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Cover photos: Juvenile Chinook salmon

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1 BACKGROUND AND SETTING

1.1 Background

This Technical Memorandum for the Eel River Valley Groundwater Sustainability Plan (GSP) addresses the extent and condition of groundwater dependent ecosystems (GDEs) in the Eel River Valley Basin (ERVB; Basin 1-010). As part of the California Sustainable Groundwater Management Act (SGMA), Groundwater Sustainability Agencies (GSAs) are required to consider GDEs and other beneficial uses of groundwater when developing their GSPs. SGMA defines GDEs as "ecological communities of 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 the GDEs are 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. This information will inform sustainable management criteria for each management unit.

Plants can rely on water infiltrating into the soil via local rainfall, groundwater, surface water, or other sources (Steinwand et al. 2006). GDEs are linked to groundwater (and or the capillary fringe above the saturated groundwater zone) through plant roots or are direct users of interconnected surface water (Klausmeyer et al. 2018, Braudrick et al. 2018). Riparian plants, which are often present in GDEs, may instead be connected to surface water through their roots. These plants may still be GDEs if the surface water they rely upon is interconnected with groundwater upstream of the GDE. Some phreatophytes may be connected to groundwater when it is available, but not require groundwater for survival and require more water than is available in the soil from rainfall (Steinwand et al. 2006). The presence of non-groundwater sources, such as surface water and soil moisture within and near a GDE, does not preclude the possibility that the GDE is supported by groundwater. A GDE is distinct from other riparian ecosystems in that it is either connected to a principal aquifer or is a beneficial user of a surface water or shallow/perched groundwater source that is connected to a principal aquifer.

1.2 Physiography

The ERVB is a coastal basin in western Humboldt County, located 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 (Figure 1.2-1). The valley floor comprises the majority of the basin's 73,700-acre surface area (DWR 2016) and ranges in elevation from 0 to 30 feet above sea level (ft asl). The foothills that mark the basin's inland perimeter reach elevations of up to 300 ft asl.

The ERVB occupies a westward-plunging syncline approximately 20 miles north of the Mendocino Triple Junction, where the Gorda, North American, and Pacific tectonic plates intersect. The subduction of the Gorda Plate below the North American Plate along the Cascadia Subduction Zone produces northeast-southwest compression, and the associated crustal deformation in the overriding North American Plate is expressed as a 90-km-wide fold and thrust belt (GHD 2021). The ERVB occupies the onshore portion of the Eel River syncline, a broad structural downwarp in the accreted terranes of the Franciscan Complex and overlying Wildcat Group sedimentary deposits (McLaughlin et al 2000).

The ERVB is bounded to the north by the Little Salmon Fault, an active, northwest-trending, northeast-dipping thrust fault that accommodates regional compression. The western boundary coincides with the Eel River Estuary. The ERVB is bounded to the south by the Wildcat Range, the southern limb of the Eel River syncline, and bounded to the east by uplifted, less permeable units of the Wildcat Group (DWR 2003). The Ferndale Fault runs along the southern edge of the ERVB, north of the Wildcat Range (McLaughlin et al., 2000), and the Goose Lake Fault runs through the terraces in the Yager Creek drainage (GHD 2021a).

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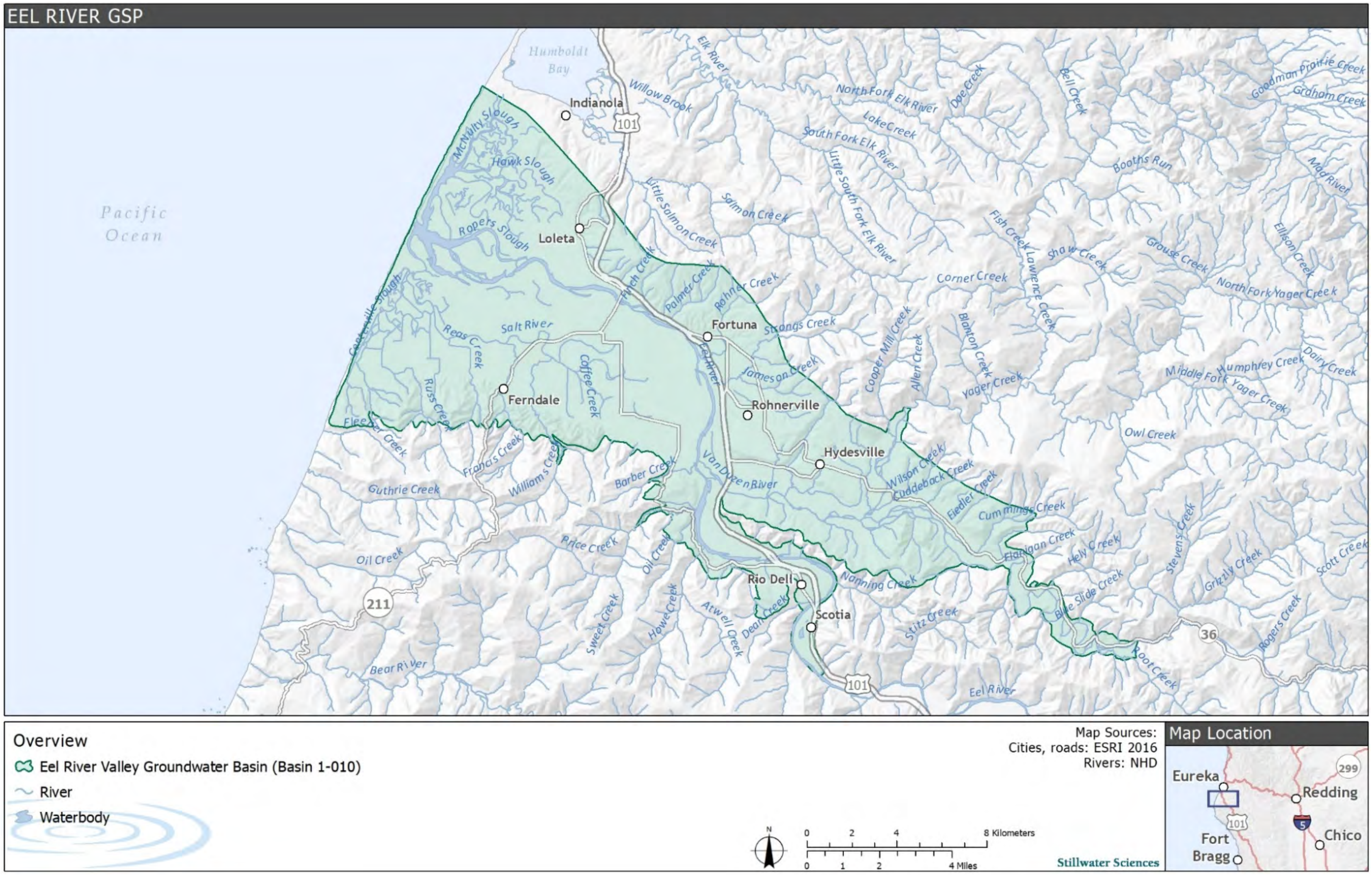

Figure 1.2-1. Eel River Valley Basin

1.3 Geology and Soils

The consolidated rocks of the Wildcat Group, deposited in the proto-basin during the late Miocene to Pleistocene (McLaughlin 2000), form the bottom of the contemporary basin. The Carlotta Formation is the uppermost unit of the Wildcat Group and is typically over 1,500 ft thick. An accumulation of unconsolidated alluvium up to 200 ft thick overlies the downwarped Carlotta Formation. The alluvium tends to be coarser (sands and gravels) near the Eel and Van Duzen channels and finer (silts and clays) on the extensive floodplain (GHD 2021a).

The Ferndale soil series covers much of the central part of the basin, grading from fine sandy loam along channels to silt loam on the floodplain (Watson et al 1925). The Ferndale soils are of alluvial origin, well drained, up to 60 inches thick, and slightly alkaline at depth (NRCS 2016). Coquille clay loam occurs on the floodplain near the coast. It is derived from tidal marsh deposits and is poorly drained. Bayside loam occurs on the foothills of the Wildcat Range along the southwestern edge of the ERVB and is intermediately drained. Willits clay loam occurs on the marine terraces and steep slopes north of Fortuna and is well drained. To the east, the Willits unit transitions to Rohnerville clay loam, a similar but deeper soil that occurs on level ground (Watson et al. 1925)

1.4 Hydrology

The primary aquifers in the ERVB are the Carlotta Formation in the Upper Wildcat Group and the sequence of overlying unconsolidated alluvial deposits. The Carlotta Formation is typically over 1,500 ft thick and may be up to 4,000 ft thick locally, but the maximum productive depth is not well defined. Groundwater in the formation is typically confined or semi-confined by silt and clay interbeds. Wells tapping the Carlotta Formation are between 200 and 400 ft deep; artesian conditions occur in wells near the foothills (GHD 2021a). The alluvial aquifer is up to 200 ft thick and unconfined, with high conductivity. Most wells in the alluvial aquifer are about 70 ft deep. Hydrologic connectivity between the alluvial aquifer and the Carlotta Formation is not well understood, but there is likely some connection between the two in the central part of the ERVB (GHD 2021a).

The alluvial aquifer is the primary water source for most agricultural wells (GHD 2021a). Irrigation is the primary groundwater use sector. Between 2011 and 2020, average annual groundwater extraction from the ERVB for irrigation was 14,077 acre-feet (acre-ft) (GHD 2021b). Average annual extraction for municipal, cannabis cultivation, and other uses was 1,733 acre-ft, 98 acre-ft, and 414 acre-ft, respectively (GHD 2021b).

Groundwater in the ERVB flows east to west, down the Eel and Van Duzen River valleys to the coast. Groundwater discharge occurs at springs and seeps into the upland areas and by subsurface flow to the tidal estuary (GHD 2021b). Both aquifers are hydraulically connected to the Pacific Ocean along approximately 10 miles of coastline. There is no evidence to suggest that the location of a freshwater-seawater transition zone has migrated landward since 1975 with the exception of modest salinity increases near the Salt River and Loleta (SHN. 2021a). North of the tidally, influenced reach of Eel River, most of the alluvial aquifer is naturally degraded by seawater (USGS 1978). South of the Eel River, elevated chloride concentrations (>100 mg/L) were detected in the alluvium along the coast where ground elevation was less than 10 ft asl. Chloride concentration increased with depth at a given distance from the coast. Substantial recharge to the groundwater system from the Eel River upstream of the tidally influenced reach sustains a seaward hydraulic gradient that moderates seawater intrusion in the area (USGS 1978).

During the dry season, tidal cycles produce fluctuations in surface water levels of as much as 1.5 ft, causing localized transitions between gaining and losing stream conditions (SHN 2019).

The Eel River is the third largest watershed in California, draining 3,684 square miles (California Department of Fish & Wildlife [CDFW] 2014). The mainstem Eel River is approximately 197 miles long, with headwaters in Mendocino County, 10 miles north of Lake Pillsbury. Upstream of the ERVB, the river is dammed at the Scott and Cape Horn dams, forming Lake Pillsbury and Van Arsdale Reservoir, respectively. Between 2010 and 2019, average annual discharge in the Lower Eel River near Scotia (USGS gage 11477000) ranged between 1,619 and 12,150 cubic feet per second (cfs); monthly average discharge ranged between 32 cfs (August 2014) and 54,201 cfs (February 2017) (USGS 2019). The Van Duzen River drains into the Eel River about 14 miles upstream of the Pacific Ocean. Other major tributaries include Yager Creek, which joins the Van Duzen below the town of Carlotta.

The tidally influenced reach of the Eel River extends approximately 12 miles inland from the river mouth, upstream of Fernbridge. The Eel River experiences very high levels of sedimentation (CDFW 2014). The Salt River, a remnant channel of the Eel River, has been significantly impacted by sedimentation; many of the Salt River's low-gradient tributaries have filled with sediment and do not convey significant surface flow. As of 2019, restoration efforts by the Humboldt County Resource Conservation District (HCRCD) have opened portions of the Salt River to tidal inundation and partial freshwater inputs (HCRCD 2021).

2 GROUNDWATER-DEPENDENT ECOSYSTEMS IDENTIFICATION

2.1 Vegetation Communities

Potential GDE units in the ERVB 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 and augmented with additional vegetation mapping datasets to produce a map of final GDE Units; 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.

2.1.1 Data sources

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 ERVB.

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 (U.S. Department of Agriculture [USDA] 2020). The refined vegetation map incorporates the following datasets:

- CalVeg – Forest Service (USDA 2014). *North Coast region: Imagery date: 2000-2007; Minimum mapping unit (MMU): 2.5-acre.*

- NAIP (USDA 2020). *Humboldt County: Imagery date: 2020; Resolution: 1 meter*.

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) was subsequently incorporated to assess the landscape position and likelihood of groundwater dependence for select vegetation types.

Maximum rooting depths from the literature are provided in Appendix A. Another way to explore the rooting depth of plants is to assess their elevation relative to the river channel surface (the relative elevation). Assuming that the groundwater elevation near the stream is similar to the stream elevation, we can assess the likely rooting depth of plants based on their relative elevation.

2.1.2 Procedure

The steps for defining and mapping GDEs outlined in Rohde et al. (2018) were used as a guideline for this process. A decision tree was applied to determine when species or biological communities were considered groundwater-dependent based on definitions found in the 23 CCR § 351(m) (State of California 2021) and Rohde et al. (2018). This decision tree, created to systematically and consistently address the range of conditions encountered, is summarized below; the term “unit” refers to an area with consistent vegetation and hydrology.

The unit is a GDE if groundwater is likely:

1. Interconnected with surface water in a stream channel;
2. An important hydrologic input to the unit during some time of the year;
3. Important to survival and/or natural history of inhabiting species; and
4. Associated with a principal aquifer used as a regionally important source of groundwater.

The unit is not a GDE if its hydrologic regime is primarily controlled by:

1. Surface discharge or drainage from an upslope human-made structure(s) with no connection to a principal aquifer (such as irrigation canal, irrigated fields, reservoir, cattle pond, or water treatment pond/facility); or
2. Precipitation inputs directly to the unit surface (this excludes vernal pools from being GDEs where units are hydrologically supplied by direct precipitation and very local shallow subsurface flows from the immediately surrounding area).

The initial potential GDE map was generated by editing the CalVeg (USDA 2014) dataset to better match NAIP 2020 imagery (USDA 2020), with a focus on the estuary, Eel River mainstem, and lower Van Duzen River areas. Surface water boundaries were reshaped, and vegetation types reassigned, to match extents in the imagery.

Several vegetation types were reviewed individually. Ponds and saltmarsh/mudflat habitats (e.g., pickleweed-cordgrass) were removed from the potential GDE map if determined, based on aerial imagery, to be tidally connected. Irrigation ditches (e.g., straightened channels) were also removed from the potential GDE map. Based on aerial imagery and landform, some vegetated features were semi-permanently inundated and were grouped into the river, stream, canal feature type. In addition, available information on maximum rooting depths was used as an additional filter to help ensure that non-GDE vegetation types were excluded.

Finally, SSUGRO landform data (USDA 2020) were overlaid and the potential GDE determination based on landform location for some vegetation types (e.g., redwood) was updated. The landform data were also used to remove agriculture and pasture areas located in backswamps, hillslopes, fan remnants, flood-plain steps, and natural levees from the potential GDE map.

The differences between the final GDE map and the iGDE map (DWR 2020) are shown in Figure 2.1-1. GDEs were added in the intertidal zone and along the upstream reaches of the Eel and Van Duzen Rivers based on refined mapping of open water features based on NAIP 2020 imagery. GDEs were removed in upstream tributaries based on landform data and along the Eel mainstem and in the intertidal zone based on refined vegetation mapping.

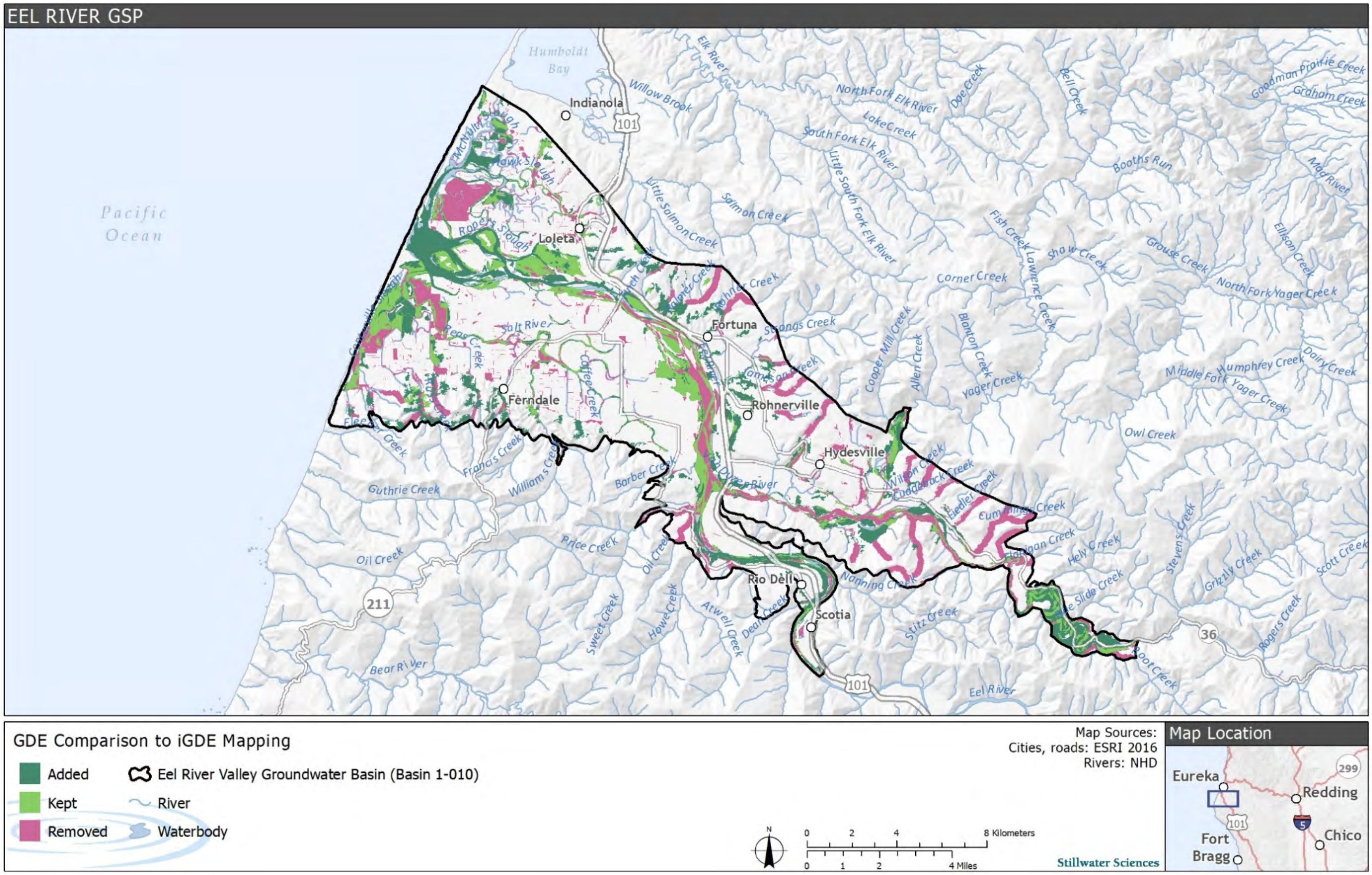

Figure 2.1-1. Comparison of the potential GDE map with the iGDE database (DWR 2020)

2.2 Special-status Species

As part of the ecological inventory, special-status species and sensitive natural communities that are potentially associated with GDEs in the ERVB were identified. For the purposes of this document, special-status species are defined as those:

- Listed, proposed, or under review as endangered or threatened under the federal Endangered Species Act (ESA) or the California Endangered Species Act (CESA);
- Designated by CDFW as a Species of Special Concern;
- Designated by CDFW as Fully Protected under the California Fish and Game Code (Sections 3511, 4700, 5050, and 5515);
- Designated as Bureau of Land Management (BLM) sensitive;
- Designated as endangered or rare under the California Native Plant Protection Act (CNPPA); and/or
- Taxa that meet the criteria for listing as described in Section 15380 of the CEQA Guidelines, including species listed on CDFW's *Special Vascular Plants, Bryophytes, and Lichens List* (CDFW 2021) or plants with a California Rare Plant Rank (CRPR) of 1, 2, 3, or 4.

Sensitive natural communities are defined as those natural community types (e.g., legacy natural communities in CDFW's California Natural Diversity Database [CNDDB], vegetation alliances and/or associations) with a state ranking of S1 (critically imperiled), S2 (imperiled), S3 (vulnerable), or an unranked association that is considered sensitive on CDFW's *California Sensitive Natural Communities List* (CDFW 2020) or in the CNDDB (CDFW 2021b).

2.2.1 Data sources

Spatial database queries included potential GDEs plus a one-mile buffer. This buffer accounts for spatial uncertainty in the data sources. Tests with different buffer sizes showed that larger buffers incorporated too many upland species unlikely to occur in the groundwater basin. Databases queried included:

- California Natural Diversity Database (CNDDB) (CDFW 2020);
- eBird (2021);
- TNC freshwater species lists generated from the California Freshwater Species Database (CAFSD) (TNC 2021);
- National Marine Fisheries Service (NMFS) California Species List tools (NMFS 2021); and
- Consortium of California Herbaria (CCH 2021) (queried from CCH1 Berkeley Mapper and CalFlora).

2.2.2 Procedure

Database query results were reviewed while special-status species and sensitive habitats that may occur within or be associated with the vegetation and aquatic communities in or immediately adjacent to potential GDEs were identified. These special-status species and sensitive community types were then consolidated into a list, along with summaries of habitat preferences, potential groundwater dependence, and reports of any known occurrences.

Wildlife species were evaluated for potential groundwater dependence using determinations from the Critical Species Lookbook (Rohde et al. 2019) or by evaluating known habitat preferences, life histories, and diets. Species GDE associations were assigned one of three categories:

- Direct: species directly dependent on groundwater for some or all water needs (e.g., cottonwood with roots in groundwater, juvenile steelhead in dry season)
- Indirect: species dependent upon other species that rely on groundwater for some or all water needs (e.g., riparian birds)
- No known reliance on groundwater

Sensitive natural communities were classified as either likely or unlikely to depend on groundwater based on species composition using the same methodology as vegetation communities (Section 2.1). Plant species were evaluated for potential groundwater dependence based on their habitat (Jepson Flora Project 2020) and association with vegetation communities classified as GDEs. Special-status plant GDE associations were assigned one of three categories: likely, possible, or unlikely. The "possible" category was included to classify plant species with limited habitat data or where a species may have an association with a vegetation community identified as a GDE.

Database query results for local and regional special-status species occurrences were combined with their known habitat requirements to develop a list of groundwater-dependent special-status species (Section 4) that satisfy the following criteria: 1) the species has been documented to occur within the GDE unit, or 2) is known to occur in the region and suitable habitat is present in the GDE unit.

2.3 GDE Units

Four (4) GDE units were identified within the ERVB (Figure 2.3-1, Table 2.3-1):

- Intertidal Zone and Tributaries: Intertidal reach downstream of Fernbridge
- Middle Eel River: Fernbridge to Eel/Van Duzen rivers' confluence
- Upper Eel River: Eel/Van Duzen rivers' confluence to Scotia
- Van Duzen River and Tributaries: Lower Van Duzen River

Table 2.3-1. GDE Unit acreages in the Eel River Valley Basin

GDE unit	Area (acres)
Intertidal Zone and Tributaries	5,981
Middle Eel River	3,809
Upper Eel River	1,136
Van Duzen River and Tributaries	2,878
Total	**13,804**

[1] Totals may not appear to sum exactly due to rounding error.

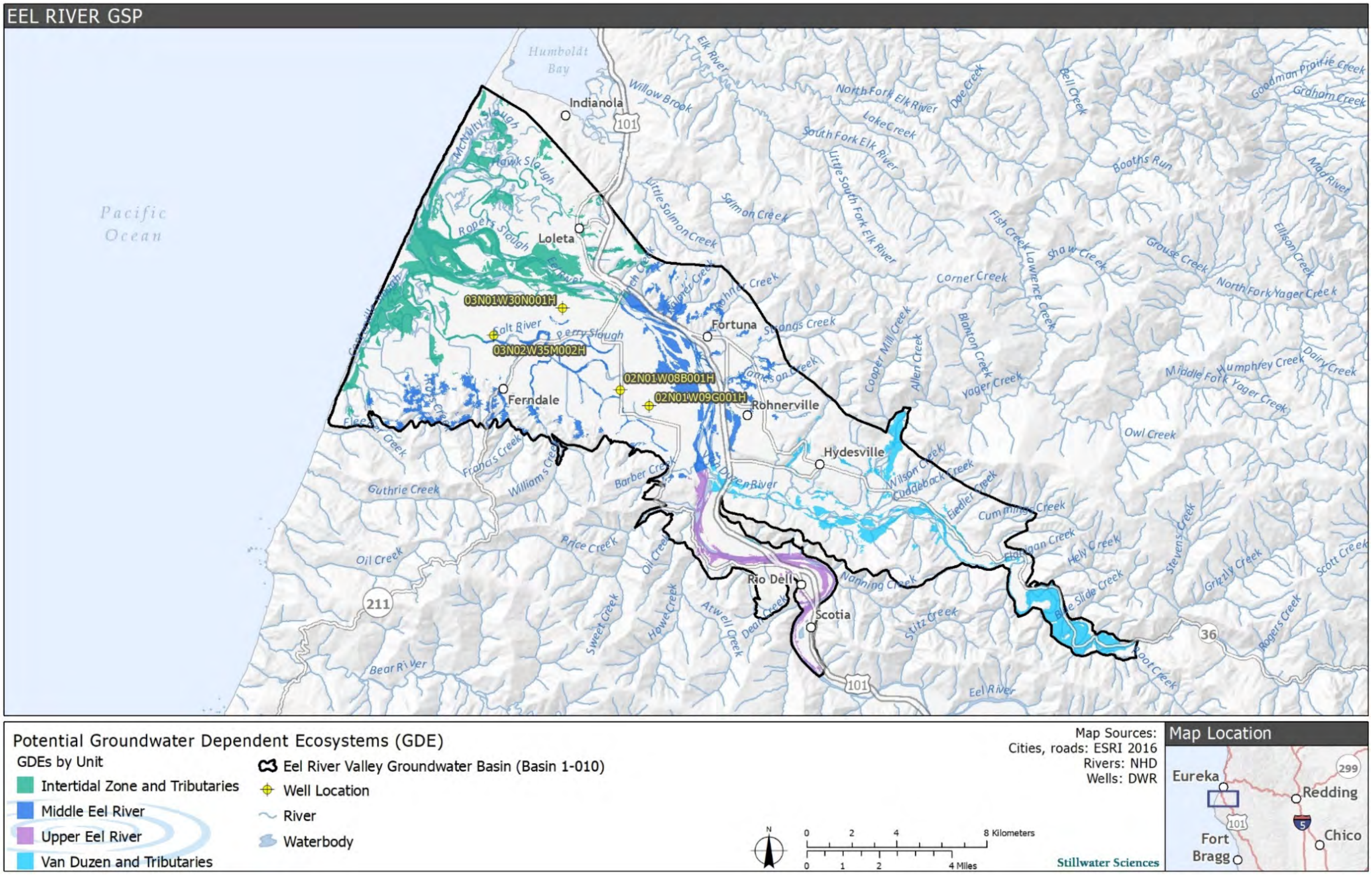

Figure 2.3-1. Potential GDE units and long-term groundwater monitoring well locations

3 HYDROLOGY

The following section (3.1) features a general description of shallow groundwater elevation in the ERVB and uses long-term monitoring well data to assess temporal trends in groundwater elevation for GDE units where well data are available. Section 3.2 covers groundwater quality and its potential effect on GDEs. Section 3.3 assesses the extent of interconnected surface water and spatial trends in interconnected surface water that can later be used to assess potential impacts of groundwater management on GDEs.

3.1 Groundwater Levels

Wet and dry season groundwater elevation contours from 2017, provided by GHD, show that groundwater elevation increases with increasing distance from the coast. Consequently, groundwater generally flows down the Eel and Van Duzen valleys from east to west. Groundwater gradients are typically shallow on the alluvial plain, increasing significantly within about 500 ft of the uplands that bound the alluvial plain to the northeast and southwest. Similarly, gradients steepen at the uplands that bound the lower Eel and Van Duzen river valleys, in which longitudinal groundwater elevation gradients are substantially steeper than in the alluvial plain, but roughly reflect the increase in land surface slope. These contours included data from 44 wells, 14 of which were installed since 2016, while the remainder are older.

Long-term records of shallow groundwater are sparse for the ERVB. This Technical Memorandum presents data from four (4) wells with a data record of shallow groundwater elevation extends from at least 2000 to 2017. Wells located on the alluvial plain, where most GDEs are located, were selected to best characterize shallow groundwater conditions at GDEs. Wells are associated with the nearest GDE unit; two (2) are associated with the Intertidal Zone and tributaries, and two (2) with the Middle Eel River (Figure 2.3-1). In general, shallow groundwater elevations have remained stable since 1990 at all four (4) wells.

There are no long-term shallow groundwater data for the Upper Eel and Van Duzen rivers, nor for tributaries units. In 2017, Humboldt County installed nine (9) new groundwater monitoring wells with pressure transducers (and installed transducers in several existing private wells), expanding the monitoring network into these upstream units (GHD 2021c). As was done for the Intertidal Zone and tributaries and Middle Eel analysis, shallow wells were sought within river valleys to provide rough constraints on shallow groundwater conditions. No suitable wells were found in the Upper Eel GDE unit; existing monitoring points either do not show shallow groundwater (<30 ft below ground surface [bgs]) or are located on terraces over 30 ft above nearby GDEs. In the Van Duzen and tributaries GDE unit, no increasing or decreasing trends in shallow groundwater levels are apparent in the minimal data available.

The wells considered in this analysis all tap the shallow alluvial aquifer, but these depths typically exceed and may not accurately represent the shallow groundwater used by GDEs. Additionally, ground elevation, and therefore depth to water (DTW), at a monitoring well site may differ from ground elevation at the GDEs it represents. A digital elevation model (DEM) from the USGS 2018 LiDAR survey (OCM Partners 2021) was used to extract ground elevations every 10 ft along a 0.5-mile long transect perpendicular to the valley axis and centered at the well location. The range of ground elevation at potential GDEs provides a rough estimate of the groundwater depth relative to the GDE. GDEs are typically located closer to the channel and at lower elevations than their associated wells. On the alluvial plain, where groundwater gradients are shallow, DTW at these GDEs is likely to be shallower than at the well.

The following sections assess long-term groundwater elevation changes for the Intertidal Zone and Tributaries and Middle Eel GDE units in sections 3.1.1 and 3.1.2, respectively. Groundwater elevation from 2016-2019 in the Van Duzen and Tributaries GDE Unit are assessed in Section 3.1.3 because of the propensity of the lower Van Duzen to go dry. Due to sparse data groundwater elevations were not assessed in the Upper Eel GDE Unit. Considering the limited number of long-term monitoring wells, the groundwater elevation data presented in this section are intended to illustrate general trends only and explore trends in groundwater elevation through time.

3.1.1 Intertidal Zone and Tributaries

Well 03N01W30N001H is an active irrigation well installed in 1973 and screened between 20 and 45 ft bgs (Table 3.1-1). The well is located on the alluvial plain 0.5 miles south of the Eel River channel, 4.8 miles from the coast (Figure 2.3-1). From 1989 to present, DTW has been stable, typically between 14 and 22 ft bgs, with seasonal fluctuations typically between 3 and 5 ft (Figure 3.1-1). Figures 3.1-1 to 3.1-4 show (in green) the range of ground elevation within GDEs within 0.5 miles of the well, as described above. Ground elevation at nearby GDEs ranges from 2 to 15 ft below the well site, approximately 3 to 16 ft above the long-term average water level in the well.

Table 3.1-1. Characteristics of wells used for groundwater level assessment. The locations of the wells are shown on Figure 2.3-1.

