Final Plan January 29, 2022

EEL RIVER VALLEY GROUNDWATER SUSTAINABILITY PLAN

Humboldt County Groundwater Sustainability Agency

Ferndale, Loleta, Fortuna, Carlotta, Hydesville, Alton, Metropolitan, Rio Dell, Scotia

Eel River Valley (Jack Rice, January 2022)

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Executive Summary

Part I: Introduction

- Groundwater within the Eel River Valley Groundwater Basin (Basin) is a valuable and essential resource for multiple beneficial uses including agricultural water supply, municipal and domestic water supply, industrial water supply, and freshwater replenishment to surface waters. The Basin is located along the coast of western Humboldt County at the downstream end of the Eel River watershed and extending from the Pacific Ocean upstream through the lower reaches of the Eel and Van Duzen River valleys.
- The Basin is situated primarily within a rural area of Humboldt County and includes the cities of Fortuna, Ferndale, and Rio Dell and the unincorporated communities of Loleta, Carlotta, Hydesville, Alton, Metropolitan, and Scotia. Public water suppliers utilizing groundwater within the basin include City of Fortuna, City of Rio Dell, Riverside Community Services District (CSD), Loleta CSD, Palmer Creek CSD, Hydesville Community Water District, Bear River Band of the Rohnerville Rancheria, and Del Oro Water Company. Del Oro Water Company is an investor-owned public utility company that provides water to the City of Ferndale and surrounding area. The primary water source for the City of Rio Dell and Scotia CSD is surface water from the Eel River; the City of Rio Dell utilizes groundwater as a secondary/emergency source.
- The Eel River Valley supports a vibrant agricultural community made up of both organic and conventional farms and ranches. Farming families produce milk, beef cattle, pasture, corn silage, truck crops, vegetables, apples, quinoa, and other crops in one of Humboldt County's finest growing regions. The mild climate and deep alluvial soils provide ideal conditions for raising livestock and growing forage crops. Dairy producers and ranchers pump groundwater for pasture irrigation, livestock watering, facility cleaning, and dairy nutrient management. In 2021, a total of 12,952 acres of agricultural land were irrigated by groundwater.
- The Basin is bisected by the lower reaches of the Eel River and its tributary the Van Duzen River, both of which provide habitat for anadromous salmonids and other fish and aquatic species. The Basing contains terrestrial and aquatic groundwater-dependent ecosystems (GDEs) which have high ecological value based on the presence of directly or indirectly groundwater-dependent special-status species and identified critical habitat.
- Following the adoption of the Sustainable Groundwater Management Act (SGMA) in 2014, the Basin was designated as medium-priority by the California Department of Water Resources (DWR) and subject to mandatory compliance requirements under SGMA.
- In 2015, Humboldt County received a planning grant from DWR for technical studies and planning which led to the submission in December 2016 of a Groundwater Sustainability Plan (GSP) Alternative, a streamlined version of a GSP. The GSP Alternative was disapproved by DWR in 2019 primarily because objective management criteria had not been established for 10 years; a quantitative estimate of sustainable yield was not developed; and the GSP Alternative did not quantify the impacts of groundwater use on surface water systems and determine at what point they are significant and unreasonable. As a result of the GSP Alternative being disapproved, formation of a Groundwater Sustainability Agency (GSA) was required and development of a full GSP is required by January 31, 2022.
- In May 2020, the Humboldt County Board of Supervisors formed the Humboldt County GSA. Also in 2020, Humboldt County received a planning grant from DWR to perform additional field work, develop an integrated groundwater-surface water computer model, and prepare a GSP in collaboration with water suppliers, water users, the Humboldt County Resource Conservation

District, and the U.S. Geological Survey. Humboldt County retained a consultant team to assist with data collection, technical studies, stakeholder outreach, and plan preparation. Several technical memoranda were prepared to document the data collection and analysis and these memoranda are provided in the Appendices to this GSP.

- The purpose of this GSP is to present a framework for sustainably managing groundwater resources within the Basin for economic, social, and environmental benefits through local control and based on the best available science and technical information. The GSP synthesizes empirical data, stakeholder input, computer simulation results, and geological interpretation to establish a management framework that best fits the current conditions and community interests of the Basin.
- The average annual groundwater use within the Basin from water year 2011 through 2020 was 14,837 acre-feet, which includes:

Agricultural Irrigation	12,559 acre-feet	(85%)
Municipal Drinking Water	1,733 acre-feet	(12%)
Domestic Drinking Water	414 acre-feet	(3%)
Other	132 acre-feet	(<1%)

- Irrigation water use was estimated based on direct measurements using monitoring data collected during the 2021 water year from eight flow meters installed on irrigation systems. The flow meters were spatially distributed across the Basin and represented the range of irrigation system types (traveling gun, center pivot, wheel line, handline, and K-line). Flow meter measurements were used to calculate total groundwater volume extracted at each meter location and this information was extrapolated across the Basin to provide an estimate of total groundwater volume extracted for agricultural irrigation by water year type.

Part II: Basin Setting

- The primary water-bearing units within the Basin are the alluvial aquifer and the underlying Carlotta formation. The alluvial aquifer is the most productive aquifer and most utilized aquifer in the Basin. The alluvial aquifer is most prominent within the central portions of the lower Eel River Valley, where the thickness is in excess of 260 feet, and extends up the Van Duzen River Valley, thinning from approximately 125 feet thick at the confluence with the Eel River to less than 40 feet in the vicinity of Carlotta. Most wells in the alluvial aquifer are less than 100 feet deep. The physical characteristics of the alluvial aquifer reflect the dynamic tectonic and geomorphic history in the area and are observed to have significant lateral variation. In general, the alluvium is an accumulation of a variety of relatively young unconsolidated sediment, tending to be coarser (sands, gravels) in areas where the river channels have migrated and finer (silts, clays) in areas where floodplain processes dominate. The surface waters of the Eel and Van Duzen Rivers are generally in direct contact and hydraulic connection with the alluvial aquifer.
- The Carlotta formation underlies the alluvial aquifer and consists of an interbedded range of materials, from coarse-grained sediments deposited in a near-shore or terrestrial setting to thick sequences of fine-grained sediments deposited in estuarine and bay environments. The Carlotta formation is known to be more than 1,500 feet thick and only the upper part of the Carlotta formation is tapped by water wells. Wells extracting groundwater from the Carlotta formation are predominantly found in upland areas, often on the order of 200 to 400 feet deep. In general, the Carlotta aquifer is not as productive as the alluvial aquifer.
- Historical data regarding groundwater levels is available going back to the early 1950s and more extensive groundwater investigation has been performed since 2016. Groundwater elevations within the Basin are generally stable. The range in elevations between the spring and fall seasons

is generally less than ten feet and the alluvial aquifer maintains a consistent gradient towards the ocean. The hydrograph data show that the fall elevations are particularly stable with only very slight deviations from what appears to be a baseline elevation, including during the severe drought conditions of 2013 and 2014.

- The alluvial aquifer within the lower Eel River Valley is in contact with the ocean on the west and surrounded on the east and north sides by the Eel River. The boundary conditions provided by the ocean and the Eel River play a critical role in the stability of groundwater conditions. The surface level of the ocean presents a physical limit to the level to which groundwater elevation can fall. Monitoring wells installed in close proximity to the Eel River generally encounter sediments with high hydraulic conductivity and their hydrographs show a strong connection with river level changes. The capacity for the Eel River to provide significant recharge to the adjacent alluvial aquifer sets up a condition where the base flow within the river channel provides a control on groundwater elevations within the alluvial aquifer. The elevations of the surface water and groundwater remain connected and at similar elevations through the year. Thus, the presence of the Eel River is a critical factor for maintaining stable groundwater levels.

- The seaward flow of fresh groundwater and the landward flow of seawater have a dynamic interface in coastal aquifers. The freshwater-seawater transition zone in the alluvial aquifer of the Basin changes seasonally but appears stable. The presence of the Eel River maintains a seaward groundwater gradient which serves to hold the seawater-freshwater interface steady in its position. Additional data is being collected to investigate the extend of seawater intrusion within the deeper portion of the aquifer system.

- Water quality within the Basin is generally of good quality and suitable for its intended uses. There are no known conditions of degradation of groundwater quality related to groundwater management or use. The Basin has naturally occurring moderate to high concentrations of total dissolved solids (TDS), iron, manganese, and arsenic. The water quality trends for these constituents do not show any significant increase in measured concentrations. The City of Fortuna, Del Oro Water Company, and Palmer Creek CSD all use filtration systems specifically to remove iron and manganese, which is a standard practice for water treatment. The municipal raw water data for water suppliers in the Basin do not show any exceedances of the secondary maximum contaminant levels for TDS or nitrate. Since 2002, arsenic has been detected in one water supply well at relatively steady concentrations below the maximum contaminant level (with the exception of one anomalous value). Arsenic was detected at depth (greater than 200 feet below ground surface) in six monitoring wells and is interpreted to represent an elevated background condition in deeper portions of the aquifer system.

- Annual changes in storage are primarily a function of the amount of recharge in the preceding water year. The magnitude of change is greatest when sequential winters are alternately wet and dry. The water budget indicates that groundwater storage within the Basin is stable with no significant change between 2000 and 2020.

- The ecological condition of groundwater-dependent vegetation is generally good based on satellite data which estimates vegetation greenness, an indicator of vigorous, growing vegetation.

- An integrated groundwater-surface water model (also known as a hydrologic model) was developed to simulate the movement of groundwater and surface water through the Basin. Development of this model was a major investment under the 2020 planning grant. Previous work by the U.S. Geological Survey provided the foundation for building the model. The modeling approach uses MODFLOW-2005 (groundwater flow), SEAWAT (seawater intrusion), the Streamflow Routing package of GSFLOW (groundwater/surface water interaction), and Precipitation Runoff Modeling System (PRMS, for watershed hydrology). The model provides a computer-based representation of the Eel River watershed, the principal aquifers in the Basin, the Pacific Ocean, and the Eel and Van Duzen Rivers to gain insight into hydrologic processes and to simulate potential future scenarios. Such models provide an essential tool for examining the interactions between groundwater and surface water but have inherent limitations. Modeling results should be interpreted with an awareness of uncertainty and in conjunction with science-based reasoning and other lines of evidence.

Part III: Sustainable Management

- The fundamental goal of SGMA is to support beneficial uses of groundwater while avoiding undesirable results for six sustainability indicators: groundwater level declines, groundwater storage reductions, seawater intrusion, water quality degradation, land subsidence, and interconnected surface water depletion. SGMA requires the establishment of sustainable management criteria for each of the six sustainability indicators, unless a GSA can demonstrate that undesirable results related to one or more sustainability indicators are not present and are not likely to occur. Undesirable results occur when significant and unreasonable effects for any of the sustainability indicators are caused by groundwater conditions occurring throughout the basin. Undesirable results are based on a quantitative description of the combination of minimum threshold exceedances that cause significant and unreasonable effects in the basin. Minimum thresholds quantify the conditions at representative monitoring sites that are used to define undesirable results. Measurable objectives are quantitative goals that reflect the basin's desired groundwater conditions.

- The sustainability goal of this GSP is to maintain high-quality and abundant groundwater resources in the Basin to support existing and long-term community needs without causing undesirable results. Groundwater is needed within the Basin for drinking water and personal use, agricultural irrigation, industrial process water, and ecosystem services. This GSP determined that the Basin's sustainability goal is being achieved, as described below for each of the six sustainability indicators.

- **Chronic lowering of groundwater levels**: The rate of groundwater pumping within the Basin has remained stable during the period of record and historical data do not reflect any significant declining trends for groundwater levels. Chronic lowering of groundwater levels could cause wells with shallow well screens (i.e., screens that are relatively close to the ground surface) to yield less water or, in the worst case, to cease production. Minimum thresholds for groundwater levels in representative monitoring sites were developed to maintain groundwater at levels that ensure at least ten feet of saturated well screen within wells installed after 1964 with appropriate sanitary seals.

- **Reduction in groundwater storage**: Maintaining groundwater elevations above the minimum thresholds for chronic lowering of groundwater levels will maintain an adequate amount of groundwater in storage, based on the well-established hydrogeologic principle that the volume of groundwater in storage is directly proportional to groundwater elevations.

- **Seawater intrusion**: Minimum thresholds for chloride concentrations were developed for representative monitoring sites to maintain the chloride concentration isocontour line near the location measured in water year 2021. In addition, minimum thresholds for groundwater levels were developed to ensure that a flow gradient toward the ocean is maintained.

- **Degraded water quality**: One constituent of concern, arsenic, was identified as a precautionary measure to ensure that concentrations within municipal supply wells remain below the maximum contaminant level for drinking water. The minimum threshold for degraded water quality is two supply wells exceeding the arsenic maximum contaminant level (currently there are none).

- **Subsidence**: The Basin is susceptible to subsidence (or uplift) caused by seismic activity associated with the Cascadia Subduction Zone, but land subsidence caused by groundwater conditions is not considered to be a concern. The granular nature of the aquifer materials, the relative stability and consistency in the range of groundwater elevation fluctuations, and the narrow range of annual groundwater fluctuation support the conclusion that the conditions that could lead to land subsidence caused by groundwater pumping do not exist in the Basin. Therefore, sustainable management criteria were not established for subsidence.
- **Depletion of interconnected surface water**: The integrated groundwater-surface water model was used to estimate the volume of surface water depletion caused by groundwater extraction in the Basin and provide the basis for minimum thresholds. The general approach focused on fish passage criteria and the minimum water depth required for passage of adult salmon. Fish passage can be limited by the river stage at critical riffles within a reach. Adult Chinook salmon begin entering the Eel River estuary in August or early September and wait, often gathering in pools, until conditions are suitable for migrating upstream to spawning areas. Steelhead begin arriving in September and coho salmon generally arrive in October. Upstream migration is typically triggered by a significant rain event and the associated increase in flows. California Department of Fish and Wildlife uses a standard of 0.7 feet as the minimum critical riffle depth to allow passage of adult salmonids. Fish have been observed at the mouth of the Van Duzen River when flows were as low as 130 cubic feet per second at the Scotia gauge.

  Because fish passage is considered one of the most sensitive indicators of surface water beneficial uses and a quantitative framework for riffle depth is available, the potential change in river stage relative to minimum fish passage depth was selected as the basis for setting minimum thresholds for surface water depletions. A reduction in stage of 0.1 feet was set as a conservative benchmark for potential impact on riffle depth and fish passage. This value represents a threshold of detection and not a threshold of significant and unreasonable impact. Exceedance of this benchmark does not mean that beneficial uses of interconnected surface waters are degraded or the viability of special-status species are threatened, but provides a starting point for analysis. Computer simulation modeling using a number of conservative assumptions indicated that groundwater pumping could increase by 150% above current conditions before the stage of the Eel River would be reduced by 0.1 feet at the downstream end of the study reach (near Fernbridge) when fish passage conditions exist.

  Minimum thresholds were developed to maintain groundwater pumping below a 100% increase from current conditions as a precautionary measure (rather than 150%) and to maintain groundwater above levels that correlate with a 100% increase in pumping using modeling simulation. If groundwater pumping within the Basin increases by 100% above current levels or if groundwater levels in two or more wells within the network of representative monitoring sites fall below their minimum thresholds for two sequential years, then further analysis would determine if beneficial uses of interconnected surface waters are degraded or the viability of special-status species are threatened, and whether reasonable reductions or limitations in groundwater pumping could avoid these effects without jeopardizing other beneficial uses of groundwater.
- The sustainable yield for the Basin is estimated to be at least 30,000 acre-feet per year.
- The Humboldt County GSA will perform the monitoring and reporting activities required by SGMA and will consider other projects and management actions as appropriate to maintain sustainable groundwater conditions and enhance beneficial uses of groundwater and interconnected surface waters. The best investment of time and resources would likely be for projects to increase streamflow entering the Basin, especially during the dry season, and for in-stream restoration projects to improve geomorphic conditions within the Eel River, Van Duzen River, and other surface waters within the Basin.

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City of Rio Dell
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Riverside Community Services District
Loleta Community Services District
Palmer Creek Community Services District
Hydesville Community Water District
Bear River Band of the Rohnerville Rancheria
Del Oro Water Company

Humboldt County Resource Conservation District

United States Geological Survey

Agencies and Tribes

Bear River Band of the Rohnerville Rancheria
California Coastal Commission
California Department of Fish & Wildlife
California Department of Water Resources
City of Ferndale
National Oceanic and Atmospheric Administration
North Coast Regional Water Quality Control Board
U.C. Cooperative Extension
USDA – Natural Resources Conservation Service
Wiyot Tribe

Non-Governmental Organizations

Buckeye Conservancy
California Cattlemen's Association
Cal-Trout
Eel River Recovery Project
Eel River Watershed Improvement Group
Friends of the Eel River
Humboldt County Farm Bureau
The Nature Conservancy
Pacific Coast Federal of Fishermen's Assoc.
Trout Unlimited
Western United Dairies
The Wildlands Conservancy

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In Memoriam: Denver Nelson (1941-2021)

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PART I: INTRODUCTION

This document serves as the Groundwater Sustainability Plan (GSP) for the Eel River Valley Groundwater Basin (Basin), shown in Figure 1, for compliance with the Sustainable Groundwater Management Act (SGMA).

1 FOUNDATION

1.1 Groundwater in California

Individuals, communities, and ecosystems all depend on water to survive and flourish. Water is needed in sufficient quantity and quality for human consumption, hygiene, and sanitation as well as to grow food, support economic productivity, and sustain the natural environment. Water supply in California is provided primarily from collecting precipitation in reservoirs and diverting water from rivers or pumping groundwater from aquifers. Systems for meeting California's water supply needs vary widely across the state, ranging from individual wells to community and municipal water systems to expansive water projects. Similarly, climate conditions and water availability range widely across the state's vast landscape. Some communities and regions rely on a diverse portfolio of water sources while others are dependent on a single source. Most precipitation in California comes in the winter from November through March, resulting in a dry season during the summer and early fall when water supplies may become limited. Water availability is affected by droughts and floods, which are a natural part of hydrologic variability, and increasingly by global climate change which alters the historical patterns of air temperature, precipitation, storm intensity, and sea level.

California promotes diversified, regional strategies to achieve long-term water resilience and ecosystem health (California Natural Resources Agency, 2020). Water resources are managed at the state level primarily by the California Department of Water Resources (DWR) and the State Water Resources Control Board (State Water Board). Water use is typically measured in units of gallons or acre-feet. One acre-foot of water is equivalent to the volume of water needed to cover one acre of land to a depth of one foot. One acre-foot is equivalent to approximately 326,000 gallons. An average household in California uses between one-half and one acre-foot of water per year for indoor and outdoor use (Water Education Foundation, 2021).

Groundwater is a critical resource for providing water supply for municipal, domestic, agricultural, commercial, and industrial uses and for sustaining aquatic and terrestrial ecosystems (DWR, 2021). Groundwater is part of the hydrologic cycle in which water continuously moves between the atmosphere and the surface and subsurface of the Earth (Diagram 1). Groundwater is water that occurs below the ground surface in saturated sediment deposits or fractured rock. An **aquifer** is a three-dimensional body of porous and permeable sediment or sedimentary rock that contains sufficient saturated material to yield significant quantities of groundwater to wells and springs [Title 23 of the California Code of Regulations (23 CCR), Section 341(f)]. The term **water table** refers to the top of the aquifer. Water can be extracted from an aquifer by drilling a well with a permeable screen a sufficient distance below the water table. A **groundwater basin** is an aquifer or stacked series of aquifers with reasonably well-defined boundaries in a lateral direction and a definable bottom [23 CCR Section 341(g)(1)]. Some basins are further subdivided into subbasins based on geologic and hydrologic barriers or institutional boundaries. Areas outside of defined groundwater basins are referred to as non-basin areas. Non-basin areas generally consist of impermeable granitic, metamorphic, volcanic, or sedimentary rocks where groundwater is found in fractures or other voids (DWR, 2021).

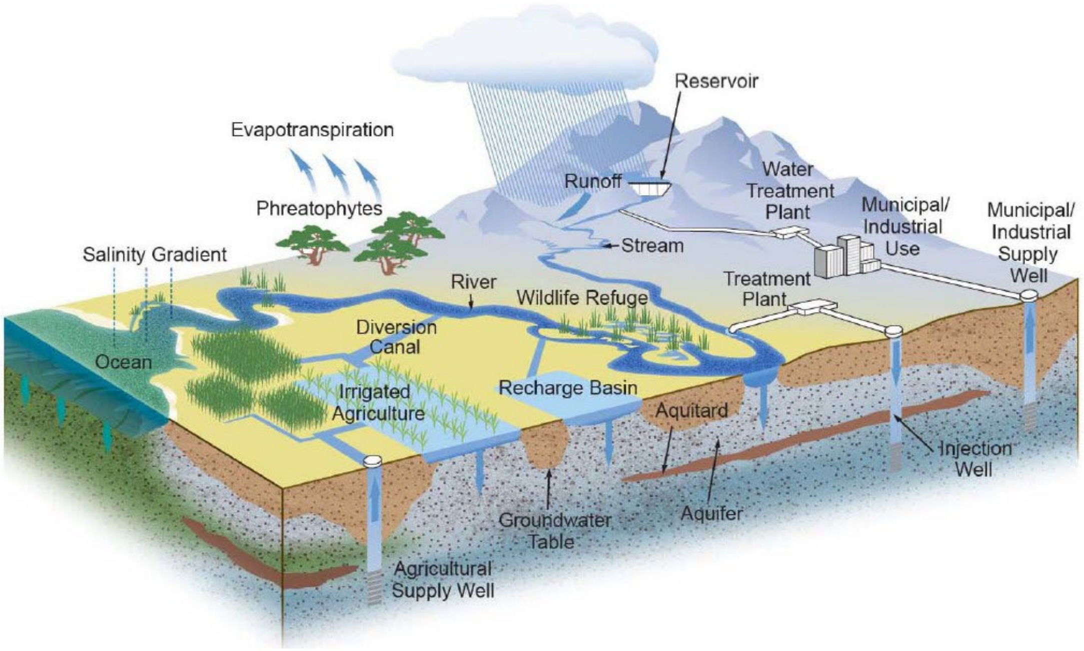


Diagram 1: A Conceptual Schematic of the Hydrologic Cycle (from DWR 2020).

DWR currently defines a total of 515 basins (or subbasins) within the state. DWR designates four priority levels (high, medium, low, and very-low) for groundwater basins based on eight criteria (Water Code Section 10933) addressing the relative importance of groundwater as a water supply source and the potential for adverse effects from groundwater use. Designation as a high- or medium-priority basin does not imply or signify that groundwater resources are impaired or threatened. Rather, these designations indicate that the basins warrant a formal level of assessment and management (see Section 1.2) based on DWR's scoring system. Similarly, designation as a low or very-low priority basin does not indicate that groundwater resources are not locally or regionally important or that the basin is not vulnerable to stresses or overuse. According to state regulations, basins designated as low- or very-low priority are not subject to mandatory compliance requirements. Historically, DWR has updated the priority levels for basins within the state based on current data and information. In 2019, DWR identified a total of 94 medium- and high-priority basins within the state.

Groundwater levels within a basin fluctuate year to year based on patterns of precipitation and recharge and rates of extraction. DWR defines the term **overdraft** as "the condition of a groundwater basin or subbasin in which the amount of water withdrawn by pumping exceeds the amount of water that recharges the basin over a period of years, during which the water supply conditions approximate average conditions" (DWR, 2021). Groundwater levels in an overdrafted basin decline over a period of years without recovering to baseline conditions, even in wet years. In 2019, DWR identified a total of 21 basins within the state as subject to critical conditions of overdraft.

A total of 15 designated groundwater basins are situated within Humboldt County. The Basin is the only medium-priority basin within Humboldt County and no high-priority basins are present. The nearest medium- or high-priority inland basins are Scott River Valley, Shasta Valley, Ukiah Valley, and Santa Rosa Plain and the nearest medium- or high-priority coastal basin is Santa Cruz Mid-County. DWR has not designated the Basin as having critical conditions of overdraft.

1.2 Water Rights

Groundwater law in California is established through the common law system whereby the law is derived from judicial decisions rather than from statutes. Three potential types of water rights may exist for pumping groundwater: overlying rights, appropriative rights, and prescriptive rights (Garner et al, 2020; DWR, 2021). In water law, groundwater is sometimes called percolating water.

An overlying right is the right of a landowner to pump groundwater from underneath that land for beneficial use on land overlying the basin. An overlying right is an inherent part of the property and, thus, is a form of real property. Overlying landowners generally do not require discretionary permission to exercise their rights to access groundwater for reasonable and beneficial use. Overlying rights are not lost through non-use. A landowner's overlying right is of equal priority and correlative with the overlying rights of other landowners within the basin. A landowner with an overlying right does not have the right to exclude others from exercising their overlying rights. If the groundwater supply is not sufficient for all overlying uses, each user is entitled to a fair and just proportion of the "safe yield" and/or "sustainable yield" of the basin. Groundwater water rights can be determined through a judicial process called an adjudication.

An appropriative right to groundwater is established by using water for a non-overlying use. Water not needed by overlying landowners for reasonable and beneficial use is available for appropriation. Appropriative rights require continued use of groundwater to preserve the right and have a lower priority than overlying rights. Municipal water suppliers are classified as appropriative users.

A prescriptive groundwater right is established through adverse possession of someone else's water right when the basin is in a condition of overdraft.

Water rights are subject to the overriding constitutional limitation of Article X, section 2 of the California Constitution which requires that "the water resources of the State be put to beneficial use to the fullest extent of which they are capable, and that the waste or unreasonable use or unreasonable method of use of water be prevented, and that the conservation of such water is to be exercised with a view to the reasonable and beneficial use thereof in the interest of the people and for the public welfare." Water rights are rights of use (usufructuary), which means that the water right holder has the right to take physical possession of the water for the purpose of putting it to reasonable and beneficial use, but the water itself remains the property of the State (Water Code Section 102).

Groundwater rights are typically not quantified. Disputes over the apportionment of groundwater may result in an adjudication by the courts to set fair and reasonable allocations. Portions of 42 basins within the state have been adjudicated (DWR, 2021). The adjudication process is expensive and time-consuming and may result in the creation of a watermaster to administer and enforce the provisions of the adjudication.

1.3 Sustainable Groundwater Management Act

SGMA was passed by the California Legislature and signed by the Governor in September 2014, creating a new state-wide framework for groundwater resource management. Management responsibility under SGMA is delegated to the local level with state oversight by DWR and the State Water Board. SGMA established the following state policy of sustainable, local groundwater management (Water Code Section 113):

> "It is the policy of the state that groundwater resources be managed sustainably for long-term reliability and multiple economic, social and environmental benefits for current and future beneficial uses. Sustainable groundwater management is best achieved locally through the development, implementation, and updating of plans and programs based on the best available science."

SGMA established Sections 10720-12934 in the Water Code and implementing regulations were adopted in 23 CCR Sections 350-358.4. The legislative intent of SGMA (Water Code Section 10720.1) is as follows:

a) To provide for the sustainable management of groundwater basins.

b) To enhance local management of groundwater consistent with rights to use or store groundwater and Section 2 of Article X of the California Constitution. It is the intent of the Legislature to preserve the security of water rights in the state to the greatest extent possible consistent with the sustainable management of groundwater.

c) To establish minimum standards for sustainable groundwater management.

d) To provide local groundwater agencies with the authority and the technical and financial assistance necessary to sustainably manage groundwater.

e) To avoid or minimize subsidence.

f) To improve data collection and understanding about groundwater.

g) To increase groundwater storage and remove impediments to recharge.

h) To manage groundwater basins through the actions of local governmental agencies to the greatest extent feasible, while minimizing state intervention to only when necessary to ensure that local agencies manage groundwater in a sustainable manner.

The fundamental goal of SGMA is to support beneficial uses of groundwater while avoiding undesirable results for six sustainability indicators: groundwater level declines, groundwater storage reductions, seawater intrusion, water quality degradation, land subsidence, and interconnected surface water depletion. The two fundamental approaches for eliminating overdraft conditions or undesirable results are supply augmentation and demand management.

SGMA contains mandatory compliance requirements for high- and medium-priority basins while actions for low- and very-low priority basins are voluntary. Where compliance is mandatory, a local agency must form a Groundwater Sustainability Agency (GSA) to fully cover the basin; prepare a GSP or Groundwater Sustainability Plan Alternative (GSP Alternative); implement the GSP and manage to achieve quantifiable objectives and sustainability no later than 20 years after GSP adoption; and perform annual monitoring and progress reporting to DWR and update the GSP every five years.

Key principles of SGMA include the following:

- Groundwater resources shall be managed for long-term reliability and multiple economic, social and environmental benefits for current and future beneficial uses (Water Code Section 113).
- Sustainable groundwater management is best achieved locally (Water Code Section 113).
- GSPs shall rely on the best available information and best available science (Water Code Section 113).
- SGMA does not determine water rights or alter the common law system of water rights [Water Code Section 10720.5 and Water Code Section 10726.4(a)].
- GSAs shall consider the interests of all beneficial uses and users of groundwater (Water Code Section 10723.2).
- GSAs have the discretion to exercise any of the powers and authorities established by SGMA (Water Code Section 10725).
- Groundwater conditions must be adequately defined and monitored to demonstrate that a GSP is achieving the sustainability goal of the basin (23 CCR 350.4).
- GSPs must include a description of the basin setting, sustainable management criteria, a description of the monitoring network, and projects and management actions (23 CCR 354). GSPs must include a detailed water budget of inflows and outflows and (effectively) use a computer model to simulate groundwater and surface water interactions.

SGMA directs DWR to review submitted GSPs based on the criteria specified at 23 CCR 355.4(b). DWR will first post a submitted GSP for a public comment period of no less than 60 days. Following the public comment period, DWR will review the submitted GSP to determine whether the plan substantially complies with the review criteria. Substantial compliance means that the supporting information is sufficiently detailed and the analyses sufficiently thorough and reasonable, in the judgment of DWR, to evaluate the plan, with any discrepancies not materially affecting the ability of the GSA to achieve the sustainability goal for the basin [23 CCR 355.4(b)]. DWR will evaluate the submitted GSPs within two years of the submittal dates and issue written assessments.

DWR’s assessment can result in three determinations: (1) the GSP is approved; (2) the GSP is incomplete but the GSA has 180 days to address deficiencies; or (3) the GSP is inadequate because it contains significant deficiencies based on one or more criteria identified in 23 CCR 355.4(b) that will take more than 180 days for the GSA to address. An inadequate plan results in DWR consulting with the State Water Board and can trigger the state intervention process, which authorizes the State Water Board to step in to manage the basin (DWR, 2021). After notice and a public hearing, the State Water Board can designate the basin as probationary. If the deficiencies identified in the probationary designation are not remedied within a year, the State Water Board, after a subsequent notice and hearing, may develop and adopt an interim plan to manage groundwater use in the basin.

1.4 Eel River Valley Groundwater Basin: Overview

Groundwater within the Eel River Valley is a valuable and essential resource with multiple beneficial uses, including agricultural water supply, municipal and domestic water supply, industrial water supply, and freshwater replenishment to surface waters. Beneficial uses of groundwater within the Basin are further discussed in Section 2.4. The Basin's abundant groundwater resources are the result of favorable climate, geology, and hydrology as detailed in the Basin Setting (Sections 3, 4, and 5).

The Basin is situated primarily within a rural area of Humboldt County and within ancestral lands of the Wiyot Tribe. The Basin includes (Figure 2):

- The cities of Fortuna, Ferndale, and Rio Dell.
- The unincorporated communities of Loleta, Carlotta, Hydesville, Alton, Metropolitan, and Scotia.
- Bear River Band of the Rohnerville Rancheria and Wiyot tribal lands.
- Units of the Eel River Wildlife Area and a small portion of the Table Bluff Ecological Reserve, owned and managed by the California Department of Fish and Wildlife.

The U.S. Census Bureau identifies Loleta, Hydesville, and Scotia as "census-designated places." According to DWR's SGMA Basin Prioritization Dashboard (https://gis.water.ca.gov/app/bp-dashboard/final/), the total resident population within the Basin was 23,384 in 2010. Resident population data from the U.S. Census Bureau for the cities and census-designated places within the Basin in 2019, 2010, 2000, and 1990 are provided in Table 1.

Water Code Section 79505.5(a) defines the term "disadvantaged community" as a community with an annual median household income less than 80 percent of the statewide annual median household income. Water Code Section 79702(k) defines the term "economically distressed area" as a municipality with a population of 20,000 persons or less, a rural county, or a reasonably isolated and divisible segment of a larger municipality where the segment of the population is 20,000 persons or less, with an annual median household income that is less than 85% of the statewide median household income, and with one or more of the following conditions: (1) financial hardship, (2) unemployment rate at least 2% higher than the statewide average, or (3) low population density. According to DWR's EDA Mapping Tool (https://gis.water.ca.gov/app/edas/), at least 77% of the Basin is considered an economically distressed area.

Table 1: Resident Populations for Cities and Census-Designated Places within the Basin

City or Census-Designated Place	2019	2010	2000	1990
Fortuna	12,259	11,926	10,497	8,788
Rio Dell	3,349	3,368	3,174	2,997
Ferndale	1,352	1,371	1,382	1,331
Hydesville	n/a	1,237	1,209	1,131
Scotia	n/a	850	n/a	n/a
Loleta	n/a	783	n/a	n/a

Sources: https://www.census.gov/prod/cen2010/cph-2-6.pdf
https://www.census.gov/programs-surveys/popest/data/tables.html

The Basin has a high reliance on groundwater for water supply with no imported water and very little surface water use. Before SGMA, there was no coordinated groundwater management within the Basin. The Basin is not adjacent to another groundwater basin subject to SGMA and does not contain areas with adjudicated groundwater rights.

Public water suppliers utilizing groundwater within the basin include City of Fortuna, City of Rio Dell, Riverside Community Services District (CSD), Loleta CSD, Palmer Creek CSD, Hydesville Community Water District, Bear River Band of the Rohnerville Rancheria, and Del Oro Water Company. Del Oro Water Company is an investor-owned public utility company that provides water to the City of Ferndale and surrounding area. The primary water source for the City of Rio Dell and Scotia CSD is surface water from the Eel River; the City of Rio Dell utilizes groundwater as a secondary/emergency source.

The Eel River Valley supports a vibrant agricultural community made up of both organic and conventional farms and ranches. Farming families produce milk, beef cattle, pasture, corn silage, truck crops, vegetables, apples, quinoa, and other crops in one of Humboldt County's finest growing regions. The mild climate and deep alluvial soils provide ideal conditions for raising livestock and growing forage crops. Dairy producers and ranchers pump groundwater for pasture irrigation, livestock watering, facility cleaning, and dairy nutrient management. The Basin contains approximately 28,750 acres actively used for agricultural production. In 2021, a total of 12,952 acres of agricultural land were irrigated by groundwater.

The Basin is bisected by the lower reaches of the Eel River and its tributary the Van Duzen River, both of which are interconnected with groundwater and provide habitat for anadromous salmonids and other fish and aquatic species. The Basin contains the lower reaches of several tributary streams including Salt River, Palmer Creek, Rohner Creek, and Yager Creek. The Basin is a coastal basin with drainage to the ocean along approximately ten miles of coastline. The Basin encompasses the Eel River estuary, which includes portions of the Eel River Wildlife Area managed by California Department of Fish and Wildlife (CDFW). The tidally influenced reach of the Eel River extends approximately 12 miles upstream from the river mouth, a few miles upstream of Fernbridge.

The physical characteristics of the Eel River and Van Duzen River were heavily impacted by the major flood of 1964 and continue to be in an overall state of recovery (CDFG, 2010; Kelsey, 1980). Coarse sediment (sand, gravel, cobble) is extracted from portions of the channels in the lower reaches of the Eel River and Van Duzen River to produce aggregate material for construction (Section 2.8). The Humboldt County Resource Conservation District (RCD) is leading a major restoration project on the Salt River and its tributaries, and other restoration projects are in various phases of development (Section 2.10). The dunes along the coastline, especially near Centerville, have experienced significant disturbance and alteration from coastal erosion, which has affected the extent of inland coastal flooding.

Historical groundwater studies of the Basin include Ogle (1953), Evenson (1959), and U.S. Geological Survey (USGS) (1978).

1.5 Groundwater Sustainability Plan Alternative (2016)

In July 2016, DWR awarded Humboldt County a Proposition 1 Sustainable Groundwater Planning Grant ($250,000) to complete the Eel River Valley Groundwater Basin Assessment (2016 Basin Assessment). The 2016 Basin Assessment was a preliminary geologic and hydrogeologic investigation combined with initial management planning efforts in response to

SGMA. The project was designed to provide data and evaluation needed to determine whether the Basin is being managed sustainably and to support the determination on the most appropriate compliance option for SGMA. SGMA contains a provision that allowed a local agency to submit a more streamlined planning document, called a Groundwater Sustainability Plan Alternative (GSP Alternative), by December 31, 2016, if there was sufficient evidence that the groundwater basin had been managed sustainably for ten years.

Field work for the 2016 Basin Assessment included installation of nine new monitoring wells, collection of water level measurements in more than 60 wells, testing of aquifer characteristics, and collection of water surface and flow measurements in the Eel River. This assessment provided the first focused study on the interaction between groundwater and surface water in the Basin. Based on information provided by groundwater users, analysis performed through the Basin Assessment, and guidance from the Eel River Valley Working Group, Humboldt County concluded that the Basin had been managed sustainably without undesirable results for at least ten years. A GSP Alternative for the Eel River Valley basin was submitted on December 30, 2016 (SHN, 2016). Formation of a GSA was deferred because SGMA allowed submittal of a GSP Alternative by a local agency without forming a GSA. During the period between submission of the GSP Alternative and DWR's determination, Humboldt County conducted annual monitoring and continued with stakeholder engagement.

On July 17, 2019, DWR issued a notification letter and staff report stating the intention to disapprove the GSP Alternative submitted by Humboldt County. The letter and staff report state that DWR does not conclude that the Basin is, or has been, managed unsustainably. Rather, the GSP Alternative was disapproved primarily because:

- Objective management criteria were not established for at least 10 years prior to 2014.
- A quantitative estimate of sustainable yield was not developed.
- The GSP Alternative did not quantify the impacts of groundwater use on surface water systems and determine at what point they are significant and unreasonable.

On October 21, 2019, Humboldt County communicated with the State Water Board regarding the presumed disapproval of the GSP Alternative and Humboldt County's plans to form a GSA and apply for Proposition 68 funds to develop a GSP (see Section 1.5). The State Water Board explained that upon final disapproval, the basin would immediately be considered an "unmanaged area" and could be designated a probationary area six months following the final disapproval if a GSA is not formed.

On November 12, 2019, the Humboldt County Board of Supervisors approved Resolution 19-111 which affirmed Humboldt County's commitment to continue working collaboratively with water users and stakeholders to form a GSA for the Basin, as described in the following section. On November 13, 2019, DWR issued their final determination with a statement of findings that the GSP Alternative was disapproved.

1.6 Humboldt County Groundwater Sustainability Agency

1.6.1 Formation

The Humboldt County Groundwater Sustainability Agency was formed on May 5, 2020, by the Humboldt County Board of Supervisors through the adoption of Resolution 20-39 (Appendix A). DWR posted Humboldt County's intent to form a GSA on May 21, 2020, and Humboldt County was immediately deemed the exclusive GSA for the Basin in accordance with Water Code Section 10724.

Contact information for the Humboldt County GSA is as follows:

Humboldt County GSA
Humboldt County Department of Public Works
1106 Second Street
Eureka, CA 95501-0579

1.6.2 Organization and Administration

The Humboldt County GSA is governed by the Humboldt County Board of Supervisors and managed by staff of the Humboldt County Department of Public Works. The Humboldt County GSA is responsible for making final policy decisions related to the GSA and adopting and implementing the Eel River Valley GSP.

Management of GSP implementation will be administered by the Humboldt County Department of Public Works consistent with the GSP and under the direction of the Humboldt County Board of Supervisors serving as the GSA. The Humboldt County GSA will continue to engage jurisdictional partners, the Eel River Valley Groundwater Working Group, and other stakeholders in the GSP implementation process.

The plan manager for the GSP is Hank Seemann, Public Works Deputy-Director (Environmental Services). Mr. Seemann's contact information is as follows:

Hank Seemann
Humboldt County Department of Public Works
1106 Second Street
Eureka, CA 95501-0579
Phone: 707-445-7741
Email: hseemann@co.humboldt.ca.us

1.6.3 Legislative Powers and Authorities

As the exclusive GSA for the Basin, SGMA provides Humboldt County with the authority necessary to develop and implement a GSP for the Basin (Water Code Section 10725-10726.9). These authorities are in addition to Humboldt County's inherent police power to manage groundwater, including well permitting authority.

1.7 Sustainable Groundwater Management Planning Grant (2020-2022)

On November 14, 2019, Humboldt County submitted a grant application to DWR to obtain a planning grant under the Sustainable Groundwater Management Planning Grant program for a project titled "Eel River Valley Groundwater Sustainability Plan and Well Monitoring Installation Project." The final grant agreement was executed on May 14, 2020, and all work shall be completed by January 31, 2022. The maximum amount payable under the grant agreement is $1,900,000. The project was eligible for a cost-share waiver because it benefits an economically disadvantaged community.

The purpose of this planning project is to perform data collection and analysis and develop the modeling tools needed to develop sustainable management criteria, investigate the presence or absence of undesirable results, and prepare a GSP document for compliance with SGMA.

The scope of work for the 2020 planning grant included:

- Administer the grant agreement.
- Conduct stakeholder engagement and outreach.
- Compile a detailed inventory of land use types within the Basin.
- Develop a detailed inventory of municipal and agricultural irrigation supply wells. Purchase and install a minimum of six flow meters to obtain direct flow measurements from representative irrigation systems.
- Collect point-in-time measurements in at least 75 wells in the fall of 2020 and the spring of 2021.
- Compile and evaluate existing data and information regarding groundwater quality within the Basin. Collect water samples from at least 15 wells distributed throughout the Basin for laboratory testing.
- Collect streamflow and stage measurements at a minimum of ten locations. Measure streamflow manually during at least three monitoring events. Purchase and install pressure transducers and data loggers to collect continuous stage data at each of the ten locations.
- Collect water samples in the fall of 2020 and in the spring of 2021 from at least 30 wells within the vicinity of the freshwater-seawater transition zone for laboratory testing of chlorides to support the delineation and evaluation of saltwater intrusion.
- Compile existing topographic data, bathymetric data, and imagery for the Basin and supplement as needed.
- Perform slug tests on 23 new wells to estimate hydraulic conductivity.
- Identify and characterize groundwater dependent ecosystems (GDEs) within the Basin. Assess if the GDEs are being impacted by current groundwater conditions and whether they could be impacted by future groundwater conditions.
- Assess the flow needs for surface water beneficial uses.
- Install at least four dual-screened monitoring well clusters (totaling eight new wells) to a depth of approximately 250 feet below ground surface and at least 15 shallow monitoring wells to a depth of approximately 60 feet below ground surface, for a total of 23 new monitoring wells.
- Prepare a GSP that meets the SGMA regulations and DWR requirements.

1.8 Purpose of the Groundwater Sustainability Plan

The purpose of this GSP is to present a framework for sustainably managing groundwater resources within the Basin for economic, social, and environmental benefits through local control and based on the best available science and technical information. The primary objectives for developing this GSP include:

- Build a strong technical foundation to support informed decision-making.
- Work collaboratively with water suppliers and groundwater users to collect accurate information on water use.
- Improve the understanding of the physical processes that affect groundwater sustainability within the Basin.
- Engage in robust public engagement to support involvement and collaboration with all interested stakeholders.
- Integrate the perspectives and interests of the diverse users and uses of groundwater resources within the Basin.
- Develop a monitoring network that provides representative and complete information.
- Identify opportunities to increase resilience to climate change and to ensure continued water availability for community needs.
- Create a framework for ongoing management that emphasizes data-driven decision-making, continuous improvement, and integration of learning through monitoring.
- Create a GSP that conforms with Water Code Sections 10720-12924, 23 CCR 350-358.6, and DWR's Best Management Practice documents.
- Create a GSP that is supported by stakeholders, approved by DWR, and efficient and affordable to implement.

1.9 GSP Overview

Several technical memoranda were prepared to develop more detailed understanding of various aspects of sustainable groundwater management in the Basin. These documents are attached as appendices in Section 12 of the GSP. Appendix B contains a table with cross-references between the GSP regulations and the contents of this GSP.

1.10 Stakeholder Engagement and Communication

On October 6, 2015, the Humboldt County Board of Supervisors approved the formation of an Eel River Valley Groundwater Working Group consisting of stakeholders representing agricultural, municipal and environmental interests to provide input regarding the local response to SGMA. The County prepared a Stakeholder Communications and Engagement Plan (December 2020) in English and Spanish (Appendix C). Stakeholder outreach was primarily conducted at in-person, indoor meetings until early 2020, when shelter-in-place orders were issued due to the Covid-19 pandemic and stakeholder outreach shifted to video-conferencing and outdoor meetings with smaller groups. Periodic updates were circulated through an e-mail list and with postings to the Humboldt County website (https://humboldtgov.org/2489/Groundwater). Appendix C contains a summary of the stakeholder outreach activities.

The draft GSP was released on November 22, 2021, for public review and comment. Comment letters received during the comment period are provided in Appendix G, along with a response to comments.

2 DESCRIPTION OF PLANNING AREA

2.1 Basin Boundary

The Basin occupies the lower portion of the Eel River watershed and encompasses a total area of 72,957 acres (Figure 1). The lateral boundaries of the Basin generally follow well-defined geologic features. The southern side of the Basin is bounded by the mountainous area known as the Wildcat Range and the northern side is bounded by the Little Salmon fault. The eastern limits of the Basin are defined by the extent of recharge areas within the two major rivers that enter the Basin, the Eel and Van Duzen Rivers. The western edge of the Basin is defined by the coastline.

2.2 Location and Climate

The Basin is situated within the North Coast Hydrologic Region along the coast of northwest California in Humboldt County (Figure 3). The North Coast region has high seismic activity due to the close proximity to the Mendocino Triple Junction (see Section 3.4). As a coastal aquifer, the Basin has a hydraulic connection with the Pacific Ocean. The natural process of seawater intrusion is discussed in Section 4.3. The climatic context is strongly conditioned by the close proximity to the Pacific Ocean and the interaction between marine air masses and the elevated terrain of the Coast Range. The average annual precipitation in Ferndale during the 30 years from 1992 through 2021 was 42.9 inches, ranging from 19.9 inches to 67.2 inches (see Section 5.2). The Basin experiences a rainy season in the winter (typically from October through April) and a mild, dry season in the summer. The summer climatic setting is strongly influenced by marine layer clouds and fog which serve to moderate temperatures, reduce solar insolation, raise humidity, and deliver direct moisture deposition on vegetation.

2.3 Water Resources

The Eel River and its tributary the Van Duzen River are the primary surface water bodies within the Basin. The Eel River drains the third largest watershed in California (3,684 square miles) and extends into five counties (Figure 3). The Basin is situated at the bottom of the Eel River watershed and includes the confluence with the Pacific Ocean. The primary aquifers in the Basin are the alluvial aquifer and the underlying Carlotta formation aquifer (see Section 3.6). Groundwater generally flows east to west, down the Eel and Van Duzen River valleys to the coast. The flows of the Eel River and Van Duzen River provide a significant component of recharge to the alluvial aquifer. Most wells drawing from the alluvial aquifer are drilled less than 100 feet below ground surface. Wells drawing from the Carlotta formation aquifer are typically screened 200 to 400 feet below ground surface. The densities of irrigation, municipal, domestic, and industrial wells per square mile are depicted on Figure 4.

The Eel River watershed receives no imported surface water from sources outside the Eel River watershed, such as canals, pipelines, diversions, or water projects. The Eel River watershed exports water to the Russian River watershed through PG&E's Potter Valley Project located in Lake and Mendocino Counties. The Potter Valley Project is a hydroelectric facility that includes Scott Dam, which forms the storage reservoir Lake Pillsbury, and Cape Horn Dam, located 12 river miles downstream from Scott Dam, where flow is diverted across the watershed divide to Potter Valley. Water diverted into the Potter Valley Project supplies the Potter Valley Irrigation District and provides supplemental water for the Russian River system, serving water users in Mendocino, Sonoma, and Marin counties. In 2017, Congressman Jared Huffman convened an ad hoc committee of stakeholders to consult on the future of the Potter Valley Project in support of principles for a "Two Basin Solution." In 2019, PG&E announced it would not seek to renew its federal license to operate the Potter Valley Project. In 2020, Humboldt County joined Sonoma Water, Mendocino Inland Water and Power Commission, Round Valley Indian Tribes, and Cal-Trout as signatories of a planning agreement to pursue a regional solution for the future of the Potter Valley Project. In 2022, the Federal Energy Regulatory Commission will likely order PG&E to begin proceedings to surrender the operating license for the Potter Valley Project and decommission the project. Removal of Scott Dam and discontinuation of dry-season water diversions are a near certainty within the next several years. The feasibility of modifying the facilities to allow winter water diversions with run-of-the-river operations will be further evaluated.

Recent studies identified declining streamflow trends in the mainstem Eel River gaging station at Scotia and most Eel River tributaries during the low-flow season over the 1953-2014 period (Asarian, 2015; Asarian and Walker, 2016). According to the Eel River Action Plan (2016):

> "Low-flow conditions were a common and natural hydrologic condition in the Eel River even when the watershed was pristine and streamflows were unimpaired. Analysis of precipitation and streamflow data for the North Coast and in the Eel basin particularly suggests that the length and severity of low flow periods in the Eel River have increased more than can be explained by variations in rainfall.
>
> It is generally accepted that natural low-flow conditions in the Eel River have been compounded by human-caused factors, the most significant being: (1) sedimentation from timber harvest, landslides, and poorly constructed and maintained road networks that cumulatively has filled pools, reduced pool volumes and reduced hyporheic (sub-surface) flow, and increased transient rates of water out of watersheds, (2) conversion of pristine old growth forests to crowded, thirsty stands in a heavily eroded landscape (conversion of conifer-dominated forests to younger and more densely stocked deciduous-dominated forests that may increase evapotranspiration rates and thereby lower surface runoff) and (3) streamflow diversions which continue to increase as a result of (legal) appropriative and riparian water rights as well as unauthorized (illegal) diversions for marijuana production."

2.4 Beneficial Uses and Users of Water

Water Code Section 10723.2 specifies that a GSA shall consider the interests of all beneficial uses and users of groundwater including, but not limited to, the following:

a) Holders of overlying groundwater rights, including:
    (1) Agricultural users, including farmers, ranchers, and dairy professionals.
    (2) Domestic well owners.
b) Municipal well operators.
c) Public water systems.
d) Local land use planning agencies.
e) Environmental users of groundwater.
f) Surface water users, if there is a hydrologic connection between surface and groundwater bodies.
g) The federal government, including, but not limited to, the military and managers of federal lands.
h) California Native American tribes.
i) Disadvantaged communities, including, but not limited to, those served by private domestic wells or small community water systems.

2.4.1 Agricultural Water Supply

This section summarizes the findings of the Agricultural Groundwater Use Technical Memorandum (Humboldt County, 2021), which is contained in the Appendices.

Non-Irrigated Agricultural Land
The Basin contains a total of approximately 28,750 acres of land in agricultural production, of which approximately 15,320 acres is operated without irrigation. Non-irrigated agricultural land includes rangeland, sub-irrigated pasture, and land that is dry farmed. Rangeland is found on the hills along the margins of the Basin where soil and topography make irrigation infeasible. Many of the pastures in the Loleta area and other western portions of the Basin, some of which are diked former tidelands, are naturally sub-irrigated and typically remain green through the growing season. Also scattered throughout the Basin are fields that are dry farmed, generally because the soil naturally retains sufficient moisture to grow crops or forage. In the water budget for the Basin (Section 5), non-irrigated agriculture land is designated as natural vegetation. The exact acreage for each type of non-irrigated agriculture is not identified, but all three are included in the natural vegetation acreages for the Basin. Sub-irrigated pasture comprises a substantial portion of the valley floor in the Loleta area and western portions of the Basin.

Irrigated Agricultural Land
The majority of dairies and ranches in the Basin use irrigation to supplement their water needs. Dairy producers and ranchers pump groundwater for pasture irrigation and ancillary activities such as dairy nutrient management and livestock watering. In 2021, the Humboldt County RCD updated the inventory of irrigated land areas within the basin, following their initial inventory in 2016. The results from this analysis are summarized in Table 2. Agricultural producers in the Basin rely on irrigation practices for crop and livestock production during the growing season. The region's Mediterranean climate brings the majority of annual precipitation from the late fall through early spring, leaving the summer growing season in need of supplemental water.

Table 2: Irrigated Land Use by Water Source in the Basin (2021)

Irrigation Water Source	Area (Acres)	% of Total Acres
Groundwater	12,952	96.4%
Surface Water	126	0.9%
Reclaimed Wastewater	352	2.6%
Total:	**13,430**	**100%**

Irrigation Methods
Groundwater wells are the main source for irrigation on farms in the Basin. In 2021, a total of 12,952 acres of agricultural land were irrigated by groundwater using five types of irrigation equipment (Table 3).

Table 3. Equipment Types Used for Irrigation with Groundwater in the Basin (2021)

Irrigation Equipment Type	Acres	% of Total Acres
Handline	6,779	53%
Traveling Gun	4,025	31%
Wheel Line	1,147	9%
K-Line	713	6%
Center Pivot	272	2%
Other	16	0.1%
Total	**12,952**	**100%**

Handlines distribute water through sprinkler pipes (aluminium pipe with a sprinkler on one end) connected in a lateral line extending off of a mainline supply. Handlines are moved by disconnecting, moving, and reconnecting each sprinkler pipe by hand to the lateral line's next location. Sprinkler pipes are typically 30 or 40 feet long and each setting lateral lines are typically moved 60 feet. The amount of water applied depends on the distance between sprinklers (length of pipe), nozzle size, pressure, distance between lateral line settings, and duration of each set.

Traveling Guns distribute water through a single large sprinkler that traverses a portion of the field each time the traveling gun is set. For each setting the traveling gun is moved to a new location and the large sprinkler pulled from the carriage and set to traverse a different portion of the field. The amount of water applied depends on the nozzle size, pressure, and speed the large sprinkler travels.

Wheel Lines distribute water through sprinkler pipes mounted on large wheels connected in a lateral line off of a mainline supply. Wheel lines are repositioned by operating a motorized mover in the center of the line with the sprinkler pipes serving as an axle. Sprinklers are typically spaced at 40-foot intervals along the wheel line and moved 60 feet each setting. The amount of water applied depends on the nozzle size, water pressure, and duration of each set.

K-Lines distribute water through a system of plastic lines with sprinkler pods spaced 40 to 50 feet along the lines. K-Lines are moved to a new location by dragging the plastic line with an ATV while the system is operating. K-Line systems are designed to maximize infiltration with the amount of water applied depending on sprinkler spacing, sprinkler size, and duration of each set.

Center Pivots distribute water through sprinklers positioned along an overhead pipe that rotates around a pivot point. The system is designed to apply water at an equal rate along the length of the pipe. The amount of water applied depends on nozzle size and the rotation speed of the center pivot.

Other irrigations systems (hoses or drip irrigation methods) are used on small scale farms of five acres or less, which account for less than 0.1% of the total irrigated acreage.

Agricultural practices are continually evolving in response to market conditions, regulations, incentive programs, climate change, available technology, and other factors. In recent years, agricultural producers in the basin have actively replaced equipment, improved infrastructure, and developed new practices. According to the U.S. Department of Agriculture, Natural Resources

Conservation Service (USDA-NRCS) Eureka Field Office, financial cost-share assistance was provided to 25 producers in the basin over the ten-year period of 2011-2021 for irrigation enhancement projects on 40 distinct farms (see letter in Appendix D). Distinct farms are those with irrigation infrastructure that are not shared or connected with another farm. Assistance was provided for 22 irrigation pipeline systems that replaced existing leaking pipelines or supported a complete system for improved efficiencies. Assistance was also provided for 30 sprinkler systems, with increased interest seen for systems with better application efficiency ratings. Sixteen irrigation well pump upgrades have also been funded to support improved water management and energy usage. USDA-NRCS staff provides follow-up on farms with funded projects to ensure the systems operate properly and are built as designed. Other conservation practices that have been implemented on farms in the basin that benefit water conservation include cover cropping, residue and tillage management, irrigation water management, compost application, and riparian forest buffers.

Irrigation Season Durations

Agricultural producers begin irrigating when applied water is needed to supplement soil moisture in order to maintain the growth of pasture grasses or crops. The start-date for irrigation in the spring varies considerably within the Basin and year to year. Factors that affect the start-date for irrigation include the amount of precipitation in late winter and early spring (especially March and April), wind and air temperature, soil type, labor availability, and overall land management approach. In general, irrigation typically starts earlier in the inland portion of the basin and later in the central and coastal portions of the basin. The end-date for irrigation in the fall is generally on or around October 1, when plant growth slows considerably as day length (photoperiod) shortens and air and soil temperatures drop. Start-dates for irrigation were estimated for each of the five water year types based on interviews with producers and professional judgement (Table 4). These estimates identify the date when some producers begin irrigation. Other producers will not start irrigating for several weeks. As a conservative assumption to avoid underestimating groundwater use, it is assumed that all irrigation in the Basin begins on the start date for that water year type.

Table 4. Water Year Types for the Basin and Irrigation Season Estimates (1992-2021)

Water Year Type	Estimated Irrigation Season	Days in Irrigation Season	Years Corresponding to Water Year Type
Wet	June 1 – October 1	121	1995, 1997, 1998, 1999, 2003, 2004, 2006, 2011, 2017
Above Normal	May 20 – October 1	133	1996, 2000, 2005, 2007, 2016, 2018
Below Normal	May 15 – October 1	138	1993, 2002, 2010, 2012, 2013, 2019
Dry	April 30 – October 1	153	1994, 2001, 2008, 2015, 2020
Critical	April 15 – October 1	168	1992, 2009, 2014, 2021

Irrigation Water Use

Irrigation water use was estimated based on direct measurements using monitoring data collected during the 2021 water year from eight flow meters (Humboldt County, 2021). Monitoring sites were spatially distributed across the basin and represented the range of irrigation system types. Monitoring results from the eight monitoring sites were grouped and averaged to provide the most representative estimate of groundwater pumping throughout the Basin. Data collected in 2021 were extrapolated to estimate total annual groundwater use for each of the five water year types (Table 5). The total volume of groundwater pumped in the basin ranges from 10,694 acre-feet in a wet year to 14,484 acre-feet in a critical year. The water use rate ranges from 0.8 acre-feet of water per irrigated acre per year in a wet year to 1.2 acre-feet of water per irrigated acre per year in a critical year. The Agricultural Groundwater Use Technical Memorandum (Humboldt County, 2021) compares these results with previous estimates.

Table 5. Total Groundwater Use for Agricultural Irrigation

Water Year Type	Volume (Acre-feet)	Water Use Rate (Acre-feet per Acre)
Wet	10,694	0.8
Above Normal	11,754	0.9
Below Normal	12,196	0.9
Dry	13,522	1.0
Critical	14,848	1.2

According to USDA (2013), the average rate of applied water with pressure systems in California was 1.7 acre-feet per acre for pastureland, 3.1 acre-feet per acre for alfalfa and alfalfa mixtures, and 2.5 acre-feet per acre for all other hay production. Based on this information, the water use rates within the Basin are approximately one to two times less than the state average for comparable crops and land use. These differences are likely attributable to a combination of natural conditions (cooler air temperatures and persistent moisture during the summer, shallow groundwater table) and landowner practices (e.g., the absence of flood irrigation). Groundwater use for agricultural irrigation has likely remained steady or decreased over the last 20 to 30 years because the area of irrigated land has not significantly changed and many producers have increased their irrigation efficiency with technology and management practices.

Dairy Nutrient Management

The Basin includes approximately 40 dairies. In addition to using groundwater for irrigating pastures, dairies use groundwater as a source of water for cleaning facilities and supplying the cooling system in milk coolers. This water is typically supplied by a different well than the irrigation well. All dairies use water to clean the milking floor and a few dairies use water to clean other areas of the facility. These activities generate dairy process water which is collected, along with precipitation runoff and manure, into earthen ponds, lagoons, or cement pits (collectively called “ponds”). Liquids in the ponds are periodically applied to surrounding pastures and cropland to replenish soil nutrients in accordance with a Nutrient Management Plan. At some dairies, irrigation water is added to flush the manure lines and condition the pond water for distribution. Approximately every 10 to 30 days (year-round), nutrients from ponds are applied as a liquid or slurry to pastures and cropland with a traveling gun or manure truck. The total water use for facility operations and nutrient management at all dairies in the Basin was estimated as 62 acre-feet per year (Humboldt County, 2021).

2.4.2 Municipal and Domestic Water Supply

Reported groundwater use by municipal water suppliers in water year 2020 is provided in Table 6. To develop the water budget (Section 5), it was assumed that approximately 1,500 parcels have domestic water wells with cumulative annual groundwater use of 414 acre-feet.

Table 6: Municipal Groundwater Use in Water Year 2020

Water Supplier	Volume (Acre-feet)
City of Fortuna	1,361
Del Oro Water Company (Ferndale)	177
Hydesville CWD	114
Loleta CSD	63
Bear River Rancheria	54
Riverside CSD	31
Palmer Creek CSD	26
City of Rio Dell (primary source is surface water)	6

The City of Fortuna provides water to approximately 5,727 service connections, including 5,170 residential connections and 557 commercial (or other) connections (City of Fortuna, 2021). The City of Fortuna projects that water demand could increase to approximately 1,400 acre-feet by 2025 (City of Fortuna, 2021).

2.4.3 Aquatic and Terrestrial Ecosystems

SGMA defines groundwater dependent ecosystems (GDEs) as “ecological communities of species that depend on groundwater emerging from aquifers on groundwater occurring near the ground surface” [23 CCR 351(m)]. GSPs are required to identify GDEs within the Basin using best available information. Aquatic GDEs include surface waters that are interconnected with groundwater. Depletion of interconnected surface waters is one of the six sustainability indicators specified by SGMA (Section 6.11). Terrestrial GDEs include vegetation communities that can tap groundwater through their root systems. Information on GDEs is provided in Section 4.7, based on a technical memorandum prepared by Stillwater Sciences (January 2022) which is provided in the Appendices.

The Eel River is an important and highly valued watershed for producing wild salmon and other native fish species. Historically, the Eel River sustained large populations of Chinook salmon, coho salmon, winter- and summer-run steelhead trout, and coastal cutthroat trout (Eel River Action Plan, 2016). Pacific lamprey and green sturgeon are also recognized as important native fish species. According to the Eel River Action Plan (2016):

> “Much of the decline in salmonid abundance may be attributed to loss or degradation of physical and biological conditions in the ecosystem caused by human activities, including commercial and recreational fish harvests and cannery operations, several periods of large-scale timber harvest, land conversions for agricultural activities, water developments and diversions, rural and urban residential development, introduction of non-native predatory pikeminnow, and

> a multitude of additional minor factors. The Eel River has thus been transformed from one of the most productive river ecosystems along the Pacific Coast to a degraded river with heavily impaired salmonid populations. The commercial fishery has been eliminated, and the recreational fishery has been reduced to a catch and release fishery." (pg. 12)

The Eel River Recovery Project (2020) estimated that between 2012 and 2019, the fall-run Chinook salmon population ranged from a high in 2012 of between 20,000 and 50,000 fish to a low in 2019 of between 7,100 and 9,000 fish. The Eel River Action Plan (2016) identifies several recommended action items to conserve the Eel River watershed's ecological resilience, restore its native fish populations, and protect other watershed beneficial uses.

2.4.4 Commercial and Industrial Water Supply

The Basin contains 49 commercial or industrial parcels not connected to municipal water. Total estimated use from these sources is 34 acre-feet per year.

2.5 General Land Use Characteristics and Jurisdictional Areas

The Basin covers a land area of approximately 72,957 acres (114 square miles) and includes land areas under the jurisdiction of four municipalities and one tribal government: the County of Humboldt, the City of Fortuna, the City of Rio Dell, the City of Ferndale, and the Bear River Band of the Rohnerville Rancheria (Figure 2). The majority of the Eel River Valley is unincorporated, where Humboldt County is the land use authority.

An inventory of land use types was prepared to support the development of the water budget (GHD, 2022b). The categories are intended to distinguish different rates of evapotranspiration. Table 7 presents the total area of six land use categories within the Basin.

Table 7: Areas of Land Use within the Basin

Land Use Category	Total Area (Acres)
Impervious Surfaces	1,916
Irrigated Agricultural Land	13,430
Natural Vegetation (Includes Non-Irrigated Agricultural Land)	29,722
Open Waters	3,824
Riparian Vegetation	11,529
Urban Landscape (Pervious Surfaces)	12,072

Each municipality has an adopted general plan with land use classifications that identify desired development, open space, and conservation purposes. Also included within the Basin are state lands managed by CDFW. Figure 5 depicts the land use designations within the Basin. The primary land uses in the Basin are agricultural, residential, and open space/conservation areas. Historical maps and aerial photographs indicate that overall land use within the Basin has remained generally stable over time with a mix of agricultural lands, small community centers, and undeveloped open space (Appendix E). Changes in land use are discussed in Section 5.7.

2.6 General Plans

Humboldt County

The Humboldt County General Plan (October 2017) contains goals, policies, standards, and implementation measures for land use planning and development. The Water Resources element of the General Plan contains county-wide policies regarding groundwater. Goals, policies, and implementation measures relevant to groundwater management are summarized in Table 8.

City of Fortuna

The Natural & Cultural Resources Element of the City of Fortuna General Plan (2010) addresses various natural and cultural resources located throughout the planning area. Goal NCR-1 is to ensure that the City has access to a quality water supply that is free from pollution. Policy NCR-1.3 states that the City shall seek additional groundwater locations to supplement existing drinking water sources. Policy NCR-2.3 states that the City shall work to implement the recommendations put forth in the Recovery Strategy for California Coho Salmon (CDFG, 2004b) to benefit salmonid species present within the General Plan Area by enhancing and restoring riparian ecosystems, improving water quality, and reducing flooding.

City of Rio Dell

The Natural Environment section of the City of Rio Dell General Plan (2015) addresses various issues including hydrology and water resources. Goal G1.2-6 is to provide an adequate, consistent, and safe supply of water to meet the City's domestic, commercial, and fire safety requirements.

City of Ferndale

The City of Ferndale's General Plan does not directly reference water resources. The Housing Element (2019) notes that all sites identified in the vacant land inventory have the ability to access water service from Del Oro water company.

Table 8: Goals, Policies, and Implementation Measures of the Humboldt County General Plan Related to Groundwater Management

Plan Component	Description
Goal WR-G1	**Water Supply, Quality, and Beneficial Uses.** High quality and abundant surface and groundwater resources that satisfy the water quality objectives and beneficial uses identified in the Water Quality Control Basin Plan for the North Coast Region.
Goal WR-G2	**Water Resource Habitat**. River and stream habitat supporting the recovery and continued viability of wild, native salmonid and other abundant coldwater fish populations supporting a thriving commercial, sport and tribal fishery.
Goal WR-G5	**Watershed Management.** A system of water resource management that recognizes watersheds as natural systems producing multiple economic, social, and environmental benefits that can be sustained in perpetuity and optimized with education, sound data, cooperative public processes, adaptive management, and science based leadership.
Goal WR-G6	**Public Water Supply.** Public water systems able to provide adequate water supply to meet existing and long-term community needs in a manner that protects other beneficial uses and the natural environment.
Policy WR-P1	**Sustainable Management.** Ensure that land use decisions conserve, enhance, and manage water resources on a sustainable basis to assure sufficient clean water for beneficial uses and future generations.
Policy WR-P2	**Protection for Surface and Groundwater Uses**. Impacts on Basin Plan beneficial water uses shall be considered and mitigated during discretionary review of land use permits that are not served by municipal water supplies.
Policy WR-P15	**Saltwater Intrusion.** Discretionary projects involving groundwater withdrawals in proximity to coastal areas with a potential to create saltwater intrusion shall demonstrate that groundwater supplies will not be adversely affected by saltwater intrusion.
Policy WR-P18	**State and Federal Regulation.** Encourage state and federal agencies to maintain responsibility for water resources supply and water quality management. The County shall not accept administrative responsibility for state or federal regulatory programs unless sustainable funding sources are secured.
Policy WR-P21	**Enhance Groundwater Recharge Capacity**. Encourage watershed management practices that enhance infiltration of rainfall into the groundwater.
Policy WR-P26	**Sufficient Water Supply.** Support the actions and facilities needed by public water systems to supply the water demands projected in the General Plan.
Policy WR-P28	**Conservation and Re-use Strategy.** Promote the use of water conservation and re-use as a strategy to lower the cost, minimize energy consumption, and maximize the overall efficiency and capacity of public and private water systems…. Encourage and support conservation for agricultural activities that increase the efficiency of water use for crop irrigation and livestock. Support the use of treated water for irrigation, landscaping, parks, public facilities, and other appropriates uses…. Avoid water reuse that could adversely affect the quality of groundwater or surface water.
WR-IM16	**Sustainable Groundwater Plans.** Support the development of Sustainable Groundwater Plans consistent with the California Water Code.

2.7 Existing Monitoring Programs

2.7.1 Groundwater Level Monitoring

California Statewide Groundwater Elevation Monitoring (CASGEM)
DWR has performed long-term monitoring at seven wells in the Basin as part of the California Statewide Groundwater Elevation Monitoring (CASGEM) program, with some records dating back to the late 1950s. The network includes five wells near Ferndale and single wells in Loleta and Fortuna. In 2014, the County of Humboldt became the designated monitoring entity for groundwater basins within the County. Data management is currently transitioning to the Monitoring Network Module of DWR's SGMA Portal (https://sgma.water.ca.gov/portal/). CASGEM data are discussed in Section 4.1.1.

County Well Monitoring
Humboldt County installed a total of 15 monitoring wells in 2016, resulting in 14 usable wells (one well has consistently been dry), and has performed semiannual monitoring in these wells following their installation. Humboldt County installed an additional 23 monitoring wells in 2021 and plans to perform semiannual monitoring in those wells henceforth.

2.7.2 Groundwater Quality Monitoring

Safe Drinking Water Information System
Municipal water providers perform periodic sampling and testing of raw water. Water quality testing results for public water systems are made available through the State Water Resources Control Board at https://sdwis.waterboards.ca.gov/PDWW/.

Groundwater Ambient Monitoring and Assessment (GAMA) Program
The State Water Resources Control Board's GAMA Program includes an on-line groundwater information system that displays groundwater data from various sources on a Google-based map platform: https://gamagroundwater.waterboards.ca.gov/gama/gamamap/public/.

2.7.3 Weather and Climate Monitoring

California Irrigation Management Information System (CIMIS)
CIMIS is a program that manages a network of automated weather stations in California, primarily to assist irrigators in managing their water resources. In August 2019, Humboldt County collaborated with DWR and a private landowner to install a local CIMIS station ("Ferndale Plain", Station Number 259) in the Eel River Valley (Figure 6). Weather data are collected and processed to produce hourly, daily, and monthly values that are stored and made publicly available (https://cimis.water.ca.gov/). The available data include precipitation, air temperature, soil temperature, relative humidity, solar radiation, vapor pressure, dew point, wind speed, and evapotranspiration.

Ferndale Weather Station
Rainfall amounts have been recorded at a rain gauge in Ferndale since 1963. From October 1994 through the present, the rain gauge has been operated at the Ferndale Museum (515 Shaw Avenue). From October 1970 through October 1994, daily rainfall measurements were collected by George Anderson at 1345 Main Street in Ferndale. Information regarding the location of the rain gauge from October 1963 through October 1970 was not readily available. A summary of the monthly rainfall totals at Ferndale from October 1963 through September 2021 is provided in Appendix F.

National Weather Service
The National Weather Service conducts weather observations at Woodley Island in Humboldt Bay and at the California Redwood Coast-Humboldt County Airport in McKinleyville. The website for the Eureka office is https://www.weather.gov/eka/.

2.7.4 Surface Water Monitoring

U.S. Geological Survey
USGS maintains streamflow gauging stations on the Lower Eel River at Scotia and Fernbridge, and on the Van Duzen River at Bridgeville (Figure 6). The Fernbridge station measures gage height only (not discharge). Data is available at https://waterdata.usgs.gov/ca/nwis/current/?type=flow.

Gravel Mining
Since 1997, commercial gravel operators have conducted fisheries monitoring activities to track habitat conditions for listed salmonids within the Lower Eel River and Lower Van Duzen River, based on federal, state, and county permitting requirements. These habitat monitoring activities record the distribution, characteristics, and trends of habitat units (pools, riffles, flatwaters) within the river channel.

Eel River Recovery Project
The Eel River Recovery Project began citizen-assisted monitoring of the Eel River fall Chinook run in 2012 (https://www.eelriverrecovery.org/). Periodic monitoring activities include dive surveys, pool depth measurements, and water quality monitoring (temperature, dissolved oxygen).

2.7.5 Land Surface Subsidence Monitoring

U.S. Geological Survey
The USGS uses Interferometric Synthetic Aperture Radar (InSAR) signals fom Earth-orbiting satellites to measure changes in land-surface altitude. The USGS InSAR website is here: https://www.usgs.gov/centers/ca-water-ls/science/interferometric-synthetic-aperture-radar-insar?qt-science_center_objects=0#qt-science_center_objects.

2.8 Existing Regulatory Programs

Water Quality Control Plan for the North Coast Region (North Coast Basin Plan)
Surface and groundwater quality in the Eel River Valley Basin are regulated by the North Coast Regional Water Quality Control Board (Regional Water Board). While the State Water Board sets statewide polices and plans for implementation of Federal and State laws and regulations, the Regional Water Board conducts planning, permitting, and enforcement activities in the North Coast Region.

Under the Porter-Cologne Water Quality Control Act, beneficial uses of the waters of the state that may be protected against quality degradation include, but are not limited to, domestic, municipal, agricultural and industrial supply; power generation; recreation; aesthetic enjoyment; navigation; and preservation and enhancement of fish, wildlife, and other aquatic resources or preserves [Water Code Section 13050(f)]. The term "waters of the state" means any surface water or groundwater, including saline waters, within the boundaries of the state [Water Code Section 13050(c)]. The Water Quality Control Plan for the North Coast Region (North Coast Basin Plan) is the central regulatory tool used by the Regional Water Board to protect water quality. The Basin Plan identifies beneficial uses of water, establishes water quality objectives to protect those uses, provides programs of implementation, describes plans and policies of the State Water Resource Control Board and monitoring activities.

The North Coast Basin Plan designates existing and potential beneficial uses for hydrologic areas within the North Coast Region. The Basin is contained within the Lower Eel River and Van Duzen River hydrologic areas. The North Coast Basin Plan designates multiple beneficial uses for one or both of these hydrologic areas, including:

- MUN (Municipal and Domestic Supply) – Uses of water for community, military, or individual water supply systems, including, but not limited to, drinking water supply.
- AGR (Agricultural Supply) – Uses of water for farming, horticulture, or ranching, including, but not limited to, irrigation, stock watering, or support of vegetation for range grazing.
- IND (Industrial Service Supply) – Uses of water for industrial activities that do not depend primarily on water quality, including, but not limited to, mining, cooling water supply, hydraulic conveyance, gravel washing, fire protection, or oil well repressurization.
- GWR (Groundwater Recharge) – Uses of water for natural or artificial recharge of groundwater for purposes of future extraction, maintenance of water quality, or halting of saltwater intrusion into freshwater aquifers.
- FRSH (Freshwater Replenishment) – Uses of water for natural or artificial maintenance of surface water quantity or quality (e.g., salinity).
- NAV (Navigation) – Uses of water for shipping, travel, or other transportation by private, military, or commercial vessels.
- REC-1 (Water Contact Recreation) – Uses of water for recreational activities involving body contact with water, where ingestion of water is reasonably possible, including, but not limited to, swimming, wading, water skiing, skin and scuba diving, surfing, whitewater activities, fishing, or use of natural hot springs.
- REC-2 (Non-Contact Water Recreation) – Uses of water for recreational activities involving proximity to water, but not normally involving body contact with water, where ingestion of water is reasonably possible, including, but not limited to, picnicking, sunbathing, hiking, beachcombing, camping, boating, tidepool and marine life study, hunting, sightseeing, or aesthetic enjoyment in conjunction with the above activities.
- COMM (Commercial and Sport Fishing) – Uses of water for commercial and recreational (sport) collection of fish, shellfish, or other aquatic organisms, including, but not limited to, uses involving organisms intended for human consumption or bait purposes.
- COLD (Cold Freshwater Habitat) – Uses of water that support cold water ecosystems, such as preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates.
- WILD (Wildlife Habitat) – Uses of water that support terrestrial ecosystems, including, but not limited to, preservation and enhancement of terrestrial habitats, vegetation, wildlife (e.g., mammals, birds, reptiles, amphibians, invertebrates), or wildlife water and food sources.
- RARE (Rare, Threatened, or Endangered Species) – Uses of water that support habitats necessary, at least in part, for the survival and successful maintenance of plant or animal species established under State or federal law as rare, threatened, or endangered.

- MIGR (Migration of Aquatic Organisms) – Uses of water that support habitats necessary for migration or other temporary activities by aquatic organisms, such as anadromous fish.
- SPWN (Spawning, Reproduction, and/or Early Development) – Uses of water that support high-quality aquatic habitats suitable for reproduction and early development of fish.
- CUL (Native American Culture) – Uses of water that support the cultural and/or traditional rights of indigenous people, such as subsistence fishing and shellfish gathering, basket weaving and jewelry material collection, navigation to traditional ceremonial locations, and ceremonial uses.
- SHELL (Shellfish Harvesting) – Uses of water that support habitats suitable for the collection of filter-feeding shellfish (e.g., clams, oysters, and mussels) for human consumption, commercial, or sports purposes. (Lower Eel River hydrologic area only)
- EST (Estuarine Habitat) – Uses of water that support estuarine ecosystems, including, but not limited to, preservation or enhancement of estuarine habitats, vegetation, fish, shellfish, or wildlife (e.g., estuarine mammals, waterfowl, shorebirds). (Lower Eel River hydrologic area only)
- WARM (Warm Freshwater Habitat) – Uses of water that support warm water ecosystems, such as preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates. (Van Duzen River hydrologic area only)

Potential beneficial uses include:

- PRO (Industrial Process Supply) – Uses of water for industrial activities that depend primarily on water quality.
- POW (Hydropower Generation) – Uses of water for hydropower generation.
- AQUA (Aquaculture) – Uses of water for aquaculture or mariculture operations, including, but not limited to, propagation, cultivation, maintenance, or harvesting of aquatic plants and animals for human consumption or bait purposes.
- MAR (Marine Habitat) – Uses of water that support marine ecosystems, including, but not limited to, preservation or enhancement of marine habitats and vegetation such as kelp, fish, shellfish, or wildlife (e.g., marine mammals, shorebirds). (Lower Eel River hydrologic area only)

General Waste Discharge Requirements for Dairies in the North Coast Region – Dairy Program

The Regional Water Board regulates waste discharge from dairies under General Waste Discharge Requirements for Dairies in the North Coast Region (Dairy GWDR). The Dairy GWDR, adopted as Order No. R1-2019-0001 on August 15, 2019, protects the beneficial uses of both surface water and groundwater through a regulatory framework that requires enrolled dairies to develop and implement Water Quality Plans, Nutrient Management Plans, and Monitoring and Reporting Programs. Dairies not enrolled in the Dairy GWDR are required to obtain an individual permit.

Site Contamination Programs

Property with site contamination that may have the potential to impact groundwater quality are regulated in accordance with the State Water Quality Control Board's contaminated site cleanup programs. The Regional Water Board implements these programs, which include the Site Cleanup Program, the Underground Storage Tank Cleanup Program, the Department of Defense

Cleanup Program, and the Brownfields Program. Other agencies that oversee cleanup work in the Basin include the California Department of Toxic Substances Control and Humboldt County Department of Public Health Division of Environmental Health.

In-stream Gravel Mining
Gravel mining from river bars is regulated by the California Department of Conservation under the State Mining and Reclamation Act (SMARA) with local oversight by the Humboldt County Building and Planning Department and the County of Humboldt Extraction Review Team (CHERT). Gravel mining is also regulated by the U.S. Army Corps of Engineers through a Letter of Permission (LOP) which is renewed every ten years in consultation with National Marine Fisheries Service and U.S. Fish and Wildlife Service. Permits and approvals are required from the Regional Water Board, CDFW, and California Coastal Commission (within the coastal zone).

2.9 Existing Management and Collaboration Programs

City of Fortuna Urban Water Management Plan
The City of Fortuna prepared a 2020 Urban Water Management Plan (Freshwater Environmental Services, June 2021) in accordance with Water Code Sections 10610-10656. Urban Water Management Plans are required by water suppliers that serve more than 3,000 urban connections or provide over 3,000 acre-feet of water annually. The purpose of an Urban Water Management Plan is to support long-term resource planning and ensure that adequate water supplies are available to meet existing and future water needs. The plans are also intended to support efficient use of water supplies and strengthen local drought planning. The City of Fortuna's Urban Water Management Plan includes an analysis of baseline and target water consumption rates, a description of the water system's reliability during different water year types, a contingency plan for water shortages, and a description of the City's efforts to promote conservation and reduce water supply demand.

City of Fortuna Municipal Stormwater Program
The City of Fortuna is subject to the State Water Resources Control Board's Water Quality Order No. 2013-0001-DWQ and National Pollutant Discharge Elimination System General Permit No. CAS000004, which applies to stormwater discharges from small municipal separate storm sewer systems (MS4s) in accordance with the federal Clean Water Act. The purpose of this permit ("MS4 General Permit" or "Order") is to control the discharge of pollutants to storm sewer systems which ultimately drain to natural waterways. The elements of the City of Fortuna's stormwater program include education and outreach, an ordinance for prohibited discharges, illicit discharge detection and elimination, construction site runoff control, post-construction low impact development standards, pollution prevention measures, and water quality monitoring.

California Department of Food and Agriculture: Climate Smart Agriculture Program
The California Department of Food and Agriculture (CDFA) – Climate Smart Agriculture Program has cost-share assistance available to producers to implement on-farm conservation practices. Two of their programs utilized by producers within the basin include the Healthy Soils Program (HSP) and the Alternative Manure Management Program (AMMP). Practices funded by HSP and AMMP help provide many benefits to farm operations and ecosystem resources such as groundwater. Practices such as manure composting and applications to fields, cover crops, woody plantings, reduced tillage, and others help build soil organic matter, improve water infiltration and water-holding capacities, and boost productivity, ultimately helping to reduce irrigation demand, conserve groundwater, and protect aquifers from undesirable constituents. Producers with farms within the Basin have been awarded funding from both HSP and AMMP, for the period 2017 through 2020 totalling nearly $4 million dollars.

Natural Resources Conservation Service: Conservation Planning

Conservation planning is a voluntary planning process where land managers work together with technical assistance professionals to produce a conservation plan for a farm or ranch operation. A conservation plan developed through this process is a site specific, comprehensive, and action-oriented plan which describes a system of practices and activities needed to solve identified natural resource problems and take advantage of opportunities. The framework for planning is based on the USDA-NRCS nine-step conservation planning process, with the purpose to develop and implement plans that protect, conserve, and enhance natural resources within a social and economic perspective.

USDA- NRCS, Humboldt County RCD staff, and other technical assistance providers develop plans with producers to evaluate soil, water, air, plant, and animal resources associated with the property and offer alternatives to address resource conditions. Thoroughly assessing an agricultural operation through a planning process provides producers a comprehensive view on how to manage their farms more effectively and efficiently. These planning processes identify conservation practices that can be implemented in order to achieve efficiencies, attain high production rates, and help meet compliance with regulatory requirements. Implementing identified practices in the plan should increase productivity, protect natural habitats, increase water conservation, and improve water quality. Conservation plans also support the application process for USDA-NRCS cost-share assistance programs.

Natural Resources Conservation Service: Environmental Quality Incentives Program

The Environmental Quality Incentives Program (EQIP) sponsored by USDA-NRCS has been a significant source of cost-share funding for producers over the past 10 to 20 years. Producers enter into cost-share assistance contracts to implement conservation practices that help address natural resource concerns identified through an extensive conservation planning process. This program assists agricultural producers with replacing inefficient or deteriorating irrigation systems, protecting waterways from erosion, and building infrastructure for operations to become more efficient.

Humboldt County RCD: Conservation and Carbon Farm Planning

A relatively new emphasis within the realm of conservation planning is carbon farm planning. Carbon farm planning is a process designed to maximize agriculture's potential for moving excess greenhouse gases from the atmosphere into the soil and vegetation, building fertility, productivity and resilience. A conservation and carbon farm plan is a whole-farm conservation plan with recommendations for practices that when implemented will increase the rate at which plants transfer carbon dioxide from the atmosphere to the soil, which then increases water infiltration, water-holding capacity, soil organic matter and promotes long-term carbon sequestration. Boosts in productivity on the farm or ranch are often seen as well. These planning outcomes allow producers to irrigate their fields more efficiently and protect water quality.

Eel River Recovery Project

The Eel River Recovery Project (https://www.eelriverrecovery.org/) was initiated in 2012 to organize volunteer and grant-funded efforts to monitor Eel River conditions and promote water conservation and habitat restoration. Focus areas of the Eel River Recovery Project include water temperatures, stream flows, and blue-green algae (cyanobacteria).

