestones. The Nature Conservancy recommends developing five-year milestones that are within the baseline range and above the recommended thresholds. This recommendation is in alignment with the SGMA requirement that the DWR reevaluate GSPs for the basin every five years.

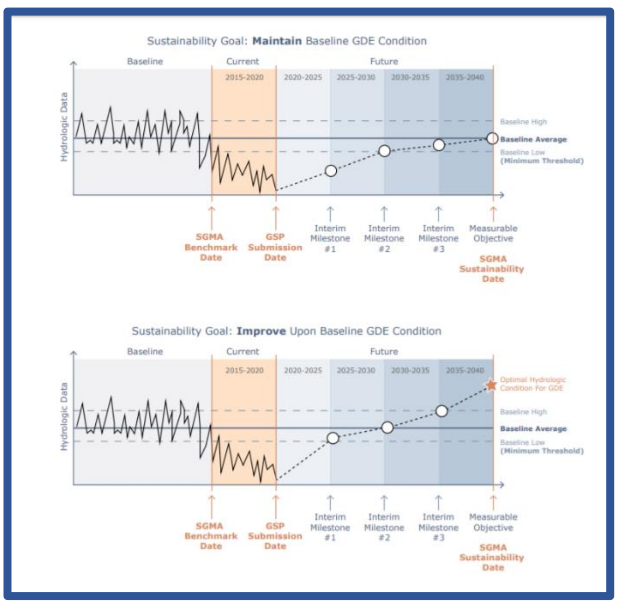

Figure 25 Potential Interim Milestones (The Nature Conservancy, 2018)

6.5 Step Five: Implement a Management Plan

Implementation should be initiated based on the outline developed in the planning process, the management objectives, resource conditions and enhanced understanding of the interactions between groundwater and surface water within the basin to ensure achievement of the identified goals. The monitoring component of the plan will provide a system to track and evaluate the success of the implementation plan. As data is obtained from the systematic monitoring network—two types of data should be collected: (1) routine analysis that tracks progress, assesses data quality and provides scheduled feedback of hydrological changes in the system, and (2) concentrated analysis to establish response measurements of the system to implementation of the plan (Tetra Tech et al., 2013). Results must be documented and communicated publicly with stakeholders and collaborating agencies so that other agencies facing similar issues may benefit from the knowledge gained.

6.6 Step Six: Measure Progress and Adjust

The California Department of Water Resources will review the groundwater sustainability plan for the Santa Rosa Plain Basin every five years to evaluate the plan's progress in achieving these goals set forth in the plan. Upon completion of the evaluation period, the DWR may recommend corrective actions to address any issues or data gaps observed during the evaluation process. Any recommendations brought forward by the DWR must to address in an updated plan for the basin. Updates to the plan must also be made periodically to include any documented changes in the basin that may alter the functionality of plan components such as the monitoring program. Data acquired through the implementation of the plan must be analyzed and compared to model projections—recommendations for future actions should be based on these results.

7. Management Summary

Sustainably managing groundwater-surface water interactions within the Santa Rosa Plain Basin is critical to the security of this valuable resource and the water supply for the basin. The requirements established in the Sustainable Groundwater Management Act comprehensively define the responsibilities of the Santa Rosa Groundwater Sustainability Agency which includes development of a Groundwater Sustainability Plan to ensure that this goal is achieved. The plan must be implemented by 2020 or 2022 and must achieve sustainability twenty years after the initiation of the GSP. Adopting the EPA's recommended methodology established in, *A Quick Guide to the Developing Watershed Plans to Restore and Protect Our Waters*, will provide a framework for the development of the GSP and for achieving the goal of sustainably managing groundwater-surface water interactions.

The SGMA defined metric by which to measure the success of the management plan for these interconnected resources is the volume or rate of surface water depletion. Baseline conditions for the basin must be established to calculate the volume or rate of surface water depletion. SGMA requires that the GSA develops a hydrological conceptual model for the basin to assist in identifying the baseline. Additionally, the health of groundwater dependent ecosystems can contribute to the overall measurement of success in achieving basin goals. The Nature Conservancy has developed, *Groundwater Dependent Ecosystems under the Sustainable Groundwater Management Act*, as a guide to help GSAs to efficiently consider the health of groundwater dependent ecosystems into GSPs. This model has provided me with invaluable scientific data to inform the completion of this document, *Sustainably Managing Groundwater-Surface Water Interactions within the Santa Rosa Plain Basin.* Through the evaluation of the two mentioned documents and numerous other articles, recommendations for minimum thresholds, potential triggers and action items have been identified, analyzed, developed, and compiled —in hopes of providing a resource for the Santa Rosa Plain Basin in the development of the Groundwater Sustainability Plan. These recommendations have been detailed in steps three and four of this paper. I discussed four recommendations for minimum thresholds, indicators for these thresholds and methods for indictor monitoring as well as two potential threshold triggers and recommendations for establishing potential locations for additional groundwater-surface water monitoring. In addition, I discussed types of viable monitoring technology and useful tools to improve monitoring success.

The completion of this document has determined that there are significant data gaps which must be addressed, and additional studies assessed prior to the design and implementation of a successful management plan. There are components of the existing management plan that do not meet the requirements established by SGMA as well a lack of understanding regarding the hydrogeological relationship between groundwater-surface water interactions within the basin. Likewise, the current monitoring plan will need to be updated and additional monitoring locations equipped with shallow wells and stream gages. Streambed conductivity must be considered in the development of the updated monitoring plan to determine viable locations for additional monitoring.

It is my hope that this document will provide a framework for groundwater resource managers to develop plans for sustainably managing groundwater-surface water interactions under the requirements set forth in the Sustainable Groundwater Management Act.

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