Well	GDE Unit	Well depth (ft bgs)	Screen depth (ft bgs)	Water level data available
03N01W30N001H	Intertidal Zone and Tributaries	50	20–45	1973–2020
03N02W35M002H	Intertidal Zone and Tributaries	42	Unknown	1973–2020
02N01W08B001H	Middle Eel River	40	Unknown	1952–2017
02N01W09G001H	Middle Eel River	30	25-30	1986–2020
MW-9s	Van Duzen River and Tributaries	25	Unknown	2016–2019

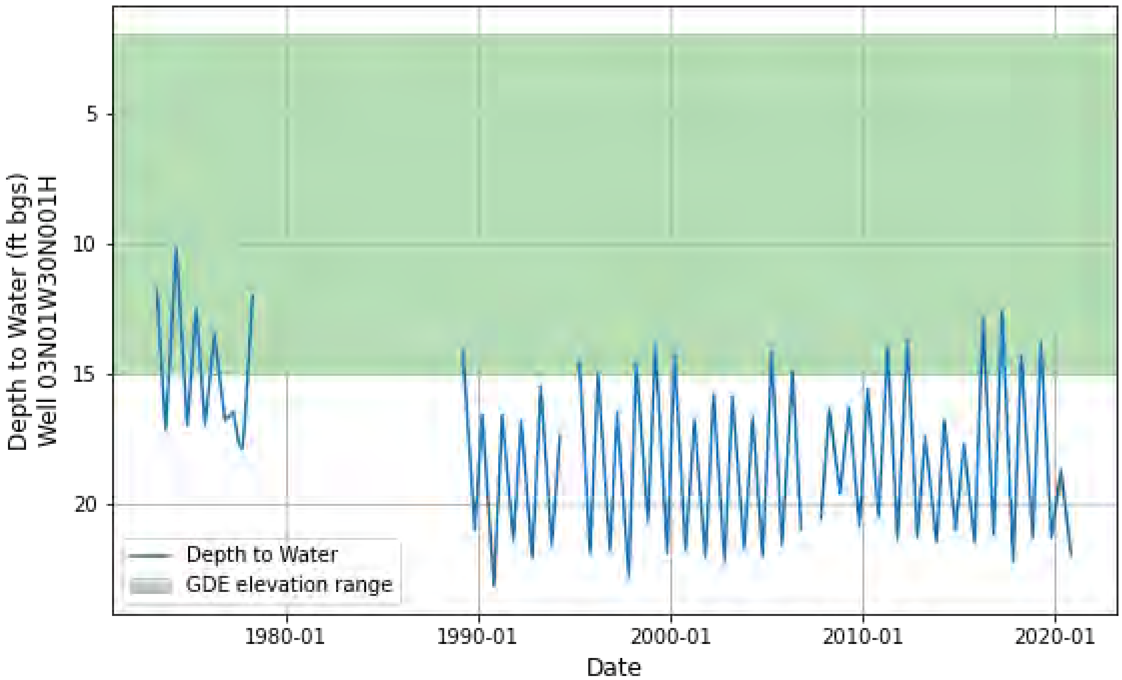

Figure 3.1-1. Depth to groundwater and land surface elevation range at GDEs on well transect, Well 03N01W30N001H, associated with the Intertidal Zone and Tributaries GDE Unit. Well site elevation is assumed to be 0 ft bgs.

Well 03N02W35M002H is an active irrigation well installed in 1973 with unknown screen depth (Table 3.1-1). The well is located on the alluvial plain north of the Salt River channel, 3.3 miles from the coast (Figure 2.3-1). From 1989 to present, DTW has been stable, typically between 4 and 11 ft bgs, with seasonal fluctuations typically between 3 and 5 ft (Figure 3.1-2). Ground elevation at nearby GDEs ranges from 8 ft below to 3 ft above the well site, approximately 0.5 to 11 ft above the long-term average water level in the well.

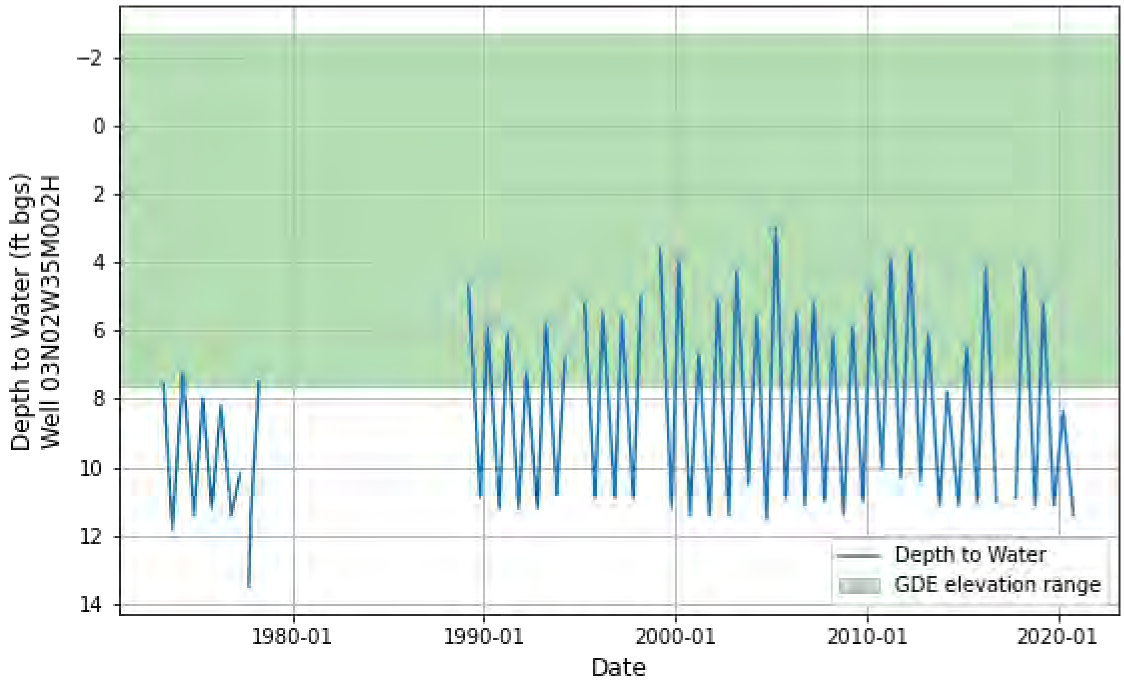

Figure 3.1-2. Depth to groundwater and ground elevation range at GDEs on well transect, Well 03N02W35M002H, associated with the Intertidal Zone and Tributaries GDE Unit. Well site elevation is assumed to be 0 ft bgs.

3.1.2 Middle Eel River

Well 02N01W08B001H is an active irrigation well installed in 1952 with unknown screen depth (Table 3.1-1). The well is located on the alluvial plain south of the Salt River Channel, 7 miles from the coast (Figure 2.3-1). At Well 02N01W08B001H, depth to water declined gradually from an annual average of approximately 17 ft bgs in 1965 to approximately 23 ft bgs in 1986. Since 1986, groundwater elevation has remained stable, typically between 10 and 27 ft bgs, with seasonal fluctuations typically between 5 and 15 ft. (Figure 3.1-3). Ground elevation at nearby GDEs ranges from 5 to 7 ft below the well site, approximately 13 to 15 ft above the long-term average water level in the well.

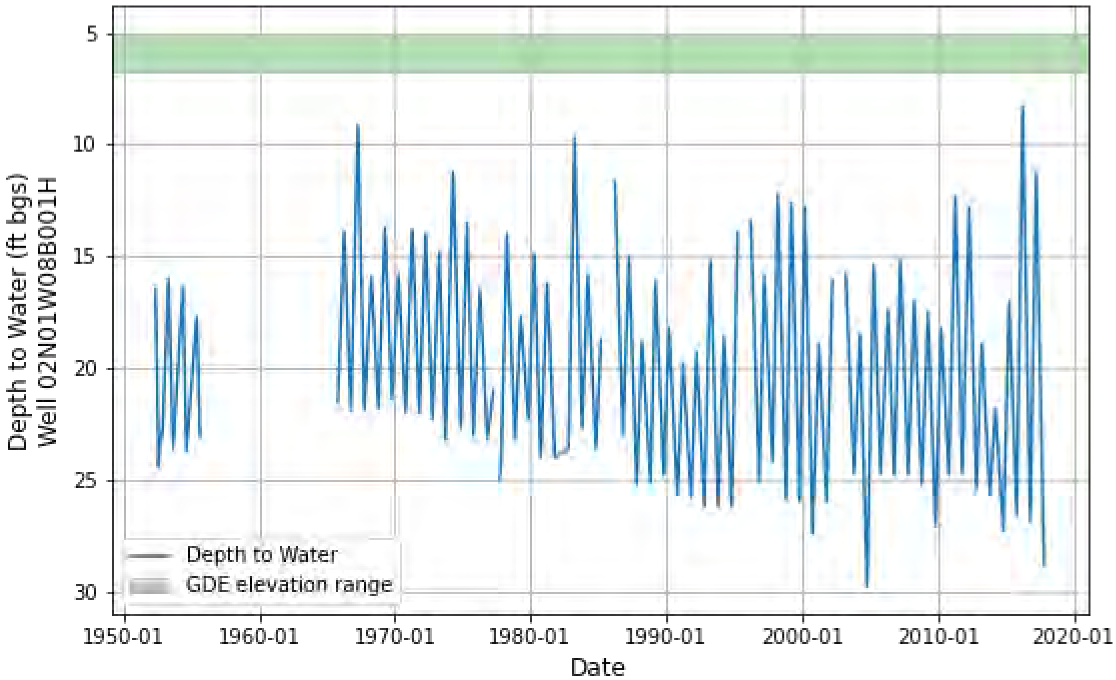

Figure 3.1-3. Depth to groundwater and ground elevation range at GDEs on well transect, Well 02N01W08B001H, associated with the Middle Eel River GDE Unit. Well site elevation is assumed to be 0 ft bgs.

Well 02N01W09G001H is an active residential well installed in 1986 and screened between 25 and 30 ft bgs. The well is located on the alluvial plain 1.5 miles west of the Eel River channel, 1.5 miles downstream of the Eel-Van Duzen confluence (Figure 2.3-1). At Well 02N01W09G001H, depth to water has remained stable since 1986, between 15 and 30 ft bgs, with seasonal fluctuations typically between 5 and 10 ft. (Figure 3.1-4). Ground elevation at nearby GDEs ranges from 7 ft below to 1 ft above the well site, approximately 17 to 19 ft above the long-term average water level in the well.

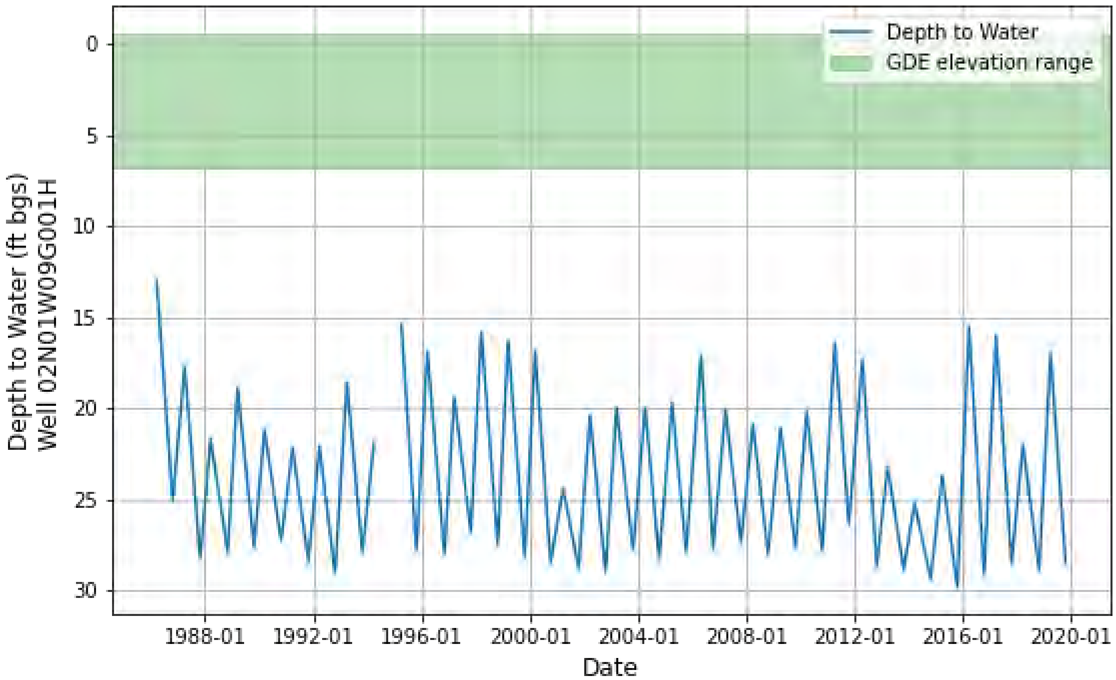

Figure 3.1-4. Depth to groundwater and ground elevation range at GDEs on well transect, Well 02N01W09G001H, associated with the Middle Eel River GDE Unit. Well site elevation is assumed to be 0 ft bgs.

The two long-term wells on the Middle Eel (02N01W08B001H and 02N01W09G001H) are located along the upper portions of Salt Creek (Figure 2.3-1). Groundwater in Figures 3.1-3 and 3.1-4 is within the 30 ft cutoff used to define GDEs, but is generally (but not always) deeper than the rooting depth of species found near the GDEs (generally <15 ft see below). Additional data may be required to better understand the role of groundwater for potential GDEs in this portion of the basin. Groundwater elevations are typically shallower along the Eel River.

3.1.3 Van Duzen River and Tributaries

MW-9s is an active shallow observation well, installed in 2016 (Table 3.1-1). Its DTW ranged from 4.5 ft bgs in Spring 2017 to 11 ft bgs in Fall 2018 (Figure 3.1-5). No long-term trends in depth to groundwater are apparent over the three-year period of record. Ground elevation at nearby GDEs ranges from 13 ft below to 1 ft above the well site, approximately 7 ft below to 7 ft above the long-term average water level in the well.

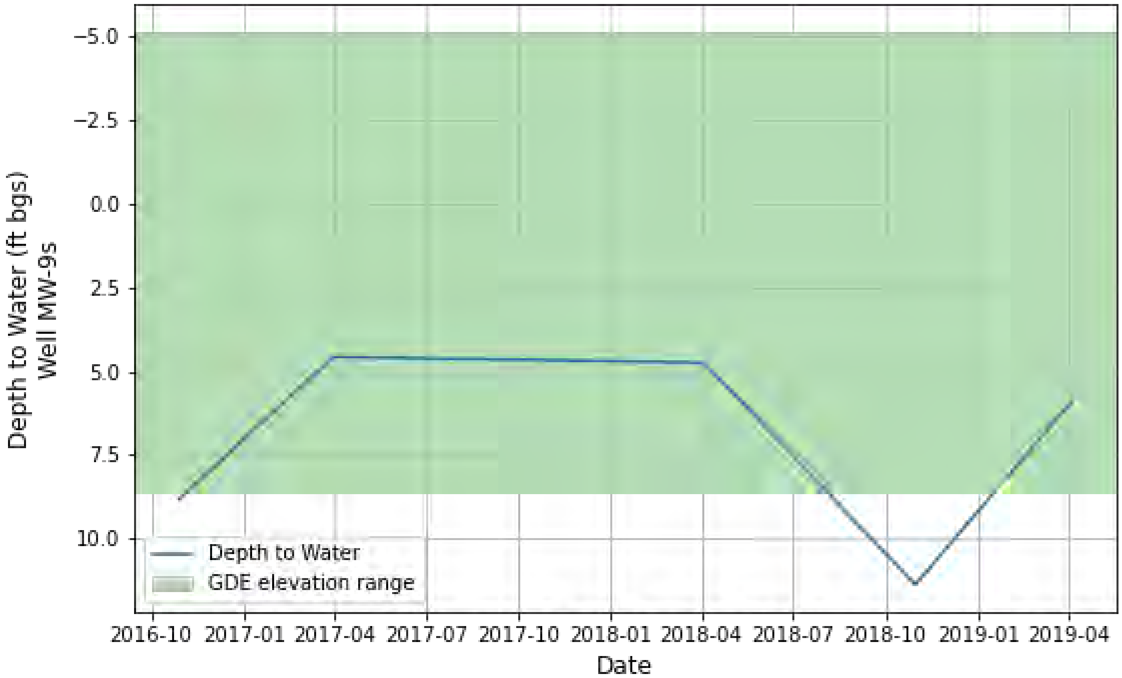

Figure 3.1-5. Depth to groundwater and ground elevation ranges at GDEs on well transect, MW-9s, associated with the Van Duzen River and Tributaries GDE Unit. Well site elevation is assumed to be 0 ft bgs.

3.2 Groundwater Quality

Fifteen (15) County wells were sampled in 2021 for constituents of concern including metals, nutrients, salts, pesticides, herbicides, Volatile organic compounds (VOCs), Semivolatile organic compounds (SVOCs), microbial, radioactive, polychlorinated biphenyl (PCB), and physical contaminants (SHN 2021b). Analytical results for five (5) of the 15 wells have been received and all results have been below primary maximum contaminant levels (MCLs), except for alkalinity.

SHN (2021b) included review of historic data and found that water quality throughout the ERVB is of good quality for its intended uses. Four (4) constituents of concern—totally dissolved solids (TDS), nitrate, manganese, and iron—were identified based on the historical data review and are discussed below.

Nutrients (e.g., nitrate) and TDS have been reported near the Ferndale area of the ERVB at levels near or above primary and secondary MCLs for drinking water (SHN 2021a). A long-term water quality monitoring program is planned to involve the sampling of nitrate and TDS on an annual basis at a subset of wells across the ERVB, with a focus on the Ferndale area to assess spatial trends in these contaminants.

Metals (e.g., iron and manganese) have been reported by the Palmer Creek Community Services District (CSD), Del Oro Water Company, and Loleta CSD at levels above primary MCLs (SHN

2021b). These metals are thought to occur naturally due to the geologic formations comprising the aquifers, and therefore are considered background concentrations.

Recent chloride concentration data from the shallow aquifer indicate no significant migration in the landward edge of the freshwater-seawater transition zone (defined as chloride concentrations exceeding 100 mg/L) between 1975 and 2021 (SHN 2021a).

3.3 Interconnected Surface Water

Surface water systems are strongly connected to the shallow alluvial aquifer (SHN 2019). Preliminary groundwater model river discharge results provided by GHD show gaining conditions on the Van Duzen River upstream of Yager Creek. Downstream of Yager Creek, losing conditions are more prevalent. For example, the Van Duzen goes dry most years in the vicinity of Highway 101, a losing reach. Continuous coupled groundwater and surface water monitoring initiated by Humboldt County in 2016 indicate that subsurface contributions from the Van Duzen strongly influence surface-groundwater connections on the east bank of the Eel River downstream of the Van Duzen confluence (SHN 2019). Due to the steep groundwater gradient toward the Eel River from the east, gaining stream conditions are thought to occur year-round in this reach, consistent with preliminary model results. Monitoring on the west bank of the Eel River between the Van Duzen River confluence and Fortuna shows losing conditions near the confluence, particularly during the dry season, transitioning to gaining conditions downstream that typically occur during the wet season (SHN 2019). Preliminary model results indicate that a slight gaining reach occurs downstream at Fortuna due to subsurface contributions from Strongs Creek and Rohner Creek losses. Gaining conditions also occur at Fernbridge and along much of the Salt River. Model results show slight losing conditions on some tributaries of the Van Duzen (Fox Creek) and Salt River (Williams, Francis, and Reas creeks).

The shallow aquifer is hydraulically connected with the ocean along approximately 10 miles of coastline. In the Eel River, tidal influence extends upstream of Fernbridge, approximately 12 miles inland from the river mouth (SHN 2021a).

4 GDE CONDITION

This section characterizes the GDE units based on their hydrologic and ecological conditions, then assigns a relative ecological value to each unit by evaluating its ecological assets and its vulnerability to changes in groundwater (Rohde et al. 2018).

4.1 Vegetation Communities and GDE Habitats

There were seven (7) dominant vegetation communities associated with groundwater in the Lower ERVB. These vegetation communities are mostly affiliated with the North Coast riparian forest and shrubland habitats within the riparian and floodplain zone along the Eel and Van Duzen rivers. The most prevalent vegetation communities (top five [5]) within each GDE unit are provided in Figures 4.1-1 through 4.1-4. All dominant vegetation communities—including their common species assemblages, typical landform position, and stand characteristics—are described in this section. In addition to these vegetation communities, the ERVB's GDE habitat encompasses areas that are frequently inundated. These features are characterized as River/Stream/Canal and are included in Figures 4.1-1 through 4.1-4.

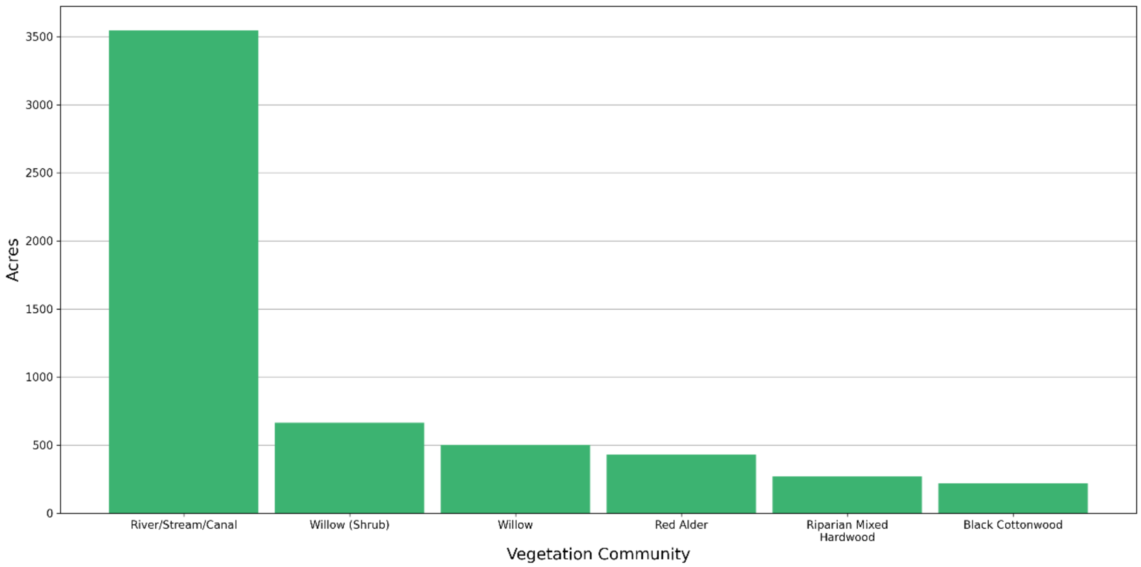

Figure 4.1-1. Dominant vegetation communities within Intertidal Zone and Tributaries GDE Unit

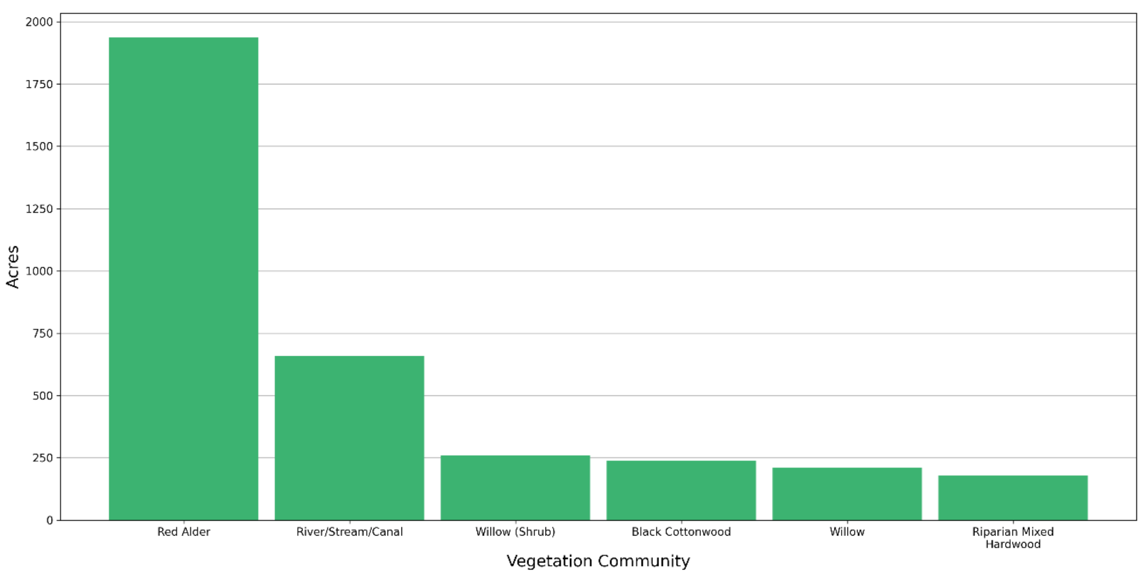

Figure 4.1-2. Dominant vegetation communities within Middle Eel River GDE Unit

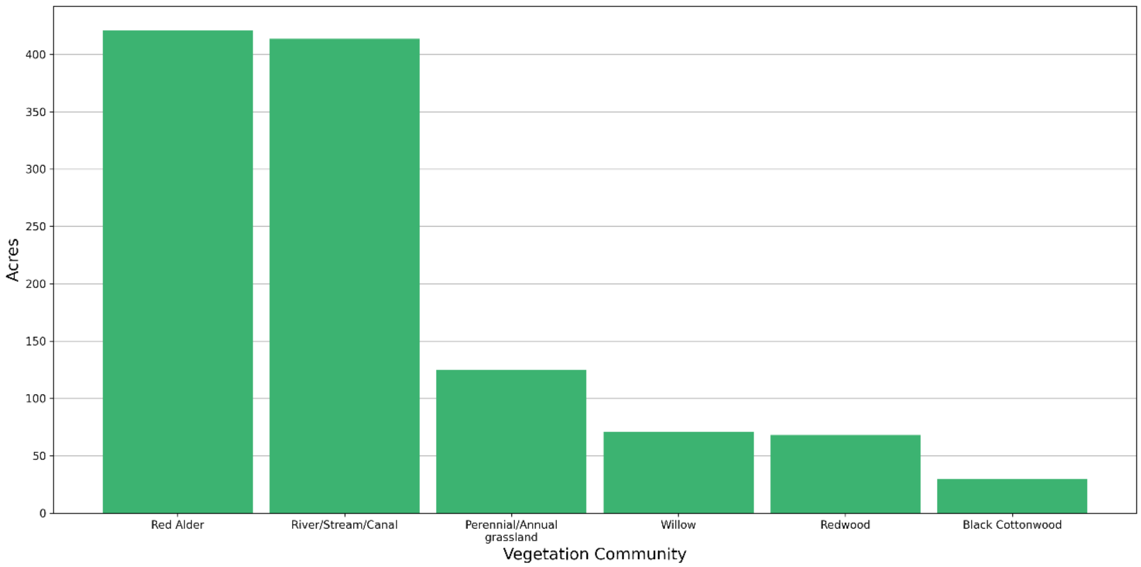

Figure 4.1-3. Dominant vegetation communities within the Upper Eel River GDE Unit

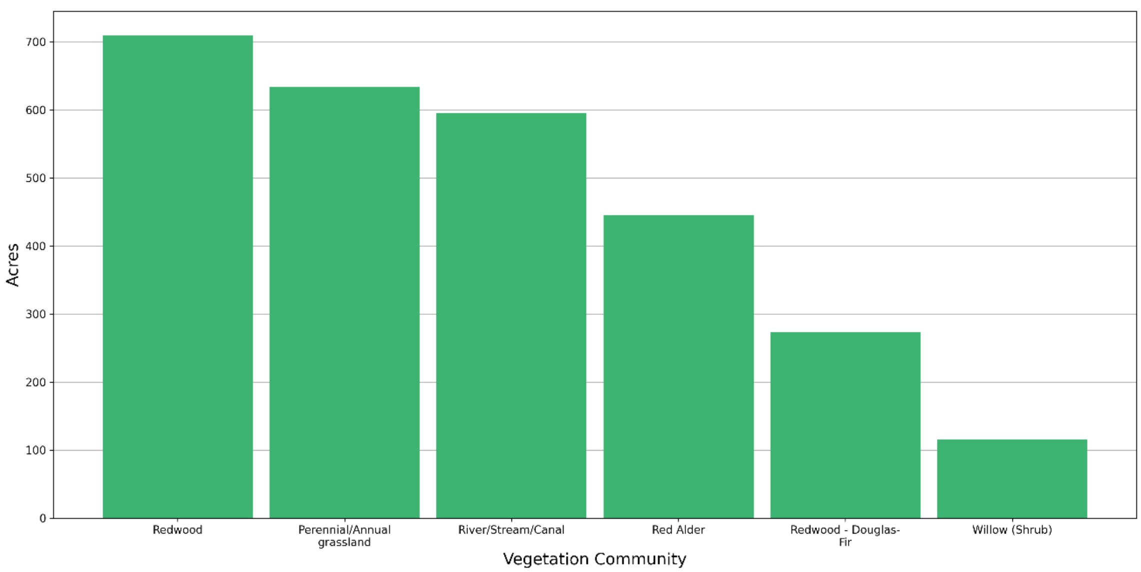

Figure 4.1-4. Dominant vegetation communities within Van Duzen River and Tributaries GDE Unit

4.1.1 River/Stream/Canal

Permanently or semi-permanently flooded areas, both bare and vegetated areas with a fresh or brackish water regime, were included in the River/Stream/Canal cover type. Some brackish and freshwater marshes and grasslands were included within this GDE habitat type based on their landform position and high inundation rate. Emergent herbaceous species found within these areas typically have a maximum rooting depth of 1 to 2 ft, such as broad-leaved cattail (*Typha latifolia*), saltmarsh bulrush (*Bolboschoenus maritimus*), various rushes *(Juncus* spp.), pale spike rush (*Eleocharis macrostachya*), and various bulrush (*Scirpus* spp.). High marsh and wet grassland species included reed canary grass (*Phalaris arundinacea*), salt grass (*Distichlis spicata*), tufted hairgrass (*Deschampsia cespitosa*), creeping bent grass *(Agrostis stolonifera*), and Pacific silverweed (*Potentilla anserina* subsp. *pacifica*). This group is found most often in drainages, low depressions, wetlands adjacent to drainages and saltmarsh, and concave isolated wetlands in active floodplains that are inundated most of the year. This GDE habitat is distributed throughout all GDE units of the ERVB and totals 5,212 acres of the mapped GDE habitat.

4.1.2 Red alder

Red alder (*Alnus rubra*) forest community is the most prevalent GDE habitat in the ERVB, composing 23% (or 3,231 acres) of the total mapped GDE habitats. Red alder, a native deciduous hardwood, is dominant in this forest community type with greater than 50% relative tree cover. The community's mostly mature and continuous tree canopy, aside from red alder, features low cover by other hardwoods and conifers such as bigleaf maple (*Acer macrophyllum*), Pacific willow (*Salix lasiandra*), California bay laurel (*Umbellularia californica*), black cottonwood (*Populus trichocarpa*), and Sitka spruce (*Picea sitchensis*). The sparse to intermittent shrub layer may include various willows (*Salix* spp.), salmonberry (*Rubus spectabilis*), and thimbleberry (*Rubus parviflorus*), while the herbaceous layer comprises various ferns (western sword fern [*Polystichum munitum*], lady fern [*Athyrium filix-femina*]) and forbs (stinging nettle [*Urtica dioica*], pig-a-back plant [*Tolmiea diplomenziesii*], and candy flower [*Claytonia sibirica*]). Red alder stands often occur along stream and river backwaters, banks, bottoms, flood plains, mouths, terraces, and slopes of all aspects (California Native Plant Society [CNPS] 2021). This riparian forest community is best characterized by the *Alnus rubra* Forest Alliance and has an estimated maximum rooting depth of 13.1 ft. (Appendix A). It is distributed within all ERVB GDE units and is the predominant community in the Middle Eel River, Upper Eel River, and Van Duzen River and Tributaries GDE units, totaling 1,937 acres, 421 acres, and 445 acres, respectively (Figures 4.1-2–4.1-4).