Eel River Forum

The Eel River Forum is a coalition of public agencies, Indian tribes, conservation partners, and other stakeholders with interest in or responsibility for the environmental stewardship of the Eel

River (https://caltrout.org/projects/eel-river-forum). The coalition was convened by Cal-Trout in July 2012 and released the Eel River Action Plan in June 2016. According to the website, the Eel River Forum works collaboratively to:

- Understand the status of Eel River salmonid populations and other native fisheries resources.
- Identify and prioritize recovery issues and challenges.
- Promote specific research, restoration, and monitoring efforts in the Eel River basin
- Develop and recommend plans and policies that will promote the recovery of the Eel River ecosystem and its native fish populations.

U.S. Fish & Wildlife Service: Humboldt Coastal Resiliency Project

U.S. Fish & Wildlife Service has been leading a project to monitor coastal dune systems and test adaptive management techniques. Centerville Beach and the Eel River Wildlife Area have been areas of focus because significant portions of the dunes near Centerville have been impacted by coastal erosion, making the inland areas vulnerable to wave overwash and ocean flooding.

North Coast Resource Partnership

The North Coast Resource Partnership (NCRP) is a voluntary partnership composed of Sonoma, Mendocino, Humboldt, Del Norte, Trinity, Siskiyou, and Modoc Counties and North Coast tribes focusing on water management, watershed and community health, and fire resiliency. The NCRP works on a regional basis to ensure coordination and adaptive management between statewide water resource planning efforts, regional priorities, and local needs. The NCRP serves as the grant administrator for State funding through the Integrated Regional Water Management (IRWM) program and distributes funding to local agencies and organizations to implement projects to improve water supply, water quality, and aquatic habitat. The NCRP emphasizes support for economically disadvantaged communities and support for working and natural lands.

The NCRP's North Coast Integrated Regional Water Management Plan (August 2014) discusses the effects of climate change vulnerability and uncertainty on regional water-related issues. In addition, the NCRP has commissioned several climate change studies including:

- Climate Mitigation Report for the North Coast Region of California (April 2018)
- North Coast Regional Climate Adaptation Strategies (January 2018)
- Climate & Natural Resource Analyses and Planning for the North Coast Resource Partnership (January 2018)
- North Coast Resource Partnership Integrated Strategic Plan – Climate Change Mitigation, GHG Emissions Reduction and Energy Independence (May 2017)

California Department of Fish and Wildlife: Salmonid Habitat Restoration Priorities

CDFW intends to implement the Salmonid Habitat Restoration Priorities (SHaRP) planning process for the lower Eel River. CDFW will collaborate with agencies and local experts to identify the most important salmon and steelhead habitat restoration actions within a ten-year planning period. This process was initiated in 2020 but then put on hold due to capacity limitations (Christopher Loomis, personal communication). CDFW and the National Marine Fisheries Service recently completed a SHaRP Plan for the South Fork Eel River.

2.10 Recent and Ongoing Restoration Projects

Humboldt County RCD: Salt River Ecosystem Restoration Project

The Humboldt County RCD has led a major multi-benefit restoration project along the Salt River and its primary tributaries to address severe sediment impairment and other factors. The Salt River discharges into the Eel River estuary approximately 0.2 miles upstream of where the Eel River discharges into the ocean. The project's four major components include upslope erosion control, Riverside Ranch tidal marsh restoration, Salt River channel excavation, and adaptive management (Humboldt County RCD, 2020). Riverside Ranch converted 330 acres of pastureland back to intertidal wetland habitat and preserved approximately 70 acres for agricultural use and Aleutian cackling geese habitat. Through 2021, the project has restored a total of 6.2 miles of Salt River channel and floodplain and reconnected two tributaries (Reas Creek and Francis Creek), along with restoring 0.5 miles of Francis Creek. The Humboldt County RCD aims to restore additional segments of the Salt River and re-connect the Williams Creek tributary to the Salt River. The Humboldt County RCD is coordinating with the Salt River Watershed Council and private landowners on adaptive management to address ongoing sedimentation.

City of Fortuna: Rohner Creek Flood Control, Habitat, and Seismic Improvement Project

The City of Fortuna implemented a multi-phase project to improve conveyance capacity and habitat quality in Rohner Creek, a tributary to the Eel River that passes through the city.

California Department of Fish and Wildlife: Ocean Ranch Restoration Project

The California Department of Fish and Wildlife in conjunction with Ducks Unlimited is implementing dune and estuary restoration work on the Ocean Ranch Unit of the Eel River Wildlife Area located north of the mouth of the Eel River near Loleta. The Ocean Ranch Unit is situated between the ocean (to the west) and McNulty Slough (to the east). The project includes approximately 571 acres of estuarine restoration to restore the tidal prism and increase hydrologic connectivity and habitat complexity, along with 279 acres of coastal dune restoration (CDFW, 2021). The estuarine restoration components include breaching internal and external levees, excavating new tidal channels, lowering and removing levees, creating high marsh habitat, and constructing various habitat features and elements.

CalTrout and California Department of Fish and Wildlife recently began planning restoration activities on Cannibal Island within the Eel River estuary. The Wildlands Conservancy has been planning restoration on the Eel River Estuary Reserve which is situated in the Ferndale bottoms near Centerville.

2.11 Well Permitting Policies and Procedures

The Humboldt County Department of Health and Human Services, Division of Environmental Health (DEH), is responsible for permitting the construction, alteration, or destruction of wells in the Basin. Wells must be sited and constructed in a manner to protect water quality, and work must be performed in accordance California Water Well Standards as set forth in DWR's Bulletin 74 by a contractor holding a C-57 license. To obtain a permit, a person must submit a completed water well application signed by both the applicant and the licensed drilling contractor and required fee to DEH. Upon approval of the permit, construction may begin, but DEH must be notified a minimum of 24 hours prior to sealing the annular space. Within 30 days of completion of work, a copy of the Well Completion Report submitted to DWR must be provided to DEH.

PART II: BASIN SETTING

Part II contains three sections which describe the physical setting and characteristics of the Basin and current conditions of the Basin, with consideration for data gaps and levels of uncertainty. This content provides the technical basis for defining and assessing reasonable sustainable management criteria and projects and management actions, provided in Part III. The information presented in Part II was prepared by or under the direction of professional geologists and professional engineers.

3 HYDROGEOLOGIC CONCEPTUAL MODEL

3.1 Overview

GSPs are required to include descriptive hydrogeologic conceptual models (HCM), based on technical studies and qualified maps to characterize the physical components of the subject basin, as well as describe the occurrence of groundwater and its movement in and out of the basin. The HCM is also the basis for developing the numerical integrated surface water-groundwater model used to simulate current and future basin conditions. This section is based on the Hydrogeological Conceptual Model Technical Memorandum (GHD, 2021b).

Only a handful of prior studies have focused on hydrogeologic conditions within the Basin. The understanding of the Basin as described within this section is primarily developed from a review of these past studies (Ogle 1953; Evenson 1959; U.S. Geological Survey [USGS] 1978), and the work that Humboldt County has completed in response to the SGMA, including the GSP Alternative. New data collection and analysis, along with the development of numerical modeling, offers significant improvement to this current understanding and insights into Basin hydrogeological uncertainties. (Data gaps and important uncertainties relative to the preliminary HCM are discussed in Section 3.8.)

3.2 Topography and Geography

This section summarizes the content of the Terrain Data and Imagery Technical Memorandum (GHD, 2021c). The Basin topographic model encompasses areas of the Basin as defined by DWR and adjacent watersheds that contribute surface and groundwater to the Basin.

A Digital Elevation Model (DEM) was developed using several surface models and topography data acquired via Light Detection and Ranging (LiDAR) to accurately model the Basin topography. The total surface model is comprised of three distinct regions: Basin Surface, Extended Drainage Surface, and River Cross-sections. Each region has a unique data resolution requirement for use in the various study applications. The Extended Drainage Surface and Basin Surface regions were compiled into a comprehensive DEM for groundwater modeling. The River Cross-sections region was then employed to compare groundwater levels with recorded river stage in GSFLOW, a coupled groundwater and surface water FLOW model based on the integration of the USGS Precipitation-Runoff Modeling System (PRMS-V) and the USGS Modular Groundwater Flow Model (MODFLOW-2005 and MODFLOW). Figure 8 in GHD (2022a) shows the extent of the Basin and the Extended Drainage Surface region.

3.2.1 Surface Data Used

The surface models and topography data used to develop the composite DEM and river bathymetry model are identified in Table 9.

Table 9: Topographic Data Sources and Application

Application	Data Source
Basin Surface	USGS National Map DEM
Basin Surface	Wiyot Tribe and Bear River Band of the Rohnerville Rancheria addendum to National Map DEM
Extended Drainage Surface	Hollister J, Shah T, Robitaille A, Beck M, Johnson M (2020). *elevatr: Access Elevation Data from Various APIs*. R package version 0.3.1. (accessed with: R Core Team. 2020. *R: A Language and Environment for Statistical Computing*. Vienna, Austria: R Foundation for Statistical Computing.)
River Cross-sections	Stillwater Sciences Bathymetry Survey of Eel and Van Duzen Rivers; River cross-section data also provided by Tom Bess Asphalt Company, Jack Noble, and Humboldt County.

3.2.2 Basin Surface

The Basin Surface was created using a USGS-developed DEM, acquired from the USGS National Map downloader (TNM Download v2.0) with a standard one-meter resolution. Two sets of tiles were downloaded. The main tile index consists of 22 tiles with bare earth elevation values referenced to the North American Vertical Datum of 1988 (NAVD88) and covers the majority of the Basin. The supplemental tile index was based on the same LiDAR acquisition of the main tile index, consisting of the Wiyot Tribe (Table Bluff Reservation) and Rohnerville Rancheria (Bear River Band) tribal areas that were clipped out of the one-meter DEMs due to delays in the tribal notification process. The final DEM represents bare earth elevation values in feet (NAVD88), at one-meter resolution, and projected in NAD_1983_StatePlane_California_I_FIPS_0401_Feet.

3.2.3 Extended Drainage Surface

The Extended Drainage Surface region extends approximately 100 miles southeast of the Basin, encompassing all surface water features that flow into the Basin. The DEM for the Extended Drainage Surface was based on the same 2019 LiDAR data as the Basin Surface region, obtained using the elevation library with a 10-meter resolution. The Extended Drainage Surface DEM was referenced to NAVD88 and NAD83 and projected in the State Plane California Zone I (FIPS 0401) coordinate system.

3.2.4 River Cross-sections

The spatial representation of creeks and rivers in the model was derived from the National Hydrologic Model (NHM) and the National Hydrography Dataset (NHD). The model's representation of the creek and river system was compared with river cross-section data provided by Stillwater Sciences and the County, who have collected cross-sections for the Van Duzen and lower Eel Rivers as part of gravel mining activities between 2004 and 2020.

3.2.5 Composite Surface

A Composite Surface model was created by merging the Basin Surface and the Extended Drainage Surface, referenced to NAVD88 vertical datum and NAD83 horizontal datum, then projected in the State Plane Coordinate System (FIPS 0401). The DEM for the Composite Surface retained one-meter resolution for the Basin Surface and 10-meter resolution for the Extended Drainage Surface.

3.2.6 Imagery

Imagery in this GSP serves two primary purposes: as background layers in figures, and as inputs for remote sensing analysis. Remote sensing analysis played a key role in the land use characterization process. Aerial images were used to delineate such land use types as impervious, open water, riparian, natural vegetation, forest land, and urban vegetation. The imagery used for the analysis was 4-band multispectral imagery provided by the 2020 USDA National Agriculture Imagery Program (NAIP).

3.3 Surface Water and Drainage Features

The Eel and Van Duzen Rivers are the primary surface water bodies within the Basin. These are large river systems that drain significant areas of northwestern California (Figure 3). The main stem Eel River is dammed near its headwaters in Lake County (far from the Basin) at Lake Pillsbury (Scott Dam) and flow is partially diverted to the Russian River system by way of the diversion at Van Arsdale Reservoir (Cape Horn Dam). Neither the South Fork Eel River nor the Van Duzen River is impounded.

Secondary surface water bodies within the Basin include the Salt River and Yager, Strongs, Price, Palmer, Howe, and Rohner creeks, along with many other smaller tributaries, generally providing year-round colder freshwater to the Eel and Van Duzen Rivers from the upland slopes and watersheds surrounding the Basin. Additionally, a log pond in Scotia and wastewater treatment facilities in the municipalities of Fortuna and Loleta are minor surface water body sources compared to the primary rivers in the Basin.

Very little direct surface water extraction of the rivers is used to supply Basin residents with potable drinking water. Although the quantity of rural creek and spring water may be slightly more significant, it is difficult to estimate. The surface water quality of the Eel and Van Duzen Rivers and Basin creeks are relatively high and not impacted from commercial or industrial pollutants. Therefore, surface waters generally provide high-quality inflows to Basin groundwater.

3.4 Geologic Setting

The Basin is in a structurally controlled valley within a complex geologic setting, approximately 20 miles north of the Mendocino Triple Junction, where three crustal plates (Gorda, North American, and Pacific plates) intersect (Figure 9). Northeast-southwest directed compression associated with collision of the Gorda and North American tectonic plates dominates the region. The Gorda plate is actively subducting beneath North America north of Cape Mendocino along the southern portion of the Cascadia Subduction Zone (CSZ). Crustal deformation in the over-riding North American plate associated with the subduction of the Gorda plate is expressed as a fold-and-thrust belt, approximately 50 miles wide, within the accretionary margin of the North American plate (Carver 1987).

A major element of this fold-and-thrust belt is a broad structural downwarp (synclinal fold), referred to as the "Eel River syncline," coincident with the lower reaches of the Eel River (Figure 10 and 11). The folding affects a series of sedimentary units from the Plio-Pleistocene period referred to as the "Wildcat Group." The result is a geologic basin formed in the consolidated basement rocks of the region (Wildcat Group and underlying Franciscan formation) that fills with large quantities of unconsolidated alluvial deposits from the Eel and Van Duzen rivers, as well as streams flowing from the surrounding uplands. The Eel River has the largest mean annual sediment load of any river on the conterminous U.S. Pacific coast (Meade et al. 1990).

Burdette Ogle initially prepared the most comprehensive and detailed description of the geologic setting of the Eel River Valley area in California Division of Mines Bulletin 164, which includes mapping and unit descriptions focused on the Eel River Valley area. More recent work by McLaughlin and others (2000) led to mapping of the broader northern coastal California. The current boundary of the Basin follows geologic contacts shown on a geologic map by Dibblee (2008), which uses unit names not generally recognized by the local geologic community. Ogle (1953) defined the consolidated rocks of the Wildcat Group; his nomenclature and mapping remain in wide use by local geologists. The Wildcat Group consists of five sedimentary formations (from oldest to youngest: the Pullen, Eel River, Rio Dell, Scotia Bluffs, and Carlotta formations) deposited in the ancestral Eel River basin. The formations represent a shallowing (upward-coarsening) sequence, ranging from inner-shelf, fine-grained sandstone, siltstone, and mudstone (Pullen, Eel River, and Rio Dell formations) to near-shore sands and gravels (Scotia Bluffs and Carlotta formations). This upward coarsening of lithologies represents the transition (regression) from a deep-water offshore environment to a near-shore marine or terrestrial alluvial environment. Wildcat Group units unconformably overlie the regional bedrock material, the Franciscan Complex.

3.5 Soil Characteristics

Soils within the Basin are derived from weathering processes affecting geologic materials exposed at the ground surface. Soil development and distribution is generally influenced by the nature of the exposed geologic ("parent") material, as well as climatic, vegetative, and topographic factors. Regional groundwater aquifer recharge is directly affected by the soil characteristics that define permeability of the near surface materials. Areas with highly weathered, or clay-rich, soils are generally associated with low permeability, whereas unweathered granular soils are associated with high permeability.

Soil hydrologic groups are assessments of soil infiltration rates determined by the water-transmitting properties of the soil, which are directly related to the relative percentage of clay-to-sand and gravel present. The USDA-NRCS soil survey information is presented in Figure 12 for the mapped hydrologic soil groups. When saturated, the hydraulic conductivity of near surface soils is an indicator of infiltration potential and, therefore, groundwater recharge potential from precipitation. Hydrologic soil groups are defined as follows:

- Group A – High Infiltration Rate: water is transmitted freely through the soil; soils typically have less than 10 percent clay and more than 90 percent sand or gravel.
- Group B – Moderate Infiltration Rate: water transmission through the soil is unimpeded; soils typically have between 10 and 20 percent clay and 50 to 90 percent sand.
- Group C – Slow Infiltration Rate: water transmission through the soil is somewhat restricted; soils typically have between 20 and 40 percent clay and less than 50 percent sand.
- Group D – Very Slow Infiltration Rate: water movement through the soil is restricted or very restricted; soils typically have greater than 40 percent clay, less than 50 percent sand.
- Groups A/D, B/D, or C/D – Soils are assigned dual hydrologic soil groups where the first letter is for drained areas and the second letter is for undrained areas.

The hydrologic soil groups indicated in Figure 12 generally correlate with moderate infiltration rates flanking both the Eel and Van Duzen rivers—including Yager Creek and a large portion of the lower Eel River Valley north of Ferndale—and represent higher sand and gravel content. These moderate infiltration Group B hydrologic soils represent significant aquifer recharge zones, especially when overlying and in direct contact with coarse sand and gravel alluvial packages associated with former river channels. Basin soils generally grade from moderate infiltration potential proximal to the river channels to relatively slow infiltration rates in the distal floodplains, elevated marine terraces (Rohnerville, Hydesville, and Table Bluff), and upland slopes surrounding the Basin.

3.6 Principal Aquifers and Aquitards

Primary water-bearing units within the Basin include the thick sequence of near-surface unconsolidated alluvial deposits that form the lower Eel River Valley and portions of the Van Duzen River Valley, and the underlying Carlotta formation. Minor, localized aquifers are also present within the poorly consolidated sediments that make up the uplifted marine, fluvial, and flood-plain terrace sediments (Rohnerville and Hookton formations; Hydesville, Metropolitan, Rio Dell, and Scotia terraces).

The contact between the alluvial aquifer and the underlying Carlotta aquifer in the western portion of the Basin, within two miles of the active Eel River channel, is only partially defined at this time due to some similarities of material types found in each of the units and a lack of relatively deep wells with screens exclusively completed into distinct Carlotta aquifer materials. Well completion reports are often prepared with generalized descriptions of stratigraphy that do not allow for identification of the contact. This uncertainty is not particularly critical in the western portion of the Basin, as there are very few wells that are believed to extend through the alluvial aquifer into the Carlotta, with most of the use concerning shallow sources in the alluvial aquifer. The eastern half and southern portion of the Basin is now understood to have a distinct, relatively thick, fine-grained Carlotta formation aquitard unit underlying the shallow alluvium.

3.6.1 Alluvial Aquifer

The alluvial aquifer within the lower Eel River Valley is the most productive aquifer and, combined with its relatively shallow depths, the most utilized aquifer in the Basin. The alluvial aquifer is generally defined as the water-bearing units within the relatively young unconsolidated sediments overlying the Carlotta formation. It is most prominent within the central portions of the lower Eel River Valley where the thickness is in excess of 260 feet. The alluvial aquifer extends up the Van Duzen River Valley, thinning from approximately 125 feet thick at the confluence with the Eel River to less than 40 feet in the vicinity of the Town of Carlotta.

The physical characteristics of the alluvial aquifer reflect the dynamic tectonic and geomorphic history in the area and are observed to have significant lateral variation. In general, the alluvium is an accumulation of a variety of materials, tending to be coarser (sands, gravels) in areas where the river channels have migrated and finer (silts, clays) in areas where floodplain processes dominate. There are also thick sequences of fine-grained alluvial material along the base of the Wildcat Hills, particularly where major streams have built alluvial fans. The alluvial aquifer is generally unconfined, though semi-confined conditions can occur where there are particularly thick fine-grained units near the surface. The alluvial aquifer is generally in direct contact and hydraulic communication with the Eel and Van Duzen Rivers. Initial comparisons of surface water to groundwater levels in adjacent wells indicate a relatively rapid aquifer response to increased river stage heights (SHN, 2019). The unconsolidated alluvium is a highly productive aquifer, with supply well capacities typically ranging from 400 to 1,200 gallons per minute (gpm), that represents the primary water source for the majority of agricultural wells. Most wells in the alluvial aquifer are less than 100 feet deep and yield relatively high volumes (Evenson 1959).

3.6.2 Carlotta Aquifer

The Carlotta formation consists of an interbedded range of materials, from coarse-grained clastic sediments deposited in a near-shore or terrestrial setting, to thick sequences of fine-grained estuarine and bay environments. Based on its texture and regional distribution within the Basin, the Carlotta aquifer represents a principal aquifer and is often characterized as having dark-grey-to-blue sand and gravel. Groundwater within the unit is generally overlain and confined by a relatively thick and continuous silt and clay aquitard in the eastern half and southern portions of the Basin. The western and central portions of the Basin are overlaid by, and grade into, discontinuous silt and clay interbeds, as well as into alluvium and terrace deposits with semi-confined to unconfined conditions.

The Carlotta formation is known to be more than 1,500 feet thick (locally as much as 4,000 feet thick [USGS 1978]) and only the upper part of the Carlotta formation is tapped by water wells. There are likely many different sequences of aquifers at depth within the Carlotta formation coarse-grained sediments, but no studies have been conducted to characterize aquifers deeper than those being used historically and currently. Wells extracting groundwater from the Carlotta formation are predominantly found in upland areas, such as the slopes flanking the northern and southern boundaries of the Basin, the Ferndale area, and up on the Hydesville/Rohnerville terrace surfaces. Wells completed in the Carlotta aquifer tend to be deeper than the shallow irrigation wells completed in alluvium, often on the order of 200 to 400 feet deep. Some of the wells that intersect the Carlotta formation along the base of the foothills are flowing (artesian) wells.

Based on a review of the DWR Well Completion Report database, in terms of utilization in the Basin, it is estimated that approximately 40 percent of irrigation wells and 67 percent of domestic wells are drawing from aquifer units within the Carlotta formation. The general locations of these wells are shown in Figure 13. In general, the Carlotta aquifer is not as productive as the alluvial aquifer, so it isn't usually targeted except for areas outside the Eel River and Van Duzen River floodplain lowlands.

3.6.3 Aquitards

Virtually all the stratigraphic sections within the Basin comprise beds of fine-grained sediments, many of which are thick enough and/or of low enough permeability to act as an aquitard. Well-defined, laterally continuous aquitards, however, are not typical of the depositional environments in the Basin alluvium and can be difficult to define with confidence based on current well and boring information. Additional, properly logged, relatively deep (300 to 500 feet or greater) boreholes and monitoring wells installed out into the western half of the Basin would help address this data gap.

The Carlotta formation does have a laterally continuous, prominent aquitard in the eastern half and southern portion of the Basin that has been identified in this study. This first aquitard represents the uppermost section of Carlotta and underlies the alluvial aquifer, characterized as distinct dark-grey-to-blue silty clay. The Carlotta aquitard, two to three miles up the Van Duzen River near the center of the valley at Hydesville, is approximately 125 feet below the ground surface (bgs), and almost 75 feet thick. Near the confluence of the Eel and Van Duzen rivers at Alton, the Carlotta aquitard is 145 feet bgs and almost 20 feet thick. At the Fortuna wellfield just south of Kenmar Road on the east side of the Eel River, the Carlotta aquitard is encountered at 101 feet bgs and almost 30 feet thick.

Wells along the southern to central portion of the Basin encounter the Carlotta aquitard between 100 and 150 feet bgs; in Ferndale the aquitard is encountered in places within 20 feet of the ground surface and can be greater than 100 feet thick. In the western and central portion of the Basin, approximately a mile north of Arlynda Corners and a mile south of the active Eel River channel, an aquitard wasn't encountered in a new County monitoring well (MW-15d) borehole that was logged to a depth of 260 feet. The lack of the prominent aquitard within the MW-15d borehole to this depth is interpreted here to mean the aquitard has been eroded and scoured significantly in some central western portions of the Basin during historical sea level minimums by the active Eel River channel. This would result in mixed, combined hydraulic properties between the two principal aquifer units in direct communication, or essentially functioning as a single aquifer in those locations.

Groundwater levels in nested County monitoring wells (MW-12s/d, MW-13s/d, MW-14s/d) screened in the alluvial aquifer above and separately below the Carlotta aquitard indicate confined groundwater conditions in the Carlotta aquifer. These groundwater levels and aquifer conditions are detailed in both the Water Levels Technical Memorandum (SHN, 2021d) and Aquifer Parameters Technical Memorandum (GHD, 2021a).

Additional spatiotemporal resolution on the confining conditions together with the distinct differences within each of the Basin's aquifers flow directions and changing hydraulic gradients will come from the ongoing analysis of water levels subsequently recorded over time in the new County monitoring wells (construction completed in June 2021).

3.6.4 Aquifer Hydraulic Characteristics

Data regarding the hydraulic characteristics of the aquifers within the Basin are generally derived from past reports (Evenson, 1959; DWR, 1965; USGS 1978) and the studies carried out as part of the 2016 GSP Alternative and this GSP.

The alluvial aquifer is a high production unit widely utilized for agricultural irrigation and municipal water. Depth to water is generally shallow, with the water table on the order of a few feet to as many as 40 feet bgs. Most wells drawing from the alluvial aquifer are less than 100 feet deep. Specific well capacities are typically on the order of 20 to 350 gpm per foot of drawdown (USGS, 1978), although they may locally be as high as 600 gpm per foot of drawdown (DWR, 1965).

Specific storage values for partially or completely confined areas of the Basin have been previously measured, with the primary data provided by Evenson (1959), who estimated an average specific yield of 22 percent. Due to the nature of the Basin abutting the Pacific Ocean down gradient to the west, a fixed head boundary influences the available aquifer storage closer to the coast. Therefore, it is important to look at the volume of water in the aquifer as storage fluxing annually (as groundwater highs and lows).

Hydraulic conductivities of the alluvial aquifer, as measured in County wells installed in 2016 and 2021, range from 3 feet per day in the shallow fine-grained sediments west of Ferndale to as high as 420 feet per day in channel alluvium gravels adjacent to the active Eel River channel. Deeper (greater than 125 feet) screened wells in the confined Carlotta aquifer containing silt, sand, and gravel range from 0.3 to 11 feet per day (GHD, 2021a).

3.6.5 Primary Aquifer Use

The primary uses of the Basin aquifers and vast majority of groundwater pumping is for irrigation of croplands, and to a much lesser extent municipal water supplier extraction, with the remaining uses for non-municipal domestic potable water and non-municipal industrial and commercial purposes. Sections 4 and 5 provide detailed discussion of groundwater use and the Basin's water budget. Annual groundwater use from 2011 through 2020 are shown in Chart 1. Average groundwater use rates from 2011 through 2020 sector are presented in Table 10.

Groundwater is pumped from municipal wells, domestic wells, commercial/industrial wells, and irrigation wells, with locations spread throughout the Basin. Figure 4 displays the density of these wells throughout the basin. Irrigated lands are widely distributed, and municipal water suppliers are a locally concentrated extraction and fairly spread out, with remaining minor uses scattered intermittently throughout the Basin.

Table 10. Average Groundwater Use, 2011-2020

Use Type	**Municipal**	**Domestic (non-municipal)**	**Commercial / Industrial**	**Agricultural Irrigation**	**Cannabis**	**Total**
Acre-feet per year	1,733	414	34	12,559	98	14,837
%	11.7%	2.8%	0.2%	84.6%	0.7%	100%

The shallow, highly productive alluvial aquifer is distinctly separate from the Carlotta aquifer in the eastern half and southern portions of Ferndale out to Centerville. In the western half and the central portion of the Basin (within approximately one to two miles of the active Eel River channel) the alluvial aquifer grades into undifferentiable portions of the upper Carlotta aquifer, where together these two aquifers supply the vast majority, if not the entirety, of extracted groundwater. Groundwater is pumped from relatively shallow depths, with most of the irrigation wells of known construction completed into less than 100 feet of alluvial sand and gravel packages, with screened intervals starting around 20 feet bgs. The bulk of the Basin groundwater is used for irrigation pumping (Table 10 and Chart 1), which occurs during a relatively short season of approximately six months or less.

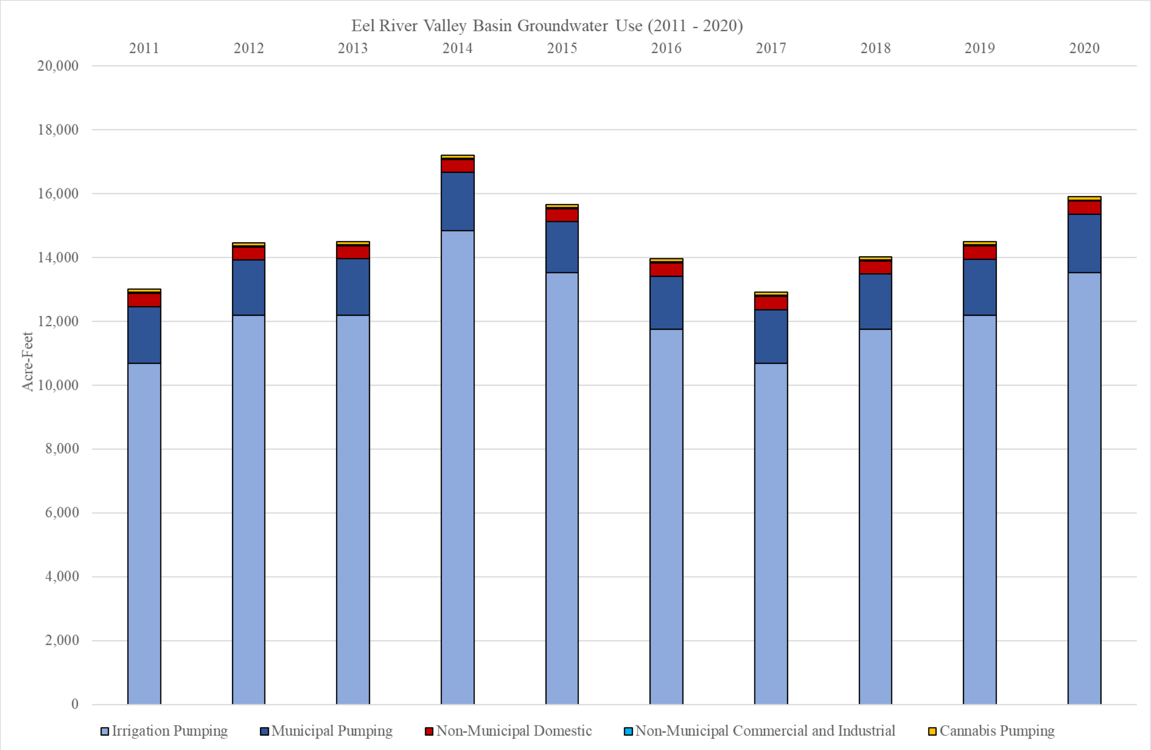


Chart 1: Annual Groundwater Use, 2011-2020

Municipal water supply wells are generally less than 200 feet deep, are fairly spread out, and have relatively deeper screened intervals than irrigation wells. Municipal supply wells serving the Bear River Band of the Rohnerville Rancheria are deeper than 600 feet, as they are located on an upland surface.

Domestic water supply wells for residences are scattered throughout the Basin and serve the entire rural and suburban populations outside of municipal water districts. The domestic water supply use is the most diverse of all use types in that residential wells are located within the agricultural lowlands in the Eel and Van Duzen River alluvial valleys, as well as in Basin periphery uplands around fringes of the municipal water suppliers (Ferndale, Table Bluff, Fortuna, Hydesville, Rio Dell, Carlotta), on the fluvial terraces with relatively shallow perched aquifers (Metropolitan, Rio Dell, Scotia, Alton), and on the marine terraces.

The shallow depth of water extraction is more critical in the western third of the Basin where the salt water-freshwater interface gets closer to the ground surface near the Pacific Ocean. Available oil and gas exploratory borings from the 1990s (and decades earlier) indicate a salt-fresh water interphase in the eastern portion of the Basin around the confluence of the Eel and Van Duzen Rivers could be at depths ranging from 600 to 1,000 feet.

3.6.6 Aquifer Recharge Areas

Important recharge areas for the Basin are shown on Figure 14. Primary sources of recharge are associated with the inputs from the river systems and infiltration from rain in the hydrologic soil groups, with relatively higher infiltration rates flanking the active riverbanks and channels. Surface flows from the Eel and Van Duzen rivers recharge the alluvial aquifer within the lower Van Duzen Valley and the lower Eel River Valley, as they are in direct hydrologic connection.

Surface water-groundwater monitoring along both the Eel and Van Duzen Rivers shows alluvial aquifer levels responding quickly to river level changes (SHN, 2019). High flows during wet winter months efficiently feed the shallow alluvial aquifer, particularly on the stretch of river between the confluence with the Van Duzen River and Fernbridge. Secondary streams draining the Wildcat Range south of the Basin also contribute to alluvial aquifer recharge.

The Carlotta formation aquifer is recharged by a variety of sources. The Van Duzen River and Yager Creek both enter the Basin from the eastern side and come in direct contact with the underlying Carlotta formation. There are opportunities to provide substantial Carlotta aquifer recharge where the coarse-grained Carlotta formation intervals meet channel alluvium. Additionally, the Carlotta formation is exposed in several upland areas directly surrounding the Basin, particularly along the southern margin and within the easternmost areas on either side of the Van Duzen Valley. In these areas, tributary streams flowing over the Carlotta formation provide direct surface flow recharge. Secondary aquifers—such as the Hookton formation, the Hydesville and Rohnerville terraces, and alluvial terraces surrounding the Basin are similarly recharged by precipitation and/or surface flows of tributary streams.

3.7 Land Subsidence

Review of 2016 to 2020 data from DWR's InSAR database indicates subsidence up to 0.25 feet with similar magnitudes of uplift measured elsewhere (Figure 15).

3.8 Data Gaps and Uncertainty

Data gaps within the current HCM include:

- The fault zone associated with the Little Salmon fault is complex and the single lineament shown on maps and in cross-sections is a simplification. Similarly, the impacts of secondary faults within the Basin, such as those of the Goose Lake faults, are not well understood in terms of their lateral extent and potential influence on groundwater flow and gradients in both the alluvial and underlying Carlotta formation aquifers.
- The stratigraphy and aquifer characteristics associated with the unique settings of the Rohnerville and Hydesville terraces are not well known and comparatively limited in data for historical water levels and overall groundwater use.
- The stratigraphy within the surficial alluvium is complex. Lateral and vertical stratigraphic variations are the result of a dynamic geologic history influenced by tectonics, sea level fluctuations, and large river systems with high sedimentation rates. The size and configuration of the aquifer(s) associated with the alluvial unit, particularly at depth, are not entirely defined. Similarly, the continuity of silt/clay layers (aquitards) across the Basin in the central western third and northern portion is not defined.

4 GROUNDWATER CONDITIONS

Prior to the implementation of SGMA, the most comprehensive review of groundwater conditions in the Eel River basin was described in the "Geology and Groundwater Features of the Eureka Area, Humboldt County, California" (Evenson, 1959) and the "Groundwater Conditions in the Eureka Area, Humboldt County, California 1975" (USGS, 1978). No focused groundwater evaluations or studies aimed at the sustainability of the groundwater resources have been carried out since that time until the implementation of SGMA. Since 2016, in response to SGMA, a wide variety of data collection and analysis efforts have been made to develop a better understanding of the current groundwater conditions.

Under the scope of the planning grants awarded in 2016 and 2020, Humboldt County conducted a variety of data collection tasks that includes the following:

1. Thirty-eight County monitoring wells were installed throughout the low-lying alluvial valleys of the Basin. Fifteen were installed in 2016 and 23 were installed in 2021. The network of County monitoring wells is shown on Figure 16.
2. Four large depth-to-water measurement campaigns have been conducted throughout the basin; fall 2016/spring 2017 and fall 2020/spring 2021.
3. Continuous water level monitoring has been conducted using pressure transducers installed in County monitoring wells, private wells, and river channels.
4. Surface flow studies were conducted on the mainstem Eel and Van Duzen Rivers during low flow seasons in 2016, 2020 and 2021.
5. Four chloride sampling campaigns have been conducted within the seawater-freshwater transition zone; fall 2016/spring 2017 and fall 2020/spring 2021.
6. Water quality sampling of 15 County monitoring wells was conducted in 2021 to evaluate existing conditions.

The results of these studies are used to build upon previous work characterizing groundwater conditions within the Basin. Continued monitoring of groundwater conditions as part of the implementation of this GSP will provide significant insight into the Basin. In addition to the field studies listed above, the integrated groundwater-surface water model developed for the Basin provides the tools necessary to evaluate conditions that have not previously been observed, such as increases in pumping, extreme droughts, or climate change.

4.1 Groundwater Elevations

4.1.1 Historical Groundwater Elevations

As far back as the early 1950s, DWR has monitored groundwater levels biannually within nine wells in the Basin as part of the CASGEM program. These wells provide the best long-term record of groundwater levels for the Basin. Figure 17 shows the locations of these wells and their associated hydrographs. Of those wells, five continue to be actively monitored.

A review of the hydrographs of the CASGEM wells indicates that the groundwater elevations within the valley are generally stable. The range in elevations between the spring and fall seasons are generally less than ten feet and on average, the wells within the western portion of the valley have slightly less range between the seasonal high and low levels (five feet to seven feet) than do the wells within the eastern side of the valley (eight feet to ten feet). This is reflective of a consistent gradient towards the ocean.

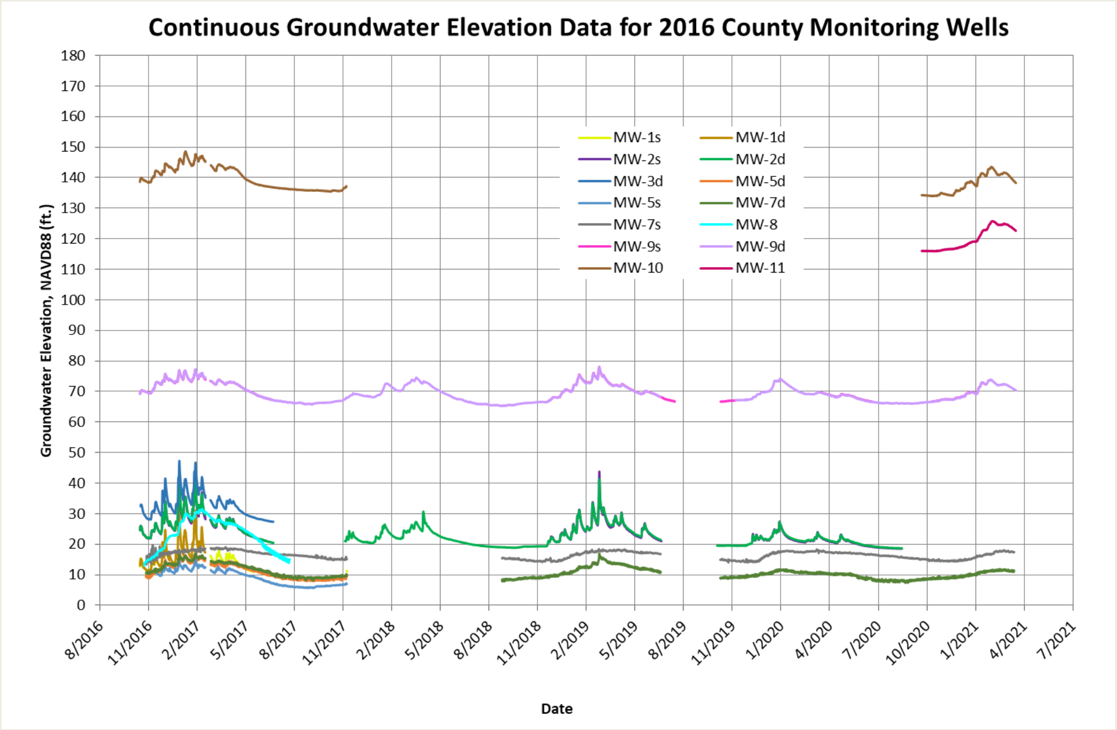
The hydrograph data also shows that the fall elevations are particularly stable with only very slight deviations from what appears to be a baseline elevation. In fact, the severe drought conditions of 2013 and 2014 showed very little response in the lower elevations. The only two wells with distinguishable effect on the fall water levels were CASGEM wells 23178 and 36942. Of the wells currently being monitored, these two wells are the furthest east and are closest to the Eel River. The relative change in the lower level in these wells was only on the order of two feet below the most recent normal year.

4.1.2 Current Groundwater Elevations

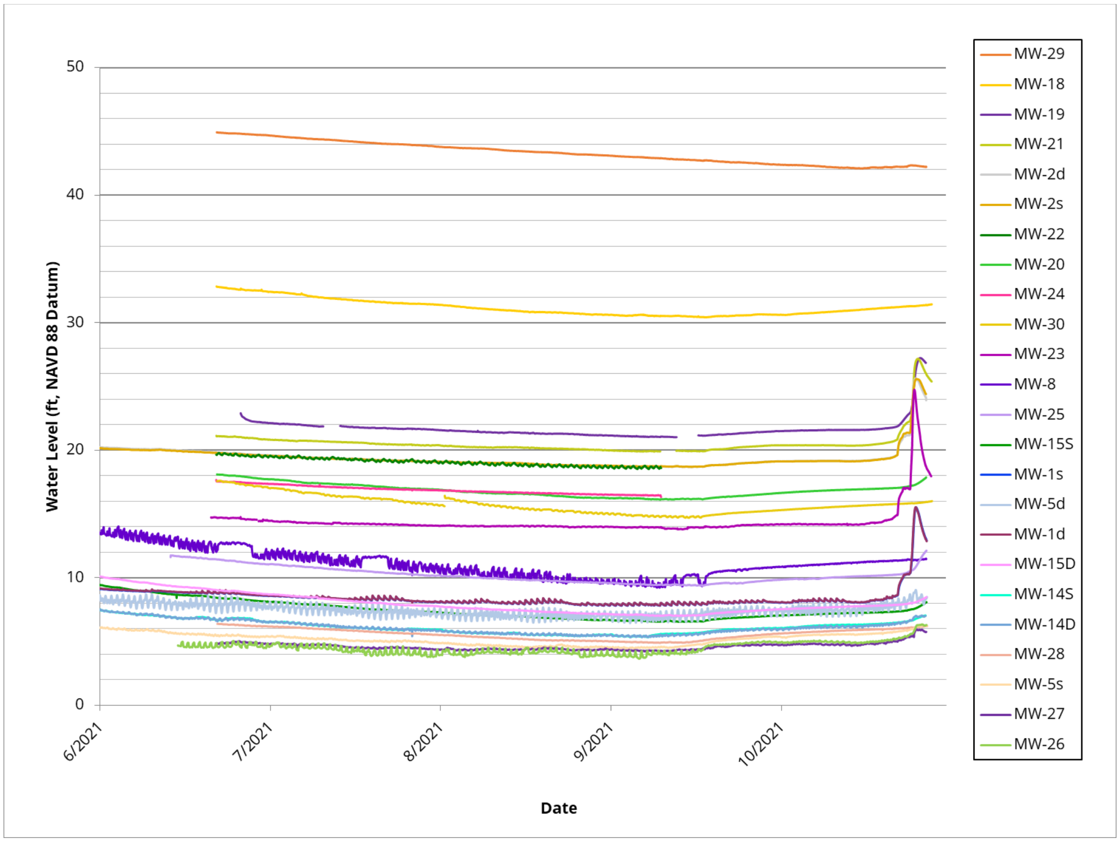
Four large-scale depth-to-water measurement campaigns have been conducted since 2016. Campaigns were conducted in fall 2016 and spring 2017, and again in fall 2020 and spring 2021. Each of these events measured groundwater levels within existing wells that included a mix of municipal wells, private wells, and County monitoring wells. The area of focus was limited to the alluvial plains of the Eel River Valley, the Van Duzen River, Yager Creek, and the Metropolitan Terrace. The groundwater contour maps associated with each of these events are provided as Figures 18 through 21.

Groundwater contour mapping shows that groundwater flow is toward the ocean (westward) with gradients and directions reflective of the topography. Flow gradients within the Eel River Valley are generally shallow with fall elevations ranging from approximately 30 feet along the eastern edge of the valley floor to five feet nearest the ocean. A much steeper groundwater gradient is observed within the Van Duzen watershed with fall elevations ranging from 130 feet within the Yager Creek drainage down to 30 feet at the intersection with the Eel River Valley.

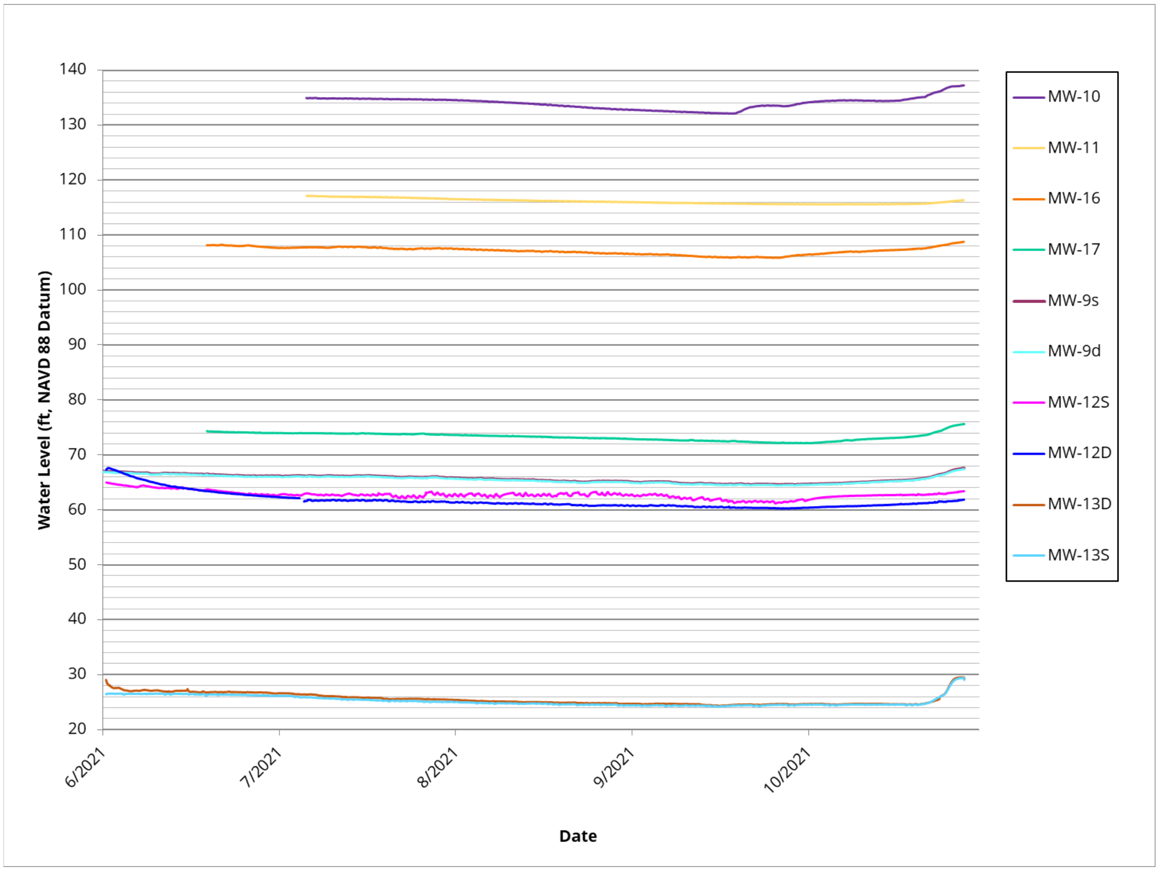
Biannual depth-to-water measurements have been collected in the 2016 County monitoring wells and most municipal wells since fall 2016. Additionally, pressure transducers have been used to record continuous groundwater levels at select well and river locations at various intervals since fall 2016. Graph 1 provides a composite graph showing the continuous water level data collected in the 2016 County monitoring wells from 2016 through Spring 2021. In 2021, the County monitoring well network was significantly expanded such that there are now 37 active monitoring wells in the Basin (Figure 16). All County monitoring wells have been outfitted with transducers beginning in June/July 2021 to record continuous water level data. A composite hydrograph of the groundwater level data collected over the Fall 2021 season in County monitoring wells within the lower Eel River Valley and the Van Duzen River Valley are provided on Graph 2 and Graph 3, respectively.



Graph 1. Continuous Groundwater Elevation Data, 2016-2021



Graph 2. Continuous Groundwater Elevation Data in the Lower Eel River Valley, Fall 2021 (see Figure 16 for locations).



Graph 3. Continuous Groundwater Elevation Data in the Van Duzen River Valley, Fall 2021 (see Figure 16 for locations).

The fall 2020 and spring 2021 groundwater-surface elevations measured within the CASGEM wells are some of the lowest on record, due to the particularly dry winters over the last two seasons. In most of the County monitoring wells, this drought condition can be seen reflected in lower-than-normal groundwater levels during the last two spring measurements (on the order of 2 to 4 feet lower than normal), but the drought condition is not as prominently reflected in fall measurements (less than 1 foot below normal). Spring groundwater levels are primarily influenced by the amount of recharge the aquifer(s) receive over the course of the winter season, which is heavily influenced by surface waters of the Eel and Van Duzen Rivers (SHN, 2019). The fall levels tend to stabilize at a base level that is likely controlled by the groundwater in storage within the adjacent upland areas and the upper portions of the Van Duzen watershed which would be slower to respond to drought conditions. Consecutive dry years may lead to lower-than-normal spring groundwater levels, but an equal lowering of the fall groundwater levels is not generally observed. This condition is also apparent in the long-term records for many of the CASGEM wells, where the spring levels vary significantly relative to the magnitude of variations in the fall.

4.1.3 Eel River Valley Alluvial Aquifer

The alluvial aquifer within the Lower Eel River Valley is in contact with the ocean on the west and surrounded on the east and north sides by the Eel River. The boundary conditions provided by the ocean and the Eel River play a critical role in the stability of groundwater conditions. The surface level of the ocean presents a physical limit to the level to which groundwater elevation can fall. Effectively, the coastal margin of the unconfined alluvial aquifer forms a down gradient hinge point in the annual fluctuation of the groundwater surface. This is evident in comparing the most recent fall and spring contour maps (Figures 18 through 21). The relative change in groundwater elevations between the fall and spring is greatest at the eastern edge of the Valley, diminishing to almost no change at the ocean interface.

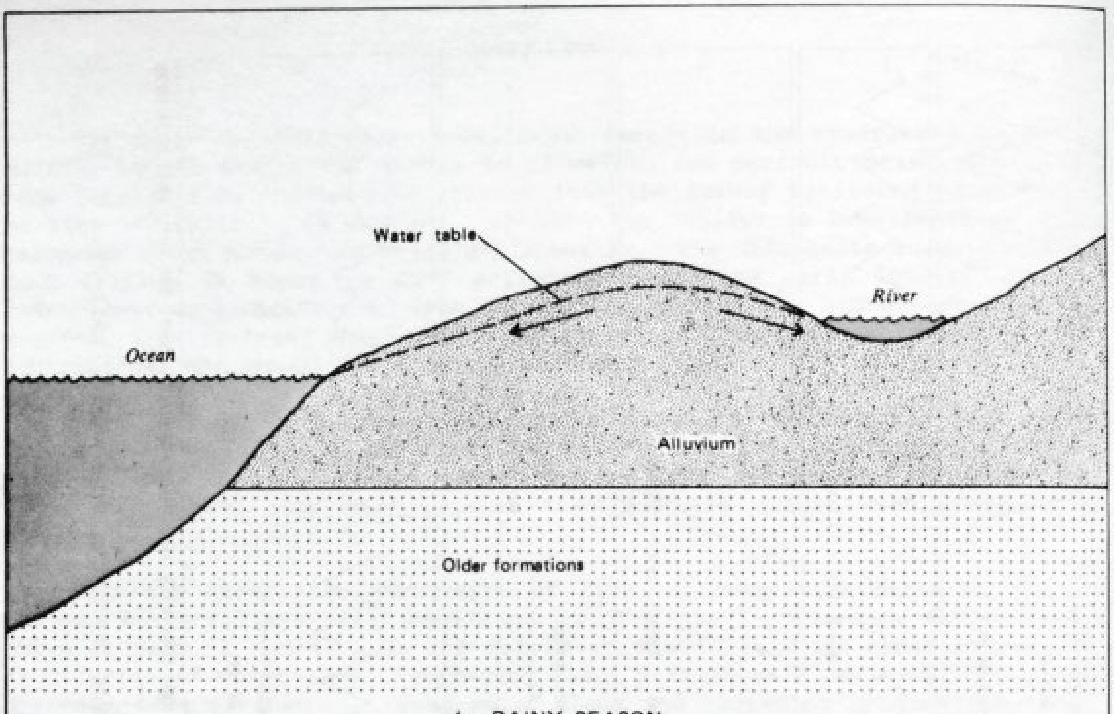
The Eel River is in close hydraulic connection with the alluvial aquifer. Monitoring wells installed in close proximity to the Eel River generally encounter sediments with high hydraulic conductivity and their hydrographs show a strong connection with river level changes. The capacity for the Eel River to provide significant recharge to the adjacent alluvial aquifer sets up a condition where the base flow within the river channel provides a control on groundwater elevations within the alluvial aquifer. Essentially, the elevations of the surface water and the groundwater remain connected and at similar elevations through the year.

The Eel River is a critical factor in the stability of the groundwater conditions in the valley. This condition was recognized by the author of the 1975 USGS study. Diagram 2, taken from the 1978 USGS report, illustrates the controlling relationship that the river and ocean play on groundwater elevations within the alluvial aquifer. The presence of the Eel River maintains stable groundwater levels and maintains a seaward groundwater gradient which holds the seawater-freshwater interface steady in its position.

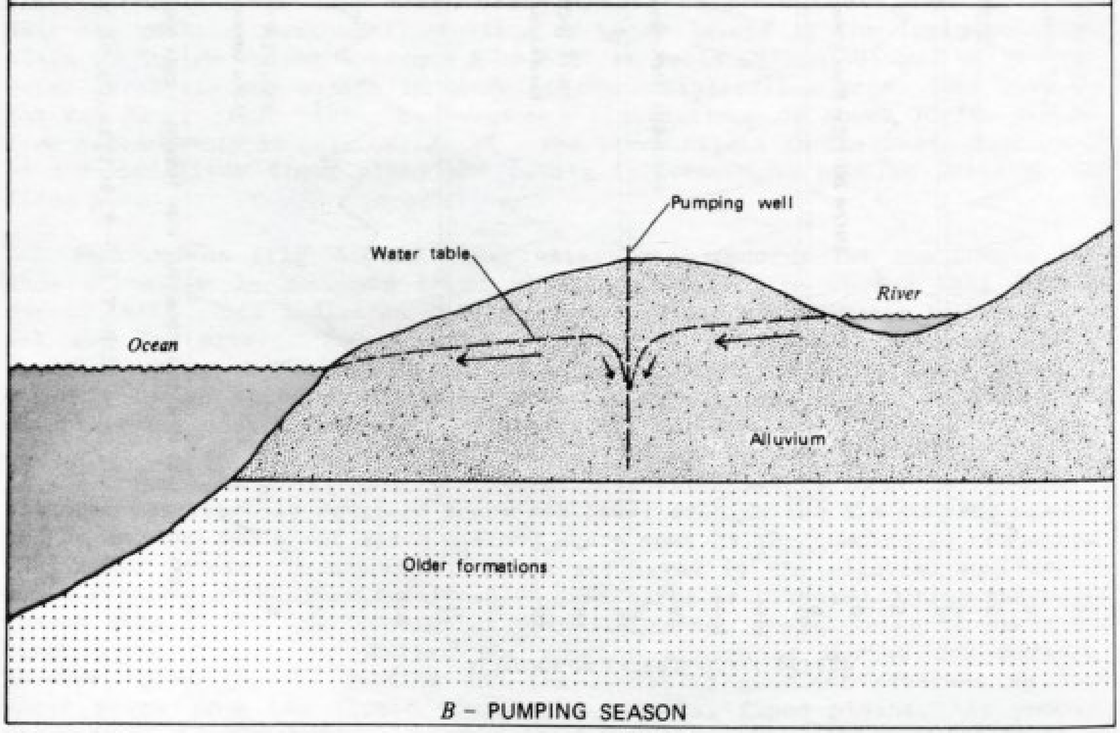
4.1.4 Van Duzen River Alluvial Valley

The primary aquifer within the Van Duzen River watershed is the thin alluvial valley fill (channel deposits interbedded with flood plain deposits), which are known to be in good hydrologic connection with the alluvial valley fill of the Lower Eel River Valley. Although there are no groundwater level records that extend back decades as in the CASGEM wells, bi-annual measurements and continuous monitoring of the County monitoring wells installed in 2016 provide some insight into the seasonal fluctuations and connections with the surface waters. The seasonal fluctuation in the groundwater elevations within the Van Duzen and Yager Creek alluvial plains generally range from seven to 12 feet. Groundwater is also well connected to the surface waters of the Van Duzen River and Yager Creek.

The groundwater contour maps for both spring and fall conditions (Figures 20 and 21) indicate a steep hydraulic gradient exists within the Van Duzen alluvial valley with measured elevations in fall ranging from approximately 130 feet in the Yager Creek drainage to 30 feet near the Van Duzen River's confluence with the Eel River. The relative change between the spring and fall groundwater elevations is on the order of approximately five to ten feet. The steep groundwater gradient within the Van Duzen alluvial valley is persistent through the year and is a constant and steady source of discharge to the east bank of the Eel River near the confluence with the Van Duzen. During the fall season, losses from the Eel River to the alluvial aquifer within the lower valley are somewhat offset by gains from the groundwater flowing westward and out of the Van Duzen River Valley.



A – RAINY SEASON



B – PUMPING SEASON

FIGURE 6.--Relation of water table to river and direction of ground-water flow during the rainy season and pumping season.

Diagram 2: Schematic Depicting Relation of Water Table to River and Ocean (from USGS, 1978)

4.1.5 Groundwater Conditions Below the Shallow Alluvial Aquifer

As discussed in Chapter 3, the stratigraphy and groundwater conditions at depth within the Basin are complex. The contact between the alluvial aquifer and the underlying Carlotta aquifer is a complex boundary that is not well delineated. Most wells within the Basin are screened within the alluvial aquifer, so there is limited available data to uniquely analyze groundwater levels or flow conditions within water bearing units at depth (lower, semi-confined alluvial aquifers or the Carlotta aquifer). Observations made in deep wells, in past studies and as part of recent work, indicate that some of the confined aquifers at depth are tidally influenced, some as far inland as Fortuna (CASGEM well 36944; USGS, 1978). Some wells that are located along the foothills of the Wildcat Range west of Ferndale and within the alluvial valley north of the Eel River near Loleta are artesian, indicating continuity with the groundwater within the adjacent slopes.

Four deep-screened wells were installed in 2016 (MW-5s and 5d, MW-7, and MW-8) and four deep-screened monitoring wells were installed in 2021 (MW-12d, MW-13d, MW-14d, and MW-15d). Groundwater levels measured in fall 2020 and spring 2021 from wells considered to be representative of deeper confined aquifers (below the shallow alluvial aquifer) is provided on Figures 4 and 6 of SHN (2021d). There is not enough resolution in the stratigraphy to associate the screened aquifers and there is hesitancy to use water levels measured at depth to define gradients and/or flow conditions, particularly within the vicinity of Ferndale. Within the Van Duzen valley, it appears that MW-12d and MW-13d can be associated with the same deep aquifer, interpreted to be within the Carlotta formation.

Six of the County monitoring well locations are deep-screened and paired with shallow wells. Relative water levels between these well pairs provide the opportunity to evaluate the relative hydrologic connection (or isolation) of the two screened intervals as well as evaluate any vertical gradients. Hydrographs and depth-to-water measurements collected in MW-5s/d and MW-7s/d since 2016 show strong vertical gradients (upward in MW-7s/d and downward in MW-5s/d). Continuous water level data collected in the new deep screened wells within the Van Duzen alluvial valley over the Fall of 2021 show that a downward vertical gradient exists in the location of MW-12s/d and an upward vertical gradient exists at MW-13s/d. Within the lower Eel River Valley, MW-14s/d does not have a notable vertical gradient whereas MW-15s/d has a persistent upward gradient. MW-14d is tidally influenced whereas MW-15d is not. Future monitoring will provide insight into how these gradients change seasonally and in response to climatic conditions.

4.2 Groundwater Storage

Previous estimates of groundwater storage (Evenson, 1959; DWR, 1965; USGS, 1978) were calculated based on storage-unit boundaries, usable saturated thicknesses, and specific yields. Evenson (1959) estimated 125,000 acre-feet (acre-feet) of storage capacity using saturated thicknesses ranging from 10 to 40 feet. Wells used for analysis at that time generally did not penetrate through the shallow alluvial aquifer, so the derived estimates were generally lower than actual total storage. The 1965 DWR study estimated 136,000 acre-feet with a usable storage capacity of 100,000 acre-feet using sea level as a base of the storage (on the west side of the Eel River Valley) and 15 feet below sea level as the base of storage (on the east side of the Eel River Valley). The rationale for a base of 15 feet below sea level was that the Eel River would continue to supply water without impacting seawater intrusion. These estimates were derived from simple volumetric calculations and judgment on the appropriate base of the storage in a “usable” context.

When considering the total freshwater volume of water in storage in the Basin, consideration of the size and saturated thickness of the alluvial and underlying Carlotta aquifers is appropriate.

The Carlotta Formation extends to depths below 3,000 feet (Ogle, 1953) and although the water isn't considered available for total consumption, it is nonetheless informative to evaluate how much freshwater is in the system. Based on calculations made using the hydrologic model (Section 5.3), the total volume of fresh water within the basin exceeds 6,000,000 acre-feet. The bottom panel of Chart 2 below plots simulated volumetric estimates of accessible freshwater (i.e., freshwater that is situated in channel deposits, alluvial aquifer, or Carlotta formation) in the Basin on a monthly basis. The freshwater volumes provide a reference for interpreting changes in storage and for interpreting how freshwater volumes are affected by water year types. Freshwater was defined as groundwater with chloride concentrations below the Secondary Drinking Water Standard of 250 mg/L and was determined using the seawater intrusion model.

Changes in storage annually and cumulatively have been calculated and reported since 2016 in the GSP Alternative and subsequent annual reports. The methodology used for these calculations was simplistic, based on spring water levels recorded in only a small number of representative CASGEM wells, and was geographically limited to the Lower Eel River Valley. Currently, and moving forward, the Basin hydrologic model can be used to compute changes to storage. The storage calculations will continue to be based on spring water levels but the geographic area will be expanded to include all the low-lying areas underlain by the alluvial aquifer.

Using the hydrologic model, annual change in groundwater storage over the twenty-year period from 2000 to 2020 was calculated by comparing March groundwater elevations to the previous year's March elevations in each quaternary alluvium model cell. This head difference is converted to a volume by multiplying by the 1,000 foot × 1,000 foot finite difference model cell area. The volume of groundwater is determined by scaling with a specific yield value of 0.21. The uppermost plot on Chart 2 presents the results of the annual change in spring storage. Changes in the spring storage are directly influenced by the annual recharge of the preceding winter months. Storage changes fluctuate and annual changes in storage are greatest when wet and dry winters alternate, as illustrated by the relatively large changes seen in 2018, 2019, and 2020. Changes in the fall storage are also presented on Chart 2. The fall water levels do not fluctuate as much as spring levels, so the values of annual change in storage are smaller.

For the purpose of calculating and presenting cumulative storage change, a reference storage condition, or starting point for comparison, is necessary. Because the hydrologic model uses simulated groundwater levels as the basis for the calculations of groundwater in storage, an "average groundwater level condition" is ideal for use as a reference condition. The groundwater levels recorded in the CASGEM wells provide the best opportunity to evaluate a long-term reference condition. Average spring groundwater levels were calculated for CASGEM wells 36943, 36942, 23181, and 23183, which are all currently active. The period of record used to develop the average included all measurements available (generally starting in the 1980s) up to 2015. To facilitate establishing a modeled reference condition, the modeled outputs were compared with the average groundwater elevations and 2003 was determined to be the best fit. The modeled groundwater levels for spring 2003 are used as a reference when calculating annual change in storage and cumulative storage change.

The cumulative change in groundwater storage for both the spring and fall conditions are presented in Chart 2. In both cases, the cumulative storage at any given year can indicate a deficit or surplus, largely based on the climatic conditions of the subject year, but the overall trends for both the spring and fall conditions indicate that a reduction in storage over time is not occurring. Additional details on the modeling and calculations for storage are provided in the Hydrologic Model Technical Memorandum (GHD, 2022a).

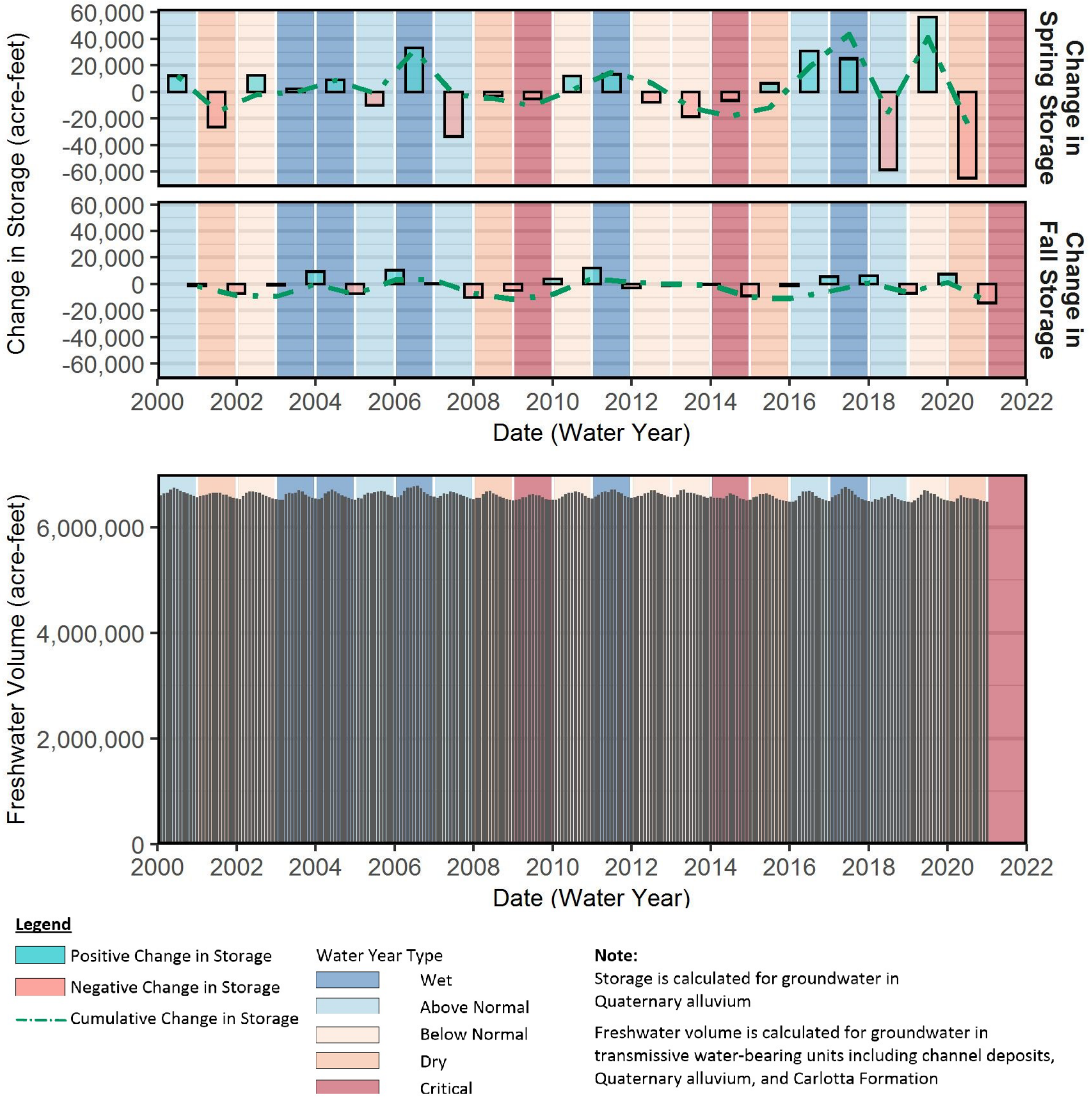


Chart 2: Modeled Annual and Cumulative Storage Changes in Groundwater within the Quaternary Alluvium (2000-2020) along with Total Freshwater Volume in the Basin.

4.3 Seawater Intrusion

The principal aquifers within the Basin are in close hydrologic connection with the ocean along approximately ten miles of coastline. The westernmost portion of the valley consists of a broad, low-lying coastal plain within intertidal/brackish marsh and wetlands. The tidal influence within the Eel River extends upstream of Fernbridge approximately 12 miles inland from the mouth.

4.3.1 Historical Conditions

The USGS's groundwater study (USGS, 1978) included an assessment of the freshwater-seawater transition zone in the Lower Eel River groundwater basin (defined as the 100 milligrams per liter [mg/L] iso-concentration line). The study concluded that the position of the freshwater-seawater transition zone in the alluvial aquifer in 1975 was approximately the same as the position of the transition zone as documented in 1952. The approximate location of the freshwater-seawater

transition zone as mapped in 1975 is shown on Figure 22. Almost all the alluvial aquifer located north of the Eel River, between the Eel River and Table Bluff, is naturally degraded by seawater (USGS, 1978). This area adjoins the stretch of the Eel River that is tidally influenced and seawater in the alluvial aquifer is expected in these areas. Between the Eel River and the Salt River, the alluvial material is composed of coarse sand and gravel which extends to the southeast to the confluence of the Eel and Van Duzen Rivers, and the freshwater-seawater transition zone in this section is moderated by the hydraulic head and subsequent recharge of the Eel River. South of the Salt River, the alluvial deposits are of low permeability (silt and clay), which deflects westward flowing groundwater to the northwest and impedes seawater movement inland.
Most of the wells sampled in the Eel River Valley in 1975 were screened within the shallow alluvial aquifer with depths generally less than 50 feet. As is expected in an unconfined coastal aquifer, it was noted that chloride concentrations at a given depth decrease with distance from the coast and generally increased with depth along the freshwater-seawater transition line (USGS, 1978). Localized temporary shifts in concentrations were observed seasonally, and this variation was attributed to the change in groundwater levels from summer to winter. According to the study, the substantial recharge from the stretch of the Eel River located above the tidal zone along the northeastern and eastern sides of the Lower Eel River Valley provides a seaward hydraulic gradient that sustains freshwater flows above sea level through the area south of the river. This freshwater head helps moderate the natural movement of seawater in the alluvium in this area.

4.3.2 Current Conditions

The current seawater intrusion conditions have been more recently evaluated through four large-scale chloride sampling campaigns. Campaigns were conducted in fall 2016 and spring 2017, and again in fall 2020 and spring 2021. During each event, chloride sampling of up to 30 wells representing a combination of municipal supply wells, private domestic/irrigation wells and County monitoring wells was performed. The geographic area of interest for these campaigns was generally focused on the western half of the lower Eel River Valley within the vicinity of the previously mapped 100 mg/L iso-concentration line. Details on these studies are provided in the 2016 Alternative Plan (SHN, 2016), annual reports prepared since 2016, and the Seawater Intrusion Technical Memorandum (SHN, 2021b).

The results from the fall 2016 and spring 2017 are provided as Figures 23 and 24, and the fall 2020 and spring 2021 results are provided as Figures 25 and 26. Although there are some areas of slight variability, the results of those studies have indicated that the freshwater-seawater interface remains in the same general position as that mapped in 1975. As initially described the 1975 study, the freshwater inflow from the Eel River and from the shallow aquifer in the Van Duzen River valley is significant and is a key component of the hydrogeologic conditions in the Basin that maintains a seaward hydraulic gradient and controls the extent of seawater intrusion. Groundwater level lowering that would be anticipated from any increases in extraction within the central portions of the valley would induce an increased inflow of freshwater from these sources and act to counter-balance the potential for inducing seawater intrusion. Results of modeling support this conclusion as discussed below in Section 4.3.4.

4.3.3 Seawater Intrusion Conditions at Depth

Most of the current and historical data useful for understanding the saltwater intrusion conditions has primarily come from the shallow alluvial aquifer. The configuration of the freshwater-seawater transition at depth is a known data gap and deeper wells that are screened within confined or semi-confined portions of the lower alluvial aquifer or the Carlotta have been sought out to gain better understanding of the conditions at depth, but deep wells with good construction characteristics for evaluating these deeper zones are hard to find. Four deep-screened County monitoring wells have been installed since 2016 (MW-5d, MW-7d, MW-14d and MW-15d) that were specifically located to explore saltwater intrusion conditions at depth.

Chloride concentrations from wells screened within deeper confined to semi-confined aquifers associated with the fall 2020 and spring 2021 sampling events are presented on Figures 27 and 28, respectively. As expected, the wells that are screened within the deeper zones tend to have higher chloride concentrations than those in the shallow zones. Some exceptions to this trend occur along the margins of the alluvial basin where wells are in the flow path of groundwater being recharged from adjacent hillslopes. A cross section of the SEAWAT model showing seawater conditions at depth is provided as Figure 29.

4.3.4 Seawater Intrusion Modeling

In support of the development of SMCs, a series of groundwater models were prepared to evaluate seawater intrusion using the SEAWAT_V4 flow model, developed by the USGS. The flow model was used to run an array of groundwater extraction scenarios designed to evaluate the relationship between water use, water levels and chloride concentrations. The models are considered appropriate for understanding the dynamics of the Basin but not suitable for making predictions of chloride concentrations in specific wells. The model runs were developed for the period between January 2000 and September 2020 and included the following scenarios:

- No-Pumping: Conditions that represent water levels and chloride concentrations if no pumping were occurring. This scenario establishes the natural variations to water levels and chloride concentrations.
- Current Pumping: Conditions that represent water levels and chloride concentrations observed under the current pumping rates.
- Increased Pumping: Conditions predicted to occur under increases to pumping rates at increments that included 10%, 20%, 30%, 40%, 50%, 100%, 150%, 200%, 250%, 300%, 400%, 500%, and 800% above current pumping rates.

Results of the increased pumping scenarios were analyzed to develop an understanding of the chloride/water level relationships and the pumping scenarios that are required to breach thresholds defined for specific well locations. The findings indicate that pumping would need to be increased by a minimum of 500% to 800% above current conditions to cause seawater to intrude inland enough to have a significant and unreasonable impact (as defined in Section 6.7). Modeled impacts were generally only predicted during years where a climatic stress was put on the Basin (low water year) and the intrusion conditions were confined to the late Fall season. The recharge associated with wet season surface water inflows and precipitation are sufficient to reset the position of the seawater/freshwater interface each year. In all cases, the model predicts that groundwater levels need to be lowered below sea level, and in many cases, well below sea level to induce seawater intrusion. These findings support the conclusion that the seawater-freshwater interface is stable under the current and historical conditions of use.

One pathway for seawater intrusion is lateral migration of shallow saline groundwater from the coastline. Modeling of how the groundwater gradients change as pumping increases shows that it takes 4x the pumping to significantly alter the groundwater gradients, and even in those cases, the gradient isn't directed eastward as much as it is to the south. There are a number of factors that limit the changes in groundwater gradients, including the induction of increases in flow of freshwater from the east that acts to counterbalance the change, but in addition, as water levels are lowered in the shallow alluvial aquifer there is an increase in the vertical gradient between the alluvial aquifer and the underlying Carlotta such that upwelling of water is increased. In areas where the groundwater at depth is higher in chloride content, upward migration of deep saline groundwater toward the surface could provide a pathway for seawater intrusion.

4.4 Groundwater Quality

This section summarizes groundwater quality issues that may affect the supply and beneficial uses of groundwater. Additional information is provided in the Water Quality Technical Memorandum (SHN, 2021c) contained in the Appendices.

4.4.1 Point Sources

The State Water Resources Control Board's online reporting resource, GeoTracker, was used to assess the distribution of contaminated or potentially contaminated sites across the Basin and to identify the constituents of concern that may be present (GeoTracker July 2021). A map of the locations of underground storage tank (UST) sites and cleanup sites is provided as Figure 30, and a map of permitted facilities including land disposal sites, wastewater treatment facilities, and hazardous waste sites that are regulated by the Department of Toxic Substances Control (DTSC) is provided as Figure 31.

The highest densities of regulated sites are located in the most populated areas of the Basin, including in or near the cities of Fortuna, Ferndale, and Rio Dell. The most common type of regulated sites are leaking UST (LUST) sites, which generally involve the release of petroleum hydrocarbons and volatile organic compounds (VOCs) to groundwater and soil. Most of these sites have localized releases that are contained within small geographic areas (usually on a single property). The majority of the UST and cleanup sites have achieved regulatory closure.

4.4.2 Municipal Raw Water Quality Data

Municipal water suppliers in the Basin include the City of Fortuna, City of Rio Dell, Palmer Creek CSD, Riverside CSD, Loleta CSD, Hydesville CSD, and Del Oro Water Company (Figure 2). Water quality data available for raw water supplies were evaluated for each of the municipal water suppliers. Municipal water suppliers report water quality data for each of their water sources (primarily wells or springs) in accordance with requirements of the California Code of Regulations, Title 22. Groundwater quality results are compared to primary and secondary drinking water standards, established by the U.S. Environmental Protection Agency (USEPA), and water quality standards established by the California State Water Resources Control Board's Division of Drinking Water (DDW). The water quality data collection and reporting are not conducted on regular intervals (i.e., yearly) and available data varies between municipality and year, but generally includes data for metals, nutrients, salts, VOCs, semi-volatile organic compounds (SVOCs), and alkalinity, among others.

Metals (nickel, silver, aluminum, arsenic, and zinc) and anions (sulfate, chloride, calcium, and magnesium) are commonly detected in the municipal raw water but do not show an increasing trend through time. VOC and SVOC detections appear rare. Based on discussions with Regional Water Board staff and the release of the Regional Water Board staff report on salts and nutrients, it is known that TDS and nitrate have been identified as constituents of concern in the Basin. Previous studies also indicate that iron and manganese can be found in high concentrations in the Basin. The City of Fortuna, Del Oro Water Company, and Palmer Creek CSD all use filtration systems specifically to remove these constituents.

The municipal raw water data for water suppliers in the Basin do not show any TDS exceedances (500 milligrams per liter [mg/L]) or any nitrate exceedances (10 mg/L) for the period of record. Iron and manganese have been reported by Palmer Creek CSD, Del Oro Water Company, and

Loleta CSD at levels above secondary MCLs (300 ug/L and 50 ug/L, respectively). Concentrations of iron and manganese have been consistently above the secondary MCLs for the period of record, suggesting that the occurrence of these constituents is related to background concentrations from the geologic formations of which the aquifers are comprised. Graphs presenting municipal data for TDS, nitrate, iron and manganese concentrations are provided in the Water Quality Technical Memorandum (SHN, 2021c).

Since 2002, arsenic has been detected in a supply well used by Del Oro at relatively steady concentrations ranging from 7.1 to 9.5 micrograms per liter (ug/L), which are below the MCL of 10 ug/L, with one anomalous value of 13.4 ug/L.

4.4.3 GAMA Data Evaluation

The Groundwater Ambient Monitoring and Assessment (GAMA) program is California's comprehensive groundwater quality monitoring program that was created by the State Water Resources Control Board in 2000. In 2016, a comprehensive evaluation of existing groundwater data from the GAMA program was evaluated and summarized in the GSP Alternative (SHN, 2016). In 2021 all available data for the last 10 years were downloaded from GAMA for the same 15 constituents that were evaluated in the 2016 and reviewed to identify specific exceedances for each constituent instead of using decadal averages, as had been done in 2016. The purpose of this analysis was to more closely evaluate trends through time for the 15 constituents. All results fell below MCLs, except for one TDS result in 2012 and an arsenic result in 2020. The four primary constituents of concern known to be present across large areas of the Basin are TDS, nitrate, iron, and manganese. These constituents of concern were queried in GAMA for all wells for the entire period of record and then again for only the last 10 years. There have been exceedances of the primary MCLs for TDS and nitrate at some points during the historical record, but not within the last 10 years. There continues to be exceedances of the secondary MCLs for iron and manganese, which is consistent with historical data from the entire period of record.

4.4.4 2021 Groundwater Quality Analytical Results

Fifteen County monitoring wells were selected for a broad suite of water quality sampling: five wells in April 2021 and ten wells in July 2021. The locations were chosen to optimize spatial coverage throughout the Basin and to represent portions of the underlying aquifers (wells screened in shallow and deep sections). Special consideration was given to areas where groundwater use is concentrated and/or has the potential to impact water quality. The well locations and tabulated analytical results are provided in the Water Quality Technical Memorandum (SHN, 2021c).

Endothall herbicide was detected at MW-27 and MW-28 but were below the MCL. There was one VOC detection at MW-15d and one SVOC detection at MW-12d. There was no detection of gasoline at any well, except for MW-28. There was one detection of E. Coli bacteria at MW-27 and there were detections of total coliform bacteria at nine of the monitoring wells. Nitrate was detected in five of the monitoring wells, but all detections were below the MCL. There was no detection that exceeded MCLs for fluoride, sulfate, or chloride, except for the chloride detection of 9,300 mg/L in MW-27 and 860 in MW-18. TDS was detected at every well below the Secondary MCL, except for MW 12d, MW-18, and MW-27. Every well had a detection that exceeded the MCL for alkalinity. Metals that were detected, but only at concentrations below the respective MCLs, include chromium, copper, nickel, selenium, and zinc. Metals that were detected at some wells above the respective MCLs include aluminum, iron, manganese, sodium, and arsenic. Arsenic was detected within six of the wells, five of which were above the primary

MCL. Arsenic was primarily detected at depth (greater than 200 feet below ground surface) and is interpreted to represent an elevated background condition. Other constituents were found to be elevated within the deeper portions of the aquifer system, such as aluminum, iron, and sodium. Shallow wells MW-18, located on the Metropolitan terrace, and MW-27, located near the intertidal zone north of the Eel River were both found to have elevated concentrations of multiple constituents, indicative of either an influence of land use or complex natural conditions.

4.4.5 Regional Salt and Nutrient Management Report

The Staff Report for North Coast Hydrologic Region Salt and Nutrient Management Planning Groundwater Basin Evaluation and Prioritization, 2020 public review draft provides Basin-wide information on salt and nutrient concentrations (Regional Water Board, 2020). The Eel River Valley has been identified as a high-priority basin for salts (defined as TDS in the report) and nutrients (defined as nitrate in the report). Based on correspondence with Regional Water Board staff, the data sources for the staff report include GAMA, the Dairy General Order, and the California Integrated Water Quality System Project (CIWQS) (CIWQS August 2021). Data from the Dairy General Order that were included in the staff report are not available online but were given by the Regional Water Board upon request, including analytical results for nitrate collected in 2013 and 2014 at dairies across the Basin. A combination of these results, data in GAMA, and locations of regulated facilities and facility types were the basis of the staff report. The central portion of the Lower Eel River Valley is presented in the staff report as the area of most concern for nitrate exceedances.

4.4.6 Water Quality Conditions and SGMA

The data review of published studies, work completed in 2016 as part of the GSP Alternative, State Water Resources Control Board and Regional Water Board data and online resources, data reported by municipal water suppliers, and recent data collected from County groundwater monitoring wells indicate that water quality within the Basin is generally of good quality and suitable for its intended uses.

GAMA and SDWIS databases provide the most comprehensive water quality data for the Basin, which indicate that the water quality trends have not shown any significant increase in measured concentrations. The municipal raw water data retrieved from the SDWIS database suggest that constituent concentrations of TDS, iron, and manganese have been reported within the same ranges since the late 1980s. The municipal data and the data retrieved through GAMA do not show increasing trends of these constituents through time, including within the last decade. The findings presented in the Regional Water Board’s staff report on salt and nutrients indicate that elevated levels of nitrate and TDS is an existing condition within portions of the Basin.

The Basin has naturally occurring moderate to high concentrations of TDS, iron, manganese, and arsenic. Municipal raw water data indicate that TDS values are generally between 100 mg/L and the secondary MCL of 500 mg/L at all municipal well locations since at least the mid-1980s. Iron concentrations have been an order of magnitude above the primary MCL of 300 ug/L at Palmer Creek CSD and Del Oro since at least the early 1990s. Manganese concentrations have been above the primary MCL of 50 ug/L at Palmer Creek CSD, Del Oro, and Loleta CSD since at least the late 1980s. The municipal data and the data retrieved from the online GAMA database do not suggest that trends for any of these constituents have been increasing over the last decade, which support the conclusion that these are background concentrations in the Basin.

While there are some constituents with elevated concentrations and some constituents of concern that are derived from land use, there are no known conditions of degradation of groundwater related to groundwater management or use. In addition, there have not been any significant changes in the groundwater management or use since 2015. Modeling scenarios that evaluate impacts associated with increased pumping scenarios are informative in that significant increases in pumping (4x and 5x current rates) are required to induce changes to the regional groundwater gradients and the direction of groundwater flow. Therefore, it can be concluded that degradation of groundwater associated with use is not likely to have initiated since 2015.