4.1.3 Willow shrub

Willow shrub is a prevalent vegetation community in the ERVB (~8% or 1,039 acres) that establishes along high-flow river bars, banks, and riparian wash areas. This vegetation community recruits on exposed riverbanks, initially forming a sparse, patchy shrub layer that develops into a fairly dense shrub-dominant stand type. These recruited areas are mostly attributed to two native willow shrubs that are clonal by root-shoots: Hinds' willow (*Salix exigua* var. *hindsiana*) and dusky willow (*Salix melanopsis*). These stands are common to sandy gravel and active floodplains with an intermittent to continuous shrub layer, a minor tree component attributed to some riparian species recruitment, and a variable herbaceous layer that consists of a mixture of forbs and annual grasses. This community type also includes arroyo willow (*Salix lasiolepis*), Sitka willow (*Salix sitchensis*), and coastal willow (*Salix hookeriana*) shrubland stands, which typically occur on stream banks and benches, slope seeps, stringers along drainages, deflation plains and swales, and floodplains (CNPS 2021). They form a continuous canopy composed of species that are less than 30 ft in height with low cover by emergent trees. The willow shrub vegetation community is characterized by the *Salix exigua* Shrubland Alliance and has a maximum rooting depth of approximately 7 ft. It is distributed in the Intertidal Zone and Tributaries, Middle Eel River, and Van Duzen River and Tributaries GDE units, where it composes 664 acres, 260 acres, and 116 acres, respectively (Figures 4.1-1, 4.1-2, 4.1-4).

4.1.4 Willow

The willow vegetation community is characterized by a complex of variously established willow stands that vary in species dominance but primarily form riparian forested habitat. It occurs along banks and benches and on low-gradient depositions along rivers and streams. Tree canopy is less than 65 ft in height and is intermittent to continuous with a sparse to intermittent shrub layer. Dominant cover is attributed to Pacific willow (*Salix lasiandra*), Sitka willow, and Scouler's willow (*Salix scouleriana*). Arroyo willow and coastal willow contribute to the midstory canopy. Other native riparian hardwoods and shrub species observed in this stand type include red alder, bigleaf maple, black cottonwood, and red elderberry (*Sambucus racemosa*). This riparian forest community is characterized by the *Salix lucida* ssp. *lasiandra* Forest and Woodland Alliance, a sensitive natural community on CDFW's *California Sensitive Natural Communities List* (CDFW 2020) with a state rarity ranking of S3 (vulnerable in the state due to a restricted range, relatively few populations [often 80 or fewer], recent and widespread declines, or other factors making it vulnerable to extirpation). Maximum rooting depth is typically up to 6.9 ft. It is distributed within all GDE units, totaling 783 acres or 6% of the total mapped GDE habitats in the ERVB (Figures 4.1-1–4.1-4).

4.1.5 Black cottonwood

Black cottonwood stands form a dominant riparian hardwood forest and woodland type in the ERVB (5% [655 acres] of the mapped GDE habitats), occurring in seasonally flooded and permanently saturated soils on stream banks and alluvial terraces (CNPS 2021). Black cottonwood is dominant within the tree canopy, intermittent to continuous and reaching to 100 ft in height. The shrub layer is open to continuous and the herbaceous understory varies from sparse to abundant. Other hardwoods present in this community include red alder, wax myrtle (*Morella californica*), Oregon ash (*Fraxinus latifolia*), various willows, and bigleaf maple. This riparian forested community is characterized by the *Populus trichocarpa* Forest and Woodland Alliance, a sensitive natural community (S3) on CDFW's *California Sensitive Natural Communities List* (CDFW 2020). Black cottonwood has a maximum rooting depth of 9.8 ft. It is distributed in all GDE units, though is most prevalent within the Intertidal Zone and Tributaries and Middle Eel River GDE units, where it totals 219 acres and 352 acres, respectively (Figures 4.1-1 and 4.1-2).

4.1.6 Annual/perennial grassland

This group is composed of a mixture of herbaceous annual forbs, perennial herbs, and naturalized annual and perennial grasses. This community type has a high percent cover of facultative and facultative-wetland grasses with low to moderate cover by herbaceous forbs. Cover within this grassland community type is mostly attributed to non-native naturalized species (e.g., reed canary grass, tall fescue [*Festuca arundinacea*], creeping bent [*Agrostis stolonifera*], common velvet grass [*Holcus lanatus*], Kentucky blue grass [*Poa pratensis* subsp. *pratensis*], rye grass [*Festuca perenne*], meadow foxtail [*Alopecurus pratensis*], and low manna grass [*Glyceria declinata*]). There is low recruitment by shrub and tree species in these grasslands, while land use involves historically diked pastureland, various agriculture, areas near development, and open space. This group typically occurs in topographically flat areas on active or other floodplains. Soil saturation and inundation vary at these locations, but these grasslands indicate typically moist conditions for at least a portion of the year. These non-native grasslands area associated with the *Phalaris aquatica - Phalaris arundinacea*, *Holcus lanatus - Anthoxanthum odoratum, Poa pratensis - Agrostis gigantea - Agrostis stolonifera*, and *Lolium perenne* Herbaceous Semi-Natural Alliances. Maximum rooting depths of these grasslands generally range from 3.2 to 4 ft. The grassland vegetation community occurs in all GDE units and is most prevalent in the Van Duzen River and Tributaries GDE Unit, where it totals 634 acres (Figures 4.1-1–4.1-4).

4.1.7 Riparian mixed hardwood

The riparian mixed hardwood vegetation community typically consists of an intermittent to continuous multi-layered tree canopy with a varied understory, composed of various riparian evergreen and deciduous tree species, including a combination of evergreen conifers (e.g., coast redwood [*Sequoia sempervirens*], Douglas-fir [*Pseudotsuga menziesii*], Sitka spruce, and grand fir [*Abies grandis*]), with a shared overstory and midstory by deciduous hardwoods (red alder, black cottonwood, Oregon ash, various willows). The shrub layer is intermittent with various *Rubus* spp., willow, and twinberry (*Lonicera involucrata*). Common ferns in the understory comprise western sword fern and lady fern. The vegetation community is located primarily on convex low-flow streambanks, active floodplains, and flat or undulating floodplains and terraces. Multiple riparian forest alliances with a state rank of S3 on CDFW's *California Sensitive Natural Communities List* are included in this complex. As such, the riparian mixed hardwood is considered a sensitive natural community in the Lower ERVB. Maximum rooting depth ranges from 2.4 to 6.9 ft. This community is predominant in the Intertidal Zone and Tributaries and the Middle Eel River GDE units, where it composes 267 acres and 179 acres of the total mapped GDE habitat, respectively (Figures 4.1-1 and 4.1-2).

4.1.8 Redwood

The redwood vegetation community is associated with coniferous forest stands dominated by coast redwood, located along raised stream terraces, benches, alluvial floodplains, and sloped regions along the floodplain. Redwood forests of the Eel River alluvial terraces are mostly pure stands of coast redwood (Sawyer 2007). Along the slopes, the redwood forest encompasses other conifers and hardwoods and forms more open canopy. Forests along the alluvial flats are dense-canopied. Some evergreen conifers associated with redwood forests include Sitka spruce, western hemlock (*Tsuga heterophylla*), red incense cedar (*Thuja plicata*), grand fir, and shore pint (*Pinus contorta* subsp. *contorta*), while hardwoods comprise bigleaf maple, black cottonwood, and red alder. Understory species vary from continuous to dense cover by shrubs (huckleberry [*Vaccinium* spp.], salal [*Gaultheria shallon*]) and ferns (sword fern, lady fern). This forest type is characterized as the sensitive natural community *Sequoia sempervirens* Forest and Woodland Alliance (S3 on CDFW's *California Sensitive Natural Communities List*). Maximum rooting depth ranges from 8.5 to 16 ft. The redwood forest community forms the dominant GDE habitat in the Van Duzen River and Tributaries Unit, where it totals 709 acres (Figure 4.1-4).

4.2 Beneficial Uses

The Water Quality Control Plan (Basin Plan) for the North Coast Region (North Coast Regional Water Quality Control Board [NCRWQCB] 2018) identifies the surface waters in the GDE management units as having a variety of beneficial uses pertaining to fish, wildlife, humans, and GDEs Beneficial uses include those that directly benefit groundwater conditions (e.g., groundwater recharge [GWR]) and those supported directly by groundwater via interconnected surface waters (e.g., freshwater replenishment [FRSH]; support of rare, threatened, or endangered species [RARE]).

The ERVB includes the Ferndale, Scotia, Hydesville, and Bridgeville Hydrologic Subareas (NCRWQCB 2018). The boundaries of these subareas do not necessarily match the GDE boundaries. The beneficial uses for these hydrologic units are provided in Table 4.2-1, which includes fish, wildlife, GDE, and human uses: RARE; cold freshwater habitat (COLD); wildlife habitat (WILD); migration of aquatic organisms (MIGR); spawning, reproduction, and/or early development (SPAWN); and warm freshwater habitat (WARM).

Table 4.2-1. Beneficial uses designated within the ERVB hydrologic units

Beneficial use – Definition	Hydrologic unit			
	Ferndale	**Scotia**	**Hydesville**	**Bridgeville**
MUN (Municipal and Domestic Supply) – Uses of water for community, military, or individual water supply systems, including, but not limited to, drinking water supply	E	E	E	E
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	E	E	E	E
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	E	E	E	E
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	E	E	E	E
FRSH (Freshwater Replenishment) – Uses of water for natural or artificial maintenance of surface water quantity or quality (e.g., salinity)	E	E	E	E
NAV (Navigation) – Uses of water for shipping, travel, or other transportation by private, military, or commercial vessels	E	E	E	E
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	E	E	E	E
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	E	E	E	E
COMM (Commercial and Sport Fishing) – Uses of water for commercial or 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	E	E	E	E
COLD (Cold Freshwater Habitat) – Uses of water that support cold-water ecosystems, including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates	E	E	E	E
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	E	E	E	E

Beneficial use **– Definition**	**Hydrologic** unit			
	Ferndale	**Scotia**	**Hydesville**	**Bridgeville**
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	E	E	E	E
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	E	E	E	E
SPWN (Spawning, Reproduction, and/or Early Development) – Uses of water that support high-quality aquatic habitats suitable for reproduction and early development of fish	E	E	E	E
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	E			
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)	E			
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	E		E	
PRO (Industrial Process Supply) – Uses of water for industrial activities that depend primarily on water quality	P	P	P	P
POW (Hydropower Generation) – Uses of water for hydropower generation	P	P	P	E
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)	P			
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	P	P	P	P
WARM (Warm Freshwater Habitat) – Uses of water that support warm-water ecosystems, including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates			E	E

Data Source: NCRWQCB 2018
E=Existing; P=Potential, habitat may not be currently present.

4.3 Special-status Species

The ERVB is ecologically important and provides habitat for numerous wildlife species that are groundwater-dependent. Within the groundwater basin, six (6) natural communities, as well as 17 plant, 21 wildlife, and 7 fish species, were identified as indirectly or directly groundwater-dependent and may occur within the ERVB. Appendix B provides information for special-status terrestrial and aquatic wildlife species identified in the database queries that were subsequently determined to be not dependent on groundwater and/or unlikely to occur in the GDE units, information that includes each species' regulatory status, habitat associations, and documented occurrences in the groundwater basins.

The ERVB GDEs feature designated critical habitat for seven federally listed species: marbled murrelet (*Brachyramphus marmoratus*), tidewater goby (*Eucyclogobius newberryi*), 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*), and Northern California Coast steelhead (*Oncorhynchus mykiss*) (U.S. Fish & Wildlife Service [USFWS] 2016, USFWS 2013, USFWS 2012a,b, USFWS 2020, NMFS 2005). The amount of critical habitat for each species within the GDE units within the ERVB is summarized in Table 4.3-1 and shown in Figure 4.3-1 and Figure 4.3-2.

Table 4.3-1. USFWS and NMFS designated critical habitat[1] within the ERVB

Common name *Scientific name*	**Intertidal Zone and Tributaries**	**Middle Eel River**	**Upper Eel River**	**Van Duzen River and Tributaries**
USFWS critical habitat (acres)				
Marbled murrelet *Brachyramphus marmoratus*	--	--	--	278
Tidewater goby *Eucyclogobius newberryi*	21	--	--	--
Western snowy plover *Charadrius alexandrinus nivosus*	71	488	60	29
All species	92	488	60	307
NMFS critical habitat (miles)				
Chinook salmon *Oncorhynchus tshawytscha* (CC ESU)	12	6	8	10
Coho salmon[2] *Oncorhynchus kisutch* (SONCC ESU)	3	6	9	17
Steelhead *Oncorhynchus mykiss* (NC DPS)	3	6	9	17
All species	18	18	26	44

Notes: CC= California Coast; ESU= evolutionarily significant unit; SONCC = Southern Oregon/Northern California Coast

[1] Data sources: USFWS 2012, USFWS 2013, USFWS 2016, USFWS 2020, NMFS 2005

[2] Critical habitat for coho salmon includes all waters accessible for coho salmon downstream of long-standing impassable barriers. Coho salmon NMFS critical habitat was estimated using the extent of steelhead critical habitat.

The following habitat management and special-status species recovery plans have been implemented in the ERVB and include protections for special-status species and associated habitats: *Recovery Plan for the Tidewater Goby* (USFWS 2005), *Southern Oregon/Northern California Coast Evolutionarily Significant Unit of Coho Salmon* (NMFS 2014), *Coastal Multispecies Recovery Plan* (NMFS 2016), and *Eel River Action Plan* (Eel River Forum 2016).

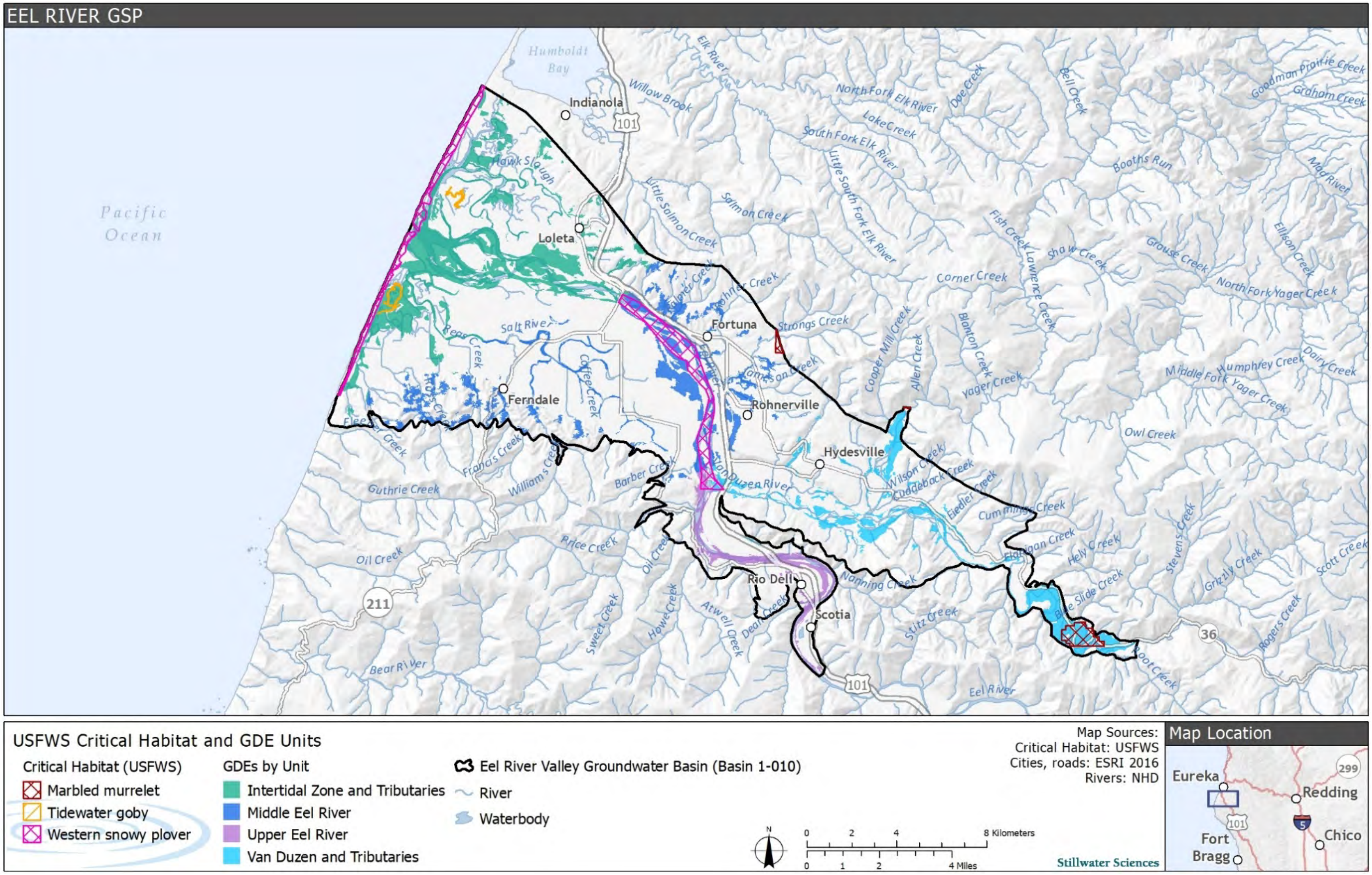

Figure 4.3-1. USFWS Critical Habitat within the ERVB

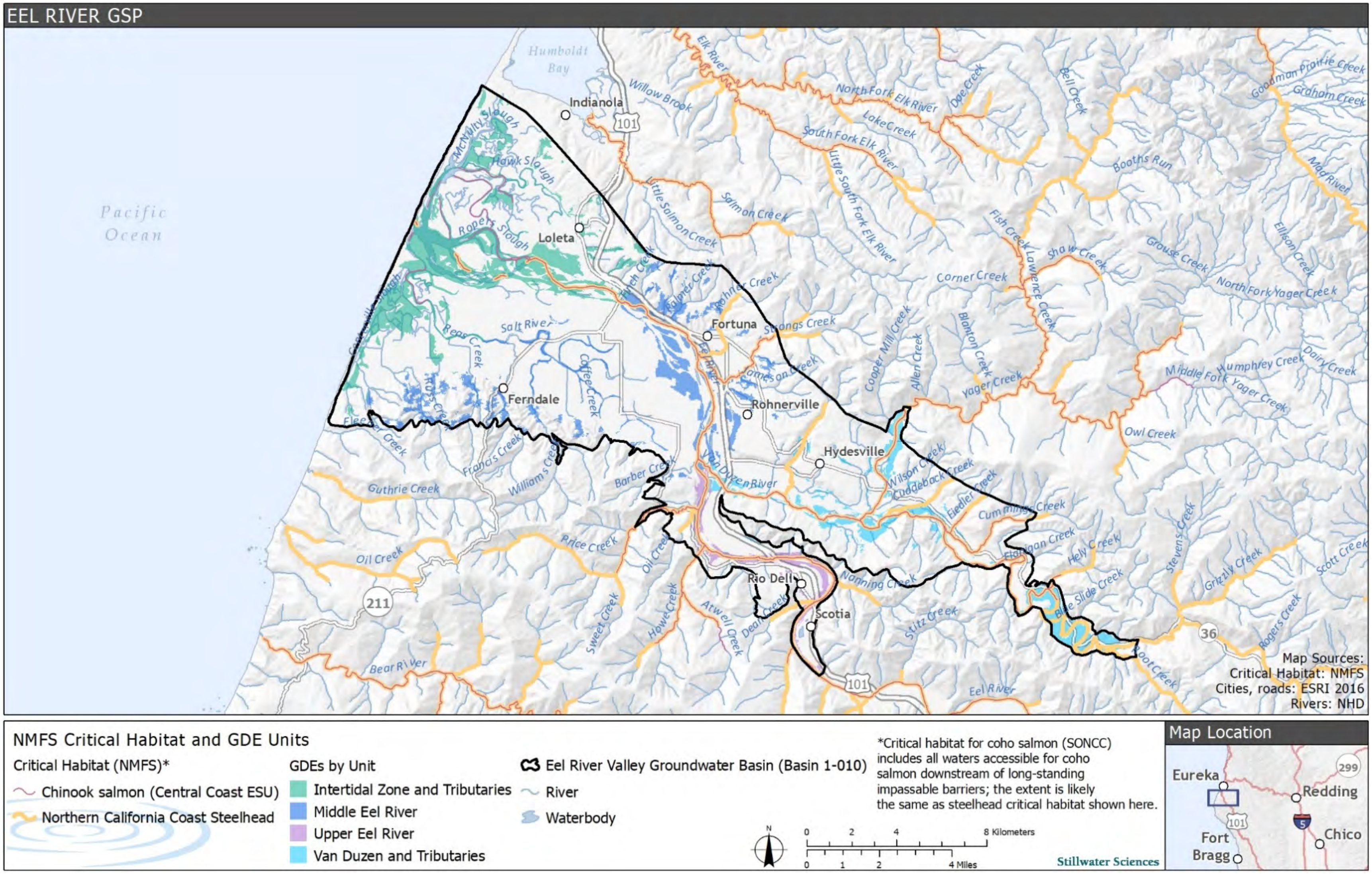

Figure 4.3-2. NMFS Critical Habitat within the ERVB

4.3.1 Plants and Natural Communities

Seventeen (17) potentially groundwater-dependent special-status plant species were documented in the ERVB. Details on these species, including their suitable habitat and the associated GDE unit(s) they have potential to occur within (based on known occurrences within the basin), are provided in Table 4.3-2.

Six (6) potentially groundwater-dependent sensitive natural communities were documented in the ERVB:

- Black cottonwood *(Populus trichocarpa)* Forest and Woodland Alliance (S3)
- Coast redwood *(Sequoia sempervirens)* Forest and Woodland Alliance (S3)
- Pacific willow (*Salix lucida* subsp. *Lasiandra)* Forest and Woodland Alliance
- Coastal Willow (*Salix hookeriana)* Shrubland Alliance (S3)
- California bay laurel *(Umbellularia californica* Forest and Woodland Alliance (S3)
- Sitka spruce *(Picea sitchensis)* Forest and Woodland Alliance (S2)

All sensitive communities are associated with riparian habitat and are distributed throughout all GDE units in the basin (see Section 4.1 for detailed descriptions).

Table 4.3-2. Special-status plant species with known occurrences in the Lower ERVB

Common name ***Scientific name***	**Status (Federal, State CRPR)[1]**	**Association with GDE**	**GDE Unit**	**Source[2]**	**Habitat and occurrence**
Seacoast angelica *Angelica lucida*	None, None, 4.2	Possible, occurs in mostly coastal upland habitats (upland levee banks), though there are known occurrences associated with a potential GDE	Intertidal Zone and Tributaries, Middle Eel	CCH	Coastal bluff scrub, coastal dunes, coastal scrub, and coastal salt marshes and swamps; known occurrences observed along mouth of Eel River and within the Humboldt Bay NWR along levee of the Hookton Slough trail
Northern clustered sedge *Carex arcta*	None, None, 2B.2	Likely, habitat and known occurrences associated with a potential GDE	Van Duzen River and Tributaries	CNDDB	Bogs and fens (wetlands supported by almost constant groundwater inflow) and mesic North Coast coniferous forest
Lyngbye's sedge *Carex lyngbyei*	None, None, 2B.2	Likely, habitat and known occurrences associated with a potential GDE	Intertidal Zone and Tributaries	CNDDB	Brackish and freshwater marshes and swamps; occurs along brackish slough margins near Eel River mouth
Tracy's collomia *Collomia tracyi*	None, None, 4.3	Possible, occurs in mostly upland forested habitat, though there are known occurrences associated with a potential GDE	Van Duzen River and Tributaries	CCH	Broadleafed upland forest, lower montane coniferous forest; known occurrences along sand bar and bed of Van Duzen River near Carlotta
Cascade downingia *Downingia willamettensis*	None, None, 2B.2	Likely, habitat and known occurrences associated with a potential GDE	Middle Eel River, Van Duzen River and Tributaries	CNDDB	Lake margins in cismontane woodland and valley and foothill grassland, also vernal pools
Pacific gilia *Gilia capitata* subsp. *pacifica*	None, None, 1B.2	Likely, habitat and known occurrences associated with a potential GDE	Van Duzen River and Tributaries, Upper Eel River	CNDDB	Coastal bluff scrub, openings in chaparral, coastal prairie, and valley and foothill grassland
Tracy's tarplant *Hemizonia congesta* subsp. *tracyi*	None, None, 4.3	Possible, occurs in mostly upland habitat, though there are known occurrences associated with a potential GDE	Middle Eel River, Van Duzen River and Tributaries	CCH	Coastal prairie, lower montane coniferous forest, and North Coast coniferous forest; known occurrences along Eel River and on a river bar along Eel River near the Van Duzen River confluence

Common name ***Scientific name***	**Status (Federal, State CRPR)[1]**	**Association with GDE**	**GDE Unit**	**Source[2]**	**Habitat and occurrence**
Glandular western flax *Hesperolinon adenophyllum*	None, None, 1B.2	Possible, occurs in mostly upland habitat, though there is a known occurrence associated with a potential GDE	Middle Eel River, Upper Eel River	CCH	Chaparral, Cismontane woodland, and valley and foothill grassland; known occurrence on an Eel River gravel bar
Harlequin lotus *Hosackia gracilis*	None, None, 4.2	Likely, habitat and known occurrences associated with a potential GDE	Intertidal Zone and Tributaries, Middle Eel River	CCH	In water, springy areas, shores, meadows, and roadside ditches within broadleafed upland forest, coastal bluff scrub, closed-cone coniferous forest, cismontane woodland, coastal prairie, coastal scrub, meadows and seeps, marshes and swamps, North Coast coniferous forest, and valley and foothill grassland
Western lily *Lilium occidentale*	FE, CE, 1B.1	Likely, habitat and known occurrences associated with a potential GDE	Intertidal Zone and Tributaries, Middle Eel River	CNDDB, USFWS	Bogs and fens, coastal bluff scrub, coastal prairie, coastal scrub, freshwater marshes and swamps, and openings in North Coast coniferous forest
Purple flowered Washington lily *Lilium washingtonianum* subsp. *purpurascens*	None, None, 4.3	Possible, occurs in mostly upland habitat, though there is a known occurrence associated with a potential GDE	Van Duzen River and Tributaries	CCH	Chaparral, lower montane coniferous forest, and upper montane coniferous forest; one known occurrence near Yager southeast of Eureka known from a Craig 1941 collection
Running-pine *Lycopodium clavatum*	None, None, 4.1	Likely, habitat and known occurrences associated with a potential GDE	Van Duzen River and Tributaries, Upper Eel River	CNDDB	Mesic lower montane coniferous forest, marshes and swamps, and mesic North Coast coniferous forest
Howell's montia *Montia howellii*	None, None, 2B.2	Possible, often occurs in seasonally wet sites and there are known occurrences associated with a potential GDE	Van Duzen River and Tributaries, Upper Eel River	CNDDB	Meadows and seeps, North Coast coniferous forest, and vernal pools; multiple known occurrences within forested habitats and roadsides

Common name ***Scientific name***	**Status (Federal, State CRPR)**[1]	**Association with GDE**	**GDE Unit**	**Source**[2]	**Habitat and occurrence**
Seacoast ragwort *Packera bolanderi* var. *bolanderi*	None, None, 2B.2	Unlikely, occurs in upland habitats and known occurrences are associated with forested habitats	Van Duzen River and Tributaries, Upper Eel River	CNDDB	Coastal scrub and North Coast coniferous forest; one known occurrence within coniferous forest habitat near the Van Duzen River and within an upland forested region along Eel River
Sierra gooseberry *Ribes roezlii* var. *amictum*	None, None, 4.3	Possible, occurs in mostly upland habitat, though there is a known occurrence associated with a potential GDE	Van Duzen River and Tributaries	CCH	Broadleafed upland forest, cismontane woodland, lower montane coniferous forest, and upper montane coniferous forest; known occurrences located near Carlotta and Hydesville along the Van Duzen River
Maple-leaved checkerbloom *Sidalcea malachroides*	None, None, 4.2	Likely, habitat and known occurrences associated with a potential GDE	Van Duzen River and Tributaries	CNDDB	Broadleafed upland forest, coastal prairie, coastal scrub, North Coast coniferous forest, and riparian woodland
Siskiyou checkerbloom *Sidalcea malviflora* subsp. *patula*	None, None, 1B.2	Possible, occurs in mostly upland coastal habitat, though there are known occurrences associated with a potential GDE	Van Duzen River and Tributaries	CNDDB	Coastal bluff scrub, coastal prairie, and North Coast coniferous forest; multiple known occurrences along Highway 36 near Alton.

[1] Status codes:
Federal
FE = Listed as endangered under the federal Endangered Species Act
State
SE = Listed as Endangered under the California Endangered Species Act
California Rare Plant Rank (CRPR)
1B Plants rare, threatened, or endangered in California and elsewhere
2B Plants rare, threatened, or endangered in California, but more common elsewhere
4 More information needed about this plant, a review list
4 Plants of limited distribution, a watch list
CRPR Threat Ranks:
0.1 Seriously threatened in California (high degree/immediacy of threat)
0.2 Fairly threatened in California (moderate degree/immediacy of threat)
0.3 Not very threatened in California (low degree/immediacy of threats or no current threats known)

[2] Sources:
CNDDB: (CDFW 2020)
CCH: Data provided by the participants of the Consortium of California Herbaria (ucjeps.berkeley.edu/consortium/) (CCH 2020),
USFWS: USFWS (2012)

4.3.2 Terrestrial and aquatic wildlife

Twenty-one (21) potentially groundwater-dependent special-status terrestrial and aquatic wildlife species were identified as having the potential to occur within the ERVB: one (1) mollusk species, five (5) amphibian species, one (1) reptile species, and 14 bird species. Additional information on these species, including regulatory status, habitat associations, and documented occurrences in the groundwater basin, is provided in Table 4.3-3. Fifteen (15) of the groundwater-dependent special-status species were documented in the Intertidal Zone and Tributaries GDE unit, 15 in the Middle Eel River GDE Unit, 8 in the Upper Eel River GDE Unit, and 11 were documented in the Van Duzen River and Tributaries GDE Unit.

Invertebrate species (California floater [*Anodonta californiensis*]), amphibian species (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 likely present (i.e., documented occurrences) in the ERVB GDE units and are classified as directly groundwater-dependent due to their association with stream and lentic habitats (Table 4.3-3). The GDE habitat these species may use within the groundwater basin include intermittent lake or pond, perennial lake or pond, and river/stream/canal habitats. One special-status amphibian species, Pacific tailed frog (*Anaxyrus californicus*), is possibly present in the ERVB, though its habitat is generally not present within the GDE units (Table 4.3-3).

Indirectly groundwater-dependent bird species use a variety of habitats within the basin's GDE units for foraging, nesting, and migratory habitat (Table 4.3-3). These GDEs include riparian (e.g., willow, cottonwood, mixed riparian alliances), wetland (e.g., pickleweed-cordgrass), aquatic (e.g., perennial lake or pond, river/stream/canal, California bay), and forest (e.g., redwood, coastal mixed hardwood) vegetation communities. Critical habitat for marbled murrelet and western snowy plover also overlap with ERVB GDE units (Table 4.3-3). One mammal species (Townsend's big-eared bat [*Corynorhinus townsendii*]) was classified as indirectly groundwater-dependent due to its association with riparian communities (Table 4.3-3).

Table 4.3-3. Groundwater-dependent special-status terrestrial and aquatic wildlife species with known occurrence or suitable habitat in the ERVB

Common name ***Scientific name***	**Status[1] federal/State**	**Potential to occur in ERVB[2]**	**Documented occurrences in GDE units**	**Query source[3]**	**GDE association[4]**	**Habitat and documented occurrences in ERVB**
Mollusk						
California floater *Anodonta californiensis*	FSC/–	Likely	Upper Eel River	CAFSD[5]	Direct	Lakes and slow, large rivers on soft substrates (mud-sand); observed in 2021 within the Eel River at Rio Dell, downstream of Scotia (Stillwater Sciences 2020)
Amphibian						
California giant salamander *Dicamptodon ensatus*	–/SSC	Likely	Intertidal Zone and Tributaries, Middle Eel River, Upper Eel River Van Duzen and Tributaries	CAFSD	Direct	Wet coastal forests in or near clear, cold permanent and semi-permanent streams and seepages; present in tributaries to the Eel and Van Duzen rivers
Foothill yellow-legged frog *Rana boylii*	–/SSC	Likely	Middle Eel River, Upper Eel River Van Duzen and Tributaries	CNDDB, CAFSD	Direct	Shallow tributaries and mainstems of perennial streams and rivers, typically associated with cobble or boulder substrate; occasionally found in isolated pools, vegetated backwaters, and deep, shaded, spring-fed pools; the frog is reliant on surface water that may be fed by groundwater; present along the lower Eel and Van Duzen rivers (CDFW 2020)
Northern red-legged frog *Rana aurora*	–/SSC	Likely	Intertidal Zone and Tributaries, Middle Eel River, Upper Eel River, Van Duzen and Tributaries	CNDDB, CAFSD	Direct	Breeds in still or slow-moving water with emergent and overhanging vegetation, including wetlands, wet meadows, ponds, lakes, and low-gradient, slow-moving stream reaches with permanent pools; uses adjacent uplands for dispersal and summer retreat. Relatively common in the groundwater basin (CDFW 2020).

Common name ***Scientific name***	**Status[1] federal/State**	**Potential to occur in ERVB[2]**	**Documented occurrences in GDE units**	**Query source[3]**	**GDE association[4]**	**Habitat and documented occurrences in ERVB**
Pacific tailed frog *Ascaphus truei*	–/SSC	Possible	Middle Eel River	CNDDB	Direct	Cool perennial tributary streams; species observed in the hills east of Fortuna (CDFW 2020); habitat generally not present in the groundwater basin
Southern torrent salamander *Rhyacotriton variegatus*	–/SSC	Likely	Van Duzen and Tributaries	CNDDB, CAFSD	Direct	Cool perennial tributary streams with low amounts of fine sediment; observed along Highway 36 near the eastern boundary of the Van Duzen River portion of the basin (CDFW 2020)
Reptile						
Western pond turtle *Emys marmorata*	–/SSC	Likely	Intertidal Zone and Tributaries, Middle Eel River, Upper Eel River Van Duzen and Tributaries	CNDDB, CAFSD	Direct	Ponds, lakes, rivers, streams, creeks, marshes, and irrigation ditches with basking sites; feeds on aquatic plants, invertebrates, worms, frog and salamander eggs and larvae, crayfish, and occasionally frogs and fish; relies on surface water that may be supported by groundwater (Rohde et al. 2019); observed on the lower Van Duzen River (CDFW 2020)

Common name *Scientific name*	**Status[1] federal/State**	**Potential to occur in ERVB[2]**	**Documented occurrences in GDE units**	**Query source[3]**	**GDE association[4]**	**Habitat and documented occurrences in ERVB**
Bird						
American white pelican *Pelecanus erythrorhynchos*	–/SSC (nesting colonies)	Likely	Intertidal Zone and Tributaries	CAFSD, eBird	Indirect	Salt ponds, large lakes, and estuaries; loafs on open water during the day; roosts along water's edge at night; forages for small fish in shallow water on inland marshes; few observations in the vicinity of the Eel River Estuary; no nesting colonies (eBird 2021)
Bald eagle *Haliaeetus leucocephalus*	FD, BLMS, BGEPA/SE, SFP	Likely	Intertidal Zone and Tributaries, Middle Eel River, Upper Eel River, Van Duzen and Tributaries	CAFSD, eBird	Indirect	Large bodies of water or rivers with abundant fish, uses snags or other perches; nests in advanced-successional conifer forest near open water (e.g., lakes, reservoirs, rivers); bald eagles are reliant on surface water that may be supported by groundwater and/or groundwater-dependent vegetation (Rohde et al. 2019); observed foraging on the lower Eel River adjacent to Fortuna (eBird 2021)
Bank swallow *Riparia riparia*	BLMS/ST	Likely	Intertidal Zone and Tributaries, Middle Eel River, Van Duzen and Tributaries	CNDDB, eBird	Indirect	Nests in vertical bluffs or banks, usually adjacent to water (i.e., rivers, streams, ocean coasts, and reservoirs) where the soil consists of sand or sandy loam; feeds on caterpillars, insects, frog/lizards, and fruit/berries; relies on surface water that may be supported by groundwater (Rohde et al. 2019); present on the lower Eel River, middle Eel River, and lower Van Duzen River (CDFW 2020, eBird 2021)

Common name ***Scientific name***	**Status[1] federal/State**	**Potential to occur in ERVB[2]**	**Documented occurrences in GDE units**	**Query source[3]**	**GDE association[4]**	**Habitat and documented occurrences in ERVB**
Black tern *Chlidonias niger*	–/SSC	Likely	Intertidal Zone and Tributaries	CAFSD, eBird	Indirect	Nests semi-colonially in protected areas of marshes with floating nests; feeds on insects; few observations in the vicinity of the Eel River Estuary (eBird 2021)
Lucy’s warbler *Leiothlypis luciae*	–/SSC	Likely	Intertidal Zone and Tributaries, Middle Eel River	CAFSD, eBird	Indirect	Breeds in riparian mesquite woodlands; preys on aquatic organisms, including insects, crustaceans, zooplankton, and invertebrates; infrequent sightings around Ferndale and floodplain (eBird 2021)
Marbled murrelet *Brachyramphus marmoratus*	FT/SE	Likely	Van Duzen and Tributaries	CNDDB, eBird	Indirect	Most time spent on the ocean; nests inland in old-growth conifers with suitable platforms, especially redwood or Douglas-fir forests near coastal areas; relies on old-growth coastal tree stands that may rely on groundwater to nest (Rohde et al. 2019); critical habitat located in the Van Duzen River and Tributaries GDE Unit (USFWS 2016); occupies old-growth redwood stands in the lower Grizzly Creek watershed on the Van Duzen River at the eastern edge of the basin (eBird 2021)
Redhead *Aythya americana*	–/SSC	Likely	Intertidal Zone and Tributaries	CAFSD, eBird	Indirect	Freshwater emergent wetlands with dense stands of cattails (*Typha* spp.) and bulrush (*Schoenoplectus* spp.) interspersed with areas of deep, open water; forages and rests on large, deep bodies of water; observed in lower Eel River downstream of Fernbridge (eBird 2021)

Common name ***Scientific name***	**Status[1] federal/State**	**Potential to occur in ERVB[2]**	**Documented occurrences in GDE units**	**Query source[3]**	**GDE association[4]**	**Habitat and documented occurrences in ERVB**
Summer tanager *Piranga rubra*	–/SSC	Likely	Middle Eel River	CAFSD, eBird	Indirect	Open mixed lowland forests, nesting in mature riparian cottonwood forests; feeds on bees, wasps, and other insects; two sightings in Fortuna (eBird 2021)
Tricolored blackbird *Agelaius tricolor*	–/ST	Likely	Intertidal Zone and Tributaries, Middle Eel River	CAFSD, CNDDB, eBird	Indirect	Feeds in grasslands and agriculture fields; nesting habitat components include open accessible water with dense tall emergent vegetation, a protected nesting substrate (including flooded or thorny vegetation), and a suitable nearby foraging space with adequate insect prey; relies on GDEs for breeding and roosting (Rohde et al 2019); observed on the floodplains downstream of the Van Duzen River (CDFW 2020, eBird 2021)
Western snowy plover *Charadrius alexandrinus nivosus*	FT/SSC	Likely	Intertidal Zone and Tributaries, Middle Eel River, Upper Eel River, and Van Duzen River and Tributaries	CNDDB, eBird	Indirect	Barren to sparsely vegetated beaches, barrier beaches, salt-evaporation pond levees, and shores of alkali lakes; also nests on gravel bars in rivers with wide flood plains; needs sandy, gravelly, or friable soils for nesting; can nest near wetlands that may be supported by groundwater, including near freshwater wetlands (Rohde et al. 2019); critical habitat located all four (4) ERVB GDE units (USFWS 2012a); present along the lower Eel River between Fernbridge and the mouth of the Van Duzen River (eBird 2021)
Willow flycatcher *Empidonax traillii*	FE/SE	Likely	Intertidal Zone and Tributaries, Middle Eel River, Upper Eel River, Van Duzen and Tributaries	CAFSD, eBird	Indirect	Dense brushy thickets within riparian woodland often dominated by willows and/or alder, near permanent standing water; reliant on groundwater-dependent riparian vegetation, including for nest sites that are typically located near slow-moving streams, or side channels and marshes with standing water and/or wet soils (Rohde et al 2019); feeds on insects, fruits, and berries; observed within all four (4) ERVB GDE units (eBird 2021)

Common name ***Scientific name***	**Status[1] federal/State**	**Potential to occur in ERVB[2]**	**Documented occurrences in GDE units**	**Query source[3]**	**GDE association[4]**	**Habitat and documented occurrences in ERVB**
Yellow-billed cuckoo *Coccyzus americanus occidentalis*	FT, BLMS/ SE	Likely	Intertidal Zone and Tributaries, Middle Eel River	CAFSD, CNDDB, eBird	Indirect	Summer resident of valley foothill and desert riparian habitats; nests in open woodland with clearings and low, dense, scrubby vegetation; reliant on groundwater-dependent riparian vegetation for habitat (Rohde et al. 2019); records showing presence on the lower Eel River downstream of Fernbridge (CDFW 2020, eBird 2021)

Common name ***Scientific name***	**Status[1] federal/State**	**Potential to occur in ERVB[2]**	**Documented occurrences in GDE units**	**Query source[3]**	**GDE association[4]**	**Habitat and documented occurrences in ERVB**
Yellow-breasted chat *Icteria virens*	–/SSC	Likely	Intertidal Zone and Tributaries, Middle Eel River, Upper Eel River, Van Duzen and Tributaries	CAFSD, eBird	Indirect	Early successional riparian habitats with a dense shrub layer and an open canopy; present throughout the Lower ERVB (eBird 2021)
Yellow-headed blackbird *Xanthocephalus xanthocephalus*	–/SSC	Likely	Intertidal Zone and Tributaries, Middle Eel River	CAFSD, eBird	Indirect	Breeds almost entirely in open marshes with relatively deep water and tall emergent vegetation, such as bulrush (*Schoenoplectus* spp.) or cattails (*Typha* spp.); nests are typically in moderately dense vegetation; forages within wetlands and surrounding grasslands and croplands; observed downstream of the Van Duzen River (eBird 2021)

Common name ***Scientific name***	**Status[1] federal/State**	**Potential to occur in ERVB[2]**	**Documented occurrences in GDE units**	**Query source[3]**	**GDE association[4]**	**Habitat and documented occurrences in ERVB**
Mammal						
Townsend's big-eared bat *Corynorhinus townsendii*	BLMS/SSC	Likely	Van Duzen and Tributaries	CNDDB	Indirect	Most abundant in mesic habitats, also found in oak woodlands, desert, vegetated drainages, caves or cave-like structures (including basal hollows in large trees, mines, tunnels, and buildings), and riparian communities; feeds on moths, beetles, and soft-bodied insects and drinks water; last recorded observation in 1924 from Carlotta area (CDFW 2020)

[1] Status codes
Federal
FD = Federally delisted
BGEPA = Federally protected under the Bald and Golden Eagle Protection Act
FE = Listed as endangered under the federal ESA
FT = Listed as threatened under the federal ESA
FSC = Federal species of concern
BLMS = Bureau of Land Management Sensitive Species

State
SE = Listed as Endangered under CESA
SSC = CDFW species of special concern
SFP = CDFW fully protected species
ST = Listed as Threatened under the CESA

[2] Potential to Occur:
Likely: the species has documented occurrences and the habitat is high quality or quantity
Possible: no documented occurrences and the species' required habitat is moderate to high quality or quantity
Unlikely: no documented occurrences and the species' required habitat is of low to moderate quality or quantity
None: no potential to occur due to lack of habitat and/or the population is assumed extirpated

[3] Query source:
CAFSD: California Freshwater Species Database (TNC 2020)
CNDDB: California Natural Diversity Database (CDFW 2020)
eBird: (eBird 2021)

[4] Groundwater Dependent Ecosystem (GDE) association:
Direct: Species directly dependent on groundwater for some or all water needs
Indirect: Species dependent upon other species that rely on groundwater for some or all water needs

4.3.3 Fish

Eight (8) special-status fish species occur within the ERVB (Table 4.3-4), though the their life history stages vary greatly, with some fish relatively stationary 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 periods. The general species descriptions below are intended to provide an understanding of the life history stages of special-status fish species that occupy the ERVB.

The mainstem Eel and Van Duzen rivers are generally used as passage corridors for adult and juvenile coho and Chinook salmon and steelhead (Figure 4.3-3). Water temperatures in the lower Eel and Van Duzen rivers generally exceed stressful conditions during the summer months, which limits juvenile salmonid rearing. The substrate in the mainstem Eel River is generally too fine and winter bedload movement too high for successful 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). Adult salmonid passage in this reach typically begins in mid-September and runs through May, beginning with the Chinook salmon in the fall and ending with runback (kelts) steelhead in the late spring (Dennis Halligan, personal observations 1997-2020). Spawning and rearing typically occur in the tributaries within the ERVB. The lone exception is that some steelhead rearing may occur near the Yager Creek confluence on the Van Duzen River, and some steelhead spawning may occur upstream of the Yager Creek confluence (Figure 4.3-3). Anadromous salmonid smolts move downstream to the estuary from their rearing areas in the spring and early summer. Critical riffles observed between 2006 and 2020 (Stillwater Sciences 2021), noted on Figure 4.3-3, block adult salmonid passage until the first high flows during the fall. Near the confluence with the Eel River, the Van Duzen River often goes dry from the late summer through the fall and does not connect to the Eel River until the first significant storm flows in the fall. The degree to which groundwater management affects fish passage will be explored using the groundwater-surface water model. Sediment deposition, particularly at the mouth of the Van Duzen River and downstream reaches of the Eel River, likely contributes to passage issues.

Coastal cutthroat trout occupy different areas of the ERVB than Chinook and coho salmon and steelhead. The Van Duzen River is considered the southernmost extent of the species. In the Eel River, this species occupies the Intertidal Zone and Tributaries and Middle Eel River GDE units (e.g., Strongs, Rohner, Barber, Francis, Reas, and Russ creeks) (Figure 4.3-3). Coastal cutthroat trout require cool, clean water with ample cover and deep pools for holding in summer, preferring small, low-gradient coastal streams (e.g, Strongs, Rohner, Barber, Francis, Reas, and Russ creeks) and estuarine habitats, including lagoons (Moyle et al. 2015). Optimal stream temperatures are less than 18°C, with preferred temperatures around 9°C to 12°C, which would limit their summer and early fall occupancy to the estuary and small cool tributaries.

The tidewater goby is a short-lived (about one year) fish that resides in lagoons and estuary areas with muted tidal flow and low to moderate salinities generally less than 12 parts per thousand (ppt), but they have been documented in salinities ranging from 0 to 44 ppt (USFWS 2013). Tidewater goby only occur in the Intertidal Zone and Tributaries GDE Unit (Figure 4.3-3). This species is known to be present in Salt River and on The Wildlands Conservancy property near the mouth of the Eel River.

Green sturgeon are known to inhabit the Eel River with a potentially persistent small spawning population using the Eel River. There are known historical and recent sightings of green sturgeon within the mainstem Eel River, with the majority of those sightings centered from the confluence of the North Fork (river kilometer [rkm] 155) to the confluence of the South Fork (rkm 65) as well as in the estuary (Stillwater Sciences and Wiyot Tribe 2017). The Eel River is proximate to the Klamath River, and it is even closer to Humboldt Bay, which is a documented feeding habitat for both the Southern and Northern Distinct Population Segments (DPS) (Lindley et al. 2011). Therefore, it is possible that any green sturgeon in the Eel River could be a mix of Northern and Southern DPS origin fish. However, the Southern DPS green sturgeon is only known to spawn in the Sacramento River and likely does not extend farther upstream in the Eel River than the mouth of the Van Duzen River. Adult green sturgeon generally return to spawn in rivers in late winter through early summer and spawn every two to six years. Post-spawn adults may choose to emigrate downstream soon after spawning or wait until the fall when water temperatures are low and early season runoff begins. Juveniles spend from one to four years in fresh and estuarine waters and disperse into salt water at lengths of 300 to 750 millimeters (mm) (USFWS 1995). Adults will return to spawn at about 13 years of age. Green sturgeon are not known to be present in the Van Duzen River and Tributaries GDE Unit.

Pacific lamprey are known to inhabit the Eel River (which was how it got its name). Pacific lampreys are anadromous, rearing in freshwater before outmigrating to the ocean, where they grow to full size prior to returning to their natal streams to spawn. Spawning typically takes place both in the mainstem of medium-sized rivers and smaller tributaries from March through July, depending on water temperature and local conditions such as seasonal flow regimes (Brumo et al. 2009, Gunckel et al. 2009). Spawning generally takes place in pool and run tailouts and low-gradient riffles. Both males and females build nests (redds) in gravel and cobble substrate. Adults die within a few weeks after spawning. Eggs hatch in about 15 days and larvae emerge from the gravel within a couple of weeks after that, then drift downstream with the current, settle out of the water column, and burrow into fine silt and sand substrate in low-velocity, depositional areas such as pools, alcoves, and side channels. They remain in this habitat for four (4) to 10 years, filter-feeding on algae and detrital matter prior to metamorphizing into smolt-like individuals known as macropthalmia (Stillwater Sciences 2010). They will then migrate downstream during high fall and winter flows to the ocean, where they mature for approximately 18 to 40 months, before returning to freshwater as sexually immature adults from late winter to early summer, beginning the cycle anew. Pacific lamprey are known to occur within all the GDEs units in the groundwater basin.

Longfin smelt are found throughout coastal northern California. Most longfin smelt exhibit a two-year life cycle, spawning and dying during their second year. However, during good growth years, longfin smelt can spawn at the end of their first year, and three-year-old smelt have also been observed (Moyle 2002). Spawning occurs in fresh water during the winter to early spring (February through April) over sandy or gravel substrate. Most smelt die after spawning, but a few (mostly females) may live another year. The eggs are adhesive and hatch in 40 days when water temperatures are 7°C. Newly hatched larvae are 5-8 millimeters (mm) long. Larvae can be moved downstream to estuaries by high flows but may also spend considerable time in fresh water. It takes almost three (3) months for longfin smelt to reach the juvenile stage (USFWS 2012b). These fish have been observed in many areas throughout the Eel River Estuary and the mainstem portions of the coastal plain (Garwood 2017). Longfin smelt used a wide range of the lower river/estuary, with individuals sampled 5.7 km from the mainstem of the river in slough waters, and as far as 20 km upriver from the mouth in alluvial portions well outside the brackish zone (Garwood 2017). There are no observations of smelt within the Upper Eel River or Van Duzen River and Tributaries GDE units.

Additional information on these fish species in the Eel River, adapted from Rohde et al. (2019), is provided in Appendix C.

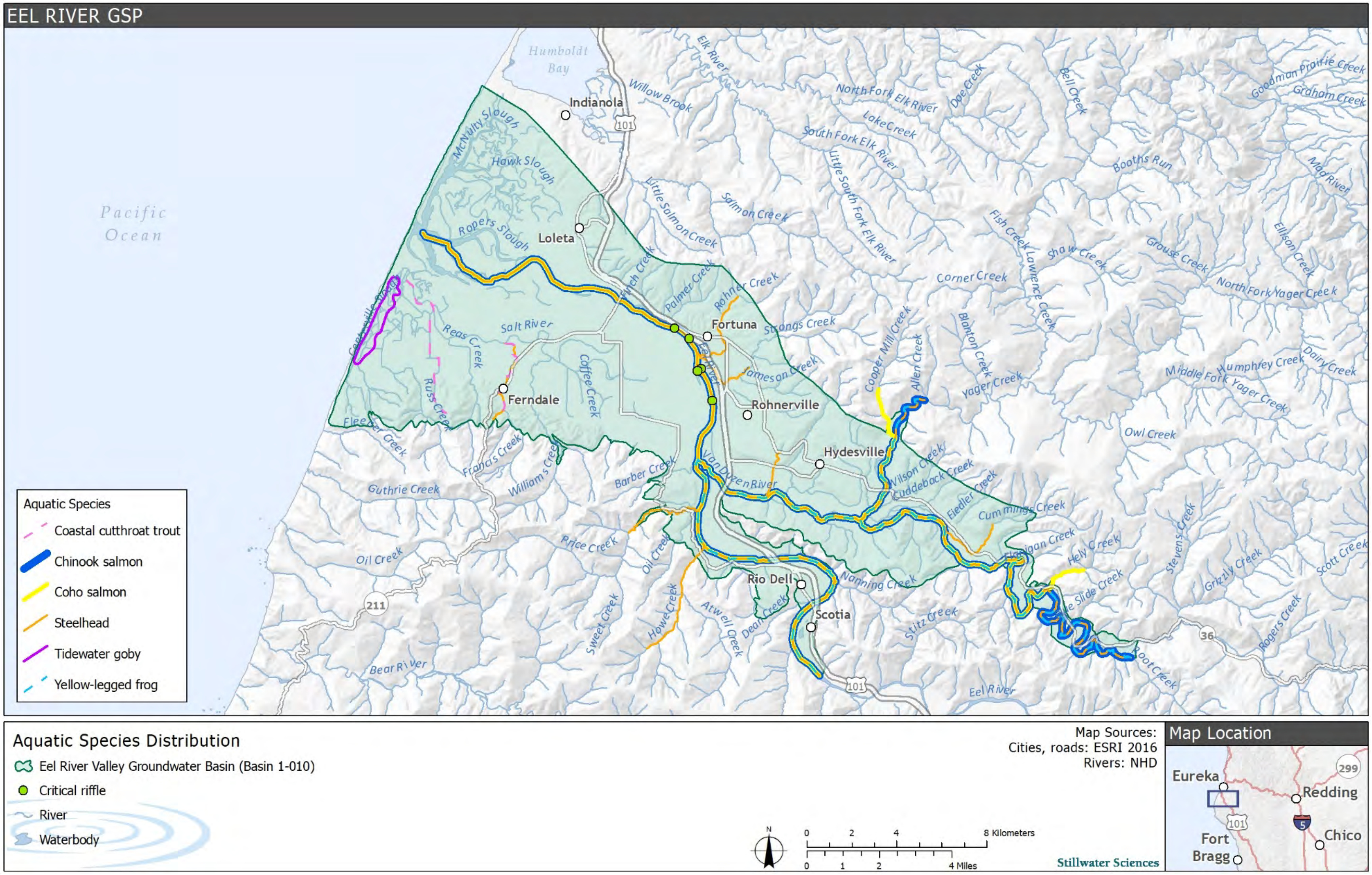

Figure 4.3-3. Aquatic species distribution in the ERVB; green circles indicate critical riffles observed from 2006 to 2020 (Stillwater Sciences 2021)

Table 4.3-4. Groundwater-dependent fish species with known occurrence or suitable habitat in the ERVB

Common name ***Scientific name***	**Status[1] federal/State**	**Potential to occur in ERVB[2]**	**Documented occurrences in GDE units**	**Query source[3]**	**GDE association[4]**	**Habitat and documented occurrences in ERVB**
Chinook salmon *Oncorhynchus tshawytscha* (CC ESU)	FT/–	Likely	Intertidal Zone and Tributaries, Middle Eel River, Upper Eel River, Van Duzen and Tributaries	NMFS	Direct	Larger rivers and tributaries for migration, spawning, and rearing; estuaries and ocean for juvenile to adult growth; critical habitat located in all four (4) ERVB GDE units (NMFS 2005); present throughout watershed.
Coho salmon *Oncorhynchus kisutch* (SONCC ESU)	FT/ST	Likely	Intertidal Zone and Tributaries, Middle Eel River, Upper Eel River, Van Duzen and Tributaries	NMFS	Direct	Rivers for migration and tributaries for spawning and rearing; estuaries and ocean for juvenile to adult growth; critical habitat located in all four (4) ERVB GDE units (NMFS 2005); present throughout watershed
Steelhead *Oncorhynchus mykiss* (NC DPS)	FT/–	Likely	Intertidal Zone and Tributaries, Middle Eel River, Van Duzen and Tributaries, Upper Eel River	NMFS	Direct	Rivers for migration and tributaries for spawning and rearing; estuaries and ocean for juvenile to adult growth; critical habitat located in all four (4) ERVB GDE units (NMFS 2005); present throughout watershed

Common name ***Scientific name***	**Status[1] federal/State**	**Potential to occur in ERVB[2]**	**Documented occurrences in GDE units**	**Query source[3]**	**GDE association[4]**	**Habitat and documented occurrences in ERVB**
Coastal cutthroat trout *Oncorhynchus clarkii clarkii*	/SSC	Likely	Intertidal Zone and Tributaries, Middle Eel River	CNDDB	Direct	Small, low-gradient coastal streams and estuaries (CDFW 2020); occurs in the Intertidal Zone and Tributaries and Lower Eel River GDE units
Tidewater goby *Eucyclogobius newberryi*	FE/SSC	Likely	Intertidal Zone and Tributaries	CNDDB	Direct	Coastal lagoons and the uppermost zone of brackish large estuaries; prefer sandy substrate for spawning, but can be found on silt, mud, or rocky substrates; can occur in water up to 15 ft in lagoons and within a wide range of salinity (0–42 ppt); critical habitat located in the Intertidal Zone and Tributaries GDE Unit (USFWS 2013)
Green sturgeon *Acipenser medirostris* (Southern and northern DPS)	FT (southern DPS, FSC (Northern DPS/SSC	Likely	Intertidal Zone and Tributaries, Middle Eel River, Upper Eel River	NMFS	Direct	Spends most of its life at sea; returns to spawn in large rivers; juveniles rear in freshwater for up to two years then migrate to estuary and ocean; observed in estuary, Fortuna area, and upper Eel River (Halligan, pers. comm 2021)
Pacific lamprey *Entosphenus tridentatus*	–/SSC	Likely	Intertidal Zone and Tributaries, Middle Eel River, Van Duzen and Tributaries, Upper Eel River	CNDDB	Direct	Migration in rivers and tributaries; spawning in medium-sized rivers and tributaries; rearing in low-velocity depositional areas for four to 10 years prior to outmigration to estuary and ocean; present throughout the watershed (Stillwater Sciences 2010)

Common name ***Scientific name***	**Status[1] federal/State**	**Potential to occur in ERVB[2]**	**Documented occurrences in GDE units**	**Query source[3]**	**GDE association[4]**	**Habitat and documented occurrences in ERVB**
Longfin smelt *Spirinchus thaleichthys*	– /ST	Likely	Intertidal Zone and Tributaries, Middle Eel River	CNDDB	Direct	Offshore areas, coastal lagoons, bays, estuaries, sloughs, and freshwater rivers and streams; spawns in freshwater; observed in the estuary in 1995 and near mouth of Van Duzen River in 1956 Garwood 2017), also captured during monitoring operations in Salt River in 2014/2015 (HCRCD 2014)

Notes: CC = California Coast; ESU = evolutionarily significant unit; SONCC = Southern Oregon/Northern California Coast

[1] Status codes

Federal
- FE = Listed as endangered under the federal ESA
- FT = Listed as threatened under the federal ESA
- FSC = Federal species of concern

State
- SSC = CDFW species of special concern
- ST = Listed as Threatened under the California Endangered Species Act

[2] Potential to Occur:
- *Likely:* the species has documented occurrences and the habitat is high quality or quantity
- *Possible*: no documented occurrences and the species' required habitat is moderate to high quality or quantity
- *Unlikely:* no documented occurrences and the species' required habitat is of low to moderate quality or quantity
- *None:* no potential to occur due to lack of habitat and/or the population is assumed extirpated

[3] Query source:
- CAFSD: California Freshwater Species Database (TNC 2020)
- CNDDB: California Natural Diversity Database (CDFW 2020)
- eBird: (eBird 2021)

[4] Groundwater Dependent Ecosystem (GDE) association:
- Direct: Species directly dependent on groundwater for some or all water needs
- Indirect: Species dependent upon other species that rely on groundwater for some or all water needs

4.4 Invasive Species

Non-native and invasive species are distributed throughout the Eel River watershed, including the Lower ERVB. Invasive species have a negative impact on the riparian corridor and threaten native species populations.

Reed canary grass (*Phalaris arundinacea*) was noted in the Intertidal Zone and Tributaries GDE Unit, where it was prevalent within the wet grassland and high marsh community types near the Salt River confluence with the Eel River (H.T. Harvey & Associates 2015). This non-native perennial rhizomatous grass invades moist wetland habitat and spreads and establishes quickly, forming dense monotypic stands that displace native herbaceous stands and are difficult to eradicate once established. Other woody non-native invasive species (listed by California Invasive Plant Council with a high rating [i.e., species have severe ecological impacts on physical processes, plant and animal communities, and vegetation structure]) included Himalayan blackberry (*Rubus armeniacus*), Scotch broom (*Cytisus scoparius*), and pampas grass (*Cortaderia jubata*), all of which establish within the riparian forest and shrubland communities as well as some grassland communities near development and roads.

American bullfrog (*Lithobates catesbeianus*), an invasive amphibian species, is documented throughout the lower Eel and Van Duzen river floodplains within isolated ponds. The bullfrog preys on practically whatever can fit in its mouth, including native amphibian species (e.g., foothill yellow-legged frogs and northern red-legged frogs).

Many non-native fish species have been introduced into the Eel River by direct stocking or releases of live bait used to catch other species. Various sunfish species (*Lepomis* spp.) (e.g., green sunfish [*Lepomis cyanellus*] and bluegill [*Lepomis macrochirus*]), and bass species (*Micropterus* spp.) (e.g., largemouth bass [*Micropterus salmoides*]), have been documented in Lake Pillsbury, which is in Lake County and outside of the Lower ERVB. The Sacramento pikeminnow (*Ptychocheilus grandis*), which is believed to have been introduced into the Eel River through release of unused live bait in Lake Pillsbury, has spread throughout the watershed. Non-native predatory fish may have a large impact on native fish populations (e.g., salmonids), reducing the size of already diminished populations and limiting their ability to recover in response to habitat restoration efforts.

5 POTENTIAL EFFECTS ON GROUNDWATER-DEPENDENT ECOSYSTEMS

5.1 Approach

SGMA describes six (6) groundwater conditions that could cause undesirable results, including adverse impacts on GDEs: 1) chronic lowering of groundwater levels, 2) reduction of groundwater storage, 3) seawater intrusion, 4) degraded groundwater quality, 5) land subsidence, and 6) depletion of interconnected surface waters. Rohde et al. (2018) identify chronic lowering of groundwater levels, degraded water quality, and depletions of interconnected surface water as the most likely conditions to have direct effects on GDEs, potentially leading to an undesirable result. Following this guidance and based on available information for the ERVB, reduction of groundwater storage and land subsidence have been removed from consideration as conditions leading to undesirable results because they are not relevant to GDE units in the ERVB. Seawater intrusion could occur due to decreased groundwater levels or rising sea level in the Intertidal Zone and Tributaries GDE Unit.

The potential for chronic lowering of groundwater levels, degraded groundwater quality, depletion of interconnected surface waters, and seawater intrusion to cause direct effects on GDE units were evaluated compared to baseline conditions. First, baseline hydrologic conditions for the GDE units were identified using available information (Section 3), then each GDE unit's susceptibility to changing groundwater conditions was determined using available hydrologic data and the GDE susceptibility classifications (Rohde et al. 2018) summarized in Table 5.1-1. Once the groundwater and interconnected surface water models are available, the potential for groundwater management to affect interconnected surface water and seawater intrusion will be evaluated. Other than algal blooms due to high nutrient concentrations in surface water and elevated nutrient levels in groundwater due to high nutrient input (State Water Resources Control Board [SWRCB] 2020), there have not been declines in water quality.