4.5 Land Subsidence

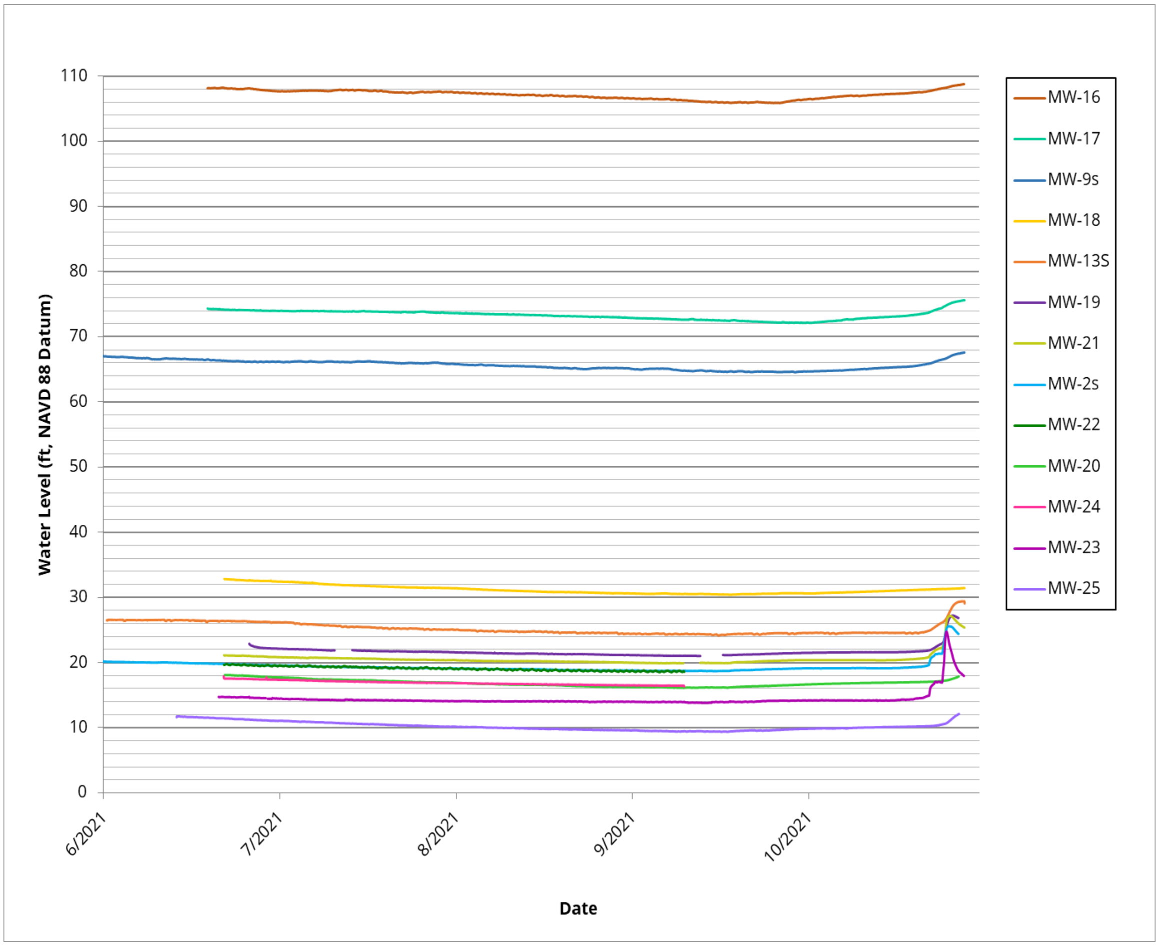
There is no known evidence of land subsidence associated with groundwater extraction in the Basin. The total fluctuation of groundwater elevations within the Lower Eel River Valley as shown in the CASGEM hydrographs (Figure 17) and recorded during groundwater level campaigns is generally on the order of 10 feet or less. To induce land subsidence, groundwater levels need to be lowered a sufficient distance and for enough time such that the dewatered formation can collapse. Fall water levels are relatively stable and have been for decades with only very minor seasonal variation. Modeling results indicate that the sustained water level lowering attributable to current groundwater use is generally less than a foot, with a maximum of two feet. Even under extreme increases in pumping, sustained water level lowering would only be on the order of 10 to 15 feet. The relative stability and consistency in the range of groundwater elevation fluctuations and the small impact that groundwater use has on these levels suggests that the conditions that could lead to land subsidence are highly unlikely to ever occur in the Basin.

DWR's InSAR database provides surface data back to 2016. Review of the available data indicates subsidence up to 0.25 feet with similar magnitudes of uplift measured elsewhere (Figure 15). Land level changes associated with the highly active tectonic environment in which the Basin occurs is expected to be an important consideration when reviewing and interpreting InSAR data into the future.

4.6 Interconnected Surface Water Systems

The primary interconnected surface waters within the boundary of the Basin include the Eel River and Van Duzen River, and presumably portions of Yager Creek and Salt River. Additional surface waters within the basin include the coastal wetlands, springs, and tributary streams within the uplands. A map of the hydrologic features of the Basin is provided as Figure 8.

The County monitoring well network was significantly expanded in 2021, with a portion of the well network specifically located to provide the ability to monitor groundwater levels near the Eel River and Van Duzen River channels. All County monitoring wells were outfitted with transducers in June/July of 2021 to record continuous water level data. This data will provide valuable resolution on the groundwater-surface water relationships through these critical reaches. A map showing a portion of the County monitoring well network that has been installed within the vicinity of the mainstem Eel and Van Duzen Rivers is provided in SHN (2022). A composite hydrograph of the water levels collected within the County monitoring network near the rivers is shown on Graph 4 below.



Graph 4. Continuous Groundwater Elevation Data near the Eel and Van Duzen Rivers during the 2021 Dry Season [see SHN (2022) for locations].

4.6.1 Eel River

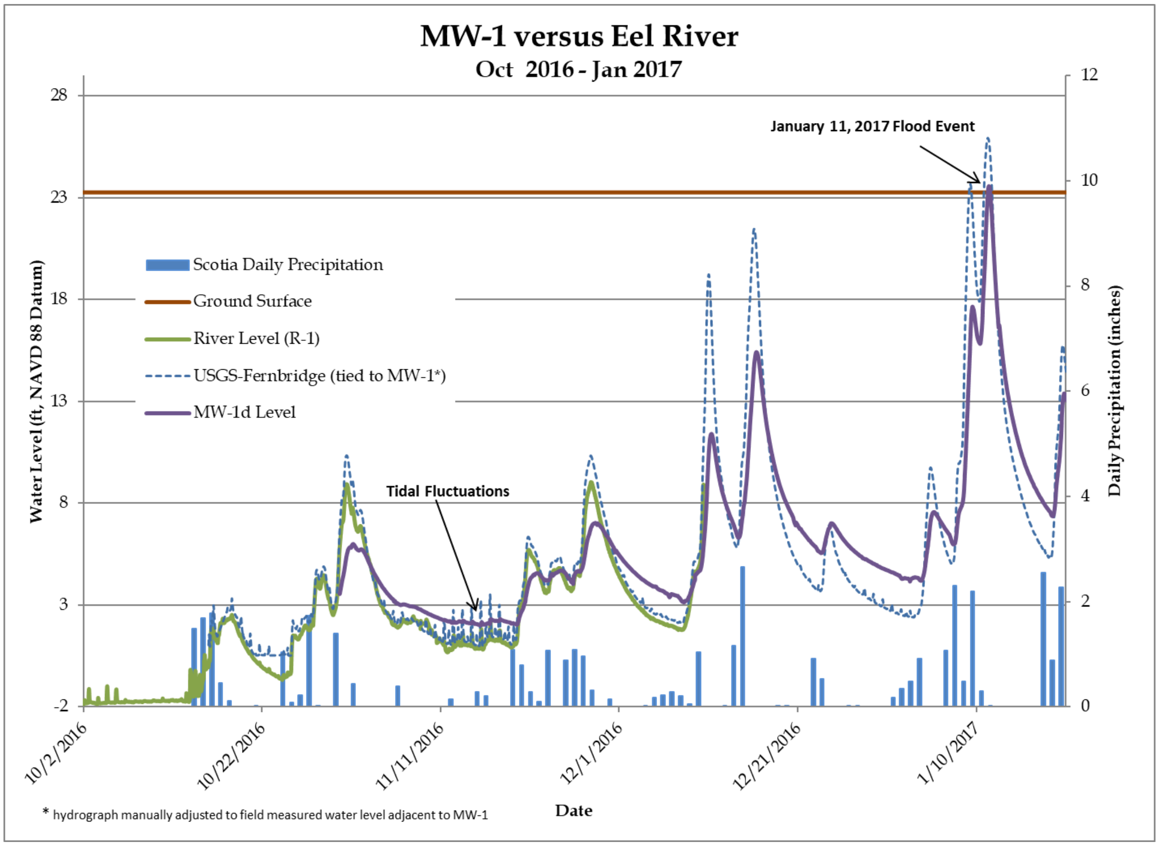
The Eel River drains the third largest watershed in California. Mean monthly flows recorded at the USGS gauging station in Scotia range from a high discharge in February of nearly 20,000 cubic feet per second (cfs) to a mean low flow in September of 140 cfs. On average, over 5,000,000 acre-feet flow into the Basin every year. The flows of the Eel River provide a significant component of the recharge to the alluvial aquifer as previously discussed.

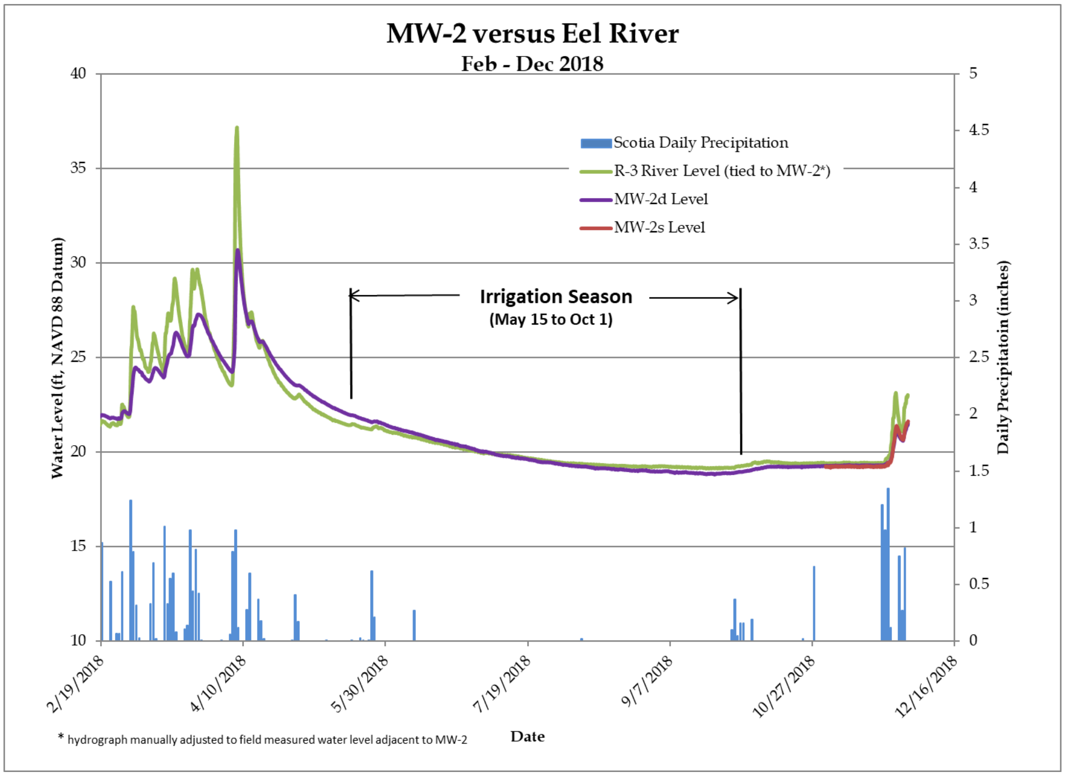
The reach of the Eel River that winds past the Scotia, Rio Dell, and Metropolitan areas flows over a bedrock channel with only a thin veneer of alluvial material. The bedrock within this reach is primarily composed of consolidated sandstone and mudstone of the lower Wildcat formation, which are not significant water bearing units. It is not until the Eel River enters into the valley, near the confluence of the Van Duzen River, where it transitions from a bedrock channel with thin alluvial cover to a low gradient alluvial plain with relatively thick deposits of channel sediments. It is within these areas that the Eel River is well connected with the groundwater.

Both the Eel River and the Van Duzen River converge in an area where the topography flattens, and the channel widens. Channel morphology is dynamic, and a significant volume of gravel can be redistributed in any given year. Bank erosion, channel widening, and braiding can affect flow velocities and patterns of scour and deposition. Stillwater Sciences (2021) provides a detailed discussion of monitoring for pool, riffle, and flatwater habitat. As a result of the thick accumulations of gravels, there is a significant amount of water that flows through the gravel beneath the channel (underflow). Accurately capturing and interpreting surface flow volumes using field measurement of discharges during low flow can be difficult in these reaches because of the complex interplay between surface flow and underflow.

The Eel River traverses the eastern perimeter of the valley for approximately five miles before it enters the intertidal zone near Fernbridge. The groundwater contour maps generated from the Fall 2020 and Spring 2021 measurement campaigns (Figures 20 and 21) indicate that groundwater consistently flows toward the Eel River from the Van Duzen drainage. Continuous groundwater levels collected in new County monitoring wells along the right bank of the Eel River indicates a complex relationship of gaining and losing tied with the morphology of the river (SHN, 2022). Riffle crests can be under losing conditions (and even go dry, as in 2014), whereas the base of riffles can be under gaining conditions.

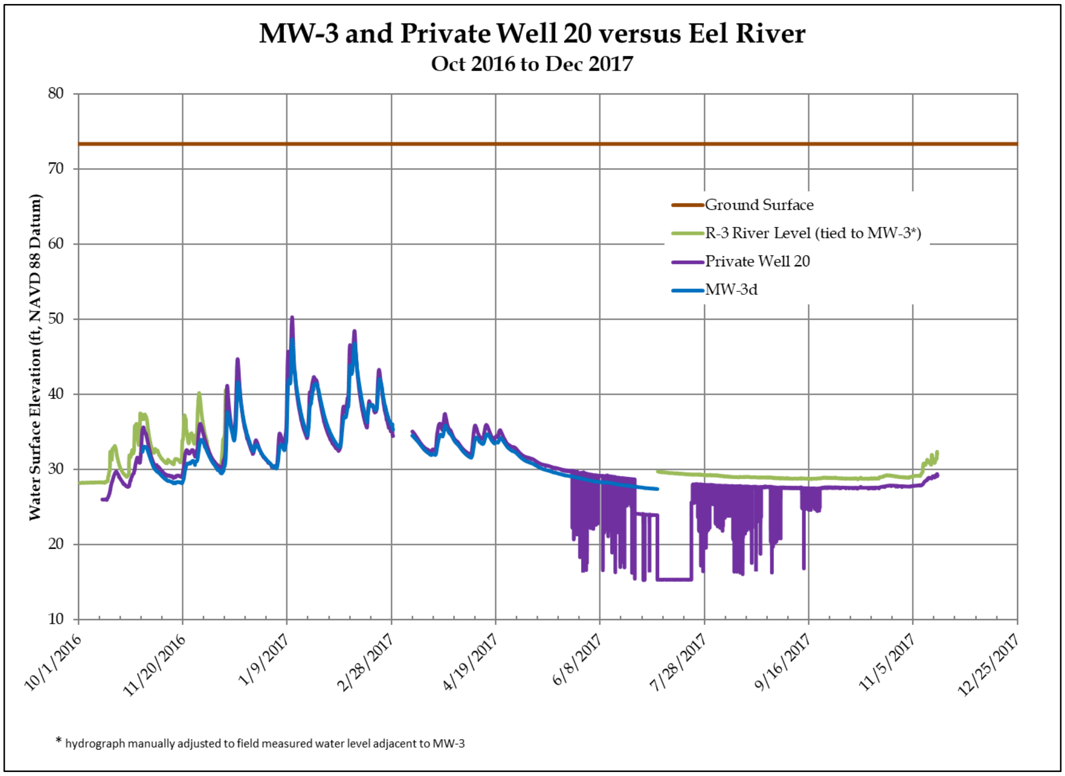
Coupled groundwater/surface water level monitoring at County monitoring wells MW-1, MW-2, and MW-3 along the left bank of the Eel River show strong connections with, and dynamic relationship between the river and the adjacent alluvial aquifer, as shown in Graphs 5-7 below. High flows during precipitation events drive groundwater gradients that discharge surface water into the aquifers. At the locations of monitoring wells MW-1 and MW-2, groundwater gradients temporarily reverse when the river levels subside, and aquifers begin to discharge back into the river. Winter season flows play a significant role in the recharge of the shallow aquifer system.




MW-2 versus Eel River
Feb - Dec 2018

* hydrograph manually adjusted to field measured water level adjacent to MW-2

Graph 6. Comparison of Water Levels Recorded in MW-2 and the Eel River (February-December 2018)


MW-3 and Private Well 20 versus Eel River
Oct 2016 to Dec 2017

* hydrograph manually adjusted to field measured water level adjacent to MW-3

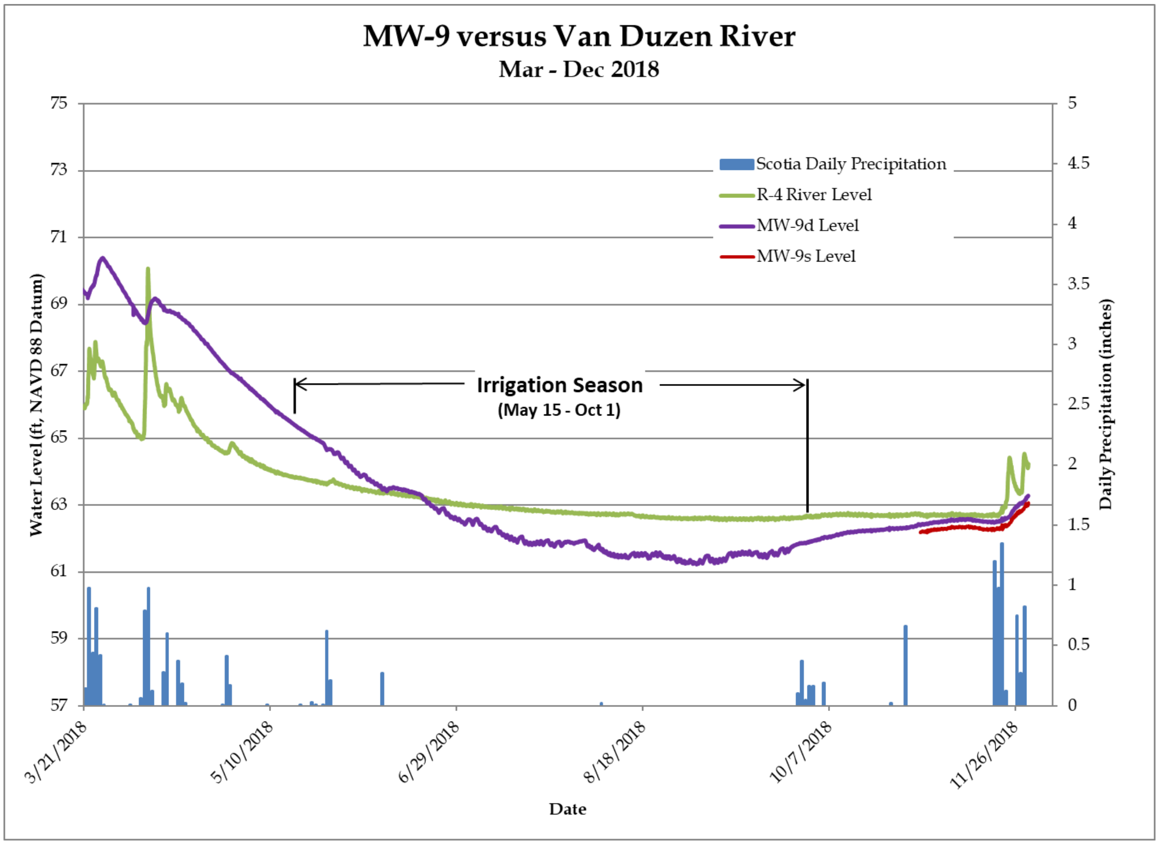
Graph 7. Comparison of Water Levels Recorded in MW-3, Well 20, and the Eel River (October 2016-December 2017)

4.6.2 Van Duzen River and Yager Creek

The Van Duzen River and the tributary Yager Creek constitute the primary surface waters within the eastern half of the Basin. Similar to the Eel River, the Van Duzen River transports and deposits a significant quantity of gravel; as such, there is a shallow alluvial aquifer consisting of older active channel deposits that generally encompasses and underlies the low-lying Van Duzen River valley floor. Nearly every year, surface flows diminish and transition completely into underflow before joining with the Eel River.

Within the upper reaches of the Van Duzen River and within the vicinity of Yager Creek the shallow alluvial aquifer is believed to be in contact with the older underlying Carlotta formation. The Carlotta formation is exposed in much of the upland slopes adjacent to the Van Duzen River valley floor and is an important source of recharge into the underlying aquifers. The elevation profile of the Van Duzen River is relatively steep as compared to the Eel River. The groundwater gradients reflect this topographic profile with a relatively steep groundwater gradient toward the west.

The analysis of coupled groundwater/surface water level data collected from within County monitoring well MW-9 in the Alton area over the 2018 low flow season indicate the surface water of the Van Duzen River is providing positive recharge to the shallow alluvial aquifer as shown in Graph 5. Similar to relationships observed in the Eel River, the groundwater levels within the aquifer show a rapid response to rises in surface water but in contrast, appear to maintain the elevations more steadily after surface water levels have receded.



Graph 8. Comparison of Water Levels Recorded in MW-9 and the Van Duzen River (March-December 2018)

4.6.3 Salt River

The Salt River watershed includes the upland tributary streams emanating from the Wildcat Range and the southern portion of the Eel River Valley. The Salt River has been significantly impacted by sediment to the point where many of its low-gradient tributary channels have been in-filled and no longer function to convey surface flow. A major restoration of the Salt River estuary and intertidal channels is underway, led by the Humboldt County RCD, and portions of the lower reaches have been opened back up to allow tidal inundation. Most of the Salt River and its tributaries within the valley floor are underlain by fine-grained flood deposits and alluvial materials shed from the southern hillslopes. Infiltration of surface water into these materials is generally slow and flooding during the wet season is common.

4.6.4 2016 Surface Flow Studies

Thomas Gast & Associates Environmental Consultants (TGAEC) conducted three rounds of surface water discharge measurements along the Eel and Van Duzen Rivers in the late summer/fall of 2016. The most comprehensive of the three studies was conducted on August 23-24, 2016, in which twelve locations within the basin were measured. The results of these measurements and pertinent features that relate to surface water flow conditions are discussed in SHN (2022).

Surface flow measurements along the Eel River show alternating gaining and losing reaches. The most significant change is between station E1 and E2 where a loss of 10 cfs is measured. This reach occurs over the general transition from shallow bedrock to thick alluvial deposits. An abrupt rise in flow between stations E2 and E3 is reflective of the inflow coming from the Van Duzen watershed (very little of which is surface water). Losing stream conditions between stations E3 and E4 are consistent with the strong left bank connection with the alluvial aquifer. An unknown volume of flow may be occurring as underflow within this reach. Gaining stream conditions are inferred from measurements between station E4 and Fernbridge (FB) associated with the inflow from upland sources north of the river and potential bank discharge from tidal fluctuations.

The flow measurements taken on the Van Duzen River and Yager Creek show predominantly losing stream conditions within the basin boundaries. This is consistent with the strong connection with shallow alluvium and the Carlotta Formation throughout this area. Both the lower reach on the Van Duzen River (stations VD2 to VD1) and the Yager Creek reach (stations Y1 to Y2) documented flows that went completely subsurface. Some of this flow is emerging in the Eel River channel and is reflective of the gaining stream measurements between stations E2 and E3.

4.6.5 2020/2021 Surface Flow Studies

Surface flow studies were conducted by TGAEC on selected sites on the Eel and Van Duzen rivers in the Fall of 2020 and 2021 to provide empirical data to support refining the Hydrogeologic Conceptual Model, developing and calibrating the integrated groundwater surface water model, and improving the understanding of the groundwater-surface water interactions along the Eel and Van Duzen Rivers. Details of the data collection methods and results of the 2020 and 2021 surface flow studies are provided in technical memorandums prepared by Thomas Gast & Associates (2022a, 2022b). A preliminary analysis of the results is detailed in a technical memorandum entitled Preliminary Analysis of 2020/2021 Surface Water and Groundwater Interaction Studies (SHN, 2022).

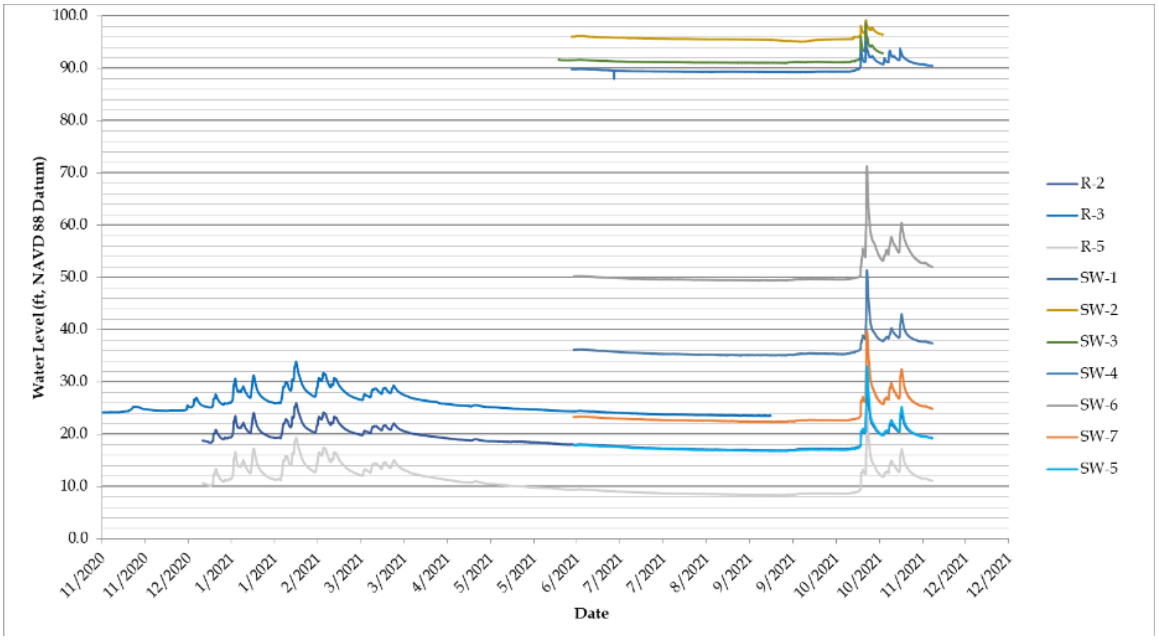
Ten locations were identified for the collection of surface water discharge measurements (three measurements at each location over the low flow season). A subset of locations was concentrated within the reach of the Eel River that traverses the head of the Lower Eel River Valley beginning at its confluence with the Van Duzen River extending downstream to the confluence with Palmer Creek (upstream of Fernbridge). This reach is of interest because it has the greatest potential for impact from groundwater use and was chosen as the focus for evaluating the sustainability indicator that relates to impacts to interconnected surface waters.

In 2020, three Eel River locations located between the confluence with the Van Duzen River and Fernbridge were measured (SHN, 2022). In 2021, an additional seven locations were added to the three measured in 2020 for a total of ten locations for surface flow measurements over the 2021 low flow season. The ten discharge measurement locations are shown on Figure 3 in SHN (2022). The findings from the 2020 and 2021 surface discharge measurements indicate that during low-flow conditions, Eel River surface flows decrease in the downstream direction through the upper and middle portions of the study area and then increase in the lower portion. This condition has been observed in the 2016 surface flow studies (SHN, 2016) and is interpreted to be in part due to the geomorphology of the Eel River channel and the sediments that form the underlying channel substrate. The upper portion of the Eel River through this reach has a series of steps, which often occurs as a sequence of pools and riffles. This stepped profile of the surface water results in a complex pattern of interaction with the groundwater, which is generally planar, and easily flows through the thick sequence of coarse deposits underlying the channel. More detailed discussion is provided in SHN (2022).

4.6.6 2021 Surface Water and Groundwater Monitoring

Coupled surface water/groundwater measurements in the Basin began in 2016. Preliminary analysis of the findings from these studies was presented in a 2019 technical memorandum (SHN, 2019).

As part of TGAEC's 2020 and 2021 surface water monitoring studies, continuous surface water level data was collected using pressure transducers at each of the ten study sites. The continuous surface water level data set extended through the latter part of the 2021 dry season and into the wet season before most of the transducers were pulled at the end of November 2021. Three transducers (R-2, R-3 and R-5) have been left in place to continue collecting surface water level data along the Lower Eel River into the future. A composite hydrograph showing the surface water level data over the 2021 low flow season is shown below (Graph 9).



Graph 9. Continuous Surface Water Level Data Collected during the 2021 Dry Season [see SHN (2022) for locations]

In 2021, the County monitoring well network was significantly expanded, with a portion of the well network specifically located to provide the ability to monitor groundwater levels near the mainstem channels. A map showing the existing County monitoring wells within the vicinity of the Eel and Van Duzen Rivers as well as the 2021 surface water level monitoring stations is provided in Figure 5 of SHN (2022). All County monitoring wells have been outfitted with transducers beginning in June/July 2021 to record continuous water level data.

A preliminary analysis of the 2021 surface water and groundwater interactions focused on the five-mile stretch of the Eel River that traverses the head of the Lower Eel River Valley using these continuous water level data is provided in SHN, 2022). Key interpretations of the data include the strong influence of the stepped topography of the river channel and how it creates a complex pattern of gaining- and losing-stream conditions. A previously unrecognized area of right bank losing-stream conditions just downstream of the R-3 location has been identified, which helps to explain the almost 10 cfs reduction in surface flow discharge between the QM-3 and QM-SW-5 locations. A signature of the irrigation season is not immediately discernable from the surface water or groundwater hydrographs. More regional effects on groundwater associated with pumping is expected to be subtle in the Basin and will be better evaluated after the collection and analysis of continuous groundwater level data that spans multiple years in a variety of climatic conditions.

4.7 Groundwater-Dependent Ecosystems

This section summarizes information and findings contained in the Groundwater Dependent Ecosystems (GDE) Assessment Technical Memorandum prepared by Stillwater Sciences (January 2022), which is contained in the Appendices.

4.7.1 GDE Introduction

GSAs are required to consider GDEs and other beneficial uses of groundwater when developing their GSPs. SGMA defines GDEs as "ecological communities or species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface" [23 CCR § 351(m)]. As described in The Nature Conservancy's (TNC) guidance for GDE analysis (Rohde et al. 2018), a GDE's dependence on groundwater refers to reliance of GDE species and/or ecological communities on groundwater or interconnected surface water for all or a portion of their water needs. SGMA defines interconnected surface water as "surface water that is hydraulically connected at any point by a continuous saturated zone to the underlying aquifer" where "the overlying surface water is not completely depleted."

Identifying riparian or terrestrial GDEs requires mapping vegetation communities that can tap groundwater through their root systems, assessing the elevation of groundwater relative to the rooting depth of that vegetation, and mapping the extent of surface water that is interconnected with groundwater (Rohde et al. 2018). Identifying the extent of aquatic GDEs requires mapping the extent of interconnected surface water, which changes based on season and water year type. Once mapped, the occurrence of special-status species can be used to assess the beneficial users of GDEs and the ecological value of GDEs in the basin, while remote sensing measurements can be used to track the health of groundwater-dependent vegetation through time.

4.7.2 Vegetation Community GDEs

Potential GDE units in the Basin were identified using the California Department of Water Resources' (DWR) indicators of groundwater-dependent ecosystems (iGDE) database, which includes vegetation and wetland natural communities, is published online, and is referred to as the Natural Communities Commonly Associated with Groundwater dataset (DWR 2020). These data were reviewed, edited, and augmented with additional vegetation mapping datasets to determine final GDE Units (Figure 33). Additional information on vegetation community composition, aerial imagery, depth to groundwater, species distributions, salinity tolerance, and rooting depths was also reviewed to support this determination.

This section includes brief descriptions of the vegetation community data and other information sources used to identify and aggregate potential GDEs into final GDE units. The iGDE database (Klausmeyer et al. 2018) was reviewed in a geographic information system (GIS) and used to generate a preliminary map to serve as a guide for initial identification of potential GDEs in the Basin. For more precise identification of potential GDEs, a refined vegetation map was developed by adjusting Classification and Assessment with Landsat of Visible Ecology Groupings (CalVeg) to better match current National Agriculture Imagery Program (NAIP) imagery. In addition, other available vegetation assessments (H.T. Harvey & Associates 2015 and Golec and Miller 2017) were reviewed to further refine vegetation boundaries. The geomorphic description classification from the National Resources Conservation Service (NRCS)-USDA Soil Survey Geographic Database (SSURGO) (USDA 2021) was subsequently incorporated to assess the landscape position and likelihood of groundwater dependence for select vegetation types. Four GDE units were identified within the Basin based on their hydrologic regime (Table 11).

Table 11: Groundwater Dependent Ecosystem Units in the Basin

GDE Unit	Area (Acres)
Intertidal zone and tributaries (intertidal reach downstream of Fernbridge)	5,981
Middle Eel River (Fernbridge to Eel/Van Duzen River confluence)	3,809
Upper Eel River (Eel/Van Duzen River confluence to Scotia)	1,136
Van Duzen River and tributaries	2,878
Total:	13,804

Seven dominant vegetation communities associated with groundwater were identified in the Basin (Table 12). These vegetation communities are mostly affiliated with the North Coast riparian forest and shrubland habitats within the floodplain of the Eel and Van Duzen Rivers (see Stillwater Sciences (August 2021) for complete descriptions of the vegetation communities). In addition to these vegetation communities, the Basin's GDE habitat encompasses areas that are frequently inundated, which CalVeg mapped as River/Stream/Canal. The mapped GDE habitats totaled 18,111 acres out of the entire 72,872 acres in the Basin.

Table 12: Vegetation Communities and Frequently Inundated Areas

Vegetation Community	Area (Acres)	Occupied GDE Units
Red alder (*Alnus rubra*) forest	3,231	All
Willow (*Salix* spp.) shrub	1,039	IZT, ME, VDRT
Willow (*Salix* spp.)	783	All
Black cottonwood (*Populus* spp.)	542	IZT, ME
Redwood	786	VDT
Annual perennial grassland	1,088	VDT
Riparian mixed hardwood	480	ITZ, ME
River/Stream/Canal	5,212	All

Notes: IZT = Intertidal Zone and Tributaries
ME = Middle Eel River
UE = Upper Eel River
VDT = Van Duzen River and Tributaries

4.7.3 Special-Status Species

Both aquatic and terrestrial/riparian special-status species occur in the Basin. These species are described in detail in Stillwater Sciences (August 2021) and summarized below.

As part of the ecological inventory, special-status aquatic species that are potentially associated with GDEs in the Basin were identified through the querying of State (California Natural Diversity Database [CNDDB] and Federal (IPac and NMFS California Species List tools) databases, monitoring reports developed by the California Department of Fish and Wildlife (CDFW), The Nature Conservancy freshwater species lists (TNC 2021), Critical Species

Lookbook (Rohde et al. 2019), and locally produced biological reports. Eight special-status fish, one mollusk, five amphibian, one reptile species occur within the Basin GDE Units.

The eight special-status fish species include Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), steelhead (*O. mykiss*), coastal cutthroat trout (*O. clarkii clarkii*), tidewater goby (*Eucyclogobius newberryi*), green sturgeon (*Acipenser medirostris*), Pacific lamprey (*Entosphenus tridentatus*), and longfin smelt (*Spirinchus thaleichthys*) occur within the Basin. The life history stages of these fish vary greatly, with some maintaining year-around presence in their habitat areas (e.g., tidewater goby and coastal cutthroat trout), while others (anadromous salmonids and green sturgeon) migrate through the Basin and only occupy it during certain life history stages.

The mainstem Eel and Van Duzen rivers are generally used as passage corridors for adult and juvenile coho and Chinook salmon and steelhead. However, early fall fish passage can be affected by seasonal low flows, which inhibit migration and result in fish concentrating in relatively few pools upstream of the intertidal area. Within the Basin, the combination of substrate that is too fine in the mainstem Eel River and frequent bedload movement typically impede successful anadromous salmonid spawning. Winter flows and bedload movement are also generally too high in the Van Duzen River downstream of Carlotta for spawning. However, a low level of spawning does occur in these reaches during dry water years when access to upstream reaches is restricted by low flows (ERRP 2014).

Water temperatures in the lower Eel and Van Duzen rivers generally exceed stressful conditions during the summer months, which limits juvenile salmonid rearing and may affect adult salmonids that enter the Middle Eel River GDE Unit in the late summer. Other challenges for salmonids include the presence of the invasive pikeminnow, the potential for harmful algal blooms (especially cyanobacteria) (Power et al, 2015), and variable ocean conditions.

Coastal cutthroat trout generally occupy the tributaries to the Eel River in the Intertidal Zone and Middle Eel GDE units. They are currently present in the Salt River watershed. They have also been recorded in Barber Creek (Middle Eel GDE Unit) in 1992 by CDFG. The Van Duzen River is the southern-most range of this species.

Tidewater gobies are present in the Intertidal Zone including the sloughs of the Eel River Delta and the Salt River restoration area. They are not present upstream of Fernbridge.

Green sturgeon are known to inhabit the lower Eel River and have been frequently observed upstream of Fernbridge in the 12th Street pool adjacent to Riverwalk during fall salmon surveys. Sturgeon have also been observed holding in the intertidal area downstream of Fernbridge. Northern DPS sturgeon are presumed to spawn in the mainstem Upper Eel River, based on observations at Fort Seward, approximately 80 miles upstream of the Basin. Spawning does not occur in the Basin. The Southern DPS green sturgeon likely enter the Eel River Estuary but are known to spawn only in the Sacramento River.

The Basin is primarily used by adult lamprey as an upstream migration corridor. However, lamprey ammocoetes may be found within the basin rearing in backwater areas containing organic silty deposits or in the fine substrate between cobbles in the mainstem river.

Longfin smelt are known to be present downstream of Fernbridge in the Salt River area. The last recorded sighting upstream of Fernbridge was near the mouth of the Van Duzen River in 1956 (Stillwater Sciences 2021b).

The mollusk (California floater [*Anodonta californiensis*]) inhabits locations in rivers that are protected from high water velocities such as root and sedge mats, rock crevices, downstream of boulder outcrops, etc. This species was recently observed in the Upper Eel River GDE Unit at Rio Dell within the interstices of bedrock and boulders where they were protected from scouring flows (Stillwater Sciences 2021).

Amphibian (foothill yellow-legged frog [*Rana boylii*]*,* northern red-legged frog [*Rana aurora*]*,* southern torrent salamander [*Rhyacotriton variegatus*]*,* and California giant salamander [*Dicamptodon ensatus*]), and reptile species (western pond turtle [*Emys marmorata*]) are present (i.e., documented occurrences) in the Basin GDE units and are classified as directly groundwater-dependent due to their association with stream and lentic habitats. One special-status amphibian species, Pacific tailed frog (*Anaxyrus californicus*), is possibly present in the Basin, though its habitat is generally limited to the steep margins of the Basin.

Similar to the aquatic species, the terrestrial species associated with GDEs in the Basin were identified through the querying of State and Federal databases, eBird, and Critical Species Lookbook (Rohde et al. 2019). The terrestrial species (14 birds and one bat) associated with GDEs in the Basin are indirectly dependent on groundwater. Bird species use a variety of habitats within the basin's GDE units for foraging, nesting, and migration. These GDEs include riparian (e.g., willow, cottonwood), wetland (e.g., pickleweed-cordgrass), aquatic (e.g., perennial lake or pond, river/stream/canal), and forest (e.g., redwood, riparian mixed hardwood) vegetation communities. The birds are primarily reliant on surface water that may be supported by groundwater and/or groundwater-dependent vegetation. For example, the marbled murrelet nests in old-growth conifer stands that are dependent of groundwater and the willow flycatcher is dependent on riparian woodlands.

The Townsend's big-eared bat (*Corynorhinus townsendii*) was classified as indirectly groundwater-dependent due to its association with riparian communities during foraging. In addition, the Townsend's big-eared bat, and unlike many other bats, due to its relatively poor urine concentrating ability, drinks water.

4.7.4 Designated Critical Habitat

The Basin GDEs also contain designated critical habitat for seven federally listed species: marbled murrelet (*Brachyramphus marmoratus*), western snowy plover (*Charadrius alexandrinus nivosus*), California Coast (CC) evolutionarily significant unit (ESU) Chinook salmon (*Oncorhynchus tshawytscha*), Southern Oregon/Northern California Coast (SONCC) ESU coho salmon (*Oncorhynchus kisutch*), Northern California Coast steelhead (*Oncorhynchus mykiss*), and tidewater goby (*Eucyclogobius newberryi*) (Figure 34).

4.7.5 Potential effects on groundwater-dependent ecosystems

The biological response to change in groundwater was assessed based on changes in Normalized Difference Vegetation Index (NDVI) data for individual vegetation polygons within the GDE units (Klausmeyer et al. 2019). The polygons correspond to different GDE mapping units (i.e., different species compositions) and the size of the GDE polygons varied. This analysis is presented in more detail in Stillwater Sciences (January 2022). NDVI, an estimate of vegetation greenness is a commonly used proxy for vegetation health in analyses of temporal trends in the health of groundwater-dependent vegetation (Rouse et al. 1974 and Jiang et al. 2006 as cited in Klausmeyer et al. 2019).

Based on the NDVI data, groundwater quality data from wells in or near GDE units in the Basin, and the likely susceptibility of the terrestrial and aquatic species and natural communities in each GDE unit to reported groundwater quality constituents, no evidence was found of a biological response associated with groundwater quality in any of the GDE units. Groundwater quality is therefore not addressed further in the analysis of potential effects.

As outlined in Stillwater Sciences (January 2022), changes to groundwater elevation are not correlated to changes in NDVI for all four GDE units. The NDVI for all of the GDE units has been steady or increasing through time and annual changes to NDVI were not correlated with changes to summer groundwater elevation. Groundwater levels in wells with long-term data are generally within the rooting depth of GDE plants in the Intertidal Zone and Tributaries GDE Unit. For the Middle Eel GDE Unit, wells with long-term data were near the Salt River and water levels were seasonally within the likely rooting zone during the wet season, but not during the dry season. GDE units along the Salt River may use other sources of water including surface flows in the Salt River and soil moisture rather than groundwater. Recent groundwater measurements near the Van Duzen and Tributaries GDE units suggest that groundwater is within the rooting zone of the plants that make up the GDE. The cooler air temperatures along the North Coast means that soil moisture lasts longer into the dry season and phreatophytes may be less dependent on groundwater than in hotter and more arid regions.

The effect of groundwater management on aquatic GDEs is assessed in Stillwater Sciences (January 2022), GHD (January 2022a), and Section 6.11. The critical time-period of the year is in the fall because of the combination of low flows, ongoing water use, and the beginning of the upstream migration period of Chinook salmon. Successful upstream migration by adult Chinook salmon through the Basin during the fall is generally dependent on the water depth over critical riffles between the mouth of the Van Duzen River and Fernbridge. Riffle depth and flow data collected between 2010–2020 suggest that riffle depths of 0.7 feet coupled with flows exceeding 130 cfs are suitable for unimpeded upstream migration. However, flows required to support passage (i.e., > 0.7 feet at critical riffles) vary annually due to changes in channel morphology. For example, a relatively linear and narrow riffle could have sufficient depth for passage at a given flow, but a nearby oblique riffle having a wider cross-sectional area and shallower depth could potentially inhibit upstream adult salmonid migration at that flow.

Potential changes in critical riffle depth resulting from agricultural and municipal water use could affect fish passage. Because surface water flows depend on surface water inflows and interconnected groundwater, the numerical modeling conducted as part of this GSP was used to evaluate changes to interconnected surface water due to groundwater management and the potential effect on aquatic GDE units and fish passage. The riffle depth data collected between 2010–2020 were reviewed and coupled with the groundwater model to assess potential impacts on fish passage due to groundwater management (Section 6.11).

In general, climate change can affect GDEs by altering the water budget, causing groundwater levels to decline, and causing interconnected surface flows to decrease (Dwire et al. 2018). Moreover, climate change could increase the risk of wildfire and promote establishment of non-native species, which could impact GDE health (Dwire et al. 2018).

Though climate change may alter the water demands of groundwater-dependent vegetation, the response is complex. Decreased transpiration associated with increased carbon dioxide in the atmosphere may counter increased evaporation due to temperature increases (e.g., Kløve et al. 2014). In addition, sea level rise may extend the existing tidal influence farther inland and increase salinity levels in inundated soils and waterways, thus impacting existing groundwater-dependent vegetation communities and possibly shifting vegetation towards more salt-tolerant species assemblages.

4.7.6 Ecological Value and Potential Effects of Groundwater Management

The potential effects on each GDE Unit are summarized here based on three primary criteria:

1. Ecological value (high, moderate, low), characterized by evaluating the presence and groundwater-dependence of special-status species and ecological communities and the vulnerability of these species and their habitat to changes in groundwater levels (Rohde et al. 2018). In addition, the presence of natural or near-natural conditions and ecosystem function was also considered.
2. Ecological condition of the GDEs within each unit (good, fair, poor).
3. Susceptibility to changing groundwater conditions (high, moderate, low) based on available hydrologic data, climate change projections, and the GDE susceptibility classifications summarized in Stillwater Sciences (August 2021).

All four GDE units were found to have high ecological value for aquatic and terrestrial GDEs based on the presence of directly or indirectly groundwater-dependent special status species and identified critical habitat. The ecological condition of GDEs is good based on stable NDVI data in all four GDE units. Due to relatively short-term data and relatively steady groundwater conditions, the potential for effects of groundwater management on these GDEs is uncertain. The major potential for effects in the Intertidal Zone and Tributaries and Middle Eel GDE units is increased salinity associated with sea level rise.

The potential effect of changes to pumping on aquatic GDEs was evaluated in GHD (2022a), where modeling suggested that pumping is unlikely to have a significant effect on fish passage in the Middle Eel River unless groundwater withdrawals are increased by more than 150% in the September to November period when fish passage is most likely to be impaired. Continued monitoring of GDE health through remote sensing and monitoring of future fish passage conditions once the GSP is adopted will help to ensure that GDE health and fish passage conditions are not being adversely impacted by groundwater management.

5 WATER BUDGET

This section summarizes the estimated basin wide water budget for the Basin. The water budget provides an inventory of the total annual volume of surface water and groundwater entering and exiting the Basin over a specified period of time, as stated in 23 CCR Section 354.18.

5.1 Overview of Water Budget Development

The water budget is an accounting of all the water entering and exiting the Basin. The water budget is comprised of surface water components and groundwater components. The water budget is derived by accounting for the combined flow into and out of surface and groundwater components. Certain components of the water budget were measured, such as municipal groundwater extraction. Other components were estimated, such as ungauged stream inflow and domestic groundwater well extraction. Further water budget components were calculated from a hydrologic model, such as precipitation infiltration and surface water seepage into groundwater.

The water budget is computed using several modeling tools and collection of existing data. The modeling tools used include Precipitation Runoff Modeling System (PRMS), Groundwater Flow Model (MODFLOW), and Cal-SIMETAW. Data sources included:

- Precipitation data
- Municipal groundwater water extraction and surface diversions
- Municipal wastewater discharge
- USGS stream gage data
- Land use zoning and mapping
- Agricultural water use inventory and metered well data

Conceptual representations of the water budget accounting model is presented in Diagram 3 and Diagram 4. A groundwater budget and surface water budget are presented for each of the three periods — historical, current, and projected.

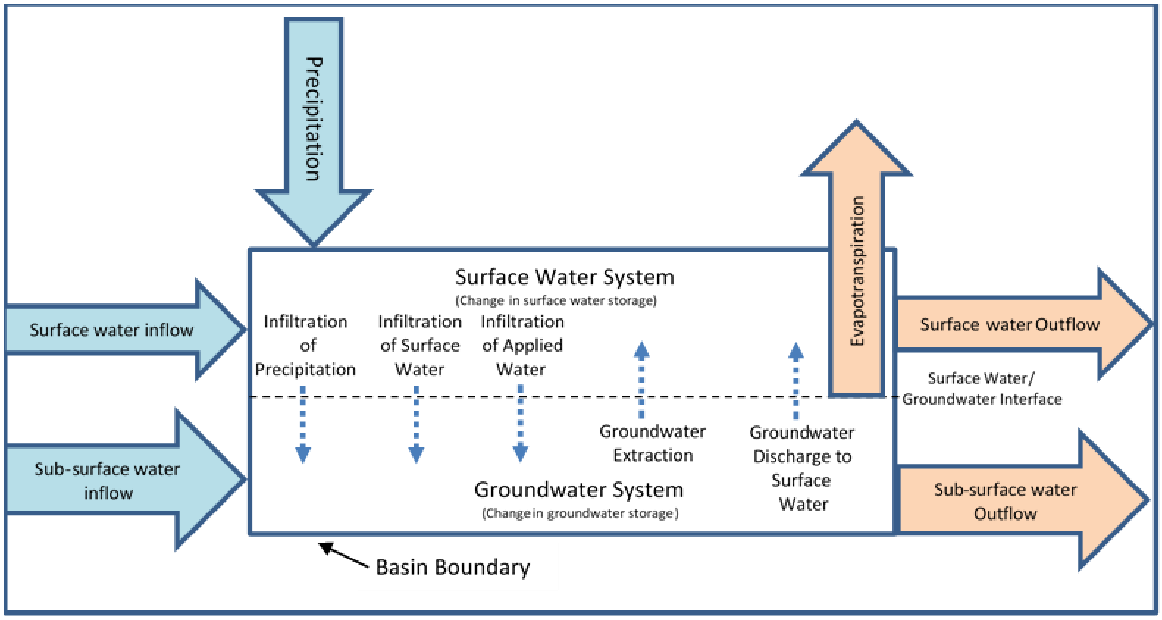
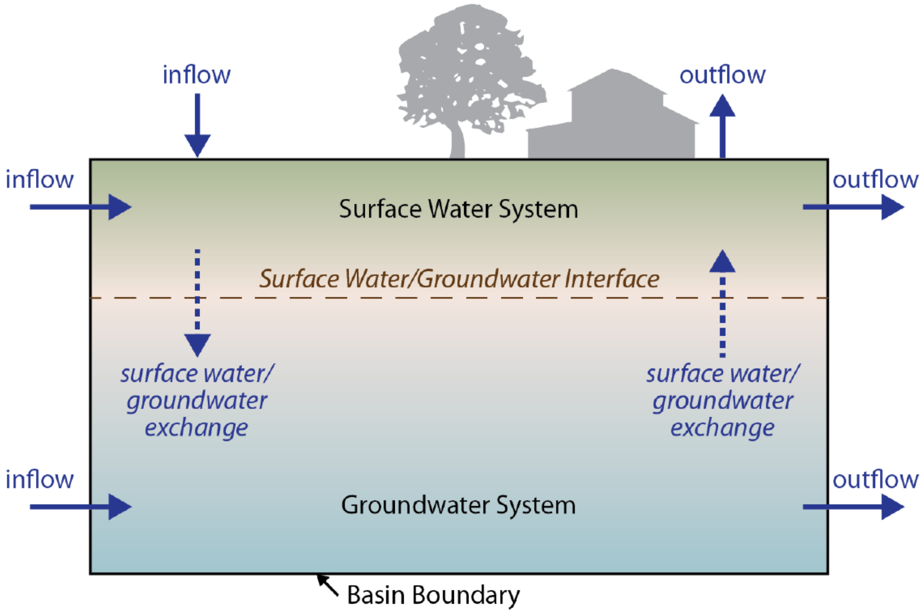


Diagram 3: Water Budget Accounting Schematic (adapted from DWR, 2016)



5.2 Water Year Types

A common practice in hydrology is to calculate total precipitation over a twelve-month period by designating a "water year" as the period extending from October 1 through September 30. For example, water year 2021 extended from October 1, 2020, through September 30, 2021. Water year 2022 began on October 1, 2021. For watersheds where the majority of precipitation falls in the winter, the water year generally encompasses the entire wet season. Annual water budgets, which quantify inflows, outflows, and change in storage for a groundwater basin, are developed based on the annual water year period.

DWR (January 2021) presented a methodology for designating water year types for watersheds outside the Sacramento and San Joaquin Valleys to support the development of GSPs. DWR's methodology is based on selecting a 30-year period and dividing the record into five categories of water year type according to specified weighting percentages (Table 13). This methodology results in 50% of the years in the 30-year period classified as Wet or Above Normal and 50% of the years classified as Below Normal, Dry, or Critical.

Table 13. Water Year Classifications (DWR, January 2021)

Classification	Weighted Percentage
Wet	30%
Above Normal	20%
Below Normal	20%
Dry	15%
Critical	15%

DWR (January 2021) published a data set of water year classifications for various hydrologic units around California, including the lower Eel River (HUC 18010105). This hydrologic unit encompasses 1,510 square miles and extends upstream to the confluence with the Middle Fork of the Eel River at Dos Rios, Mendocino County. This hydrologic unit encompasses a wide range of climatic conditions including a combination of coastal and inland areas. However, the representation of water year types for the Basin can be improved by using local rainfall data, as described below. DWR (January 2021) notes that GSAs have the option of developing their own water year types based on best available information.

Long-term rainfall records (October 1963 through September 2021) from Ferndale were obtained (Section 2.7.3). Rainfall data collected at these Ferndale sites is presumed to be more representative of the Basin than the regional composite data used in DWR (January 2021). A summary of the monthly rainfall totals at Ferndale from October 1963 through June 2021 is provided in Appendix F.

DWR's methodology for designating water year type for a given year takes into account the annual precipitation during the previous year by applying weighting factors to calculate an index value using the following equation:

> Water Year Index =
> (0.70 x current water year precipitation) + (0.30 x previous water year precipitation)

The equation is applied to each year in the 30-year period to develop index values, which are then ranked from highest to lowest. The ranking position based on index values is used to allocate the years of the 30-year period into the designated distribution of five water year type categories. The results from applying this methodology to the Ferndale rainfall data for the 30-year period from 1992 through 2021 are summarized on Table 14 and depicted on Chart 3. Chart 3 illustrates the four-year drought from 2012 through 2015 and the current drought that began in 2019. Over the last 30 years, the second 15-year period had more drier years than the first 15-year period.

Table 14. Water Year Types with Annual Precipitation, Index Values, and Ranking (1992-2021)

Water Year	Annual Precipitation (inches)	Water Year Index	Index Rank (30 = highest #, 1 =lowest #)	Water Year Type
2017	67.2	61.9	30	Wet
1998	66.2	61.8	29	Wet
1999	53.3	57.2	28	Wet
2003	61.6	55.3	27	Wet
2006	58.0	54.5	26	Wet
1995	56.4	49.2	25	Wet
1997	51.5	49.0	24	Wet
2004	43.1	48.6	23	Wet
2011	47.8	47.8	22	Wet
2000	45.1	47.6	21	Above Normal
1996	43.3	47.2	20	Above Normal
2016	49.6	46.0	19	Above Normal
2005	46.1	45.2	18	Above Normal
2018	34.8	44.5	17	Above Normal
2007	38.0	44.0	16	Above Normal
2019	47.9	43.9	15	Below Normal
2010	47.9	42.7	14	Below Normal
2012	39.7	42.1	13	Below Normal
1993	45.1	38.6	12	Below Normal
2013	36.2	37.3	11	Below Normal
2002	40.7	36.9	10	Below Normal
2020	31.7	36.5	9	Dry
1994	32.4	36.2	8	Dry
2008	33.7	35.0	7	Dry
2001	28.0	33.1	6	Dry
2015	37.5	32.2	5	Dry
2009	30.5	31.5	4	Critical
2021	30.3	30.7	3	Critical
2014	19.9	24.8	2	Critical
1992	23.3	23.7	1	Critical

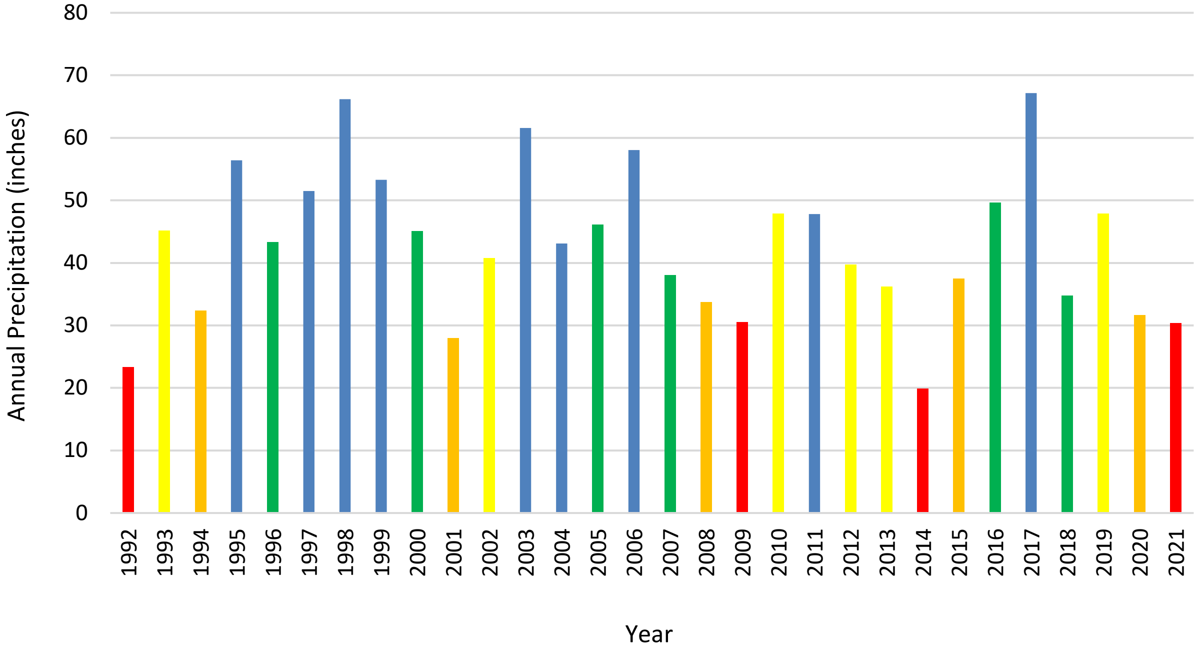


Chart 3. Water Year Types (1992-2021), Based on Annual Rainfall Data Collected in Ferndale

5.3 Groundwater-Surface Water Model

Overview

This section summarizes the development of the hydrologic model based on more detailed discussion in the Hydrologic Model Technical Memorandum (GHD, 2022a), which is contained in the Appendices. The integrated groundwater/surface water and seawater intrusion models were applied to evaluate the key sustainability management criteria to understand whether water uses in Basin can be sustained currently and into the future without creating undesirable results. Models were developed to represent current and historical conditions.

Data Sources

Data sources included USGS streamflow data, precipitation data from Ferndale, pumping, drinking water, and wastewater data from municipalities and CSDs within the Basin, available spatial datasets, and land use information.

Model Selection

The groundwater modeling application was selected based on the following considerations:

- The ability of the program to represent the key components of the HCM.
- The demonstrated verification that the program correctly represents the hydrologic processes being considered.
- Acceptance of the program by regulatory agencies and the scientific/engineering community.

In addition, DWR has published Guiding Principles for Models Used in Support of GSPs is to promote transparency, coordination, and data sharing to ultimately expedite GSP-related modeling and analysis review, which were also considered during model selection. The four DWR guiding principles are as follows:

1. Model documentation is publicly available at no cost and provides explanations for how the mathematical equations for the various model code components were derived from physical principles. This documentation shall also provide guidance on limitations of the model code.
2. The mathematics of the model code have been peer reviewed for the intended uses.
3. Descriptions of the conceptual model, site-specific model assumptions, input parameters, calibration, application scenarios, and analytical results demonstrate that the forecasted water budget, SMC, proposed project, and management actions are reasonable and within the range of identified uncertainties.
4. A working copy of the complete modeling platform will be provided to the DWR upon request.

Given these considerations and inclusive of DWR's guiding principles, groundwater modeling applications were combined to complete the ERV groundwater modeling effort. Groundwater modeling applications were combined in this effort to integrate groundwater, surface water, and seawater intrusion modeling, including:

- USGS's MODFLOW, which is capable of simulating steady-state or transient groundwater flow in two or three dimensions and MODFLOW's subcomponent model GSFLOW for groundwater/surface water interaction.
- PRMS, which simulates hydrologic processes as determined by the energy and water budgets of plant canopy, snowpack, and soil zone according to distributed climate information such as temperature, precipitation, and solar radiation.
- SEAWAT, a density-dependent flow and seawater intrusion model, which is capable of accounting for the effects of irrigation pumping on seawater intrusion.
- Parameter Estimation ++ (PEST), which integrates seawater intrusion modeling with a groundwater/surface water model.
- Graphical User Interface (GUI), which served as the interface between the assembled hydrogeologic data, the required MODFLOW family of codes, and PEST input files.
- Pre- and post-processing, using R (R Core Team, 2020) and python (Van Rossum and Drake, 2009) programming languages, which both make use of open source libraries of human-readable functions and are script-based languages that permit reproducible analyses of model files.

Model Construction and Calibration

Constructing numerical groundwater flow models involves developing the horizontal and vertical discretization of the selected model domain, specifying hydraulic properties, and implementing boundary conditions consistent with the HCM. To construct the model, a model domain was established. The model domain was oriented with its vertical and horizontal axes arranged northwest-southeast and southwest-northeast respectively to align the average observed groundwater flow directions within the Basin, which flow predominantly northwest towards the Pacific Coast. The model domain was fitted with a finite-difference grid. Grid spacing was 1,000 feet by 1,000 feet to provide sufficient resolution for integrated groundwater/surface water simulations and analysis, as well as for the seawater intrusion simulations. The number of model layers varied depending on the application. A total of six and 15 model layers was assigned to the integrated groundwater/surface water and seawater intrusion models, respectively, with the larger number for the seawater intrusion model layers intended to limit numerical dispersion in the vertical direction.

The integrated groundwater/surface water and seawater intrusion models were represented from calendar year 1980 through September 2020 (end of water year 2020) and from 1995 through September 2020, respectively using the transient mode (i.e., SFR and well boundary conditions and recharge varied over time) in MODFLOW-2005. For each model, the period of interest is water year 2000 through water year 2020. (As such, models were provided a substantial warm-up period to improve the accuracy of model results.) These simulation periods are divided into stress periods within which boundary conditions are constant, which are then subdivided into timesteps to permit the flow system to adjust to the change in stress period. Each of the integrated groundwater/surface water and seawater intrusion models had stress periods that spanned one month and timesteps that spanned one day.

Boundary conditions for the integrated groundwater/surface water and seawater intrusion models consist of the following:

- No-flow boundary conditions representing anticipated flow divides located along topographic highs at the model domain limits, with vertical no-flow boundary conditions at depths corresponding to the inferred base of the lower Carlotta formation and the bottom of the groundwater flow system.
- Constant head boundary conditions representing the Pacific Ocean.
- Streamflow routing and river boundary conditions representing surface water features throughout the Eel River and Van Duzen River watersheds.
- Groundwater pumping wells.
- Recharge over the top of the model domain due to precipitation infiltration.

The integrated groundwater/surface water model was calibrated under transient conditions to provide a reasonable match to average monthly surface water flow and stage elevations and observed groundwater elevations for the period between 2000 and September 2020 (i.e., end of Water Year 2020). Model calibration was completed concurrent with an uncertainty analysis that generated ten equally calibrated model realizations.

The integrated groundwater/surface water model was calibrated by adjusting model input parameter and boundary conditions so that simulated results provide a reasonable representation of observed groundwater and surface water flow conditions. The objective of model calibration was to determine a unique combination of input parameters to produce a numerical solution that best matches the observed groundwater elevations, observed groundwater flow directions, and observed stream discharge rates. Model calibration was performed in a two-stage approach—first matching simulated to observed surface water flows and stage elevations, then matching simulated to observed groundwater elevations. The integrated groundwater/surface water model was calibrated according to surface water flows and stage elevations in an iterative manner. The process involved:

1. Manually adjusting the parameters on the USGS provisional PRMS model.
2. Assigning PRMS runoff and evapotranspiration outputs to each SFR boundary condition model cell.

3. Using the integrated groundwater/surface water model to transiently simulate 1980 through to the end of water year 2020, with stress periods from 1980 to the end of 1999 used as model warm-up periods.
4. Qualitatively comparing simulated flow and stage elevations to target observations.

The cumulative transient volumetric water budget was observed for the calibrated Base Model. A discrepancy between simulated inflows and outflows of less than 0.2 percent for each stress occurs in the budget, demonstrating that a good numerical convergence was achieved throughout the model domain and across the simulation period used for calibration (i.e., 2000 through 2020).

Climate Change Scenarios

The Base Model for the calibrated integrated groundwater/surface water model (Base Model) was used to evaluate a range of potential future climatological conditions. DWR provides necessary and relevant climate change datasets, generated from climate and hydrologic modeling studies, to assess projected groundwater conditions and water budgets for specific groundwater management projects (DWR, 2018). These datasets are available as 3.75 mile × 3.75 mile grids. GSP criteria described in DWR (2018) require that each of the presented climate change scenarios represent projected conditions over a 50-year SGMA planning and implementation horizon.

Projected precipitation, minimum temperature, and maximum temperature under near future (i.e., 2030) and late future (i.e., 2070) scenarios were used as inputs to the calibrated PRMS model. DWR climate change datasets were assigned as PRMS inputs by developing area-weighted average values that were then assigned to each of the PRMS HRUs. Select outputs from the PRMS models were then assigned as MODFLOW-2005 input parameters to simulate the projected 50-year near future and late future groundwater conditions. Sea level rise is included in each of these scenarios as constant head boundary conditions specified as 15 cm (i.e., 0.49 feet) and 45 cm (i.e., 1.48 feet) for the near and late future climate scenarios, respectively. These 50-year projections were centered around 2030 (i.e., 2005 to 2054) and 2070 (i.e., 2045 to 2094) for the near and late future climate scenarios, respectively.

Model Predictions

Model predictions were used to inform the current water budget. The model's uncertainty analysis indicated the transient groundwater flow model is reasonably constrained where there are numerous observations, such as near the channel deposits and surficial alluvium. These areas provide greater reliability in model predictions. This area also is where much of the water use is occurring within the Basin and therefore is the area of focus for application of the model.
The integrated groundwater/surface water model also was applied to represent near (2030) and late (2070) future conditions. This analysis supported a historical comparison to identify trends for key water budget components, summarized below:

- Groundwater levels - Based on the historical water use in the basin and the seasonal nature of the water level recovery, chronic lowering of water levels in the basin are not likely. It is only during extreme increases in water use, corresponding to four- and five-times current pumping rates, that water is drawn from the Eel River towards the valley.
- Groundwater storage - Groundwater storage in Basin exhibits an increasing trend over the last 20 years. Reduction in groundwater storage is not expected in Basin.
- Seawater intrusion - There is a natural seasonal advance and retreat that occurs with seawater intrusion such that chlorides advance when water levels are low in the summer and retreat towards the Pacific Ocean when wet season weather causes substantial amounts of freshwater to move through the groundwater/surface water flow systems.

Under extreme groundwater pumping conditions, on the order of four times current conditions, areas in the basin that once experienced 100 mg/L chloride concentrations 5% of the time begin experiencing those concentrations on the order of 95% of the time. This is an extreme scenario that requires pumping at rates that are much greater than the amount that would be required by irrigation to replace evapotranspiration. The modeling results indicate seawater intrusion is not occurring and would only occur under extreme conditions for sea level rise, extreme drought, and increased groundwater pumping.

- Interconnected Surface Waters – The forecast models tend to show an increasing water level in the Basin (compare, for example, the 2030 and 2070 model scenarios). These rising levels will make the Basin more resilient to chronic lowering of water levels and storage loss. Surface water depletion due to groundwater depletion is not expected to occur, based on modeling results.

5.4 Water Budget Components

A water budget is an inventory of surface water and groundwater inflows and outflows. Certain components of the water budget are measured, such as municipal groundwater pumping while other components are estimated, such as ungauged stream inflow. Further water budget components are calculated from a hydrologic model, such as precipitation infiltration, and surface water seepage into groundwater. Figure 3 depicts the lateral boundaries of the Basin and the extended watershed. The bottom of the Basin extends 100-200 feet bgs into the alluvium, and 800-1,200 feet bgs into the Carlotta formation in the eastern half of the Basin.

5.4.1 Surface Water Inflows

The calculation of the Basin water inflow was estimated using several sources and tools. The following list describes the water budget component used in the Basin inflow summary and identifies the source of the data.

- Stream flow gage data – This is a surface water inflow. Stream gage data was used for the Eel River at Scotia [USGS 11477000] and the Van Duzen River at Bridgeville [USGS 11478500]. Data from 2000 through 2020 were used for this analysis. Daily average flow rate rates were used to calculate monthly totals flow volumes for the period of record.
- Precipitation runoff to streams – This is a surface water inflow. Precipitation runoff to stream was estimated using the Precipitation Runoff Modeling System (PRMS) modeling system. The application of PRMS is described in Section 3.3. PRMS was used to estimate the monthly flow rates and yearly total volume of runoff entering streams. This flow was added to the flow of the Eel and Van Duzen Rivers below the gage stations. It was also used to estimate the un-gaged stream in the Yager, Salt River, and Price Creek drainages. It should be noted that the PRMS estimates runoff from areas of these contributing watersheds that are outside of the Basin boundary.
- Wastewater Treatment Plant (WWTP) Effluent Discharge - This is a surface water inflow. Treated wastewater is directly discharge to rivers during certain times of the year, when minimum river flow rates permit discharge. The discharge data was provided by the municipalities or was estimated as a percent of the metered drinking water.
- Groundwater to Stream – This is a surface water inflow. Stream reaches that receive flow from groundwater are known as gaining. Stream reaches may vary from gaining to loosing throughout the year and may vary from year to year. The MODFLOW groundwater model calculates the monthly average volumes of the gain/loss for all stream reaches in Basin. This process is described in more in Section 4.2.3.

The surface water inflows include streamflow, precipitation runoff to streams, wastewater discharge, and groundwater seepage into creeks. Streamflow and precipitation runoff to streams are the largest inflow components of the water budget. Gauged USGS streamflow data is available for the Eel River at Scotia and the Van Duzen River at Bridgeville for the 2011 through 2020 period. Eel River and Van Duzen streamflow is variable by water year, based on water year type. Surface water inflows from ungauged tributaries entering subbasin were modeled using PRMS and include Yager Creek, Salt River, Howe Creek, Oil Creek, and Price Creek. Overland runoff was calculated using the PRIMS model to account for runoff, which routed to stream networks. Modeled tributary inflows are also variable and reflective of water year conditions for the 2011 through 2020 period. Streamflow ranged from a minimum of 1,651,399-acre feet in 2020 (Dry water year) to a maximum of 11,841,926 acre-feet in 2017 (Wet water year). Similarly, precipitation runoff to streams ranged from a minimum of 2,483,401 acre-feet in 2020 (Dry water year) to a maximum of 8,218,832 acre-feet in 2017 (Wet water year).

Groundwater seepage into streams is the second largest inflow component of the water budget. Groundwater seepage into surface waters was also modeled and assumed 20% gaining of all flow. Modeled groundwater seepage was variable and reflective of water year conditions for the 2011 through 2020 period, ranging from a minimum of 147,826 acre-feet in 2014 (Critically Dry water year) to a maximum of 208,4012 acre-feet in 2017 (Wet water year). Wastewater effluent is the smallest inflow component of the water budget and is less sensitive to water year conditions. Wastewater discharge from the cities of Ferndale, Fortuna, and Rio Dell, Loleta CSD, and Scotia CSD also constitute surface water inflows. Within the water budget, these are measured inputs based on data provided by each city or CSD and ranged from 793 to 897 acre-feet annually. Precipitation was input to the model based on long-term rainfall records (October 1963 through September 2021) in Ferndale. Rainfall data collected at these Ferndale sites is presumed to be the most representative data available for the Basin. The yearly volume of surface water inflow for each of the components above, along with the yearly total volumes are presented for the 2000 through 2020 water years in Table 15.

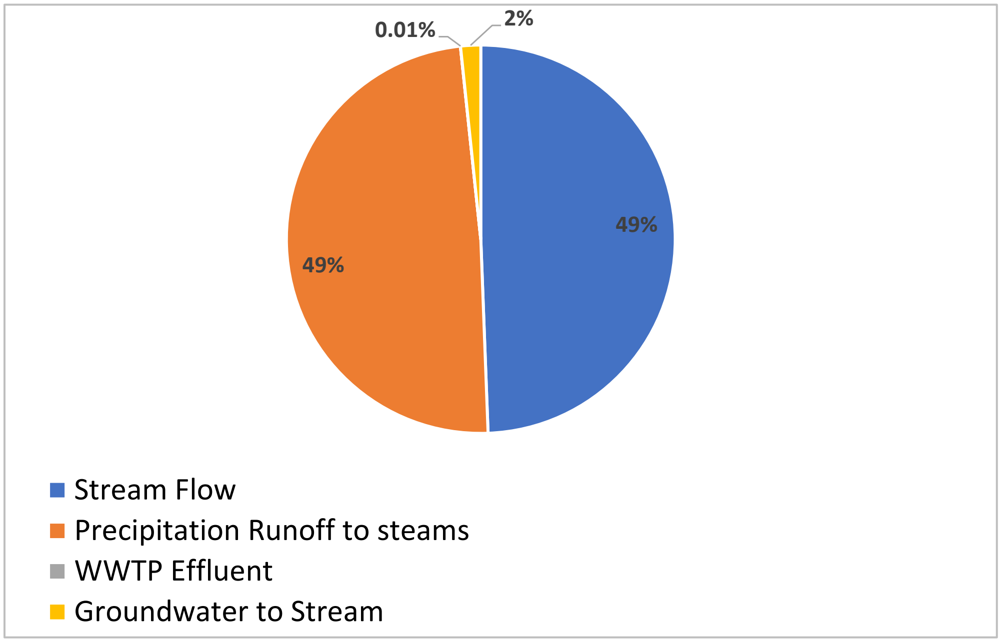


Chart 4. Surface Water Inflow Components of the Water Budget, 2011 to 2020 Average, Based on Percentage of Acre-feet.

Table 15. Surface Water Inflow for 2011 through 2020 Water Years

Water Year	Type	Water Budget Component (af/yr)				
		Stream Flow	Precipitation Runoff to Steams	WWTP Effluent	Groundwater to Stream	Yearly Total
2011	Wet	7,626,192	6,991,753	838	196,018	14,814,801
2012	Below Normal	3,897,813	5,804,851	823	181,950	9,885,436
2013	Below Normal	3,872,532	4,727,514	872	168,448	8,769,365
2014	Critical	1,827,870	2,654,822	869	147,826	4,631,386
2015	Dry	3,445,258	4,471,740	810	166,485	8,084,294
2016	Above Normal	7,195,455	6,591,416	797	188,655	13,976,323
2017	Wet	11,841,926	8,218,832	793	208,412	20,269,963
2018	Above Normal	3,436,646	3,664,620	822	161,373	7,263,461
2019	Below Normal	7,226,047	5,905,487	814	183,230	13,315,578
2020	Dry	1,651,399	2,483,401	897	153,463	4,289,160

5.4.2 Groundwater Inflows

Groundwater inflows into the Basin include surface water seepage into groundwater, wastewater application return flows, precipitation infiltration, and irrigation and septic return flows (Chart 5). Surface water seepage and precipitation infiltration were computed by the model, vary based on water year type and are more substantial inputs during wetter water year conditions. Streamflow infiltration (seepage) into groundwater is the largest groundwater inflow component of the water budget, ranging from a minimum of 130,016 acre-feet in 2020 (Dry water year) to a maximum of 188,665 acre-feet in 2017 (Wet water year). Infiltration of precipitation into groundwater is the second largest groundwater inflow component, ranging from 8,312 in 2014 (Critically Dry water year) to 116,417 acre-feet in 2017 (Wet water year).

Wastewater application return flows and irrigation and septic return flow information resulted from direct measurement and are much smaller groundwater inflow components of the water budget, with less variability and independence of water year conditions. Groundwater inflows in the water budget include wastewater application from the communities of Rio Dell, Loleta, Ferndale, Scotia, Fortuna (which includes the Palmer Creek CSD), and Bear River Band of Rohnerville Rancheria along with commercial, industrial and residential septic systems. Wastewater application return flows ranged from 858 to 1,252 acre-feet annually, and irrigation and septic return flows were input as 426 acre-feet annually.

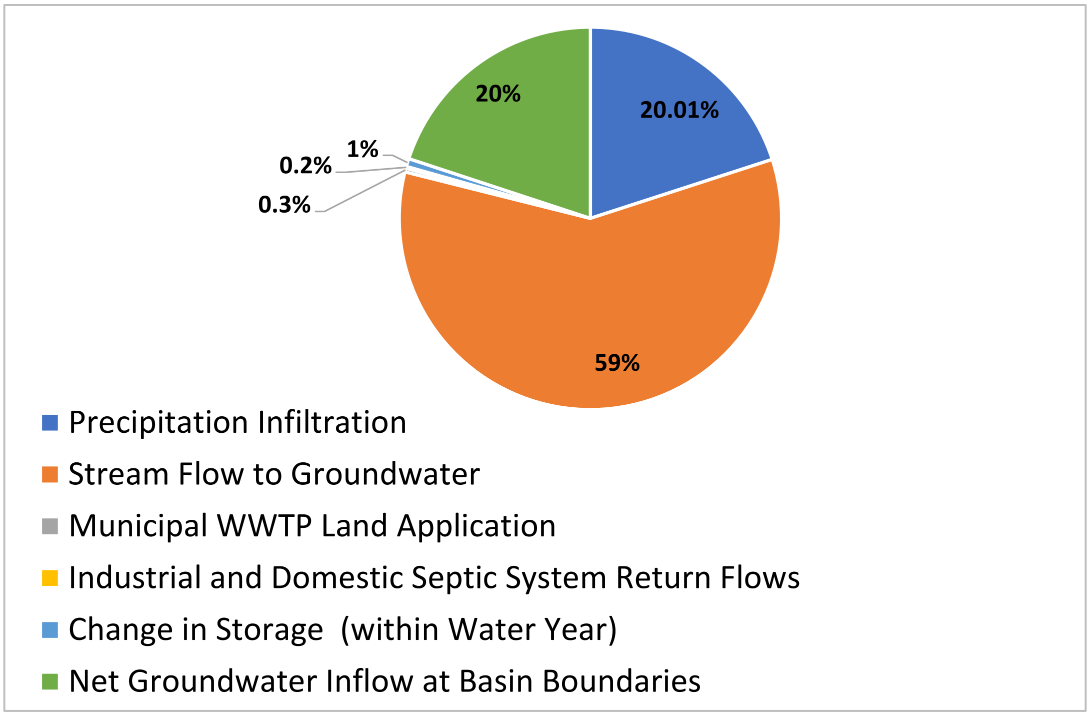


Chart 5. Groundwater Inflow Components of the Water Budget, 2011 to 2020 Average, based on Percentage of Acre-feet.

Groundwater inflows include surface water seepage into groundwater, wastewater application return flows, precipitation infiltration, and irrigation and septic return flows (Table 16). The water budget components include:

- Precipitation Infiltration – Precipitation infiltration is estimated using PRMS. The infiltration volumes are estimated on a monthly basis and are used in the water budget and as a groundwater model input.
- Stream Flow to Groundwater – This is calculated the same as groundwater to stream and represents the losing reach condition.
- Municipal WWTP Land Application - When municipal wastewater is not discharged to rivers it may be discharged to infiltration ponds or land applied. The volume of treated wastewater disposed in leach fields or infiltration ponds was either provided by the municipalities or estimated as a percentage of metered water use.
- Industrial and Domestic Septic System - The amounts of the industrial and domestic septic system discharged in leach fields was estimated for parcels that are outside of municipal wastewater collection systems. The amount of septic discharge was based upon the water use estimate for the given parcels. Water use for the parcel was based upon land use zoning, parcel improvements, and parcel size.
- Net Groundwater Inflow at Basin Boundaries – This component includes all the subsurface groundwater flow into or out of the Basin. This includes groundwater flow from up-basin boundaries and the boundary to the ocean. Boundary flow is not directly measured. This component is calculated using the method outlined in the DWR Water Budget BMP where all other component flows are known or estimated, and this component is solved for using the sum of the other components.

Table 16. Groundwater Inflows for 2011 through 2020 Water Years

Water Year	Type	Water Budget Component (af/yr)						
		Precipitation Infiltration	Stream Flow to Groundwater	Municipal WWTP Land Application	Industrial and Domestic Septic System	Change in Storage (note 1)	Groundwater Inflow at Basin Boundaries (note 2)	Yearly Total
2011	Wet	71,383	183,413	869	426	--	52,732	308,823
2012	Below Normal	51,015	177,473	784	426	--	57,700	287,397
2013	Below Normal	45,288	171,097	1,047	426	--	50,795	268,653
2014	Critical	8,312	147,646	1,002	426	--	102,702	260,090
2015	Dry	38,181	167,894	1,038	426	--	58,392	265,931
2016	Above Normal	79,360	181,308	726	426	5,560	24,900	292,281
2017	Wet	116,417	188,665	744	426	6,192	--	312,444
2018	Above Normal	41,591	143,895	842	426	--	85,251	272,005
2019	Below Normal	85,027	169,965	864	426	7,389	23,025	286,696
2020	Dry	27,953	130,016	1,038	426	--	107,117	266,551

Notes:

(1) Change in Storge based on fall groundwater levels to coincide with water year end

(2) Includes up basin boundary and groundwater/sea water exchange

5.4.3 Surface Water Outflows

The Eel River Valley subbasin surface water outflows include streamflow to the Pacific Ocean, streamflow seepage into groundwater, direct diversions for irrigation and municipal drinking water, and evapotranspiration (Chart 6). Streamflow to the Pacific Ocean, streamflow seepage to groundwater, and evapotranspiration were computed by the model, vary based on water year type, and are more substantial inputs during wetter water year conditions.

Streamflow to the Pacific Ocean is the most substantial surface water outflow component in the water budget, ranging from a minimum of 4,158,247 acre-feet in 2020 (Dry water year) to a maximum of 20,080,430 acre-feet in 2017 (Wet water year). Streamflow seepage into groundwater is the second largest water outflow component of the water budget, ranging from a minimum of 130,016 acre-feet in 2020 (Dry water year) to a maximum of 188,665 acre-feet in 2017 (Wet water year). Evapotranspiration outflows from surface water included evapotranspiration from open water, riparian, and urban landscape land uses. Evapotranspiration ranged from a minimum of 96,967 acre-feet in 2012 (Below Normal water year) to a maximum of 106,304 acre feet in 2017 (Wet water year).

Direct diversions for irrigation were input into the model using data from direct measurements are the smallest surface water outflow component of the water budget (<1%), ranging from 63 to 114 acre-feet annually. Municipal pumping by the City of Rio Dell and the Scotia CSD is also a small component of surface water outflow (< 1,000 acre-feet annually) and input into the model using data from measurement recordkeeping from both municipalities.

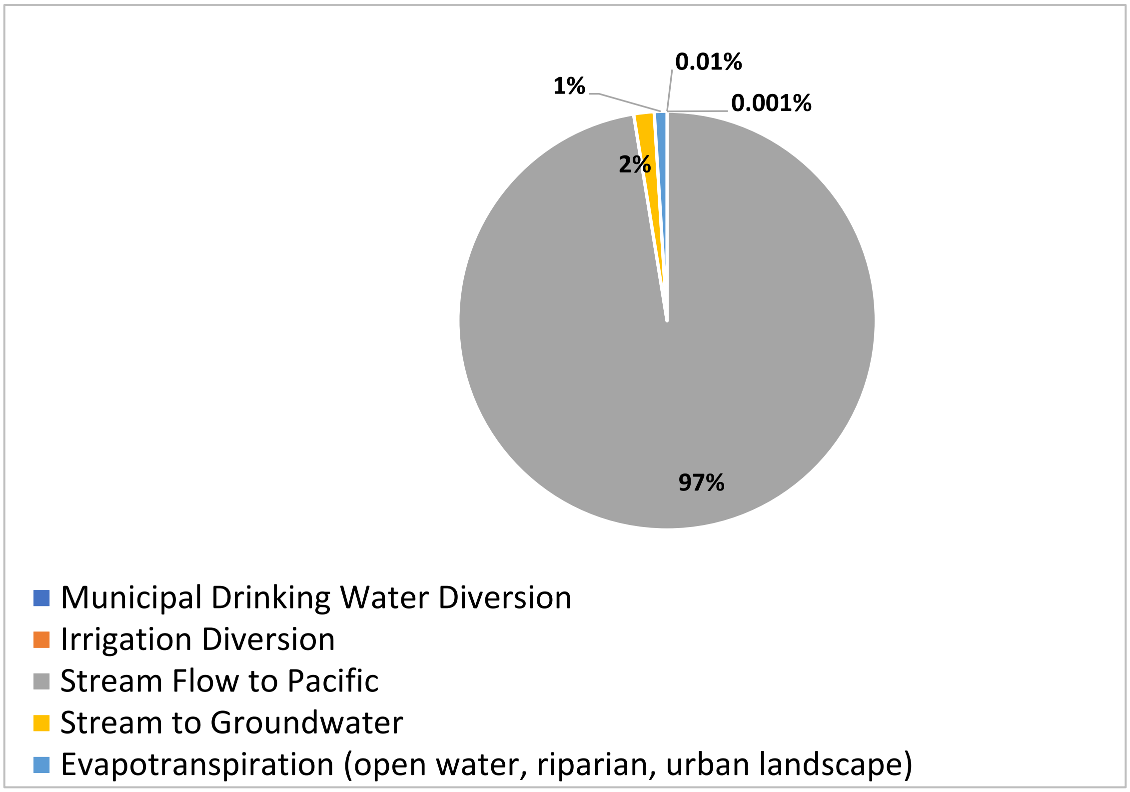


Chart 6. Surface Water Outflow Components of the Water Budget, 2011 to 2020 Average, Based on Percentage of Acre-feet.

The Basin outflow summary is estimated similarly to the Basin inflow. The following list describes the water budget component used in the surface water outflow summary and identifies the source of the data. The components included in the surface water outflows include:

- Municipal Drinking Water Diversion – The city of Rio Dell and Scotia CSD both pump water from the Eel River to supply their potable water demand, via their water treatment plants. Water production records were provided by the municipalities.
- Irrigation Diversion - Surface water diversion for irrigation is a relatively small portion of basin outflow. The volume of water for this component was based upon mapped irrigation area and annual irrigation water demand estimate.
- Stream Flow to Pacific - Stream flow to the Pacific is not directly measured and is difficult to estimate due to tidal fluctuations. This component is calculated using the method outlined in the DWR Water Budget BMP where all other surface water flows are known or estimated.
- Stream to Groundwater - This is calculated the same as groundwater to stream and represents the losing reach condition.
- Evapotranspiration (open water, riparian, urban landscape) - This parameter was estimated using the DWRs Cal-SIMETAW model. The model produces monthly ET rates for various crop types, native (or natural) vegetation, riparian and open water. The land use areas were determined by combining the irrigated areas land use and remote image analysis. This produced area of natural vegetation, riparian, impervious, and open water. These areas were used with the Cal-SIMETAW ET rates to calculate the monthly water demand. The monthly demand was summed up for each water year to calculate the annual amount.

The yearly volume of surface water outflows for each of the components above, along with the yearly total volumes are presented for the 2011 through 2020 water years below in Table 17.

Table 17. Surface Water Outflow for 2011 through 2020 Water Years

Water Year	Type	Water Budget Component (af/yr)					
		Municipal Drinking Water Diversion	**Irrigation Diversion**	**Stream Flow to Pacific**	**Stream to Groundwater**	**Evapotranspiration (open water, riparian, urban landscape)**	**Yearly Total**
2011	Wet	847	101	14,526,798	183,413	103,641	14,814,801
2012	Below Normal	857	114	9,610,025	177,473	96,967	9,885,436
2013	Below Normal	893	114	8,495,807	171,097	101,454	8,769,365
2014	Critical	837	88	4,482,815	147,646	104,332	4,735,718
2015	Dry	797	76	7,915,528	167,894	104,653	8,188,947
2016	Above Normal	816	76	13,794,123	181,308	104,669	14,080,992
2017	Wet	805	63	20,080,430	188,665	106,304	20,376,267
2018	Above Normal	809	76	7,118,681	143,895	104,669	7,368,130
2019	Below Normal	765	76	13,144,773	169,965	102,534	13,418,112
2020	Dry	812	76	4,158,257	130,016	104,909	4,394,070

5.4.4 Groundwater Outflows

Groundwater outflows in the water budget include municipal, domestic, irrigation, commercial, industrial, and cannabis pumping, subsurface outflow to the Pacific Ocean, and evapotranspiration from groundwater sources (Chart 7). Outflow into the Pacific Ocean was the largest groundwater outflow component, ranging from 72,478 acre-feet in 2014 (Critically Dry water year) to 161,824 acre-feet in 2017 (Wet water year). Evapotranspiration from groundwater sources was the second largest outflow component, ranging from 85,580 acre-feet in 2015 (Dry water year) to 98,467 acre-feet in 2011 (Wet water year). Subsurface outflow to the Pacific Ocean and evapotranspiration from groundwater sources are variable based on water year conditions. Municipal and irrigation uses were smaller groundwater outflow components of the water budget and show less variability among water year types, as follows:

- Municipal pumping ranged from 1,599 to 1,832 acre-feet annually.
- Non-municipal domestic pumping was stable at 414 acre-feet annually.
- Irrigation pumping ranging from 10,694 to 14,848 acre-feet annually and was higher during drier water year types.
- Cannabis pumping was assumed to be 98 acre-feet annually for all years.
- Non-municipal commercial and industrial pumping was assumed to be 34 acre-feet annually for all years.

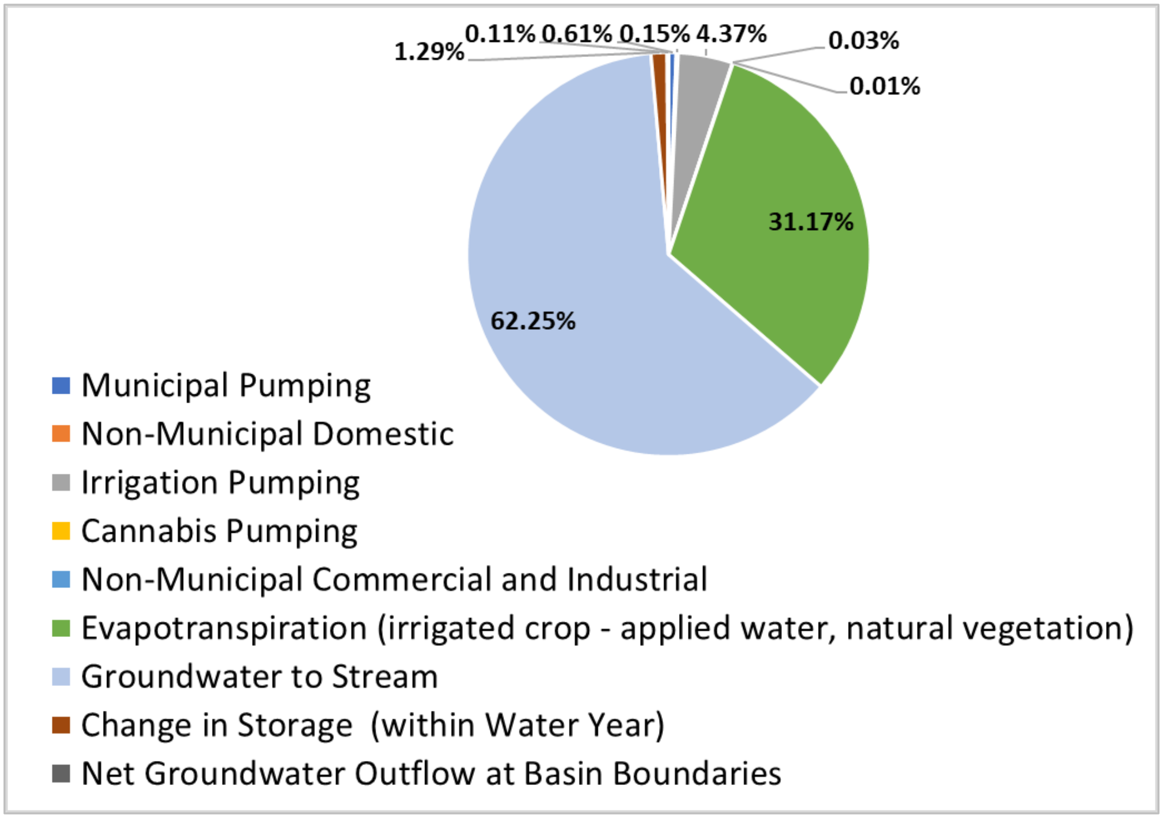


Chart 7. Groundwater Outflow Components of the Water Budget, 2011 to 2020 Average, Based on Percentage of Acre-feet.

The following list describes the water budget component used in the groundwater outflow summary and identifies the source of the data. The components of groundwater outflow include:

- Municipal Groundwater Pumping – Municipal groundwater pumping volumes were provided by the municipalities. Monthly and annual amounts were used for this analysis.
- Non-Municipal Domestic Pumping - The non-municipal domestic pumping was estimated for parcels that are outside of municipal water supply systems. The amount of water pumped was based upon the number of dwelling units for the given parcels. Water use for the parcel was based upon land use zoning, parcel improvements, and parcel size.
- Irrigation pumping - The volume of water for this component was based upon mapped irrigation area and annual irrigation water demand estimate. The annual estimate was determined by Humboldt County using flow meter data from several irrigated facilities (Humboldt County, November 2021). These rates vary by water year type. The demand rates are presented as a volume of water per land area.
- Cannabis pumping - The water demand for cannabis irrigation is assumed to come from groundwater wells. The water demand for cannabis irrigation was developed by estimating the number of plants and irrigated areas. These estimates were based upon permitted cannabis cultivation sites within the Basin, which include five permitted indoor sites and 50 permitted outdoor sites (note some outdoor sites also include an indoor cultivation component). The number of plants per site is based upon the permitted area for each site and the cultivation type (indoor vs. outdoor). Outdoor cultivation sites

assumed a growing season of June through October. Indoor cultivation was assumed to be year round. Water demand per plant estimates were evaluated from several sources. Demand rates ranged from 1 to 15 gallons per plant per day. For this analysis a value of 6 gallons per plant per day was used. Indoor cannabis had a much lower demand of 0.5 gallons per plant per day. The demand for unpermitted cannabis sites was estimated as an additional 30% of the permitted demand, which is sourced from Bauer et al. (2015) and based on unpermitted cultivation in the upper Mad River basin as a surrogate to this analysis. Given the Basin is in the lower portion of the Eel River watershed, estimating illegal cultivation as an additional 30% of the permitted demand based on the upper Mad River watershed is a conservative estimate.

- Non-Municipal Commercial and Industrial pumping – This component is estimated for parcels outside of municipal water supply systems. The amount of water pumped was based upon the number of dwelling units or industrial process for the given parcels. Water use for the parcel was based upon land use zoning, parcel improvements, and parcel size.
- Evapotranspiration (irrigated crop, natural vegetation) - This parameter was estimated using the DWRs Cal-SIMETAW model. The model produces monthly ET rates for various irrigated crop types, native (or natural) vegetation, riparian and open water. The land use areas were determined by combining the irrigated areas land use and remote image analysis. The irrigated land areas were developed by the Humboldt County RCD and recently updated. These areas were used with the Cal-SIMETAW ET rates to calculate the monthly crop evapotranspiration. The monthly demand due to evapotranspiration was summed up for each water year to calculate the annual amount.
- Net Groundwater Outflow at Basin Boundaries – This component includes all the subsurface groundwater flow into or out of the Basin. This includes groundwater flow from up-basin boundaries and the boundary to the ocean. Boundary flow is not directly measured. This component is calculated using the method outlined in the DWR Water Budget BMP where all other component flows are known or estimated, and this component is solved for using the sum of the other components. Over the ten-year period, the net groundwater outflow only occurred during a wet year (2017).
- Change in Groundwater Storage - The change in groundwater storage is estimated using the groundwater model. Change in groundwater storage is calculated by subtracting the average groundwater elevations in spring 2003 from March groundwater elevations model cell for each year.

The yearly volume of groundwater outflows for each of the components above, along with the yearly total volumes are presented for the 2011through 2020 water years below in Table 18.

Table 18. Groundwater Outflow for 2011 through 2020 Water Years

Water Year	Type	Municipal	Non-Municipal Domestic	Irrigation	Cannabis	Non-Municipal Commercial and Industrial	ET (irrigated crop, natural vegetation) (note 1)	Groundwater to Stream	Change in GW Storage	Net Groundwater Out flow at basin boundaries (note 2)	Yearly Total
		Water Budget Component (af/yr)									
2011	Wet	1,772	414	10,694	98	34	96,881	196,018	2,912	--	308,823
2012	Below Normal	1,727	414	12,196	98	34	89,551	181,950	1,428	--	287,397
2013	Below Normal	1,764	414	12,196	98	34	84,998	168,448	700	--	268,653
2014	Critical	1,814	414	14,848	98	34	86,118	147,826	8,937	--	260,090
2015	Dry	1,599	414	13,522	98	34	82,571	166,485	1,207	--	265,931
2016	Above Normal	1,660	414	11,754	98	34	89,666	188,655	--	--	292,281
2017	Wet	1,673	414	10,694	98	34	88,050	208,412	--	3,069	312,444
2018	Above Normal	1,729	414	11,754	98	34	89,666	161,373	6,936	--	272,005
2019	Below Normal	1,758	414	12,196	98	34	88,965	183,230	--	--	286,696
2020	Dry	1,832	414	13,522	98	34	82,884	153,463	14,303	--	266,551

Notes:

(1) ET does not include applied irrigation water, which is shown in the Irrigation column.
(2) This column includes the upper basin boundary and groundwater/sea water exchange.
af-yr = Acre-feet per year
GW = Groundwater
ET = Evapotranspiration

5.4.5 Change in Groundwater Storage

The difference between groundwater inflow and outflow is equal to the change in groundwater storage. Across the 2011 through 2020 period, the change in groundwater storage was the lowest (and negative) in 2020 (Dry water year), at -14,303 acre-feet. Change in groundwater storage was highest at 7,389 acre-feet in 2019 (Below Normal water year).

The Basin is unique compared to other landlocked groundwater basins in that it has a flux boundary to the ocean. Any water that comes into the Basin that is not used by a consumptive use or evapotranspiration flows to the ocean. Change in storage is evaluated from the end of each water year, which is in the fall (October 1). The interannual change in storage is dependent on the water year conditions of the preceding water year. Change in storage for a Dry water year followed by consecutive Dry water year could result in a very small change in storage. In contrast, a Wet water year followed by a Dry year could result in a larger change in storage. Chart 2 shows the modeled fall changed storage for the 2000 through 2020 period. Annual deficits in groundwater storage do occur. However, the generally horizontal trend line over the past twenty years indicates the Basin is not chronically overdrafted. Groundwater deficits do not result entirely from consumptive uses. Groundwater deficits in the Basin are driven by natural climate variability (e.g., precipitation and streamflow input into the Basin). The greatest groundwater deficit of -14,303 acre-feet occurred at the end of water year 2020, which was a Dry water year preceded by a Below Normal water year. Smaller deficits in groundwater storage occurred in 2014 (-8,937 acre-feet, Critically Dry water year preceded by a Below Normal water year) and 2007 (-10,121 acre-feet, Dry water year preceded by an Above Normal water year). Across all twenty years, the average change in modeled groundwater storage was a deficit of -621 acre-feet.

Change in groundwater storage is affected by variables beyond consumptive surface and groundwater uses in the Basin, namely surface water inflows into the Basin boundary. Aside from variable climatic conditions, surface water inflows are also subject to managed Potter Valley Project streamflow releases from Cape Horn Dam in the upper Eel River watershed, legal and illegal surface water diversions upstream of the Basin, and legal and illegal consumptive groundwater uses upstream of the Basin. Thus, annual deficits in groundwater storage, as well as seasonal Eel River low flow conditions observed in drier water years within the Basin, are attributable to hydrologic conditions both upstream of and within the Basin.

5.5 Historical and Current Water Budgets

GSPs must present water budgets for three distinct timeframes: a historical water budget, a current water budget, and a projected water budget. DWR's water budget best management practices (BMP) guidance document (December 2016) states that the historical water budget should inform an understanding of how historical conditions concerning hydrology, water demand, and surface water supply availability and reliability have impacted water users to operate the basin within the sustainable yield. Reliable surface water deliveries are calculated based on planned surface water deliveries, by surface water source and water year type. The historical water budget is also intended to calibrate the methods and tools used to project future water budget conditions. SGMA regulations further stipulate that historical water budgets use the previous 10 years of water budget information.

The current water budget is intended to inform existing groundwater supply, demand, and change in groundwater storage according to the most recent population, land use, and hydrologic conditions. The DWR water budget BMP guidance document mandates the current water budget quantify all seven criteria specified in 23 CCR Section 354.18(b).

The projected water budget is used to estimate the future conditions of groundwater supply, demand, and aquifer response requiring groundwater management and then defining which management actions must be taken. Despite significant differences between wet and dry seasons, the SGMA mandates GSPs only contain an annual quantification of historical, current, and projected water budgets.

5.5.1 Historical Water Budget Time Period

SGMA requires at least the most recent ten years of water supply information be used for estimating a historical water budget. The water budget is computed using Precipitation Runoff Modeling System (PRMS), Groundwater Flow Model (MODFLOW), and incorporates data from 2011 through 2020. The hydrologic model covers water years 2011 through 2020, therefore the historical water budget period is selected to encompass these water years. This time period encompasses the period of best available science and data for the Basin. The historic water budget values are presented in the surface/groundwater inflow/outflow tables in Section 5.4. The combined inflow and outflow water budget is shown in Chart 9.

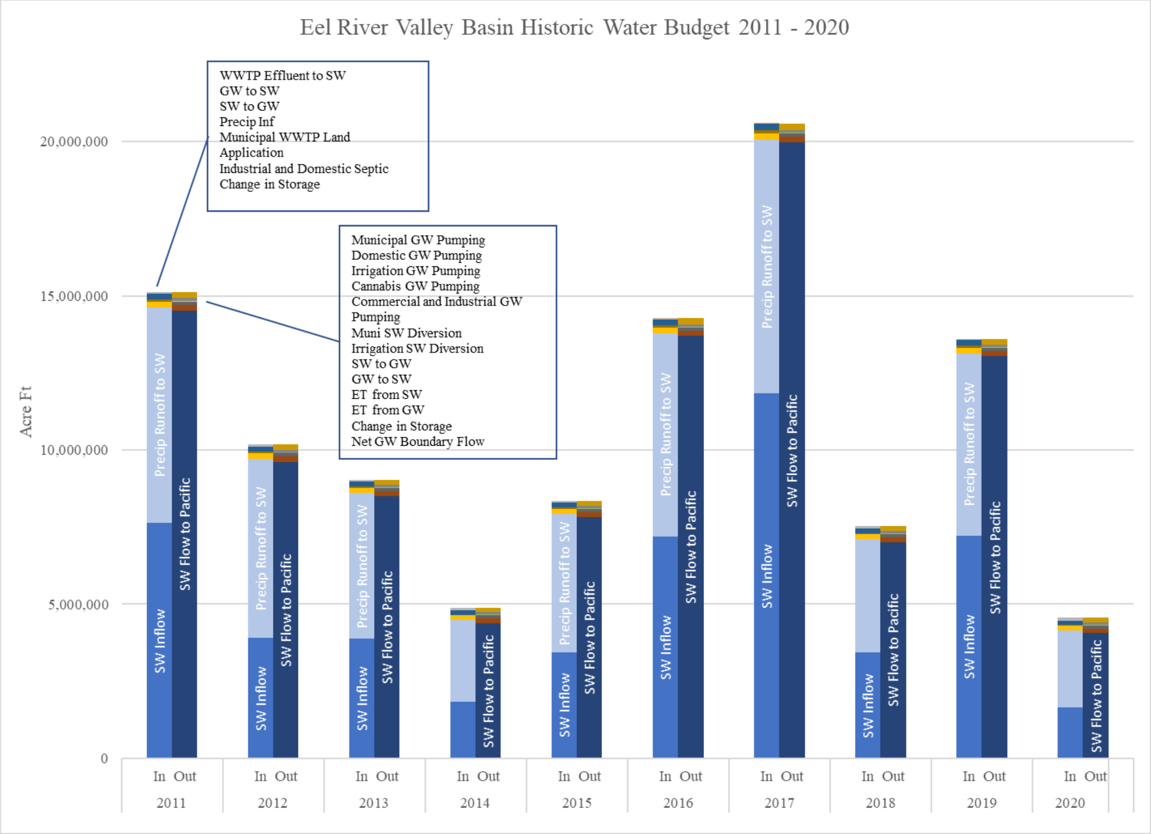


Chart 9: Historic Water Budget, 2011 through 2020

5.5.2 Current Water Budget Time Period

The current water budget is computed using the PRMS surface water model and MODFLOW (with PCG2) groundwater model. The current water budget time period encompasses the water years 2011 through 2020. Data from these water years reflect the period of best available science and data. A particular water year can fall under one of five categories, as defined by DWR water year types presented in Section 5.2. This time period most accurately reflects average current conditions with respect to land use, groundwater pumping and recharge, and surface water deliveries. The water budget for each water year type is shown in Charts 10 through 14.

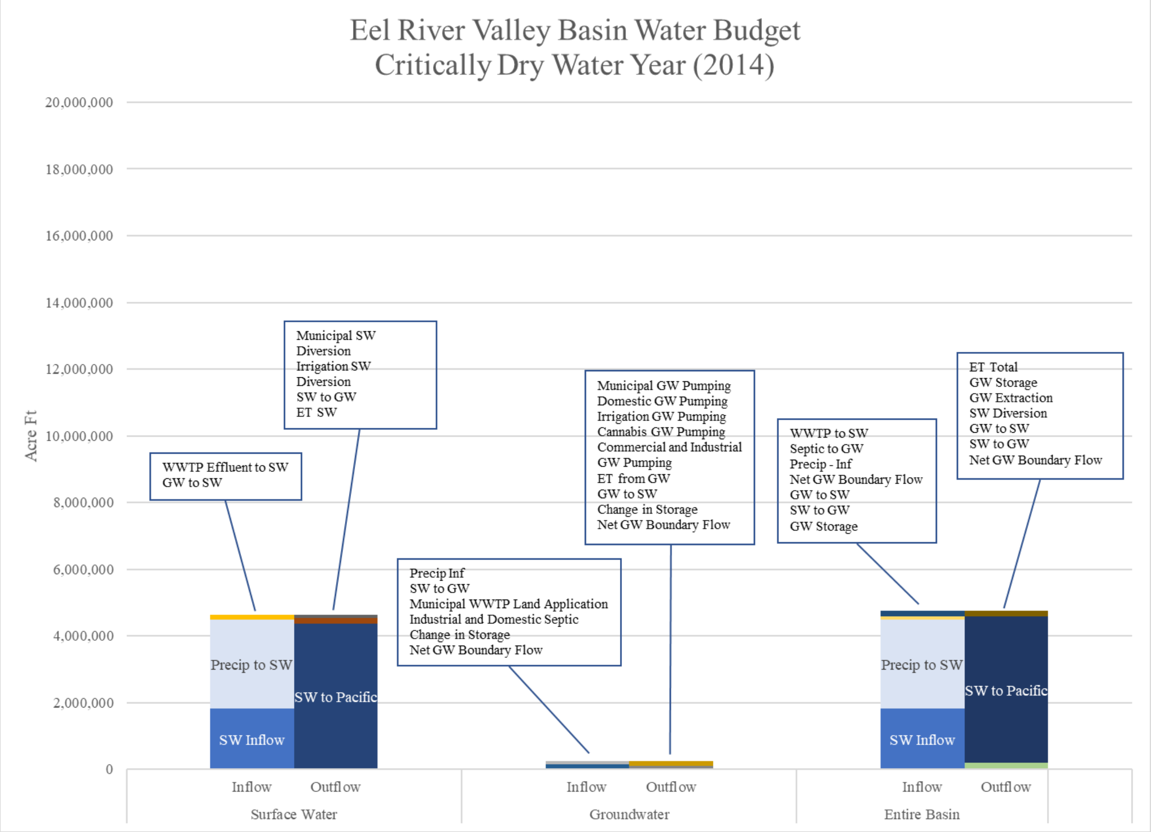


Chart 10: Critically Dry Water Year Water Budget

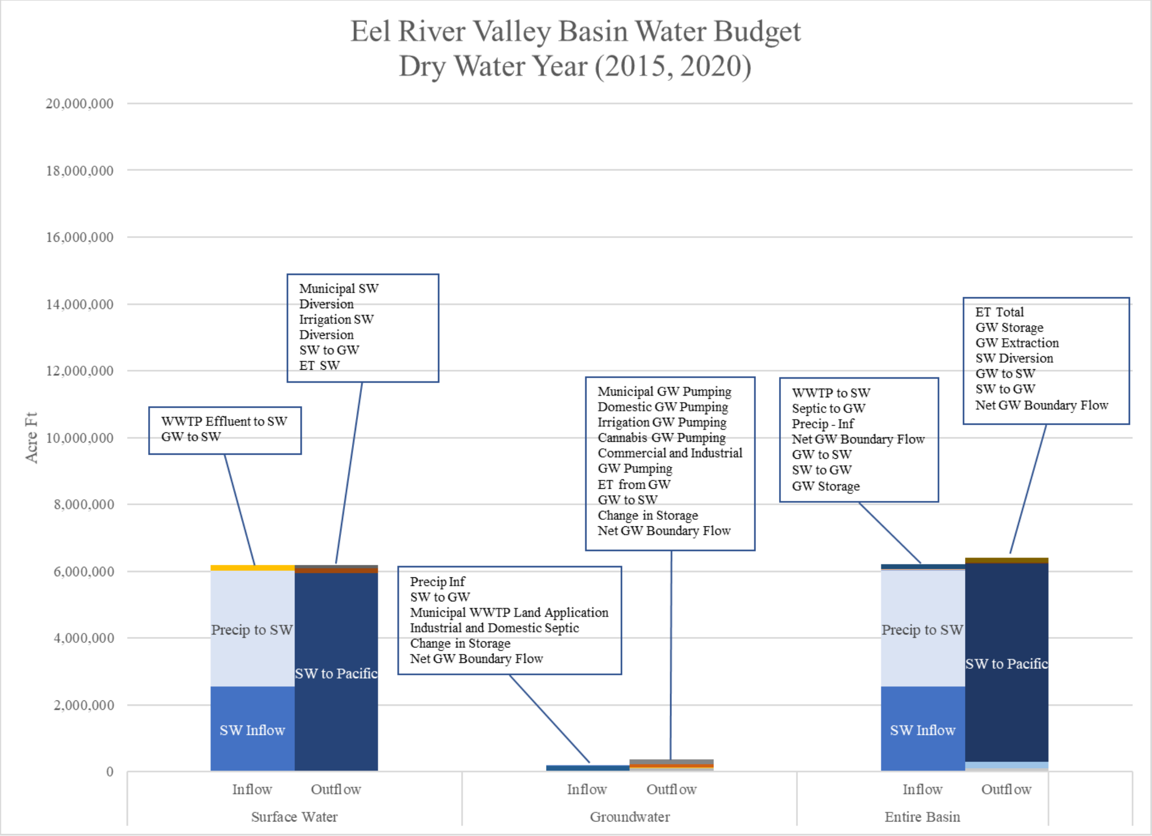


Chart 11: Dry Water Year Water Budget

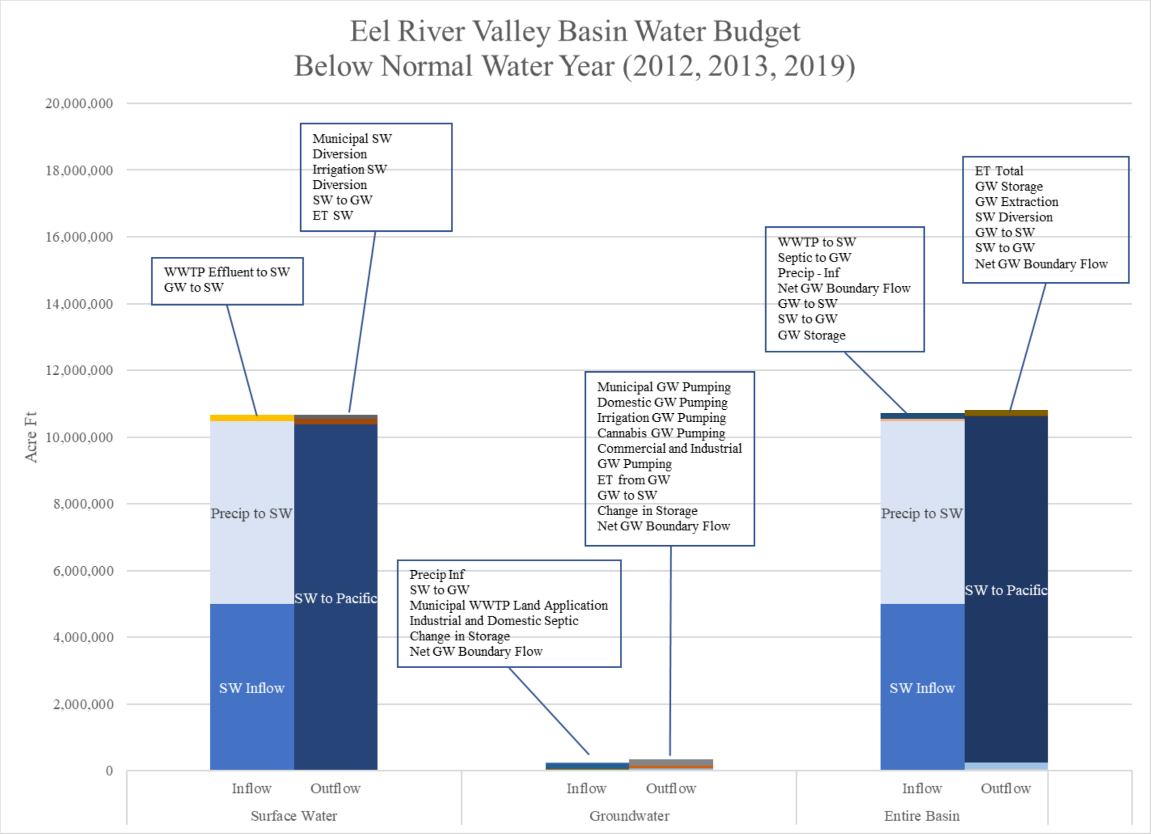


Chart 12: Below Normal Water Year Water Budget

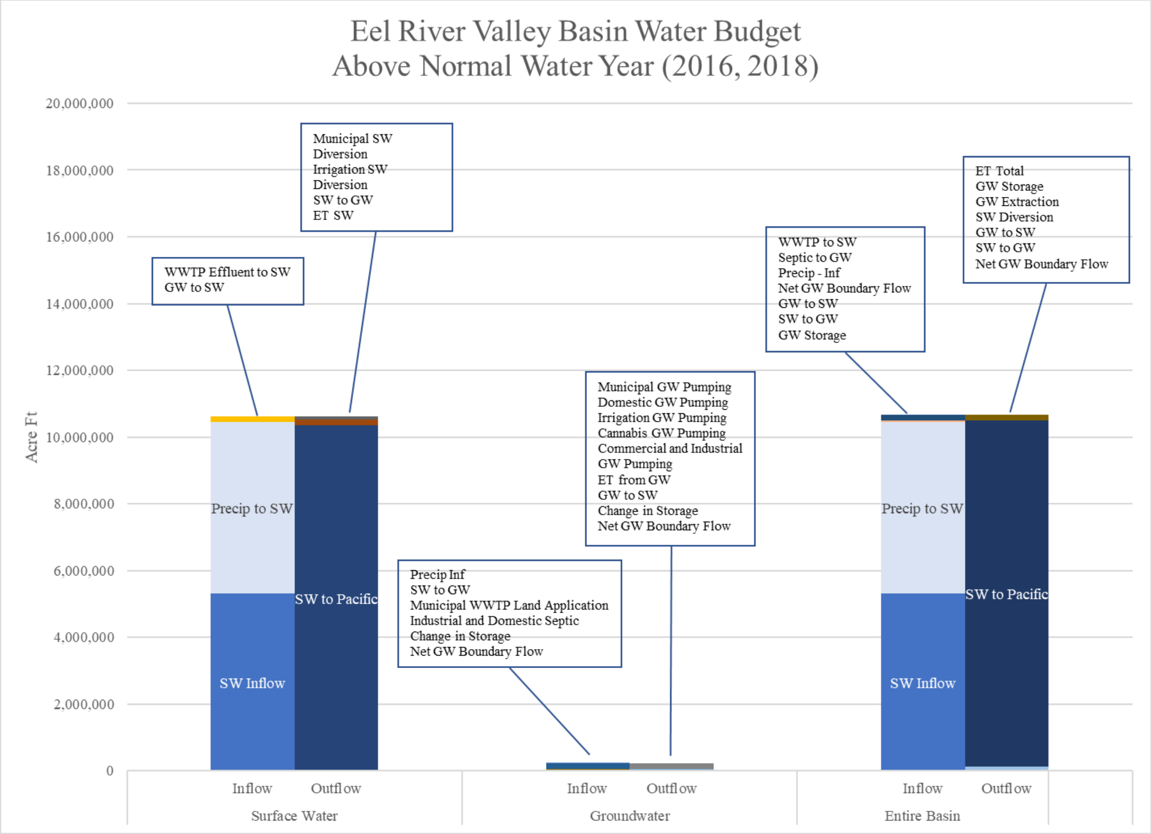


Chart 13: Above Normal Water Year Water Budget

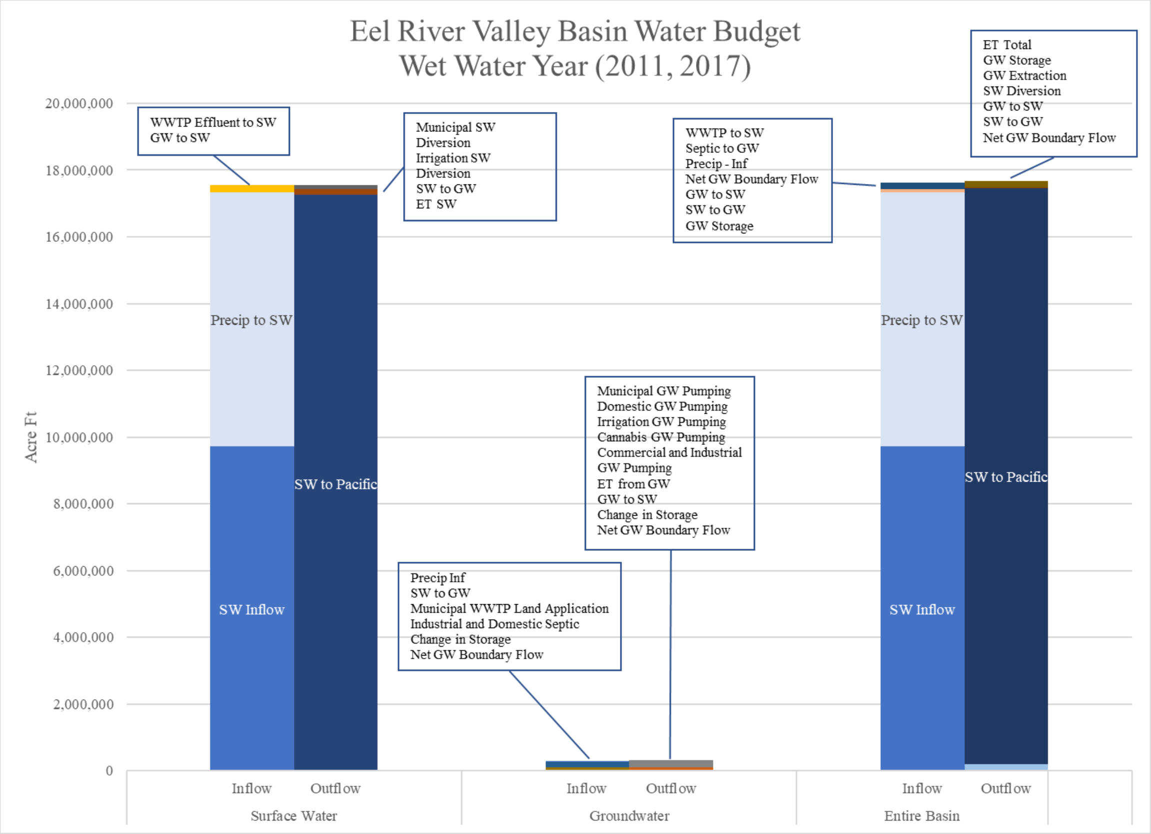


Chart 14: Wet Water Year Water Budget

5.6 Uncertainties in Water Budget Calculations

Groundwater models contain assumptions and uncertainty, especially when forecasting future conditions. Model uncertainty propagates from climate change, imperfect data on subbasin geology and hydrology, and assumptions surrounding unmetered groundwater pumping. Model inputs are carefully selected, and reflect the best, most complete science and data available. Accordingly, as model inputs and assumptions are refined, the hydrologic model can be recalibrated to maintain accuracy.

Table 19 provides an inventory of model assumptions and gaps in model data.

Table 19. Model assumptions and gaps in model data for water budget calculations

Data Gap Notes and Assumptions		
Water Provider	**Data Gap**	**Method for Addressing Data Gap**
City of Fortuna	No records for October-December of 2010; several data points missing or inaccurate (e.g., due to error with equipment)	Use monthly average water production for missing or inaccurate data points
City of Rio Dell	Annual data received	Use City of Fortuna data to scale monthly water production used based on annual water production
Scotia Community Service District	No metered data available	Use average annual water production estimated in the town's Municipal Service Review (LAFCo 2010); use City of Fortuna data to scale monthly water production based on annual water production (1)
Del Oro (City of Ferndale)	N/A - Complete	N/A - Complete
Loleta Community Service District	No data available from 2011 to 2014	Use average annual water production for 2011 to 2014; use City of Fortuna data to scale monthly water production based on annual water production
Bear River Band of the Rohnerville Rancheria	No data available from 2011 to 2013	Use average annual water production for 2011 to 2013; use City of Fortuna data to scale monthly water production based on annual water production
Hydesville Water Service District	N/A - Complete	N/A - Complete
Riverside Community Service District	No data for 2014 and from 2016 to 2020; annual data received	Use average annual water production based on available data from 2005 to 2015; use City of Fortuna data to scale monthly water used based on annual water production
Palmer Creek Community Service District	N/A - Complete	N/A - Complete

Notes:

(1) Water estimate for Scotia CSD includes water conveyed to mill. Population for Scotia since 2010 has decreased by approximately 35% (Census Reporter 2019; City-Data 2021). Use 2010 data to provide conservative estimate.

5.7 Projected Water Budgets

DWR requires the projected water budget to identify and evaluate uncertainties in the future conditions concerning hydrology, water demand, and surface water supply reliability over a 50-year planning horizon. The estimation methods used for this analysis must conform to the following criteria:

1. The projected water budget must utilize 50 years of historical precipitation, evapotranspiration, and stream flow information as the future baseline hydrologic conditions, while taking into consideration climate change and sea level rise projections (DWR 2016).
2. The projected water budget must incorporate the most recent land use, evapotranspiration, and crop coefficient information as baseline conditions for estimating

future water demand, while accounting for changes to future water demands related to changes in land use planning, population, and climate change.

3. The projected water budget must incorporate the most recent water supply information as the baseline for estimating future water supply, while applying the historical surface water supply reliability established in §354.18(c)(2) and considering the projected changes in land use planning, population, and climate (DWR 2016).

The projected water budget is generated (or gauged for consistency with previous water budget descriptions) using historical hydrologic data, PRMS surface water model, and MODFLOW-NWT groundwater model. Hydrologic data used to calibrate the groundwater and surface water model extend back to 1931. Projected changes in land use, population, climate, and sea level are incorporated into the projected water budget. The projected water budget extrapolates historical and current subbasin parameters through water year 2071.

Assumptions

The projected water budget was based on key assumptions specific to climate change, sea level rise, land use and population changes, and future groundwater demand. Applied assumptions are summarized below.

- Climate change and sea level rise assumptions –Based on the most recent sea level rise increase projections, the 0.5% probability (medium-high risk aversion) for the year 2070 ranges from 3.5 to 4.0 feet (OPC 2018). Modeled scenarios did evaluate changes in the water budget due to climate change and sea level rise.
- Land use changes – Within the Basin, current land uses, as designated in the Humboldt County General Plan, are not expected to significantly change. Thus, any effect on the projected water budget would be *de minimis.*
- Population changes – Based on current population data, the population of Humboldt County is expected to consistently decrease until 2071. The rate of population decrease for the county overall has been applied to the Basin as a ratio to quantify the expected population decrease for the basin specifically.
- Groundwater demand – Future groundwater demand are not anticipated to change based on irrigation use. Significant increases in irrigation are not expected because crop evapotranspiration is consistent with reference evapotranspiration (measured at CIMIS #259) and met with existing irrigation rates. Significant additional irrigation would simply infiltrate back into the ground unused by plants. *De minimis* increase in water use could result from modest changes in land use, predominantly due to parcel subdivision and resulting private development. However, increases attributable to parcel subdivision could balance with anticipated decreases in population between now and 2071.

Methods

Climate Change and Sea Level Rise Scenarios

The Base Model for the calibrated integrated groundwater/surface water model (Base Model) was used to evaluate a range of potential future climatological conditions. DWR provides necessary and relevant climate change datasets, generated from climate and hydrologic modeling studies, to assess projected groundwater conditions and water budgets for specific groundwater management projects (DWR, 2018). These datasets are available as 3.75 mile × 3.75 mile grids. GSP criteria described in DWR (2018) require that each of the presented climate change scenarios represent projected conditions over a 50-year SGMA planning and implementation horizon.

Projected precipitation, minimum temperature, and maximum temperature under near future (i.e., 2030) and late future (i.e., 2070) scenarios were used as inputs to the calibrated PRMS model. DWR climate change datasets were assigned as PRMS inputs by developing area-weighted average values that were then assigned to each of the PRMS HRUs. Select outputs from the PRMS models were then assigned as MODFLOW-2005 input parameters (see Sections 4.2.3 and 4.2.5) to simulate the projected 50-year near future and late future groundwater conditions. Sea level rise is included in each of these scenarios as constant head boundary conditions specified as 15 cm (i.e., 0.49 feet) and 45 cm (i.e., 1.48 feet) for the near and late future climate scenarios, respectively. These 50-year projections were centered around 2030 (i.e., 2005 to 2054) and 2070 (i.e., 2045 to 2094) for the near and late future climate scenarios, respectively. The results provided in Section 6.4 of GHD (2022a) do not indicate significant changes to groundwater storage or the groundwater sustainability indicators due to climate change.

Anticipated Changes in Land Use

Future land uses were assessed by reviewing the Humboldt County General Plan land use designations and outreaching to the Humboldt County Planning and Building Departments Long Range Planning staff. Land uses and population changes were evaluated in the Humboldt County General Plan only through the 2040 (Humboldt County 2017). Anticipated land use and population changes were further discussed with County Long-Range Planner John Miller. Within the Basin, land uses are not expected to differ from their current General Plan and zoning designations. Within the Basin, forest and timberland land uses designations would not occur, and there are no proposed changes in land use intensification. Where the coastal zone overlaps the Basin, changes to agricultural land use designations are also not expected, as the California Coastal Commission would not entertain changes to agricultural land use designations, nor would the County propose such changes. Within and near the communities of Hydesville, Carlotta, and Fortuna, modest changes to land use designations could occur (e.g., parcel subdivisions); however, such changes would not affect parcels used for agriculture or forest resources. Parcel subdivisions could result in additional private roads and structures, which would slightly increase the area of impervious surface in the predicted water budget, balanced against an equivalent reduction in pervious land uses.

Anticipated Changes in Population

Key sources of information that pertain to current and future population estimates with varying ranges of available data include the US Census, California Department of Finance (2021), and the Humboldt County General Plan. US Census population estimates extend only through 2020, while the California Department of Finance projections extend through 2060 for each California county. Population estimates in the Humboldt County General Plan extend to 2040.

The US Census data includes annual population estimates. The most recent population estimate from the US Census reported for Humboldt County was 134,613 in 2020, which is a 0.27% increase (0.02% annual increase) over the 2010 US Census population estimate of 134,613 (Table 20, US Census 2021). The population estimates provided by the California Department of Finance are similar but not identical and represent a slight population decrease over the same period of 1.81% (0.16% annual decrease. The 2010 through 2020 population estimates in the Humboldt County General Plan were based on 2014 and 2016 data (Humboldt County 2017) and are greater than those currently reported by both the US Census and California Department of Finance (2021).

Table 20 Comparison of 2010-2020 Population Data

Year	US Census Population Estimates	California Dept. of Finance	Humboldt County General Plan Projections[1]
2010	134,613	135,102	134,623
2011	135,257	135,383	-
2012	134,597	134,730	-
2013	134,447	134,562	-
2014	134,556	134,252	-
2015	135,177	134,596	-
2016	136,477	135,300	135,116
2017	136,710	135,141	-
2018	136,502	134,819	-
2019	135,839	133,820	-
2020	134,977	132,706	139,033
Total Percent Change	0.27%	-1.81%	3.17%
Annual Percent Change	0.02%	-0.16%	0.26%
Notes: [1] Humboldt County General Plan data is only available for 2010, 2016, and 2020.			

The Humboldt County General Plan predicts population growth to peak in 2030, followed by a 1.64% decline through 2040. The 2040 population prediction in the General Plan is 138,307 for the entire county. The County has not yet updated growth projections beyond those provided in the current General Plan. The estimates in the General Plan assumed that growth in the three incorporated cities would remain constant. However, in recent years, Fortuna and, to a lesser degree, Rio Dell, have experienced growth at higher rates than the County. These cities have drinking water and wastewater systems that can support future growth and thus may be centers of appreciable growth in the future.

The most recent California Department of Finance (DOF) population projections extend through 2060. The DOF projections include a 2021 population of 134,977 and a 2060 population of 121,972, which represents a 9% decrease in population over 40 years and an average annual decrease of 0.23% (CA DOF 2021).

Uncertainties affecting future population trends in Humboldt County and the Basin include the following:

- Post-COVID population migration from urban to rural areas, which are not currently reflected in the California Department of Finance projections through 2060;
- Changes in the future due to sea level rise adaptation and retreat, transportation, and energy system changes may lead to internal county migration and could increase population in areas like Fortuna and Rio Dell; and
- There are a number of expected economic changed in the near term that could influence growth, such as the expansion of Humboldt State University to a polytechnic, off shore energy, port development, and shifts in the cannabis industry.

The DOF projections extend farthest into the future, compared to other available population data sources. Thus, to estimate population for 2071, the 2060 DOR 2060 estimate has been extended to 2071 using the annual rate of decrease that results from 2040 through 2060 (0.23% decrease). This results in an estimated 2071 Humboldt County population of 118,648. The validity of this estimate is uncertain, but at a minimum it indicates that population growth is not expected to be a stressor for groundwater resources.

Conclusion

The projected future water budget for the Basin is equivalent (within the associated levels of uncertainty) to the current water budget (Section 5.5), due to the anticipated limited effects from climate change, land use changes, and population growth within the next 50 years.

PART III: SUSTAINABLE MANAGEMENT

6 SUSTAINABLE MANAGEMENT CRITERIA

Section 6 includes the following content:

- Key definitions under SGMA.
- The sustainability goal for the Basin is presented.
- The conditions that constitute sustainable groundwater management are defined.
- The process to characterize undesirable results is discussed.
- Minimum thresholds and measurable objectives are established for each applicable sustainability indicator.

6.1 Definitions

Terms governing the implementation of SGMA are defined in Water Code Section 10721 and 23 CCR Section 351. Definitions of several key terms are provided below.

The term **Sustainable Groundwater Management** means the management and use of groundwater in a manner than can be maintained during the planning and implementation horizon without causing undesirable results.

The term **Sustainability Indicator** refers to any of the effects caused by groundwater conditions occurring throughout the basin that, when significant and unreasonable, cause undesirable results. The six sustainability indicators are: groundwater levels, groundwater storage, seawater intrusion, water quality, land subsidence, and interconnected surface water depletion.

The term **Undesirable Result** means one or more of the following effects caused by groundwater conditions occurring throughout the basin:

1. Chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply if continued over the planning and implementation horizon. Overdraft during a period of drought is not sufficient to establish a chronic lowering of groundwater levels if extractions and groundwater recharge are managed as necessary to ensure that reductions in groundwater levels or storage during a period of drought are offset by increases in groundwater levels or storage during other periods.
2. Significant and unreasonable reduction of groundwater storage.
3. Significant and unreasonable seawater intrusion.
4. Significant and unreasonable degraded water quality, including the migration of contaminant plumes that impair water supplies.
5. Significant and unreasonable land subsidence that substantially interferes with surface land uses.
6. Depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water.

The term **Interconnected Surface Water** refers to 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.

The term **Representative Monitoring Site** refers to a monitoring site within a broader network of sites that typifies one or more conditions within the basin or an area of the basin. Some GSAs use the term representative monitoring point interchangeably.

The term **Minimum Threshold** refers to a numeric value for each sustainability indicator used to define undesirable results. The minimum threshold represents the groundwater condition in a representative monitoring site that when exceeded, may cause an undesirable result.

The term **Measurable Objectives** refers to specific, quantifiable goals for the maintenance or improvement of specified groundwater conditions that have been included in an adopted GSP to achieve the sustainability goal for the basin.

The term **Interim Milestones** refers to a target value representing measurable groundwater conditions, in increments of five years, set by a GSA as part of a GSP.

The term **Management Area** refers to an area within a basin for which the GSP may identify different minimum thresholds, measurable objectives, monitoring, or projects and management actions based on differences in water use sector, water source type, geology, aquifer characteristics, or other factors.

The term **Sustainable Yield** means the maximum quantity of water, calculated over a base period representative of long-term conditions in the basin and including any temporary surplus, that can be withdrawn annually from a groundwater supply without causing an undesirable result.

6.2 Management Area

GSAs may choose to define management areas for portions of their basins using natural or jurisdictional boundaries to facilitate groundwater management and monitoring. Management areas could have different minimum thresholds and measurable objectives than the rest of the basin if such differences are appropriate. The Humboldt County GSA has determined that the Basin will be managed as a whole rather than designating management areas.

6.3 Sustainability Goal

Sustainability Goal:

The goal of this GSP is to maintain high-quality and abundant groundwater resources in the Eel River Valley Groundwater Basin to support existing and long-term community needs without causing undesirable results. Groundwater is needed within the Basin for drinking water and personal use, agricultural irrigation, industrial process water, and ecosystem services.

This sustainability goal was developed based on the current understanding of the Basin's hydrogeology, groundwater conditions, and overall water budget. As discussed in this section, the sustainability goal for the Basin is currently being met. Measures to ensure that the Basin will continue to be operated within its sustainable yield over a 20-year planning horizon are discussed in Section 8.

6.4 General Process for Establishing Sustainable Management Criteria

Sustainable management criteria (SMCs) are composed of four elements:

1. **Significant and Unreasonable Statement**. This statement is a narrative description of the effects caused by an undesirable result.
2. **Minimum Threshold**. Minimum thresholds quantify the conditions at representative monitoring sites that are used to define undesirable results. A minimum threshold is the quantitative value that represents the groundwater conditions at a representative monitoring site that, when exceeded individually or in combination with minimum thresholds at other monitoring sites, may cause an undesirable result (DWR, November 2017).
3. **Measurable Objective** (and Interim Milestones, if warranted). Measurable Objectives are quantitative goals that reflect a basin's desired groundwater conditions and allow a GSA to achieve the sustainability goal within 20 years (DWR, November 2017). Measurable objectives are set for each sustainability indicator at the same representative monitoring sites and using the same metrics as minimum thresholds. Measurable objectives should be set with consideration for a reasonable margin of operational flexibility that will accommodate droughts, climate change, and other groundwater management activities.
4. **Undesirable Results**. Undesirable results are based on a quantitative description of the combination of minimum threshold exceedances that cause significant and unreasonable effects in the Basin [23 CCR 354.26(b)(2)]. Undesirable results occur when significant and unreasonable effects for any of the sustainability indicators are caused by groundwater conditions occurring throughout the Basin.

SMCs are not required for a sustainability indicator if a GSA can demonstrate that undesirable results related to that sustainability indicator are not present and are not likely to occur in a basin.

The SMCs for this Basin were developed through technical analysis of data and information, review of draft and final GSPs from other basins, meetings with the County's consultant team, and stakeholder feedback. The general process for developing the SMCs included:

- Identify relevant technical data sources and review information developed for the GSP.
- Develop initial approaches for each sustainability indicator and consider whether any of the sustainability indicators are not present and/or are not likely to occur.
- Release the Administrative Draft GSP and reach out to stakeholders who may be interested in commenting on the draft SMCs.
- Discuss the SMCs at a public meeting of the Humboldt County Board of Supervisors (January 4, 2022).
- Modify the SMCs where appropriate based on further technical analyses and input from stakeholders.

In addition to compliance with SGMA, the process of developing SMCs represents the Humboldt County GSA's consideration of the potential impacts of groundwater pumping on public trust resources within the Basin and the conditions when measures to protect those resources may be appropriate.

6.5 Summary

A summary of the SMCs for the Basin is provided in Table 21. The information and methods to develop these SMCs are discussed in the following sections.

Table 21: Sustainable Management Criteria Summary

Sustainability Indicator	Significant and Unreasonable Statement	Minimum Threshold	Measurement	Measurable Objective	Undesirable Result
Chronic lowering of groundwater levels (SMC #1)	Chronic lowering of groundwater levels would be considered significant and unreasonable if a substantial number of private, agricultural, industrial, and/or municipal production wells could no longer provide sufficient groundwater to supply beneficial uses.	Maintain groundwater levels to ensure at least ten feet of saturated well screen within wells installed after 1964 with appropriate sanitary seals.	Semiannual groundwater levels measured at RMS wells.	Maintain groundwater levels above the depth projected to correspond to a 75% increase in pumping.	An undesirable result would exist if one of the following scenarios occurs: 1. Groundwater levels in four or more RMS wells fall below their MTs in any one year. 2. Groundwater levels in two or more RMS wells fall below their MTs for two sequential years.
Reduction in groundwater storage (SMC #2)	Reduction in groundwater storage would be considered significant and unreasonable if the net volume of groundwater extraction causes other sustainability indicators to have undesirable results.	Maintain groundwater use below the sustainable yield (30,000 acre-feet) so that other sustainability indicators do not have undesirable results.	Annual groundwater pumping (direct reporting and estimates based on any significant land use changes).	Maintain groundwater use below 75% of the sustainable yield (22,500 acre-feet).	An undesirable result would exist if the total annual average groundwater extraction over a three-year period exceeds the sustainable yield.
Seawater intrusion (SMC #3)	Seawater intrusion would be considered significant and unreasonable if a substantial number of unintruded wells become impacted by seawater due to groundwater conditions and can no longer provide sufficient groundwater to supply beneficial uses.	1. Maintain the 100 mg/L chloride concentration isocontour line near the location measured in Water Year 2021. 2. Maintain groundwater levels to ensure a flow gradient toward the ocean.	Chloride concentrations in selected monitoring and production wells used to define the isocontour line.	1. Maintain chloride concentrations with a buffer below minimum thresholds. 2. Maintain groundwater levels with a buffer above minimum thresholds.	An undesirable result would exist if one of the following scenarios occurs: 1. Chloride concentrations in two or more unintruded RMS wells exceed their MT values over two consecutive monitoring events. 2. Chloride concentrations in two or more intruded wells exceed their MT values over two consecutive monitoring events. 3. Groundwater levels in two or more RMS wells fall below their MT values for two sequential years.

Table 21: Sustainable Management Criteria Summary (Continued)

Sustainability Indicator	**Significant and Unreasonable Statement**	**Minimum Threshold**	**Measurement**	**Measurable Objective**	**Undesirable Result**
Degraded water quality (SMC #4)	Degraded water quality would be considered significant and unreasonable if direct actions by the Humboldt County GSA to implement this GSP result in adverse impacts on beneficial users or uses of groundwater.	Two municipal water supply wells exceeding the arsenic MCL of 10 ug/L.	Laboratory analysis of samples collected from municipal raw water.	Zero municipal water supply wells exceeding the arsenic MCL of 10 ug/L.	An undesirable result would exist if two supply wells exceed the arsenic MCL of 10 ug/L as a direct result of projects or management actions taken as part of GSP implementation.
Subsidence (SMC #5)	N/A	N/A	N/A	N/A	N/A
Depletion of interconnected surface water (SMC #6)	Depletion of interconnected surface water within the Basin would be considered significant and unreasonable if surface water depletion caused by groundwater extraction degrades the beneficial uses of an interconnected surface water or threatens the viability of special-status species, and reasonable reductions or limitations in groundwater pumping could avoid these effects without jeopardizing other beneficial uses of groundwater.	1. Maintain groundwater pumping below 30,000 acre-feet, which represents a 100% increase from current conditions. 2. Maintain groundwater levels above levels modeled to correlate with a 100% increase in pumping.	1. Annual groundwater pumping (direct reporting and estimates based on any significant land use changes). 2. Semiannual groundwater levels measured at RMS wells.	1. Maintain groundwater pumping below a 75% increase from current conditions. 2. Maintain groundwater levels above levels modeled to correlated with a 75% increase in pumping.	An undesirable result would exist if one of the following scenarios occurs: 1. Groundwater pumping increases 100% from current conditions. 2. Groundwater levels in two or more RMS wells for SMC #6 fall below their MT values for two sequential years. If one of these scenarios occurs, then further analysis would be needed to determine if significant and unreasonable conditions exist.

Notes:

RMS = Representative Monitoring Sites
MT = Minimum Threshold
NA = Not Applicable

6.6 SMC #1: Chronic Lowering of Groundwater Levels

6.6.1 Introduction

As described in Section 4.1, the amount of seasonal variation in groundwater levels within the principal aquifers of the Basin is relatively small and the available groundwater records indicate relatively stable groundwater-level conditions. Groundwater levels generally drop during dry and critical water years but rebound quickly during wet years. The rate of groundwater pumping within the Basin has remained stable during the period of record and historical data do not reflect any significant declining trends for groundwater levels.

Chronic lowering of groundwater levels could cause wells with shallow well screens (i.e., screens that are relatively close to the ground surface) to yield less water or, in the worst case, to cease production. The term “chronic” generally means continuing for a long time or recurring frequently. As described below, SMC #1 was developed to avoid future impacts to supply wells as a result of groundwater conditions.

Groundwater levels have the most robust data among all the sustainability indicators, and groundwater levels relate directly or indirectly to the other indicators. SGMA allows GSAs to use groundwater levels as a proxy for other sustainability indicators if a significant correlation is established between groundwater levels and the other metrics. In this GSP, groundwater levels are used as a proxy for groundwater storage (Section 6.7), seawater intrusion (Section 6.8), and depletion of interconnected surface water (Section 6.11).

6.6.2 Significant and Unreasonable Conditions

Chronic lowering of groundwater levels within the Basin would be considered significant and unreasonable if a substantial number of private, agricultural, industrial, and/or municipal production wells could no longer provide sufficient groundwater to supply beneficial uses. The height of saturated well screen is used as the metric for this condition. There is no prescriptive standard for the minimum height of saturated well screen because the productivity of a well depends on the rate of recharge, which varies widely. For the purpose of this GSP, a well is considered potentially impacted if lowering of groundwater levels results in less than ten feet of saturated well screen.

6.6.3 Minimum Thresholds

SGMA specifies that the minimum threshold for chronic lowering of groundwater levels shall be the groundwater elevation indicating a depletion of supply at a given location that may lead to undesirable results [(23 CCR 354.28(c)(1)].

6.6.3.1 Well Impacts

Information and Methodology for Establishing Minimum Thresholds
The process to determine minimum thresholds based on potential well impacts included the following steps:

1. Set the study area boundary.

This analysis focused on the alluvial valley from the coastline to just east of Alton, inclusive of the Ferndale and Loleta bottom lands. This area was selected because it encompasses the highest concentration of groundwater wells and has sufficient historical groundwater level data available to establish baseline conditions.

2. Query DWR's well completion report database.

DWR's well completion report (WCR) database was queried to obtain available information on groundwater wells within the study area including well location, total completed depth, bottom of perforated interval (if available), and construction date. The WCR database provides well locations based on the center point of the Public Land Survey System (PLSS) Section which has a size of one square mile. To improve location accuracy, an effort was made to refine locations for any wells that had a total completed depth of 80 feet or less using information included in the WCR. (Wells deeper than 80 feet are far below the level of potential impact by lowering of groundwater levels.) Private wells with known depths that have been volunteered for use in the County's water level measurement campaigns in 2016/2017 and 2010/2021 were also included.

3. Select study wells.

The total number of wells in the initial well inventory was 221 and included all water supply wells (domestic, agricultural, industrial, public). Of these, wells that had total completed depths of less than 30 feet (14 wells) and/or wells that were constructed prior to 1965 (67 wells) were filtered out to establish the final well dataset for analysis, herein referred to as the "study wells" (140 total). Wells with depths less than 30 feet were excluded because these were determined to likely be improperly or marginally constructed, because current standards for well construction require a sanitary seal of 20 feet for private wells. Wells that were constructed prior to 1965 were excluded because these wells were likely impacted by the 1964 flood and may no longer exist. All study wells were assigned elevations using the Digital Elevation Model, based on their specific location (preferred) or, if the specific location could not be determined, based on the center point of the PLSS Section in which they are situated.

4. Identify analysis areas and regions.

The study area was subdivided into ten analysis areas to associate groups of study wells with a nearby well that has historical groundwater level data. The ten analysis areas are shown in Figure 37. Through this initial analysis it became clear that wells within the western half of the Study Area were generally deeper than the wells within the eastern half, and that the study area could be subdivided into two general regions based on the existing well depths. Figure 37 shows the west threshold region and east threshold region. The West Threshold Region includes Analysis Areas 1 through 5 and the East Threshold Region includes Analysis Areas 6 through 10.

5. Establish baseline groundwater levels.

Existing historical groundwater level records were reviewed to establish a baseline condition for this analysis. Water levels are lowest in the Fall, and our analysis focused on conditions at this time of year. Groundwater levels recorded in seven CASGEM wells, four County monitoring wells (installed in 2016), two private wells, and the City of Fortuna municipal supply wells were used to establish an average fall groundwater elevation for each well location.

6. Compare well bottom elevations to baseline groundwater levels and various lowering scenarios.

The 140 study wells were grouped into the two regions based on location. First, well bottom elevations in each area were compared to the established baseline fall groundwater level to determine the saturated thickness of each well at the baseline condition and to assess whether any wells have less than ten feet of saturated well screen, which was the impact criteria. Then a series of groundwater level scenarios were analyzed that included various intervals below the baseline.

7. Set analysis criteria.

For the purposes of establishing minimum thresholds associated with well impacts, a statistical threshold of significance was established as the groundwater level lowering at which 10% or more of the wells have less than ten feet of water above the bottom of the well.

8. Determine which lowering scenario exceeds the analysis criteria.

Groundwater level lowering scenarios were evaluated to determine what magnitude of groundwater level lowering would cause 10% or more of the wells within each region to have less than ten feet of water. For the West Threshold Region, a 13-foot lowering of groundwater levels would exceed the analysis threshold. For the East Threshold Region, a 4-foot lowering of groundwater levels would exceed the analysis threshold.

9. Calculate Minimum Thresholds at Representative Monitoring Sites.

A total of 24 representative monitoring sites were selected for monitoring potential well impacts (Figure 38). For the West Threshold Region, the minimum threshold in each well was set at 13 feet below the average Fall groundwater elevation for that well. For the East Threshold Region, the minimum threshold in each was set at four feet below the average Fall groundwater elevation for that well. Table 22 provides a summary of the representative monitoring sites and their respective minimum thresholds.

Table 22: Minimum Thresholds and Measurable Objectives for Chronic Lowering of Groundwater Levels

Representative Monitoring Site	Average Fall Groundwater Level (ft NAVD88)	Well Impact Region	Minimum Threshold for Well Impact (ft NAVD88)	Note	Measurable Objective (ft NAVD88)
Active CASGEM Wells					
36942	16.7	East	12.7	(1)	14.2
36943	8.2	West	-4.8	(2)	7.2
23183	6.5	West	-6.5	(2)	5.5
23181	6.9	West	-6.1	(2)	5.4
2016 County Monitoring Wells					
MW-1s	8.7	East	4.7	(1)	5.7
MW-2s	19.7	East	15.7	(2)	19.2
MW-3d	25.6	East	21.6	(1)	22.6
MW-5s	6.2	West	-6.8	(2)	5.2
MW-7s	14.5	West	1.5	(2)	6.8
MW-8	12.5	East	8.5	(1)	9.5
2021 County Monitoring Wells					
MW-13s	25.4	East	21.4	(2)	23.2
MW-14s	7.0	West	-6.0	(2)	5.5
MW-15s	9.0	East	5.0	(2)	7.5
MW-19	22.0	East	18.0	(1)	19.0
MW-20	18.0	East	14.0	(1)	15.5
MW-21	20.7	East	16.7	(1)	17.7
MW-22	19.7	East	15.7	(2)	18.2
MW-23	13.0	East	9.0	(1)	10.0
MW-24	17.0	East	13.0	(1)	14.0
MW-25	12.0	East	8.0	(2)	11.0
MW-26	3.0	West	-10.0	(2)	1.5
MW-27	3.0	West	-10.0	(2)	2.0
MW-28	6.5	West	-6.5	(2)	4.8
MW-30	15.0	East	11.0	(1)	12.0

Notes:

(1) This value is the highest minimum threshold for this representative monitoring site.

(2) This value is superseded by the minimum threshold established for other sustainability indicators.

Relationship between Individual Minimum Thresholds

The minimum thresholds for chronic lowering of groundwater levels were developed by examining historical groundwater level data at each individual representative monitoring site and reviewing the depths of nearby water wells. Therefore, the minimum thresholds are unique at every well but intended to be evaluated collectively.

Effect on Beneficial Uses and Users
The minimum thresholds for chronic lowering of groundwater levels are generally advantageous to beneficial users and land uses in the Basin. For agricultural, municipal, and domestic land uses and users, the minimum thresholds protect users' ability to meet their water supply needs by maintaining groundwater at levels that will not impact their supply wells. For ecological land uses and users, the minimum thresholds will help maintain the interconnected nature of groundwater and surface water in the Basin.

Relation to Federal, State, or Local Standards
No federal, state, or local standards exist that are specific to chronic lowering of groundwater levels.

Method for Quantitative Measurement of Minimum Thresholds
Depth to groundwater will be directly measured in representative monitoring sites within the monitoring network for comparison with the minimum thresholds. Groundwater level data will be collected as described in Section 7. Depth readings will be converted to groundwater elevations by subtracting the measured depth to groundwater from the reference point elevation corresponding to the respective monitoring wells.

6.6.4 Measurable Objectives

Measurable objectives for chronic lowering of groundwater levels represent target groundwater elevations that provide a protective buffer above the minimum thresholds. Measurable objectives provide a metric to detect potential trends in advance before minimum thresholds are reached.

Methodology for Establishing Measurable Objectives
The hydrologic model was used to estimate groundwater levels at representative monitoring sites for the 75% increased-pumping scenario. The model provided a prediction of the difference in groundwater elevation between current conditions and the 75% increased-pumping scenario. For 14 representative monitoring sites, the model predicted a groundwater elevation difference of 1.0 feet or more. For these sites, the measurable objective was established by subtracting the modeled groundwater elevation difference from the average fall groundwater level. For ten representative monitoring sites, the model predicted a groundwater elevation difference of less than 1.0 feet. For these sites, the measurable objective was established by adding 1.0 feet to the minimum threshold.

Interim Milestones
Interim milestones were not established because the Basin is being managed within its sustainability goal.

6.6.5 Undesirable Results

Definition
An undesirable result would exist if one of the following scenarios occurs:

1. Groundwater levels in four or more representative monitoring sites fall below their minimum thresholds over the course of any one year.
2. Groundwater levels in two or more representative monitoring sites fall below their minimum thresholds for two sequential years.

This definition of undesirable results balances an allowance for unanticipated hydrologic conditions and consideration of the potential for non-representative outliers with the primary objective of preventing users from being impacted by significant and unreasonable conditions.

Potential Causes of Undesirable Results

Potential causes of undesirable results for chronic lowering of groundwater levels include:

- Significantly increased groundwater pumping the Basin leading to chronic groundwater-level declines.
- A significant reduction in natural recharge as a result of climate change, increased upstream diversions, or changes in land surface processes.

Potential Effects of Undesirable Results

Potential effects of undesirable results for chronic lowering of groundwater levels on beneficial users and land use include:

- Some portion of the agricultural, municipal, domestic, and industrial supply wells could lose capacity and fail to meet the water needs due to the reduced saturated thickness of the aquifer. This situation could result in the need to drill new deeper wells which would increase the cost of using groundwater as a water source.

6.7 SMC #2: Reduction in Groundwater Storage

6.7.1 Introduction

The reduction in groundwater storage SMC will be evaluated using groundwater levels as a proxy based on well-established hydrogeologic principle that the volume of groundwater in storage is directly proportional to groundwater elevations. The minimum thresholds for chronic lowering of groundwater levels are established to maintain adequate groundwater supplies and avoid impacts to supply wells. Therefore, maintaining groundwater elevations above the minimum thresholds for chronic lowering of groundwater levels will, by definition, maintain an adequate amount of groundwater in storage.

6.7.2 Significant and Unreasonable Conditions

Reduction in groundwater storage would be considered significant and unreasonable if the net volume of groundwater extraction causes other sustainability indicators to have undesirable results.

6.7.3 Minimum Thresholds

SGMA specifies that the minimum threshold for reduction in groundwater storage shall be a total volume of groundwater that can be withdrawn from the basin without causing conditions that may lead to undesirable results. Minimum thresholds for reduction of groundwater storage shall be supported by the sustainable yield of the basin, calculated based on historical trends, water year type, and projected water use in the basin [(23 CCR 354.28(c)(2)].

The sustainable yield of the Basin is at least 30,000 acre-feet per year, based on an average across the five water year types (Section 6.13). Historical trends for groundwater levels are stable (Section 4.1) and water use in the Basin is projected to remain comparable to current conditions (Section 5.7). The minimum threshold for reduction in groundwater storage will be set at the sustainable yield of 30,000 acre-feet per year.

6.7.4 Measurable Objectives

The measurable objective for reduction in groundwater storage represents a target volume of annual groundwater use that provides a protective buffer above the minimum threshold. The measurable objective provides a metric to detect potential trends in advance before the minimum threshold is reached.

Methodology for Establishing Measurable Objectives
The measurable objective for reduction in groundwater storage was established as 75% of the sustainable yield (30,000 acre-feet), resulting in 22,500 acre-feet of annual groundwater use. This percentage was determined to provide a conservative buffer below the sustainable yield while still providing reasonable capacity for increases in groundwater use.

Interim Milestones
Interim milestones were not established because the Basin is being managed within its sustainability goal.

6.7.5 Undesirable Result

An undesirable result would exist if the total annual average groundwater extraction over a three-year period exceeds the sustainable yield.

6.8 SMC #3: Seawater Intrusion

6.8.1 Introduction

The seaward flow of fresh groundwater and the landward flow of seawater have a dynamic interface in coastal aquifers. A lens of seawater plunges under the fresh groundwater due to seawater's higher density and the interface is a diffuse mixing zone rather than a sharply defined boundary. The inland extent of seawater intrusion is generally limited by the seaward flow of fresh groundwater. Increases in ocean levels or decreases in the seaward flow of fresh groundwater could allow seawater to migrate further inland and threaten to make groundwater wells unusable for serving beneficial uses.

Chlorides are chemical ions that combine with sodium, calcium, and magnesium to form the salts which are found in seawater. Chloride concentrations in water are a metric for monitoring the extent of seawater intrusion.

The term "intruded well" refers to a well where groundwater entering the well has been impacted by seawater. For the purpose of this GSP, the threshold for an intruded well is set at a chloride concentration of 250 mg/L, which is the secondary maximum contaminant level for chloride in drinking water. The term "unintruded well" refers to a well that has not been impacted by seawater (chloride concentrations less than 250 mg/L). The Basin contains mostly unintruded wells and only a few intruded wells.

In 1975, the USGS collected data that allowed mapping chloride isocontour lines near the coastline. An isocontour line is an extrapolation between data points to estimate a line of equal concentration. The USGS mapped the isocontour lines for chloride concentrations of 30 mg/L and 100 mg/L. As discussed in Section 4.3, based on data collected in 2016-2017 and 2020-2021, the chloride isocontour lines have not moved substantially.

Two issues related to seawater intrusion in groundwater are coastal erosion of the dune system and the cumulative effects of restoring tidal influence on the sloughs and tributaries of the Eel River estuary. Dune erosion has the potential to allow salt water to temporarily or permanently impact inland land use. The potential effects of restored sloughs and tributaries on fresh groundwater warrants further evaluation.

6.8.2 Significant and Unreasonable Conditions

Seawater intrusion within the Basin would be considered significant and unreasonable if a substantial number of unintruded wells become impacted by seawater due to groundwater conditions and can no longer provide sufficient groundwater to supply beneficial uses.

6.8.3 Minimum Thresholds

SGMA specifies that the minimum threshold for seawater intrusion shall be defined by a chloride concentration isocontour for each principal aquifer where seawater intrusion may lead to undesirable results [(23 CCR 354.28(c)(3)].

6.8.3.1 Chloride Concentration Isocontour Line

<u>Information and Methodology for Establishing Minimum Thresholds</u>
For this GSP, the minimum threshold for seawater intrusion is set at the 100 mg/L chloride concentration isocontour line measured in Water Year 2021. For practical purposes of monitoring the isocontour line, minimum thresholds of chloride concentrations are set at selected monitoring and production wells used to define the isocontour line.

The process to determine minimum thresholds of chloride concentrations included the following steps:

1. Select representative monitoring sites. Wells were chosen for consistency with historical monitoring and to provide wells located both seaward and landward of the recent 100 mg/L isocontour. A total of 20 representative monitoring sites were selected for monitoring seawater intrusion (Figure 38).

2. Evaluate the observed historic range of chloride concentrations of each well.

3. Assign minimum thresholds according to the following:
    - Wells with insufficient or inconsistent historical data – no minimum threshold
    - Unintruded wells with historical ranges less than 100 mg/L – minimum threshold is 125 mg/L
    - Unintruded wells with historical ranges between 100 mg/L and 250 mg/L – minimum threshold of 250 mg/L
    - Intruded wells with historical ranges between 250 mg/L and 500 mg/L – minimum threshold of 500 mg/L

This tiered approach was developed to ensure that any increasing trends in chloride concentrations will be detected in advance of potentially irreversible impacts from seawater intrusion. The resulting minimum thresholds for chloride concentrations are shown on Table 23.

Table 23: Chloride Concentration Minimum Thresholds and Measurable Objectives for Seawater Intrusion

Representative Monitoring Site	Screened Interval (ft bgs)	No. of Historical Samples	Historical Maximum (mg/L)	Historical Minimum (mg/L)	MT (mg/L)	MO (mg/L)
2016 County Monitoring Wells						
MW-5s	100-110	9	62	45	125	50
MW-5d	200-210	10	72	54	125	60
MW-7s	30-40	10	41	22	125	30
MW-7d	240-250	8	320	170	500	250
2021 County Monitoring Wells						
MW-14s	55-65	2	35	29	125	30
MW-14d	225-235	2	120	16	250	115
MW-26	30-40	2	150	110	250	130
MW-27	45-50	2	9,300	770	n/a	n/a
MW-28	35-45	2	100*	94*	250	100
Municipal Wells						
Del Oro - Van Ness Well	146-166	10	52	41	125	45
Riverside CSD - Well 6	85-105	7	49	19	125	45
Loleta CSD - Well 4	tbd	4	17	14	125	15
Private Wells						
Private Well 3	tbd	4	41	30	n/s	n/s
Private Well 4	60-80	4	62	49	n/s	n/s
Private Well 6	tbd	4	33	29	n/s	n/s
Private Well 7	24-35	4	26	22	n/s	n/s
Private Well 24	60-80	2	130	22	n/s	n/s
Private Well 51	40-60	2	140	110	n/s	n/s
Private Well G	140-160	4	51	37	n/s	n/s
Private Well H	60-70	4	280	38	n/s	n/s
Private Well L	tbd	4	180	110	n/s	n/s
Private Well Q	tbd	4	250	120	n/s	n/s
Private Well R Shop	tbd	3	1,600	1,500	n/s	n/s

Notes:

ft bgs = feet below ground surface
mg/L = milligrams per liter
MT = Minimum threshold
MO = Measurable objective
n/a = not applicable
n/s = not set (will be used for mapping the chloride isocontour line)
tbd = to be determined
* = chloride value may be associated with water quality conditions not related to seawater

Relationship between Individual Minimum Thresholds
The minimum thresholds for seawater intrusion associated with chloride concentrations were developed by examining historical and current data for the location of the 100 mg/l isocontour line and developing a network of representative monitoring sites that will allow future monitoring of the isocontour line. While the SMC is specified as an isocontour line, chloride concentrations were used to develop minimum thresholds as a method of quantitatively tracking the movement of the isocontour line.

Effect on Beneficial Uses and Users
The minimum thresholds for seawater intrusion associated with chloride concentrations are generally advantageous to beneficial users and land uses in the western portion of the Basin near the coast. For agricultural, municipal, and domestic land uses and users, the minimum thresholds protect users' ability to meet their water supply needs by maintaining chloride concentrations at levels that will not impact their supply wells. For ecological land uses and users, the minimum thresholds will help maintain a balance of fresh, brackish, and saline conditions.

Relation to Federal, State, or Local Standards
No federal, state, or local standards exist that are specific to seawater intrusion.

Method for Quantitative Measurement of Minimum Thresholds
Chloride concentrations will be directly measured in representative monitoring sites within the monitoring network for comparison with the minimum thresholds. Water samples will be collected as described in Section 7 and submitted to a laboratory for analytical testing. The results will be used to map the 100 mg/L isocontour line for comparison with historical data.

6.8.3.2 Groundwater levels

Information and Methodology for Establishing Minimum Thresholds
A significant reduction in groundwater levels due to excessive groundwater extraction would be an indicator of reduced seaward flows of fresh groundwater. In addition to the chloride concentration isocontour line, groundwater elevation minimum thresholds were developed as a proxy for seawater intrusion using the groundwater models described in Section 4.3.4 and the Hydrologic Model Technical Memorandum (GHD, 2022a).

The models were used to run an array of groundwater extraction scenarios designed to evaluate the relationship between water use, water levels, and chloride concentrations. The model runs included scenarios for no-pumping, current pumping, and increased pumping at various increments above current pumping rates. Results of the increased pumping scenarios were analyzed to develop an understanding of the chloride/water level relationships. The representative monitoring sites for chloride concentrations were evaluated by plotting graphs of the predicted water levels and chloride concentrations through the timeframe of the model (2000 to 2020). For each well, the years that the predicted chloride concentration exceeded the minimum thresholds set in Table 22 were evaluated. The magnitude of water level lowering required to cause the exceedance was noted and an average value over the years in which it occurred was calculated.

In over half the wells analyzed, the established chloride concentration minimum thresholds (from Table 22) were not exceeded with the scenarios run (up to 800% increase in pumping). For wells that did predict exceedances, a greater than 500% increase in pumping was required, and exceedances were often only predicted during years where a climatic stress was put on the Basin (i.e., critical or dry water year). Where exceedances were predicted, the associated reduction of groundwater levels ranged from approximately eight feet to as much as 20 feet below the Base

Case scenario, with an average of approximately 12 feet of lowering required to exceed thresholds. In all cases, the model predicts that groundwater level needs to be lowered below sea level, and in many cases, well below sea level, to induce seawater intrusion.

The protective water levels estimated using the analysis of modeling scenarios are considered unreasonably low for setting thresholds. A more conservative and simpler approach to establishing water levels protective of seawater intrusion is to use mean sea level as a lower limit. This approach ensures that a groundwater gradient towards the ocean is maintained and a reversed groundwater gradient is prevented. Using this approach, wells generally located near the 100 mg/L isocontour have been assigned a minimum threshold groundwater level of 3.8 feet NAVD88 (approximately equal to 0 feet Mean Sea Level). Wells further inland are adjusted up one or two feet based on the natural fall groundwater gradient, and some wells closer to the coast are adjusted down one or two feet.

Using the methodology described above, water level minimum thresholds have been assigned to ten representative monitoring sites within the western portion of the lower Eel River Valley (Table 24).

Table 24: Water Level Minimum Thresholds and Measurable Objectives for Seawater Intrusion

Representative Monitoring Site	Average Fall Groundwater Level (ft NAVD88)	Minimum Threshold for Seawater Intrusion (ft NAVD88)	Note	Measurable Objective (ft NAVD88)
Active CASGEM Wells				
36943	8.2	4.8	(1)	7.2
23183	6.5	3.8	(1)	5.5
23181	6.9	3.8	(1)	5.4
2016 County Monitoring Wells				
MW-5s	6.2	3.8	(1)	5.2
MW-7s	14.5	5.8	(1)	6.8
2021 County Monitoring Wells				
MW-14s	7.0	3.8	(1)	5.5
MW-15s	9.0	4.8	(2)	7.5
MW-26	3.0	0.8	(1)	1.5
MW-27	3.0	0.8	(1)	2.0
MW-28	6.5	3.8	(1)	4.8

Notes:

(1) This value is the highest minimum threshold for this representative monitoring site.
(2) This value is superseded by the minimum threshold established for other sustainability indicators.

Relationship between Individual Minimum Thresholds

The minimum thresholds for seawater intrusion associated with water levels were developed by examining historical and current data, applying simulation models, developing a network of representative monitoring sites, and evaluating the distance between the monitoring wells and the coast. The individual minimum thresholds were developed based on the relative distances of the wells to the coast.

Effect on Beneficial Uses and Users
The minimum thresholds for seawater intrusion associated with water levels are generally advantageous to beneficial users and land uses in the western portion of the Basin near the coast. For agricultural, municipal, and domestic land uses and users, the minimum thresholds protect users' ability to meet their water supply needs by maintaining groundwater at levels that will not impact their supply wells. For ecological land uses and users, the minimum thresholds will help maintain a balance of fresh, brackish, and saline conditions.

Relation to Federal, State, or Local Standards
No federal, state, or local standards exist that are specific to seawater intrusion.

Method for Quantitative Measurement of Minimum Thresholds
Depth to groundwater will be directly measured in representative monitoring sites within the monitoring network for comparison with the minimum thresholds. Groundwater level data will be collected as described in Section 7. Depth readings will be converted to groundwater elevations by subtracting the measured depth to groundwater from the reference point elevation corresponding to the respective monitoring wells.

6.8.4 Measurable Objectives

6.8.4.1 Chloride Concentration Isocontour Line

The measurable objective for seawater intrusion represents a more seaward position of the 100 mg/L chloride concentration isocontour line compared to the location measured in Water Year 2021. For practical purposes of monitoring the isocontour line, measurable objectives for chloride concentrations are set at selected monitoring and production wells used to define the isocontour line. These measurable objections provide a metric to detect potential trends in the movement of the isocontour before the minimum threshold is reached.

Methodology for Establishing Measurable Objectives
Measurable objectives for chloride concentrations are shown in Table 23. The measurable objectives for chloride concentrations were established by using professional judgment to select concentrations slightly below the historical maximum measured concentrations. Some of these representative monitoring sites have only two historical samples so there is limited data on which to draw conclusions. These objectives may be adjusted in the future based on additional monitoring data.

Interim Milestones
Interim milestones were not established because the Basin is being managed within its sustainability goal.

6.8.4.2 Groundwater Levels

Measurable objectives for seawater intrusion were developed for groundwater levels in addition to the chloride concentration isocontour line. These measurable objectives represent target groundwater elevations that provide a protective buffer above the minimum thresholds. Measurable objectives provide a metric to detect potential trends in advance before minimum thresholds are reached.

Methodology for Establishing Measurable Objectives
Measurable objectives for groundwater levels associated with seawater intrusion are shown in Table 24. These measurable objectives were developed using the methodology described in Section 6.6.4.

Interim Milestones
Interim milestones were not established because the Basin is being managed within its sustainability goal.

6.8.5 Undesirable Result

An undesirable result would exist if one of the following scenarios occurs:

1. Chloride concentrations in two or more unintruded wells within the network of representative monitoring sites exceed their minimum thresholds over the course of two consecutive monitoring events.
2. Chloride concentrations in two or more intruded wells within the network of representative monitoring sites exceed their minimum thresholds over the course of two consecutive monitoring events.
3. Groundwater levels in two or more wells within the network of representative monitoring sites fall below their minimum thresholds for two sequential years.

6.9 SMC #4: Degraded Water Quality

6.9.1 Introduction

An important component of maintaining the supply and beneficial uses of groundwater is having high-quality water that meets applicable regulatory standards. Water quality is subject to multiple regulatory programs at the federal, state, and local levels. Potential causes of degraded water quality include natural background conditions, land use activities, groundwater pumping, and actions by the GSA to implement the GSP. Examples include:

- Concentrations of naturally occurring constituents could be elevated due to geologic conditions.
- Land use activities could result in the release of chemical constituents into the environment that could migrate to groundwater.
- Groundwater pumping could influence the transport of contaminated groundwater and potentially induce poor-quality water into areas not previously impacted by water quality degradation.
- Projects such as aquifer storage and recovery (ASR) could deliver treated water or other sources of water to recharge an aquifer when water is available, for later recovery when needed. In 2012, the State Water Board adopted a general waste discharge requirement for ASR projects that inject treated drinking water into aquifers.

The primary focus of this GSP is to ensure that activities associated with implementing the GSP do not degrade current water quality conditions. GSAs are not responsible for enforcing water quality standards or for collecting data to support existing water quality programs. In addition, GSAs are not responsible for mitigating elevated background levels of chemical constituents.

As discussed in Section 4.4, there are no known conditions of degradation of groundwater related to groundwater management or use. The Basin has naturally occurring moderate to high concentrations of TDS, iron, and manganese, and in some areas arsenic. Iron and manganese are often elevated in municipal raw water and exceed the respective secondary MCLs for these constituents. The City of Fortuna, Del Oro Water Company, and Palmer Creek CSD use filtration systems to remove iron and manganese. TDS concentrations in raw municipal water are consistently below the secondary MCL for TDS. Nitrate concentrations in raw municipal water are consistently below the primary MCL for nitrate. Arsenic appears to be elevated in deeper portions of the aquifer system (greater than 200 feet below ground surface) and does not appear to be affecting municipal water supplies. Arsenic was detected in six County monitoring wells screened across the deeper portion of the aquifer system at concentrations above the MCL (SHN, 2021c). One water supplier has had one detection of arsenic in raw water above the MCL since 2002.