Table 5.1-1. Susceptibility classifications developed for evaluation of a GDE unit's susceptibility to changing groundwater conditions (Rohde et al. 2018)

Susceptibility classifications	
High Susceptibility	Current groundwater conditions for the selected hydrologic data fall outside the baseline range.[1]
Moderate Susceptibility	Current groundwater conditions for the selected hydrologic data fall within the baseline range, but future changes in groundwater conditions are likely to cause it to fall outside the baseline range. The future conditions could be due to planned or anticipated activities that increase or shift groundwater production, causing a potential effect on a GDE.
Low Susceptibility	Current groundwater conditions for the selected hydrologic data fall within the baseline range and no future changes in groundwater conditions are likely to cause the hydrologic data to fall outside the baseline range.

[1] For purposes of this analysis, the baseline range is defined as the range of variability of the shallow groundwater depth for the period of record through 2015, with a minimum of 10 years (2005–2015).

Susceptibility classifications were used to trigger further evaluation of potential effects on GDE units. If a GDE unit was determined to have moderate or high susceptibility to changing groundwater conditions, biological information was used to assess whether evidence exists of a biological response to changing groundwater levels or degraded groundwater quality. The biological response analysis was 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. The Normalized Difference Moisture Index (NDMI) was also evaluated, but the results were very similar to NDVI and are not included here.

NDVI, which estimates vegetation greenness, was generated from surface reflectance corrected multispectral Landsat imagery corresponding to the period from July 9 to September 7 of each year, which represents the summer period when GDE species are most likely to use groundwater (see Klausmeyer et al. 2019 for further description of methods). Vegetation polygons with higher NDVI values indicate increased density of chlorophyll and photosynthetic capacity in the canopy, an indicator of vigorous, growing vegetation. NDVI 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).

Critical riffle depth data collected within the GDE units were used to assess the potential effects late summer and fall groundwater use may have on passage during the upstream anadromous salmonid migration.

Based on the NDVI data, groundwater quality data from wells in or near GDE units in the ERVB, 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.

The extent and magnitude of interconnected surface waters is a key component supporting aquatic ecosystem health. Because surface water flows depend on surface water inflows and interconnected surface water, the numerical modeling conducted as part of this GSP will be used to evaluate changes to interconnected surface water due to groundwater management and the potential effect on aquatic GDE units. The extent of interconnected surface water and the effect of groundwater management on interconnected surface water and aquatic habitat will be evaluated in the GSP. The assessment of interconnected surface water is dependent upon the groundwater model. The comparisons will therefore be included in the final GSP.

5.2 Biological Data

Tracking the health of key components of groundwater dependent ecosystems through time would involve systematic tracking of populations and key ecosystem functions through that same duration and accounting for changes in driving variables such as floods, climate, and other stressors on populations. Accordingly, this section focuses on changes in vegetation through time using remote sensing data.

While increases or decreases in vegetation health do not provide a definitive indication that other components of the ecosystem are thriving or under stress, they do provide a reasonable first-order check on the clear linkage between groundwater and the other communities that compose the ecosystem. NDVI is not useful for tracking changes to aquatic GDE units that rely on interconnected surface water. Previous work has shown that decreases in vegetation vigor correlate to decreases in remote sensing metrics such as NDVI (e.g., Huntington et al. 2015), and that decreases in vegetation health often correspond with decreases in overall ecosystem health. Tracking the change in NDVI for individual polygons shows how the greenness of those polygons change through time. It is crucial to remember that the rivers in the ERVB, particularly the Eel and Van Duzen rivers, have very high sediment loads and are quite dynamic. This shifting uproots vegetation and creates new surfaces upon which seedlings can germinate. Following floods, the proximity to the river channel (and often depth to groundwater), the relative elevation of a given vegetation polygon, or location of riffles that may hinder upstream salmonid migration may change. It is therefore useful to average these changes across the different GDE polygons to account for and address them.

To assess potential groundwater thresholds for vegetation health, average NDVI from July 9 to September 7 for each year in each GDE unit is compared to DTW at corresponding monitoring wells. For each year, the DTW measurement taken at the closest date within three months of August 8, the median summer NDVI date, is used, where available. Long-term well data (since

1985) is only available for a limited number of wells in the coastal plain of the Intertidal Zone and Tributaries and Middle Eel GDE units.

5.2.1 Intertidal Zone and Tributaries

The median NDVI in the Intertidal Zone and Tributaries GDE Unit ranges from 0.48 to 0.74 and has generally been increasing through time (Figure 5.2-1), which occurs across the entire range of GDE units. Short-term changes in NDVI are not systematically tied to water-year type. The reasons for the increase in NDVI are not known but appear to reflect establishment and maturation of riparian vegetation in the past few decades on some bars and islands along the mainstem Eel River.

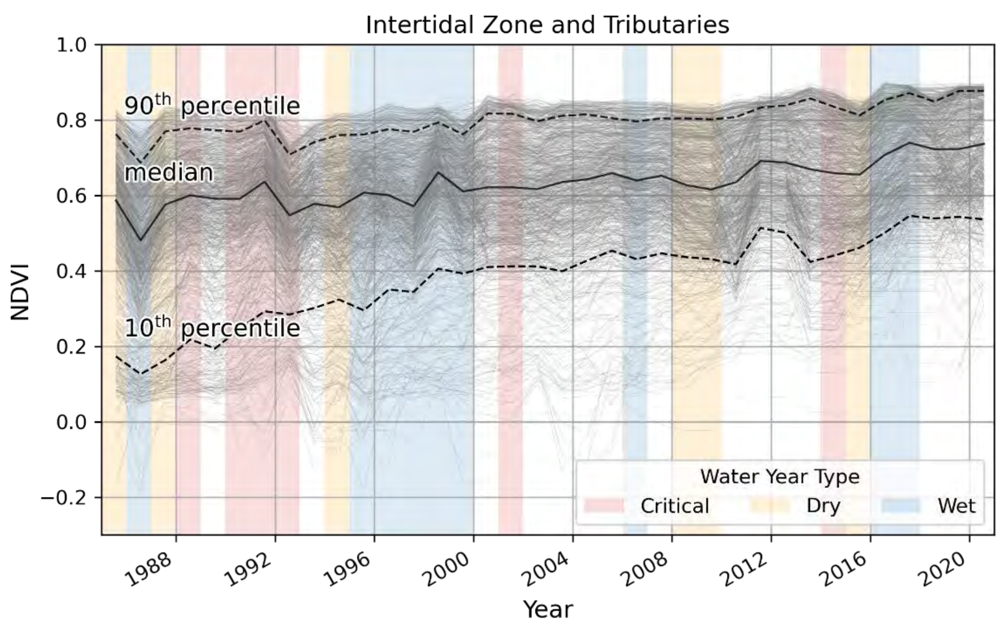

Figure 5.2-1. NDVI changes through time for the Intertidal Zone and Tributaries GDE Unit; the solid black line is the median value, and the dashed lines represent the 10th and 90th percentiles

There is no apparent correlation between median summer NDVI and DTW (within three [3] months of August 8; see Section 5.2) at either of the associated monitoring wells in the Intertidal Zone and Tributaries GDE Unit (Figure 5.2-2).

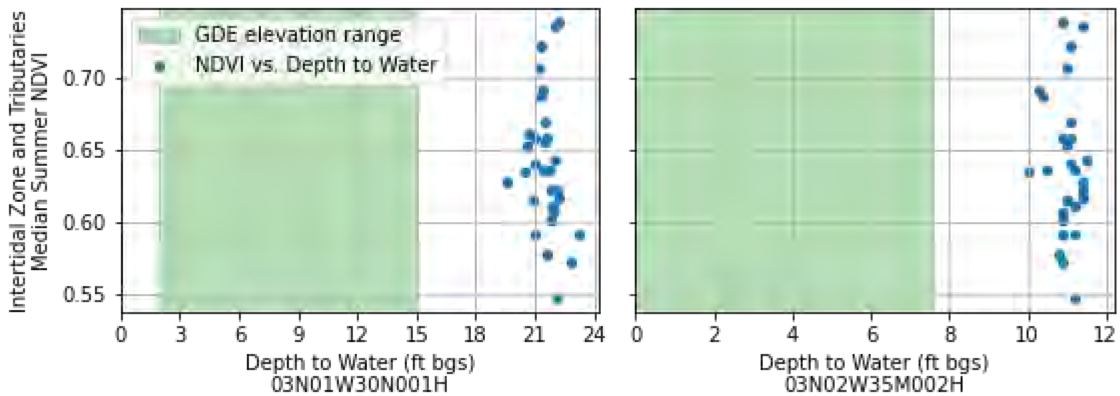

Figure 5.2-2. Median summer NDVI in the Intertidal Zone and Tributaries GDE Unit versus DTW at the two associated monitoring wells (DTW data selection method is outlined in Section 5.2.)

Willow shrub and willow are the dominant vegetation types in the Intertidal Zone and Tributaries GDE Unit. The dominant willow species in these vegetation types have reported maximum rooting depths of 6.9 ft (Appendix A). Groundwater is typically within the rooting depth of the dominant vegetation types at the lowest-elevation GDEs when adjusted for the difference in elevation between GDEs and monitoring well sites (Figure 5.2-3, see methods in Section 3.1.1).

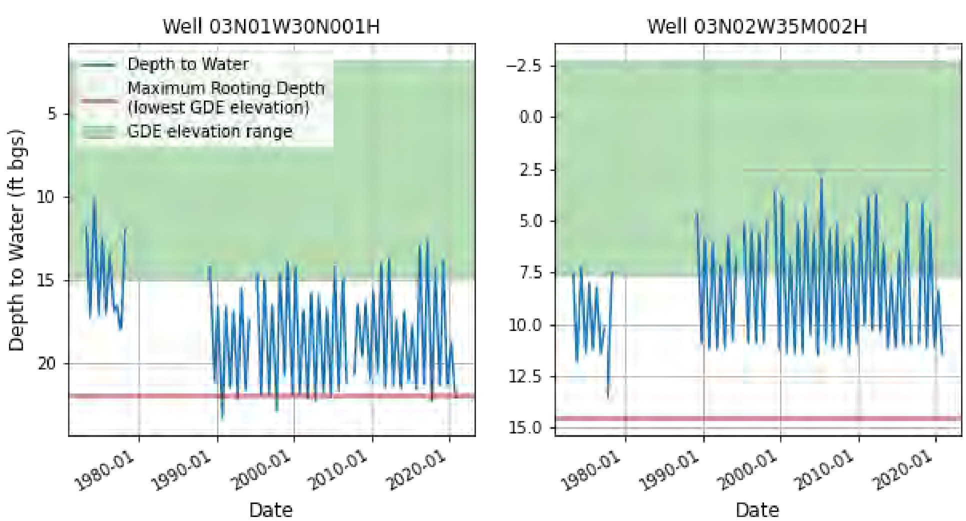

Figure 5.2-3. Depth to groundwater and maximum rooting depth of dominant vegetation type in the Intertidal Zone and Tributaries GDE Unit. Maximum rooting depth is plotted relative to the lowest-elevation GDEs.

Depths of riffles and anadromous salmonid fish passage in the Intertidal Zone and Tributaries GDE Unit are not fully dependent on surface flow inputs from upstream due to the intertidal nature of the GDE.

5.2.2 Middle Eel River

The median NDVI for the Middle Eel River GDE Unit was relatively steady through time, with slight increases in the mid-1990s and from 2010 through 2011. The median NDVI over the period of record was 0.57-0.80 (Figure 5.2-3). Between these increases NDVI was relatively steady, with slight drops in 1992 (critically dry) and in 2002 (a normal year following critically dry 2001). Similar to at the Intertidal Zone GDE Unit, the reasons for the generally increasing trend are not known but appear to reflect establishment and maturation of riparian vegetation in the past few decades on some bars and islands along the mainstem Eel River.

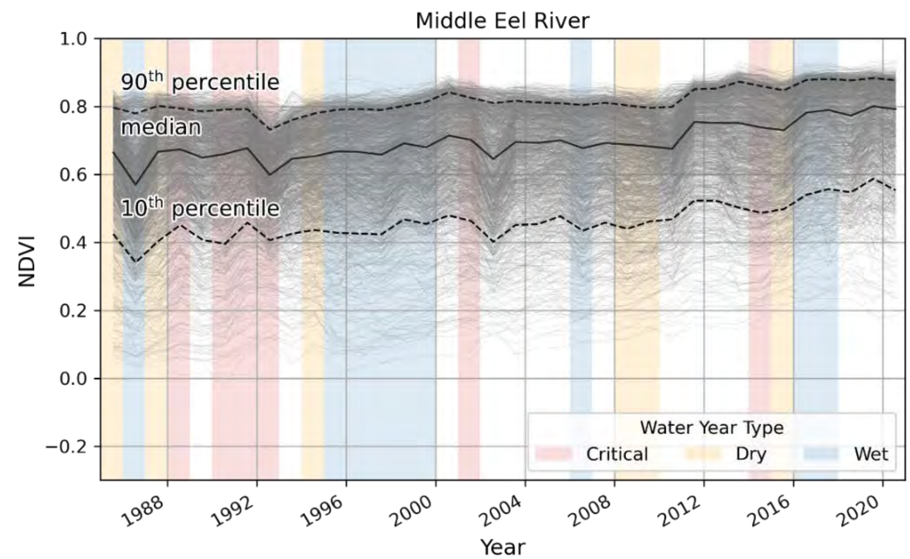

Figure 5.2-4. NDVI changes through time for the Middle Eel River GDE Unit; the solid black line is the median value and the dashed lines represent the 10th and 90th percentiles

There is no apparent correlation between median summer NDVI and DTW at either of the associated monitoring wells in the Middle Eel River GDE Unit (Figure 5.2-4).

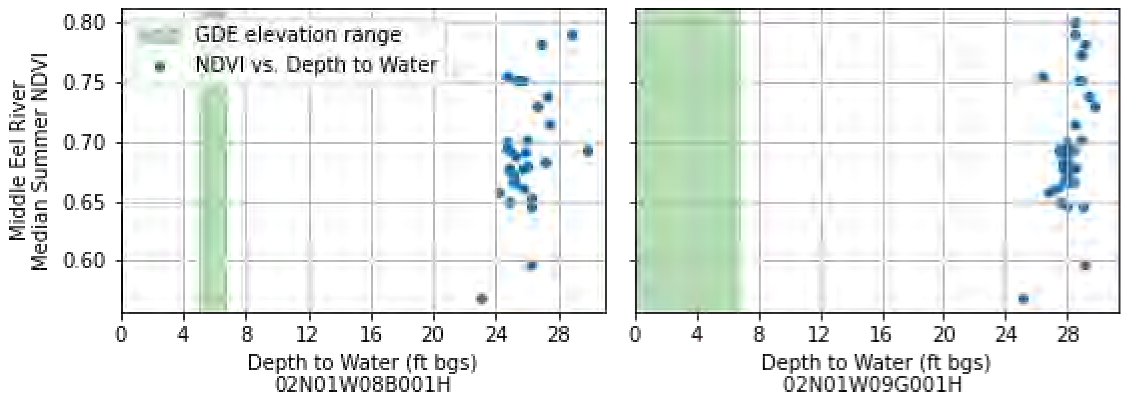

Figure 5.2-5. Median summer NDVI in the Middle Eel River GDE Unit versus DTW at the two (2) associated monitoring wells (DTW data selection method is outlined in Section 5.2.)

Red alder is the dominant species in the Middle Eel River GDE Unit and has a maximum rooting depth of approximately 13 ft (Appendix A). Spring groundwater elevations are typically within the rooting depth of the dominant vegetation types at the lowest-elevation GDE units when adjusted for the difference in elevation between GDEs and monitoring well sites (Figure 5.2-6, see methods in Section 3.1.1). The GDEs within 0.5 miles of the long-term wells in this reach are former channels and oxbow lakes (see Figure 2.3-1).

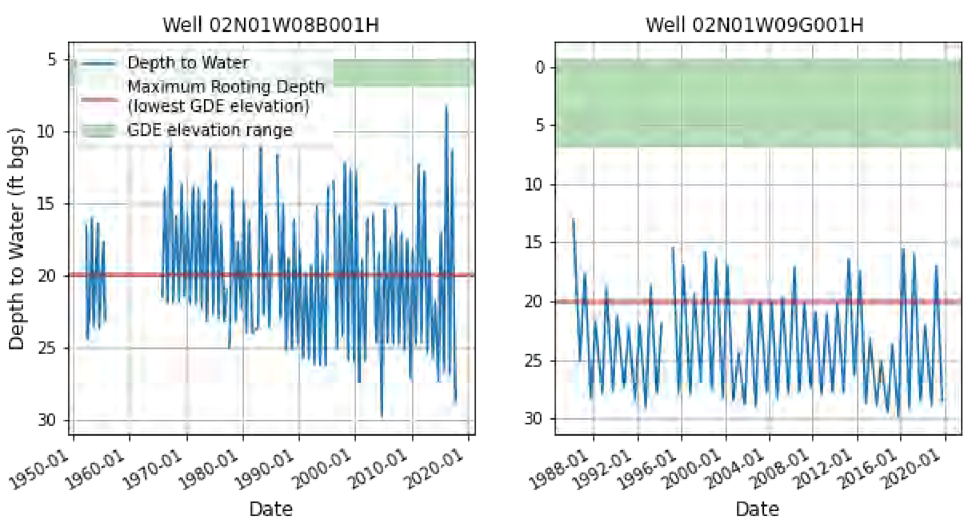

Figure 5.2-6. Depth to groundwater and maximum rooting depth of dominant vegetation type in the Middle Eel River GDE Unit; maximum rooting depth is plotted relative to the lowest-elevation GDE units

Critical riffle depths in the Middle Eel River GDE have been recorded between 2005 and 2020 (Stillwater Sciences 2021). The shallowest riffles appeared only to be loosely correlated with river flow as measured at the USGS Scotia gauge (Figure 5.2-7). It is possible that riffle depth is more a function of geomorphic processes than total inflow into the GDE. The role of interconnected surface water will be explored once the model results are available.

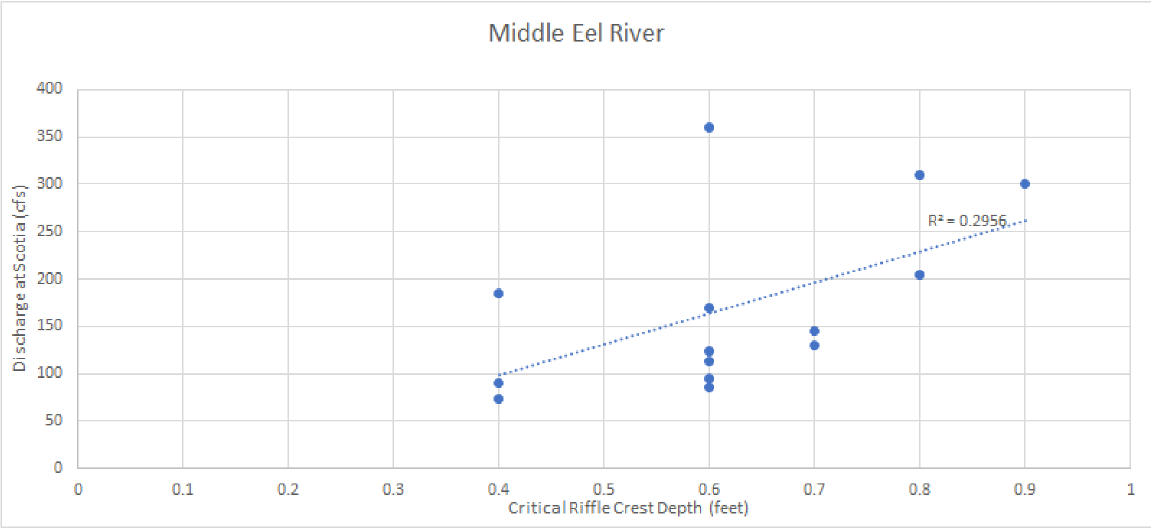

Figure 5.2-7. Shallowest riffle depths vs. discharge at Scotia within the Middle Eel River GDE Unit

5.2.3 Upper Eel River

The NDVI in the Upper Eel River shows similar trends to the other GDE units, with median values that gradually increased over time from 0.46 to 0.76 (Figure 5.2-8). The declines in 1993 and 2003 lasted one (1) year and were less than those for the Middle Eel River GDE Unit.

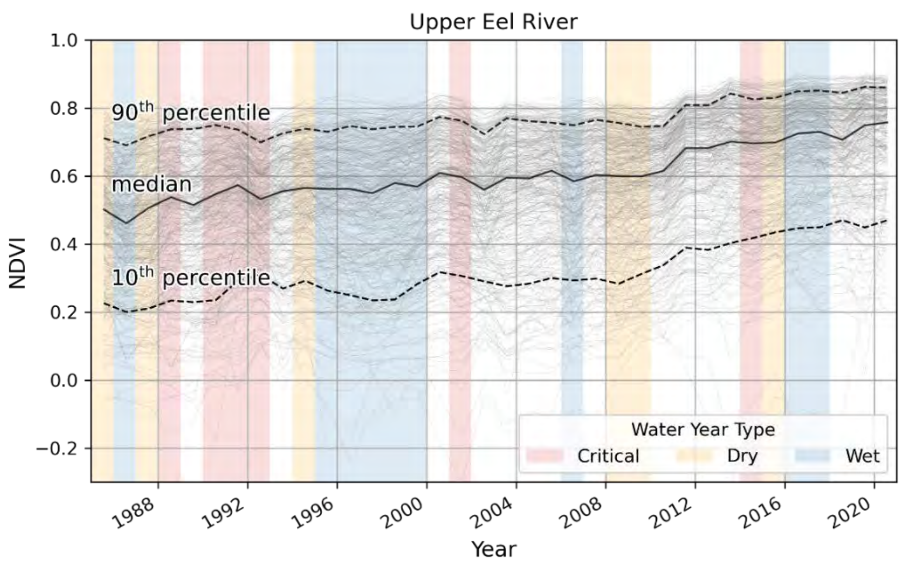

Figure 5.2-8. NDVI changes through time for the Upper Eel River GDE Unit; the solid black line is the median value and the dashed lines represent the 10th and 90th percentiles

Red alder is the dominant species in the Upper Eel River GDE Unit and has a reported maximum rooting depth of 13.12 ft (Appendix A). There are no shallow well data in this unit.

Critical riffle depths are not available for the Upper Eel River GDE Unit.

5.2.4 Van Duzen River and Tributaries

NDVI was relatively constant in the Van Duzen River and Tributaries GDE Unit from 1985 to 2011, increasing in 2012 and remaining relatively steady through 2020 (Figure 5.2-9). The median NDVI ranged from 0.56 to 0.75.

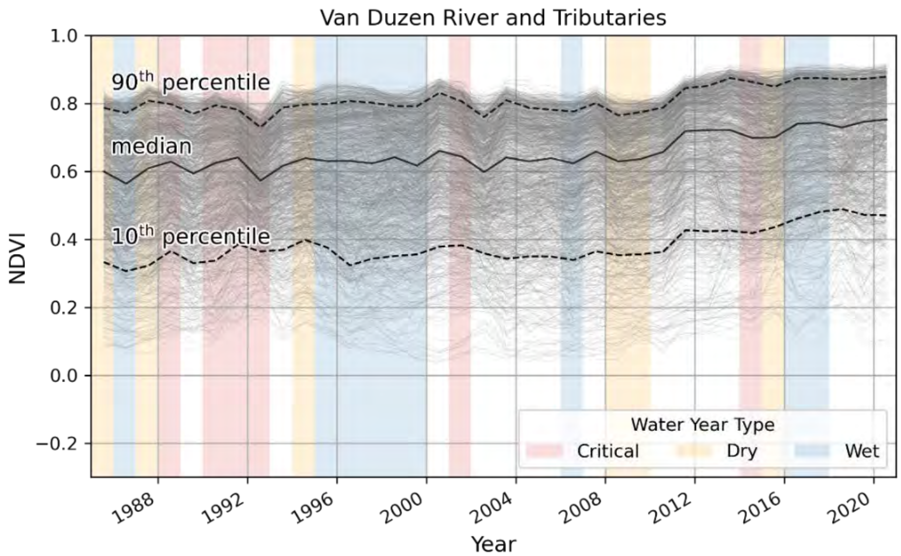

Figure 5.2-9. NDVI changes through time for the Van Duzen River and Tributaries GDE Unit; the solid black line is the median value, and the dashed lines represent the 10th and 90th percentiles

No DTW data within three months of August 8 (the midpoint of the NDVI data) are available for the Van Duzen River and Tributaries GDE Unit.

Redwood and annual/perennial grassland are the dominant species in the Van Duzen River and Tributaries GDE Unit, with likely maximum rooting depths ranging from 8.5 to 16.4 (redwood) and 2.3 to 4.6 ft (grassland) (Appendix A). Recent shallow groundwater elevations (Section 3.1.3) are typically within the rooting depth of the dominant vegetation types at the lowest-elevation GDE units when adjusted for the difference in elevation between GDEs and monitoring well sites (Figure 5.2-10, see methods in Section 3.1.1).

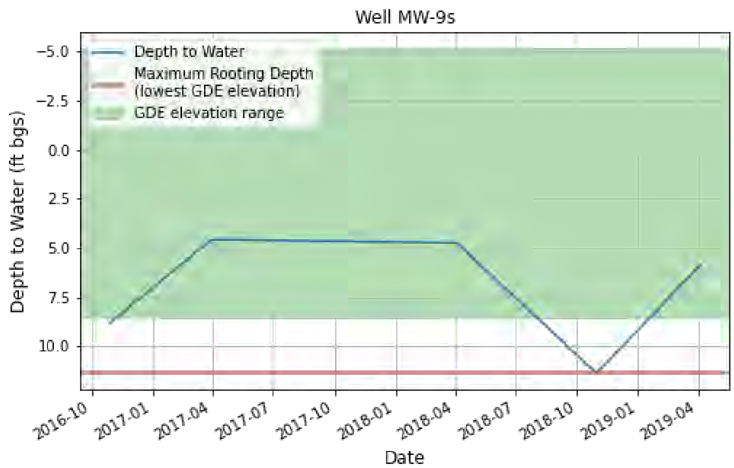

Figure 5.2-10. Depth to groundwater and maximum rooting depth of dominant vegetation type in the Van Duzen River and Tributaries GDE Unit; maximum rooting depth is plotted relative to the lowest-elevation GDE units

The delta at the mouth of the Van Duzen River goes subsurface during all but the wettest water years (Dennis Halligan, Stillwater Sciences, pers. comm. 2021) and creates a complete barrier to upstream anadromous salmonid migration. In addition, other reaches within the Van Duzen River and Tributaries GDE Unit (e.g., Carlotta area) experience intermittent flow characteristics during below-normal water years. Riffle crest depth data for the years 2006-2021 were collected by Stillwater Sciences (2021). The average riffle crest data show correlation (R^2=0.6978) with the USGS Bridgeville gauge data at the time of collection (Figure 5.2-11) suggesting that passage is related to surface water inflows to the basin.

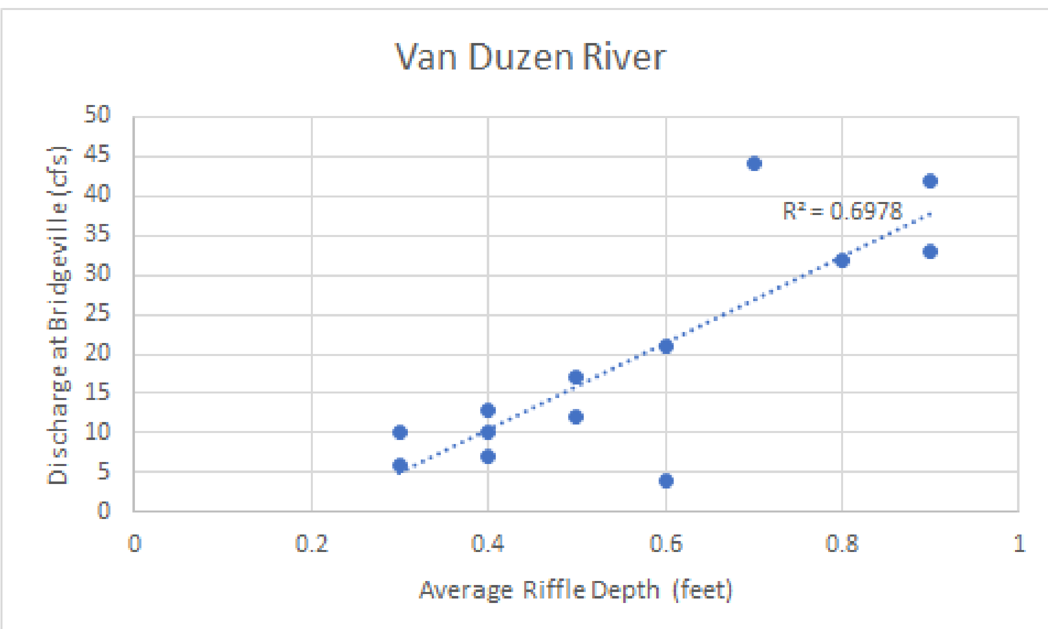

Figure 5.2-11. Average riffle depth vs. discharge at Bridgeville within the Van Duzen River and Tributaries GDE Unit

5.3 Climate Change Effects

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.

5.4 Summary of Potential Effects

The potential effects of groundwater management on GDEs can be used to assess the likely future susceptibility to groundwater management and climate change. This is based on an analysis of the data presented in previous sections, plus the ecological value of the GDE units (following Rohde et al. 2018). The potential effects can be used to prioritize monitoring and to develop sustainable management criteria.

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), based on the information summarized in Section 4 and the NDVI/NDMI data presented in Section 5.2.
3. Susceptibility to changing groundwater conditions (high, moderate, low) based on available hydrologic data, climate change projections, and the GDE susceptibility classifications summarized in Table 5.1-1. Susceptibility determinations may be changed following the completion of the groundwater model.

The groundwater-dependence of each GDE unit, including any interconnected surface water, is also summarized to provide context for the effects assessment. Groundwater-dependence was determined based on the reported or assumed rooting depths relative to the depth to groundwater and the presence of interconnected surface water based on field observations and the groundwater model.

5.4.1 Intertidal Zone and Tributaries

The Intertidal Zone and Tributaries GDE Unit contains 43% of the total GDE acreage in the ERVB (Table 3.3-1). The reach of the lower Eel River in the Intertidal Zone and Tributaries GDE Unit is considered perennial and intertidal and is typically connected to groundwater. The degree to which interconnected surface waters affect the salinity in this reach varies by season and flow. Salinity is generally reduced during periods of high runoff and groundwater accretion, increasing during the low flow season.

Groundwater-dependence

Both terrestrial and aquatic species and habitat in the Intertidal Zone and Tributaries GDE Unit are likely dependent on groundwater. Additionally:

- Shallow groundwater elevations in the limited long-term well data have remained stable since 1990. Groundwater levels in wells installed in 2016 show no systematic changes over a limited period of record. Groundwater elevations are within the rooting depth of dominant species within the GDE.
- Terrestrial components of this GDE unit are mostly composed of riparian forested vegetation communities formed by a mixture of willows, red alder, and black cottonwood that are likely connected to groundwater.
- Perennial surface water flows are likely connected to groundwater in the Eel and Salt rivers.

Ecological value

Aquatic

The Intertidal Zone and Tributaries GDE Unit was determined to have high ecological value for aquatic species and habitat because: 1) It supports many aquatic special-status species, including two (2) amphibian, one (1) aquatic reptile, and eight (8) fish species (Tables 4.3-3 and 4.3-4); 2) it contains designated critical habitat for listed anadromous salmonids (Chinook salmon, coho salmon, and steelhead) and tidewater goby (Table 4.3-1, Figures 4.3-1 and 4.3-2); 3) it supports native special-status species with a known or high likelihood of direct groundwater-dependence (six [6] ESA- and/or CESA-listed fish [Chinook and coho salmon, steelhead, Southern and Northern DPS green sturgeon, longfin smelt, and tidewater goby]) (Tables 4.3-3 and 4.3-4); and 4) it includes species and ecological communities that are highly or moderately vulnerable to changes in groundwater discharge or groundwater levels that could alter their distribution, species composition, and/or health (Rohde et al. 2018, 2019). The Intertidal Zone area also provides important habitat for other special-status semi-aquatic species, including, but not limited to, western snowy plover, black tern, and bald eagle.