Modeling that evaluated potential impacts associated with increased pumping scenarios indicated that significant increases in pumping (four to five times current rates) would be required to induce changes to the regional groundwater gradients and the direction of groundwater flow.

Elevated levels of chlorides associated with seawater intrusion could affect water quality. This component of water quality is addressed separately in Section 6.8.

6.9.2 Significant and Unreasonable Conditions

Degraded water quality would be considered significant and unreasonable if direct actions by the Humboldt County GSA to implement this GSP result in adverse impacts on beneficial users or uses of groundwater.

6.9.3 Minimum Thresholds

SGMA specifies that the minimum threshold for degraded water quality shall be based on the number of supply wells, a volume of water, or a location of an isocontour that exceeds concentrations of constituents determined by the GSA to be of concern for the basin [(23 CCR 354.28(c)(4)].

For this GSP, one constituent of concern, arsenic, was selected as a precautionary measure. The level of concern is the drinking water MCL. The representative monitoring sites are the water supply wells of the municipal water suppliers located in the Basin. The minimum threshold for degraded water quality is set as follows:

- Two supply wells exceeding the arsenic MCL of 10 ug/L.

Relationship between Individual Minimum Thresholds

The minimum thresholds for degraded water quality were developed by examining historical and current data for raw municipal drinking water and selecting a network of representative monitoring sites that will allow future monitoring of water quality. The collective results from the municipal water supply testing will be used to assess whether elevated arsenic becomes a concern and the spatial extent of elevated concentrations.

Effect on Beneficial Uses and Users

The minimum thresholds for degraded water quality are generally advantageous to beneficial users and land uses. For municipal and domestic water users, the minimum thresholds protect users' ability to meet their water supply needs by maintaining arsenic concentrations below drinking water standards. For ecological land uses and users, the minimum thresholds will help avoid water quality impacts to GDEs.

Relation to Federal, State, or Local Standards

The minimum threshold incorporates the federal drinking water MCL standard for arsenic.

Method for Quantitative Measurement of Minimum Thresholds

Arsenic concentrations will be directly measured in representative monitoring sites within the monitoring network for comparison with the minimum thresholds. Water samples will be collected by water suppliers using their standard methods and submitted to a laboratory for analytical testing.

6.9.4 Measurable Objectives

The measurable objective for degraded water quality is set as follows:

- No supply wells exceeding the arsenic MCL of 10 ug/L.

This measurable objective was established to ensure that drinking water standards are being met.

6.9.5 Undesirable Result

An undesirable result would exist if two supply wells exceed the arsenic MCL of 10 ug/L as a direct result of projects or management actions taken as part of GSP implementation. Changes in groundwater quality that are independent of GSA activities would not constitute an undesirable result. If the raw water from a municipal supplier in the Basin has a detection of arsenic above the MCL, then the Humboldt County GSA would evaluate whether GSA activities were a potential factor in the exceedance of the concentration levels.

6.10 SMC #5: Subsidence

Land subsidence is a change in land surface elevation caused by natural processes or human activity. Potential causes of subsidence include seismic activity, underground mining, compaction of soil or sediment, and groundwater overdraft. Subsidence caused by groundwater conditions is a concern if reduction in groundwater levels causes irreversible compaction of clay-rich sediments. Subsidence can be elastic (recoverable) or inelastic (irreversible).

Background information on land subsidence is provided in Section 4.5. Land surface elevations measured by InSAR indicate that land surface elevations within the Basin are relatively stable with some areas demonstrating slight increasing elevations and others demonstrating slight decreasing elevations. InSAR measures total subsidence and is not able to distinguish elastic or inelastic subsidence. The inherent error in InSAR technology is approximately 0.1 feet.

The Basin is susceptible to subsidence (or uplift) caused by seismic activity associated with the Cascadia Subduction Zone, but land subsidence caused by groundwater conditions is not considered to be a concern in the Basin for the following reasons. The majority of the sediments within the zone of groundwater fluctuation consist of granular deposits. Some thick deposits of silt and clay can be found within the vicinity of Ferndale, but these areas are not generally tapped for groundwater due to their poor water-bearing characteristics. The total fluctuation of groundwater elevations within the Basin is generally less than 10 feet. Land surface movement, where it is occurring, is most likely caused by seismic activity rather than groundwater pumping.

The granular nature of the aquifer materials, the relative stability and consistency in the range of groundwater elevation fluctuations, and the narrow range of annual groundwater fluctuation support the conclusion that the conditions that could lead to land subsidence caused by groundwater pumping do not exist in the Basin. Therefore, SMCs were not developed for this sustainability indicator.

6.11 SMC #6: Depletion of Interconnected Surface Water

6.11.1 Introduction

The alluvial aquifer in the Basin is hydraulically connected to the Eel River, Van Duzen River, Yager Creek, and likely portions of the Salt River and other surface waters. Features of the interconnected surface water systems in the Basin are described in Section 4.6. Beneficial uses of interconnected surface waters are described in detail in Stillwater Sciences (September 2021) and summarized in Section 2.4.3. GHD (2022a) describes the development and application of the integrated groundwater/surface water flow model for the Basin. SHN (2022) discusses existing data regarding groundwater/surface water interactions in the Basin and provides a preliminary analysis of the observed patterns of gaining and losing reaches of the Eel River between the mouth of the Van Duzen River and the tidal reach. Potential influences on surface water flow include channel morphology and the potential for underflow; natural groundwater elevations and the dominant flow pattern from east to west; and the influence of groundwater pumping (SHN, 2022). Groundwater pumping could influence the exchange of water between the aquifer and interconnected surface waters and potentially reduce instream flows and river stage (the height of water in the channel).

6.11.2 Significant and Unreasonable Conditions

Depletion of interconnected surface water within the Basin would be considered significant and unreasonable if surface water depletion caused by groundwater extraction degrades the beneficial uses of an interconnected surface water or threatens the viability of special-status species, and reasonable reductions or limitations in groundwater pumping could avoid these effects without jeopardizing other beneficial uses of groundwater.

6.11.3 Minimum Thresholds

SGMA specifies that 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 [(23 CCR 354.28(c)(6)]. Alternatively (or in addition), SGMA allows the use of groundwater levels as a proxy if a significant correlation between groundwater levels and surface water depletions can be demonstrated.

The development of minimum thresholds for this sustainability indicator encounters a number of challenges, including the following:

- Depletion caused by groundwater use cannot be measured directly.
- Studies of minimum instream flow requirements for fisheries or other beneficial uses have not been conducted for the segments of the Eel River and Van Duzen River within the Basin.
- Beneficial uses for fisheries are partially a function of geomorphic conditions which change annually as sediment transport modifies features such as riffle crests and pool depths.
- Surface water flows within the Basin are affected by upstream withdrawals outside the Basin. Similarly, habitat conditions depend on upstream inputs (e.g., nutrient loading affects algal blooms).

For this GSP, the integrated groundwater-surface water model that was developed for the Basin (GHD, 2022a) can be used to estimate the volume of surface water depletion caused by groundwater extraction in the Basin and provide the basis for the minimum threshold. In addition, groundwater levels will be used as complementary measure, as described below.

6.11.3.1 Volume of Surface Water Depletion Caused by Groundwater Use

Information and Methodology for Establishing Minimum Thresholds
Surface water depletion caused by groundwater pumping can be estimated using the integrated groundwater-surface water model for the Basin. The model can simulate existing conditions and a range of scenarios including no-pumping and increased-pumping scenarios. Important notes about the model include the following:

- The model period is Water Year 2000 through 2020. Groundwater pumping has not changed significantly during this period (Section 2.4).
- The model estimates groundwater levels and river flows on a monthly time-scale (i.e., results are provided as monthly averages).
- The model is robust for estimating monthly average river flows and changes in flows caused by pumping. The model is not robust for predicting daily flows or storm hydrographs.
- The model is less robust for estimating river stage. The model assumes an idealized channel geometry which rarely matches actual conditions. River stage is sensitive to channel geometry. As flows change, the associated change in stage depends on channel geometry (width and depth). Thus, instream flows and stage are correlated but not directly proportional. Therefore, rating curves developed at stream monitoring locations are used to estimate changes in river stage using the modeled changes in river flows.
- The model can be used with discretion to investigate scenarios that extend beyond the range of conditions for which the model was calibrated. These scenarios can provide insights into the characteristics and dynamics of the aquifer and interconnected surface waters. However, the specific modeling results should be interpreted with caution and an understanding of the inherent uncertainty associated with applying the model for hypothetical scenarios.

The general approach focused on fish passage criteria and the minimum water depth required for passage of adult salmon (minimum fish passage depth). Fish passage can be limited by river stage at critical riffles within a reach. Adult Chinook salmon begin entering the Eel River estuary in August or early September and wait, often gathering in pools, until conditions are suitable for migrating upstream to spawning areas (Stillwater Sciences, September 2021). Steelhead begin arriving in September and coho salmon generally arrive in October. Upstream migration is typically triggered by a significant rain event and the associated increase in flows. According to Stillwater Sciences (September 2021):

> “A review of migration timing and riffle depth data collected from 2010 to 2020 showed that upstream migration by adult Chinook salmon in the Lower Eel River during the early fall is blocked by riffle depths 0.4 feet or less and inhibited by riffles that are 0.5–0.6 feet deep. Adult Chinook salmon have generally been observed in the pool at the confluence of the Eel/Van Duzen rivers when riffle depths met or exceeded 0.7 feet deep. In addition, for most years, entry by adult anadromous salmonids into the Van Duzen River is blocked by a dry reach at the mouth of the river until there is enough runoff to breach the barrier.”

California Department of Fish and Wildlife uses a standard of 0.7 feet as the minimum critical riffle depth to allow passage of adult salmonids (CDFW, 2017). Fish have been observed at the mouth of the Van Duzen River when flows were as low as 130 cfs at the Scotia gauge (Dennis Halligan, pers. comm). Because fish passage is considered one of the most sensitive indicators of surface water beneficial uses and a quantitative framework for riffle depth is available, the potential change in river stage relative to minimum fish passage depth was selected as the basis for setting minimum thresholds for surface water depletions.

The process to determine minimum thresholds for depletion of interconnected surface water included the following steps:

1. Identify locations for detailed stream depletion analysis.

Sub-regions were identified where critical riffles have been observed (ME-1 through ME-7), as shown on Figure 39. ME-1 is located near the confluence of the Eel and Van Duzen Rivers. ME-7 is located near Fernbridge.

2. Select time period of analysis.

The time period for potential fish passage is September through November. The model is calibrated for the years 2000 through 2020.

3. Establish a benchmark for potential impacts.

California Department of Fish and Wildlife uses a standard of 0.7 feet as the minimum critical riffle height to allow fish passage. For modeling purposes, the benchmark for potential impacts was defined as a lowering in stage of 0.1 feet. This height corresponds to the inherent measurement limit of measuring stage with a stadia rod in the field. This height represents a threshold of detection and not a threshold of significant and unreasonable impact.

4. Use the model to estimate the differences in river flows between existing conditions and the no-pumping scenario for each month in the study period (September through November, 2000 through 2020).

Monthly average flows under existing conditions and the no-pumping scenario were estimated in each sub-region. The difference in flows was tabulated for each of the sub-regions (Tables 8 through 14 in GHD, 2022a). The minimum change, average change, and maximum change were noted.

5. Use the stream rating curves to estimate the change in river stage corresponding to the change in river flows between existing conditions and the no-pumping scenario. As a worst-case scenario, the maximum change in river flows was utilized.

The rating curves for each sub-region were used to calculate the river stage when the minimum fish passage flow occurs (130 cfs) under existing pumping conditions. Then the rating curves were used to calculate the river stage under the no-pumping scenario. The difference in stage was tabulated (Table 16 in GHD, 2022a).

6. Determine if the changes in river stage exceed the benchmark for potential impacts.

The change in river stage caused by current pumping levels ranges from 0.02 to 0.05 feet, which does not exceed the benchmark for potential impacts.

7. Use the model to estimate differences in river flows between existing conditions and various increased-pumping scenarios.

The model was used to calculate the difference in river flows between existing conditions and a range of increased-pumping scenarios. The increased-pumping scenarios included increasing existing pumping levels by 10%, 20%, 40%, 50%, 100%, 150%, 200%, 250%, 300%, 400%, 500%, and 800%. Monthly average flows for each scenario were estimated for each model node in each sub-region. The difference in flows between the increased-pumping scenario and existing conditions was tabulated for each of the sub-regions (Tables 8 through 14 in GHD, 2022a). As a worst-case scenario, the maximum change in river flows was utilized.

8. Use the stream rating curves to estimate the change in river stage corresponding to the changes in river flows between existing conditions and the various pumping scenarios.

The rating curves for each sub-region were used to calculate the river stage when the minimum fish passage flow occurs (130 cfs) under existing pumping conditions. Then the rating curves were used to calculate the river stage under the various increased-pumping scenarios. The differences in stage were tabulated (Table 16 in GHD, 2022a).

9. Identify the lowest increased-pumping scenario that causes a decrease in river stage of 0.1 feet.

The lowest increased-pumping scenario to exceed the benchmark for potential impacts of 0.1 feet (at ME-7) is a 150% increase from existing pumping conditions. This pumping scenario corresponds to a modeled streamflow depletion ranging from 18 to 37 cfs at ME-7. These values are specific to the modeling scenario and the underlying assumptions.

10. Consider the effects of the increased-pumping scenario on other sustainability indicators.

The hydrologic model was used to estimate groundwater levels that would result from the 150% increased-pumping scenario. First, a comparison was made with the depths of the screens for the domestic wells used in the analysis for SMC #1, and it was determined that this pumping scenario would not lead to a condition where 10% or more of the wells would have less than 10 feet of water. Second, a comparison was made with the minimum thresholds established for SMC #1 at representative monitoring sites. Water levels at three representative monitoring sites were predicted to drop below their respective minimum thresholds under the 150% increased-pumping scenario. This occurrence could represent an undesirable result if the minimum thresholds were exceeded during two sequential years. Therefore, as a precautionary measure, the scenario involving a 100% increase from existing pumping conditions, rather than 150%, was selected as the minimum threshold for SMC #6.

The sustainable management criteria for seawater intrusion include chloride concentration-based and groundwater level-based approaches. The analysis evaluating groundwater levels as a proxy included an array of model run scenarios for no-pumping, current pumping, and increased pumping at various increments above current pumping rates. The results showed that a greater than 500% increase in pumping would be required to breach the established chloride concentration thresholds. Based on the findings from the modeling analysis, it can be concluded that the groundwater withdrawal corresponding to a 100% or 150% increase in use will not have an adverse effect on seawater intrusion.

There are no known conditions of degradation of groundwater related to groundwater management or use. Modeling that evaluated potential impacts associated with increased pumping scenarios indicated that increases in pumping four to five times current rates would be required to induce significant changes to the regional groundwater gradients and the direction of groundwater flow (Section 6.9). A groundwater withdrawal corresponding to a 100% or 150% increase in use is not anticipated to have an adverse effect on water quality.

Summary
A reduction in stage of 0.1 feet was set as a conservative benchmark for potential impact on riffle depth and fish passage. Exceedance of this benchmark does not mean that beneficial uses of the interconnected surface water are degraded or the viability of special-status species are threatened but provides a starting point for analysis. Simulation modeling using a number of conservative assumptions indicated that groundwater pumping could increase by 150% above current conditions before the stage of the Eel River would be reduced by 0.1 feet at the downstream end of the study reach (sub-region ME-7) when fish passage conditions exist. After comparing the modeled groundwater levels under the 150% increased pumping scenario with the minimum thresholds for SMC #1, a decision was made to set the minimum threshold for SMC #6 at the 100%-increase scenario as a precautionary measure.

6.11.3.2 Groundwater Levels as a Proxy for Surface Water Depletion

Information and Methodology for Establishing Minimum Thresholds
The Eel River is hydraulically connected with the alluvial aquifer, and river flows are generally correlated with groundwater levels, although the patterns are complex and difficult to predict. It follows that surface water depletion caused by groundwater pumping would generally be correlated with changes in groundwater levels. The hydrologic model that was used in Section 6.11.3.1 to explore rates of streamflow depletion associated with various pumping scenarios was also used to explore changes in groundwater levels at representative monitoring sites and support the development of groundwater level minimum thresholds for surface water depletion.

Challenges in defining groundwater levels as a proxy for surface water depletion include:

- Many of the candidate wells in the vicinity of the subject reach of the Eel River are newly constructed (installed in 2021) and don't yet have a sufficient period of record to develop a statistically significant average fall groundwater level or understand the natural range of fluctuation.
- Groundwater levels are affected by a number of factors and it is difficult to determine the relative contribution of the multiple factors.

The process to determine minimum thresholds using groundwater levels as a proxy for depletion of interconnected surface water included the following steps:

1. Identify potential monitoring wells for use as representative monitoring sites.

An array of 13 monitoring wells within the vicinity of the Eel River was initially chosen as candidates for use as an RMS for SMC#6. These candidate sites included one CASGEM well, three 2016 County monitoring wells, and nine 2021 County monitoring wells.

2. Assign each candidate well to a sub-region.

Each candidate well was assigned to a sub-region (ME) based on its proximity and the groundwater gradient in the area. Where a well is located between sub-regions or is a significant distance from the river, then the sub-region that is impacted by the smaller increased-pumping scenario was chosen.

3. Use the model to estimate the differences in groundwater elevations between existing conditions and the increased-pumping scenario at each candidate well.

Modeled results for various increased-pumping scenarios provide water level lowering at specific well sites. Graphs of modeled head change were reviewed and the identified increased-pumping scenario for each sub-region was used to determine the associated water level lowering. The predicted water level lowering varies based on the water year type and other components of the water balance. To be consistent, the model results from 2003 were used as this has been identified as a best-fit model for average observed water levels.

Modeled groundwater lowering at some locations were very small (less than one foot) or there was no change at all. This typically occurred where the well was not in the zone of influence from pumping or was too close to the river, where fluctuations in groundwater can get small. Six wells were taken off the candidate list for this reason. The remaining seven wells had modeled groundwater lowering values ranging from 1.6 feet to 7.2 feet.

4. Develop average fall groundwater levels for each representative monitoring site.

Historical groundwater data and more recent groundwater data collected in County monitoring wells has been done biannually with one measurement made in spring and one measurement in fall. To maintain consistency, the baseline groundwater levels established for the representative monitoring site wells is meant to represent the average fall groundwater elevations that would be observed at the end of October. An average fall groundwater level was developed for each candidate well location based on the best available information. Most of the wells have limited to no history of groundwater level measurements, so an estimation of what would be a fall groundwater elevation had to be made based on the results of groundwater contour mapping.

5. Define the minimum threshold for each representative monitoring site.

Minimum threshold values for each representative monitoring site were defined by subtracting the modeled water level lowering (from Step 3) from the average fall water level (from Step 4) to develop the minimum threshold for the representative monitoring site. The final list of representative monitoring sites is provided as Table 25.

<u>Summary</u>

Seven wells were selected as representative monitoring sites for monitoring water levels associated with potential impacts to interconnected surface waters. The limited period of record for the County monitoring wells adds uncertainty to the assigned average fall groundwater levels and the minimum thresholds. All County monitoring wells are currently outfitted with pressure transducers that record groundwater levels at 30-minute intervals. As additional data is collected and analyzed, the defined average fall levels may change and the minimum thresholds may be adjusted.

Table 25: Groundwater Level Minimum Thresholds and Measurable Objectives for Surface Water Depletion

Representative Monitoring Site	Average Fall Groundwater Level (ft NAVD88)	Threshold Pumping Scenario (% Increase)	Modeled Drawdown (ft)	Minimum Threshold for Surface Water Depletion (ft NAVD88)	Note	Measurable Objective (ft NAVD88)
Active CASGEM Wells						
36942	16.7	200%	-5.7	11.0	(2)	14.2
2016 County Monitoring Wells						
MW-2s	19.7	400%	-1.6	18.2	(1)	19.2
2021 County Monitoring Wells						
MW-13s	25.4	800%	-3.2	22.2	(1)	23.2
MW-15s	9.0	150%	-2.9	6.1	(1)	7.5
MW-20	18.0	300%	-7.2	10.8	(2)	15.5
MW-22	19.7	300%	-3.8	15.9	(1)	18.2
MW-25	12.0	150%	-2.1	9.9	(1)	11.0

Notes:

(1) This value is the highest minimum threshold for this representative monitoring site.
(2) This value is superseded by the minimum threshold established for other sustainability indicators.

Relationship between Individual Minimum Thresholds

The minimum thresholds for surface water depletion were developed by model simulation for various increased-pumping scenarios. The collective results from ongoing monitoring and recordkeeping of groundwater pumping and groundwater levels will be used to assess whether groundwater pumping is having a potential effect on beneficial uses of interconnected surface waters and the spatial extent of these effects.

Effect on Beneficial Uses and Users

The minimum thresholds for surface water depletion could affect agricultural, municipal, and domestic land uses and users if undesirable results occur in the future and limitations on groundwater pumping are considered. The minimum thresholds will help maintain beneficial uses of interconnected surface waters and the associated users.

Relation to Federal, State, or Local Standards

No federal, state, or local standards exist that are specific to depletion of interconnected surface water. Studies to determine minimum in-stream flows in the Eel River are a recommendation of the Eel River Action Plan but have not been completed.

Method for Quantitative Measurement of Minimum Thresholds

The minimum threshold for volume of stream flow depletion will be measured through monitoring and recordkeeping of groundwater pumping in the Basin. The groundwater level minimum thresholds for surface water depletion will be measured by annual depth-to-water measurements in the representative monitoring site wells.

6.11.4 Measurable Objectives

6.11.4.1 Volume of Surface Water Depletion Caused by Groundwater Use

The measurable objective for depletion of interconnected surface water represents a target volume of annual groundwater use that provides a protective buffer above the minimum threshold. The measurable objective provides a metric to detect potential trends in advance before the minimum threshold is reached.

Methodology for Establishing Measurable Objectives
The measurable objective for depletion of interconnected surface water was established as 75% of the sustainable yield (30,000 acre-feet), resulting in 22,500 acre-feet of annual groundwater use. This percentage was determined to provide a conservative buffer above the minimum threshold while still providing reasonable capacity for increases in groundwater use.

Interim Milestones
Interim milestones were not established because the Basin is being managed within its sustainability goal.

6.11.4.2 Groundwater Levels as a Proxy for Surface Water Depletion

Measurable objectives for depletion of interconnected surface water were developed for groundwater levels in addition to the volume of surface water depletion. These objectives provide a metric to detect potential trends in advance before the minimum threshold is reached.

Methodology for Establishing Measurable Objectives
Measurable objectives for groundwater levels associated with depletion of interconnected surface water are shown in Table 25. These measurable objectives were developed using the methodology described in Section 6.6.4.

Interim Milestones
Interim milestones were not established because the Basin is being managed within its sustainability goal.

6.11.5 Undesirable Result

An undesirable result would exist if one of the following scenarios occurs:

1. Groundwater pumping within the Basin increases by 100% above current levels.
2. Groundwater levels in two or more wells within the network of representative monitoring sites for SMC #6 fall below their minimum thresholds for two sequential years.

If one of these two scenarios occurs, then further analysis would be needed to determine if beneficial uses of the interconnected surface water are degraded or the viability of special-status species are threatened, and whether reasonable reductions or limitations in groundwater pumping could avoid these effects without jeopardizing other beneficial uses of groundwater.

6.12 Relationship between Minimum Thresholds for All Applicable Sustainability Indicators

A summary of the groundwater level minimum thresholds and measurable objectives is provided in Table 26.

Table 26: Summary of Water Level Minimum Thresholds and Measurable Objectives (Elevations in ft NAVD88)

Representative Monitoring Site	Average Fall Groundwater Level	MT for Well Impact	MT for Seawater Intrusion	MT for Surface Water Depletion	Final MT	Measurable Objective
Active CASGEM Wells						
36942	16.7	12.7	n/a	11.0	12.7	14.2
36943	8.2	-4.8	4.8	n/a	4.8	7.2
23183	6.5	-6.5	3.8	n/a	3.8	5.5
23181	6.9	-6.1	3.8	n/a	3.8	5.4
2016 County Monitoring Wells						
MW-1s	8.7	4.7	n/a	n/a	4.7	5.7
MW-2s	19.7	15.7	n/a	18.2	18.2	19.2
MW-3d	25.6	21.6	n/a	n/a	21.6	22.6
MW-5s	6.2	-6.8	3.8	n/a	3.8	5.2
MW-7s	14.5	1.5	5.8	n/a	5.8	6.8
MW-8	12.5	8.5	n/a	n/a	8.5	9.5
2021 County Monitoring Wells						
MW-13s	25.4	21.4	n/a	22.2	22.2	23.2
MW-14s	7.0	-6.0	3.8	n/a	3.8	5.5
MW-15s	9.0	5.0	4.8	6.1	6.1	7.5
MW-19	22.0	18.0	n/a	n/a	18.0	19.0
MW-20	18.0	14.0	n/a	10.8	14.0	15.5
MW-21	20.7	16.0	n/a	n/a	16.0	17.7
MW-22	19.7	15.7	n/a	15.9	15.9	18.2
MW-23	13.0	9.0	n/a	n/a	9.0	10.0
MW-24	17.0	13.0	n/a	n/a	13.0	14.0
MW-25	12.0	8.0	n/a	9.9	9.9	11.0
MW-26	3.0	-10.0	0.8	n/a	0.8	1.5
MW-27	3.0	-10.0	0.8	n/a	0.8	2.0
MW-28	6.5	-6.5	3.8	n/a	3.8	4.8
MW-30	15.0	11.0	n/a	n/a	11.0	12.0

Notes: MT = Minimum threshold
n/a = not applicable

6.13 Sustainable Yield

SGMA requires that GSPs include an estimate of the basin's sustainable yield, which is the amount of groundwater that can be withdrawn annually without causing undesirable results [(23 CCR 354.18(b)(7)]. The sustainable yield is calculated as a single value for the entire basin. The sustainable yield is a theoretical value and not a target level for increasing pumping. According to DWR (2017), the sustainable yield estimate can be helpful for estimating the projects and programs needed to achieve sustainability, but sustainability is only demonstrated by avoiding undesirable results for the six sustainability indicators.

The analysis of each sustainability indicator (Section 6.6 through 6.11) determined that undesirable results as defined by SGMA do not currently exist within the Basin. Therefore, the estimate of sustainable yield is not needed for working to achieve sustainable conditions but may be helpful to characterize the Basin and ensure that sustainable conditions are maintained.

The estimated annual groundwater withdrawal under current conditions varies based on water year type, ranging from 12,963 acre-feet during a wet year to 17,209 acre-feet during a critical year. For the purposes of developing the sustainable yield for the Basin, the average of the five different water year types (14,888 acre-feet) is used as the baseline volume. The integrated hydrologic model for the Basin was used to simulate increases in groundwater withdrawals above this baseline volume to identify the point at which undesirable results have the potential to occur.

As described in Section 6.11 for SMC #6, the first increased-pumping scenario to exceed the benchmark of reducing the water depth in the Eel River by 0.1 feet (at ME-7) is a 150% increase from existing pumping conditions. To ensure that minimum thresholds for chronic lowering of groundwater levels (SMC #1) are not exceeded, the minimum threshold for SMC #6 was set at a level of 100% increase from existing pumping conditions. The volume of annual groundwater withdrawal that corresponds to a 100% increase above the baseline is 14,888 x 2 = 29,776 acre-feet/year, rounded up to 30,000 acre-feet.

The sustainable yield for the Basin is estimated to be at least 30,000 acre-feet per year. It's important to recognize that this value is based on numerically modeled outputs and thus has inherent uncertainty. In addition, the development of SMC #6 used conservative assumptions for the purpose of developing minimum thresholds. Therefore, the value of 30,000 acre-feet/year should be considered a minimum estimate of the Basin's sustainable yield.

Chart 15 depicts the modeled cumulative change in storage over the period from 2000 to 2020 for current pumping conditions (orange line) and the 100% increased pumping scenario (blue line). The 20-year historical trends and comparative cumulative groundwater storage volumes are not significantly different. Therefore, the 100% increased-pumping scenario does not indicate a significant impact on the changes to storage within the Basin.

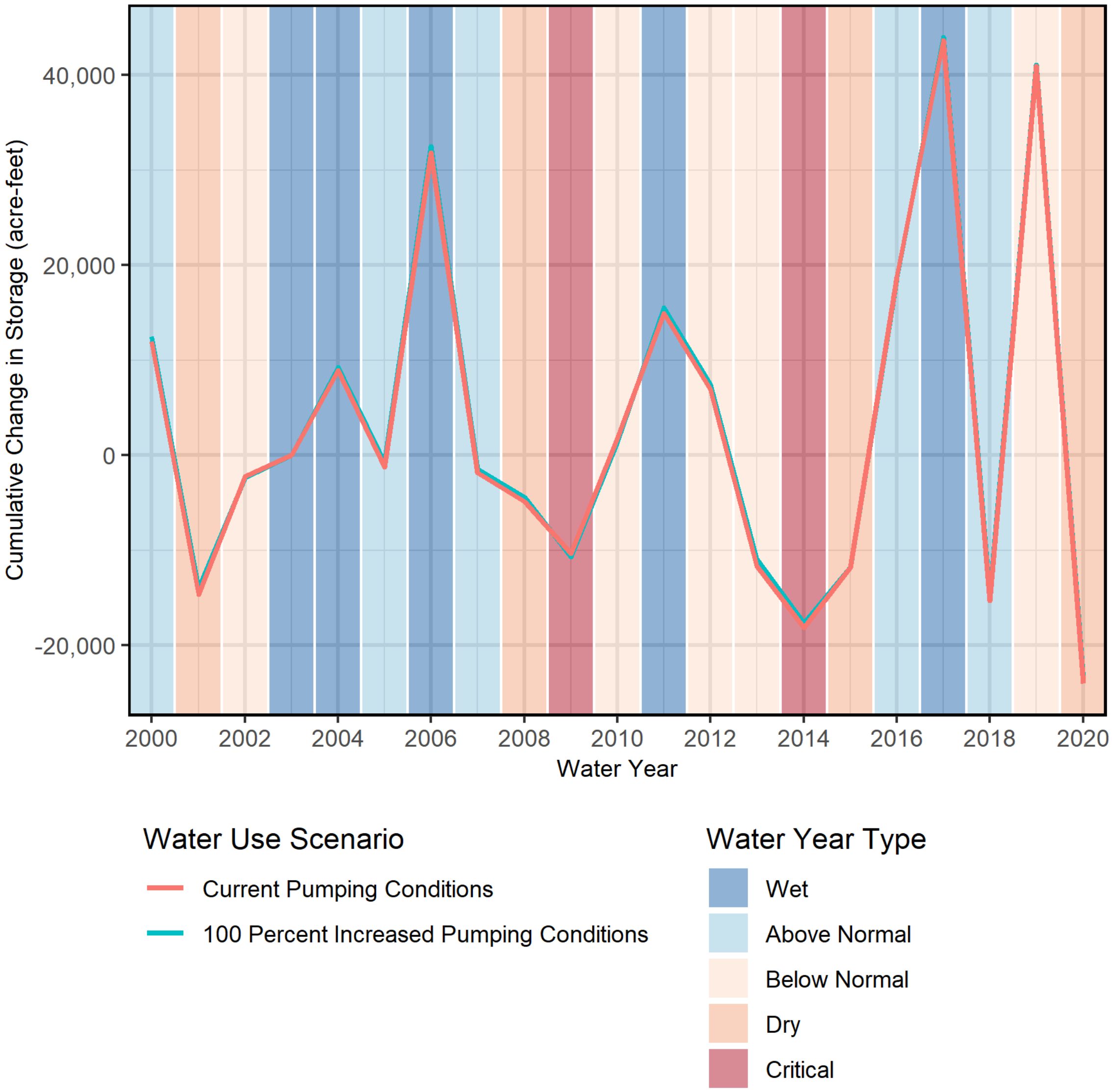


Chart 15: Cumulative Change in Storage under Current Pumping Conditions and 100% Increased Pumping Conditions

7 MONITORING NETWORK

The GSP proposes a monitoring network that will provide representative data and information regarding conditions within the Basin. The monitoring network is intended to promote the collection of data of sufficient quality, frequency, and distribution to characterize groundwater and related surface water conditions and evaluate changing conditions that occur through implementation of the GSP in accordance with 23 CCR 354.32. The monitoring network described below is inclusive of all types of data and information related to characterizing groundwater and surface water conditions. A subset of monitoring sites is designated as "representative monitoring sites" in accordance with 23 CCR 354.36. These representative monitoring sites are designated as points at which sustainability indicators are monitored and for which quantitative values for minimum thresholds and measurable objectives are defined.

7.1 Monitoring Objectives

The monitoring network is intended to accomplish the following objectives [23 CCR 354.34(b)]:

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

The network of monitoring wells was developed to provide a sufficient number of wells with adequate spatial distribution to characterize groundwater levels in the Basin. The network includes wells within the primary areas of current and projected groundwater use and includes a series of nested wells that provide information on confined conditions within the Carlotta formation (Section 4.1.5). The network includes a concentration of wells on the seaward and landward sides of the 100 mg/L chloride isocontour and a series of wells in close proximity to the Eel River and Van Duzen River. The locations of the County wells were selected with consideration for the existing CASGEM wells that have historic data (Section 4.1.1) and to address previously identified data gaps and limitations in the hydrogeologic conceptual model.

The elements of the monitoring network are shown on Figures 40 and 41. Specific monitoring objectives for each of the monitoring network elements are described below.

7.2 Elements

7.2.1 Groundwater Pumping

Data and information will be collected for the two types of groundwater users (agricultural irrigation and municipal) that comprise approximately 95% of the groundwater use within the Basin. Data from flow meters on six agricultural irrigation systems (Sites 1 through 6) where Humboldt County has cooperative agreements with the landowners will be collected on an annual basis. Flow meter operation and data collection methods are described in Humboldt County (2021). A map of the flow meter locations is provided in Figure 3 of Humboldt County (2021). Flow meter data from landowners who provide it on a voluntary basis will also be incorporated. The Humboldt County GSA will consult with the Humboldt County Building and Planning Department, USDA-NRCS, and Humboldt County RCD on an annual basis to determine if there have been changes in the amount of irrigated land. The flow meter data and information regarding irrigated land will be used to update the estimate of groundwater use for agricultural irrigation.

Data and information related to municipal water use will be collected from the municipal water suppliers in the Basin. The water suppliers collect water use data for their own purposes and share it with the Humboldt County GSA.

Specific objectives for monitoring groundwater pumping include the following:

- Develop an accurate estimate of total annual groundwater use for comparison with the sustainable yield and for evaluation of SMC #2 and SMC #6. Confirm that the annual groundwater use is below the minimum threshold of 30,000 acre-feet and below the measurable objective of 22,500 acre-feet.
- Identify short-term and long-term trends in the context of historical data.

7.2.2 Groundwater Levels

The monitoring network includes 37 County wells and four CASGEM wells for measuring groundwater levels. The Humboldt County GSA maintains an Excel spreadsheet with information on the attributes of the wells in accordance with DWR's Monitoring Network Module specifications. Groundwater levels will be monitored with manual depth-to-water measurements during semiannual monitoring campaigns in the network of County monitoring wells listed on Table 27 and shown on Figures 40 and 41. In addition, a subset of the monitoring wells will be equipped with pressure transducers to collect continuous data.

Specific objectives for monitoring groundwater levels include the following:

- Produce seasonal groundwater contour maps depicting groundwater-flow direction and horizontal hydraulic gradient (slope of the water table) for the alluvial aquifer.
- Collect data from paired shallow and deep wells to characterize the vertical hydraulic gradient where paired wells are located.
- Collect data that allows a comparison between groundwater levels and surface water levels to assess flow direction and hydraulic gradient between the alluvial aquifer and monitored reaches of the Eel River.
- Identify short-term and long-term trends and seasonal fluctuations in the context of historical data.
- Track water levels relative to minimum thresholds and measurable objectives (Table 26).

Monitoring Protocol: Depth-to-water Measurements
Practices and procedures to ensure quality and consistency of groundwater level data collected with depth-to-water measurements include the following:

- Depth-to-groundwater will be measured relative to an established reference point (normally the top of the well casing).
- The elevation of the reference point will be surveyed to the NAVD88 datum with a minimum accuracy of 0.5 feet and a target accuracy of 0.1 feet or less.
- Depth-to-groundwater below the reference point will be measured to a minimum accuracy of 0.1 feet and target accuracy of 0.01 feet or less.
- Depth-to-groundwater will be measured using an electronic water level meter in accordance with the manufacturer's instructions.
- All measurements will be made in consistent units of feet, tenths of feet, and hundredths of feet (not feet and inches).

- The field technician will record data and information using standardized field forms. Information to record includes well number, date, time, depth-to-water, and comments regarding any factors that may influence the readings. In the event there is a questionable measurement or the measurement cannot be maintained, proper notations will be made.
- The field technician will remove the well cap and listen for pressure release. If a release is observed, a period of time will be provided to allow the water level to equilibrate, and multiple measurements will be collected to ensure the well has reached equilibrium such that no significant changes in water level are observed. If a well does not stabilize, the measurement will be qualified as questionable.
- Well caps will be closed and locked upon completion of the measurements.
- The water level meter will be cleaned after measuring each well.
- All data will be entered into the data management system as soon as possible. Care will be taken to avoid data entry mistakes and quality-assurance checks will be performed.
- Groundwater elevations will be calculated as:

  Groundwater elevation = reference point elevation – depth-to-water measurement

Monitoring Protocol: Pressure Transducers

Practices and procedures to ensure quality and consistency of groundwater level data collected with pressure transducers include the following:

- The field technician will follow the manufacturer's specifications for installation, calibration, programming, data acquisition, battery management, and maintenance.
- The transducer cable will be secured to the well and the cable position will be marked to allow for estimates of potential cable movement.
- The field technician will perform manual depth-to-water measurements using the protocol described above during initial installation and data download events to support programming and quality-control.
- Transducers will be able to record groundwater levels to a minimum accuracy of 0.1 feet.
- The field technician will be trained to check battery life and data storage capacity and to use professional judgment when setting the transducer to account for the range of groundwater level fluctuations and barometric pressure changes.
- A dedicated transducer will be used to record barometric pressure within the Basin. Data collected from the down-well transducers will be corrected for natural barometric pressure changes.
- Transducer data will be reviewed to check for any indications of drift or disturbance.
- Data will be downloaded at an appropriate frequency to avoid or minimize data loss due to issues with data logger memory or battery life.

7.2.3 Seawater Intrusion

Chloride concentrations will be collected at least annually in the 20 wells listed on Table 23. Specific objectives for monitoring chloride concentrations include the following:

- Produce maps depicting the 100 mg/L chloride isocontour within the alluvial aquifer to allow evaluation of SMC #3.
- Collect data from paired shallow and deep wells to characterize the vertical concentration gradient where paired wells are located.

- Track chloride concentrations relative to minimum thresholds and measurable objectives (Table 23).

The wells listed on Table 23 were selected to obtain data on both the seaward and landward side of the historical location of the chloride isocontour and to obtain data to better characterize the variation of seawater intrusion with depth. The location of the 100 mg/L chloride isocontour did not change substantially between spring and fall during measurements collected in water year 2017 and water year 2021 (Figures 23-26); therefore, the minimum frequency of chloride sampling will be annual.

Monitoring Protocol

Practices and procedures to ensure quality and consistency of chloride concentration data include the following:

- Groundwater samples will be collected using low-flow sampling methods in accordance with the U.S. Environmental Protection Agency's Low Stress (Low Flow) Purging and Sampling Procedure for the Collection of Groundwater Samples from Monitoring Wells. Low-flow sampling will be performed using either a peristaltic pump or a downhole bladder pump.
- Depth-to-water measurements will be made prior to water sampling.
- Water will be pulled directly from the screened interval to ensure that the groundwater collected is fresh from the aquifer formation.
- Field measurements of temperature, pH, and electrical conductance will be collected every five minutes until stabilization is achieved. Field meters will be calibrated in accordance with manufacturer's recommendations and evaluated for drift throughout the day.
- Equipment will be cleaned and rinsed in between monitoring wells.
- Samples will be collected by decanting water directly into laboratory-supplied bottles. Sample containers will be labeled prior to sample collection.
- Samples will be transported promptly to the analytical laboratory using standard chain-of-custody documentation.

7.2.4 Groundwater Quality

Municipal water suppliers will conduct sampling and testing of their raw water in accordance with their own management programs and regulatory requirements applicable to public water systems. New water quality data from sampling and testing of the raw water of municipal water suppliers within the Basin will be reviewed annually to track the status of SMC #4.

7.2.5 Surface Water Levels

Surface water levels will be measured with transducers at three monitoring stations (R-2, R-3, R-5). The protocol for operating the transducers will follow the protocol described in Section 7.2.2.

Specific objectives for monitoring surface water levels include the following:

- Collect data that allows a comparison between groundwater levels and surface water levels to assess flow direction and hydraulic gradient between the alluvial aquifer and monitored reaches of the Eel River.

This data is not used to monitor sustainability indicators directly, but rather to improve understanding about the spatial and temporal variability of groundwater-surface water interactions.

7.2.6 Streamflow

The USGS will continue to operate its stream gages at Scotia, Fernbridge, and Bridgeville. This data is not used to monitor sustainability indicators directly, but rather to characterize general conditions within the Eel River and Van Duzen River and to support updates of the water budget.

7.2.7 Land Elevation

USGS and DWR are expected to continue to collect and process satellite InSAR data to monitor land subsidence. As discussed in Section 6.10, subsidence caused by groundwater conditions is not a concern for the Basin but the InSAR data would be available to confirm the absence of concern.

7.2.8 Rainfall and Evapotranspiration

The Ferndale Museum will operate their rain gage and provide monthly totals. This data is not used to monitor sustainability indicators directly, but rather to characterize the water year type within the context of the water year classifications developed for the 30-year period from 1992 through 2021 (Section 5.2).

Humboldt County and DWR will coordinate on operating the CIMIS station located in Ferndale. Data from the CIMIS station will not be used for monitoring sustainability indicators directly, but rather to improve understanding about local weather conditions and rates of evapotranspiration. This data may be used in conjunction with efforts by DWR to refine the Cal-SIMETAW model.

7.3 Data Management System

Data management will follow the standards and protocols of DWR's monitoring network module for the SGMA portal in accordance with 23 CCR Section 352.6.

7.4 Assessment and Improvement of Monitoring Networks

Assessment of needs and opportunities to improve the monitoring network will be ongoing during implementation of the GSP (Section 8.2). The work that was performed under the Sustainable Groundwater Management Planning Grant (Section 1.7) to support the development of this GSP was intended to create a monitoring network that is appropriate for monitoring changing conditions. Needs for specific improvements have not been identified. Opportunities for improvements will be considered as described in Section 9.2.4.

7.5 Reporting

Annual reporting is described in Section 8.3.

Table 27: Monitoring Network Summary

Well/Station	Type	State Well Number	Latitude	Longitude	Location	Representative Monitoring Site (Y/N)	Sustainability Indicator					
							SMC #1	SMC #2	SMC #3	SMC #4	SMC #5	SMC #6
CASGEM 36942	Domestic well	02N02W02G001H	40.5702	-124.1874	Pleasant Point Rd., Ferndale	Y	X					X
CASGEM 36943	Irrigation well	02N02W02G001H	40.5859	-124.2638	Humboldt County Fair Grounds, Ferndale	Y	X		X			
CASGEM 23183	Irrigation well	03N02W35M002H	40.5974	-124.2696	Dillon Rd., Ferndale	Y	X		X			
CASGEM 23181	Irrigation well	03N01W30N001H	40.6087	-124.2334	Goble Ln., Ferndale	Y	X		X			
MW-1s	Monitoring well	03N01W29Q002H	40.60970	-124.20512	Sub Station Rd, Fernbridge	Y	X					
MW-1d	Monitoring well	03N01W29Q001H	40.60970	-124.20512	Sub Station Rd, Fernbridge	N						
MW-2s	Monitoring well	02N01W10R002H	40.56403	-124.15996	East Ferry Road, Ferndale	Y	X					X
MW-2d	Monitoring well	02N01W10R001H	40.56403	-124.15996	East Ferry Road, Ferndale	N						
MW-3d	Monitoring well	02N01W22H002H	40.54460	-124.16337	Grizzly Bluff Road near Weymuth Bluff, Ferndale	Y	X					
MW-5s	Monitoring well	03N02W34A001H	40.60535	-124.27432	Dillon Rd near Goble Ln, Ferndale	Y	X		X			
MW-5d	Monitoring well	03N02W34A001H	40.60535	-124.27432	Dillon Rd near Goble Ln, Ferndale	Y			X			
MW-7s	Monitoring well	02N02W03C002H	40.58859	-124.28398	Meridian Rd, Ferndale	Y	X		X			
MW-7d	Monitoring well	02N02W03C001H	40.58859	-124.28398	Meridian Rd, Ferndale	Y			X			

MW-8	Monitoring well	02N01W07J001H	40.56940	-124.21857	Grizzly Bluff Road near Coffee Ck Rd, Ferndale	Y	X					
MW-9s	Monitoring well	02N01E19Q002H	40.53420	-124.10680	River Bar Road, Alton	N						
MW-9d	Monitoring well	02N01E19Q001H	40.53420	-124.10680	River Bar Road, Alton	N						
MW-10	Monitoring well	02N01E16R001H	40.55221	-124.06362	Fischer Rd east, Carlota	N						
MW-11	Monitoring well	02N01E23N002H	40.53484	-124.04151	Wilder Rd, Cuddeback Elem School road, Carlotta	N						
MW-12s	Monitoring well	02N01E19L002H	40.53991	-124.11172	River Bar Road, Van Duzen	N						
MW-12d	Monitoring well	02N01E19L001H	40.53991	-124.11172	River Bar Road, Van Duzen	N						
MW-13s	Monitoring well	02N01W14Q002H	40.54961	-124.14797	Sandy Prairie Road, Fortuna	Y	X					X
MW-13d	Monitoring well	02N01W14Q001H	40.54961	-124.14797	Sandy Prairie Road, Fortuna	N						
MW-14s	Monitoring well	03N01W36B002H	40.60636	-124.24261	Goble Ln, Ferndale	Y	X		X			
MW-14d	Monitoring well	03N01W36B001H	40.60636	-124.24261	Goble Ln, Ferndale	Y			X			
MW-15s	Monitoring well	03N01W32E003H	40.59916	-124.21217	Waddington Rd, Ferndale	Y	X		X			X
MW-15d	Monitoring well	03N01W32E002H	40.59916	-124.21217	Waddington Rd, Ferndale	N						
MW-16	Monitoring well	02N01E22P002H	40.53410	-124.05830	Memory Ln, Carlotta	N						
MW-17	Monitoring well	02N01E29C001H	40.53247	-124.09514	River Bar Road, Van Duzen	N						
MW-18	Monitoring well	02N01W35B001H	40.51781	-124.14508	Metropolitan Road	N						
MW-19	Monitoring well	02N01W15Q001H	40.54980	-124.16389	Grizzly Bluff Rd, Ferndale	Y	X					

MW-20	Monitoring well	02N01W15D002H	40.56300	-124.17729	Grizzly Bluff Rd, Ferndale	Y	X					X
MW-21	Monitoring well	02N01W14C001H	40.56077	-124.15398	Sandy Prairie Road, Fortuna	Y	X					
MW-22	Monitoring well	02N01W11K003H	40.56847	-124.14736	Eel River Drive Fortuna	Y	X					X
MW-23	Monitoring well	03N01W34K001H	40.59863	-124.16642	S 3rd St, Fortuna	Y	X					
MW-24	Monitoring well	02N01W11C001H	40.57722	-124.15250	Kenmar Rd, Fortuna	Y	X					
MW-25	Monitoring well	02N01W04C001H	40.59078	-124.18901	Pleasant Point Rd, Fernadale	Y	X					X
MW-26	Monitoring well	03N01W18E001H	40.64302	-124.23487	Cannibal Island Road, Loleta	Y	X		X			
MW-27	Monitoring well	03N02W14H001H	40.64300	-124.25937	Cannibal Island Road, Loleta	Y	X		X			
MW-28	Monitoring well	03N02W35P001H	40.59441	-124.26703	Port Kenyon Rd, Ferndale	Y	X		X			
MW-29	Monitoring well	02N02W12F002H	40.57166	-124.24559	Grizzly Bluff Rd, Ferndale	N						
MW-30	Monitoring well	02N01W09N001H	40.56654	-124.19431	Grizzly Bluff Rd, Ferndale	Y	X					
Private Well 3	Domestic well	not applicable	40.5984	-124.2798	Riverside Rd., Ferndale	N						
Private Well 4	Irrigation well	not applicable	40.5992	-124.2744	Dillon Rd., Ferndale	N						
Private Well 6	Irrigation well	not applicable	40.6046	-124.2626	Bertelsen Ln., Ferndale	N						
Private Well 7	Irrigation well	not applicable	40.6082	-124.2644	Nissan Ln., Ferndale	N						
Private Well 24	Irrigation well	not applicable	40.6338	-124.2323	Hawks Hill Rd., Loleta	N						
Private Well 51	Irrigation well	not applicable	40.6100	-124.2841	Camp Weott Rd., Ferndale	N						
Private Well G	Domestic well	not applicable	40.5847	-124.2843	Meridian Rd., Ferndale	N						
Private Well H	Domestic well	not applicable	40.5961	-124.2902	Pot Kenyon Rd., Ferndale	N						

Private Well L	Domestic well	not applicable	40.6123	-124.2694	Goble Ln., Ferndale	N						
Private Well Q	Irrigation well	not applicable	40.6136	-124.2813	Camp Weott Rod., Ferndale	N						
Private Well R Shop	Domestic well	not applicable	40.6390	-124.2494	Cannibal Island Rd., Loleta	N						
Del Oro Water Co. – Van Ness Well	Municipal well	02N02W01E01H	40.5877	-124.2519	Ambrosini Ln., Ferndale	Y				X		
Riverside CSD – Well 6	Municipal well	not determined	40.5809	-124.2813	Centerville Rd., Ferndale	Y				X		
Loleta CSD – Well 4	Municipal well	not determined	40.6470	-124.2203	Eel River Dr., Loleta	Y				X		
Palmer Creek CSD - Well 1	Municipal well	03N01W33H	40.6041	-124.1786	Palmer Blvd., Fortuna	Y				X		
Palmer Creek CSD - Well 2	Municipal well	03N01W33H	40.6041	-124.1785	Palmer Blvd., Fortuna	Y				X		
Hydesville WSD - Well 1	Municipal well	02N01E-21H	40.5428	-124.0697	Ward Creek Rd., Hydesville	Y				X		
Hydesville WSD - Well 2	Municipal well	not determined	40.5428	-124.0689	Ward Creek Rd., Hydesville	Y				X		
Bear River Rancheria - Well 1	Municipal well	not determined	40.6275	-124.2081	Singley Hill Rd., Loleta	Y				X		
Bear River Rancheria - Well 2	Municipal well	not determined	40.6294	-124.2075	Singley Hill Rd., Loleta	Y				X		
Rio Dell - Well 1	Municipal well	02N01W36	40.5134	-124.1237	Northwestern Ave., Rio Dell	Y				X		
Rio Dell – Well 3	Municipal well	02N01W36	40.5131	-124.1236	Northwestern Ave., Rio Dell	Y				X		
Fortuna – Well 1	Municipal well	02N01W11H	40.5711	-124.1471	Eel River Dr., Fortuna	Y				X		

Fortuna – Well 2	Municipal well	02N01W11H	40.5708	-124.1467	Eel River Dr., Fortuna	Y				X		
Fortuna – Well 4	Municipal well	not determined	40.5707	-124.1473	Eel River Dr., Fortuna	Y				X		
Fortuna - Well 5	Municipal well	not determined	40.5705	-124.1469	Eel River Dr., Fortuna	Y				X		
Site 1	Irrigation water meter	not applicable	40.6118	-124.2522	Fulmor Rd., Ferndlae	N						
Site 2	Irrigation water meter	not applicable	40.5992	-124.2744	Dillon Rd., Ferndale	N						
Site 3	Irrigation water meter	not applicable	40.6045	-124.2535	Fulmor Rd., Ferndale	N						
Site 4	Irrigation water meter	not applicable	40.5987	-1242245	Hwy 211 and Sage Rd., Ferndale	N						
Site 5	Irrigation water meter	not applicable	40.5717	-124.1962	Grizzley Bluff Rd., Ferndale	N						
Site 6	Irrigation water meter	not applicable	40.5436	-124.0935	Walker Ln., Hydesville	N						
R-2	Surface water station	not applicable	40.5828	-124.1577	Eel River, Riverwalk Dr., Fortuna	N						
R-3	Surface water station	not applicable	40.5539	-124.1557	Eel River, Sandy Prairie Rd., Fortuna	N						
R-5	Surface water station	not applicable	40.6028	-124.1789	Eel River, Palmer Blvd., Fortuna	N						

Notes: bgs = below ground surface

8 PROJECTS AND MANAGEMENT ACTIONS

8.1 Achieving the Sustainability Goal

The sustainability goal of maintaining high-quality and abundant groundwater resources in the Basin to support existing and long-term community needs for drinking water and personal use, agricultural irrigation, industrial process water, and ecosystem services without causing undesirable results, as defined under SGMA, is currently being met within the Basin. Therefore, projects and management actions are not needed to achieve sustainability. The Humboldt County GSA may choose to pursue projects and management actions to help maintain or improve groundwater conditions, enhance beneficial uses of groundwater and interconnected surface waters, improve the resilience of water resources, or prepare for future climate conditions to ensure that the Basin continues to be managed sustainably (Section 8.2). The Humboldt County GSA will perform annual monitoring and reporting as required by SGMA and will continue to engage with stakeholders (Section 8.3).

8.2 Maintaining the Sustainability Goal and Improving Groundwater Conditions

Undesirable results caused by groundwater conditions in the Basin have not occurred and are not imminent. Because current groundwater use is well below the Basin's sustainable yield, undesirable results are not expected to occur under foreseeable future conditions. Therefore, the projects and management actions listed below focus on continued monitoring, improving water resilience, and developing additional understanding of the Basin to ensure changing conditions do not cause undesirable results. In this context, water resilience refers generally to the capacity of the Basin to provide for beneficial uses during periods of stress caused by droughts, climate change, or human-caused pressures and to recover quickly from periods of reduced storage. While projects and management actions are not necessary to alleviate or prevent imminent undesirable results, improving water resiliency is inherently in the public interest. Some of the following projects and management actions will be incorporated into the Humboldt County GSA's normal operations, while other projects and management actions will depend on staffing capacity, available funding, and whether strategic opportunities are present. Projects and management actions are summarized on Table 28.

8.2.1 Planned Projects and Management Actions

The Humboldt County GSA plans to pursue the following projects and management actions:

1. **Coordinate with DWR's Airborne Electromagnetic (AEM) Survey**. DWR intends to conduct Airborne Electromagnetic (AEM) surveys in selected high and medium priority groundwater basins throughout the state. If DWR elects to perform an AER survey of the Basin, this survey may provide information about subsurface hydrogeologic characteristics that could be used to refine the hydrogeologic conceptual model developed for the Basin. Data from the AEM survey may help fill some of the data gaps described in Section 3.8. The Humboldt County GSA will coordinate with DWR during planning and conducting the survey. Once available, the AEM survey information will be appropriately utilized by the Humboldt County GSA during the five-year assessment following the AEM survey.
2. **Encourage Irrigation Efficiency Upgrades**. The Humboldt County GSA will coordinate with stakeholders, USDA-NRCS, the Humboldt County RCD, and others to encourage water users to implement irrigation efficiency improvements. Such activities may include advocating for funding to NRCS' EQIP program, posting information about NRCS' EQIP

program on the GSA website, discussing the program at stakeholder meetings, and periodically requesting information from NRCS on water conservation practices.

3. **Increase the Number of Irrigation System Flow Meters.** Humboldt County installed flow meters on six irrigation systems and obtained data from two existing meters to estimate irrigation water use (Humboldt County, 2021). The Humboldt County GSA will seek grant funding to install additional water meters with interested landowners on a voluntary basis, with the goal of obtaining grant funding to install an additional six flow meters by January 1, 2027. All available water meter data will be used to calculate irrigation water use on an annual basis.
4. **Share Information for New Municipal Wells**. The Humboldt County GSA will coordinate with municipalities to share technical information and ensure that new or expanded groundwater supply wells are located and designed to prevent significant localized or regional impacts or potential conflicts with the sustainability management criteria in this GSP. While Basin characteristics do not suggest that existing or future wells would cause such impacts, coordination with municipalities on new or expanded wells will reduce the likelihood of occurrence.
5. **Advocate for Potter Valley Project Modifications**. Humboldt County plans to continue advocating for removal of Scott Dam to provide access to upstream fish habitat and for discontinuation of dry-season water diversions from the Eel River to the Russian River. The level of effort and the engagement strategy will depend on how regional discussions develop regarding the future of the Potter Valley Project.
6. **Support Watershed Improvement Activities**. Where feasible and appropriate, the Humboldt County GSA may support watershed improvement projects and activities that could enhance the beneficial uses of interconnected surface waters within the Basin, especially efforts to increase streamflow entering the Basin, particularly in the dry season. While specific projects are not identified at this time, potential projects could include ecologically-based forest thinning, fire risk reduction, seasonal water storage and forbearance, bank stabilization, wetland restoration, and groundwater recharge.
7. **Support Channel Sediment Management and Habitat Restoration**. Where feasible and appropriate, the Humboldt County GSA may support projects to manage sediment to improve geomorphic conditions within the Eel River, Van Duzen River, and other surface waters. While channel sedimentation is not influenced by groundwater pumping, it became evident through the GSP development process that conditions for beneficial uses of interconnected surface waters could potentially be enhanced by actively managing channel sediments and/or implementing in-stream habitat restoration projects. Such efforts may be coordinated with CHERT and resource agencies in conjunction with in-stream gravel mining (see Section 2.8).

8.2.2 Potential Projects and management Actions

Potential projects and management actions that could be considered by the Humboldt County GSA include the following:

8. **Enhance the Monitoring Network**. The existing monitoring network includes a total of 38 monitoring wells installed by Humboldt County for monitoring of groundwater levels and chloride concentrations and three stations for monitoring surface water levels. Other elements of the monitoring network include water quality data from water suppliers in the Basin, USGS streamflow gauges, USGS InSAR data, rainfall and evapotranspiration data from the Ferndale CIMIS station, and rainfall data from the Ferndale Museum. While these sources are not under the control of the Humboldt County GSA, they are considered reliable. The analysis of data gaps in the hydrogeological conceptual model (Section 3.8)

and the assessment of the monitoring network (Section 7.4) did not indicate that additional monitoring wells are warranted at this time to ensure the Basin's sustainability goal is maintained. Therefore, construction of additional monitoring wells is not expected. If conditions in the Basin change or more information is made available indicating additional monitoring wells are required, such wells will be considered based on available funding. Changes to the monitoring network will be discussed in the annual report.

9. **Perform Additional Hydrologic Modeling**. A variety of tasks involving the hydrologic model may be desirable. Examples include updating the calibration with new data, refining the model construction to improve the model's representation of the natural system, and developing new modeling simulations to address specific questions.

Table 28: Summary of Projects and Management Actions

Project and Management Action	Type	Timing	Expected Benefit
1. Coordinate with DWR's Airborne Electromagnetic (AEM) Survey	Planned	Expected in 2022-2023	SMC #1, SMC #2, SMC #3, SMC #4, SMC #5, SMC #6
2. Encourage Irrigation Efficiency Upgrades	Planned	Ongoing	SMC #1, SMC #2, SMC #3, SMC #4, SMC #6
3. Increase the Number of Irrigation System Flow Meters	Planned	Ongoing	SMC #1, SMC #2, SMC #3, SMC #4, SMC #6
4. Share Information for New Municipal Wells	Planned	Ongoing	SMC #1, SMC #2, SMC #3, SMC #4, SMC #6
5. Advocate for Potter Valley Project Modifications	Planned	Ongoing	SMC #6
6. Support Watershed Improvement Activities	Planned	Contingent on need and opportunity	SMC #6
7. Support Channel Sediment Management and Habitat Restoration	Planned	Contingent on need and opportunity	SMC #6
8. Enhance the Monitoring Network	Potential	Contingent on need and opportunity	SMC #1, SMC #2, SMC #3, SMC #4, SMC #6
9. Perform Additional Hydrologic Modeling	Potential	Contingent on need and opportunity	SMC #1, SMC #2, SMC #3, SMC #4, SMC #6

8.3 Required Management Actions

8.3.1 Annual Report

Beginning in 2022, the Humboldt County GSA will submit an annual report to DWR by April 1 of each year. In accordance with 23 CCR Section 356.2, the annual report will include the following:

a) General information, including an executive summary and a location map depicting the basin covered by the report.

b) A detailed description and graphical representation of the following conditions of the basin managed in the Plan:

- (1) Groundwater elevation data from monitoring wells identified in the monitoring network shall be analyzed and displayed as follows:
  - (A) Groundwater elevation contour maps for each principal aquifer in the basin illustrating, at a minimum, the seasonal high and seasonal low groundwater conditions.
  - (B) Hydrographs of groundwater elevations and water year type using historical data to the greatest extent available, including from January 1, 2015, to current reporting year.
- (2) Groundwater extraction for the preceding water year. Data shall be collected using the best available measurement methods and shall be presented in a table that summarizes groundwater extractions by water use sector, and identifies the method of measurement (direct or estimate) and accuracy of measurements, and a map that illustrates the general location and volume of groundwater extractions.
- (3) Surface water supply used or available for use, for groundwater recharge or in-lieu use shall be reported based on quantitative data that describes the annual volume and sources for the preceding water year.
- (4) Total water use shall be collected using the best available measurement methods and shall be reported in a table that summarizes total water use by water use sector, water source type, and identifies the method of measurement (direct or estimate) and accuracy of measurements. Existing water use data from the most recent Urban Water Management Plans or Agricultural Water Management Plans within the basin may be used, as long as the data are reported by water year.
- (5) Change in groundwater in storage shall include the following:
  - (A) Change in groundwater in storage maps for each principal aquifer in the basin.
  - (B) A graph depicting water year type, groundwater use, the annual change in groundwater in storage, and the cumulative change in groundwater in storage for the basin based on historical data to the greatest extent available, including from January 1, 2015, to the current reporting year.

(c) A description of progress towards implementing the Plan, including achieving interim milestones, and implementation of projects or management actions since the previous annual report.

Because the Basin is currently being managed sustainably, the annual report is the primary management action used to determine whether the Basin's sustainability goal continues to be met and whether changed conditions are present that may affect continued sustainable groundwater management.

8.3.2 Periodic GSP Evaluation

The Humboldt County GSA will evaluate the GSP every five years and provide a written assessment to DWR (23 CCR Section 356.4). Periodic evaluations of the GSP must be completed and assessments submitted to DWR in 2027, 2032, 2037, and 2042. The periodic assessment must describe whether the GSP is meeting the Basin's sustainability goal and will include the following:

a) A description of current groundwater conditions for each applicable sustainability indicator relative to measurable objectives, interim milestones and minimum thresholds.

b) A description of the implementation of any projects or management actions, and the effect on groundwater conditions resulting from those projects or management actions.

c) Elements of the Plan, including the basin setting, management areas, or the identification of undesirable results and the setting of minimum thresholds and measurable objectives, shall be reconsidered and revisions proposed, if necessary.

d) An evaluation of the basin setting in light of significant new information or changes in water use, and an explanation of any significant changes. If the Agency's evaluation shows that the basin is experiencing overdraft conditions, the Agency shall include an assessment of measures to mitigate that overdraft.
e) A description of the monitoring network within the basin, including whether data gaps exist, or any areas within the basin are represented by data that does not satisfy the requirements of 23 CCR Sections 352.4 and 354.34(c).
f) A description of significant new information that has been made available since Plan adoption or amendment, or the last five-year assessment. The description shall also include whether new information warrants changes to any aspect of the Plan, including the evaluation of the basin setting, measurable objectives, minimum thresholds, or the criteria defining undesirable results.
g) A description of relevant actions taken by the Agency, including a summary of regulations or ordinances related to the Plan.
h) Information describing any enforcement or legal actions taken by the Agency in furtherance of the sustainability goal for the basin.
i) A description of completed or proposed Plan amendments.
j) Where appropriate, a summary of coordination that occurred between multiple Agencies in a single basin, Agencies in hydrologically connected basins, and land use agencies.
k) Other information the Agency deems appropriate, along with any information required by the Department to conduct a periodic review as required by Water Code Section 10733.

The periodic GSP evaluation is important to ensuring that the Basin's sustainability goal continues to be met and changed conditions that may affect continued sustainable groundwater management are identified. Current projections do not indicate that conditions will change enough to impact the sustainable management criteria in the Basin, but this process will provide an opportunity to validate this assumption.

8.4 Other Activities in the Basin Potentially Related to Sustainability Goal

Other activities occurring in the Basin may affect groundwater or the beneficial uses and users of groundwater. While these are not directly within the purview of this GSP, inclusion here may be helpful to ensure the potential effects of those projects on groundwater are considered.

City of Fortuna Municipal Stormwater Program
As part of the City of Fortuna's Municipal Stormwater Program, construction and development projects are subject to State and Regional Water Quality Control Board requirements (Section 2.9). These include "low impact development" (LID) standards which "are intended to maintain a site's pre-development runoff characteristics by using design techniques that capture, treat, and infiltrate stormwater on site." The City of Fortuna partnered with Humboldt County and other cities to develop and adopt the Humboldt Low Impact Development Stormwater Manual. By ensuring that post-development stormwater infiltration characteristics substantially match pre-development conditions, this will help ensure that the Basin is impacted by reduced recharge during the rainy season.

Dune and Estuary Restoration
Projects to restore and enhance dunes and estuaries as well as projects to address sea level rise are under consideration in various areas of the Basin. These projects have the potential to alter tidal influence and the extent to which brackish surface water comes into the Basin. This GSP will be

a useful resource for these projects to understand whether and how these projects can be designed to promote the GSP's sustainability goal, including to avoid seawater intrusion on fresh groundwater in a manner that could be impactful to beneficial uses.

8.5 Changing Conditions

One of the primary objectives of periodic monitoring is to identify changing conditions that could potentially lead to undesirable results. In the event that changing conditions result in exceedances of minimum thresholds, the Humboldt County GSA (1) may consider new projects and management actions, and/or (2) may revisit the sustainable management criteria to ensure that the interests of all beneficial uses and users of groundwater in the Basin are appropriately balanced. It is important to note that the sustainable management criteria in this GSP are protective of the most sensitive beneficial uses and users of groundwater and interconnected surface waters that may be affected by groundwater conditions but do not necessarily balance all uses and users of groundwater. Decisions by the Humboldt County GSA regarding projects and management actions will consider the appropriate balancing of beneficial uses.

No projects or management actions are proposed at this time to limit groundwater extractions because increases in pumping to the levels required to trigger minimum thresholds are unlikely. This scenario is unlikely because agricultural productivity and yield in the Basin are essentially optimized with current irrigation water use rates. While small increases for some individual operations could potentially improve crop production, an order-of-magnitude increase of pumping volumes across the Basin is not foreseeable because crops could not use the water. The excess applied water would either run off or infiltrate back into the groundwater system. Producers have economic incentives (through costs of power and labor) not to apply excess water.

8.6 Other Regulatory Requirements

The requirements in 23 CCR Section 354.44 are summarized below for the projects and management actions listed above.

Measurable Objective Benefited [23 CCR Section 354.44(b)(1)]
Because the Basin is currently being sustainably managed and total groundwater use is well below the sustainable yield, the purpose of the identified projects and management actions is to ensure groundwater continues to be sustainably managed. Therefore, measurable objectives are not set as benchmarks to desired future conditions but reflect the goal of avoiding the presence of undesirable results.

Public Outreach [23 CCR Section 354.44(b)(1)(B)]
The projects and management actions identified are being done as part of GSP implementation or are anticipated to involve subsequent public processes. For those projects and management actions which are part of the GSP implementation, the GSP itself is sufficient public outreach of the detail and timing of those actions. The exceptions to this are projects and management actions to encourage irrigation efficiency upgrades, sharing information for new municipal wells, and coordinating with DWR's AEM survey. The management action to encourage irrigation efficiency upgrades is by its nature a public outreach effort. Coordinating with municipalities on any new or expanded municipal well will involve public outreach through decision-making and CEQA processes that are adequate to inform the public. DWR coordinates with local government prior to conducting AEM surveys to inform the local community.

Permitting [23 CCR Section 354.44(b)(3)]
Projects 6 and 7 on Table 28 would require additional permitting and regulatory approvals prior to implementation once the scopes of specific projects are sufficiently defined. The other projects and management actions identified on Table 28 are either planning efforts or involve *de minimis* physical changes and would not require permitting or regulatory approvals.

Status [23 CCR Section 354.44(b)(4)]
The monitoring wells have been installed. Other projects and management actions are ongoing.

Benefits [23 CCR Section 354.44(b)(5)
The planned projects and management actions will monitor groundwater conditions and groundwater use in the Basin to ensure the sustainability goal is maintained.

How Projects and Management Actions will be Accomplished [23 CCR Section 354.44(b)(6)]
The projects and management actions will be implemented by Humboldt County GSA staff and consultants, in coordination with water users and stakeholders.

Legal Authority [23 CCR Section 354.44(b)(7)]
SGMA provides the Humboldt County GSA with the requisite authority to implement the projects and management identified in this GSP.

Costs & Funding [23 CCR Section 354.44(b)(8)]
The cost of implementing the identified projects and management actions will need to be determined. Some projects and management actions can be performed under baseline annual budgets, while more expansive projects and management actions will depend on outside funding.

Drought Management of Extractions and Recharge [23 CCR Section 354.44(b)(9)]
Historically and in modeled future scenarios, Basin groundwater levels and groundwater supply fully recover during non-drought years with no extraction or recharge actions.

8.7 Potential Future Change in Basin Priority Level

DWR may reevaluate the priority levels of basins throughout the state in the future. Data and information gathered through the development of this GSP may be pertinent to the criteria that DWR uses to evaluate the priority level of the Basin. The Humboldt County GSA will engage in DWR’s future re-prioritization process, if conducted, to ensure that DWR has the best available scientific data and information for its scoring and decision-making.

9 IMPLEMENTATION

This section provides a summary of the anticipated activities and costs associated with implementing the GSP based on the current understanding of Basin conditions and needs for projects and management actions. The Humboldt County GSA will adapt over time based on new data and information, feedback from stakeholders, and changing conditions within the Basin. The Humboldt County GSA will strive to be as efficient and effective as possible in implementing the GSP with consideration for limited resources and competing priorities.

9.1 Governance Structure and Planned Administrative Approach

The current governance structure and administrative approach (Section 1.4) is expected to remain in place for the foreseeable future. The Humboldt County Board of Supervisors will serve as the governing body of the Humboldt County GSA and make decisions regarding funding, major projects and management actions, and other governance issues. The Humboldt County Department of Public Works will lead GSA administration; communication and stakeholder engagement; annual monitoring, data evaluation, and reporting; and implementation of projects and management actions. Other County departments including County Counsel and the County Administrative Office will provide support services. The Department of Building and Planning will continue to take the lead role in administering Humboldt County's land use jurisdiction and the Environmental Health division of the Department of Health and Human Services will continue to take the lead role on administering well permitting.

The Humboldt County GSA may consider forming a groundwater resources advisory committee as an element of communication and stakeholder engagement (Section 9.2.2). Advisory committees are created to advise the Board of Supervisors on specific subjects, typically ranging from five to nine members, with committee members appointed by the Board. An important consideration in forming a committee is ensuring appropriate representation of diverse interests. Meetings of advisory committees are subject to the notice and agenda requirements of Brown Act (Government Code 54950 et seq), which ensures open and public meetings. Agendas can include informational items (no action) and action items subject to vote by committee members. Serving on a committee is a significant commitment of time by committee members. Creating an advisory committee would give the committee elevated standing for advising the Board. Advisory committees provide an opportunity for members to participate in ongoing dialogue and seek consensus in trying to identify solutions to complex issues. A tradeoff of forming an advisory committee is that meetings have a more rigid structure and there would likely be increased time and cost to administer the meetings. If the Humboldt County GSA determines that it would be important for the Board to be advised by an appointed committee of stakeholders, then a process for forming a groundwater resources advisory committee will be developed.

9.2 GSP Implementation Components

9.2.1 Administration

Administration duties and tasks include budgeting and financial management, personnel management, professional development, contracting, purchasing, insurance, legal services, applying for grants, and administering grant agreements.

9.2.2 Communication and Stakeholder Engagement

Communication and stakeholder engagement encompasses all interactions with stakeholders having an interest in groundwater within the Basin. The Humboldt County GSA envisions maintaining the informal Eel River Valley Groundwater Working Group, which is open to participation from anyone who is interested. Meetings of the working group were most successful (2015 through 2019) when they could be convened in person and were less successful (2020-2021) when they shifted to video-conference because not all participants were familiar or comfortable with the video-conference platform. Therefore, in 2021 the Humboldt County GSA shifted to a more flexible and diversified approach of individual and small group meetings (often outside), either by video-conference or in person, based on stakeholder preference, along with e-mail updates and postings to the County's GSP website. Going forward, the structure of the stakeholder engagement process will depend in part on the progression of the Covid-19 pandemic. At least initially, stakeholder engagement will continue to be implemented with a flexible and diversified approach of video-conference and in-person meetings. The Humboldt County GSA will continue to share e-mail updates to the stakeholder list and update the County's GSP website.

The Humboldt County GSA will aim to participate in programs, meetings, and planning efforts with a nexus to groundwater conditions within the Basin in order to stay informed on developments related to groundwater beneficial uses, water resource management, scientific studies, and ecological restoration priorities. In particular, the Humboldt County GSA will coordinate with entities leading technical studies to seek opportunities to fill data gaps and improve the understanding of Basin conditions.

9.2.3 Annual Monitoring, Data Evaluation, and Reporting

The Humboldt County GSA will monitor groundwater levels, operate the CIMIS weather station, collect water samples for chloride testing (for seawater intrusion monitoring), monitor surface water levels, and collect data on groundwater extractions. Monitoring data will be compiled, analyzed, and uploaded to the SGMA Portal as applicable.

The Humboldt County GSA will perform annual reporting as described in Section 8.3.

Municipal water providers will continue to monitor groundwater levels and water quality with their own resources.

9.2.4 Projects and Management Actions

Section 8.2 identified a range of discretionary projects and management actions that could help maintain the sustainability goal, increase water resiliency, and improve the understanding of Basin conditions. The Humboldt County GSA will strive to implement as many projects and management actions as possible within the constraints of staffing capacity and available funding.

9.3 Addressing Data Gaps and Limitations

Data gaps and uncertainty associated with the hydrogeologic conceptual model are discussed in Section 3.8. Uncertainty associated with the hydrologic modeling is discussed in GHD (2022a). No critical data gaps that substantially limited the development of the GSP were identified.

The existing monitoring network (Section 7) is adequate to provide the data needed to ensure that sustainable groundwater management continues. Data collected from this network through implementation of annual monitoring will provide longer data sets that will be more representative of long-term conditions and will improve the understanding of annual variability.

9.4 Five Year Update of GSP

Section 8.3.2 described the requirement for a five-year update of the GSP. The level of effort necessary for updating the plan is uncertain at this time but a best estimate of cost was developed.

9.5 Costs and Funding (2022-2027)

9.5.1 Estimated Costs

Estimated costs for implementing the GSP from Fiscal Year 2022-2023 through 2026-2027 are provided in Table 29.

Table 29: Estimated Costs for Plan Implementation, 2022-2027(1, 2)

Budget Categories	Type	FY 2022-2023	FY 2023-2024	FY 2024-2025	FY 2025-2026	FY 2026-2027
Administration	Required	\$5,000 - \$10,000	\$5,000 - \$10,000	\$5,000 - \$10,000	\$5,000 - \$10,000	\$5,000 - \$10,000
Communication and Stakeholder Engagement	Required	\$5,000 - \$10,000	\$5,000 - \$10,000	\$5,000 - \$10,000	\$5,000 - \$10,000	\$5,000 - \$10,000
Annual Monitoring, Data Evaluation, and Reporting	Required	\$30,000 - \$45,000	\$30,000 - \$45,000	\$30,000 - \$45,000	\$30,000 - \$45,000	\$30,000 - \$45,000
Projects and Management Actions	Discretionary (contingent on funding)	To be determined	To be determined	To be determined	To be determined	To be determined
Five-year Update(3)	Required	\$0	\$0	\$0	\$25,000 - \$40,000	\$100,000 - \$140,000
Total:		\$40,000 - \$65,000	\$40,000 - \$65,000	\$40,000 - \$65,000	\$65,000 - \$115,000	\$140,000 - \$215,000

Notes:

1) The fiscal year begins July 1.

(2) This table includes direct costs only (labor, materials, professional services), and does not include indirect costs.

(3) The level of effort for the five-year update is uncertain. The cost estimate assumed that the cost for updating the plan will be approximately 10% of the cost of preparing the initial plan. The cost for updating the plan will be higher if new technical studies or extensive modeling are required.

9.5.2 Funding Sources

The funding source for the required components of GSP implementation identified in Section 9.2 is presumed to be the Humboldt County General Fund, through the Water Management budget unit of the Public Works Department. This budget unit receives an annual allocation from the General Fund and is used to fund work involving levee maintenance, municipal stormwater permit implementation, sea level rise planning, contaminated property investigation and remediation, ecological restoration, and involvement in regional water resources matters (e.g., Potter Valley Project decommissioning, Klamath River dam removal, Trinity River flow management). Work on implementing the GSA will be balanced with these other duties and responsibilities within the limits of the annual allocation from the General Fund.

Alternative or supplemental funding sources include grants, technical assistance from other agencies (such as USGS and DWR), and voluntary contributions from water users. The

Humboldt County GSA will consider opportunities for grant funding and/or technical assistance to implement discretionary projects and management actions. The Humboldt County GSA may consider requesting voluntary contributions from water suppliers and/or other groundwater users to support implementation of the required elements of the GSP.

SGMA provides GSAs with the authority to impose fees to fund the costs of a groundwater sustainability program (Water Code Section 10730 et seq.). The Humboldt County GSA is not considering fees as a funding source for GSP implementation at this time. If fees are considered in the future, the initial step would likely be to retain a consultant to conduct a fee study, including stakeholder outreach, that evaluates and provides recommendations for a fee program.

9.6 Schedule

The final GSP will be submitted to DWR no later than January 31, 2022. While DWR has up to two years to review the GSP, the Humboldt County GSA will begin implementing the GSP immediately. GSP implementation includes biannual monitoring (spring and fall), annual reporting, ongoing stakeholder engagement, and consideration of discretionary projects and management actions. Certain projects may be multi-phase, multi-year initiatives. Annual reports will be submitted to DWR by April 1 of each year. Periodic GSP updates will be submitted to DWR by April 1 at least every five years (starting in 2027).

9.7 Affect on Land Use Plans

The GSP will be an important source of information for updates to land use plans within the Basin. Implementation of the plan is not expected to alter the water supply assumptions of the applicable land use plans (Section 2.6) over the planning and implementation horizon because land use is not expected to change significantly (Section 5.7), current groundwater use is well below the sustainable yield (Section 6.13), and limitations on groundwater use are not envisioned.

PART IV: SUPPORTING INFORMATION

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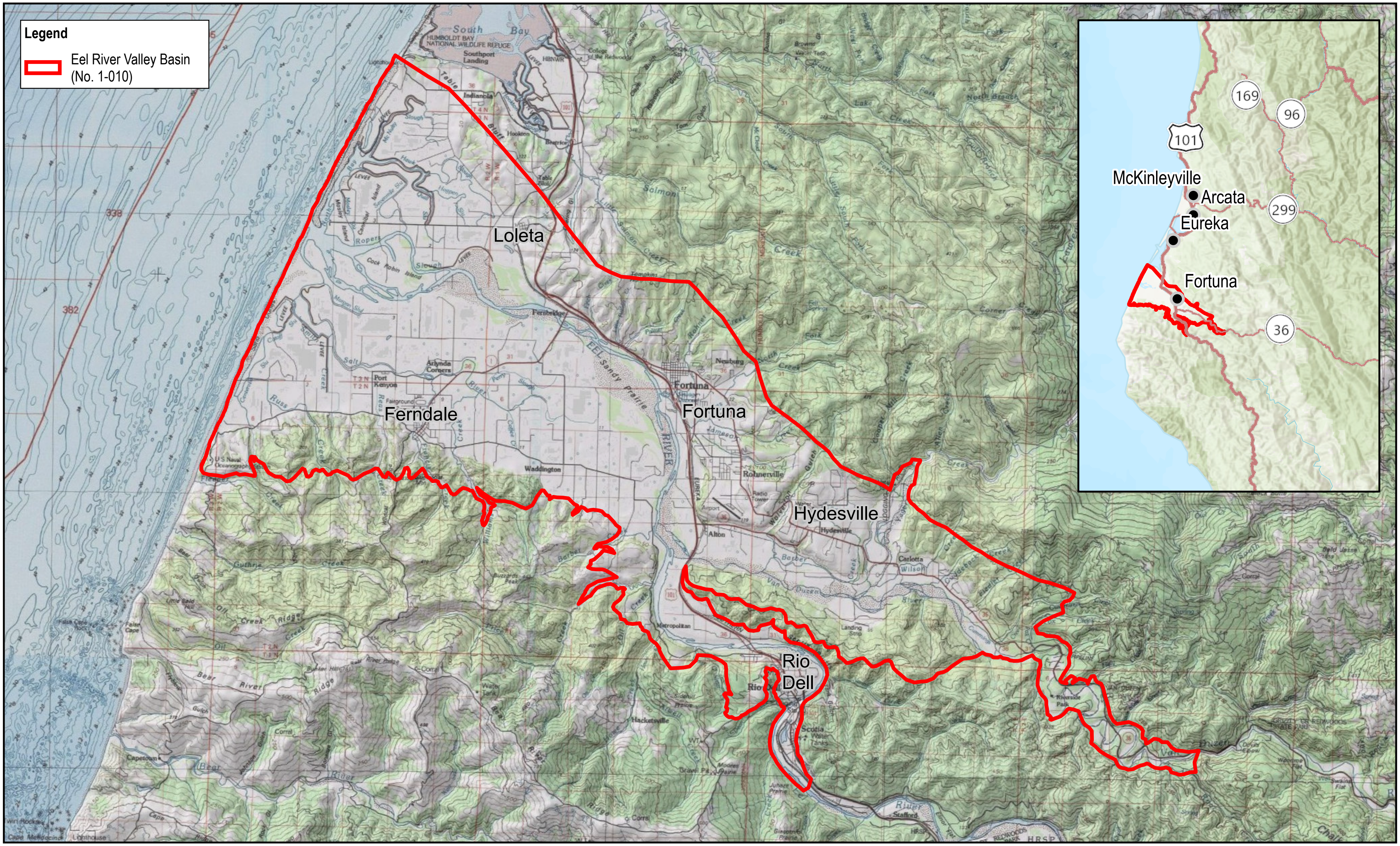
11 FIGURES

Figures are provided as separate documents.

12 APPENDICES

Appendices are provided as separate documents.

Figures



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Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane California I FIPS 0401 Feet

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COUNTY OF HUMBOLDT
The Home of the Redwoods

Humboldt County Groundwater Sustainability Agency
Eel River Valley Groundwater
Sustainability Plan

Site Location Map

Project No. **11217388**
Revision No. **-**
Date **Jan 2022**

FIGURE 1

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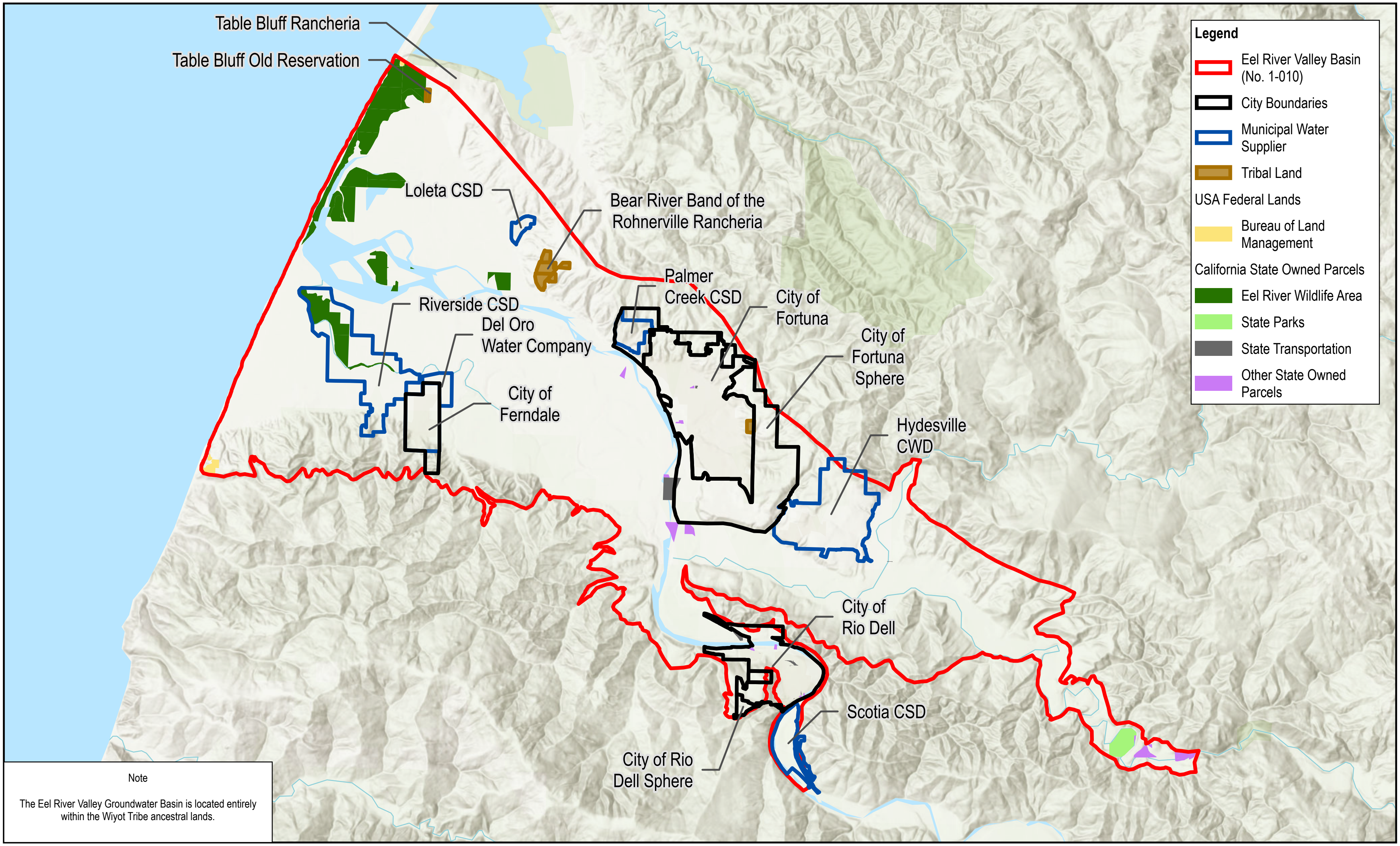
Data source: DWR Basin, 2013; World Topographic Map - labelless: Esri, HERE, Garmin, FAO, NOAA, USGS, Bureau of Land Management, EPA, NPS; transportation: USGS The National Map: National Transportation Dataset;U.S. Census Bureau – TIGER/Line; U.S. Forest Service. Data Refreshed October, 2021.; World Hillshade: Esri, USGS; USGS National Map: USGS The National Map: National Boundaries Dataset, NationalElevation Dataset, Geographic Names Information System, National Hydrography Dataset, National Land Cover Database, National Structures Dataset, and National Transportation Dataset; U.S. Census Bureau- TIGER/Line; HERE Road Data. Created by: jclark2



Note

The Eel River Valley Groundwater Basin is located entirely within the Wiyot Tribe ancestral lands.

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Map Projection: Lambert Conformal Conic
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Sustainability Plan

Jurisdictions, Cities
and Municipal Water Suppliers

Project No. **11217388**
Revision No. **-**
Date **Jan 2022**

FIGURE 2

N:\US\Eureka\Projects\561\11217388\GIS\Maps\Deliverables\11217388_ERVP_GSP\11217388_ERVP_GSP.aprx - F002_CitiesMuniWaterSupply_RevB
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Data source: DWR basin, 2013; Humboldt County parcels, Jan 2022; City and municipal boundaries, 2021;World Topographic Map - labelless: California State Parks, Esri, HERE, Garmin, SafeGraph, METI/NASA, USGS, Bureau of Land Management, EPA, NPS, USDA; World Hillshade: Esri, NASA, NGA, USGS. Created by: jclark2

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Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane California I FIPS 0401 Feet

Humboldt County Groundwater Sustainability Agency
Eel River Valley Groundwater
Sustainability Plan

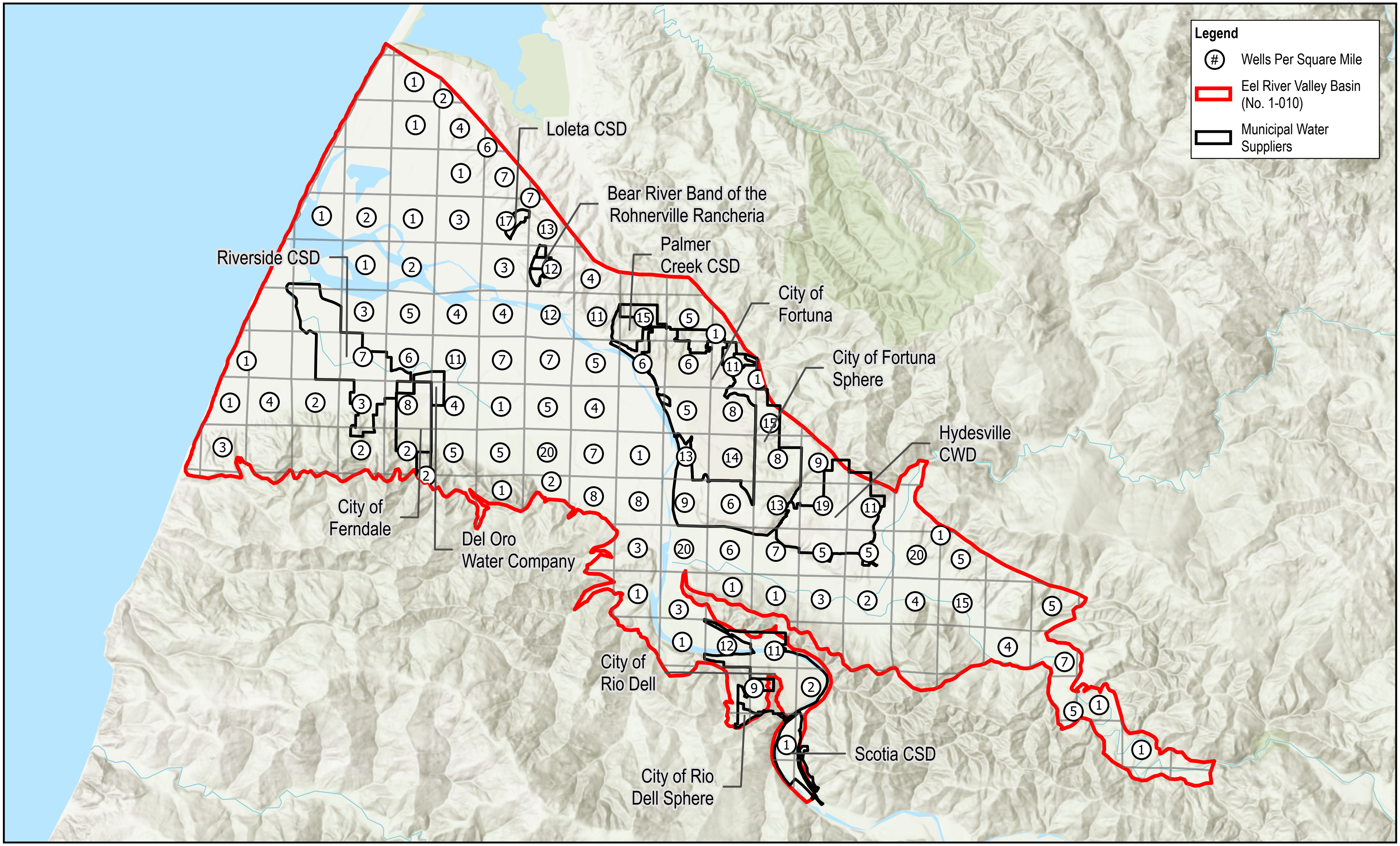
Project No.	**11217388**
Revision No.	**-**
Date	**Jan 2022**

Watershed Map

FIGURE 3

N:\US\Eureka\Projects\561\11217388\GIS\Maps\Deliverables\11217388_ERVP_GSP\11217388_ERVP_GSP.aprx
Print date: 20 Jan 2022 - 10:03

Data source: DWR basin, 2013; USDA-NRCS watershed; Populated places, 2021; NHD; World Topo Base: This work is licensed under the Esri Master License Agreement.View Summary | View Terms of UseAlignment of boundaries is a presentation of the features provided by our data vendors and does not imply endorsement by Esri or any governing authority.Important Note: This item is in beta and is not intended for use in production applications.; Terrain: Hillshade: Airbus,USGS,NGA,NASA,CGIAR,NCEAS,NLS,OS,NMA,Geodatastyrelsen,GSA,GSI and the GIS User Community. Created by: jclark2



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Eel River Valley Groundwater
Sustainability Plan

Project No. **11217388**
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Date **Jan 2022**

Well Densities

FIGURE 4

N:\US\Eureka\Projects\561\11217388\GIS\Maps\Deliverables\11217388_ERVP_GSP\11217388_ERVP_GSP.aprx - F004_WellDensities
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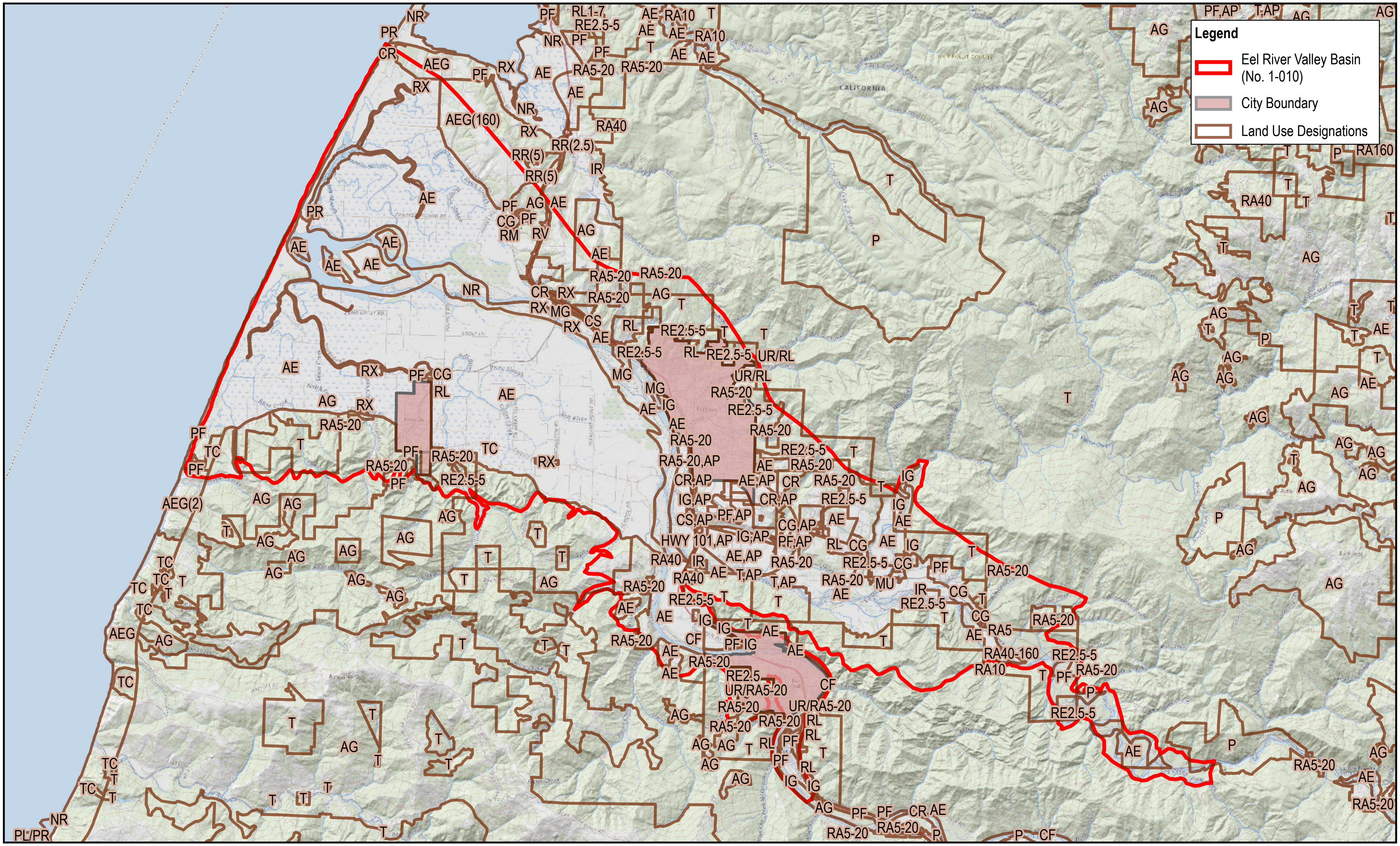

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Sustainability Plan

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Land Use Designations

FIGURE 5

N:\US\Eureka\Projects\561\11217388\GIS\Maps\Deliverables\11217388_ERVP_GSP\11217388_ERVP_GSP.aprx - F005_LandUse
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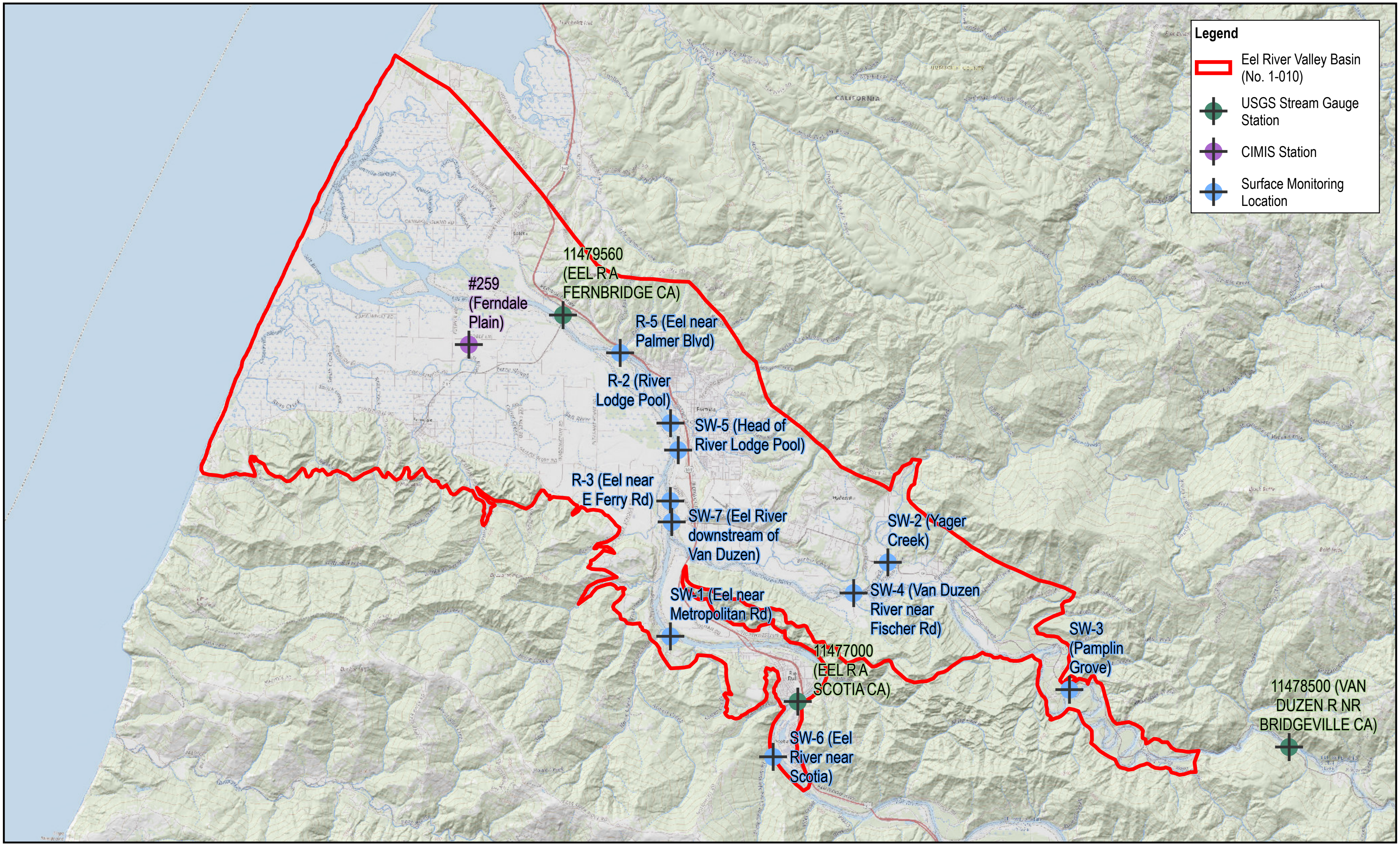

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Humboldt County Groundwater Sustainability Agency
Eel River Valley Groundwater
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Surface Water and Weather Monitoring Stations

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FIGURE 6

N:\US\Eureka\Projects\561\11217388\GIS\Maps\Deliverables\11217388_ERVP_GSP\11217388_ERVP_GSP.aprx - F006_ClimateSurfWaterMonitoring_RevC
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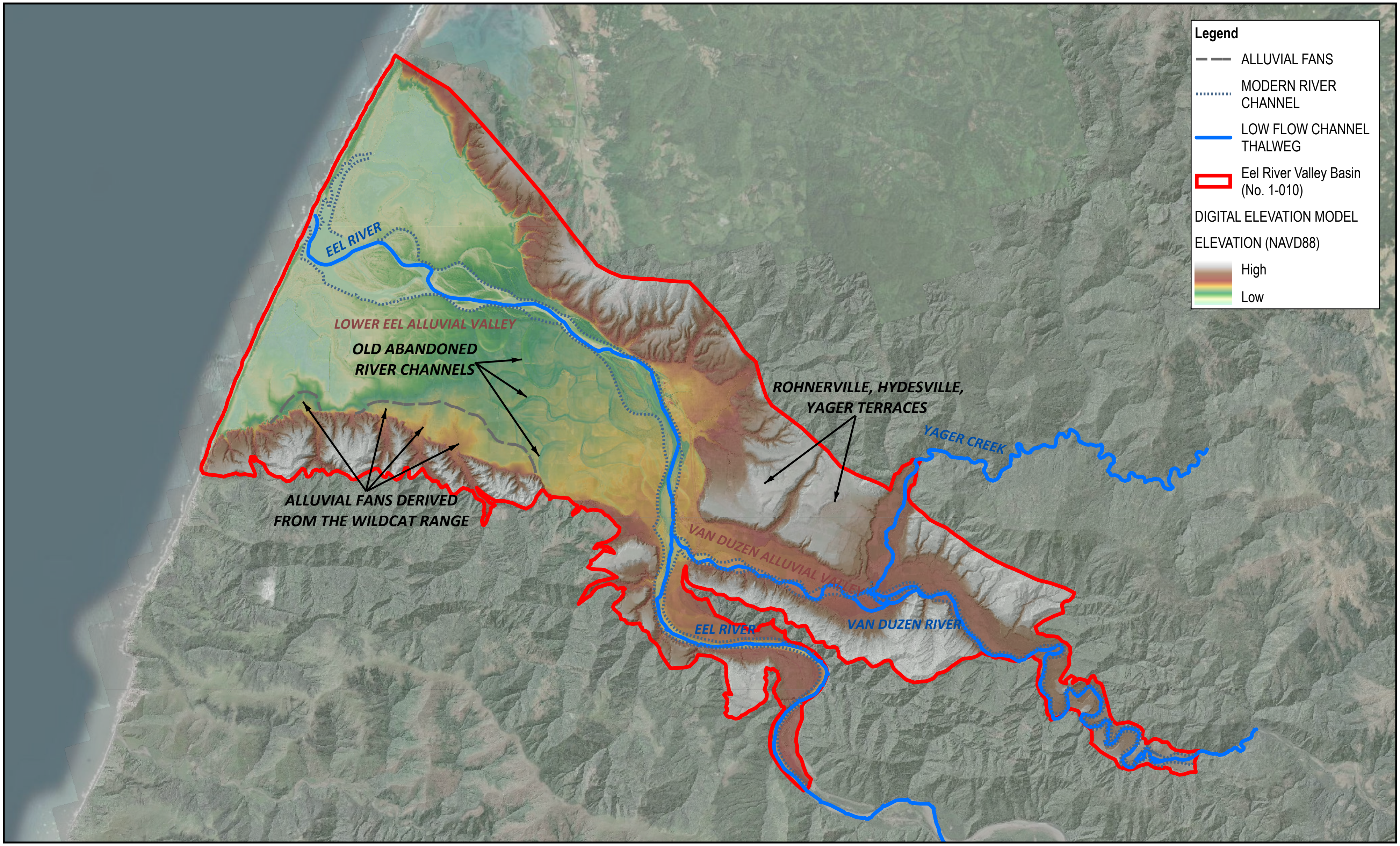

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Map Projection: Lambert Conformal Conic
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Grid: NAD 1983 StatePlane California I FIPS 0401 Feet

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Humboldt County Groundwater Sustainability Agency
Eel River Valley Groundwater
Sustainability Plan

Project No. **11217388**
Revision No. **-**
Date **Jan 2022**

Geomorphology

FIGURE 7

N:\US\Eureka\Projects\561\11217388\GIS\Maps\Deliverables\11217388_ERVP_GSP\11217388_ERVP_GSP.aprx - F007_Geomorphology
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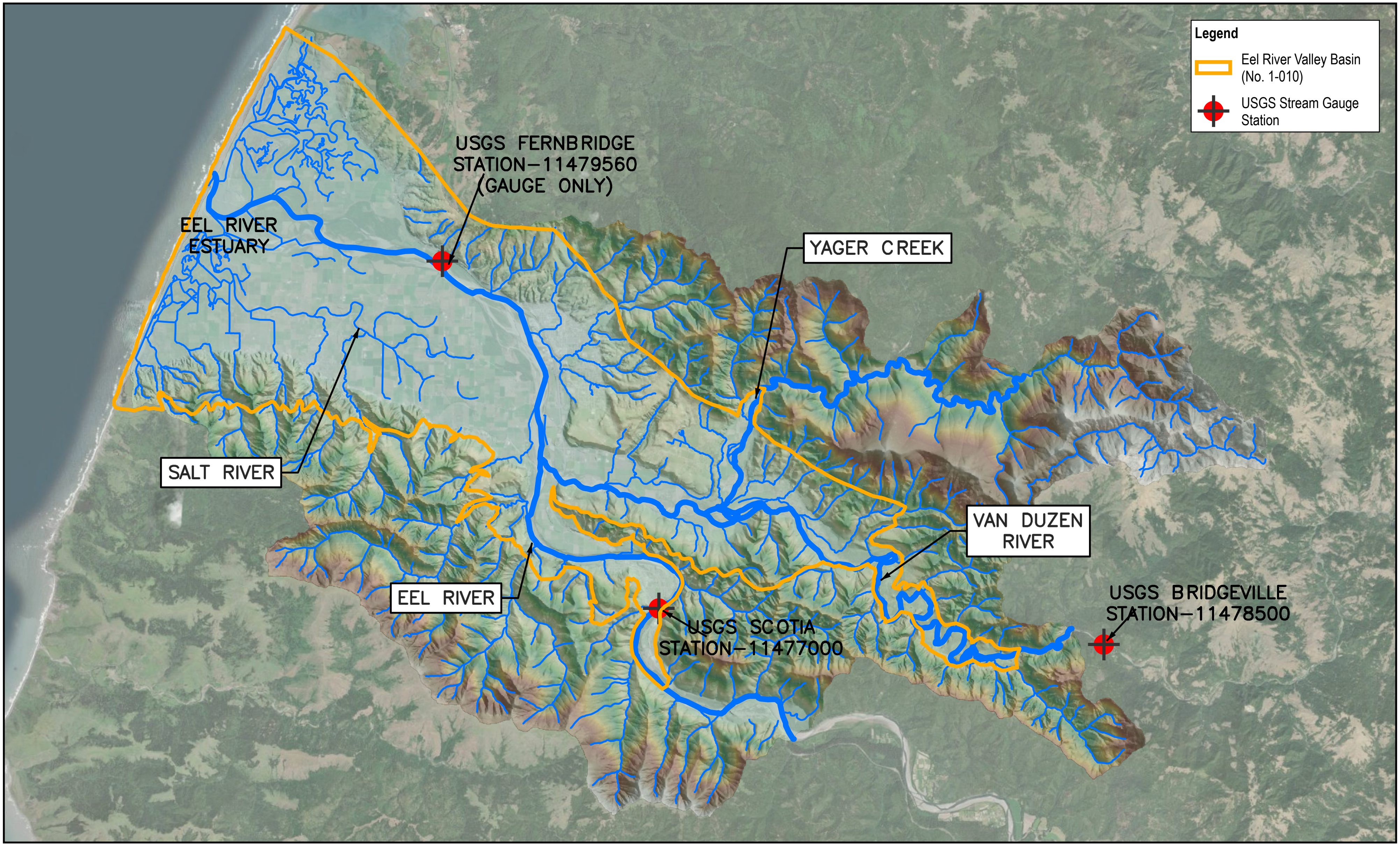

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Map Projection: Transverse Mercator
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Grid: NAD 1983 UTM Zone 10N

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Eel River Valley Groundwater
Sustainability Plan

Project No. **11217388**
Revision No. **-**
Date **Jan 2022**

Surface Waters

FIGURE 8

N:\US\Eureka\Projects\561\11217388\GIS\Maps\Deliverables\11217388_ERVP_GSP\11217388_ERVP_GSP.aprx - F008_SurfaceWaters
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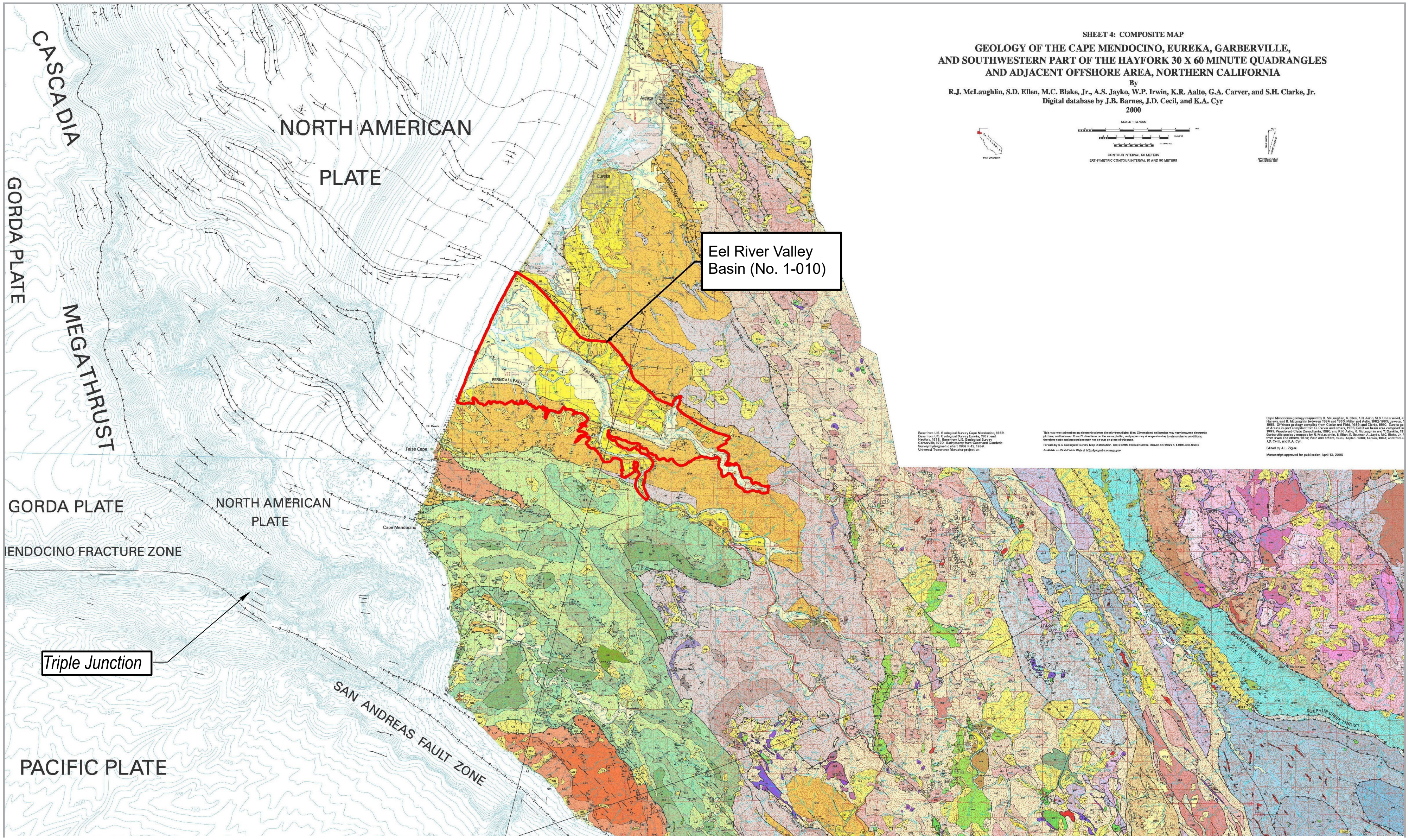

Humboldt County Groundwater Sustainability Agency
Eel River Valley Groundwater Sustainability Plan

Project No. **11217388**
Revision No. **-**
Date **Jan 2022**

Geologic Map (McLaughlin 2002)

FIGURE 9

N:\US\Eureka\Projects\561\11217388\GIS\Maps\Deliverables\11217388_ERVP_GSP\11217388_ERVP_GSP.aprx - F009_GeologicMcLaughlin
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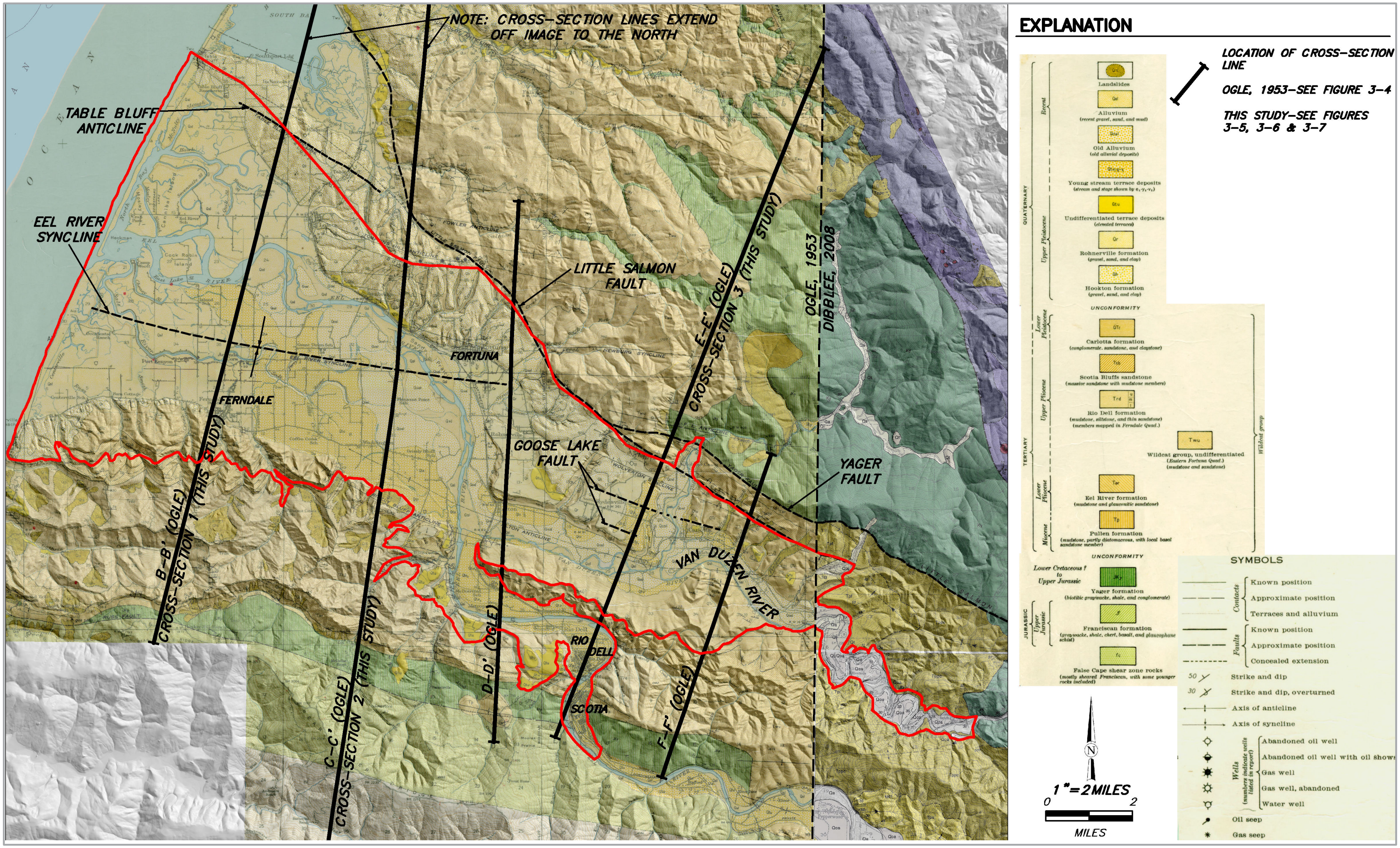

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Eel River Valley Groundwater
Sustainability Plan

Geologic Map
(Ogle, 1953; Dibblee, 2008)

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FIGURE 10

N:\US\Eureka\Projects\561\11217388\GIS\Maps\Deliverables\11217388_ERVP_GSP\11217388_ERVP_GSP.aprx - F010_GeologicOgle
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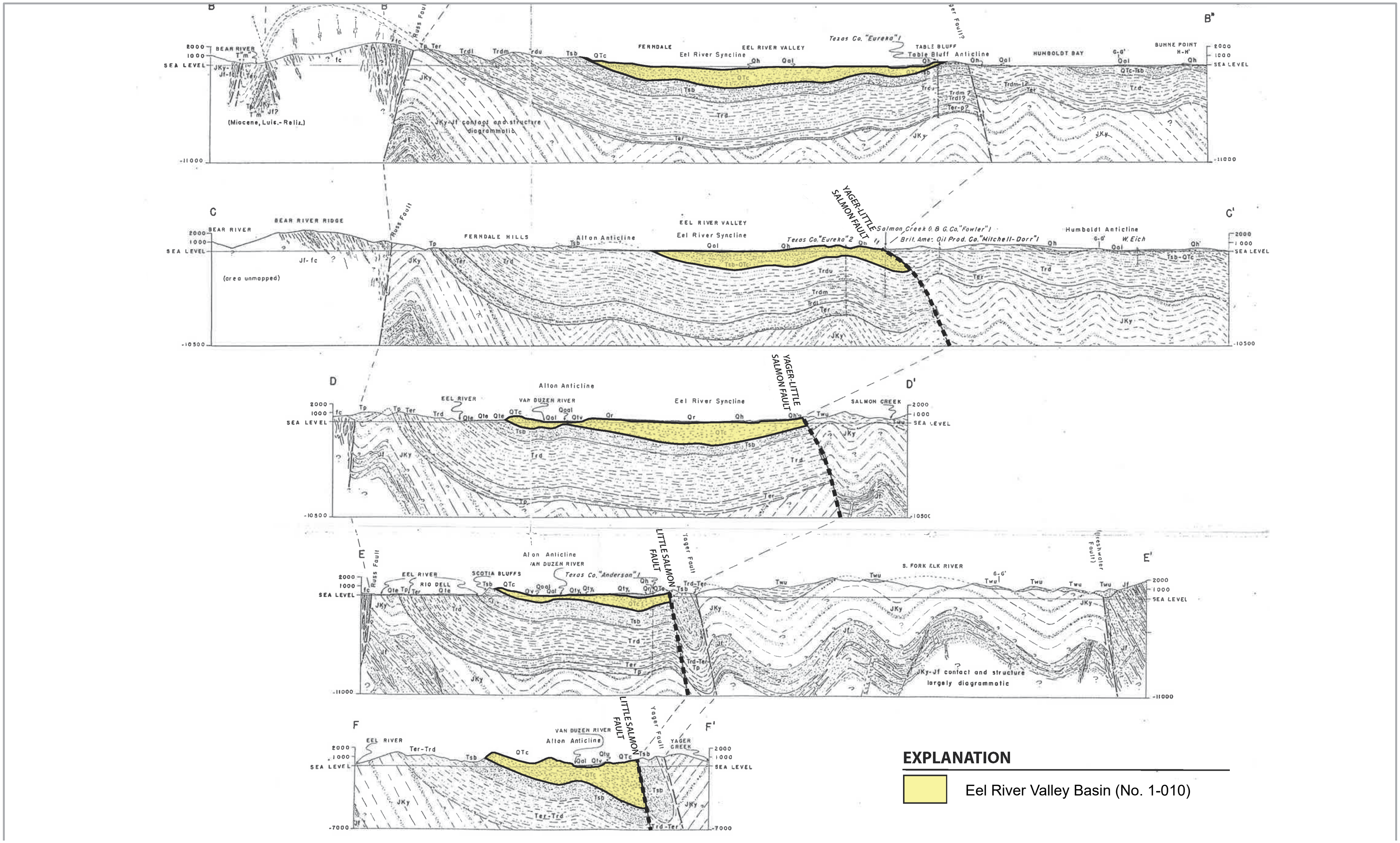

EXPLANATION

▨ Eel River Valley Basin (No. 1-010)

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Geological Cross Sections (Ogle, 1953)

Project No. **11217388**
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FIGURE 11

N:\US\Eureka\Projects\561\11217388\GIS\Maps\Deliverables\11217388_ERVP_GSP\11217388_ERVP_GSP.aprx - F011_GeologicCrossSectionsOgle
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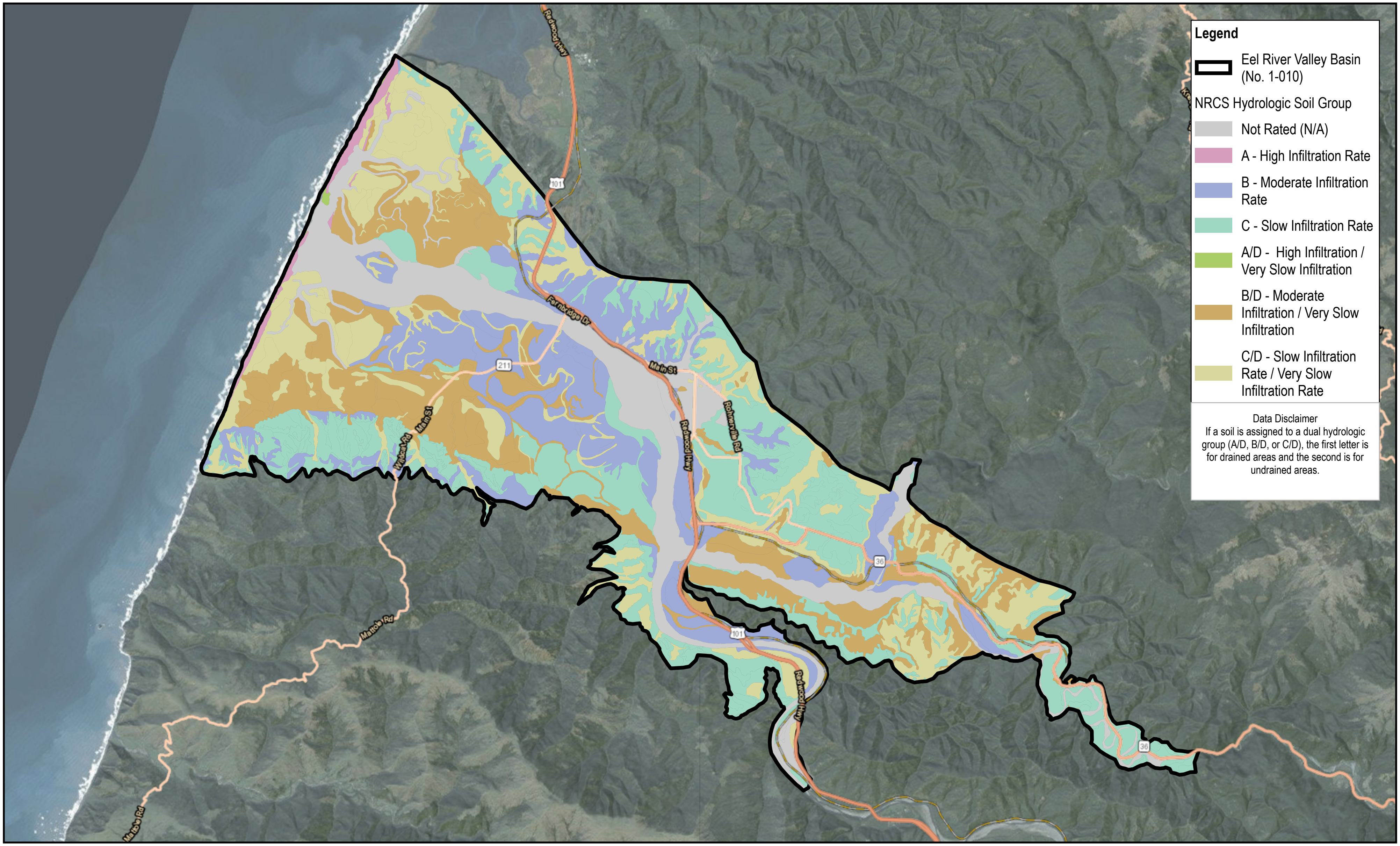

Data Disclaimer
If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas.

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Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane California I FIPS 0401 Feet

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Humboldt County Groundwater Sustainability Agency
Eel River Valley Groundwater
Sustainability Plan

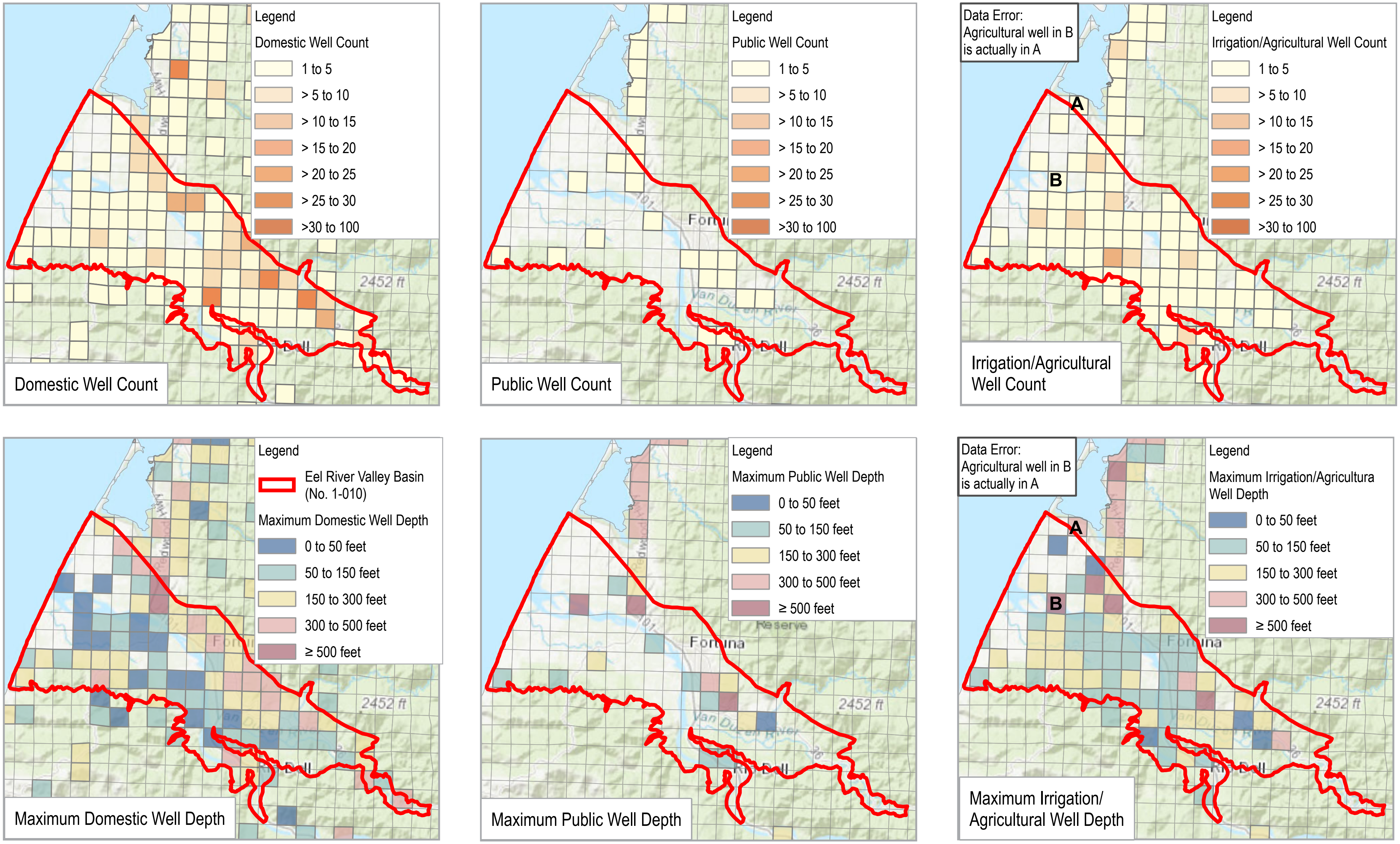
NRCS Mapping by Hydrologic Soil Group

Project No. **11217388**
Revision No. **-**
Date **Jan 2022**

FIGURE 12

N:\US\Eureka\Projects\561\11217388\GIS\Maps\Deliverables\11217388_ERVP_GSP\11217388_ERVP_GSP.aprx - F012_NRCSHydroSoilGroup
Print date: 20 Jan 2022 - 10:33

Data source: DWR basin, 2013; NRCS 2021; World Imagery (Clarity): This work is licensed under the Esri Master License Agreement.View Summary | View Terms of UseExport: This layer is not intended to be used to export tiles for offline. Data Collection and Editing: This layer may be used in various ArcGIS apps to support data collection and editing, with the results used internally or shared with others, as described for these use cases.; World_Transportation: Esri, HERE; World Hillshade: Esri, NASA, NGA, USGS. Created by: jclark2



Engineers & Geologists

Stillwater Sciences

GHD

Paper Size ANSI A

0 2 4 6 8

Miles

Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane California I FIPS 0401 Feet

N

Humboldt County Groundwater Sustainability Agency
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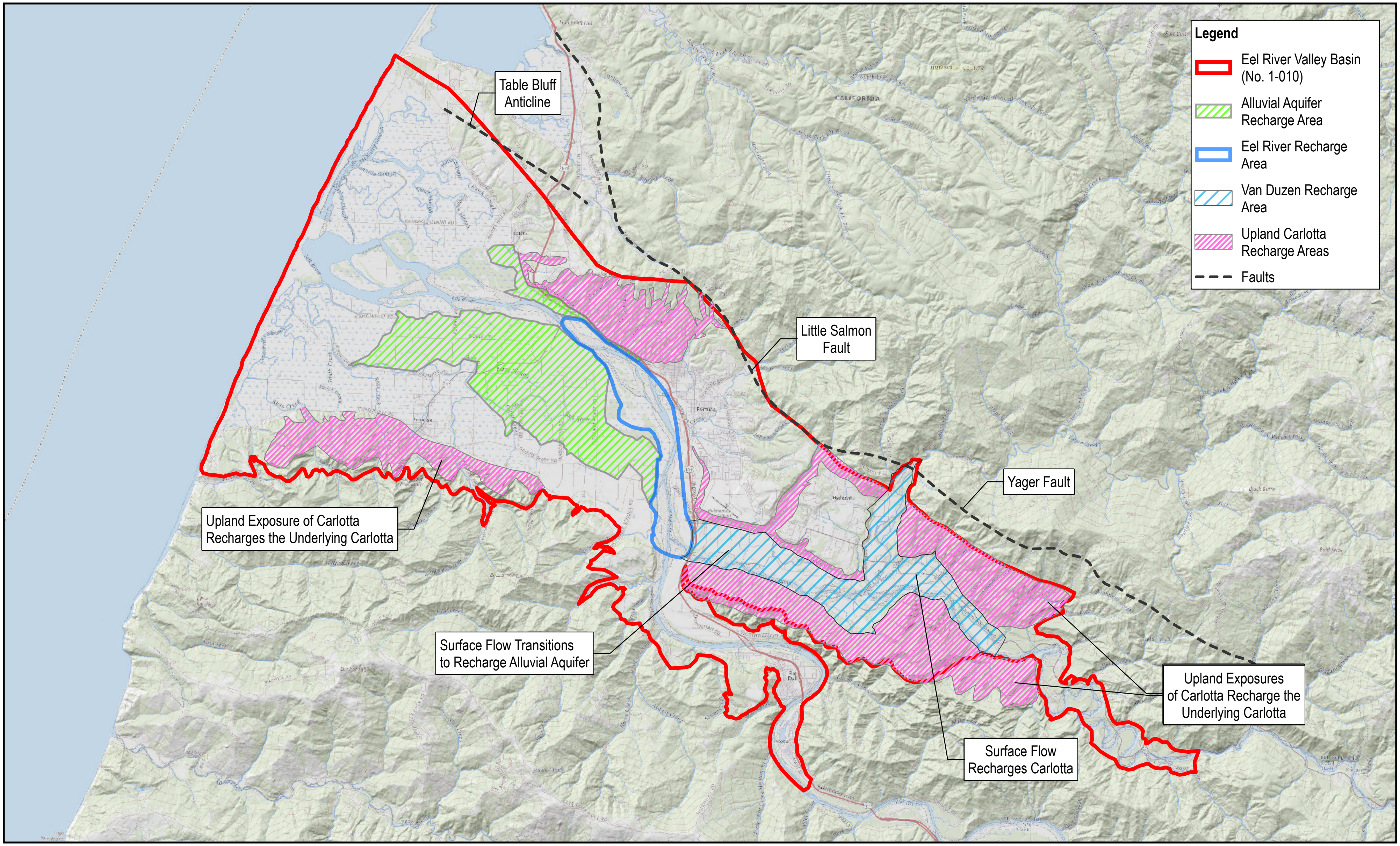
Revision No. **-**
Date **Jan 2022**

Aquifer Use Map

FIGURE 13

N:\US\Eureka\Projects\561\11217388\GIS\Maps\Deliverables\11217388_ERVP_GSP\11217388_ERVP_GSP.aprx - F013_AquiferUse
Print date: 20 Jan 2022 - 10:34

Data source: DWR basin, 2013; CA Dept Water, Nov 2021; World Topographic Map: Esri, HERE, Garmin, USGS, NGA, EPA, USDA, NPS. Created by: jclark2



Engineers & Geologists

Paper Size ANSI A

0 1 2 3

Miles

N

Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane California I FIPS 0401 Feet

Humboldt County Groundwater Sustainability Agency
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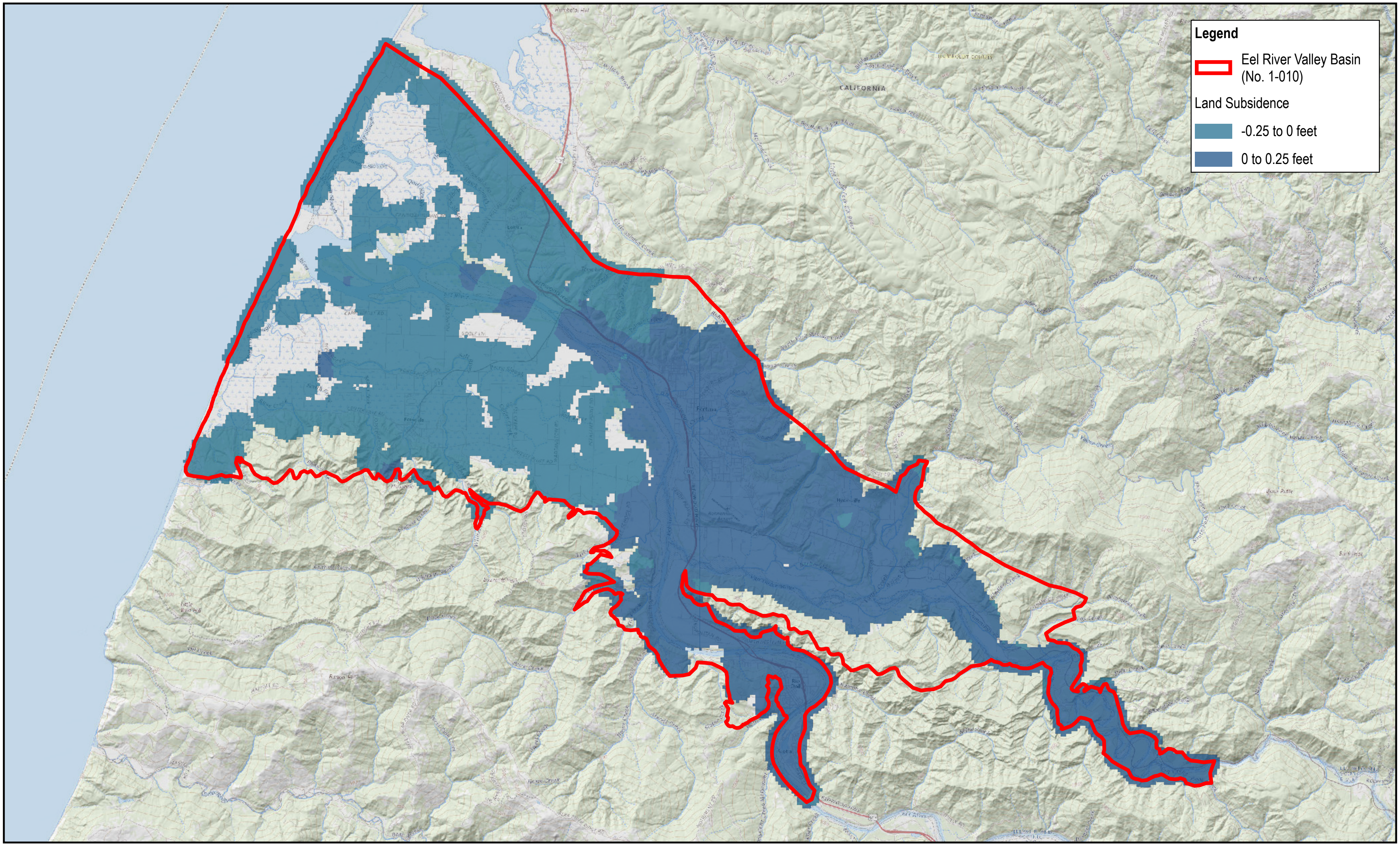
Important Recharge Areas

FIGURE 14

N:\US\Eureka\Projects\561\11217388\GIS\Maps\Deliverables\11217388_ERVP_GSP\11217388_ERVP_GSP.aprx - F014_ImportantRechargeAreas
Print date: 20 Jan 2022 - 10:35

Data source: DWR basin, 2013; SHN;USGS National Map: USGS The National Map: National Boundaries Dataset, National Elevation Dataset, Geographic Names Information System, National Hydrography Dataset, National Land Cover Database, National Structures Dataset, and National Transportation Dataset; U.S. Census Bureau - TIGER/Line; HERE Road Data. Created by: jclark2



Engineers & Geologists

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GHD

Paper Size ANSI A

0 1 2 3

Miles

Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane California I FIPS 0401 Feet

N

Humboldt County Groundwater Sustainability Agency
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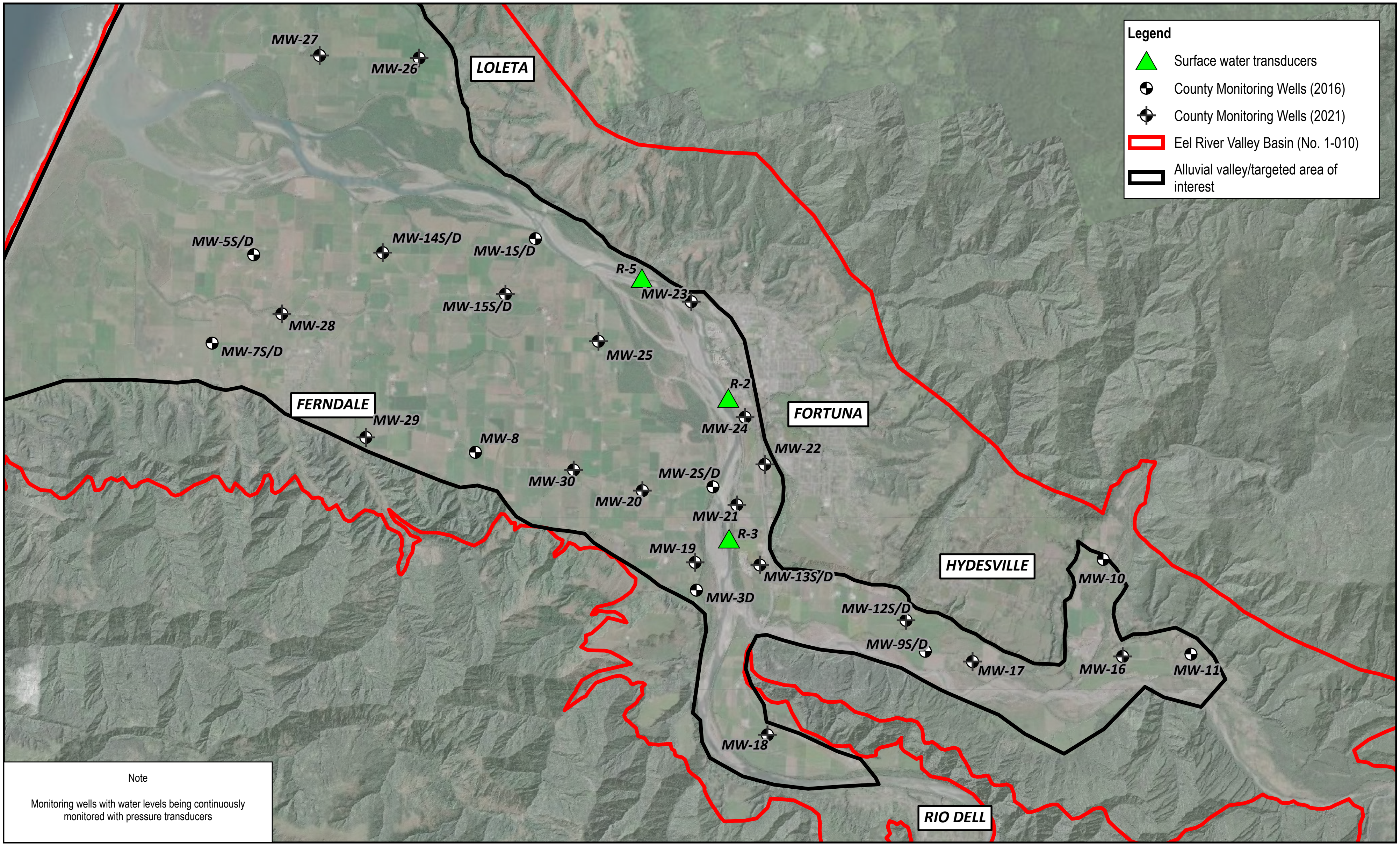
Land Subsidence

FIGURE 15

N:\US\Eureka\Projects\561\11217388\GIS\Maps\Deliverables\11217388_ERVP_GSP\11217388_ERVP_GSP.aprx - F015_LandSubsidence
Print date: 20 Jan 2022 - 10:38

Data source: DWR basin, 2013; SAR\Vertical_Displacement_TRE_ALTAMIRA_v2020_Total_Since_20150613_Mosaic: California Department of Water Resources
USGS National Map: USGS The National Map: National Boundaries Dataset, National Elevation Dataset, Geographic Names Information System, National Hydrography Dataset, National Land Cover Database, National Structures Dataset, and National Transportation Dataset; U.S. Census Bureau - TIGER/Line; HERE Road Data. Created by: jclark2



Note

Monitoring wells with water levels being continuously monitored with pressure transducers

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Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane California I FIPS 0401 Feet

Humboldt County Groundwater Sustainability Agency
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County Monitoring Wells

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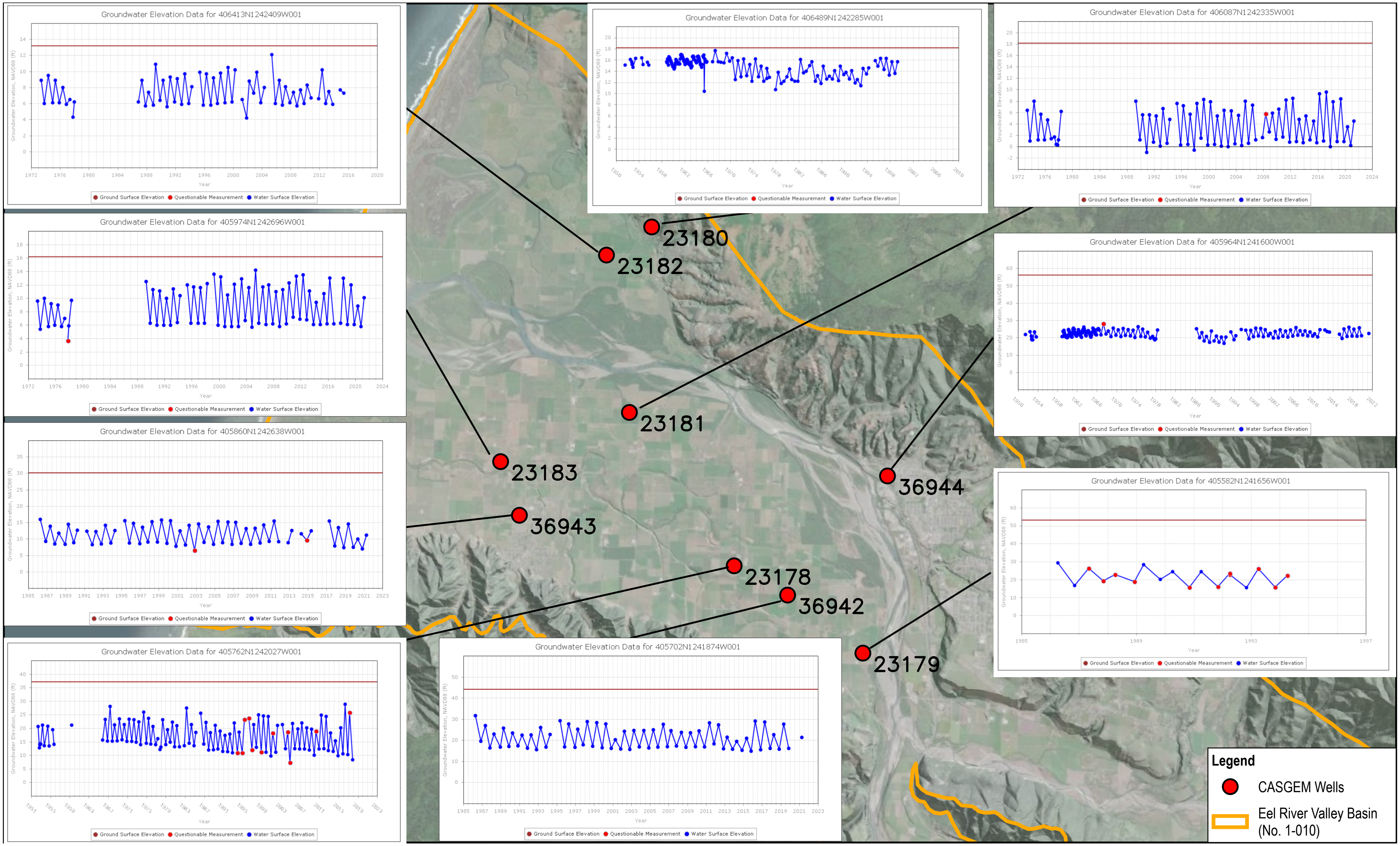
FIGURE 16

N:\US\Eureka\Projects\561\11217388\GIS\Maps\Deliverables\11217388_ERVP_GSP\11217388_ERVP_GSP.aprx - F016_CountyMW
Print date: 20 Jan 2022 - 10:40

Data source: DWR basin, 2013; SHN; Humboldt County; USGS elevation; World Imagery: Earthstar Geographics. Created by: jclark2



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Stillwater Sciences

Paper Size ANSI A

0 1 2

Miles

Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane California I FIPS 0401 Feet

N

Humboldt County Groundwater Sustainability Agency
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CASGEM Hydrographs

Project No. **11217388**
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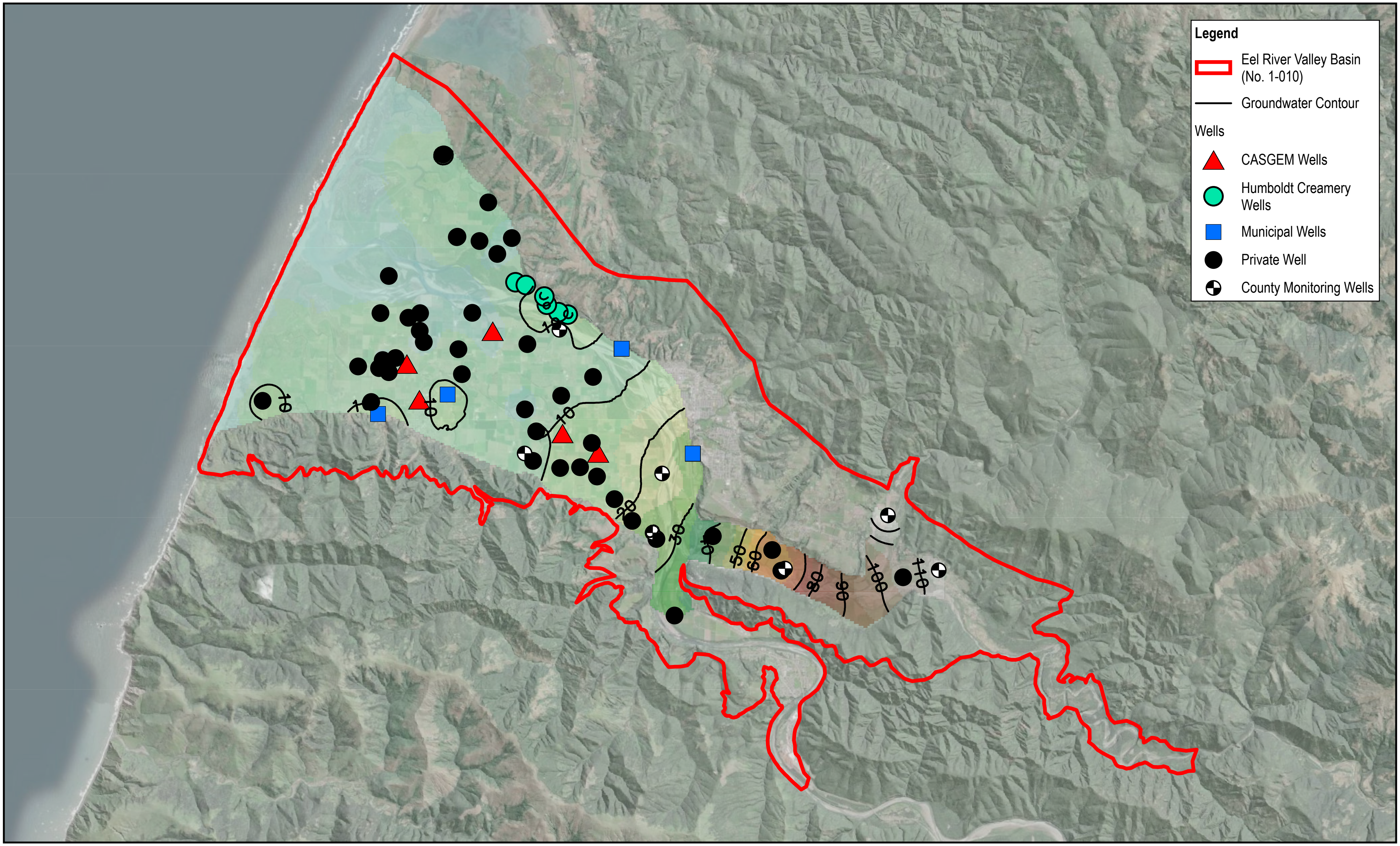
Date **Jan 2022**

FIGURE 17

N:\US\Eureka\Projects\561\11217388\GIS\Maps\Deliverables\11217388_ERVP_GSP\11217388_ERVP_GSP.aprx - F017_CASGEMhydrographs
Print date: 20 Jan 2022 - 10:42

Data source: DWR basin, 2013; SHN; CASGEM; World Imagery: Earthstar Geographics. Created by: jclark2



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Stillwater Sciences

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Paper Size ANSI A

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Miles

Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane California I FIPS 0401 Feet

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Humboldt County Groundwater Sustainability Agency
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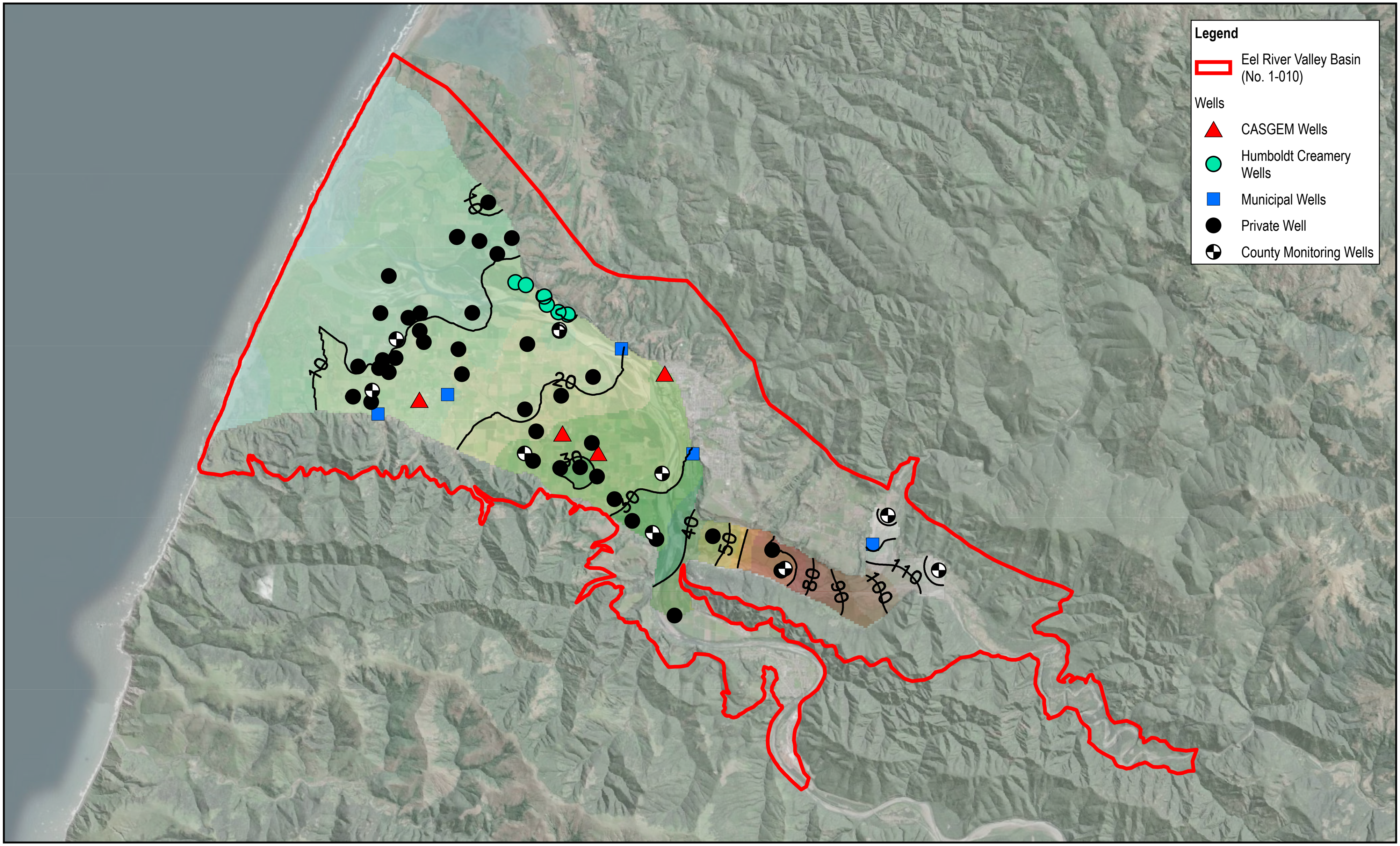
Revision No. **-**
Date **Jan 2022**

Fall 2016 Groundwater Contour Map

FIGURE 18

N:\US\Eureka\Projects\561\11217388\GIS\Maps\Deliverables\11217388_ERVP_GSP\11217388_ERVP_GSP.aprx -
F018_Fall2016GWContour
Print date: 20 Jan 2022 - 10:46

Data source: DWR basin, 2013; CASGEM; SHN; Humboldt County; World Imagery: Earthstar Geographics. Created by: jclark2



Paper Size ANSI A

0 1 2 3

Miles

Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane California I FIPS 0401 Feet

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Sustainability Plan

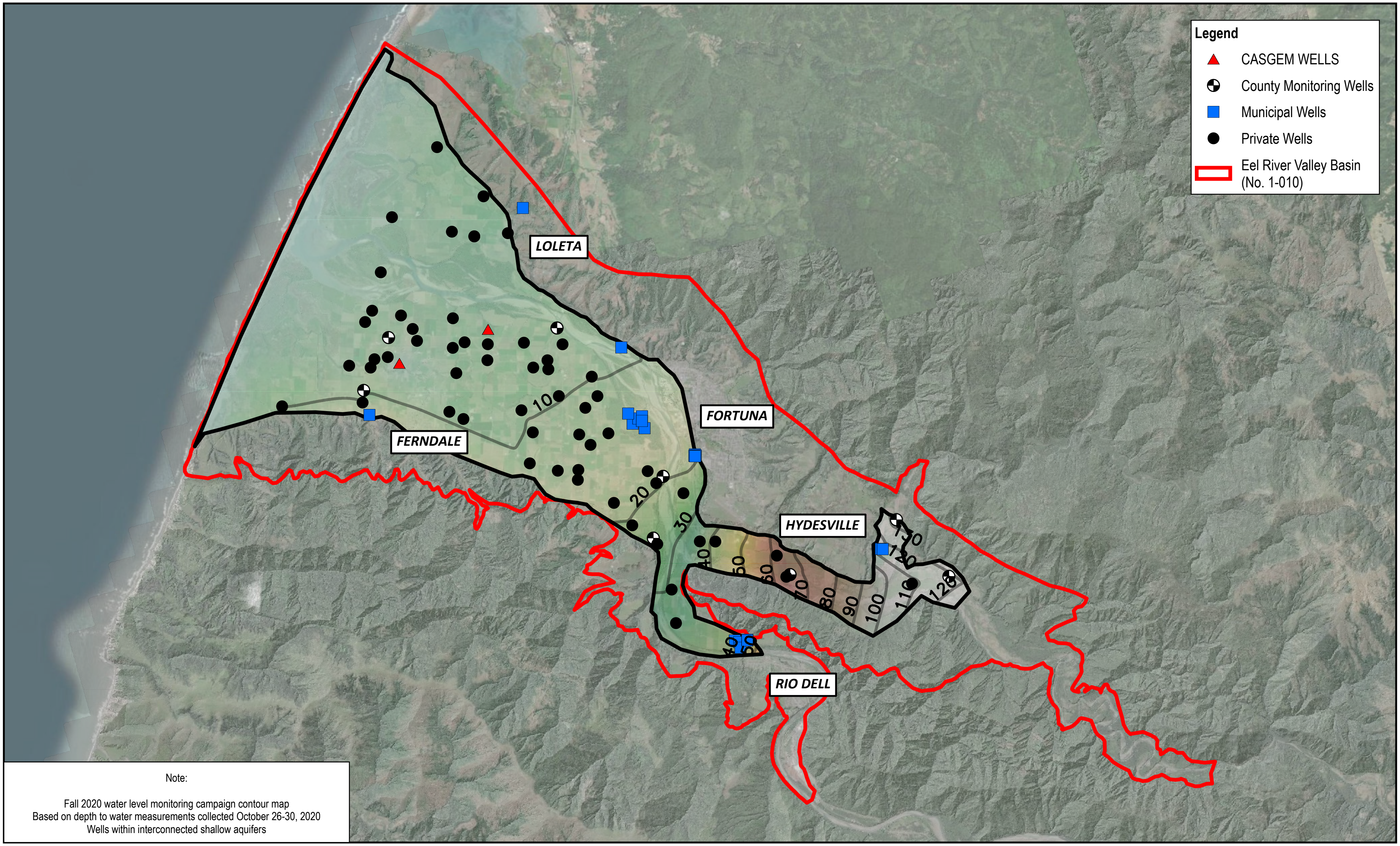
Project No. **11217388**
Revision No. **-**
Date **Jan 2022**

Spring 2017 Groundwater Contour Map

FIGURE 19

N:\US\Eureka\Projects\561\11217388\GIS\Maps\Deliverables\11217388_ERVP_GSP\11217388_ERVP_GSP.aprx - F019_Spring2017GWContour
Print date: 20 Jan 2022 - 10:47

Data source: DWR basin, 2013; CASGEM; SHN; Humboldt County; World Imagery: Earthstar Geographics. Created by: jclark2



Note:

Fall 2020 water level monitoring campaign contour map
Based on depth to water measurements collected October 26-30, 2020
Wells within interconnected shallow aquifers

Engineers & Geologists

Paper Size ANSI A

0 1 2 3

Miles

Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane California I FIPS 0401 Feet

N

Humboldt County Groundwater Sustainability Agency
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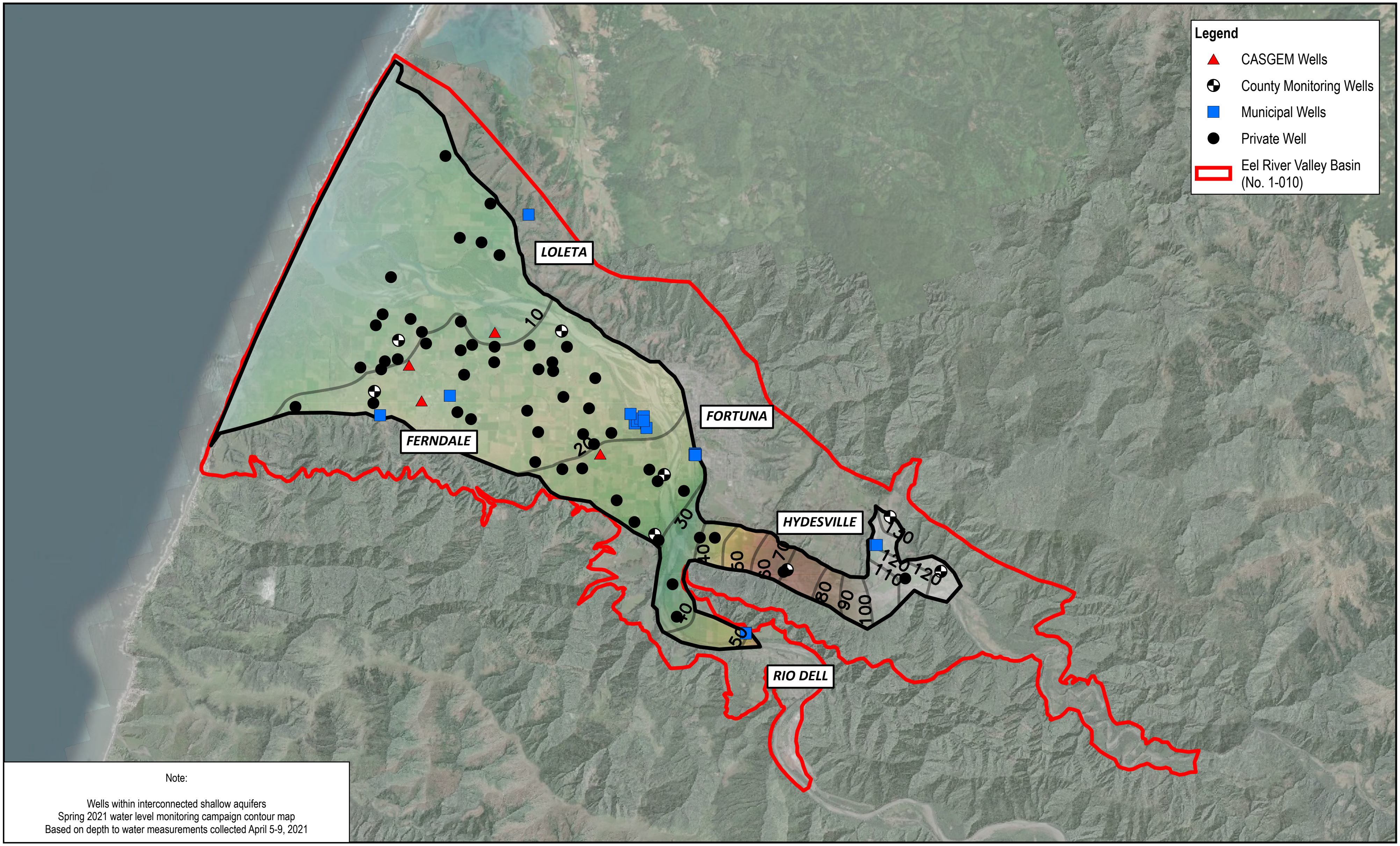
Fall 2020 Groundwater Contour Map

Project No. **11217388**
Revision No. **-**
Date **Jan 2022**

FIGURE 20

N:\US\Eureka\Projects\561\11217388\GIS\Maps\Deliverables\11217388_ERVP_GSP\11217388_ERVP_GSP.aprx - F020_Fall2020GWContour
Print date: 20 Jan 2022 - 10:43

Data source: DWR basin, 2013; CASGEM; Humboldt County; SHN; USGS; World Imagery: Earthstar Geographics. Created by: jclark2



Note:

Wells within interconnected shallow aquifers
Spring 2021 water level monitoring campaign contour map
Based on depth to water measurements collected April 5-9, 2021

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Paper Size ANSI A
0 1 2 3
Miles

N

Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane California I FIPS 0401 Feet

Humboldt County Groundwater Sustainability Agency
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Spring 2021 Groundwater Contour Map

Project No. **11217388**
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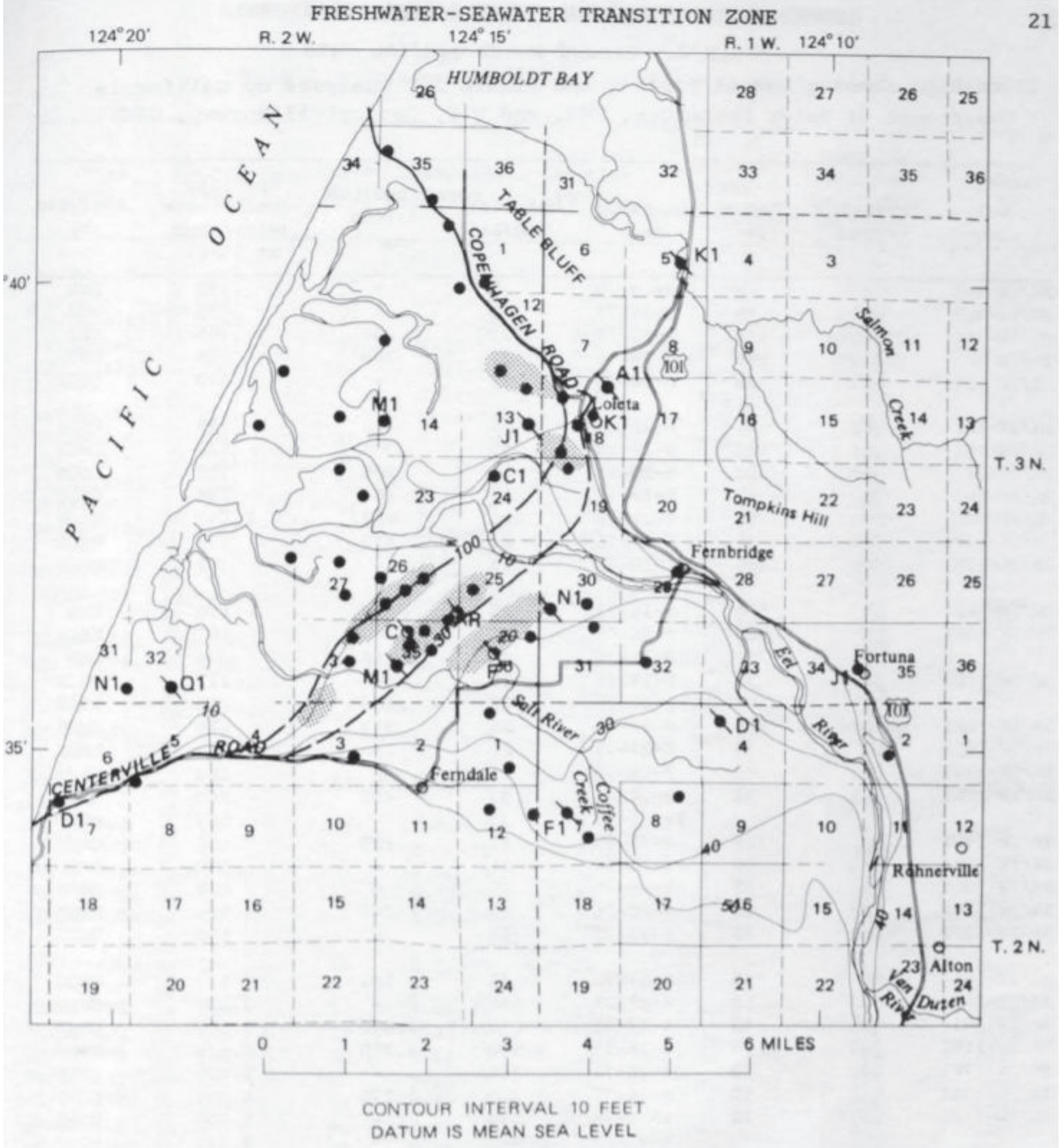
Date **Jan 2022**

FIGURE 21

N:\US\Eureka\Projects\561\11217388\GIS\Maps\Deliverables\11217388_ERVP_GSP\11217388_ERVP_GSP.aprx - F021_Spring2021GWContour
Print date: 20 Jan 2022 - 10:49