Terrestrial

The Intertidal Zone and Tributaries GDE Unit was determined to have high ecological value for terrestrial groundwater-dependent species and habitat because: 1) It supports four (4) special-status plant species in marsh and riparian groundwater-dependent habitats, multiple sensitive natural riparian communities, and 12 special-status bird species (Tables 4.3-2 and 4.3-3); 2) it contains designated critical habitat for one (1) listed bird species (western snowy plover) (Table 4.3-1, Figure 4.3-1); 3) it supports native special-status wildlife species with a known or high likelihood of groundwater dependence (six [6] ESA- and/or CESA-listed bird species [bald eagle, bank swallow, tricolored blackbird, western snowy plover, willow flycatcher, and western yellow-billed cuckoo]) (Table 4.3-3); and 4) it includes species and ecological communities that are highly or moderately vulnerable to changes in groundwater discharge or groundwater levels that could alter their distribution, species composition, and/or health (Rohde et al. 2018, 2019).

Ecological condition

The ecological condition for the Intertidal Zone and Tributaries GDE Unit is good. Additionally:

- NDVI suggests that vegetation in mapped GDEs is relatively robust, and the GDE unit's general health (as indicated by NDVI) has been increasing over the past few decades.
- Habitat suitability for special-status species (e.g., yellow-headed blackbird) and the habitat condition of sensitive natural communities in floodplain grassland areas of the unit may be compromised by the presence of reed canary grass, which forms dense monotypic stands that reduces botanical and biological diversity.
- Suitable habitat is present for those special-status species with likelihood to occur in the unit.
- Groundwater contributes to the ecological function and habitat value of the Intertidal Zone and Tributaries GDE Unit, which supports native aquatic and terrestrial species and beneficial uses in and adjacent to the unit.

Susceptibility to changing groundwater conditions

The Intertidal Zone and Tributaries GDE Unit's susceptibility to changing groundwater conditions is uncertain. Additionally:

- Shallow groundwater conditions have remained stable since 1990.
- The rooting depth of dominant species in this unit included willows that ranged from a minimum of 1 ft to a maximum of 6.9 ft, black cottonwood from 2.5 ft to 16 ft, and red alder from 2.5 ft to 13.1 ft, whereas shallow groundwater depth varied in this unit from 2 to 7 ft bgs, 14-22 ft bgs, and 4-11 ft bgs, respectively, for each of the three vegetation types. Future changes will be explored once the model results are available.
- Tidal influence may extend further inland due to sea level rise, causing a shift in dominant vegetation stands with lower salinity tolerances toward species assemblages with greater salt tolerance.
- Future changes in groundwater conditions in the unit related to increased groundwater pumping, reduced inflows to the basin, or climate change could cause groundwater levels to fall below the baseline range and result in mortality of the trees that comprise the GDE. Projections of climate change and groundwater pumping suggest that changes in groundwater elevation are unlikely.
- Due to daily tidally influenced water surface elevation changes, aquatic habitat within the mainstem Eel River in this unit may be minimally affected by groundwater management. The assessment of interconnected surface water is dependent upon the groundwater model. The effect of groundwater management on surface water in this unit will be included in the final GSP.

Potential for effects

Given the relative stability of the vegetation health as indicated by NDVI, current pumping levels are unlikely to impact terrestrial GDEs. The major potential for effects in this unit is saltwater intrusion associated with sea level rise. The degree to which intrusion could be exacerbated by pumping is unknown, but will be assessed using the groundwater model. The effect of pumping on aquatic GDEs is unknown, although passage issues for anadromous salmonids occur upstream of this unit. Saltwater intrusion could potentially increase salinity in freshwater waterbodies, which could reduce available habitat and reproductive success for amphibian species. Habitat for snowy plover on the bars of the Intertidal Zone and Tributaries GDE Unit may also be impacted by sea level rise, but the degree to which sedimentation will compensate is unknown.

5.4.2 Middle Eel River

The Middle Eel River GDE Unit contains 28% of the total GDE acreage in the ERVB (Table 3.3-1). The mainstem Middle Eel River is interconnected with groundwater for most of this reach. Groundwater is relatively shallow and is within 15 ft of the ground surface. The Middle Eel River GDE Unit contains barriers to anadromous fish passage prior to the first storm flows in the fall.

Groundwater-dependence

Both the terrestrial and aquatic species and habitats in the Middle Eel River GDE Unit are likely connected to groundwater. Additionally:

- Shallow groundwater elevations in the limited long-term well data have remained stable since 1990. Groundwater levels in wells installed in 2016 show no systematic changes over a limited period of record. Groundwater elevations are within the rooting depth of dominant species within the GDE unit.
- This GDE unit is mostly composed of red alder stands. Other riparian stands dominated by willow and black cottonwood are also notable components of this unit. All are likely connected to groundwater.
- Perennial surface water flows are connected to groundwater. Losing conditions may occur in some reaches of the river during summer and fall. The degree to which losing conditions are due to groundwater pumping or sedimentation will be explored using the groundwater model.

Ecological value

Aquatic

The Middle Eel River GDE Unit was determined to have high ecological value for aquatic species and habitat because: 1) It supports many aquatic special-status species, including four (4) amphibian, one (1) aquatic reptile, and seven (7) fish species (Tables 4.3-3 and 4.3-4); 2) it contains designated critical habitat for listed anadromous salmonids (Chinook salmon, coho salmon, and steelhead) (Table 4.3-1 and Figure 4.3-2); 3) it supports native special-status species with a known or high likelihood of direct groundwater-dependence (five [5] ESA- and/or CESA-listed fish [Chinook and coho salmon, steelhead, Northern and possibly Southern DPS green sturgeon, and longfin smelt]) (Table 4.3-4); and 4) it includes species and ecological communities that are highly or moderately vulnerable to changes in groundwater discharge or groundwater levels that could alter their distribution, species composition, and/or health (Rohde et al. 2018, 2019).

Terrestrial

The Middle Eel River GDE Unit was determined to have high ecological value for terrestrial groundwater-dependent species and habitat because: 1) It supports six (6) special-status plant species in wetland, grassland, and riparian potentially groundwater-dependent habitat, multiple sensitive natural riparian communities, and 10 special-status bird species (Tables 4.3-2 and 4.3-3); 2) it contains designated critical habitat for two (2) listed bird species (western snowy plover and western yellow-billed cuckoo) (Table 4.3-1, Figure 4.3-1); 3) it supports native special-status wildlife species with a known or high likelihood of groundwater-dependence (six [6] ESA- and/or CESA-listed bird species [bald eagle, bank swallow, tricolored blackbird, western snowy plover, western yellow-billed cuckoo, and willow flycatcher]) (Table 4.3-1); and 4) it includes species and ecological communities that are highly or moderately vulnerable to changes in groundwater discharge or groundwater levels that could alter their distribution, species composition, and/or health (Rohde et al. 2018, 2019).

Ecological condition

The Middle Eel River GDE Unit has a good ecological condition. Additionally:

- NDVI is relatively stable and increased slightly through time.
- Suitable habitat is present for those special-status species with likelihood to occur in the unit.
- Fish passage through the reach typically begins during the first storm flows.
- Groundwater contributes to the ecological function and habitat value of the Middle Eel River, which supports native aquatic terrestrial species and beneficial uses in and adjacent to the unit.

Susceptibility to changing groundwater conditions

The Middle Eel River GDE Unit has an undetermined susceptibility to changing groundwater conditions. Additionally:

- Shallow groundwater conditions have remained stable since 1990 at long-term wells on the coastal plain.
- The rooting depth of red alder depends on soil characteristics and tree size. It has a spreading fibrous root system and remains shallow in poorly drained soils but can also root deeply if soil aeration is not limiting and in soils with good drainage (ranging from 2 to 13.1 ft deep [the reported maximum for the *Alnus* genus]) (Harrington 2006, TNC 2018). Other dominant species in this unit included willows (6.9 ft maximum rooting depth) and black cottonwood (16 ft maximum rooting depth). Shallow groundwater depth in long-term wells in this unit is between 10 and 30 ft bgs, which is within the rooting zone of some of the vegetation.
- The susceptibility of interconnected surface water in the reach to groundwater pumping is uncertain and will be explored with the groundwater model.
- Future changes in groundwater conditions in the unit related to increased groundwater pumping or climate change could cause groundwater levels to fall below the baseline range and result in mortality of the trees that comprise the GDE. Projections of climate change and groundwater pumping suggest that changes in groundwater elevation are unlikely.

Potential for effects

Given the relative stability of the vegetation health as indicated by NDVI, current pumping levels are unlikely to impact terrestrial GDEs. The effect of pumping on aquatic GDEs and critical riffle conditions is unknown and will be investigated in using the groundwater model. Tidal influence may move upstream into this reach as sea levels rise. The degree to which sedimentation will compensate for sea level rise is unknown. Saltwater intrusion could potentially increase salinity in freshwater waterbodies, which could reduce available habitat and reproductive success for amphibian species and potentially cause a shift in adjacent vegetation towards more salt-tolerant species.

5.4.3 Upper Eel River

The Upper Eel River GDE Unit contains 8% of the total GDE acreage in the ERVB (Table 3.3-1). The reach of the Upper Eel River is considered perennial and is typically connected to groundwater.

Groundwater-dependence

The Upper Eel River GDE Unit is likely dependent on groundwater. Additionally:

- There is no shallow groundwater data available in the Upper Eel GDE Unit to verify groundwater levels.
- This GDE unit is mostly composed of red alder stands. Other dominant vegetation includes stands of naturalized grassland, redwood, willow, and black cottonwood. These stands are all likely connected to groundwater.

Perennial surface water flows are connected to groundwater in places within the mainstem Eel River and Price, Howe, Barber, and Oil creeks. However, surface flow connection at the mouths of these creeks with the Eel River varies depending on location of gravel bars, secondary channels, and other geomorphic features. The extent of the interconnection with groundwater and the effect of groundwater management on interconnected surface water will be evaluated using the groundwater model. The effect of groundwater management on surface water in this unit will be included in the final GSP.

Ecological value

Aquatic

The Upper Eel River GDE Unit was determined to have high ecological value for aquatic species and habitat because: 1) It supports many aquatic special-status species, including one (1) mollusk, three (3) amphibian, one (1) aquatic reptile, and five (5) fish species (Tables 4.3-3 and 4.3-4); 2) it contains designated critical habitat for listed anadromous salmonids (Chinook salmon, coho salmon, and steelhead) (Table 4.3-1 and Figure 4.3-2); 3) it supports native special-status species with a known or high likelihood of direct groundwater-dependence (four [4] ESA- and/or CESA-listed fish [Chinook and coho salmon, steelhead, and Northern DPS green sturgeon]) (Table. 4.3-4); and 4) it includes species and ecological communities that are highly or moderately vulnerable to changes in groundwater discharge or groundwater levels that could alter their distribution, species composition, and/or health (Rohde et al. 2018, 2019).

Terrestrial

The Upper Eel River GDE Unit was determined to have high ecological value for terrestrial groundwater-dependent species and habitat because: 1) It supports five (5) special-status plant species in wetland, grassland, and riparian potentially groundwater-dependent habitat, multiple sensitive natural riparian communities, and four (4) special-status bird species (Tables 4.3-2 and 4.3-3); 2) it contains designated critical habitat for one (1) listed bird species (western snowy plover) (Table 4.3-1, Figure 4.3-1); 3) it supports native special-status wildlife species with a known or high likelihood of groundwater-dependence (three [3] ESA- and/or CESA-listed bird species [bald eagle, western snowy plover, and willow flycatcher]) (Table 4.3-3); and 4) it includes species and ecological communities that are highly or moderately vulnerable to changes in groundwater discharge or groundwater levels that could alter their distribution, species composition, and/or health (Rohde et al. 2018, 2019).

Ecological condition

The ecological condition for the Upper Eel River GDE Unit is good. Additionally:

- NDVI values have remained stable through time.
- Suitable habitat is present for those special-status species with likelihood to occur in the unit.
- Groundwater contributes to the ecological function and habitat value of the Upper Eel River, which supports native aquatic and terrestrial species and beneficial uses in and adjacent to the unit.

Susceptibility to changing groundwater conditions

The susceptibility of the Upper Eel River GDE Unit to changing groundwater conditions is uncertain. Additionally:

- Shallow groundwater conditions have remained stable since 1990.
- The rooting depth of red alder ranges from 2.5 ft to 13.1 ft. Other dominant species in this unit have the following reported maximum rooting depths (Appendix A): naturalized grasses (2 to 5 ft), redwood (8.5 to 16.4 ft), willows (6.9 ft), and black cottonwood (16 ft). No shallow groundwater depth was available for this unit. The groundwater model will be used to evaluate the DTW relative to rooting depth beneath the mapped GDEs.
- Future changes in groundwater conditions in the unit related to increased groundwater pumping or climate change could cause groundwater levels to fall below the baseline range and result in mortality of the trees that comprise the GDE. Projections of climate change and groundwater pumping suggest that changes in groundwater elevation are unlikely.

Potential for effects

Given the relative stability of the vegetation health as indicated by NDVI, current pumping levels are unlikely to impact mapped terrestrial GDEs. The effect of pumping on aquatic GDEs is unknown and will be investigated with the groundwater model.

5.4.4 Van Duzen River and Tributaries

The Van Duzen River and Tributaries GDE Unit contains 21% of the total GDE acreage in the ERVB (Table 3.3-1). The Van Duzen River in this unit is generally connected to groundwater, but has losing reaches, particularly at its downstream end.

Groundwater-dependence

The Van Duzen River and Tributaries GDE Unit is likely dependent on groundwater, but the groundwater-dependence is somewhat uncertain due to a paucity of groundwater wells. Additionally:

- Groundwater levels in wells installed in 2016 show no systematic changes over a limited period of record. Groundwater elevations are within the rooting depth of dominant species within the GDE.
- This GDE unit is composed of stands of redwood, naturalized grassland, red alder, and willow that are associated with channel floodplain and floodplain steps. These stands are all likely connected to groundwater.

- Perennial surface water flows in the Van Duzen River and Yager Creek are connected to groundwater, at least in some reaches. The assessment of interconnected surface water is dependent upon the groundwater model. The effect of groundwater management on surface water in this unit will be included in the final GSP.
- The dry reach at the mouth of the Van Duzen River that is present during the late summer and early fall may be caused more by sediment deposition in the delta than to groundwater use.

Ecological value

Aquatic

The Van Duzen River and Tributaries GDE Unit was determined to have *high ecological value* for aquatic species and habitat because: 1) It supports many aquatic special-status species, including four (4) amphibian, one (1) aquatic reptile, and four (4) fish species (Tables 4.3-3 and 4.3-4); 2) it contains designated critical habitat for listed anadromous salmonids (Chinook salmon, coho salmon, and steelhead) (Table 4.3-1 and Figure 4.3-3); 3) it supports native special-status species with a known or high likelihood of direct groundwater-dependence (three ESA- and/or CESA-listed fish [Chinook and coho salmon and steelhead]) (Table 4.3-4); and 4) it includes species and ecological communities that are highly or moderately vulnerable to changes in groundwater discharge or groundwater levels that could alter their distribution, species composition, and/or health (Rohde et al. 2018, 2019).

Terrestrial

The Van Duzen River and Tributaries GDE Unit was determined to have *high ecological value* for terrestrial groundwater-dependent species and habitat because: 1) It supports 12 special-status plant species in wetland, grassland, and riparian potentially groundwater dependent habitat, multiple sensitive natural riparian communities, seven (7) special-status bird species, and one (1) special-status mammal species (Tables 4.3-2 and 4.3-3); 2) it contains designated critical habitat for two (2) listed bird species (western snowy plover and marbled murrelet) (Table 4.3-1, Figure 4.3-1); 3) it supports native special-status wildlife species with a known or high likelihood of groundwater-dependence (five [5] ESA- and/or CESA-listed bird species [bald eagle, bank swallow, marbled murrelet, western snowy plover, and willow flycatcher]) (Table 4.3-3); and 4) it includes species and ecological communities that are highly or moderately vulnerable to changes in groundwater discharge or groundwater levels that could alter their distribution, species composition, and/or health (Rohde et al. 2018, 2019).

Ecological condition

The Van Duzen River and Tributaries GDE Unit is in a good ecological condition. Additionally:

- The NDVI values were relatively stable and increased slightly with time.
- Suitable habitat is present for those special-status species with likelihood to occur in the unit.
- Groundwater contributes to the ecological function and habitat value of the Van Duzen River and Tributaries GDE Unit, which supports aquatic and terrestrial species and beneficial uses in and adjacent to the unit.

Susceptibility to changing groundwater conditions

The Van Duzen River and Tributaries GDE Unit's susceptibility to changing groundwater conditions is unknown. Additionally:

- There are no long-term groundwater wells in this unit. One (1) well installed in 2016 has very shallow groundwater, but the variation in groundwater depth in this unit is unknown.
- The reported maximum rooting depth of redwood ranges from 8.5 to 16.4 ft, while that of local grassland species ranges from 2 to 5 ft. Maximum rooting depths for other dominant species in this unit include 7.9 ft for Douglas-fir, 6.9 ft for willows, and 13.1 ft for red alder. The modeled depth to groundwater under the GDEs will be explored when the model is available.
- Future changes in groundwater conditions in the unit related to increased groundwater pumping or climate change could cause groundwater levels to fall below the baseline range and result in mortality of the trees that comprise the GDE. However, projections of climate change and groundwater pumping suggest that changes in groundwater elevation are unlikely.

Potential for effects

Given the relative stability of the vegetation health as indicated by NDVI, current pumping levels are unlikely to impact terrestrial GDEs. The effect of pumping on aquatic GDEs, particularly the dry reach near the confluence with the Eel River, is unknown and will be investigated using the groundwater model. The model results will help to determine the relative importance of sedimentation and groundwater pumping on this dry reach at the mouth of the Van Duzen River. In the event of a change in the water balance in the reach due to increased upstream water withdrawals or climate change, the extent of the dry reach could change, impacting aquatic GDEs.

6 SUSTAINABLE MANAGEMENT CRITERIA AND PROJECTS AND MANAGEMENT ACTIONS

Sustainable management criteria (SMCs), projects and management actions, and monitoring will be addressed in the final GSP. GDEs will be considered as part of the development of SMCs and Projects and Management Actions.

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Appendices

Appendix A

Special-status Terrestrial and Aquatic Wildlife Species Identified in Database Queries but Determined to Have No Reliance on Groundwater Dependent Ecosystem Units

Table. A-1. Special-status terrestrial and aquatic wildlife species identified in database queries that are not groundwater-dependent and/or unlikely to occur in the ERVB GDE units

Common name *Scientific name*	**Status[1] federal/State**	**Potential to occur in ERVB[2]**	**Documented occurrences in GDE units**	**Query source[3]**	**GDE association[4]**	**Habitat and documented occurrences in ERVB**
Insect						
Western bumble bee *Bombus occidentalis*	–/SCE	Likely	Middle Eel River	CNDDB	No known reliance on groundwater	Uses flowering plants in meadows and forested openings; abandoned rodent burrows are used for nest and hibernation sites for queens; present in groundwater basin. Observed in Rio Dell along the Eel River (CDFW 2020)
Birds						
Black swift *Cypseloides niger*	–/SSC	Likely	Intertidal Zone and Tributaries	CAFSD, eBird	No known reliance on groundwater	Nests in moist crevices behind or beside permanent or semipermanent waterfalls in deep canyons, on perpendicular sea cliffs above surf, and in sea caves; forages widely for insects over many habitats; observed sporadically in the Lower Eel River groundwater basin (eBird 2021)
Grasshopper sparrow *Ammodramus savannarum*	–/SSC	Likely	Middle Eel River	CNDDB	No known reliance on groundwater	Typically found in moderately open grasslands with scattered shrubs; observed in the pastures south of Fernbridge (CDFW 2020)
Mountain plover *Charadrius montanus*	FPT, BLMS/SSC	None	Intertidal Zone and Tributaries	CNDDB, eBird	No known reliance on groundwater	Occupies open plains or rolling hills with short grasses or very sparse vegetation; nearby bodies of water are not needed; may use newly plowed or sprouting grain fields; preys on insects; isolated record in Eel River. Winter resident (eBird 2021); does not breed in California

Common name ***Scientific name***	**Status[1] federal/State**	**Potential to occur in ERVB[2]**	**Documented occurrences in GDE units**	**Query source[3]**	**GDE association[4]**	**Habitat and documented occurrences in ERVB**
Yellow rail *Coturnicops noveboracensis*	–/SSC	None	None	CNDDB	Indirect	Marshes, often next to sedges; feeds on invertebrates in wetlands (e.g., aquatic insects and mollusks) (CDFW 2020)
Mammal						
Humboldt marten *Martes caurina humboldtensis*	–/SE	None	Van Duzen and Tributaries	CNDDB	No known reliance on groundwater	Mid- to advanced-successional stands of conifers with complex structure near the ground and dense canopy closure; observed in 1913 in forestland adjacent to Carlotta (CDFW 2020); no habitat present in the ERVB
Pallid bat *Antrozous pallidus*	BLMS/SSC	Possible	Middle Eel River	CNDDB	No known reliance on groundwater	Roosts in rock crevices, tree hollows, mines, caves, and a variety of vacant and occupied buildings; feeds in a variety of open woodland habitats; Habitat and prey (e.g., insects and arachnids) not associated with aquatic ecosystems; Last recorded observation in 1924 in Ferndale (CDFW 2020)

Common name ***Scientific name***	**Status[1] federal/State**	**Potential to occur in ERVB[2]**	**Documented occurrences in GDE units**	**Query source[3]**	**GDE association[4]**	**Habitat and documented occurrences in ERVB**
Sonoma tree vole *Arborimus pomo*	–/SSC	Likely	Intertidal Zone and Tributaries, Middle Eel River, Van Duzen and Tributaries, Upper Eel River	CNDDB	No known reliance on groundwater	Occupies primarily mid- to late-successional conifer stands with a high component of Douglas-fir; present in conifer forests in the hillslopes surrounding the Lower ERVB (CDFW 2020)

[1] Status codes
Federal
FPT = Proposed as threatened under the federal ESA
BLMS = Bureau of Land Management Sensitive Species

State
SE = Listed as Endangered under CESA
SSC = CDFW species of special concern

[2] Potential to Occur:
Likely: the species has documented occurrences and the habitat is high quality or quantity
Possible: no documented occurrences and the species' required habitat is moderate to high quality or quantity
Unlikely: no documented occurrences and the species' required habitat is of low to moderate quality or quantity
None: no potential to occur due to lack of habitat and/or the population is assumed extirpated

[3] Query source:
CAFSD: California Freshwater Species Database (TNC 2020)
CNDDB: California Natural Diversity Database (CDFW 2020)
eBird: (eBird 2021)

[4] Groundwater Dependent Ecosystem (GDE) association:
Direct: Species directly dependent on groundwater for some or all water needs
Indirect: Species dependent upon other species that rely on groundwater for some or all water needs

Appendix B

Vegetation Communities, Associated Alliances and Characteristics

Table B-1. Maximum rooting depth of dominant species.

Cover Type[1]	Associated Alliance[2]	Dominant species	Minimum rooting depth (in)[3]	Maximum rooting depth (ft)[4]	Season with water needs[5]	Salt Tolerance[6]
Annual/Perennial Grasses and Forbs	Phalaris aquatica - Phalaris arundinacea Herbaceous Semi-Natural Alliance Holcus lanatus - Anthoxanthum odoratum Herbaceous Semi-Natural Alliance Poa pratensis - Agrostis gigantea - Agrostis stolonifera Herbaceous Semi-Natural Alliance Lolium perenne Herbaceous Semi-Natural Alliance	Phalaris arundinacea Holcus lanatus Agrostis stolonifera Poa pratensis Festuca perennis	14 4 12 10 10	4.6 - 2.3 4.2 3.8	Spring–Fall Spring Spring–Summer Spring–Fall Spring and Fall	Mild (<4 dS m-1) High (8-12 dS m-1)
Black Cottonwood	Populus trichocarpa Forest & Woodland Alliance	Populus trichocarpa	30	10–16.0	Spring–Summer	Mild (<4 dS m-1)
California Bay	Umbellularia californica Forest & Woodland Alliance	Umbellularia californica	16	3	Spring–Fall	Mild (<4 dS m-1)
Coastal Mixed Hardwood	Umbellularia californica Forest & Woodland Alliance	Umbellularia californica	16	3	Spring–Fall	Mild (<4 dS m-1)
	Acer macrophyllum Forest & Woodland Alliance	Acer macrophyllum	24	5.7	Spring and Summer (April)	Mild (<4 dS m-1)
	Quercus garryana (tree) Forest & Woodland Alliance	Quercus garryana	42	6.7	Spring and Summer	Mild (<4 dS m-1)

Cover Type[1]	Associated Alliance[2]	Dominant species	Minimum rooting depth (in)[3]	Maximum rooting depth (ft)[4]	Season with water needs[5]	Salt Tolerance[6]
Red Alder	Alnus rubra Forest Alliance	Alnus rubra	25	13.12[7]	Spring-Fall	Mild (<4 dS m-1)
Redwood	Sequoia sempervirens Forest & Woodland Alliance	Sequoia sempervirens	40	8.5–16.4	Spring and Summer	Mild (<4 dS m-1)
Redwood - Douglas-Fir	Sequoia sempervirens Forest & Woodland Alliance	Sequoia sempervirens	40	8.5–16.4	Spring and Summer	Mild (<4 dS m-1)
		Pseudotsuga menziesii	26	7.87	Spring and Summer	Mild (<4 dS m-1)
Riparian Mixed Hardwood	Alnus rubra Forest Alliance	Alnus rubra	24	13.12	Spring–Fall	Mild (<4 dS m-1)
	Acer macrophyllum Forest & Woodland Alliance	Acer macrophyllum	24	5.7	Spring and Summer	Mild (<4 dS m-1)
River/Stream/Canal	N/A	Typha latifolia Eleocharis macrostachya Bolboschoenus maritimus Distichlis spicata	14 14 12	No data available	Spring and Summer Spring Summer	Very High (> 12 dS m-1) Very High (> 12 dS m-1) Very High (> 12 dS m-1) Very High (> 12 dS m-1)
Sitka Spruce	Picea sitchensis Forest & Woodland Alliance	Picea sitchensis	30	6.5	Spring and Summer	Mild (<4 dS m-1)

Cover Type[1]	Associated Alliance[2]	Dominant species	Minimum rooting depth (in)[3]	Maximum rooting depth (ft)[4]	Season with water needs[5]	Salt Tolerance[6]
Willow	**Salix lucida ssp. lasiandra Forest & Woodland Alliance** Salix sitchensis Provisional Shrubland Alliance Salix lasiolepis Shrubland Alliance Salix hookeriana Shrubland Alliance	**Salix lasiandra (lucida)**	36	6.9[7]	Spring and Summer	Mild (<4 dS m-1)
		Salix sitchensis	24	6.9[7]	Spring and Summer	Mild (<4 dS m-1)
		Salix lasiolepis	26	6.9[7]	Spring and Summer	Mild (<4 dS m-1)
		Salix hookeriana	20	6.9[7]	Spring and Summer	Mild (<4 dS m-1)
Willow (Shrub)	**Salix exigua Shrubland Alliance** Salix lasiolepis Shrubland Alliance Salix hookeriana Shrubland Alliance Salix sitchensis Provisional Shrubland Alliance	Salix exigua	20	6.9[7]	Spring and Summer	Mild (<4 dS m-1)
		Salix melanopsis	see *S. exigua*	*6.9*[7]		
		Salix scouleriana	12	6.9[7]	Spring and Summer	Mild (<4 dS m-1)
		Other willows	20–26	6.9[7]	Spring and Summer	Mild (<4 dS m-1)
Intermittent Lake or Pond	N/A No vegetation associated with this cover type					
Perennial Lake or Pond	N/A No vegetation associated with this cover type					
Pickleweed - Cordgrass	Sarcocornia pacifica (Salicornia depressa) Herbaceous Alliance Spartina (alterniflora, densiflora) Herbaceous Semi-Natural Alliance	N/A not determined to be a GDE Habitat				

1 Based on cover types describe in the CalVeg regional data set (USDA 2014)
2 *Manual of California Vegetation*, online edition (CNPS 2021)
3 Minimum rooting depth as noted in the USDA Plants Database (2021)
4 Maximum rooting depth sources: Fann et al. 2017, Burns and Honkala 1990, TNC 2018, *Fire Effects Information System* (online database)
5 Months with water needs is based on the reported active growth period provided in USDA Plants Database (2021)
6 Salinity tolerance based on NRCS eVegGuide reported salt tolerances.
7 Rooting depth assigned by genus or close species association.

Appendix C

Special-status Fish

The text below adapts the Critical Species Lookbook (Rohde et al. 2019) for fish species found the ERVB. Note: The *italicized text* presented below in the reliance on groundwater and groundwater-related threats sections for each species are direct quotes from Rohde et al. (2019).

California Coast EST Chinook salmon (*Oncorhynchus tshawytscha*)
Status: Federally threatened
Reliance on groundwater: *Direct. Chinook salmon are reliant on groundwater-fed rivers to provide adequate water quality, temperature, and volume for upstream migration in the fall before rainfall elevates river flows, as well as for spawning and freshwater residency.*
Habitat: Chinook salmon in the Eel River spend a relatively short time in fresh water as juveniles before heading to estuaries or marine environments for the bulk of this phase of their lives. Adult Chinook spawn in larger rivers and streams, where they require sufficient flows for migration and largely sediment-free gravel for spawning. Juveniles need areas of refuge from high water velocities during the wet season (e.g., floodplains, backwaters, etc.). Water quality, including temperature and dissolved oxygen, is important for juveniles living in estuaries.
Groundwater-Related Threats: *Groundwater pumping can have an adverse impact on the survival of this species by depleting surface water flows for upstream migration, impeding migration by disconnecting groundwater and surface water, destabilizing water temperatures by decreasing baseflow at spawning sites, and reducing riparian habitat.*
Presence in the Eel River Valley groundwater basin: Chinook salmon in the Eel River are primarily fall-run, although a small number of spring-run fish do spawn and rear in the Middle Fork Eel River. They can be found in the Eel River Valley during the fall adult upstream migration, early juvenile rearing, and spring downstream smolt migration periods. Fall-run juvenile Chinook salmon generally do not rear in freshwater during the summer and fall. Spring-run juveniles will rear for a year prior to migrating downstream to the estuary and the ocean.

SONCC ESU Coho salmon (*Oncorhynchus kisutch*)
Status: Federally threatened
Reliance on groundwater: *Direct. Coho salmon are reliant on groundwater-fed rivers to provide adequate water quality, temperature, and volume for upstream migration in the fall before rainfall elevates river flows, as well as for spawning and freshwater residency. Juveniles can rear in mainstem rivers but are dependent on locations that contain cold water tributary inflow, bank seeps, or subsurface flow upwelling. Backwater alcoves with stratified water temperatures also provide habitat during the warm summer months.*
Habitat: Juveniles spend one year in freshwater prior to migrating to the estuary and ocean during the spring. Juveniles require deep pools with cool water temperatures, slow water velocities, and abundant instream cover during their rearing phase. Juveniles are associated with native riparian vegetation that provides instream cover and food resources from insect drop. Adult coho salmon return to freshwater to spawn in the fall of their third year. They primarily spawn in tributaries to rivers but would spawn in larger rivers during drought years when tributary flows are low. However, mainstem rivers typically do not provide suitable habitat for rearing juveniles.
Groundwater-Related Threats: *Groundwater conditions that alter groundwater baseflow into rivers can negatively affect coho salmon habitat. Juvenile salmonids generally require cold, clear, well-oxygenated water and adequate streamflow volume during their time in fresh water. Adult salmon similarly require adequate water quality and volume during their upstream migration. Groundwater pumping can have a negative impact on instream habitat by depleting streamflow volume and interrupting the influx of cold groundwater into the stream environment.*
Presence in the Eel River Valley groundwater basin: Mainstem Eel and Van Duzen rivers are primarily used for migration only. Juveniles have been found in Price Creek, Williams Creek, Francis Creek, Howe Creek, and Yager Creek tributaries.