Data source: DWR basin, 2013; CASGEM; SHN; Humboldt County; USGS; World Imagery: Earthstar Geographics. Created by: jclark2

FRESHWATER-SEAWATER TRANSITION ZONE



EXPLANATION

▨ Area suggested for additional water-quality monitoring

— 30 — — LINE OF EQUAL CHLORIDE CONCENTRATION, 1975 – Dashed where approximately located. Concentration in milligrams per liter. The 100-milligrams-per-liter line indicates the landward edge of the freshwater-seawater transition zone. Area generally east of the 30-milligrams-per-liter line contains shallow ground water with chloride concentrations less than 30 milligrams per liter

D1● Control well and identification for well referred to in text

M1● Well monitored by California Department of Water Resources and identification for well referred to in text

C○ Recommended additional monitoring well and identification for well referred to in text

Humboldt County Groundwater Sustainability Agency
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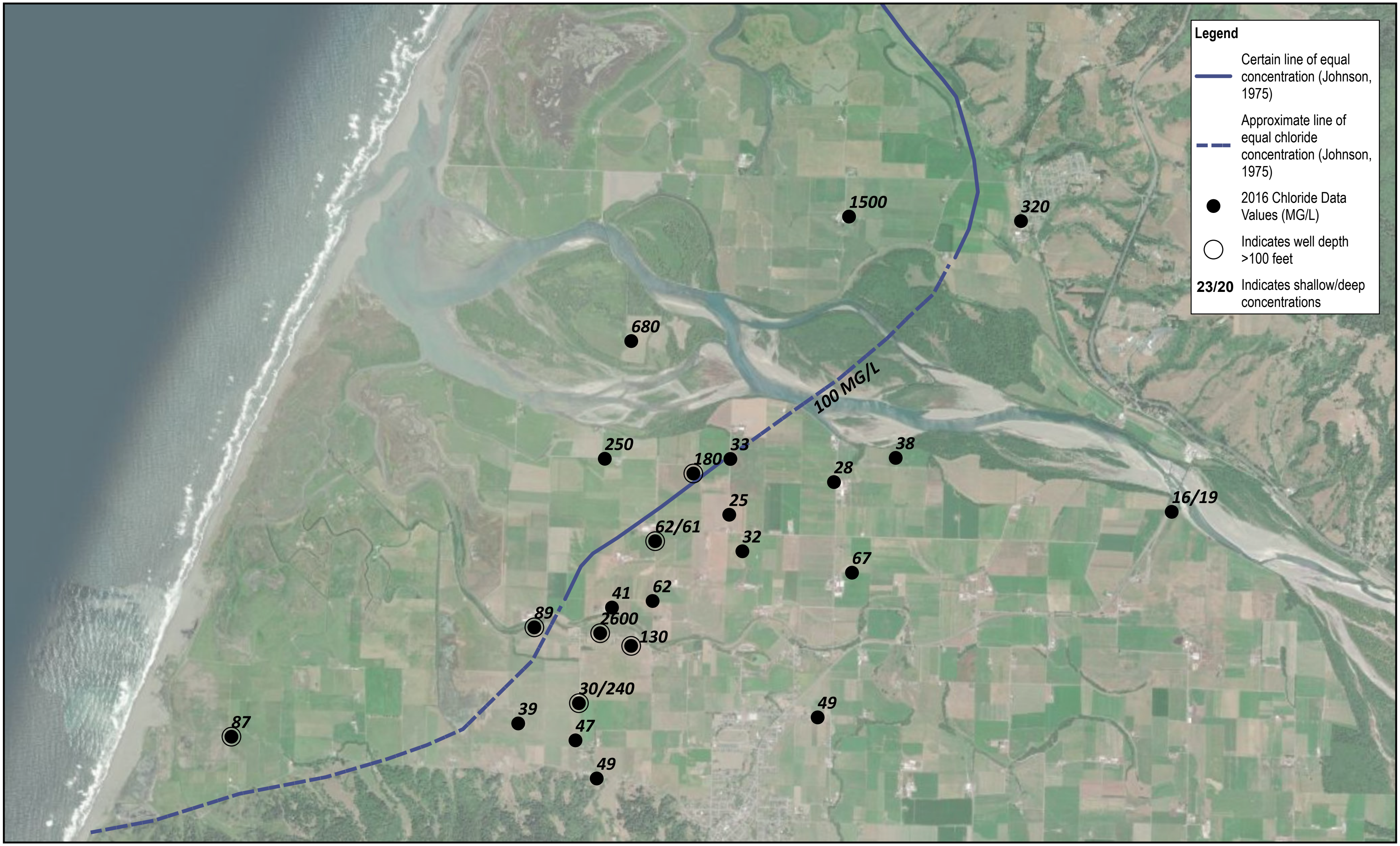
1975 Chloride Map

FIGURE 22

N:\US\Eureka\Projects\561\11217388\GIS\Maps\Deliverables\11217388_ERVP_GSP\11217388_ERVP_GSP.aprx
Print date: 20 Jan 2022 - 10:50

Data source: USGS, 1978 . Created by: jclark2



Paper Size ANSI A

0 5,000

Feet

Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane California I FIPS 0401 Feet

N

Humboldt County Groundwater Sustainability Agency
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Fall 2016 Chloride Map

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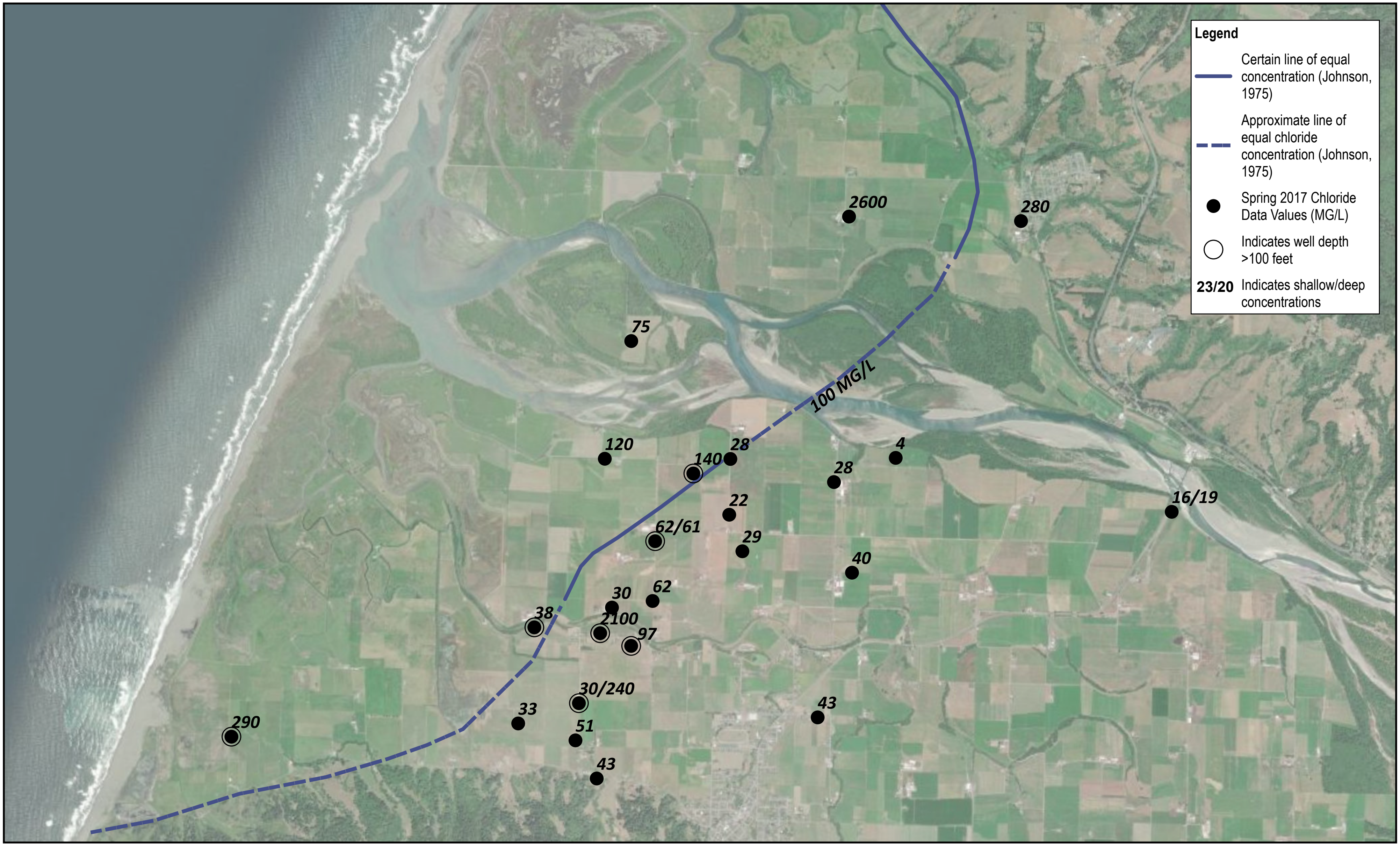
Date **Jan 2022**

FIGURE 23

N:\US\Eureka\Projects\561\11217388\GIS\Maps\Deliverables\11217388_ERVP_GSP\11217388_ERVP_GSP.aprx -
F023_Fall2016Chloride
Print date: 20 Jan 2022 - 10:52

Data source: Johnson, 1975; SHN; World Imagery: Earthstar Geographics. Created by: jclark2



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Stillwater Sciences

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Paper Size ANSI A

0 5,000

Feet

Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane California I FIPS 0401 Feet

N

COUNTY OF HUMBOLDT
The Home of the Redwoods

Humboldt County Groundwater Sustainability Agency
Eel River Valley Groundwater
Sustainability Plan

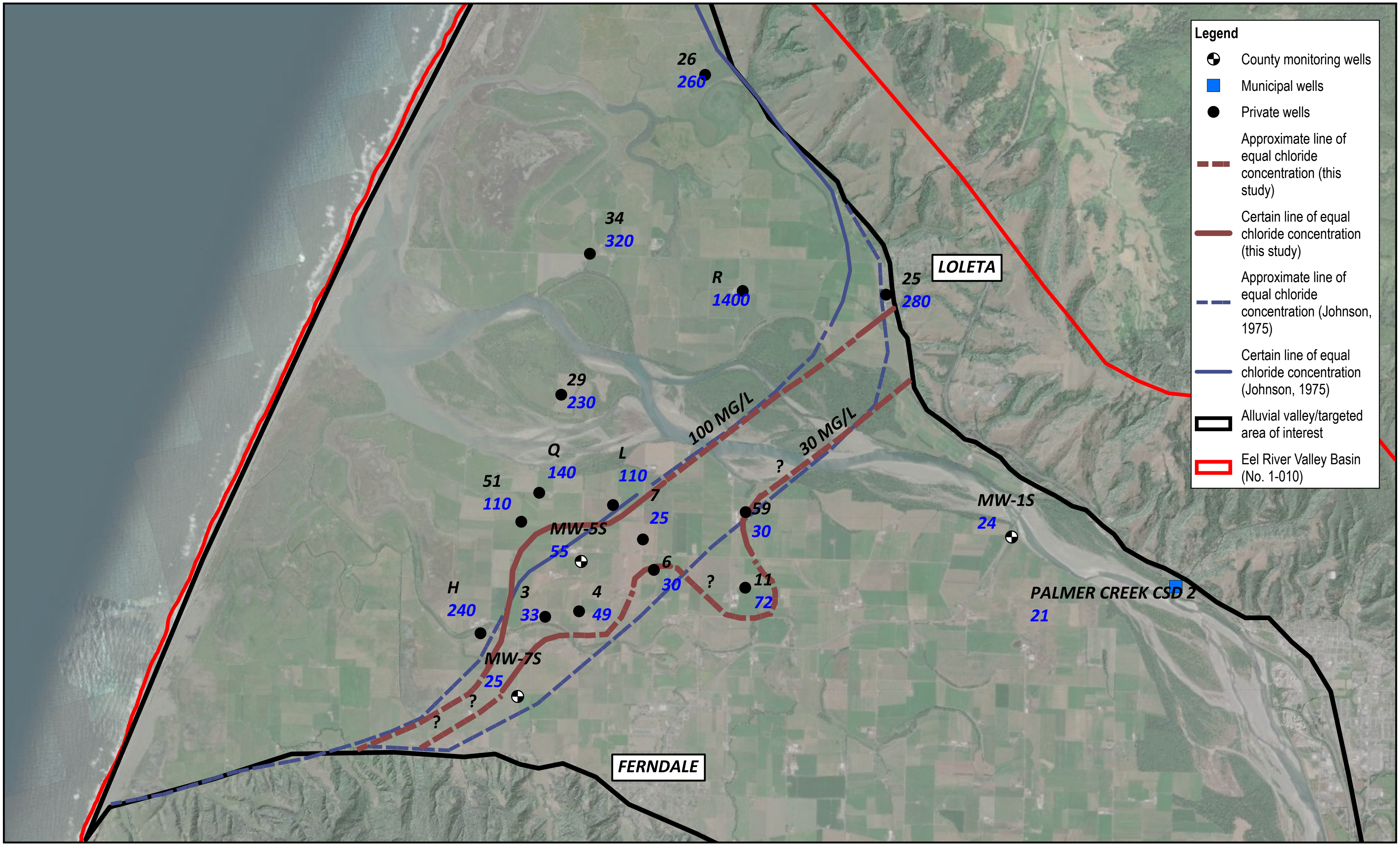
Project No. **11217388**
Revision No. **-**
Date **Jan 2022**

Spring 2017 Chloride Map

FIGURE 24

N:\US\Eureka\Projects\561\11217388\GIS\Maps\Deliverables\11217388_ERVP_GSP\11217388_ERVP_GSP.aprx - F024_Spring2017Chloride
Print date: 20 Jan 2022 - 10:53

Data source: Johnson, 1975; SHN; World Imagery: Earthstar Geographics. Created by: jclark2



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Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane California I FIPS 0401 Feet

Humboldt County Groundwater Sustainability Agency
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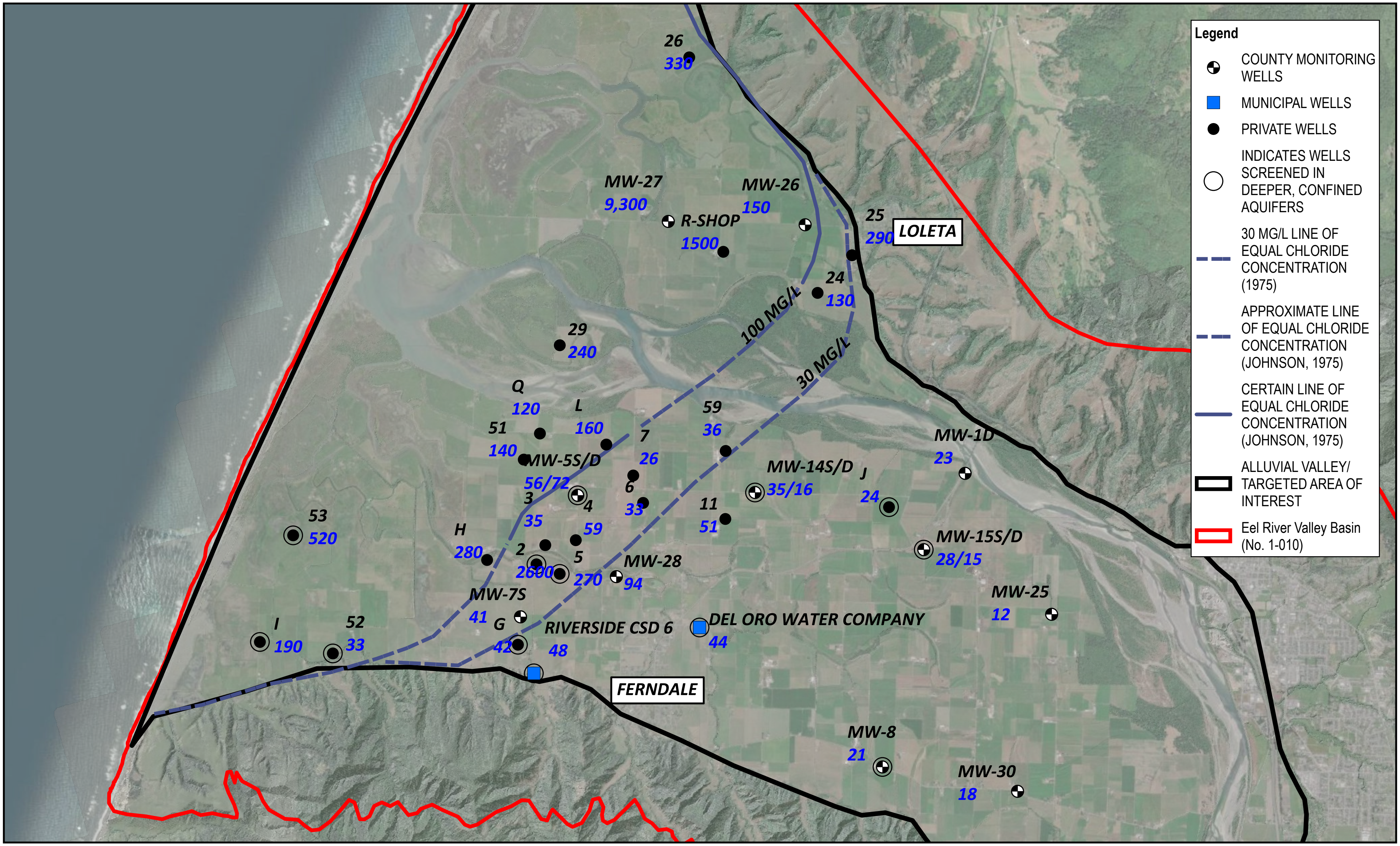
Date **Jan 2022**

Fall 2020 Chloride Map

FIGURE 25

N:\US\Eureka\Projects\561\11217388\GIS\Maps\Deliverables\11217388_ERVP_GSP\11217388_ERVP_GSP.aprx - F025_Fall2020Chloride
Print date: 20 Jan 2022 - 10:56

Data source: DWR basin, 2013; Johnson, 1975; SHN; Humboldt County; World Imagery: Earthstar Geographics. Created by: jclark2



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Paper Size ANSI A

0 2,000 4,000 6,000

Feet

Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane California I FIPS 0401 Feet

N

COUNTY OF HUMBOLDT
The Home of the Redwoods

Humboldt County Groundwater Sustainability Agency
Eel River Valley Groundwater
Sustainability Plan

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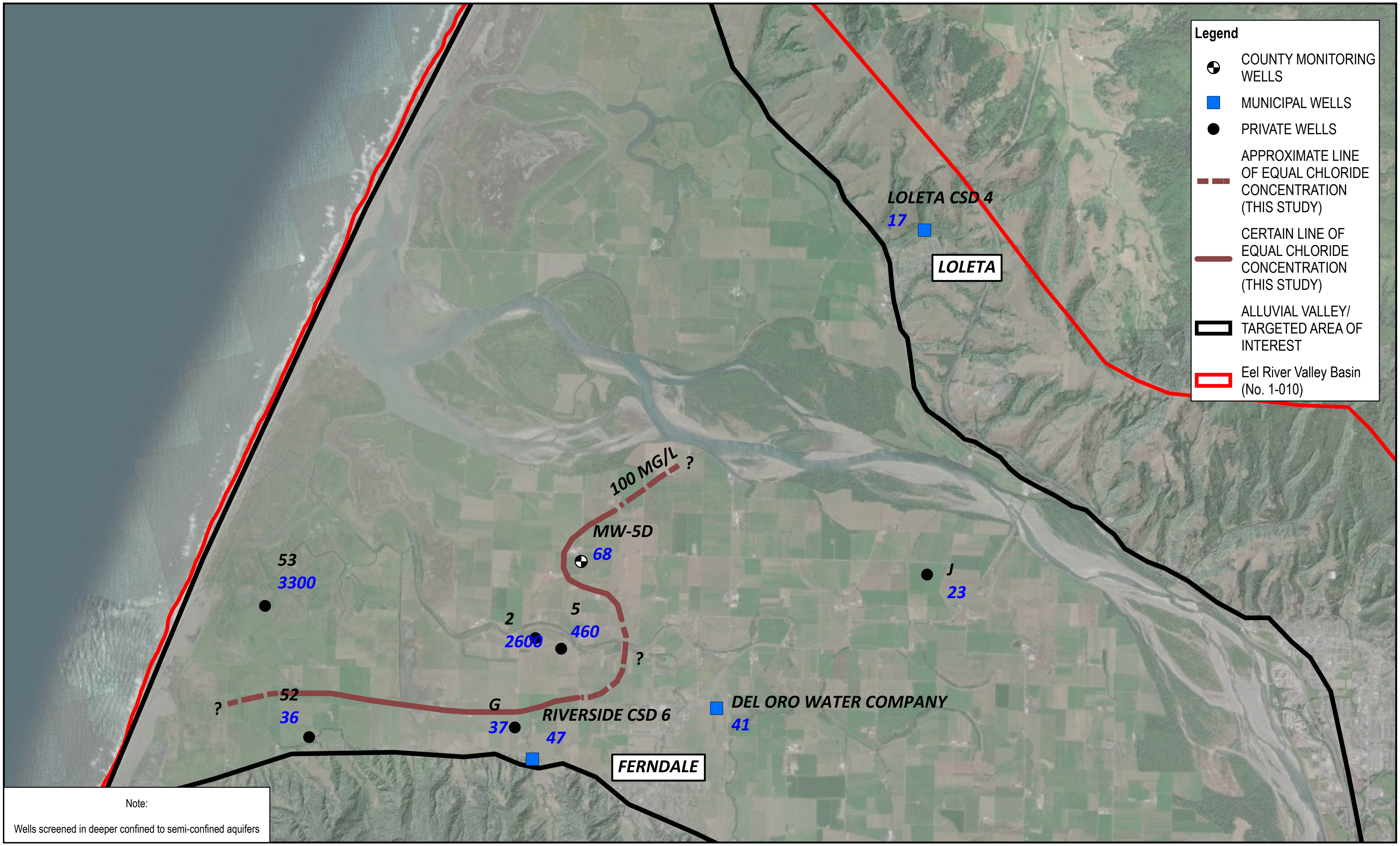
Date **Jan 2022**

Spring 2021 Chloride Map

FIGURE 26

N:\US\Eureka\Projects\561\11217388\GIS\Maps\Deliverables\11217388_ERVP_GSP\11217388_ERVP_GSP.aprx - F026_Spring2021Chloride
Print date: 20 Jan 2022 - 10:57

Data source: DWR basin, 2013; Johnson, 1975; SHN; Humboldt County; World Imagery: Earthstar Geographics. Created by: jclark2



Note:

Wells screened in deeper confined to semi-confined aquifers

Engineers & Geologists

Paper Size ANSI A

0 2,000 4,000 6,000

Feet

Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane California I FIPS 0401 Feet

N

Humboldt County Groundwater Sustainability Agency
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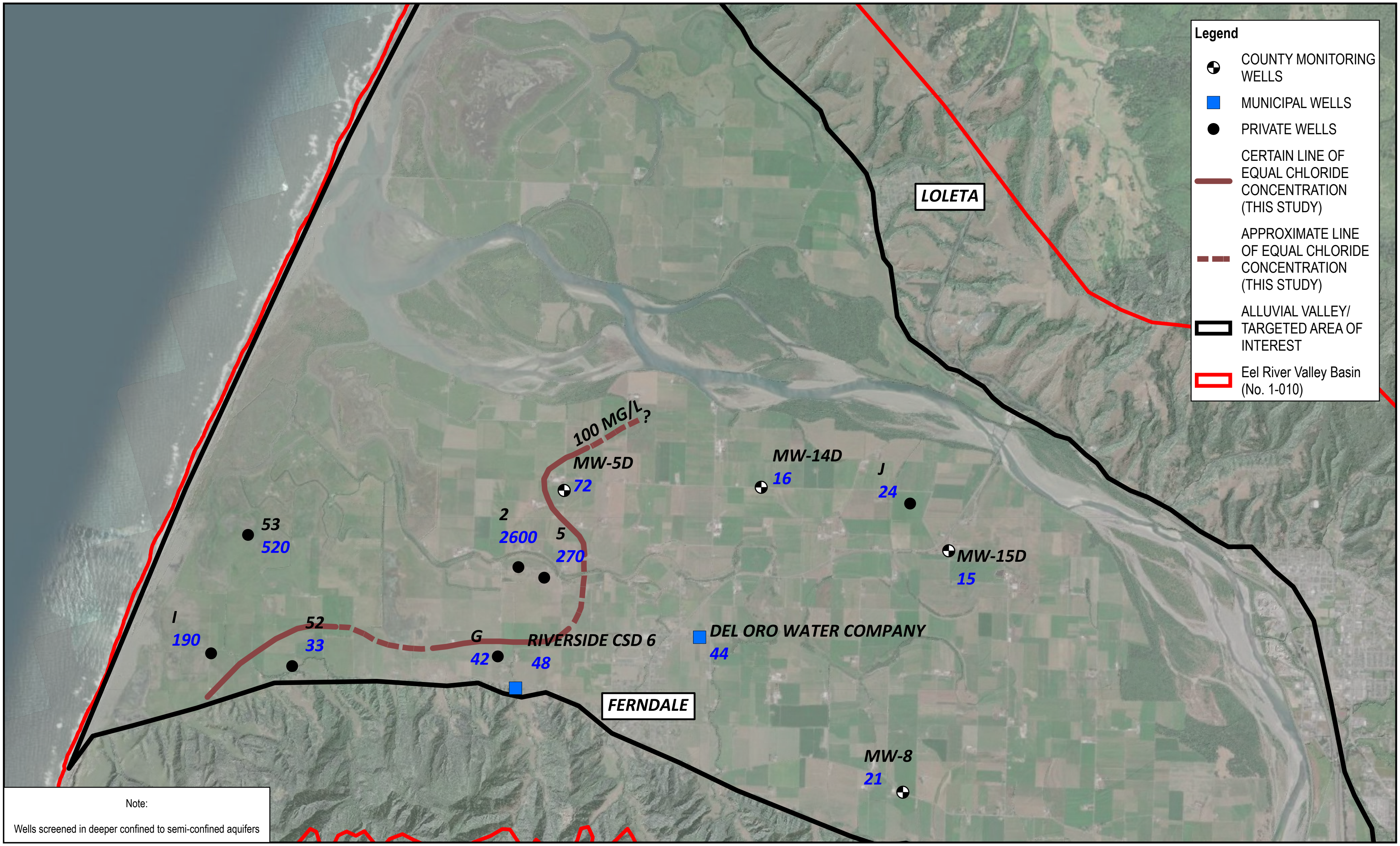
Project No. 11217388
Revision No. -
Date Jan 2022

Fall 2020 Deep Chloride Map

FIGURE 27

N:\US\Eureka\Projects\561\11217388\GIS\Maps\Deliverables\11217388_ERVP_GSP\11217388_ERVP_GSP.aprx - F027_Fall2020DeepChloride
Print date: 20 Jan 2022 - 10:59

Data source: DWR basin, 2013; SHN; Humboldt County; World Imagery: Earthstar Geographics. Created by: jclark2



Engineers & Geologists

Paper Size ANSI A

0 2,000 4,000 6,000

Feet

Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane California I FIPS 0401 Feet

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Humboldt County Groundwater Sustainability Agency
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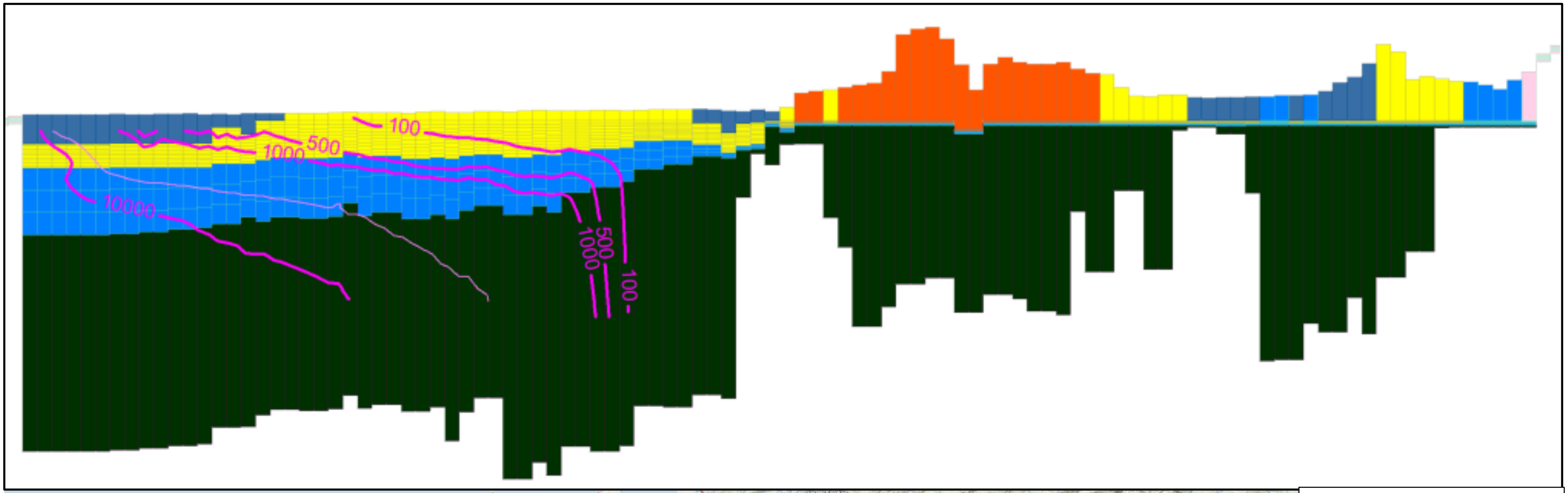
Date **Jan 2022**

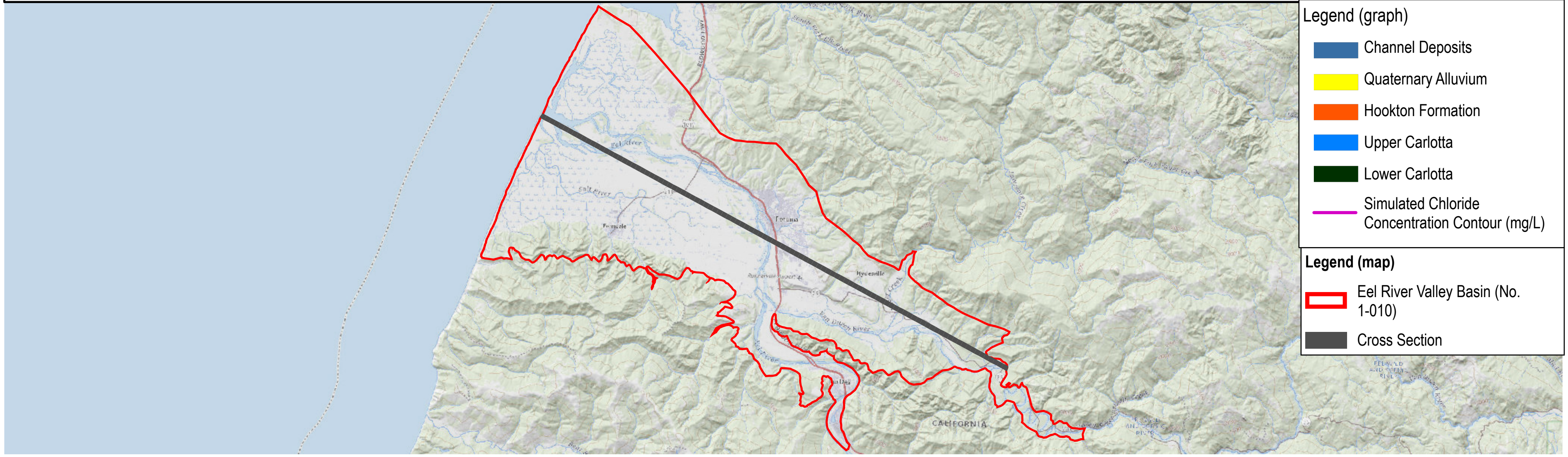
Spring 2021 Deep Chloride Map

FIGURE 28

N:\US\Eureka\Projects\561\11217388\GIS\Maps\Deliverables\11217388_ERVP_GSP\11217388_ERVP_GSP.aprx - F028_Spring2021DeepChloride
Print date: 20 Jan 2022 - 10:59

Data source: DWR basin, 2013; SHN; Humboldt County; World Imagery: Earthstar Geographics. Created by: jclark2





Legend (graph)

- 🟦 Channel Deposits
- 🟨 Quaternary Alluvium
- 🟧 Hookton Formation
- 🟦 Upper Carlotta
- ⬛ Lower Carlotta
- — Simulated Chloride Concentration Contour (mg/L)

Legend (map)

- 🟥 Eel River Valley Basin (No. 1-010)
- ▬ Cross Section

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Miles

Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane California I FIPS 0401 Feet

N

Humboldt County Groundwater Sustainability Agency
Eel River Valley Groundwater
Sustainability Plan

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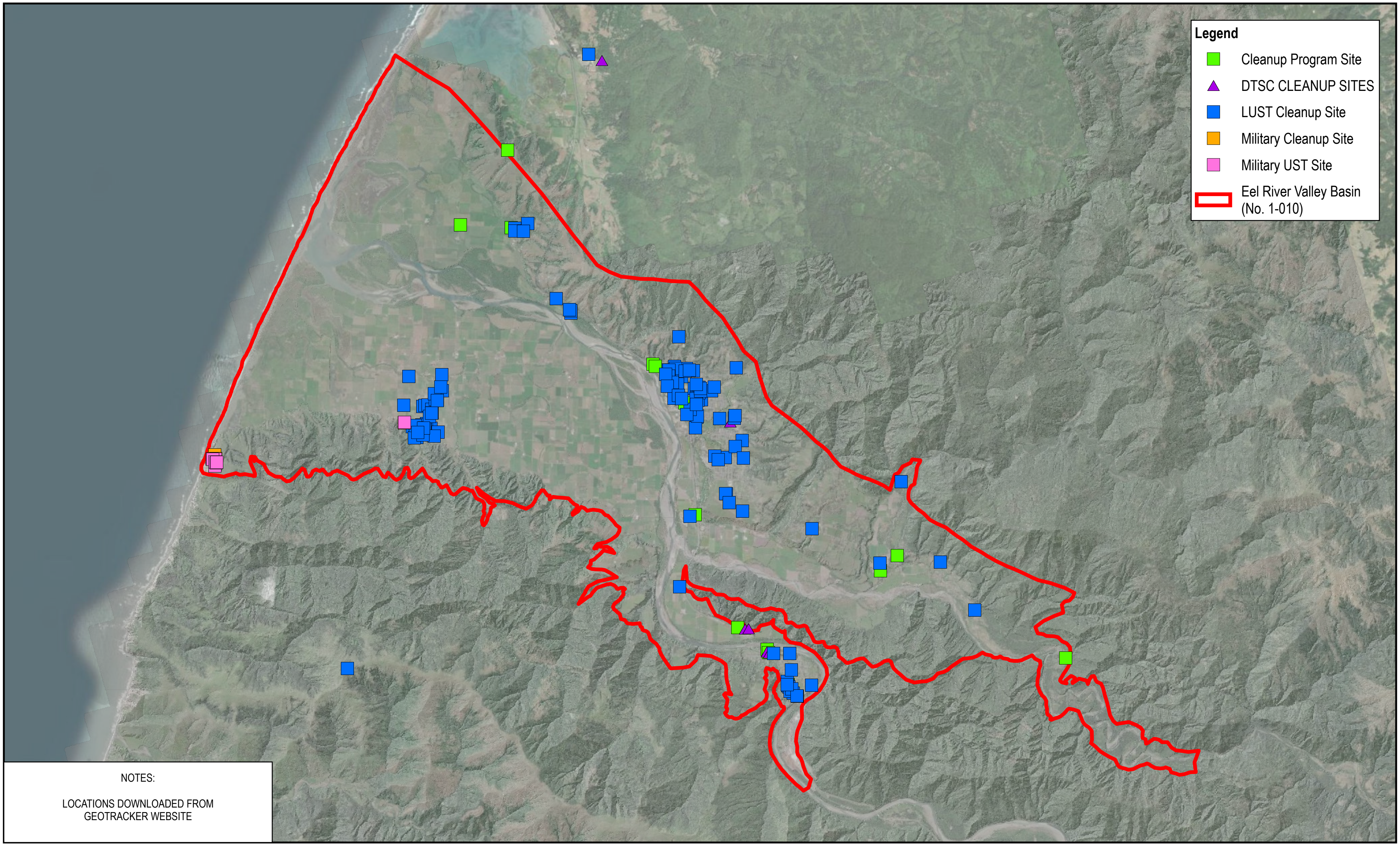
Date **Jan 2022**

Seawater Deep Chloride Cross Section

FIGURE 29

N:\US\Eureka\Projects\561\11217388\GIS\Maps\Deliverables\11217388_ERVP_GSP\11217388_ERVP_GSP.aprx - F029_SeawaterDeepChlorideCrossSection_RevA
Print date: 20 Jan 2022 - 11:01

Data source: DWR basin, 2013; GHD; USGS National Map: USGS The National Map: National Boundaries Dataset, National Elevation Dataset, Geographic Names Information System, National Hydrography Dataset, National Land Cover Database, National Structures Dataset, and National Transportation Dataset; U.S. Census Bureau - TIGER/Line; HERE Road Data. Created by: jclark2



NOTES:

LOCATIONS DOWNLOADED FROM GEOTRACKER WEBSITE

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Paper Size ANSI A

0 1 2 3

Miles

Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane California I FIPS 0401 Feet

N

Humboldt County Groundwater Sustainability Agency
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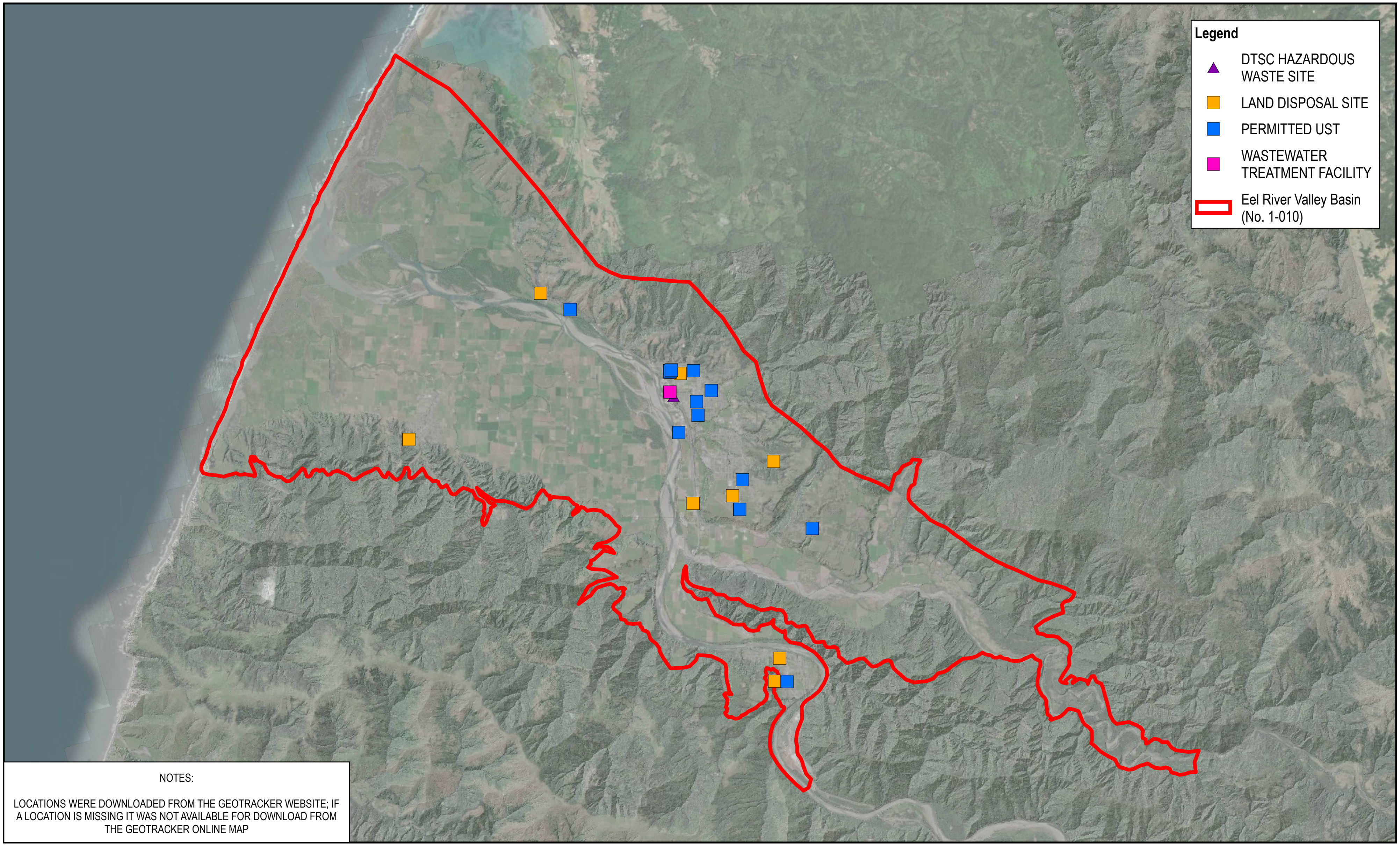
Date **Jan 2022**

Geotracker UST and CleanUp Sites

FIGURE 30

N:\US\Eureka\Projects\561\11217388\GIS\Maps\Deliverables\11217388_ERVP_GSP\11217388_ERVP_GSP.aprx - F030_GeoTrackerUSTCleanup
Print date: 20 Jan 2022 - 11:04

Data source: DWR basin, 2013; Geotracker; USGS; World Imagery: Earthstar Geographics. Created by: jclark2



NOTES:

LOCATIONS WERE DOWNLOADED FROM THE GEOTRACKER WEBSITE; IF A LOCATION IS MISSING IT WAS NOT AVAILABLE FOR DOWNLOAD FROM THE GEOTRACKER ONLINE MAP

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GHD

Paper Size ANSI A
0 1 2 3
Miles

Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane California I FIPS 0401 Feet

N

COUNTY OF HUMBOLDT
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Humboldt County Groundwater Sustainability Agency
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Project No. **11217388**
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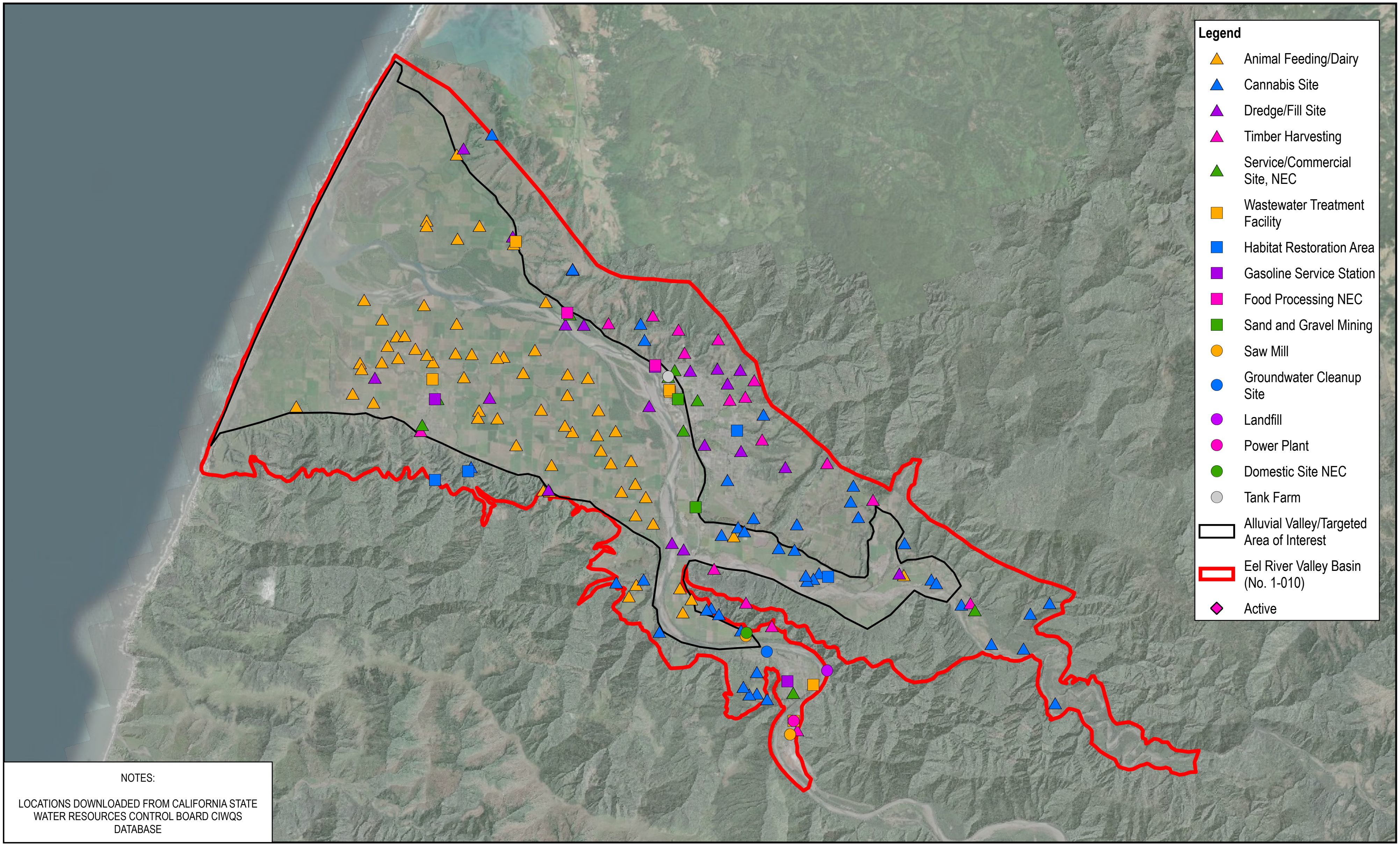
Date **Jan 2022**

Geotracker Permitted Facilities

FIGURE 31

N:\US\Eureka\Projects\561\11217388\GIS\Maps\Deliverables\11217388_ERVP_GSP\11217388_ERVP_GSP.aprx - F031_GeotrackerPermittedFacilities
Print date: 20 Jan 2022 - 11:05

Data source: DWR basin, 2013; Geotracker; USGS; World Imagery: Earthstar Geographics. Created by: jclark2



NOTES:

LOCATIONS DOWNLOADED FROM CALIFORNIA STATE WATER RESOURCES CONTROL BOARD CIWQS DATABASE

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Paper Size ANSI A

0 1 2 3

Miles

N

Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane California I FIPS 0401 Feet

Humboldt County Groundwater Sustainability Agency
Eel River Valley Groundwater
Sustainability Plan

Regulated Facilities with Active Permits Listed in CIWQS

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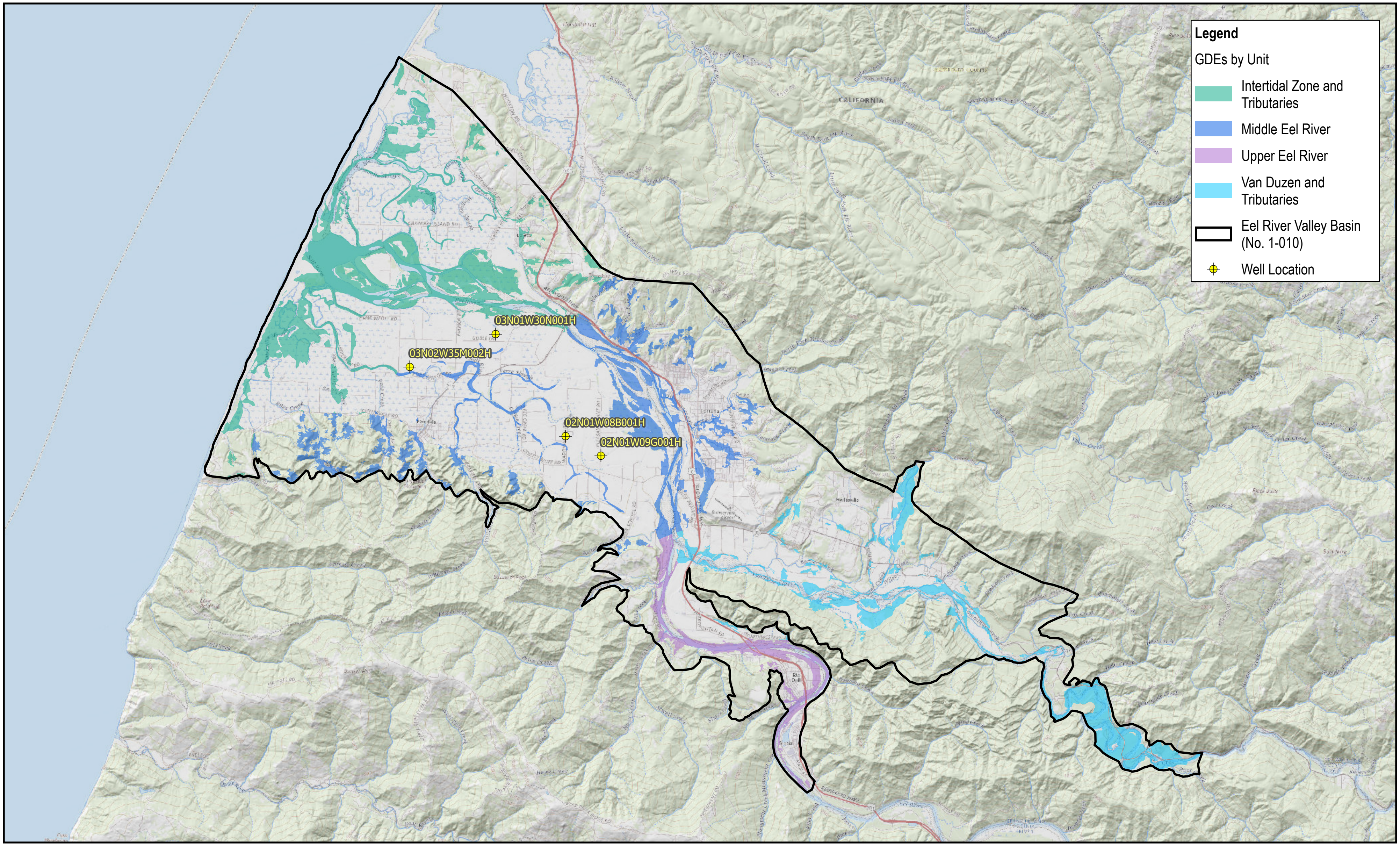
Date **Jan 2022**

FIGURE 32

N:\US\Eureka\Projects\561\11217388\GIS\Maps\Deliverables\11217388_ERVP_GSP\11217388_ERVP_GSP.aprx - F032_RegulatedFacilities
Print date: 20 Jan 2022 - 11:07

Data source: DWR basin, 2013; USGS; CIWQS; World Imagery: Earthstar Geographics. Created by: jclark2



Engineers & Geologists

Stillwater Sciences

GHD

Paper Size ANSI A
0 1 2 3
Miles

Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
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Humboldt County Groundwater Sustainability Agency
Eel River Valley Groundwater
Sustainability Plan

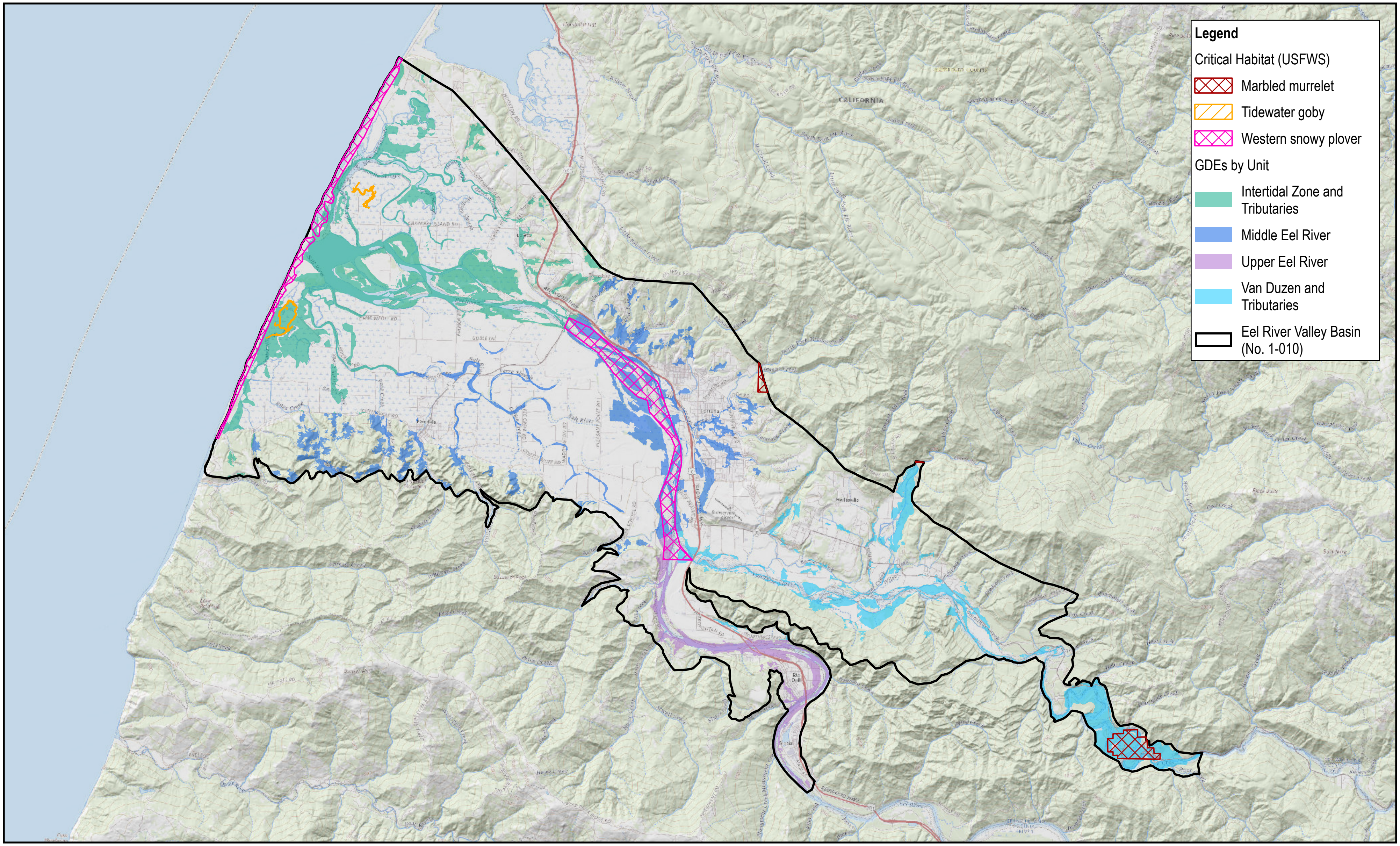
Potential Groundwater Dependent Ecosystems

Project No. **11217388**
Revision No. **-**
Date **Jan 2022**

FIGURE 33

N:\US\Eureka\Projects\561\11217388\GIS\Maps\Deliverables\11217388_ERVP_GSP\11217388_ERVP_GSP.aprx - F033_PotentialGDE
Print date: 20 Jan 2022 - 11:09

Data source: DWR basin, 2013; GDE, Stillwater Sciences; USGS National Map: USGS The National Map: National Boundaries Dataset, National Elevation Dataset, Geographic Names Information System, National Hydrography Dataset, National Land Cover Database, National Structures Dataset, and National Transportation Dataset; U.S. Census Bureau - TIGER/Line; HERE Road Data. Created by: jclark2



SHN Engineers & Geologists

Stillwater Sciences

GHD

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Map Projection: Lambert Conformal Conic
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Humboldt County Groundwater Sustainability Agency
Eel River Valley Groundwater
Sustainability Plan

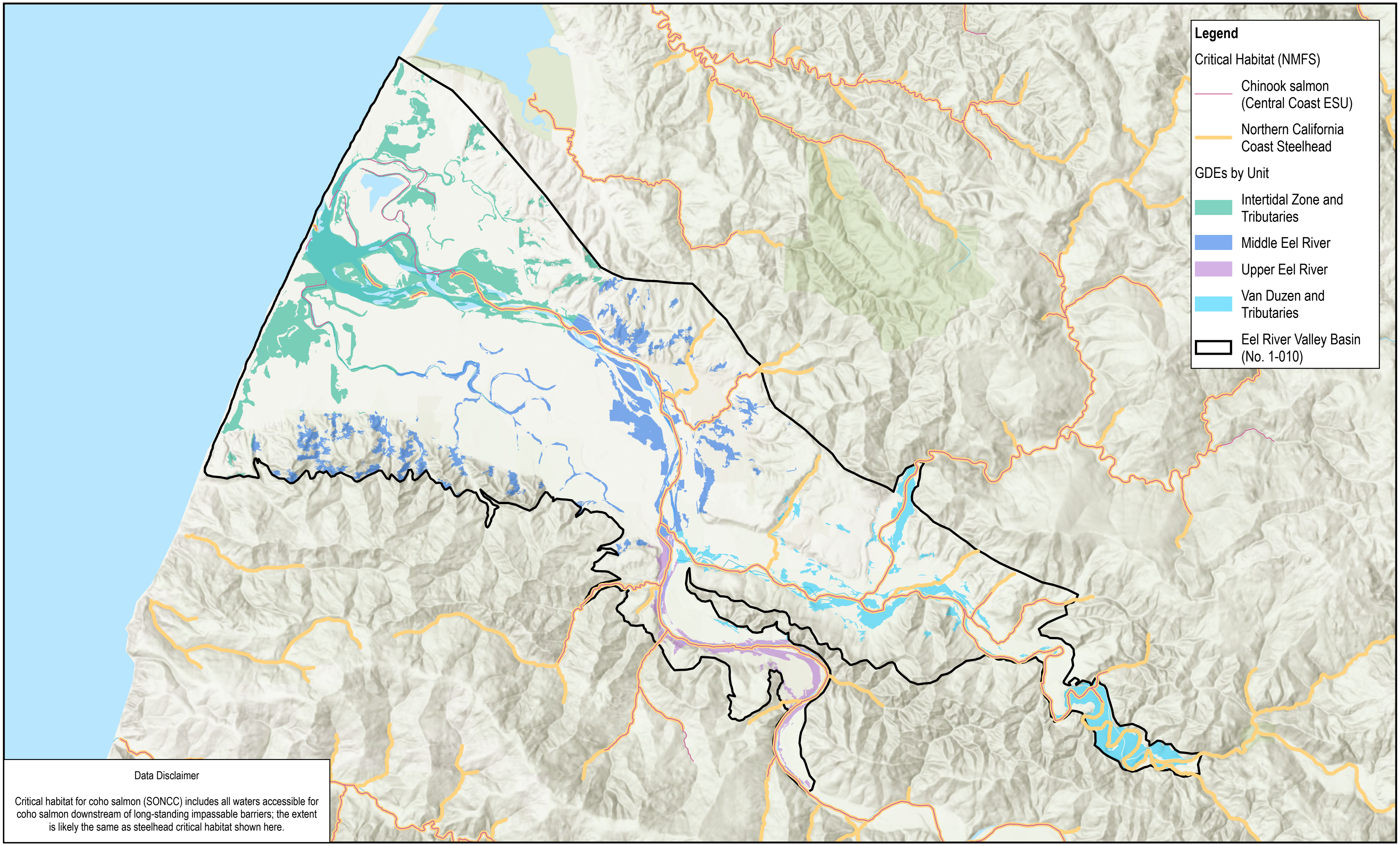
USFWS Critical Habitat and GDE Units

Project No. **11217388**
Revision No. **-**
Date **Jan 2022**

FIGURE 34

N:\US\Eureka\Projects\561\11217388\GIS\Maps\Deliverables\11217388_ERVP_GSP\11217388_ERVP_GSP.aprx - F034_USFWSCritHabGDE
Print date: 20 Jan 2022 - 11:10

Data source: DWR basin, 2013; USFWS; GDE, Stillwater Sciences; USGS National Map: USGS The National Map: National Boundaries Dataset, National Elevation Dataset, Geographic Names Information System, National Hydrography Dataset, National Land Cover Database, National Structures Dataset, and National Transportation Dataset; U.S. Census Bureau - TIGER/Line; HERE Road Data. Created by: jclark2



Data Disclaimer

Critical habitat for coho salmon (SONCC) includes all waters accessible for coho salmon downstream of long-standing impassable barriers; the extent is likely the same as steelhead critical habitat shown here.

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Stillwater Sciences

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Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane California I FIPS 0401 Feet

County of Humboldt — The Home of the Redwoods

Humboldt County Groundwater Sustainability Agency
Eel River Valley Groundwater
Sustainability Plan

NMFS Critical Habitat and GDE Units

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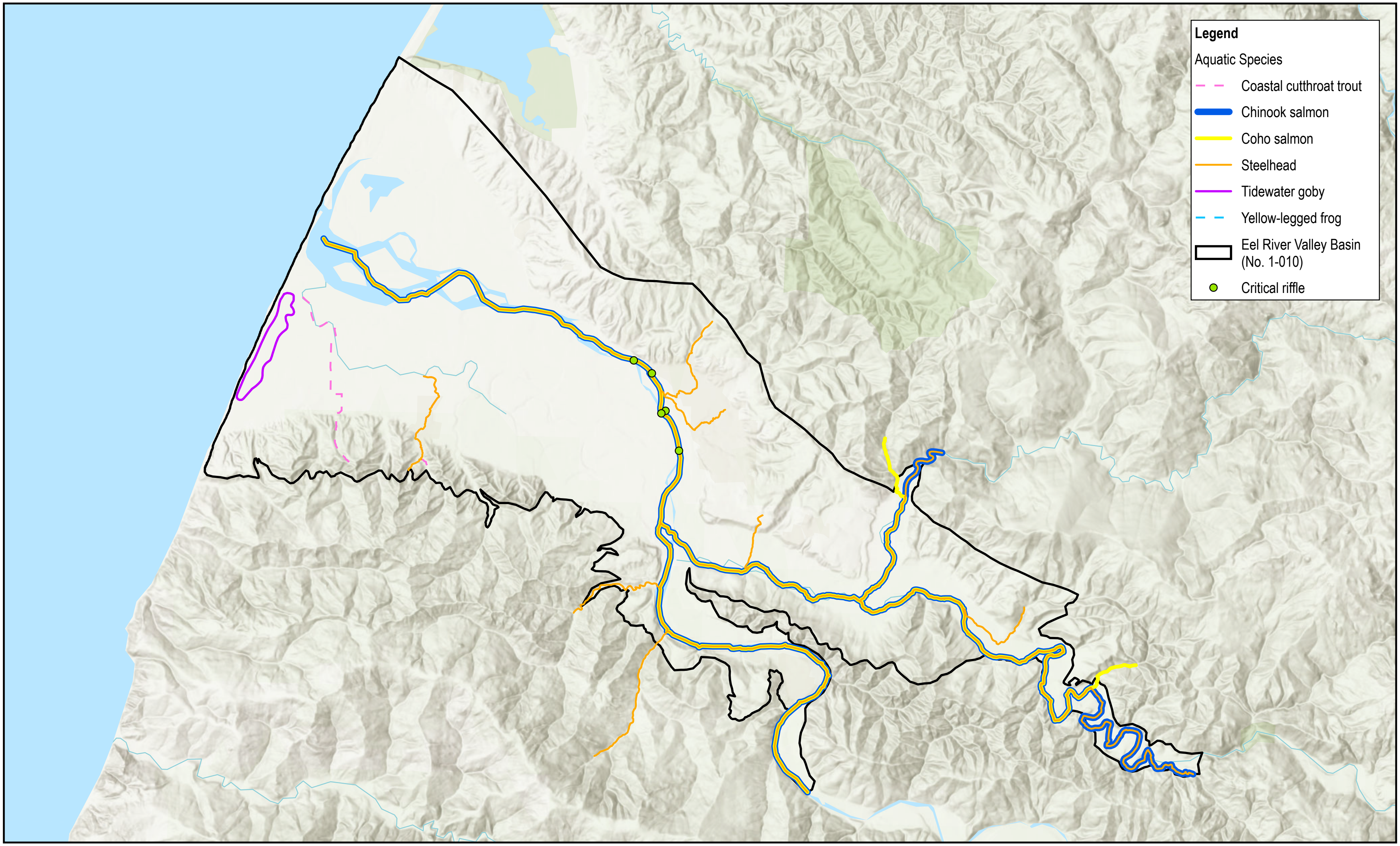
FIGURE 35

N:\US\Eureka\Projects\561\11217388\GIS\Maps\Deliverables\11217388_ERVP_GSP\11217388_ERVP_GSP.aprx - F035_NMFSCritHabGDE
Print date: 20 Jan 2022 - 11:11

Data source: DWR basin, 2013; NMFS; GDE, Stillwater Sciences; World Topographic Map - labelless: California State Parks, Esri, HERE, Garmin, SafeGraph, METI/NASA, USGS, Bureau of Land Management, EPA, NPS, USDA; World Hillshade: Esri, NASA, NGA, USGS. Created by: jclark2



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Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane California I FIPS 0401 Feet

Humboldt County Groundwater Sustainability Agency
Eel River Valley Groundwater
Sustainability Plan

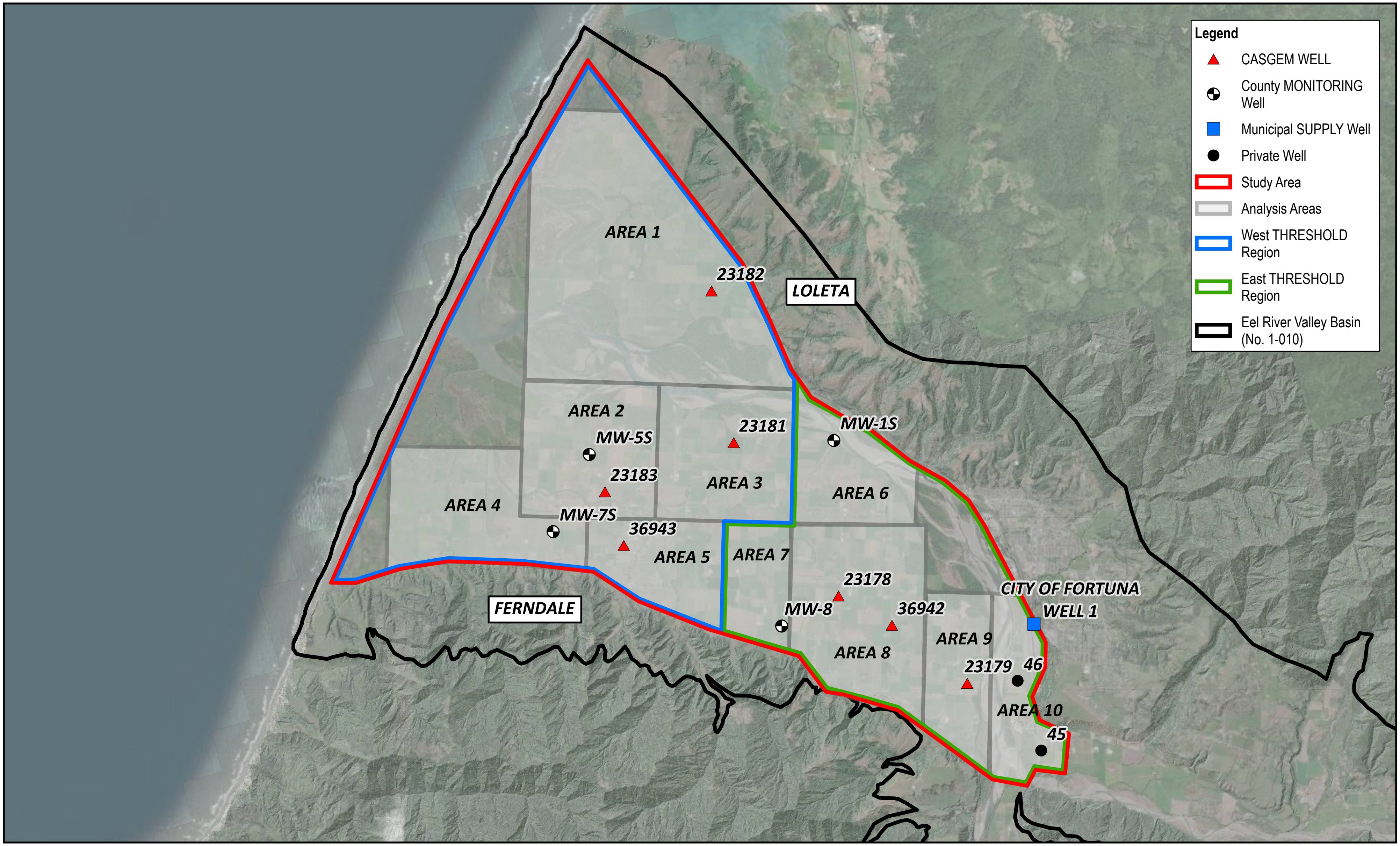
Aquatic Species Distribution

Project No. **11217388**
Revision No. **-**
Date **Jan 2022**

FIGURE 36

N:\US\Eureka\Projects\561\11217388\GIS\Maps\Deliverables\11217388_ERVP_GSP\11217388_ERVP_GSP.aprx - F036_AquaticSpeciesDist
Print date: 20 Jan 2022 - 11:13

Data source: DWR basin, 2013; Stillwater Sciences;World Topographic Map - labelless: California State Parks, Esri, HERE, Garmin, SafeGraph, METI/NASA, USGS, Bureau of Land Management, EPA, NPS, USDA; World Hillshade: Esri, NASA, NGA, USGS. Created by: jclark2



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Stillwater Sciences

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Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
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Humboldt County Groundwater Sustainability Agency
Eel River Valley Groundwater
Sustainability Plan

Well Locations and Areas Used for Well Impacts Analysis

Project No. **11217388**
Revision No. **-**
Date **Jan 2022**

FIGURE 37

N:\US\Eureka\Projects\561\11217388\GIS\Maps\Deliverables\11217388_ERVP_GSP\11217388_ERVP_GSP.aprx - F037_WellImpactAnalysis
Print date: 20 Jan 2022 - 11:14

Data source: DWR basin, 2013; USGS; CASGEM; Humboldt County; SHN; World Imagery: Earthstar Geographics. Created by: jclark2

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Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
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Humboldt County Groundwater Sustainability Agency
Eel River Valley Groundwater
Sustainability Plan

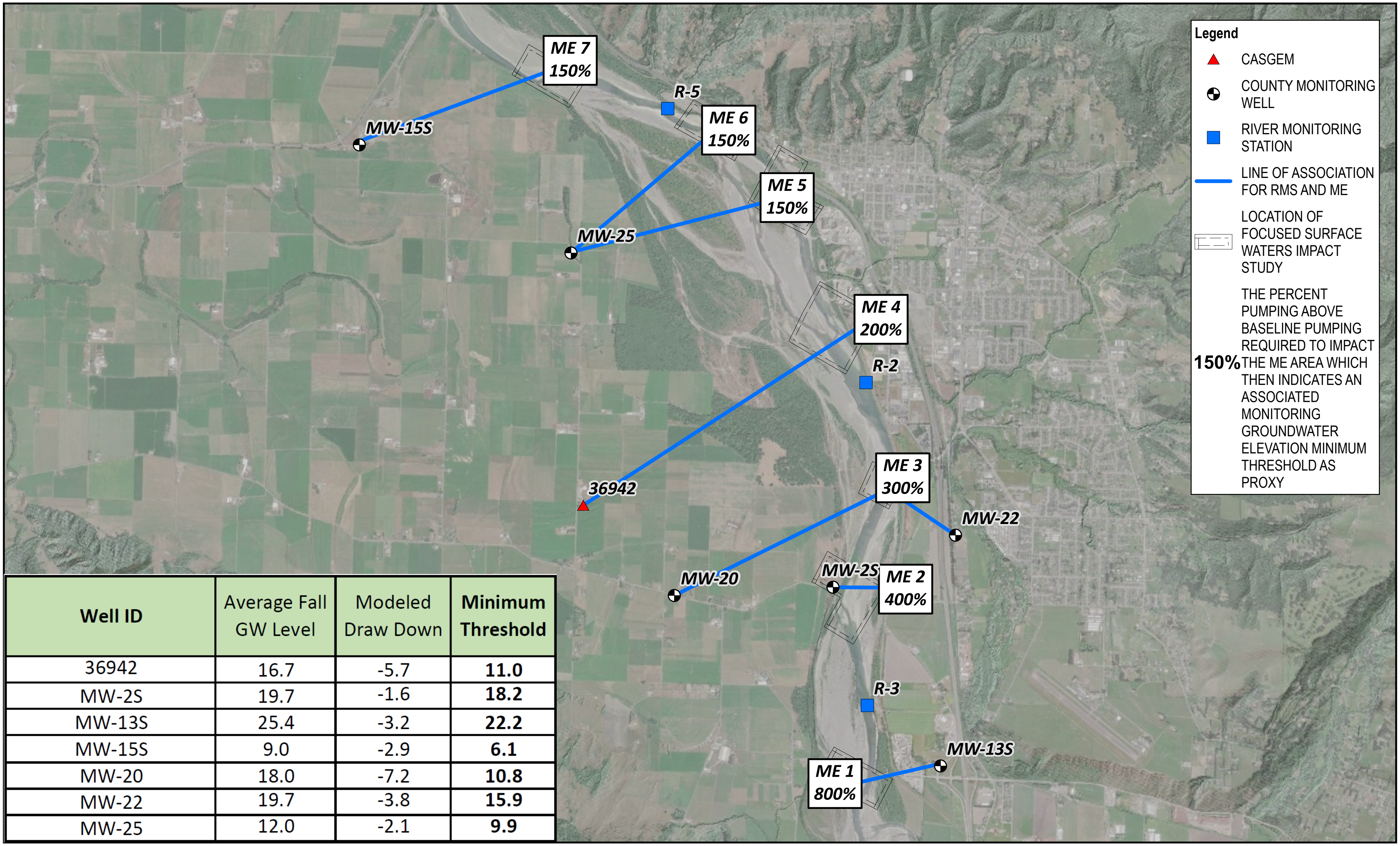
Representative Monitoring Sites for Well Impacts

Project No. 11217388
Revision No. -
Date Jan 2022

FIGURE 38

N:\US\Eureka\Projects\561\11217388\GIS\Maps\Deliverables\11217388_ERVP_GSP\11217388_ERVP_GSP.aprx - F038_RepresentativeMonitorSites
Print date: 20 Jan 2022 - 11:15

Data source: DWR basin, 2013; CASGEM; Humboldt County; World Imagery: Earthstar Geographics. Created by: jclark2



Well ID	Average Fall GW Level	Modeled Draw Down	**Minimum Threshold**
36942	16.7	-5.7	**11.0**
MW-2S	19.7	-1.6	**18.2**
MW-13S	25.4	-3.2	**22.2**
MW-15S	9.0	-2.9	**6.1**
MW-20	18.0	-7.2	**10.8**
MW-22	19.7	-3.8	**15.9**
MW-25	12.0	-2.1	**9.9**

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Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
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Humboldt County Groundwater Sustainability Agency
Eel River Valley Groundwater
Sustainability Plan

Project No. **11217388**
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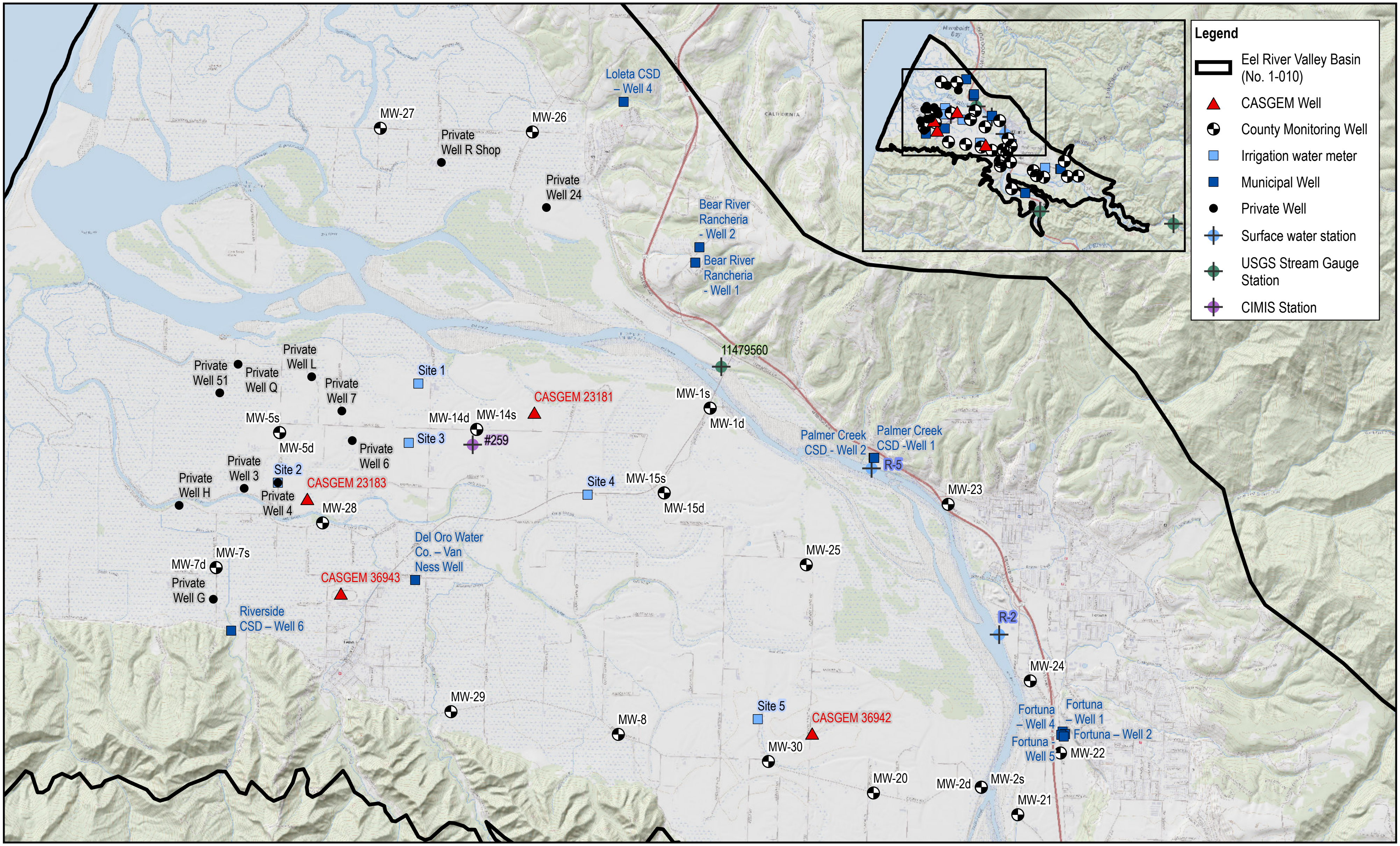
Date **Jan 2022**

Proxy Groundwater Sites for Surface Water Depletion

FIGURE 39

N:\US\Eureka\Projects\561\11217388\GIS\Maps\Deliverables\11217388_ERVP_GSP\11217388_ERVP_GSP.aprx - F039_ProxyGWSitesforSurfaceWaterDepletion
Print date: 20 Jan 2022 - 11:16

Data source: CASGEM; Humboldt County; USGS; SHN; World Imagery: Maxar. Created by: jclark2



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GHD

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Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane California I FIPS 0401 Feet

County of Humboldt
The Home of the Redwoods

Humboldt County Groundwater Sustainability Agency
Eel River Valley Groundwater
Sustainability Plan

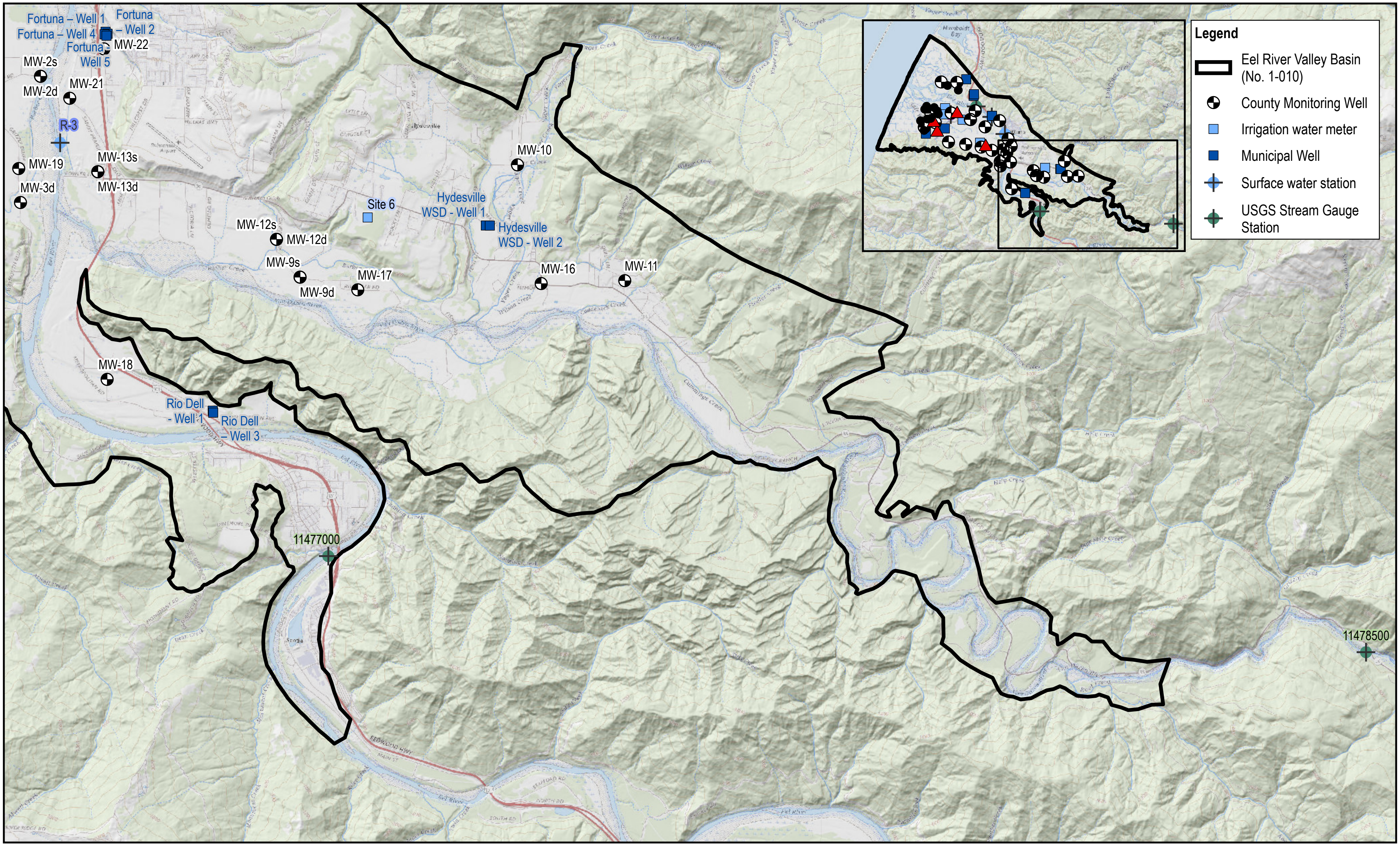
Monitoring Network
West side of Eel River Valley Basin

Project No. **11217388**
Revision No. **-**
Date **Jan 2022**

FIGURE 40

N:\US\Eureka\Projects\561\11217388\GIS\Maps\Deliverables\11217388_ERVP_GSP\11217388_ERVP_GSP.aprx - F040_MonitoringNetworkWest
Print date: 28 Jan 2022 - 09:00

Data source: DWR basin, 2013; CASGEM; Humboldt County; CIMIS; USGS; USGS National Map: USGS The National Map: National Boundaries Dataset, National Elevation Dataset, Geographic Names Information System, National Hydrography Dataset, National Land Cover Database, National Structures Dataset, and National Transportation Dataset; U.S. Census Bureau - TIGER/Line; HERE Road Data.
Created by: jclark2



Engineers & Geologists

Stillwater Sciences

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Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane California I FIPS 0401 Feet

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Humboldt County Groundwater Sustainability Agency
Eel River Valley Groundwater
Sustainability Plan

Project No. **11217388**
Revision No. **-**
Date **Jan 2022**

Monitoring Network
East side of Eel River Valley Basin

FIGURE 41

N:\US\Eureka\Projects\561\11217388\GIS\Maps\Deliverables\11217388_ERVP_GSP\11217388_ERVP_GSP.aprx - F041_MonitoringNetworkEast
Print date: 28 Jan 2022 - 08:59

Data source: DWR basin, 2013; CASGEM; Humboldt County; CIMIS; USGS; USGS National Map: USGS The National Map: National Boundaries Dataset, National Elevation Dataset, Geographic Names Information System, National Hydrography Dataset, National Land Cover Database, National Structures Dataset, and National Transportation Dataset; U.S. Census Bureau - TIGER/Line; HERE Road Data.
Created by: jclark2

Agricultural Groundwater Use Technical Memorandum (TM-1)

Agriculture Water Use Technical Memorandum

Eel River Valley Groundwater Basin

October 19, 2021

PREPARED BY:
County of Humboldt Department of Public Works
Environmental Services
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Contents

1. Introduction

This technical memorandum develops an estimate of groundwater use for agricultural irrigation within the Eel River Valley Groundwater Basin (ERVB) utilizing representative monitoring data collected from eight flow meters in 2021. This memorandum was prepared to support development of the Groundwater Sustainability Plan (GSP) for the ERVB. The estimate for total irrigation groundwater use within the basin is based on:

1. An inventory of irrigated lands and the associated irrigation methods (Section 2).
2. Classifications of water year types for a 30-year period (1992-2021) using local rainfall data (Section 3).
3. Estimates of irrigation season duration based on water year type (Section 3).
4. Monitoring data collection and analysis (Section 4).