Northern California Coast Steelhead (*Oncorhynchus mykiss*)
Status: Federally threatened
Reliance on groundwater: *Direct. Steelhead are reliant on rivers and streams that are likely supported by groundwater.*
Habitat: While steelhead are generally more adaptable to habitat extremes than either coho or Chinook salmon, they nevertheless require cold water and complex instream habitat during their freshwater juvenile residency, which generally lasts at least one year, including at least one dry season. Estuaries can provide important rearing habitat for steelhead, with opportunities for rapid growth prior to entering the marine environment. For spawning, all adult salmonids require sufficient flow and suitably cool water temperature for upstream migration to spawning grounds and streambeds with clean gravel, free of excessive fine sediment deposition, to spawn in. Some adult steelhead will survive to spawn a second or third time; thus, adequate streamflows are required for post-spawn adult steelhead to migrate downstream during spring.
Groundwater-Related Threats: *Groundwater conditions that alter instream flow and water quality can have an adverse impact on steelhead habitat conditions. Juvenile steelhead generally require cold, clear, well oxygenated water and adequate streamflow volume while residing in freshwater. Adult steelhead also require adequate water quality and instream flows during their upstream and downstream migration, which can be limited by streamflow depletion. However, adult steelhead typically conduct upstream migrations in the winter and spring when streamflow are usually adequate. Cold groundwater inputs can provide local areas of water temperature refugia in which rearing juvenile steelhead are less susceptible to stress or mortality that can otherwise result from elevated water temperatures during warm, dry months when streamflows are typically lowest. Groundwater pumping can affect instream habitat particularly in the summer by depleting streamflow volume and interrupting the influx of cold groundwater into the stream.*
Presence in the Eel River Valley groundwater basin: mainstem Eel and Van Duzen rivers and tributaries

Longfin smelt (*Spirinchus thaleichthys*)
Status: State threatened
Reliance on groundwater: *Direct. These fish rely directly on groundwater discharge that supports estuarine wetlands and sloughs used by the species for spawning, feeding and rearing.*
Habitat: These smelt depend on a diverse range of habitats, including offshore areas, coastal lagoons, bays, estuaries, sloughs, and freshwater rivers and streams. Longfin smelt are euryhaline and able to tolerate a variety of salinity in their habitats, from completely freshwater to marine. Spawning occurs preferentially in freshwater and areas of low salinity.
Groundwater-related threats: *Longfin smelt have a low tolerance for warm waters. Water diversion and drought may lead to increased water temperatures. Groundwater management that decreases groundwater discharge to estuaries can negatively impact temperature and salinity conditions important to this species' spawning, rearing, and survival.*
Presence in the Eel River Valley groundwater basin: Longfin smelt have not been recorded in the Eel River basin since 1995. The last recorded sighting was in the estuary downstream of Fernbridge in 1995. Prior to that a sighting was recorded near the mouth of the Van Duzen River in 1956.

Tidewater goby (*Eucyclogobius newberryi*)
Status: Federal endangered
Reliance on groundwater: *Direct. Tidewater gobies rely on surface waters in coastal areas that are likely to be supported by groundwater discharge.*
Habitat: These fish live in lagoons and estuaries with submerged and emergent aquatic vegetation that can provide protection from predators and flooding. They also occupy locations characterized by muted tidal flow in areas subject to tides. They can also be found in backwater marshes and freshwater tributaries to estuarine environments. Their food sources include macroinvertebrates (e.g., amphipods, aquatic insects).
Groundwater-related threats: *Groundwater conditions that alter surface water flows in coastal lagoons and estuaries can have a negative impact on the species' breeding and foraging activities.*

Presence in the Eel River Valley groundwater basin: Gobies are present in the sloughs of the Eel River delta. They are not present upstream of Fernbridge.

Pacific lamprey (*Entosphenus tridentatus*)
Status: California species of special concern
Reliance on groundwater: *Direct. This species relies on surface water flows that may be supported by groundwater.*
Habitat: Spawning typically takes place from March through July depending on water temperature and local conditions such as seasonal flow regimes. Spawning occurs both in the mainstem of medium-sized rivers and smaller tributaries and generally takes place in pool and run tailouts and low-gradient riffles. Both males and females build nests (redds), which are approximately 40 x 40 cm in area and constructed in gravel and cobble substrate. After about 30 days, the larvae emerge from the gravel and begin drifting downstream. The eyeless larvae, known as ammocoetes, settle out of the water column and burrow into fine silt and sand substrate in low-velocity, depositional areas such as pools, alcoves, and side channels where they may spend between 4 and 10 years prior to migrating to the ocean. They reside in the ocean for approximately 18–40 months before returning to freshwater.
Groundwater-related threats: *Groundwater conditions that either temporarily or permanently alter surface water flows can have a negative impact on the spawning and rearing capabilities of this fish and decrease its population.*
Presence in the Eel River Valley groundwater basin: The Eel River Valley groundwater 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.

Green sturgeon (*Acipenser medirostris*)
Status: Southern DPS — Federal threatened; Northern DPS — Federal species of concern; State species of special concern; Designated critical habitat
Reliance on groundwater: *Direct. This species relies on surface water flows that may be supported by groundwater.*
Habitat: This anadromous species spends most of its life at sea but returns to freshwater to spawn. Young fish may remain in these freshwater environments for up to two years. Adults spawn in fast, deep water during the first half of the year. Post-spawn adults then move back down the river during the fall and re-enter the ocean.
Groundwater-related threats: *Groundwater conditions that either temporarily or permanently alter surface water flows can have a negative impact on the spawning capabilities of this fish and decrease its population. However, spawning does not occur in the Lower Eel River Groundwater Basin.*
Presence in the Eel River Valley groundwater basin:
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. Finally, Northern DPS sturgeon are presumed to spawn in the upper mainstem Eel River, based on observations at Fort Seward, approximately 80 miles upstream of the Lower Eel River Groundwater Basin. The Southern DPS spawn in the Sacramento River.

Hydrogeologic Conceptual Model Technical Memorandum (TM-4)

Hydrogeologic Conceptual Model for the Eel River Valley Basin

Prepared for: Eel River Valley Groundwater Basin GSP, 2021

Humboldt County Department of Public Works

August 18, 2021

PREPARED BY: GHD, Inc., 718 3rd Street, Eureka, CA 95501

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Appendices

1. Hydrogeologic Conceptual Model

1.1 Overview

Descriptive hydrogeologic conceptual models (HCM), based on technical studies and qualified maps (23 CCR § 354.14), are required in Groundwater Sustainability Plans (GSP) 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 technical memorandum provides a summary, for public review, of the preliminary HCM for the Eel River Valley basin (ERVB), for inclusion in and prior to completion of the Eel River Valley GSP.

Within the ERVB (Figure 1), only a handful of studies have focused on the hydrogeologic conditions of the basin. The understanding of the ERVB 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 Sustainable Groundwater Management Act (SGMA), including the Alternative Plan (2016). New data collection and analysis, along with the development of numerical modeling, is underway and will offer a significant improvement to this current understanding. (Data gaps and important uncertainties relative to the preliminary HCM are discussed in Section 1.9.)

1.2 Geologic Setting

The ERVB is located in a structurally controlled valley within a complex geologic setting, approximately 20 miles north of the Mendocino Triple Junction, where three (3) crustal plates (Gorda, North American, and Pacific plates; see Figure 2) intersect. 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 90-kilometer (km) wide fold-and-thrust belt 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 3 and Figure 4). The folding affects a series of sedimentary units from the Plio-Pleistocene period referred to as the “Wildcat Group,” as shown on geologic cross-sections in Figure 4. 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 both mapping and unit descriptions focused on the Eel River Valley area. More recent work by McLaughlin and others (2000) has led to mapping of the broader northern coastal California. The current boundary of the ERVB 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.

1.2.1 Basin Stratigraphy

Upstream of the Eel River Valley, the Eel and Van Duzen rivers flow in narrow bedrock canyons that empty into the valley at Rio Dell and Alton, respectively. Fluvially-derived alluvium within the valley includes a wide variety of materials, ranging from coarse gravels near active stream channels to fine-grained flood deposits (silts, clays) in floodplain settings far removed from the active channels. Figures 5, 6, and 7 (modified from SHN 2016) show shallow geologic cross-sections highlighting the stratigraphy within the ERVB. The installation, recently completed, of new monitoring wells at 19 locations throughout the ERVB will provide additional stratigraphic resolution. Cross-sections will be amended to include recently installed wells along the alignment and are currently being cross-referenced with the California Department of Water Resources' (DWR) online well completion database. Long-term regional uplift has resulted in the formation of a series of terraces along the valley margins.

1.2.2 Basin Alluvium

Overlying the Wildcat Group in the Eel River Valley is alluvium consisting of gravel, sand, and silt (Ogle 1953). The sediment-rich Eel River and its tributaries flow into the Eel River syncline, depositing a thick section of unconsolidated alluvium over the downwarped Wildcat Group. This accumulation of alluvium, up to 200 feet (ft) thick, consists of a variety of materials, tending to be coarser (sands, gravels) in near proximity to the active river channel and finer (silts, clays) beneath the extensive floodplain upon which agriculture and grazing occur. Evenson (1959) identified an area in the southwest part of the Eel River Valley dominated by fine sediments derived from periodic Eel River floods, as well as fine material washed down from the Wildcat Range upland areas bordering the south side of the ERVB.

1.2.3 Terrace Deposits

Terrace deposits are primarily located near the communities of Fortuna, Rohnerville, and Hydesville, along the Eel and Van Duzen river valleys at elevations ranging between 400 to 600 ft above sea level (Ogle 1953; Dibblee 2008). The most prominent terrace surfaces occur along the northern side of the ERVB, including terraces in Hydesville in the Van Duzen River Valley and the Rohnerville Formation surface (Ogle 1953). The terrace deposits are planar surfaces bounded by mountainous terrain to the north. The Carlotta formation underlies the terrace deposits.

The uplifted terrace deposits and Rohnerville Formation primarily comprise poorly sorted alluvial gravel and sand with small amounts of sandy clay and pebbly clay. Ogle describes the Rohnerville Formation deposits as primarily poorly sorted gravel with lesser amounts of sand, silt, and clay. Boulders up to 1 ft in diameter are common. The terrace sediments have a typical orange-brown or yellow-brown color. The upper few feet of the terrace deposit are made up of silt and clay and usually grades into 6 inches to 1 ft of dark soil (Ogle 1953). The deposits likely age to the Pleistocene with a maximum thickness of approximately 100 ft.

The upper surface of the Rohnerville Formation dips approximately 5 degrees north near Alton, flattens out near Strongs Creek, and dips 1 to 2 degrees south at Fortuna. Along the axis of the Eel River syncline, the surface has been subtly tectonically warped.

Terrace sediments form minor aquifers in the area, which are recharged by precipitation and surface flows from tributary streams. Portions of the terrace sediments are recharge zones for upland Carlotta and the Van Duzen (recharge areas are discussed in Section 1.4.6).

1.2.4 Carlotta Formation

Available information suggests the Carlotta formation underlies most, if not all, of the Eel River Valley, consisting of coarse-grained clastic sediments (i.e., conglomerate), sandstone, and claystone deposited in a near-shore or terrestrial setting during the Plio-Pleistocene period (Ogle 1953). These sediments are difficult to differentiate from the overlying alluvium, and in some places extend up to 4,000 ft below present-day ground surface (Ogle 1953; USGS 1978).

The conglomerate consists of rock fragments ranging in size from boulders of sandstone 8 inches in diameter to fine interstitial sand, silt, and clay. The conglomerate is interbedded with sandstone or claystone. Many outcrops show an iron-oxide coating abundant enough in places to bind the grains together to form a hard resistant rock. Typically, the conglomerate lies in troughs cut 2 ft or more into the claystone. The beds of sandstone and claystone can contain large limbs, trunks, and stumps of carbonized wood. These features represent a change from quiet water, marshy, or mudflat depositional conditions to erosion by stream channeling with concurrent deposition of coarse clastics and woody debris (Ogle 1953). The formation is predominantly overlain by alluvium or terrace deposits.

1.2.5 Geomorphic and Depositional Setting

As we see it today, the geomorphic character of the ERVB is the result of complex and dynamic tectonic and fluvial processes. Compressional forces over millions of years have resulted in a broad tectonic basin (see Figure 4) that receives alluvium from the sediment-laden Eel and Van Duzen rivers. Sea level changes at the coastline associated with glacial cycles have corresponded to significant base level changes as the coastline moves in and out. Rivers incise during periods when sea level has retreated, creating canyons and valleys that are then backfilled with sediment as sea level rises.

The importance of the Eel and Van Duzen river systems to the hydrogeologic character of the ERVB cannot be understated. Together the Eel and Van Duzen watersheds directly supply all of the water for municipal wells, domestic well, industrial and irrigation wells. The sediment transported by these rivers has infilled the lower valley, which over time has created the very aquifers that they currently recharge.

The Eel River is particularly influential on the development of the upper stratigraphy in the lower Eel River Valley. The Eel River watershed is associated with high rainfall in an area with steep slopes underlain by unstable geologic materials. Therefore, sediment loading in the Eel River is exceedingly high, such that alluvial material is readily available to infill any space resulting from ocean base level changes, tectonic land level changes, and deformation associated with the Eel River syncline.

The Eel River currently flows along the eastern and northern margins of the lower valley, but old abandoned channels and river meanders visible throughout the axis of the lower Eel River Valley provide strong geomorphic evidence for the range of past alignments extending as far south as Ferndale (Figure 8). The shallow stratigraphy underlying these abandoned channels reflect a high-energy fluvial environment consisting primarily of course sediments (sands/gravels). In contrast, the smooth, elevated alluvial fan surfaces that have built up from sediment eroded from the Wildcat Range are predominately underlain by fine grained sediments (silts/clays). Ferndale is situated on one of the more prominent fan surfaces associated with Francis Creek drainage.

Flooding is common within the north coast of California, playing an important role in the geomorphic evolution of the main stem river channels, tributaries, and active floodplains. The geologic setting of the ERVB is characterized by steep, unstable slopes influenced by active tectonic processes and high annual rainfall. Significant floods within the Eel and Van Duzen watersheds are often accompanied by channel scour, erosion of riverbanks, and landslide activity. The eroded materials carried by flood waters are either washed out to sea or are redistributed within the river channels lower in the watershed. Aggradation of sediment typically occurs in areas where channels widen and/or where stream gradients are reduced. The coastal floodplain of the Eel River Valley is subject to these processes.

Bedload transport and aggradation within the mainstem channels of the Eel and Van Duzen rivers can change the alignment of the thalweg, fill holes, and generally raise overall channel elevations. Major floods in 1955 and 1964 resulted in substantial geomorphic changes to the channel, adjacent terraces, and tributaries. An aggraded condition, particularly when the materials are coarse, can increase the relative proportion of underflow within the channel and increase the opportunity for sections of the river to flow entirely subsurface. The lower section of the Van Duzen River channel, just before its confluence with the Eel River, often goes dry as water flows through a thick deposit of alluvial material. In Fall 2014, a few hundred yards of the Eel River channel near Fortuna went dry as the surface elevation of the water dropped below the channel surface near a knickpoint.

The impacts of active channel processes within the ERVB, and the effect of the spatial and temporal patterns of erosion and deposition on surface flows, is an important consideration in the development of sustainable criteria for impacts to beneficial uses of surface waters.

1.2.6 Faults within the Basin

The Little Salmon fault is one of the most active fault zones within the on-land fold-and-thrust belt, forming the northern boundary of the ERVB. Since highly sheared fault zone materials often have relatively low hydraulic conductivities, they provide distinct boundary conditions from surrounding geologic formations. Total displacements of up to 7 km and a late Quaternary slip rate as much as 10 to 12 mm per year (mm/yr) have been estimated for the Little Salmon fault zone (Carver 1987; Clarke 1992; McCrory 1996). It is inferred that the Little Salmon fault represents a significant barrier to groundwater flow into the ERVB.

The Goose Lake faults have been mapped along two east-west striking lineaments that offset terraces within the Yager Creek drainage. The lateral extent of these faults is not well understood, but the northern fault trace (geologic evidence of faulting) likely extends towards the west into and potentially through the lower Eel River Valley and eastward across the Yager Creek drainage. Recent geomorphic mapping of the Yager Creek terraces (Samuel Bold personal communication 2021) and paleoseismic work on the more prominent northern fault trace suggests that at least one of these lineaments may be Holocene active (Tyler Ladinsky personal communication 2021).

1.2.7 Basin Boundaries

The ERVB boundary as currently defined by DWR in Bulletin 118 is shown on Figure 1. 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 basin encompasses portions of the Wildcat Range underlain by the uppermost, coarse-grained member of the Wildcat Group (the Carlotta formation). The northern side of the ERVB is bounded by the axis of the Table Bluff anticline to the west and the Little Salmon fault to the east. The western edge of the ERVB abuts the estuary where the Eel River flows into the ocean (that is, the saltwater-freshwater interface along the coast). The eastern limit of the ERVB is 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.

The ERVB bottom is defined by the base of the Carlotta formation, as described by Ogle (Figure 4; Carlotta is depicted in yellow), 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 has not penetrated to that depth.

1.3 Soil Characteristics

Soils within the ERVB 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 U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Soil Geographic Database (SSURGO) is presented in Figure 9 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 9 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.

The 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 ERVB.

1.4 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 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 ERVB, with two (2) miles of the active Eel River channel, is not entirely understood 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 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 ERVB, as there are very few wells that are believed to extend through the alluvial aquifer into the Carlotta, with the majority of use being 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.

1.4.1 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 ERVB. The alluvial aquifer is generally defined as the water-bearing units within the relatively young unconsolidated sediments overlying the Carlotta formation. The alluvial aquifer is most prominent within the central portions of the lower Eel River Valley where the thickness is in excess of 260 ft. The alluvial aquifer extends up the Van Duzen River Valley, thinning from approximately 125 ft thick at the confluence with the Eel River to less than 40 ft 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 surface waters of the Eel and Van Duzen rivers are generally in direct contact and hydraulic communication with the alluvial aquifer. Monitoring of surface and groundwater levels show rapid aquifer response to changes in river levels.

The unconsolidated alluvium is a highly productive aquifer, with supply wells capacities' typically ranging from 400 to 1,200 gallons per minute (GPM), that represents the primary water source for a majority of agricultural wells. Most wells in the alluvial aquifer are less than 100 ft deep and yield relatively high volumes (Evenson 1959).

1.4.2 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 ERVB, 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 ERVB. The western and central portions of the ERVB 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 in excess of 1,500 ft thick (locally as much as 4,000 ft thick per DWR [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 ERVB, 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 ft 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 ERVB, 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 10. In general, the Carlotta aquifer is not as productive as the alluvial aquifer, so it isn't usually targeted except for areas outside the valley floodplain lowlands.

1.4.3 Aquitards

Virtually all the stratigraphic sections within the ERVB comprise 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, however, are not typical of the depositional environments in the ERVB alluvium, not laterally continuous, and can be difficult to define with confidence.

The Carlotta formation does have a laterally continuous, prominent aquitard in the eastern half and southern portion of the ERVB 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 (2) to three (3) miles up the Van Duzen River near the center of the valley at Hydesville, is approximately 125 ft below the ground surface (bgs), almost 75 ft thick. Near the confluence of the Eel and Van Duzen rivers at Alton, the Carlotta aquitard is 145 feet bgs and almost 20 ft 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 ft bgs and almost 30 ft thick.

Wells along the southern to central portion of the ERVB encounter the Carlotta aquitard between 100 and 150 ft bgs; in Ferndale the aquitard is encountered in places within 20 ft of the ground surface and can be greater than 100 ft thick. In the western and central portion of the ERVB, approximately a mile north of Arlynda Corners and a mile south of the active Eel River channel, the aquitard wasn't encountered in a new County monitoring well (MW-14d) installed to a depth of 260 ft.

Groundwater levels in nested County monitoring wells 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 (Draft from SHN) and Aquifer Parameters Technical Memorandum (in preparation by GHD).

Additional resolution on the confining conditions within the ERVB aquifers will come from the ongoing analysis of stratigraphy and water levels recorded in the new County monitoring wells that were completed in June 2021.

1.4.4 Aquifer Hydraulic Characteristics

Data regarding the hydraulic characteristics of the aquifers within the ERVB are generally derived from past DWR/USGS reports (1959, 1965, 1978) and the current and previous studies carried out as part of the County's response to SGMA (Alternative Plan 2016, and the ERVB GSP).

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

Hydraulic conductivities of the alluvial aquifer, as measured in County wells installed in 2016 and 2021, range from 3 ft per day in the shallow fine-grained sediments west of Ferndale to as high as 420 ft per day in channel alluvium gravels adjacent to the active Eel River channel. Deeper (>125 ft) screened wells in the confined Carlotta aquifer containing silt, sand, and gravel range from 0.3 to 11 ft per day and are detailed in the Aquifer Parameters Technical Memorandum (in preparation by GHD).

1.4.5 Primary Aquifer Use

The primary uses of the ERVB aquifers and vast majority of groundwater pumping is for irrigation of croplands (including permitted and unpermitted cannabis), 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 (see Table 1 below). A detailed description of groundwater use and water balance are presented in the Water Use Technical Memorandum (GHD, 2021) and the Water Budget Technical Memorandum (GHD, 2021).

Groundwater is pumped from municipal wells, domestic wells, commercial/industrial wells and irrigation wells. These well locations are spread throughout the ERVB. Figure 10 displays the density of these wells throughout the basin. The irrigated lands are pervasive in the ERVB's spatial extent, and the municipal water suppliers are fairly spread out with the remaining minor uses scattered intermittently throughout the entire ERVB.

Table 1. ERVB Groundwater Use by Use Type

Use Type	Municipal	Domestic (non-municipal)	Commercial / Industrial (non-municipal)	Agricultural Irrigation	Cannabis (permitted and non-permitted)	Total
AF/YR	1,733	414	34	10,585	98	12,864
%	13.5%	3.2%	0.3%	82.3%	0.8%	

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 ERVB (within approximately one [1] to two [2] 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 ft of alluvial sand and gravel packages, with screened intervals starting around 20 ft bgs. The bulk of the ERVB groundwater is used for irrigation pumping (see Chart 1 below) which occurs during a relatively short season of approximately six (6) months, or less, as detailed in the Water Use Technical Memorandum (in preparation by GHD).

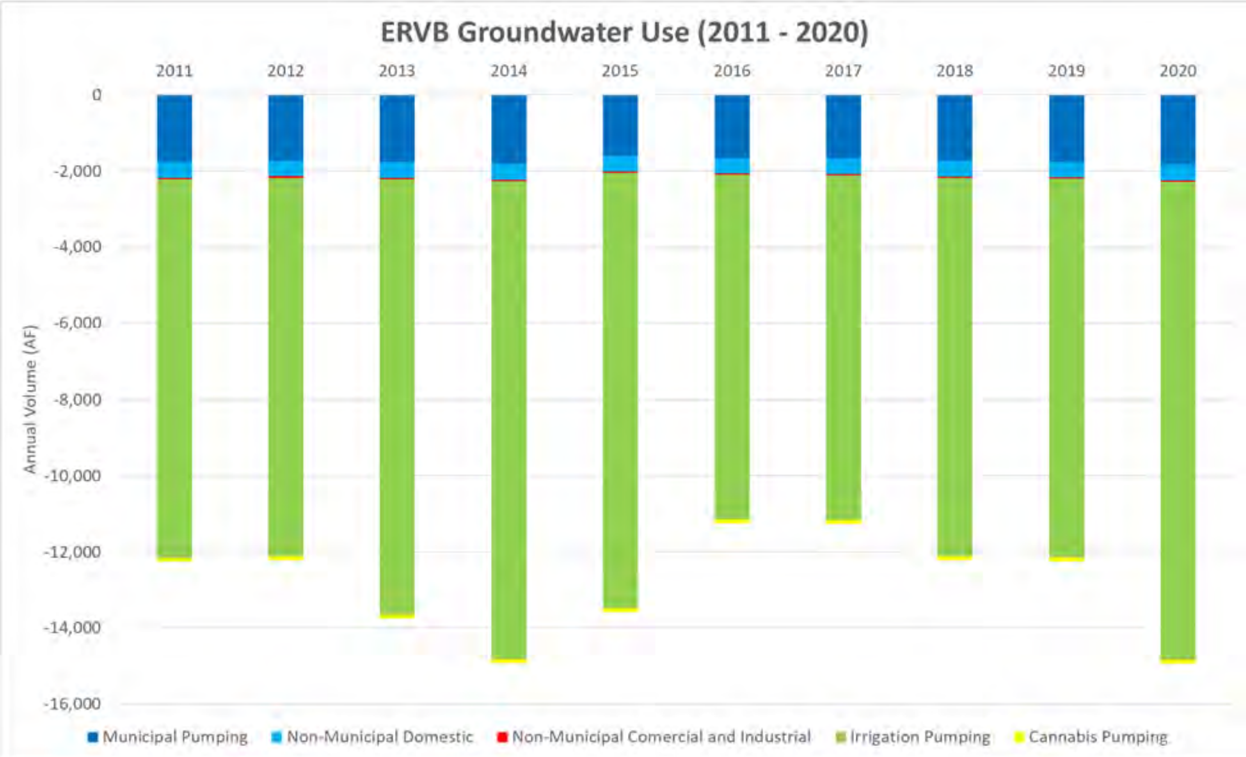

Chart 1. Groundwater Use 2011-2020.

Municipal water supply wells are generally less than 200 ft 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 ft, as they are located on an upland surface.

Domestic water supply wells for residences are scattered throughout the ERVB 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 ERVB 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) or underflow directly connected to the rivers, and on the marine terraces.

Although due to the relatively productive nature of the alluvial aquifer, the shallow depth of water extraction is more critical in the western third of the ERVB 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 ERVB around the confluence of the Eel and Van Duzen rivers could be at depths ranging from 600 to 1,000 ft.

The ERVB receives no water from sources outside of the Eel River watershed, such as canals, pipelines, or diversions coming from outside the basin limits. Portions of the upper Eel River watershed surface waters are diverted in Mendocino County at Cape Horn Dam to supply supplemental water for the Russian River system that serves water users in Mendocino, Sonoma and Marin counties.

1.4.6 Aquifer Recharge Areas

Important recharge areas for the ERVB are shown on Figure 11. 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 directly hydrologic connection. Surface water-groundwater monitoring along both the Eel and Van Duzen rivers shows a strong connection with alluvial aquifer levels responding quickly to river level changes. High flows during the 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 ERVB 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 ERVB from the eastern side and come in direct contact with the underlying Carlotta formation. Where the coarse-grained Carlotta formation intervals come in contact with channel alluvium, opportunities to provide substantial Carlotta aquifer recharge are realized. Additionally, the Carlotta formation is exposed in several upland areas directly surrounding the ERVB, 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 ERVB, are similarly recharged by precipitation and/or surface flows of tributary streams.

1.5 General Water Quality

Water quality conditions in the ERVB have been described in past DWR/USGS reports (1959, 1965, 1978). Available online data indicates that groundwater in the ERVB is generally of good quality and suitable for the intended municipal and agricultural uses (Water Quality Technical Memorandum; SHN 2021). Water quality of groundwater emanating from the alluvial aquifer is adequate for irrigation and stock watering and has been used as such for decades.

High concentrations of iron and manganese has been recognized as a natural condition within groundwater of the ERVB (Ogle 1953; Evenson 1959). Raw water sampling for municipal suppliers within the ERVB, as reported in the Safe Drinking Water Information System (SDWIS) online database, indicate that raw water collected by Palmer Creek Community Services District (CSD), Del Oro Water Company, and Loleta CSD regularly have concentrations of iron and magnesium above secondary MCLs (300 ug/L and 50 ug/L, respectively).

Water quality data made available online as part of the California State Water Resources Control Board's online Groundwater Ambient Monitoring and Assessment Program (GAMA), was initially compiled and presented in the 2016 Groundwater Sustainability Plan Alternative (SHN 2016). Fifteen (15) constituents were queried and analyzed in the GAMA database, including aluminum, arsenic, barium, boron, cadmium, chloride, chromium, lead, mercury, nitrate, selenium, silver, sodium, specific conductance, and total dissolved solids (TDS). Six (6) of the 15 constituents had concentration levels that were detected above method detection limits, including arsenic, chloride, nitrate-N, sodium, specific conductance, and TDS. For the six (6) constituents that were selected for further analysis, all datasets in the database were used to provide an assessment of the average concentration for each constituent for each 10-year period of record (decadal averages). None of the detected constituents were found to be above their respective water quality objectives, and analysis of the data trends indicated that there was little to no increase in concentrations in the last 10-year period of record as compared to the entire data set.

As a follow-up to the 2016 work, tabular data were downloaded from GAMA in April 2021 to update the analysis of the 15 constituents initially evaluated. All data available for each constituent for the last 10 years were downloaded and reviewed to identify any specific exceedances during the last decade. All results fell below MCLs except for one (1) TDS result in 2012 and an arsenic result in 2020.

The ERVB was recently identified as a high-priority basin for salts as TDS and nutrients (nitrates) in a 2020 North Coast Regional Water Quality Control Board (NCRWQCB) Staff Report entitled *North Coast Hydrologic Region Salt and Nutrient Management Planning Groundwater Basin Evaluation and*

Prioritization (2020). Sampling results from wells within the ERVB from 2010 to 2020 show exceedances for water quality objectives for nitrates within the central portion of the lower Eel River Valley.

Groundwater quality sampling and testing of a broad suite of analytes was performed within 15 of the County monitoring wells in July 2021. The results from this effort will provide a better baseline of understanding for water quality conditions within the primary aquifers underlying the alluvial flood plains.

1.6 Surface Water Bodies Significant to Basin

The Eel and Van Duzen rivers are the primary surface water bodies within the ERVB. These are large river systems that drain significant areas of northwestern California (Figure 12). The main stem Eel River is dammed near its headwaters in Lake County (far from the ERVB) at Lake Pillsbury (Scott Dam) and some flow is 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 ERVB 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 ERVB. 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 ERVB.

Very little direct surface water extraction of the rivers is used to supply ERVB residents with potable drinking water. Although the quantity of rural creek and spring water may be slightly more significant, it is difficult to estimate due to the remote nature of many of those permitted or unpermitted surface water extraction systems. The surface water quality of the Eel and Van Duzen rivers and ERVB creeks are relatively high and not impacted from commercial or industrial pollutants, and as such provide significant high-quality inflows to ERVB groundwater.

1.7 Hydrogeologic Conceptual Model Data Gaps and Uncertainty

Data gaps within the current HCM include the following:

- 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 ERVB, such as those of the Goose Lake faults, are not well understood in terms of their lateral extent and impact on some of the younger overlap and alluvial deposits.
- The stratigraphy and aquifer characteristics associated with the Rohnerville and Hydesville terraces are not well known. These areas are unique in their setting but do not play a significant role in water use in the ERVB, and therefore have not been studied in detail. Future studies should consider researching historical water levels and current conditions.
- 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 well understood. Similarly, the continuity of silt/clay layers (aquitards) across the ERVB in the central western third and northern portion is not well understood.