This memorandum includes a discussion regarding uncertainty in estimating irrigation water use (Section 5) and provides an estimate of groundwater use for dairy nutrient management (Section 6). Finally, the memorandum provides a comparison with previous irrigation groundwater use estimates using alternative methods (Section 7).

2. Inventory of Irrigated Land Areas and Irrigation Methods

Irrigated Land Areas

The Eel River Valley is the center of Humboldt County's dairy and beef cattle economy. Dairy producers and ranchers pump groundwater for pasture irrigation and ancillary activities such as dairy nutrient management and livestock watering. In 2021, the Humboldt County Resource Conservation District (HCRCD) updated the inventory of irrigated land areas within the basin, following their initial inventory in 2016. The results from this analysis are incorporated into the Land Use Technical Memorandum (GHD, 2021) and summarized in Table 1 and depicted on Figure 1.

Table 1. Irrigated Land Use by Water Source in the ERVB (2021).

Irrigation Water Source	Acres	% of Total Acres
Groundwater	12,952	96.4%
Surface Water	126	0.9%
Reclaimed Wastewater	352	2.6%
Total:	**13,430**	**100%**

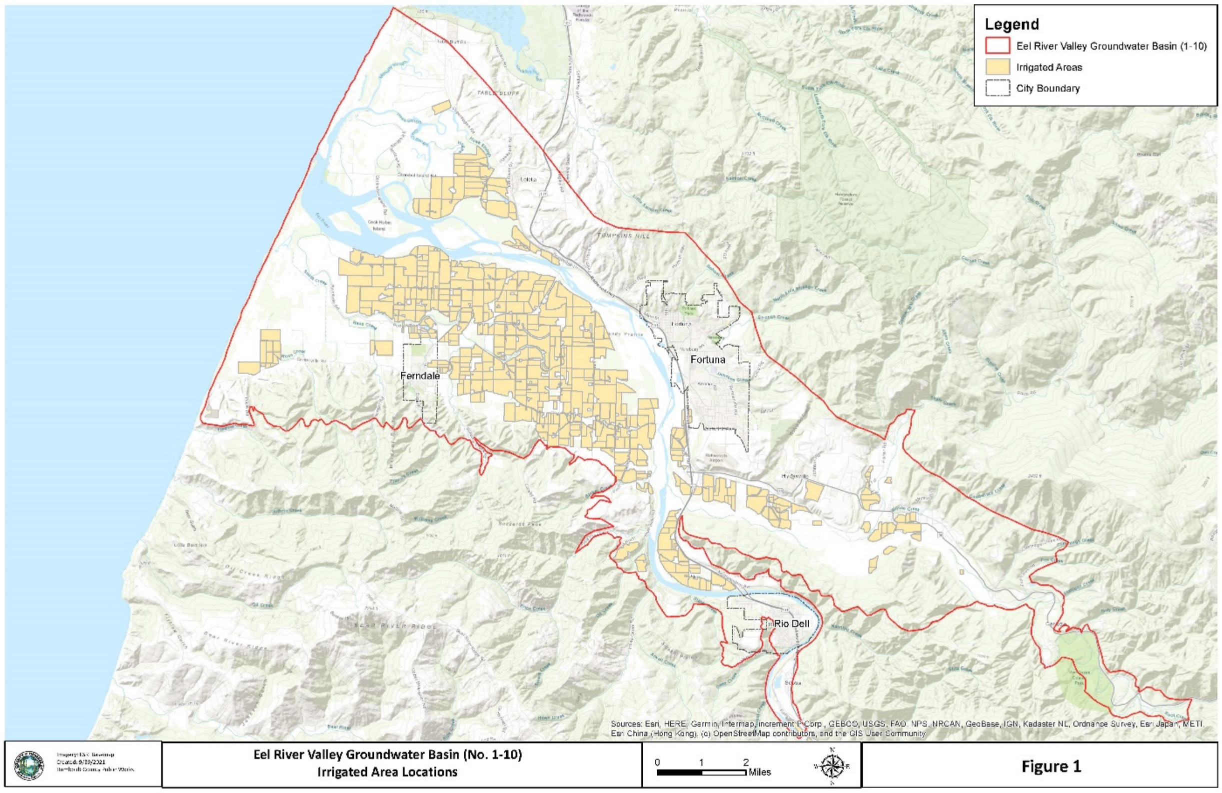


Figure 1. Irrigated Acreage Locations within the ERVB, updated 2021.

Irrigation Methods

In 2021, a total of 12,952 acres of agricultural land were irrigated by groundwater using five types of irrigation equipment (Table 2).

Table 2. Equipment Types Used for Irrigation with Groundwater in the ERVB (2021).

Irrigation Equipment Type	Acres	% of Total Acres
Handline	6,779	53%
Traveling Gun	4,025	31%
Wheel Line	1,147	9%
K-Line	713	6%
Center Pivot	272	2%
Other	16	0.1%
Total	**12,952**	

Handlines distribute water through sprinkler pipes (aluminium pipe with a sprinkler on one end) connected in a lateral line extending off of a mainline supply. Handlines are moved by disconnecting, moving, and reconnecting each sprinkler pipe by hand to the lateral line's next location. Sprinkler pipes are typically 30 or 40 feet long and each setting lateral lines are typically moved 60 feet. The amount of water applied depends on the distance between sprinklers (length of pipe), nozzle size, pressure, distance between lateral line settings, and duration of each set.

Traveling Guns distribute water through a single large sprinkler that traverses a portion of the field each time the traveling gun is set. For each setting the traveling gun is moved to a new location and the large sprinkler pulled from the carriage and set to traverse a different portion of the field. The amount of water applied depends on the nozzle size, pressure, and speed the large sprinkler travels.

Wheel Lines distribute water through sprinkler pipes mounted on large wheels connected in a lateral line off of a mainline supply. Wheel lines are repositioned by operating a motorized mover in the center of the line with the sprinkler pipes serving as an axle. Sprinklers are typically spaced at 40-foot intervals along the wheel line and moved 60 feet each setting. The amount of water applied depends on the nozzle size, water pressure, and duration of each set.

K-Lines distribute water through a system of plastic lines with sprinkler pods spaced 40 to 50 feet along the lines. K-Lines are moved to a new location by dragging the plastic line with an ATV while the system is operating. K-Line systems are designed to maximize infiltration with the amount of water applied depending on sprinkler spacing, sprinkler size, and duration of each set.

Center Pivots distribute water through sprinklers positioned along an overhead pipe that rotates around a pivot point. The system is designed to apply water at an equal rate along the length of the pipe and the amount of water applied depends on the speed the center pivot rotates and nozzle size.

Other irrigations systems are used in less than 0.1% of the basin and include hoses, flood irrigation, or drip irrigation methods. These methods are used on small scale farms of 5 acre or less.

3. Water Year Type and Irrigation Season

Water Year Type Designations

A common practice in hydrology is to calculate total precipitation over a twelve-month period by designating a “water year” as the period extending from October 1 through September 30. For example, Water year 2021 extended from October 1, 2020, through September 30, 2021. Water year 2022 began on October 1, 2021. For watersheds where the majority of precipitation falls in the winter, the water year generally encompasses the entire wet season. Annual water budgets, which quantify inflows, outflows, and change in storage for a groundwater basin, are developed based on the annual water year period.

DWR (January 2021) presented a methodology for designating water year types for watersheds outside the Sacramento and San Joaquin Valleys to support the development of GSPs. DWR’s methodology is based on selecting a 30-year period and dividing the record into five categories of water year type according to specified weighting percentages (Table 3). This methodology results in 50% of the years in the 30-year period classified as Wet or Above Normal and 50% of the years classified as Below Normal, Dry, or Critical.

Table 3. Water Year Classifications (DWR, January 2021)

Classification	Weighted Percentage
Wet	30%
Above Normal	20%
Below Normal	20%
Dry	15%
Critical	15%

DWR (January 2021) published a data set of water year classifications for various hydrologic units around California, including the lower Eel River (HUC 18010105). This hydrologic unit encompasses 1,510 square miles and extends upstream to the confluence with the Middle Fork of the Eel River at Dos Rios, Mendocino County. This hydrologic unit encompasses a wide range of climatic conditions including a combination of coastal and inland areas. DWR (January 2021) notes that Groundwater Sustainability Agencies have the option of developing their own water year types based on best available information. Soil moisture, the primary factor determining when irrigation starts in the ERVB, is presumed to have a stronger correlation with local rainfall conditions rather than regional composite data. Therefore, the representation of water year types for the ERVB can be improved by using local rainfall data, as described below.

Long-term rainfall records (October 1963 through September 2021) were obtained from Jerry Lema of the Ferndale Museum. A rain gauge has been operated at the Ferndale Museum (515

Shaw Avenue) since October 1994. The current rain gauge was manufactured by Productive Alternatives and was provided by the National Weather Service in the 1990s when the museum served as an official gauging site. From October 1970 through October 1994, daily rainfall measurements were collected by George Anderson at 1345 Main Street in Ferndale. Information regarding the location of the rain gauge from October 1963 through October 1970 was not readily available. A summary of the monthly rainfall totals at Ferndale from October 1963 through June 2021 is provided in Appendix 1.

DWR's methodology for designating water year type for a given year takes into account the annual precipitation during the previous year by applying weighting factors to calculate an index value using the following equation:

Water Year Index =

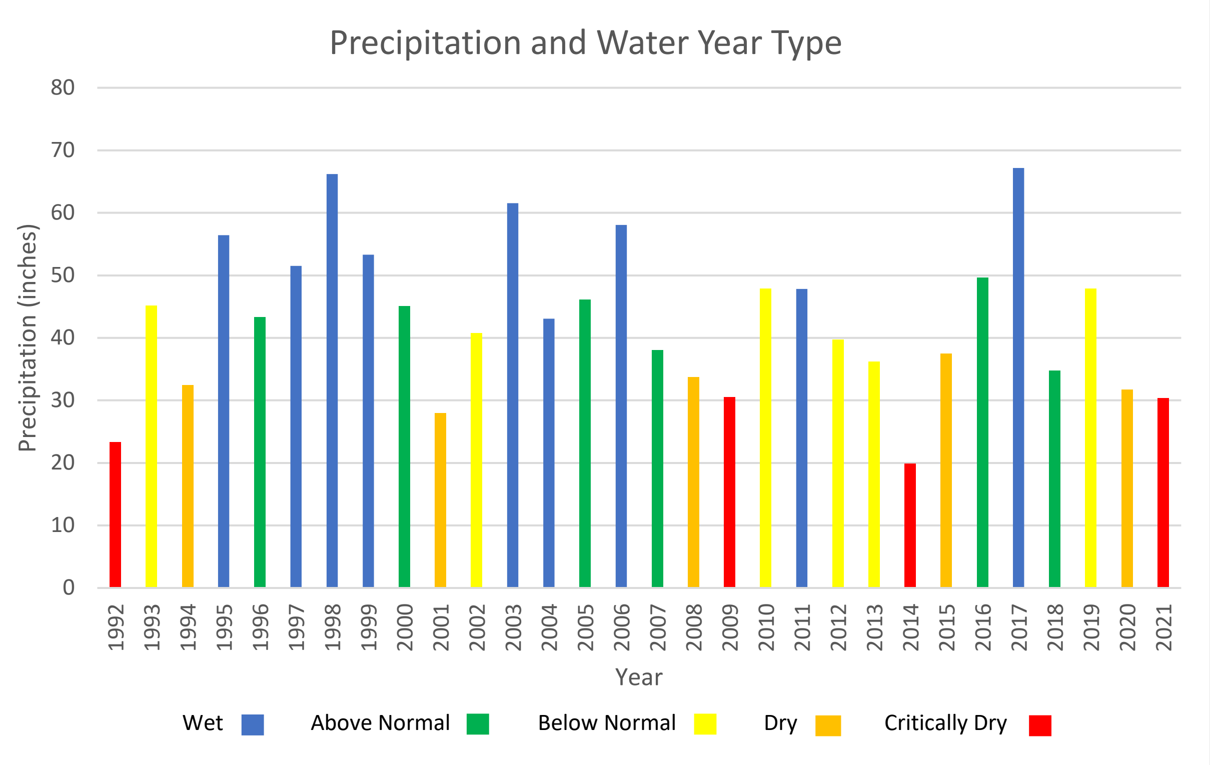
(0.70 x current water year precipitation) + (0.30 x previous water year precipitation)

The equation is applied to each year in the 30-year period to develop index values, which are then ranked from highest to lowest. The ranking position based on index values is used to allocate the years of the 30-year period into the designated distribution of five water year type categories. The results from applying this methodology to the Ferndale rainfall data for the 30-year period from 1992 through 2021 are summarized on Table 4 and depicted on Figure 2. Based on this analysis, water year 2021 is considered a critical water year.

Table 4. Water Year Types with Annual Precipitation, Index Values and Ranking (1992-2021).

Water Year	Annual Precipitation (inches)	Water Year Index	Index Rank (30 = highest #, 1 =lowest #)	Water Year Type
2017	67.2	61.9	30	Wet
1998	66.2	61.8	29	Wet
1999	53.3	57.2	28	Wet
2003	61.6	55.3	27	Wet
2006	58.0	54.5	26	Wet
1995	56.4	49.2	25	Wet
1997	51.5	49.0	24	Wet
2004	43.1	48.6	23	Wet
2011	47.8	47.8	22	Wet
2000	45.1	47.6	21	Above Normal
1996	43.3	47.2	20	Above Normal
2016	49.6	46.0	19	Above Normal
2005	46.1	45.2	18	Above Normal
2018	34.8	44.5	17	Above Normal
2007	38.0	44.0	16	Above Normal
2019	47.9	43.9	15	Below Normal
2010	47.9	42.7	14	Below Normal
2012	39.7	42.1	13	Below Normal
1993	45.1	38.6	12	Below Normal
2013	36.2	37.3	11	Below Normal
2002	40.7	36.9	10	Below Normal
2020	31.7	36.5	9	Dry
1994	32.4	36.2	8	Dry
2008	33.7	35.0	7	Dry
2001	28.0	33.1	6	Dry
2015	37.5	32.2	5	Dry
2009	30.5	31.5	4	Critical
2021	30.3	30.7	3	Critical
2014	19.9	24.8	2	Critical
1992	23.3	23.7	1	Critical

Figure 2. Water Year Types (1992-2021), Based on Rainfall Data Collected in Ferndale



Irrigation Season Durations

Agricultural producers begin irrigating when applied water is needed to supplement soil moisture in order to maintain the growth of pasture grasses or crops. The start-date for irrigation in the spring varies considerably within the ERVB and year to year. Factors that affect the start-date for irrigation include the amount of precipitation in late winter and early spring (especially March and April), wind and air temperature, soil type, labor availability, and overall land management approach. In general, irrigation typically starts earlier in the inland portion of the basin and later in the central and coastal portions of the basin. The end-date for irrigation in the fall is generally on or around October 1, when plant growth slows considerably as day length (photoperiod) shortens and air and soil temperatures drop. For the purpose of this memorandum, start-dates for irrigation were estimated for each of the five water year types based on interviews with producers and professional judgement (Table 5). These estimates identify the date when some producers begin irrigation. Other producers will not start irrigating for several weeks. As a conservative assumption to avoid underestimating groundwater use, this memorandum assumes that all irrigation in the ERVB begins on the start date for that water year type.

Table 5. Water Year Types for the ERVB and Irrigation Season Estimates (1992-2021).

Water Year Type	**Estimated Irrigation Season**	**Days in Irrigation Season**	**Years Corresponding to Water Year Type**
Wet	June 1 – October 1	121	1995, 1997, 1998, 1999, 2003, 2004, 2006, 2011, 2017
Above Normal	May 20 – October 1	133	1996, 2000, 2005, 2007, 2016, 2018
Below Normal	May 15 – October 1	138	1993, 2002, 2010, 2012, 2013, 2019
Dry	April 30 – October 1	153	1994, 2001, 2008, 2015, 2020
Critical	April 15 – October 1	168	1992, 2009, 2014, 2021

4. Irrigation Water Use Estimate

Previous studies provided indirect estimates of groundwater use for agricultural irrigation in the ERVB using a variety of methods (discussed in Section 7). Here, irrigation water use is estimated based on direct measurements using monitoring data collected during the 2021 water year from eight flow meters. Flow meter data are used to calculate total groundwater volume extracted at each meter location and this information is then used to extrapolate across the ERVB to provide an estimate of total groundwater volume extracted for agricultural irrigation by water year type.

4.1. Flow Meter Data Collection

Flow meters were purchased and installed by the Humboldt County Groundwater Sustainability Agency in 2021 prior to the initiation of irrigation on six private wells to measure water use rates (Sites 1-6 on Figure 4). The general goal was to select sites that are spatially distributed across the basin and represent the range of irrigation system types. In addition, two producers volunteered to provide data from their existing flow meters (Sites 7 and 8). Collectively, the eight sites include three traveling guns, two center pivots, one wheel line, one handline, and one K-line. At all sites, the flow meters began measuring total cumulative water volume at the start of irrigation. At five sites, the flow meters did not begin measuring daily pumping rates until after irrigation had begun. At site 3, the daily pumping rate data were affected by a software problem and are considered questionable. Readings of total cumulative water volume were used as the basis for water use calculations as described in Section 4.2.

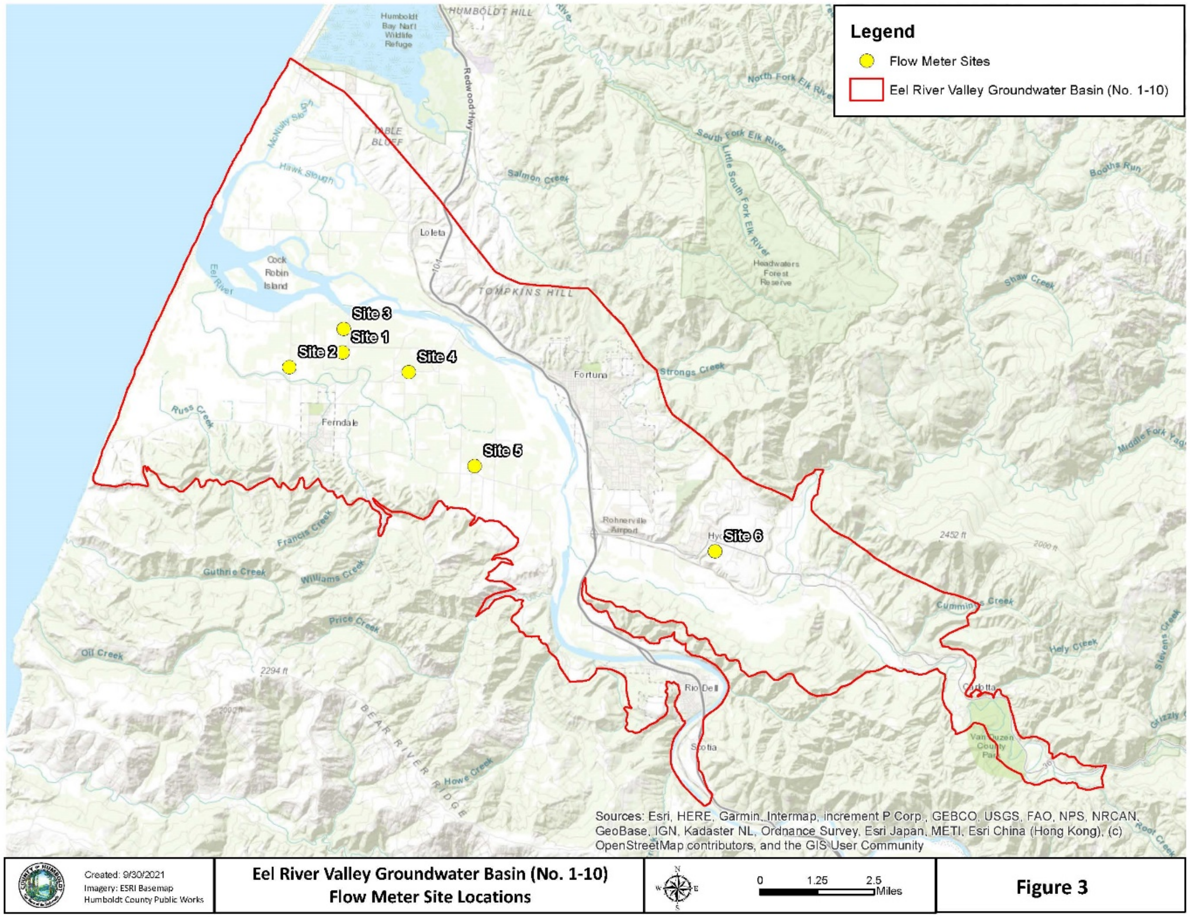


Figure 3. Locations of Six Installed Flow Meters for Irrigation Water Use Calculations.

Sites 1-7 are equipped with Seametrics AG3000 Series Flanged Magmeters. The AG3000 Series is a spool-type electromagnetic flowmeter for use in irrigation applications in two-inch to 12-inch diameter pipe. The flow meter has no moving parts, provides unobstructed flow, and is resistant to wear from debris found in ground or surface water (Seametrics 2021). Data from Sites 1-7 were downloaded directly from the flow meters by HCRCD staff using Flowinspector Version 2.5.0. Flow meters record the date, time, gallons per minute, and total gallons or acre-feet every minute or every hour. Data were downloaded as recorded (minute or hour intervals) every 21 to 30 days beginning in May 2021. Site 8 is equipped with a Lindsay Growsmart IM 3000 magnetic flow meter which records the date and total gallons per hour. Data from Site 8 were downloaded via online access every 21-30 days beginning in April 2021.

Figures 4-10 show daily pumping rates (acre-feet per day) where that data is available for each site except Site 3. Figures 4-10 indicate that groundwater is not pumped continuously through the entire irrigation season. Breaks in irrigation occur to allow for harvesting, moving equipment, and other activities.

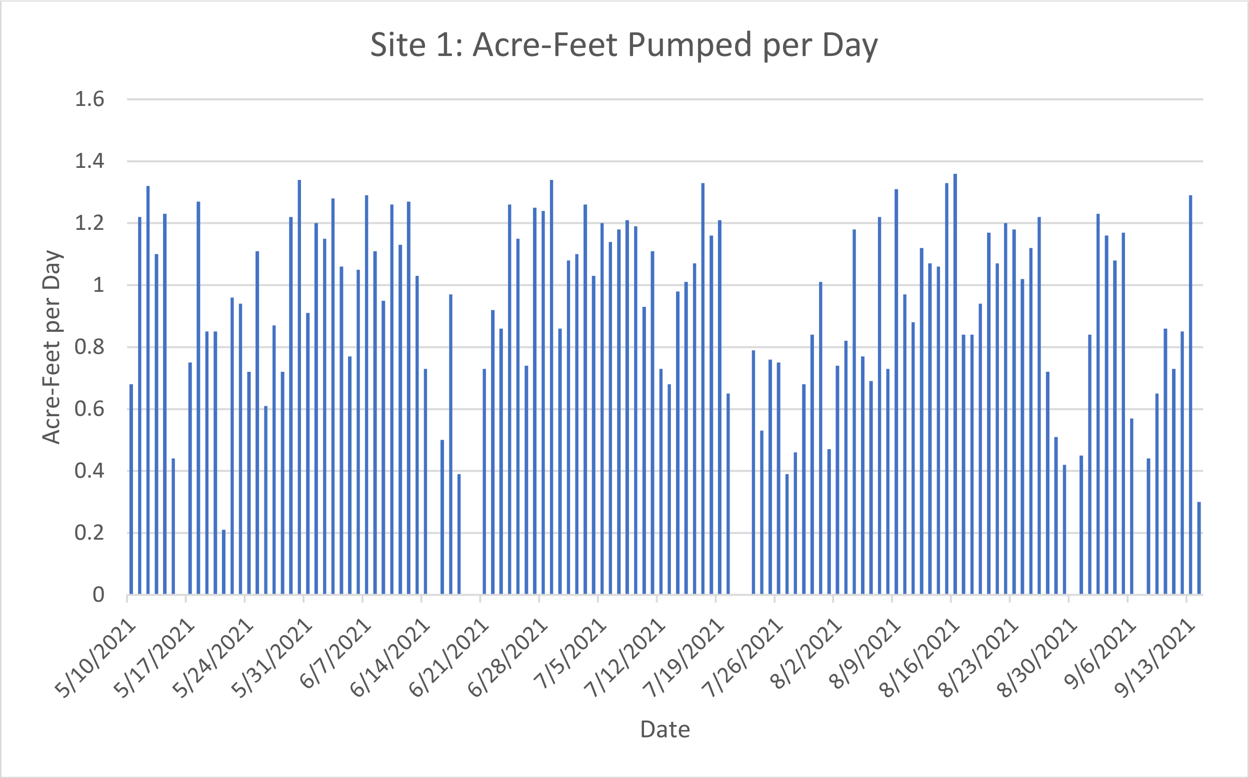


Figure 4. Site 1 Daily Groundwater Pumping Rates (Acre-feet per day).

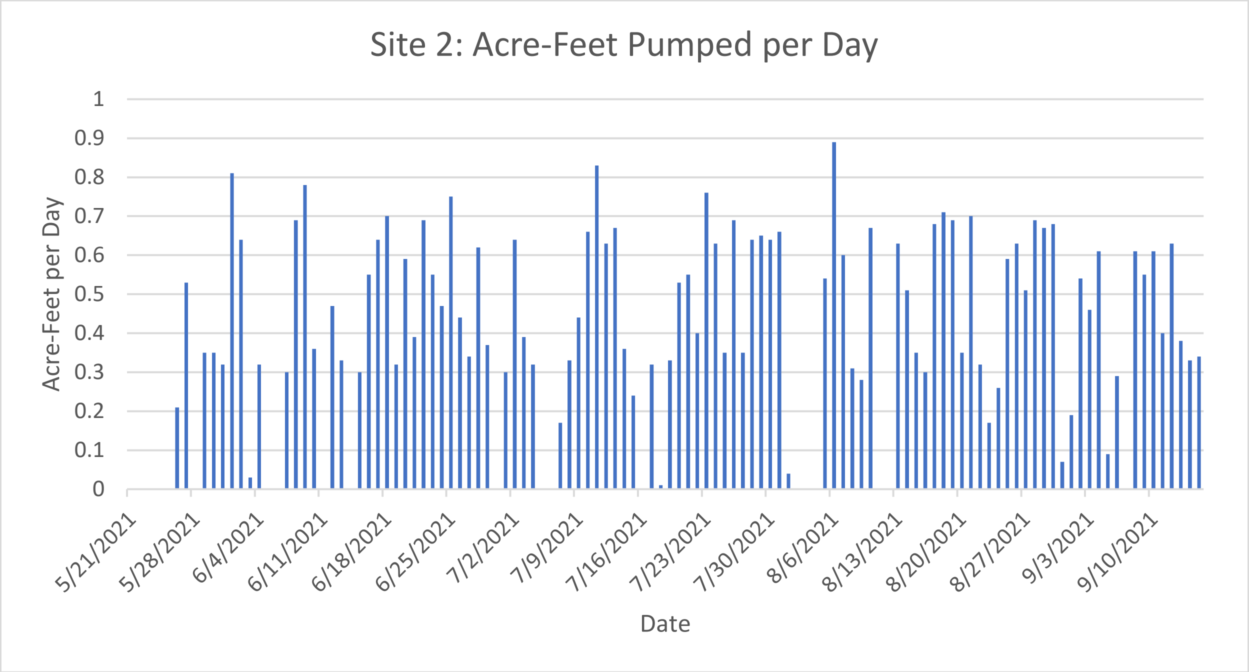


Figure 5. Site 2 Daily Groundwater Pumping Rates (Acre-feet per day).

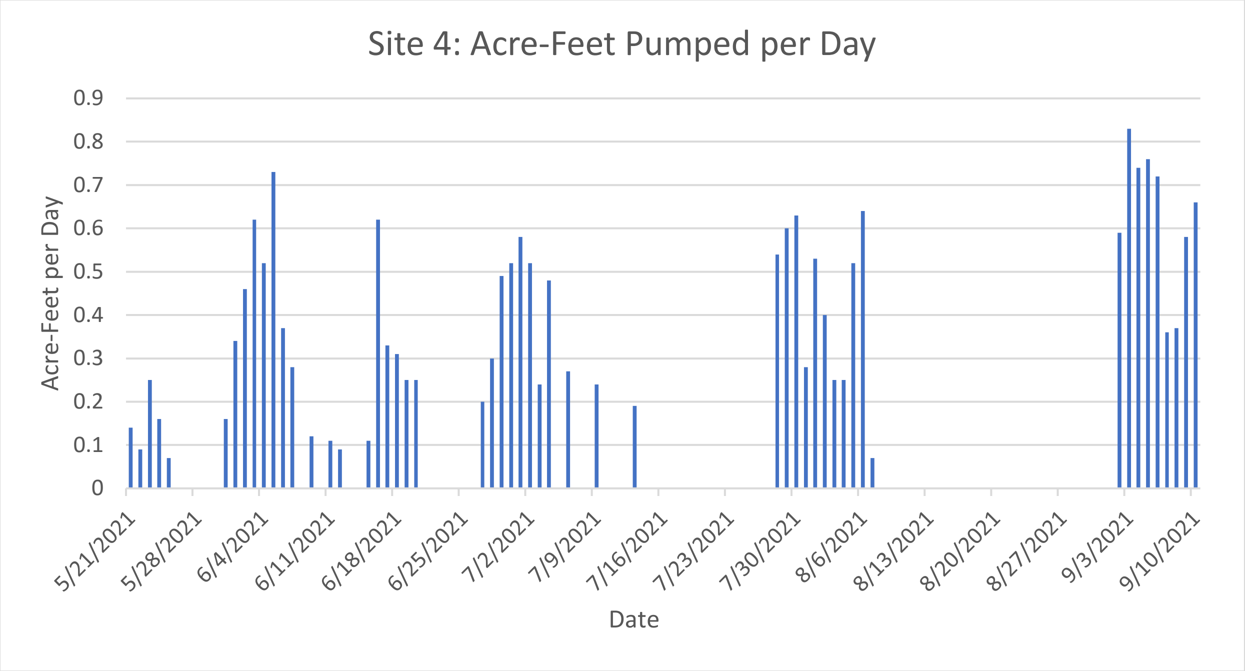


Figure 6. Site 4 Daily Groundwater Pumping Rates (Acre-feet per day).

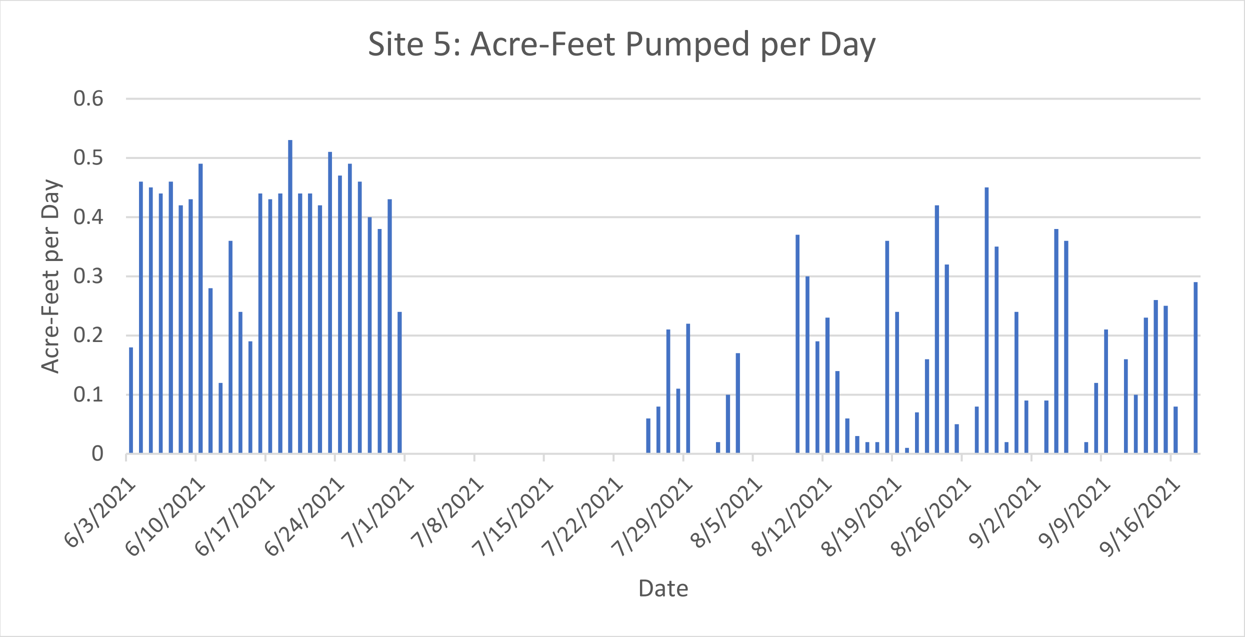


Figure 7. Site 5 Daily Groundwater Pumping Rates (Acre-feet per day).

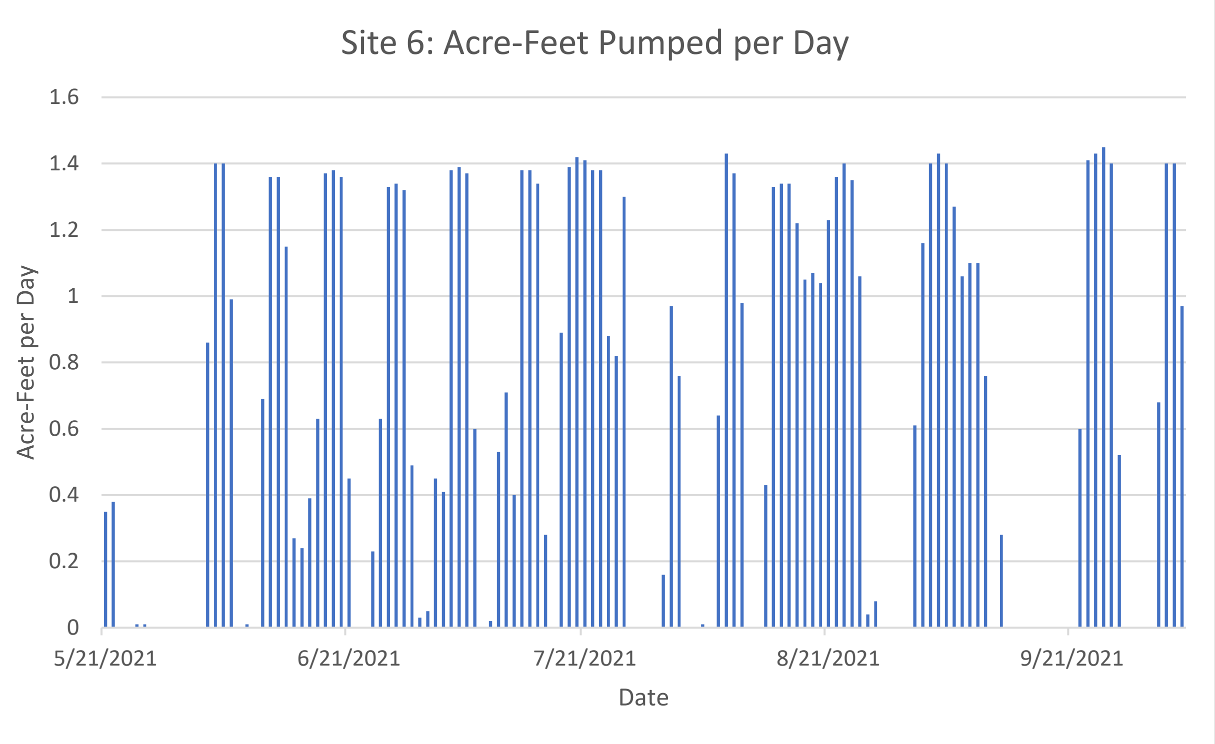


Figure 8. Site 6 Daily Groundwater Pumping Rates (Acre-feet per day).

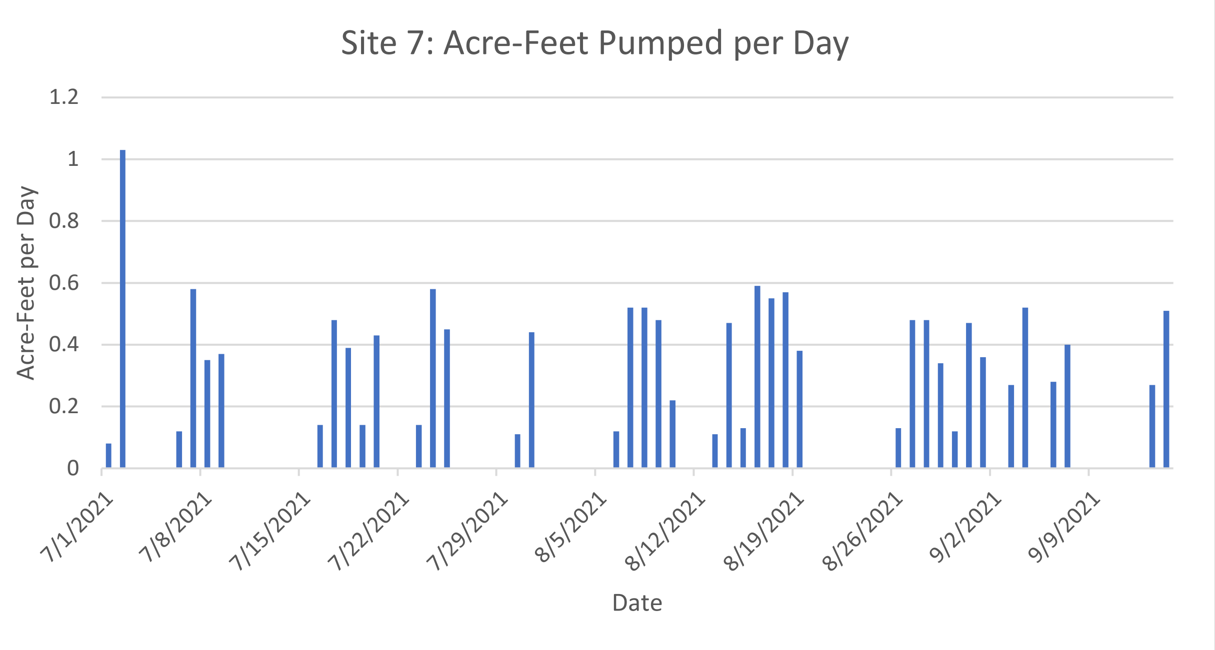


Figure 9. Site 7 Daily Groundwater Pumping Rates (Acre-feet per day).

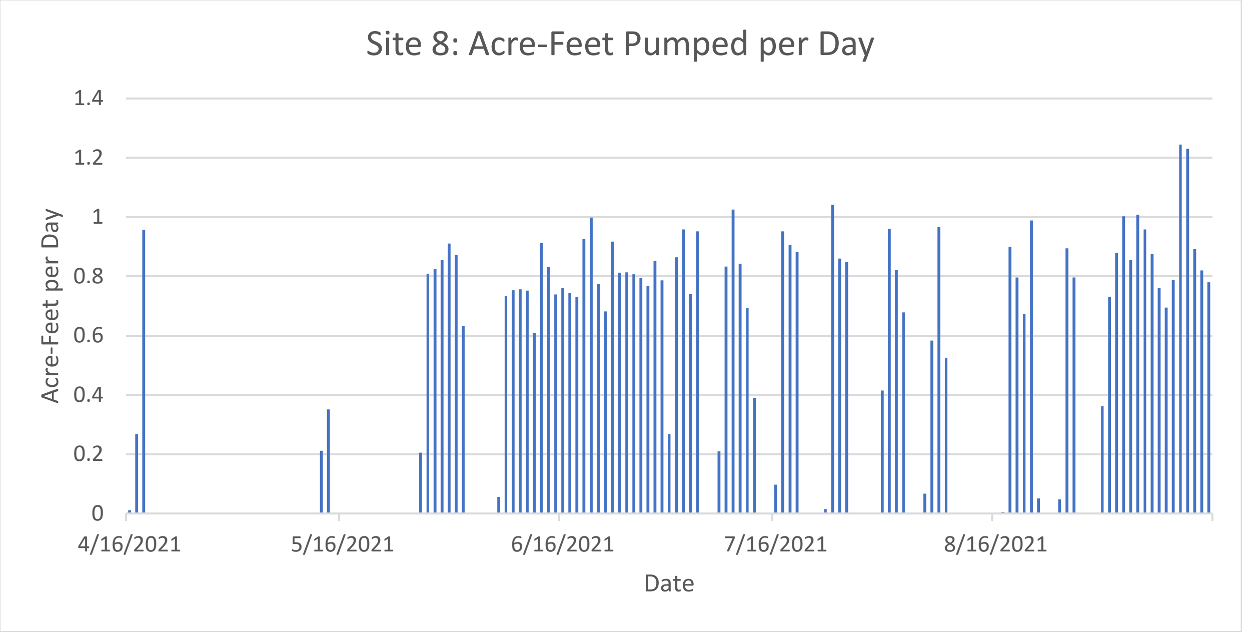


Figure 10. Daily Groundwater Pumping Rates (Acre-feet per day).

4.2. Calculations

Table 6 provides a summary of flow meter data collected during the 2021 water year.

Table 6. Summary of 2021 Flow Meter Data.

Site:	1	2	3	4	5	6	7	8
Irrigation System	Traveling Gun	Traveling Gun	K-Line	Wheel Line	Handline	Center Pivot	Traveling Gun	Center Pivot
Acres	60	96	124	22	47	83	49	55
Date Flow Meter Installed	4/5/2021	4/19/2021	4/12/2021	4/19/2021	5/18/2021	4/19/2021	2017	2017
Irrigation Period	5/10/2021-9/14/2021	5/9/2021-9/15/2021	4/29/2021-10/5/2021	5/18/2021-9/10/2021	6/3/2021-9/18/2021	5/3/2021-10/5/2021	4/29/2021-9/14/2021	4/16/2021-9/15/2021
Date Range for collection of daily use rates	5/21/2021-10/11/2021	5/21/2021-10/11/2021	N/A (Note 1)	5/21/2021-10/11/2021	5/21/2021-10/11/2021	5/21/2021-10/11/2021	7/1/2021-10/11/2021	4/16/2021-10/11/2021
Duration of irrigation period (days)	127	129	159	115	107	155	138	152
Total groundwater pumped during water year (Acre-feet)	114.47	51.22	182.14	21.19	19.25	101.29	28.41	62.64

Note 1: The flow meter at Site 3 did not collect accurate daily flow measurements due to a programming problem. However, the total water use value measured by the totalizer was accurate.

Table 6 indicates that the start-date for irrigation in 2021 varied over a range of approximately seven weeks (from April 16 to June 3) and the end-date ranged over three and a half weeks (from September 10 to October 5). Although water year 2021 was classified as “critical,” the assumed start-date of April 15 does not correspond well with the actual start-dates for the eight irrigation systems with flow meters. However, the estimated irrigation start-dates indicated on Table 5 are used in the calculations for total annual groundwater use based on the assumption that these start-dates are representative over a 30-year period.

Total annual groundwater use for each site as a function of water year type was estimated by extrapolating the monitoring data from the 2021 water year using the following equation:

Total Groundwater Pumping (Acre-feet per Acre per year) =

$$\frac{\substack{\text{Total Groundwater Extracted} \\ \text{during WY 2021 (Acre−Feet)}}}{\text{Irrigated Land (Acres)}} \text{ x } \frac{\text{\# Days in Irrigation Season based on Water Year Type}}{\text{\# Days Pumping Ocurred in WY 2021}}$$

Estimates of total annual groundwater use based on the five water year types for each of the eight monitoring sites are provided in Table 7.

Table 7. Extrapolated Total Annual Groundwater Use for Monitoring Sites (Acre-feet per Acre per year).

Site:	1	2	3	4	5	6	7	8
Irrigation System	Traveling Gun	Traveling Gun	K-Line	Wheel Line	Handline	Center Pivot	Traveling Gun	Center Pivot
Wet	1.8	0.5	1.1	1.0	0.5	1.0	0.5	0.9
Above Normal	2.0	0.6	1.2	1.1	0.5	1.0	0.6	1.0
Below Normal	2.1	0.6	1.3	1.2	0.5	1.1	0.6	1.0
Dry	2.3	0.6	1.4	1.3	0.6	1.2	0.6	1.1
Critical	2.5	0.7	1.6	1.4	0.6	1.3	0.7	1.3

As shown on Table 7, two of the traveling gun sites (sites 2 and 7) had nearly identical results, while one travel gun site (site 1) had a considerably higher rate. Site 1 fields were generally irrigated for longer periods than Sites 2 and 7. The producer at this site had less concerns about electricity costs and did not have limitations on labor in 2021. The two center pivot sites (sites 6 and 8) had similar results.

The distribution of irrigation system types measured at the eight monitoring sites does not exactly match the distribution of irrigation system types throughout the basin (Table 2). For example, handlines account for over half the irrigation systems in the basin; however, only one of the eight monitored sites was a handline. In order to provide the most representative estimate of groundwater pumping throughout the entire basin, the monitoring results from the eight monitoring sites were grouped and averaged, as follows:

- Results from the three travel gun sites were averaged (Sites 1, 2, 7).
- Results from the two center pivot sites were averaged (Sites 6, 8).
- Results from the handline and wheel-line sites were averaged because these equipment types are very similar (Sites 4, 5).
- Results from the k-line system were assumed to represent all k-line systems (Site 3).

Total annual groundwater use as a function of water year type was estimated by multiplying the water use rate for each equipment grouping by the total acres irrigated with that equipment, from Table 2. The results from these calculations are provided in Table 8.

Table 8. Extrapolated Total Annual Groundwater Use for the Entire Basin.

	Traveling Gun		K-Line		Handline and Wheel-line		Center Pivot		Total Basin	
	Acre-ft/Acre	Total Acre-ft	Acre-ft/Acre	Total Acre-ft	Acre-ft/Acre	Total Acre-ft	Acre-ft/Acre	Total Acre-ft	Total Acre-ft	Acre-ft/Acre
Wet	0.9	3,792	1.1	797	0.7	5,852	0.9	253	10,694	0.8
Above Normal	1.0	4,168	1.2	876	0.8	6,432	1.0	278	11,754	0.9
Below Normal	1.1	4,325	1.3	909	0.8	6,674	1.1	288	12,196	0.9
Dry	1.2	4,795	1.4	1,008	0.9	7,399	1.2	320	13,522	1.0
Critical	1.3	5,265	1.6	1,107	1.0	8,125	1.3	351	14,848	1.2

The total volume of groundwater pumped in the basin ranges from 10,694 acre-feet in a wet year to 14,484 acre-feet in a critical year. The water use rate ranges from 0.8 acre-feet of water per irrigated acre per year in a wet year to 1.2 acre-feet of water per irrigated acre per year in a critical year.

5. Uncertainty

This section discusses the uncertainty associated with the assumptions and data inputs utilized for the estimate of irrigation groundwater use in this memorandum.

- Irrigated acres. The accuracy of this number is considered high. The estimate was developed as an update to a previous inventory of irrigated land in the basin (HCRCD, 2016) so there was strong baseline information. The estimate for this study was based on a parcel-by-parcel review with information collected through interviews with landowners and site visits for field verification. Areas were calculated using Geographic Information System (GIS) software.
- Flow meter data quality. The quality of the flow meter data is considered high. Flow meters are established, conventional technology. The meters were installed by Northcoast Pumphouse according to the manufacturer's specifications. Calculations were based on the totalizer measurements which provide a running total of water volume passing through the meter. Totalizer readings were collected manually for seven of the eight sites and through an on-line interface for one of the sites. One of the sites (Site 3) had software problems that impacted the daily use rate data but the totalizer reading was not affected.
- Representativeness of monitoring sites. Water use varies across the basin based on location, soils, management approach, and other factors. Water use was directly measured at eight sites which irrigated a total of 536 acres, or 4% of the irrigated land in the basin. Each of the five irrigation system types was represented in the monitoring sites. However, only one site utilized a handline system which accounts for 53% of the irrigation in the basin. To avoid reliance on a single data point for this large portion of the basin, the results for handline and wheel line were averaged because these systems are very similar. The results from the three monitoring sites with traveling gun systems were averaged, as were the two results from the two sites with center pivot systems. Averaging of multiple measurements helps reduce the potential for an outlier to skew the results.
- Duration of irrigation season. The duration of the irrigation season varies considerably year to year and from producer to producer. For this memorandum, a method was developed to estimate the duration of irrigation season based on water year type. This approach assumes that there is a significant correlation between irrigation start-date and water year type. However, this correlation has not been verified. The presumed end-date of October 1 also has some uncertainty based on soil moisture and temperature, although the end-date is expected to vary less than the start-date. This approach was conservative for the 2021 water year because irrigation at the eight monitoring sites started an average of three weeks after the estimated start-date of April 15 for a critical water year and an average of 12 days before the estimated end-date of October 1. Alternative approaches for estimating the duration of the irrigation season could be investigated in the future to improve the correlation between meteorological data and local irrigation practices.

6. Dairy Nutrient Management

The ERVB includes approximately 40 dairies which have considerable variability in terms of dairy operations and nutrient management system designs. In addition to using groundwater for irrigating pastures, dairies use groundwater as a source of water for cleaning facilities and supplying the cooling system in milk coolers. This water is typically supplied by a different well than the irrigation well. All dairies use water to clean the milking floor, and a few dairies use water to clean other areas of the facility. These activities generate dairy process water which is collected, along with precipitation runoff and manure, into earthen ponds, lagoons, or cement pits (collectively called “ponds”). Liquids in the ponds are periodically applied to surrounding pastures and cropland to replenish soil nutrients in accordance with a Nutrient Management Plan. At some dairies, irrigation water is added to flush the manure lines and condition the pond water for distribution. Approximately every 10 to 30 days (year-round), nutrients from ponds are applied as a liquid or slurry to pastures and cropland with a traveling gun or manure truck.

A typical rule of thumb is that each dairy uses approximately 500 to 1,000 gallons per day for milk cooling and wash-down water for the milking floor. A conservative estimate of 1,000 gallons per day yields an annual use of 1.1 acre-feet. The majority of dairies use equipment to scrape holding pens without using wash-down water, while a small percentage (approximately 10%) use water to flush the holding pens. Pen flushing uses approximately 12,000 gallons per day one-third of the year (120 days), yielding a total of 5.5 acre-feet per year. Some dairies with pen flushing have systems that recycle the wash water, so the amount of pumped water is less than the estimate of daily use.

Assuming 36 dairies use equipment to scrape the holding pens (no wash water) and four dairies use groundwater for pen flushing, the total water use for facility operations and nutrient management at all dairies in the ERVB would be:

$$(36 \times 1.1 \text{ acre-feet}) + (4 \times 5.5 \text{ acre-feet}) = 62 \text{ acre-feet per year}$$

This conservative estimate is 0.4% of the total volume of irrigation water used in a wet year and 0.6% of the total volume used for irrigation in a critical year.

7. Review of Published Groundwater Use Values

Previous estimates of irrigation water use in the ERVB are summarized on Table 9 and discussed below.

Table 9. Comparison of Previously Estimated Irrigated Acreages and Water Use Studies

Source	Irrigated Land (Acres)	Irrigation Water Use Volume (Acre-Feet per year)	Water Use Rate per Acre (Acre-Feet per Acre per year)
DWR (1978) [from USGS (1968)]	11,700	18,800	1.0 to 1.7
USGS (1978)	Not reported	17,300	1.0
DWR (2003)	Not reported	49,000	Not reported
DWR (2014)	33,309	Not reported	Not reported
HCRCD (2016)	13,558	10,265 to 16,680	0.8 to 1.2
DWR (2019)	13,446	40,848	3.0
Humboldt County/HCRCD/WRS (2021)	12,952	10,694 to 14,848	0.8 to 1.2

USGS (1978)

The U.S. Geological Survey published “Ground-Water Conditions in the Eureka Area, Humboldt County, California, 1975” (Water-Resources Investigations 78-127) in December 1978. The estimated groundwater use in the Eel River floodplain and the Eel River and Van Duzen River valleys for 1975 was 17,300 acre-feet (Table 3 in USGS, 1978). This estimate is based on electrical-energy use and pump-efficiency test information provided by the utility company PG&E. The 1978 USGS report also presents data compiled by DWR from 1968 which indicated an estimated total of 18,800 acre-feet of water was applied over 11,700 acres within the same study area. The 1968 DWR data were based on the “land-use” method which utilized a unit applied-water factor ranging from 1.0 to 1.7 acre-feet per acre based on crop type. USGS (1978) concluded that groundwater pumping had remained fairly stable from the late 1950s to the mid-1970s.

DWR (2003)

DWR updated “California’s Groundwater” (Bulletin 118) in 2003. The description for the Eel River Valley Groundwater Basin includes an estimate of 49,000 acre-feet of water use for agricultural purposes. The document does not provide an estimate of irrigated acreage or water use rate (acre-feet per acre) within the basin. The document references a survey conducted by

DWR in 1996; however, additional information regarding the survey data or methodology is not provided.

DWR (2014)

In June 2014, DWR published a spreadsheet for the California CASGEM and Groundwater Sustainability Basin Prioritization. This spreadsheet reported 33,309 acres of irrigated land in the ERVB. An estimate of groundwater use for agriculture was not provided but the spreadsheet listed total groundwater use in the basin as 55,000 acre-feet. These estimates for irrigated land and total groundwater use are significantly higher than other estimates for the basin. Discussion regarding the methodology and supporting information for the estimates in DWR (2014) have not been published.

HCRCD (2016)

In December 2016, the HCRCD published a technical memorandum documenting an estimate of irrigation groundwater use to support the preparation of a Groundwater Sustainability Plan Alternative for ERVB. The 2016 study utilized estimates of pumping capacity for different irrigation systems based on pump size and rating curves through consultation with equipment suppliers and agricultural producers. The estimates of pumping capacity were extrapolated across the basin based on an estimate of irrigate acreage and estimates of the irrigation season duration as a function of three water year types (dry, normal, wet). Total water use in the basin ranged from 10,265 acre-feet in a wet year (0.8 acre-feet per acre per year) to 16,680 acre-feet in a dry year (1.2 acre-feet per acre per year).

DWR (2019)

In January 2019, DWR released updated prioritization levels for a majority of the groundwater basins in California including ERVB. The spreadsheet accompanying these results reported 13,446 acres of irrigated land and 40,848 acre-feet of agricultural groundwater use. DWR issued a paper entitled Sustainable Groundwater Management Act 2018 Basin Prioritization – Process and Results, which discussed the components of the point system that was used by DWR to set basin priority levels. Agricultural groundwater use was estimated using the Cal-SIMETAW model (California Simulation of Evapotranspiration of Applied Water), which calculates water use demand by crop type based on soil information, growth dates, crop coefficients, and evapotranspiration data. Cal-SIMETAW calculates theoretical water demand for optimizing plant growth and applies an efficiency percentage for losses during the application process to calculate total pumped water. DWR applied the model based on hydrological conditions and land use information for the 2014 water year.

The results for agricultural groundwater use in DWR (2019) are approximately three times higher than the results in HCRCD (2016) and the results in this current Technical Memorandum.

This deviation raises questions about the applicability of Cal-SIMETAW for estimating groundwater use in ERVB. The source of the climatological data for the Cal-SIMETAW modelling in DWR (2019) is not well documented, but it was not local data because the first California Irrigation Management Information System (CIMIS) in the basin became operational in August 2019. ERVB has unique climatological conditions due to the close proximity to the Pacific

Ocean, with relatively low air temperatures, high relative humidity, and regular occurrences of fog and dew during the irrigation season. In addition, an important physical property is the relatively high water table in the alluvial floodplain portions of the basin. Groundwater in these areas can be found within five to ten feet below ground surface during much of the year. Therefore, a significant portion of the water demand from plants may be supplied by soil moisture and the capillary fringe above the water table, which reduces the need for applied water. Humboldt County is having ongoing discussions with DWR regarding the appropriateness of using Cal-SIMETAW for groundwater-related evaluations in the ERVB.

8. Summary

This study determined that the total volume of groundwater pumped for agricultural irrigation in the basin ranges from 10,694 acre-feet in a wet year to 14,848 acre-feet in a critical year. The water use rate ranges from 0.8 acre-feet of water per irrigated acre per year in a wet year to 1.2 acre-feet of water per irrigated acre per year in a critical year. This study is the first effort to rely on direct measurements and represents the best available information for estimating groundwater use for agricultural irrigation in the ERVB. Groundwater use for dairy nutrient management is less than 1% of the water used for irrigation.

The results from this study are consistent with the results in HCRCD (2016) and the older studies of USGS (1978) and DWR (1968) but vary from the results of DWR (2003) and DWR (2019). The basis for the results in DWR (2003) have not been published. DWR (2019) is based on computer modelling using Cal-SIMETAW, which may not be appropriate for estimating groundwater use in the ERVB due to the unique climatological and groundwater conditions in the basin.

9. References

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APPENDIX 1

Ferndale Monthly Rainfall Totals (October 1963-September 2021)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Annual
1964	4.20	7.12	3.44	10.72	1.18	5.25	0.43	1.42	0.54	0.23	0.22	0.07	34.82
1965	2.59	11.50	18.55	7.26	1.61	1.06	6.01	0.29	0.51	0.07	0.35	0.06	49.86
1966	0.74	7.01	6.58	9.88	3.85	6.37	1.39	0.03	0.36	0.22	0.44	1.25	38.12
1967	0.71	9.87	7.48	8.49	0.97	8.51	4.73	1.16	0.58	0.02	0.06	1.84	44.42
1968	2.29	4.77	4.66	9.32	2.98	4.10	0.62	0.81	0.17	0.22	2.11	0.35	32.40
1969	2.56	5.81	11.55	13.88	11.1	1.45	3.57	1.10	0.53	0.16	0.01	0.38	52.10
1970	1.85	3.96	9.72	12.4	3.77	2.88	1.62	0.80	0.21	0.00	0.00	0.00	37.21
1971	1.57	10.91	10.75	6.32	3.49	7.93	2.73	0.77	1.25	0.13	0.45	1.03	47.33
1972	1.36	7.20	8.21	6.61	6.89	4.30	3.29	0.71	0.47	0.02	0.07	0.48	39.61
1973	4.77	5.23	7.12	8.13	4.48	7.25	0.77	0.00	0.49	0.01	0.11	1.88	40.24
1974	3.45	19.67	7.89	9.66	6.78	8.24	4.08	0.38	0.49	0.35	0.37	0.00	61.36
1975	1.18	2.14	8.71	5.45	9.30	11.92	3.07	0.56	0.29	0.15	0.31	0.00	43.08
1976	6.91	5.51	5.95	2.19	7.66	3.00	3.50	0.28	0.16	0.00	0.17	3.37	38.70
1977	2.14	5.32	7.38	10.35	8.59	3.88	4.80	0.94	0.19	0.14	1.58	0.06	45.37
1978	0.16	3.65	0.62	1.93	3.20	4.72	1.13	2.44	0.32	0.06	0.41	2.71	21.35
1979	0.04	0.99	2.80	4.63	6.97	3.31	3.20	1.81	0.03	0.28	0.67	0.55	25.28
1980	7.66	5.86	4.19	3.51	7.21	5.58	4.45	1.27	0.14	0.01	0.08	0.25	40.21
1981	1.05	2.07	6.83	11.55	4.40	5.32	0.72	1.46	0.24	0.05	0.06	0.93	34.68
1982	3.57	10.91	7.57	5.47	4.68	8.42	7.61	0.06	0.56	0.18	0.14	0.48	49.65
1983	5.91	7.89	11.64	9.26	11.40	10.97	6.23	1.32	0.71	0.90	3.78	0.18	70.19
1984	1.04	12.69	14.46	0.66	4.97	4.35	2.77	1.60	1.00	0.02	0.05	0.13	43.74
1985	3.68	16.34	4.47	0.76	4.18	4.94	0.27	0.70	0.96	0.05	0.32	1.10	37.77
1986	3.97	3.42	2.66	8.50	11.65	6.31	1.58	1.88	0.14	0.02	0.02	2.92	43.07
1987	1.53	1.90	4.80	6.76	4.43	10.03	0.90	0.31	0.17	0.24	0.08	0.05	31.20
1988	0.75	3.87	12.55	6.78	0.18	1.21	2.14	1.89	2.68	0.09	0.03	0.05	32.22
1989	0.56	9.93	7.67	5.08	3.11	7.98	1.66	1.16	0.25	0.02	0.37	0.95	38.74
1990	3.25	2.01	0.71	7.46	5.77	3.18	1.45	3.65	0.23	0.43	0.51	0.12	28.77
1991	2.07	2.89	2.63	0.91	3.36	7.84	1.43	1.88	0.31	0.43	0.93	0.08	24.76

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Annual
1992	1.24	2.33	2.10	3.18	6.70	4.41	1.87	0.22	0.72	0.19	0.15	0.17	23.28
1993	1.98	2.57	10.44	8.20	6.20	4.36	4.60	3.70	1.71	0.49	0.64	0.27	45.16
1994	0.47	1.77	7.61	5.54	8.59	2.86	3.12	1.49	0.57	0.13	0.04	0.20	32.39
1995	0.50	7.21	7.69	16.22	2.17	12.52	6.72	1.38	1.11	0.26	0.19	0.46	56.43
1996	0.58	1.32	11.97	9.70	8.53	3.33	5.02	1.90	0.03	0.07	0.11	0.75	43.31
1997	2.43	5.19	23.13	9.71	2.50	2.65	2.76	0.44	1.13	0.07	0.63	0.85	51.49
1998	2.68	8.36	5.95	14.76	17.08	8.79	3.51	3.48	0.76	0.53	0.14	0.17	66.21
1999	2.26	11.80	6.05	4.95	12.13	10.43	3.00	1.40	0.30	0.17	0.65	0.15	53.29
2000	1.79	7.97	4.93	10.70	9.71	3.00	3.38	2.22	0.56	0.26	0.14	0.44	45.10
2001	3.13	3.41	2.29	5.18	5.61	2.96	3.04	0.46	0.77	0.33	0.54	0.24	27.96
2002	0.95	7.66	11.50	6.36	5.58	4.87	2.45	0.80	0.22	0.11	0.05	0.18	40.73
2003	0.26	3.93	26.71	4.98	3.63	6.55	12.98	1.45	0.09	0.06	0.47	0.45	61.56
2004	0.72	6.39	11.08	7.65	11.01	2.36	1.35	1.36	0.23	0.19	0.43	0.31	43.08
2005	6.29	2.34	8.79	7.25	3.07	6.88	4.86	3.27	3.03	0.10	0.14	0.08	46.10
2006	1.83	6.17	14.52	9.89	6.42	13.04	4.69	0.89	0.27	0.14	0.02	0.16	58.04
2007	0.54	7.36	7.78	1.96	12.04	3.01	2.66	1.23	0.29	0.84	0.05	0.23	37.99
2008	3.15	2.28	7.85	10.70	4.12	2.59	1.84	0.11	0.43	0.15	0.44	0.06	33.72
2009	1.25	3.87	6.37	1.43	7.91	5.44	1.11	1.99	0.24	0.21	0.16	0.56	30.54
2010	2.86	3.80	4.41	11.29	5.57	5.85	7.94	3.28	1.81	0.08	0.35	0.62	47.86
2011	4.29	5.41	11.19	1.71	5.08	12.30	4.22	1.37	1.62	0.20	0.17	0.27	47.83
2012	3.25	4.53	1.67	5.81	3.42	12.10	5.09	0.66	1.78	1.16	0.11	0.10	39.68
2013	2.41	8.90	11.11	2.88	1.73	3.64	1.87	0.85	0.46	0.06	0.23	2.07	36.21
2014	0.14	1.32	0.61	0.89	6.06	5.74	1.50	0.72	0.16	0.14	0.17	2.45	19.90
2015	5.56	4.15	10.72	1.13	7.82	2.20	4.06	0.25	0.13	0.19	0.57	0.68	37.46
2016	1.01	4.34	13.16	13.29	3.33	10.05	3.24	0.59	0.05	0.16	0.14	0.23	49.59
2017	9.9	7.7	7.55	13.05	13.21	7.35	5.92	1.03	0.52	0.17	0.11	0.66	67.17
2018	1.11	6.54	1.87	7.07	2.03	9.79	4.37	0.99	0.53	0.09	0.14	0.25	34.78
2019	0.7	4.89	5.69	8.31	15.63	5.5	2.09	3.14	0.07	0.09	0.61	1.16	47.88
2020	0.96	1.35	9.82	7.32	0.96	3.3	2.33	4.28	0.62	0.14	0.13	0.46	31.67
2021	0.34	3.34	3.51	8.41	6.06	5.09	0.9	0.35	0.47	0.68	0.18	0.99	30.32

Notes:

Data provided by J. Lema, Ferndale CA. Gauge located at 515 Shaw Ave. since October 1994, and at 1345 Main Street from October 1970 to October 1994.

Location prior to October 1970 was not determined.

Aquifer Parameters Technical Memorandum
(TM-2)

Aquifer Parameters

Technical Memorandum Eel River Valley Groundwater Basin

Humboldt County Department of Public Works

Prepared for:

County of Humboldt Department of Public Works
Environmental Services
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1. Aquifer Parameters

1.1 Overview

Descriptive hydrogeologic conceptual models (HCM) are required in Groundwater Sustainability Plans (GSP) to characterize the physical components of the subject basin, as well as to describe the occurrence of groundwater and its movement in and out of the basin. The HCM is also the basis for the numerical integrated surface water-groundwater model used to simulate current and future basin conditions. The purpose of this technical memorandum (TM) is to provide a detailed description of the physical properties of the Eel River Valley Basin's (ERVB) aquifers and aquitards in relation to the HCM and to the numerical integrated surface water-groundwater model.

1.2 Principal Aquifers and Aquitards

Primary water-bearing units within the ERVB include the thick sequence of near-surface unconsolidated alluvial deposits that form the lower Eel River Valley and portions of the Van Duzen River Valley, and the underlying Carlotta formation. Minor, localized aquifers are also present within the poorly consolidated sediments that make up the uplifted marine, fluvial, and floodplain terrace sediments (Rohnerville and Hookton formations; Hydesville, Metropolitan, Rio Dell, and Scotia terraces).

1.2.1 Alluvial Aquifer

The alluvial aquifer is most prominent within the central portions of the lower Eel River Valley, where it is 260 feet thick, or greater. The alluvial aquifer extends up the Van Duzen River Valley thinning to less than 40 feet in the vicinity of the Town of Carlotta.

The alluvial aquifer is generally unconfined, however semi-confined conditions can occur where there are particularly thick fine-grained units near the surface. The surface waters of the Eel and Van Duzen rivers are generally in direct contact with the alluvial aquifer.

The physical characteristics of the alluvial aquifer reflect the dynamic tectonic and geomorphic history in the area and is observed to have significant lateral variation within the ERVB. In general, the alluvium is an accumulation of a variety of materials, tending to be coarser (sands, gravels) in areas where the river channels have migrated and finer (silts, clays) in areas where floodplain processes dominate. There are also thick sequences of fine-grained alluvial material along the base of the Wildcat hills, particularly where major streams have built alluvial fans (generally in the Ferndale area).

1.2.2 Carlotta Formation Aquifer

The Carlotta formation consists of coarse-grained clastic sediments interbedded with fine-grained units of variable thickness, deposited in a near-shore or terrestrial setting. Based on its texture and regional distribution, the Carlotta aquifer represents a principal aquifer in the ERVB. Groundwater within the unit is generally overlain and semi-confined by discontinuous silt and clay interbeds, and alluvium and terrace deposits. In general, it is not as productive as the alluvial aquifer.

The Carlotta formation is known to be in excess of 1,500 feet thick, locally as much as 4,000 feet thick (Ogle 1953; California Department of Water Resources [DWR], U.S. Geological Survey [USGS] 1978). However, only the upper part of the Carlotta formation has been tapped by wells, principally in upland areas such as the slopes flanking the northern and southern boundaries of the ERVB and up on the Hydesville/Rohnerville terrace surfaces.

1.2.3 Aquitards

Virtually all the stratigraphic sections within the ERVB include beds of fine-grained sediments, many of which are thick enough and/or of low enough permeability to act as aquitards. Well-defined, laterally continuous aquitards are not typical of the depositional environments in the ERVB and can be difficult to define with confidence.

Thick fine-grained units have been logged in many of Humboldt County's deeper monitoring wells (MW-5d, MW-7d, MW-8, MW-13d, MW-12d and MW-13d). Groundwater level monitoring in wells screened in aquifers above and below these units often indicate that a confined or semi-confined condition exists below these units. The Carlotta formation is known to contain fine-grained interbeds that form localized aquitards up to 50 feet thick, but these are not well understood because very few wells penetrate deeper than 200 feet.

A significant aquitard was identified recently, in the spring of 2021, during the installation of MW-12d and MW-13d within the lower Van Duzen River Valley. The aquitard was also identified in an exploratory boring installed at the City of Fortuna's well field, off Eel River Drive just south of the City. The approximately 40-foot-thick aquitard is encountered at depths of 100 to 140 feet below grade and is interpreted to be laterally continuous east of the Eel River; it is not known if the aquitard extends beneath the Eel River. This aquitard is believed to separate the alluvial and Carlotta formations, with groundwater levels separated by the aquitard, differing by up to a few feet.

1.3 Aquifer Hydraulic Characteristics

There are two (2) general types of aquifer properties relevant to groundwater management:

1. **Groundwater transmission properties**: control the relationship between hydraulic gradients and the rate of groundwater flow
2. **Aquifer storage properties**: control the relationship between the volume of groundwater stored in the aquifer and the water elevation measured in the aquifer

It is understood that the hydraulic characteristics of the aquifers within the ERVB are generally derived from past DWR/USGS reports (1959, 1965, 1978) and the studies carried out as part of the County's response to the Sustainable Groundwater Management Act (SGMA) (Alternative Plan 2016 and current study). Where hydrogeologic properties have not been measured in the ERVB, aquifer properties have been estimated through model calibration. Aquifer property calibration has been completed for numerous published modeling studies, including by Durbin (1974), Yates (1988), and WRIME (2003).

Recent data collection and analysis from the County's 2016 Alternative Plan, as well as through the development of this 2021 GSP and related numerical modeling, offer insight to the ERVB's physical characteristics. Still, ERVB geometry and hydrogeological components are complex, so future data and monitoring integrated with numerical modeling will significantly improve understanding of the basin. Data gaps and important uncertainties are discussed in Section 2.1 of this TM.

1.3.1 Groundwater Transmission Properties

To evaluate the alluvial and Carlotta formations aquifers' parameters, aquifer testing has been conducted on 36 County monitoring wells, installed at key locations in the ERVB in 2016 and 2021, shown in Figure 1. Hydraulic conductivity within the screened aquifers of the wells was evaluated by analyzing data from pneumatic slug tests performed following the wells' initial construction and development. Wells MW-1s/d, MW-2s/d, MW-3d, MW-7s/d, MW-9s/d, MW-10, and MW-11 were tested between November 1, 2016 and November 15, 2016, while wells MW-12 through MW-30 were tested between June 17, 2021 and July 2, 2021. Depths of the wells range from 20 to 250 feet below the ground surface (bgs).

The method for pneumatic slug testing involves:

1. Attaching a valve cluster and regulator to the well head
2. Installing a pressure transduce in the well

3. Determining the pre-test equilibrium water level
4. Pressurizing to between 30 and 40 pounds per square inch (psi)
5. Releasing the pressure and recording data until the water level returns to the pre-test level

At least three (3) tests were performed to ensure stable results. The test data was then analyzed using either Bouwer and Rice (1976) or the van der Kamp (1976) methods. The Bouwer and Rice method is used for water levels that smoothly and gradually returned to the pre-test level, and the van der Kamp method is used when the water level oscillated back to the pre-test level. Results of the analysis are included in Appendix 1, Table 1.

Hydraulic conductivities of the alluvial aquifer, as measured in County wells, range from 0.1 feet per day (ft/day) in the shallow fine-grained sediments west of Fortuna to as high as 420 ft/day in the channel alluvium adjacent to the active Eel River channel.

Monitoring wells MW-1s/d, MW-2s/d, MW-3d, MW-7d, MW-8, MW-12s, MW-14d, MW-24, and MW-26 had the highest hydraulic conductivities, ranging from 110 to 420 ft/day. These values, with exception to MW-8, correspond to the alluvial aquifer adjacent to the Eel River, which is composed of relatively shallow channel deposits of unconsolidated sand and gravel. MW-8 is screened in the gravelly alluvium below a 120-foot-thick deposit of silt.

Monitoring wells MW-5d, MW-9s/d, MW-10, MW-11, MW-13s/d, MW-14s, MW-15s/d, MW-18, MW-19, MW 25, MW-28, and MW-30 had low to moderate hydraulic conductivities, between 10 and 100 ft/day. These values correspond to older (deeper) alluvium deposits and/or Carlotta deposits.

Monitoring wells MW-7s, MW-12d, MW-16, MW-17, MW-20, MW-21, MW-22, MW-23, MW-27, and MW-29 had low hydraulic conductivities, between 0.1 and 8.3 ft/day, which correspond to relatively consolidated alluvium or areas with a higher percentage of fine-grained soils, predominantly silt.

Vertical hydraulic conductivities throughout the ERVB, particularly between the contacts of the alluvial aquifer and the Carlota formation, have not been previously studied, though they have been estimated through finite-difference flow modeling calibration in this GSP. In general, estimated vertical hydraulic conductivities range from 6 to 10 percent of lateral hydraulic conductivities.

1.3.2 Aquifer Storage Properties

The alluvial aquifer is a high production unit that is widely used for agricultural irrigation and municipal water. The depth to groundwater is generally shallow, with the water table measuring a few feet to as many as 40 feet bgs. This indicates a relatively high specific yield for the alluvial aquifer and high specific capacities of production wells completed in this unit, with water levels responding quickly to recharge rain events. Specific well capacities are typically 20 to 350 gallons per minute (GPM) per foot (GPM/ft) of drawdown (Johnson 1978), although they may locally be as high as 600 GPM/ft of drawdown (DWR 1965).

Specific storage values for partially or completely confined areas of the ERVB have been previously measured, with the primary data provided by Evenson (1959), who estimated an average specific yield of 22 percent. Due to the nature of the ERVB abutting the Pacific Ocean, a fixed head boundary influences the available aquifer storage. Therefore, it is important to look at the volume of water in the aquifer as storage fluxing annually, where years of above average precipitation increase aquifer storage and years of below average precipitation decrease aquifer storage.

1.4 Eel River Valley Basin Boundaries

The boundaries of the ERVB influence the hydraulic transmission properties of the aquifer's groundwater flow direction and are currently unquantified. The ERVB is bounded on the south side by the Wildcat Range, a mountainous area formed by north-dipping sediments of the Wildcat Group in the southern limb of the Eel River syncline. Specifically, the ERVB includes the portions of the Wildcat Range underlain by the uppermost, coarse-grained member of the Wildcat Group (the Carlotta formation).

The northern side of the Basin is bounded by the axis of the Table Bluff anticline to the west and the mapped main trace of the Little Salmon fault to the east. The Little Salmon fault is a prominent, active, northwest-trending, northeast-dipping thrust fault that accommodates triple-junction related crustal shortening and is generally believed to be the confining boundary to groundwater flow to the north side of the ERVB. This boundary is generally considered and assumed here to be a groundwater flow boundary.

The western boundary of the ERVB abuts the Pacific Ocean, where the Eel River and underlying aquifers flow and mix with seawater.

The eastern limits of the ERVB are defined by the extent of the mapped Carlotta formation with some extensions to include the terraces and shallow alluvial materials of the Eel and Van Duzen rivers. Bedrock inflows from the southern and eastern limits of the basin have been relatively unstudied and are preliminarily considered to contribute a negligible amount of groundwater on a year-to-year basis, until more information is collected.

The ERVB bottom is defined by the base of the Carlotta formation where it is in contact with the Scotia Bluffs Sandstone and other finer-grained units of the Wildcat Group. The base of the ERVB is not well constrained, as the Carlotta formation is several thousand feet thick in places and exploration of groundwater potential, flow characteristics, and aquifer parameters has not penetrated to those depths.

Due to the uncertainty of the ERVB bottom and the fact that no wells tap into the middle or lower portions of the Carlotta formation, the ERVB bottom has been initially modeled in this GSP, using geologic cross-sections and lithological descriptions of the exposed sections of the Wildcat Group south and north of the Basin (Ogle 1953), to terminate at 1,500 feet with no vertical conductivity between the Carlotta formation and the underlying Wildcat Group.

2. Conclusions

The vast majority of groundwater use in the ERVB occurs in the alluvial aquifer channel deposits, where the range of hydraulic conductivities and specific yield are relatively high, and the overall aquifer depth to water from the ground surface is relatively shallow. Thus, the following conclusions apply:

1. Water supply wells generally have a limited radius of influence and minimal interference with near vicinity wells.
2. Annual aquifer recharge occurs rapidly.
3. The volume of water in the aquifer as storage within any given year occurs as with an annual flux, not as a closed system, and likely cannot be used for groundwater banking as a specific management approach.

2.1 Aquifer Parameters Data Gaps and Uncertainty

Data gaps within the current aquifer parameters include:

- The stratigraphy within the surficial alluvium is complex. Lateral and vertical stratigraphic variations are the result of a dynamic geologic history influenced by tectonics, sea level fluctuations, and large river systems with high sedimentation rates. The size and geometric configuration of the aquifer(s) associated with the alluvial unit, particularly at depth, are not entirely understood. Similarly, the thicknesses and continuity of silt/clay layers (aquitards) across the ERVB are not fully delineated.
- Although the 2016 Alternative Plan and this 2021 GSP have generally defined the uppermost portions of the Carlotta formation aquifer, little is known about the hydrogeologic characteristics of the lower underlying Carlotta formation aquifers. The aquifer transmission and storage relationship between the base of the alluvial aquifer and top of the Carlotta aquifer is not well understood, particularly in the central and westernmost portion of the ERVB. Further, there

is little available information about lower aquitards within the Carlotta formation; multiple aquifers likely exist within the unit. Additionally, there are no data in relation to the thickness of the water-bearing part of the unit; the unit is up to 4,000 feet thick in places.

- The stratigraphy and aquifer characteristics associated with the Rohnerville and Hydesville terraces have not been studied in detail. These areas are unique in their setting, but do not play a significant role in overall water use in the ERVB.
- The fault zone associated with the Little Salmon fault and secondary faults within the ERVB are not well understood in terms of their impact and control of groundwater flow dynamics at the boundaries of and internally within the ERVB.

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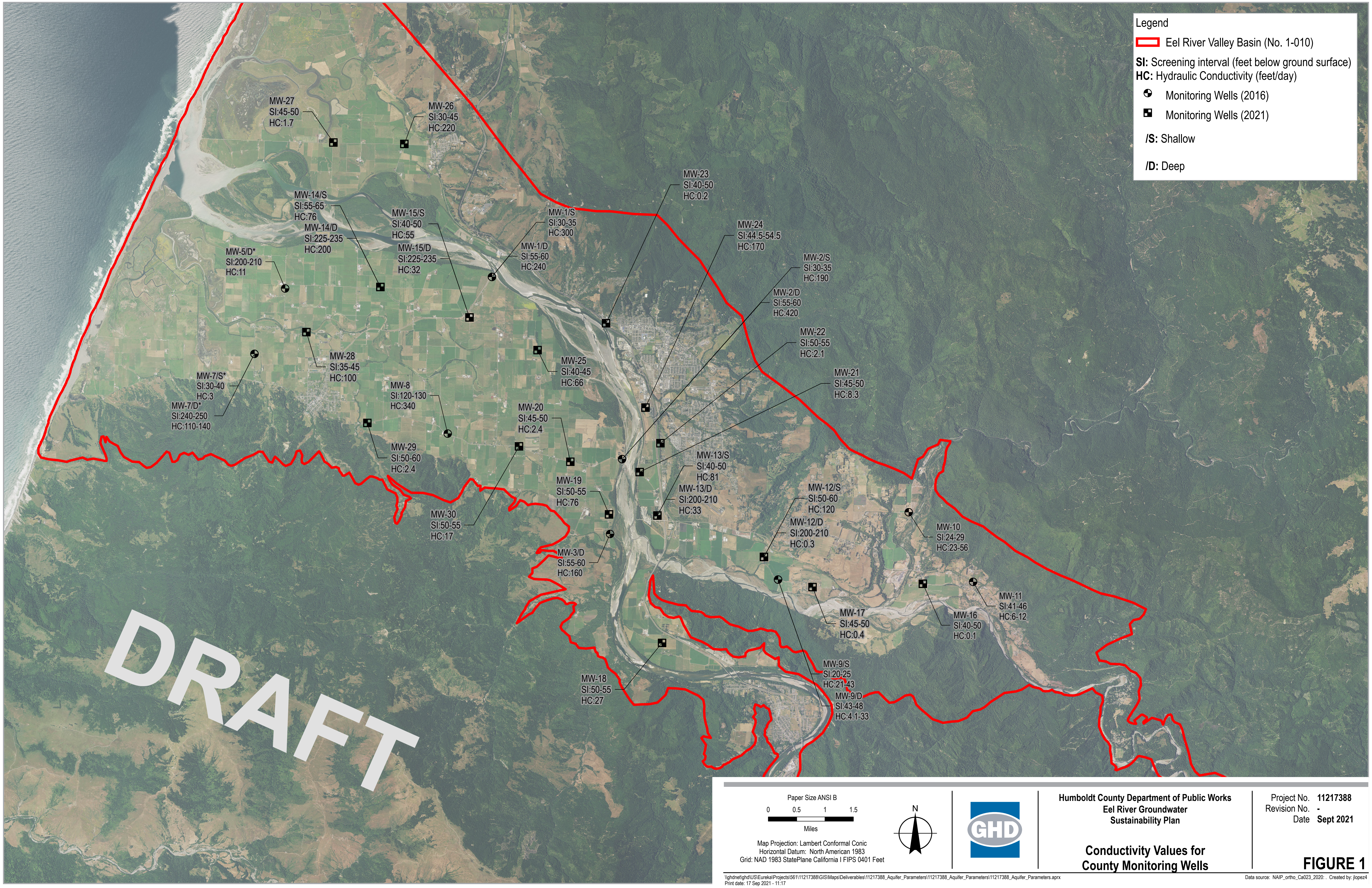
Appendix A Figures and Tables



Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane California I FIPS 0401 Feet

Humboldt County Department of Public Works
Eel River Groundwater
Sustainability Plan

Conductivity Values for County Monitoring Wells

Project No.	**11217388**
Revision No.	**-**
Date	**Sept 2021**

FIGURE 1

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Print date: 17 Sep 2021 - 11:17

Data source: NAIP_ortho_Ca023_2020: . Created by: jlopez4

Table 1
Aquifer Slug Test Results

Monitoring Well ID	Screened Interval[1] (feet)	Aquifer Material	Hydraulic Conductivity (feet per day)
MW-1d[2]	55-60	Sand and Gravel	240
MW-1s[3]	30-35	Sand and Gravel	300
MW-2d	55-60	Gravel	420
MW-2s	30-35	Sand and Gravel	190
MW-3d	55-60	Sand and Gravel	160
MW-5d[4]	200-210	Sand and Gravel	11
MW-7d[4]	240-250	Sand and Gravel	110-140
MW-7s[4]	30-40	Silt	3
MW-8	120-130	Gravel	340
MW-9d	43-48	Sand	4.1-33
MW-9s	20-25	Sand and Gravel	21-43
MW-10	24-29	Sand and Gravel	23-56
MW-11	41-46	Sand and Gravel	6-12
MW-12s	50-60	Sand and Gravel	120
MW-12d	200-210	Sand, Silt, Clay, and Gravel	0.3
MW-13s	40-50	Sand and Gravel	81
MW-13d	200-210	Sand	33
MW-14s	55-65	Sand and Gravel	76
MW-14d	225-235	Sand and Gravel	200
MW-15s	40-50	Sand and Gravel	55
MW-15d	225-235	Sand and Gravel	32
MW-16	40-50	Silt	0.1
MW-17	45-50	Sand, Silt, and Gravel	0.4
MW-18	50-55	Silt and Gravel	27
MW-19	50-55	Sand and Gravel	76
MW-20	45-50	Sand	2.4
MW-21	45-50	Sand and Gravel	8.3
MW-22	50-55	Sand and Gravel	2.1
MW-23	40-50	Sand and Silt	0.2
MW-24	44.5-54.5	Sand and Gravel	170
MW-25	40-45	Sand and Gravel	66
MW-26	30-45	Sand and Gravel	220
MW-27	45-50	Sand and Silt	1.7
MW-28	35-45	Sand, Silt, and Gravel	100
MW-29	50-60	Silt and Gravel	2.4
MW-30	50-55	Sand and Gravel	17

1. depth reference off of the top of the well box
2. d: deep
3. s: shallow
4. Additional well development at monitoring wells was performed following the performance of the pneumatic slug testing, so the actual hydraulic conductivity may be higher than shown.

Assessment of Groundwater Dependent Ecosystems (TM-3)

TECHNICAL MEMORANDUM ◦ AUGUST 2021

Assessment of Groundwater Dependent Ecosystems for the Eel River Valley Basin Groundwater Sustainability Plan

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