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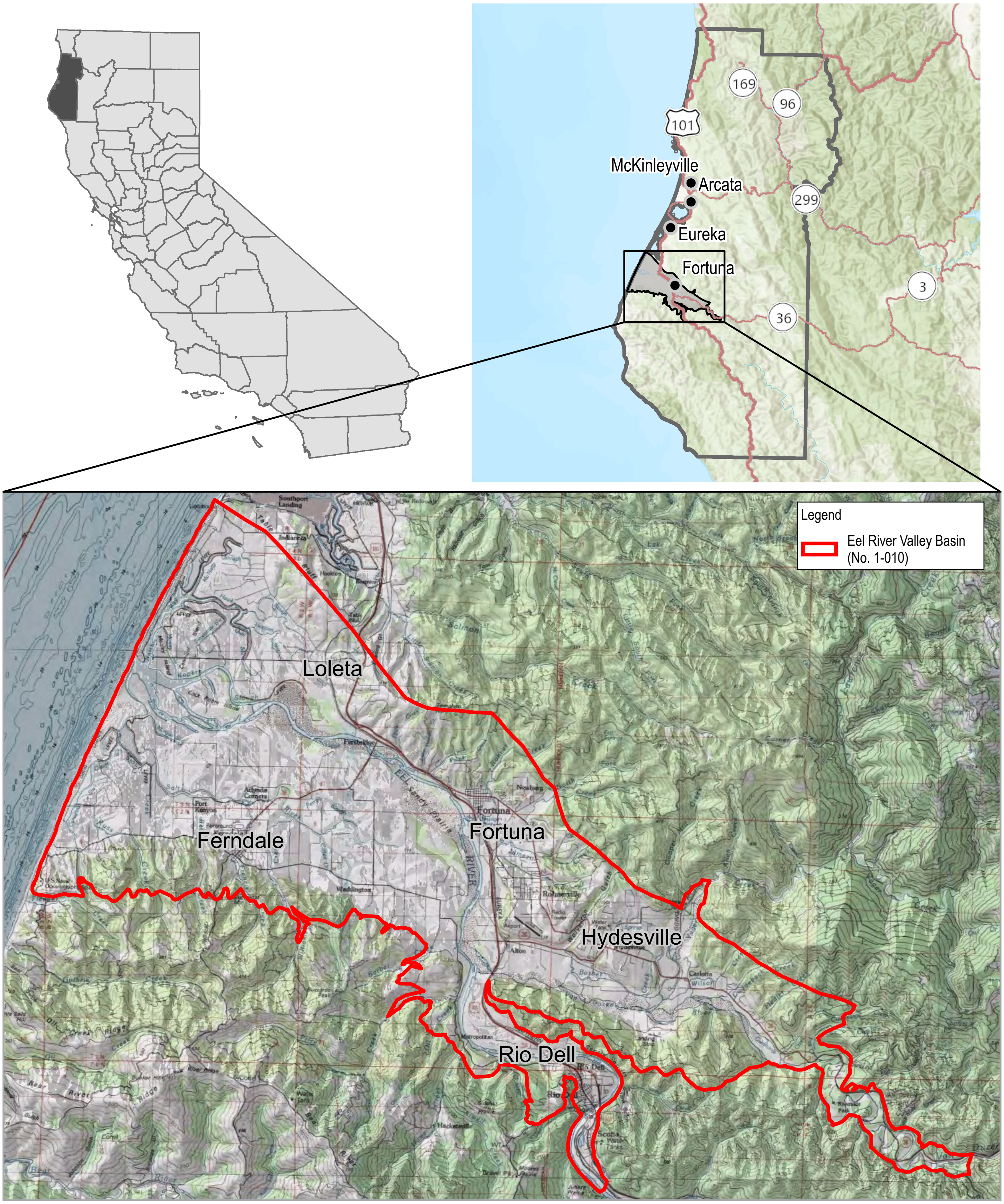
Appendix A Figures



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Humboldt County Department of Public Works
Eel River Valley Groundwater
Sustainability Plan

General Basin
Vicinity Map

Project No. **11217388**
Revision No. **-**
Date **August 2021**

FIGURE 1

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Data source: Terrain: Aspect: Airbus,USGS,NGA,NASA,CGIAR,NCEAS,NLS,OS,NMA,Geodatastyrelsen,GSA,GSI and the GIS User Community; World Imagery (Clarity): This work is licensed under the Esri Master License Agreement.
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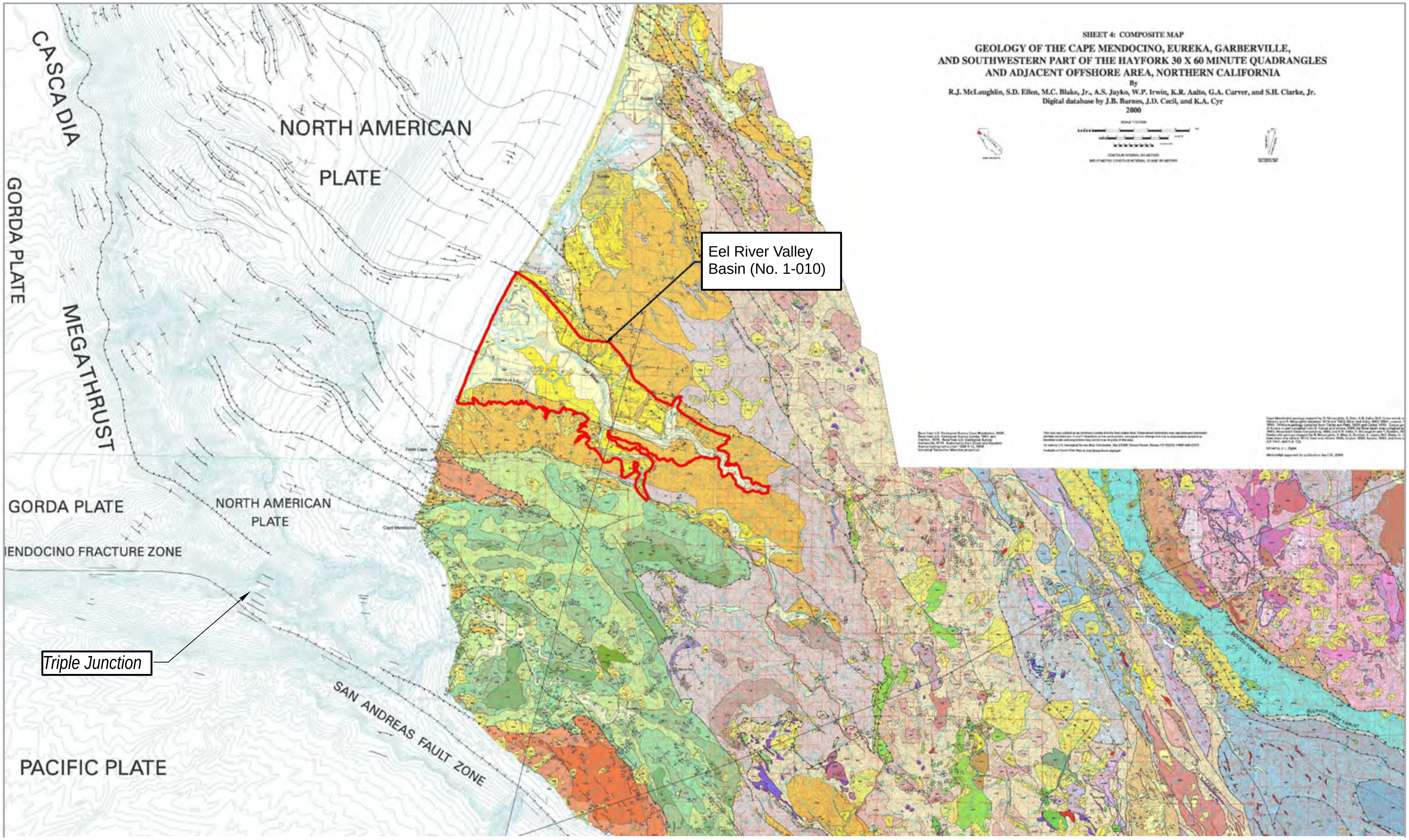

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Eel River Valley Groundwater Sustainability Plan

Geologic Map (McLaughlin 2002)

Project No. 11217388
Revision No. -
Date August 2021

FIGURE 2

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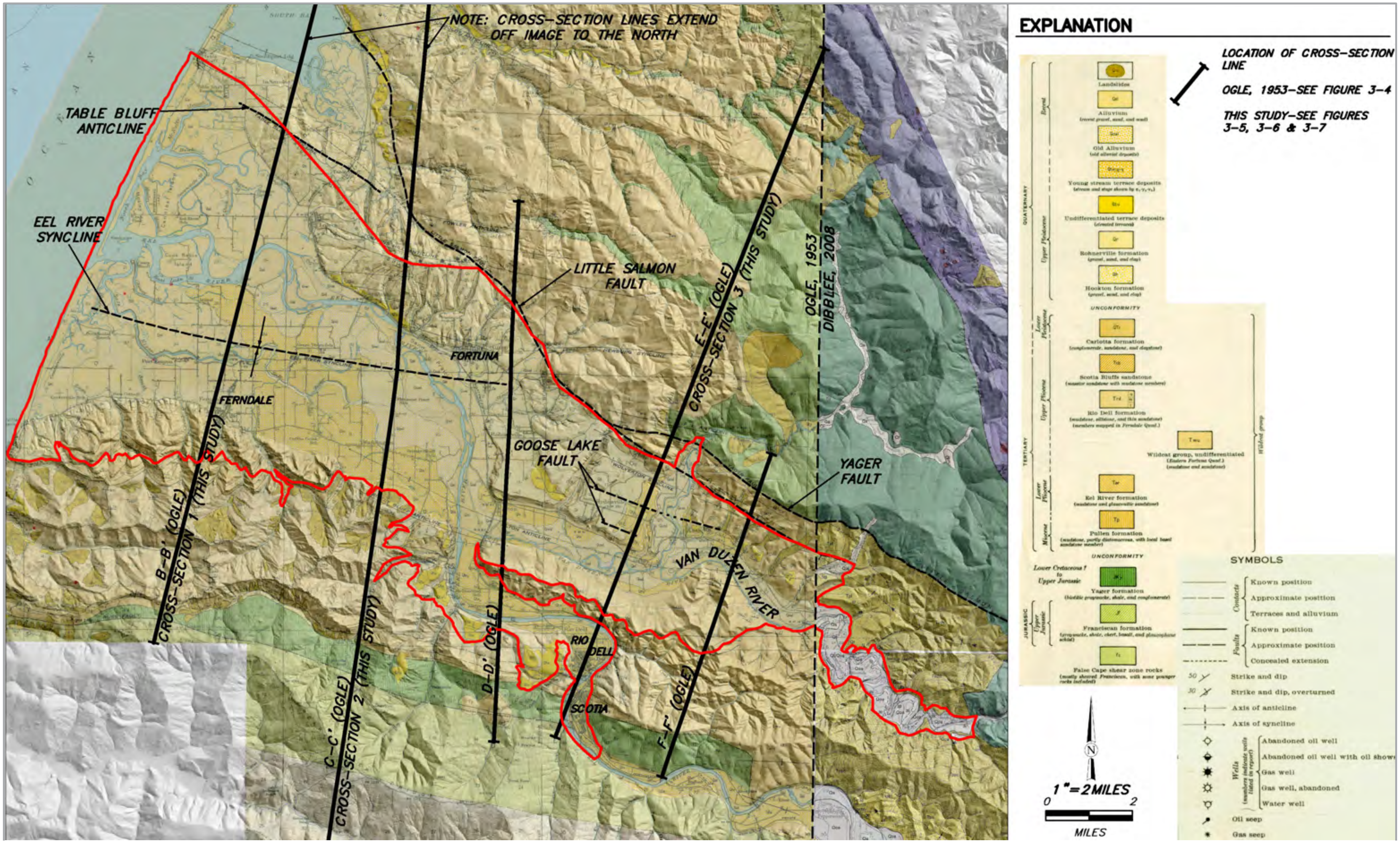

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Sustainability Plan

Project No. 11217388
Revision No. -
Date August 2021

Geologic Map
(Ogle, 1953; Dibblee, 2008)

FIGURE 3

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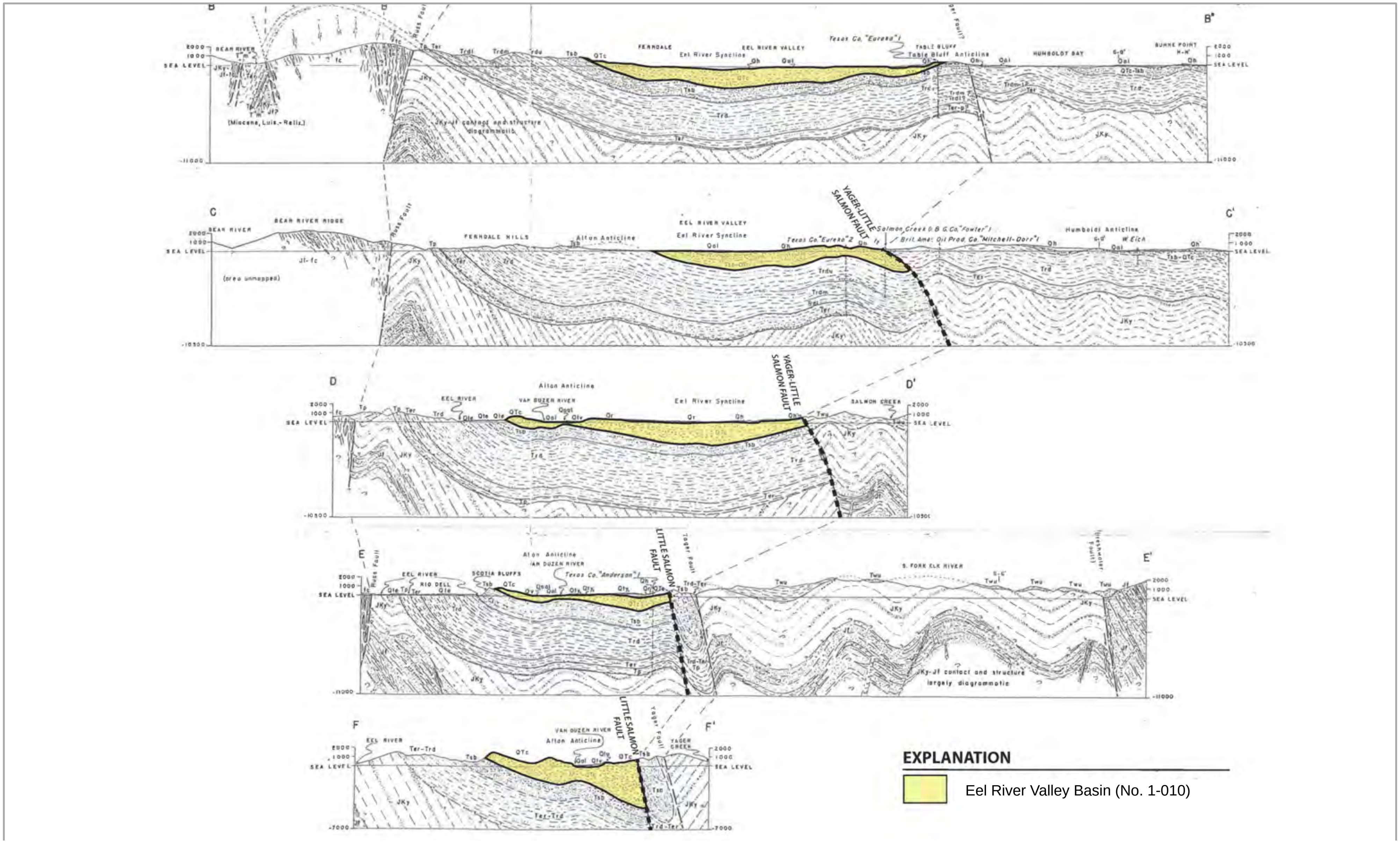

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Sustainability Plan

Geological Cross Sections

Project No. 11217388
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Date August 2021

FIGURE 4

N:\US\Eureka\Projects\561\11217388\GIS\Maps\Deliverables\11217388_HCM_Tech_Memo\11217388_HCM_Tech_Memo_Maps.aprx - 11217388_004_GeoCrossSect_RevD
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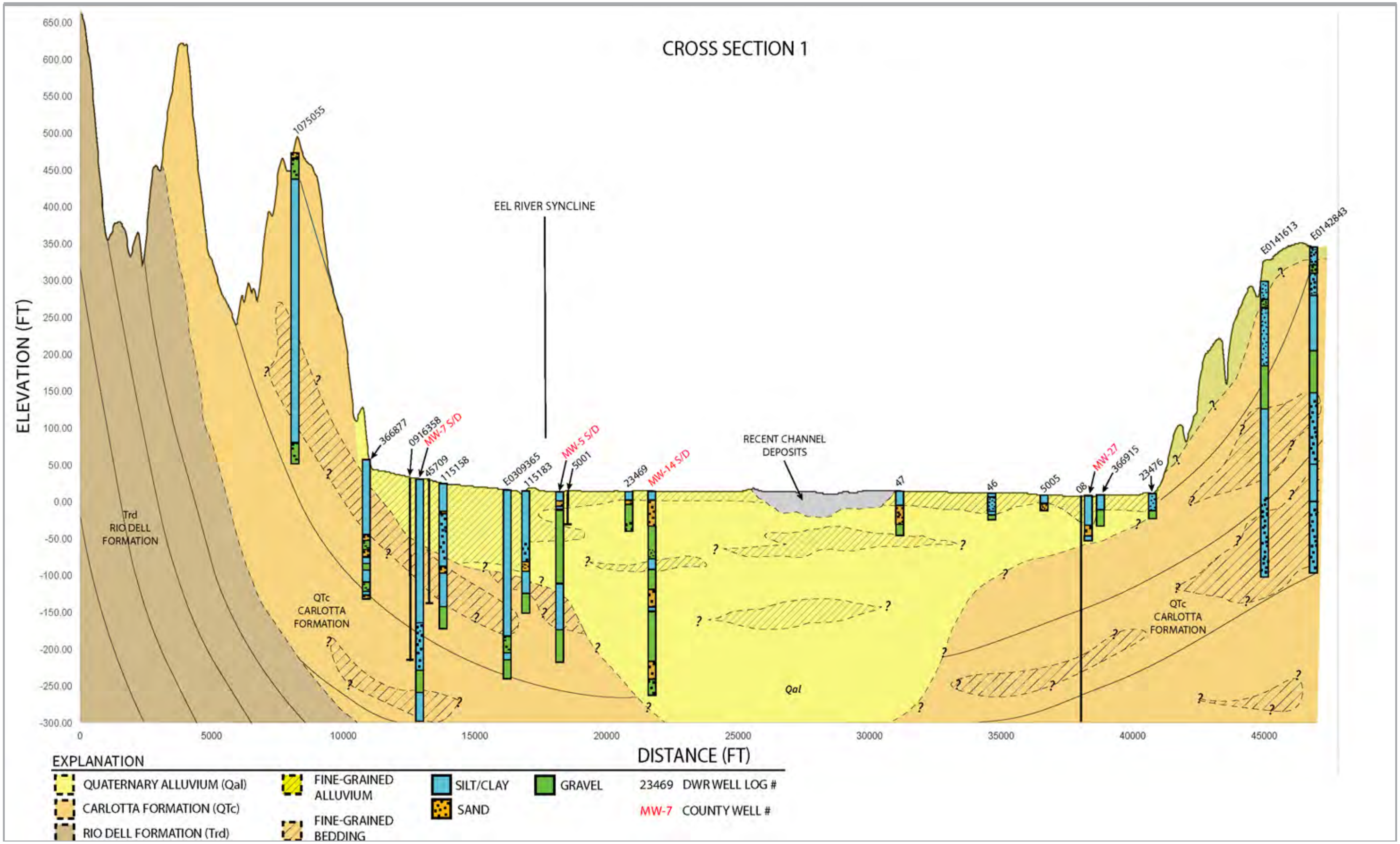

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Sustainability Plan

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Date **August 2021**

Geologic Cross-Section 1

FIGURE 5

N:\US\Eureka\Projects\561\11217388\GIS\Maps\Deliverables\11217388_HCM_Tech_Memo\11217388_HCM_Tech_Memo_Maps.aprx - 11217388_005_ShallowCrossSect1_RevB
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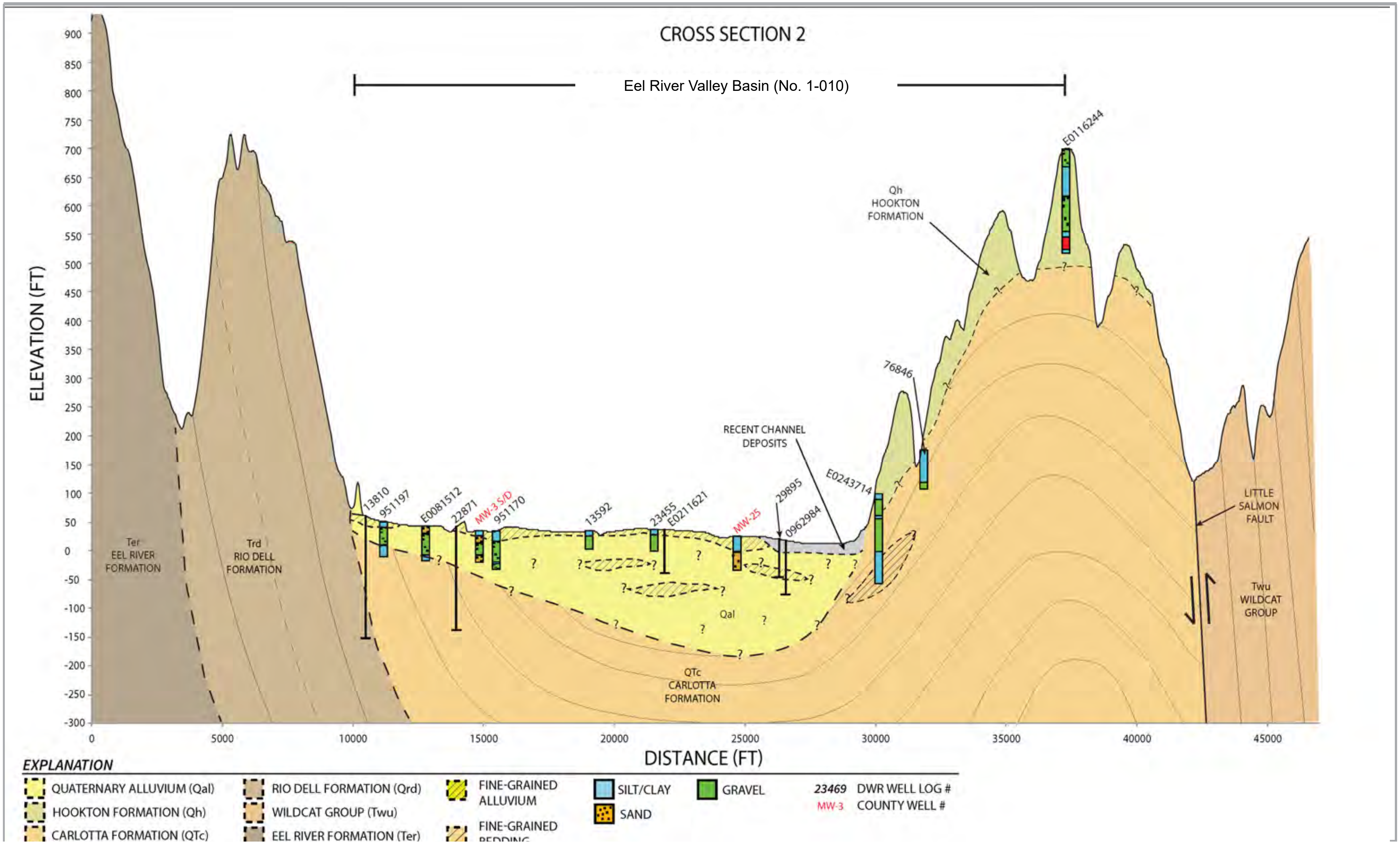

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Date **August 2021**

Geologic Cross-Section 2

FIGURE 6

N:\US\Eureka\Projects\561\11217388\GIS\Maps\Deliverables\11217388_HCM_Tech_Memo\11217388_HCM_Tech_Memo_Maps.aprx - 11217388_006_ShallowCrossSect2_RevC
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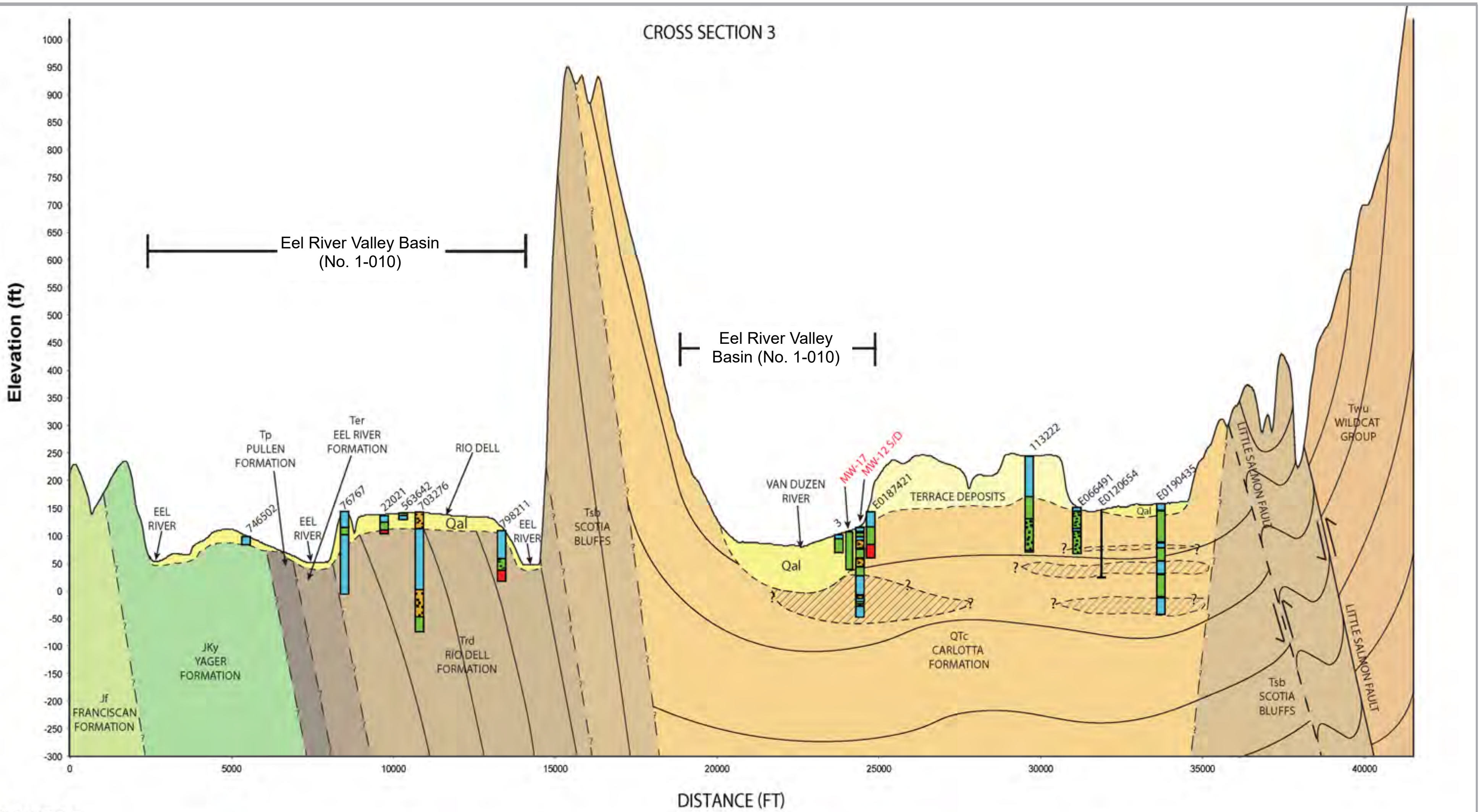

EXPLANATION

QUATERNARY ALLUVIUM (Qal)	RIO DELL FORMATION (Trd)	YAGER FORMATION (JKy)	FINE-GRAINED ALLUVIUM	SILT/CLAY	GRAVEL	23469 DWR WELL LOG #
CARLOTTA FORMATION (QTc)	EEL RIVER FORMATION (Ter)	FRANCISCAN FORMATION (Jf)		SAND	BEDROCK	MW-17 COUNTY WELL #
SCOTIA BLUFFS (Tsb)	PULLEN FORMATION (Tp)					

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Geologic Cross-Section 3

FIGURE 7

N:\US\Eureka\Projects\561\11217388\GIS\Maps\Deliverables\11217388_HCM_Tech_Memo\11217388_HCM_Tech_Memo_Maps.aprx - 11217388_007_ShallowCrossSect3_RevC
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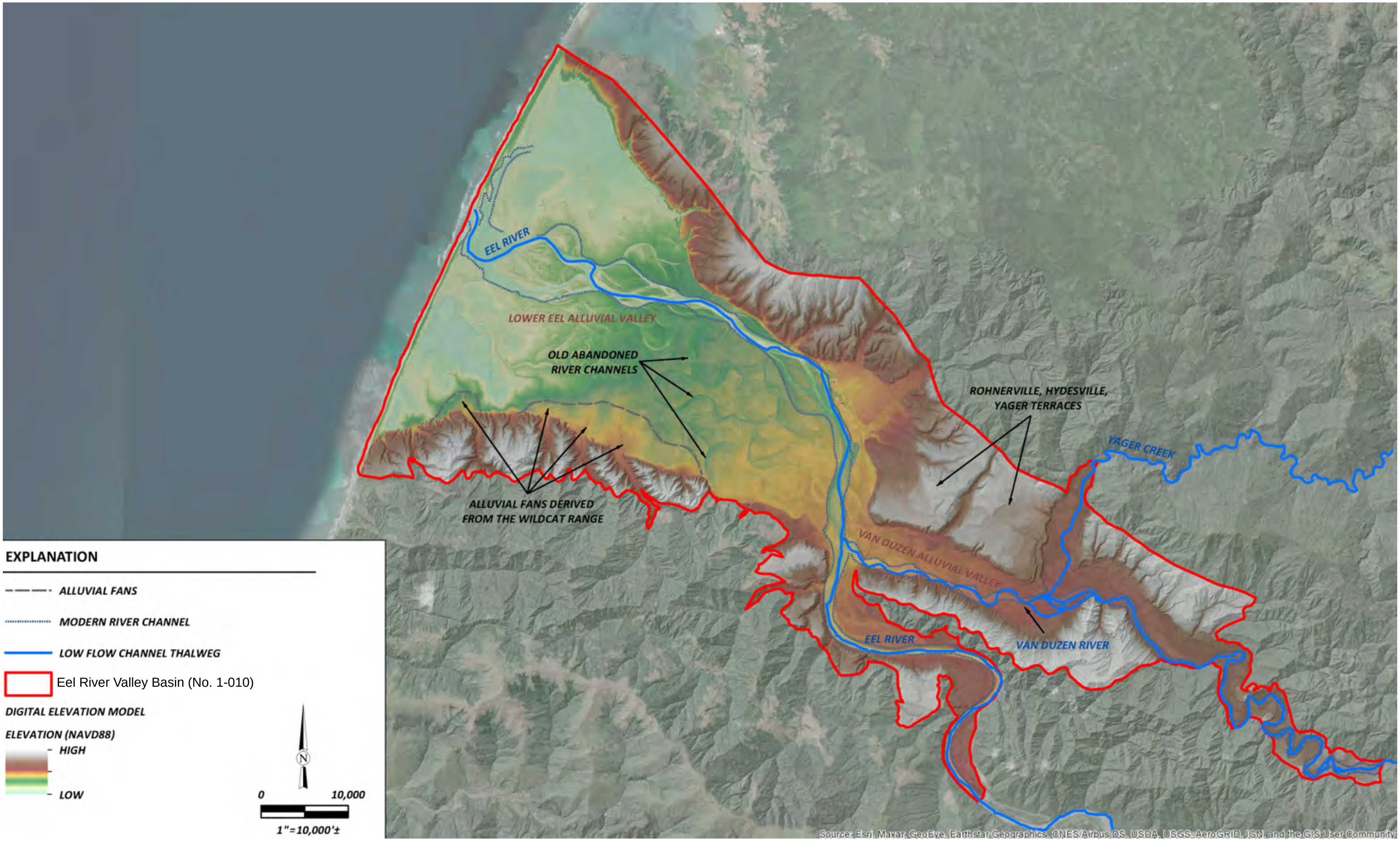

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Sustainability Plan

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Geomorphology

FIGURE 8

N:\US\Eureka\Projects\561\11217388\GIS\Maps\Deliverables\11217388_HCM_Tech_Memo\11217388_HCM_Tech_Memo_Maps.aprx - 11217388_008_Geomorphic_RevB
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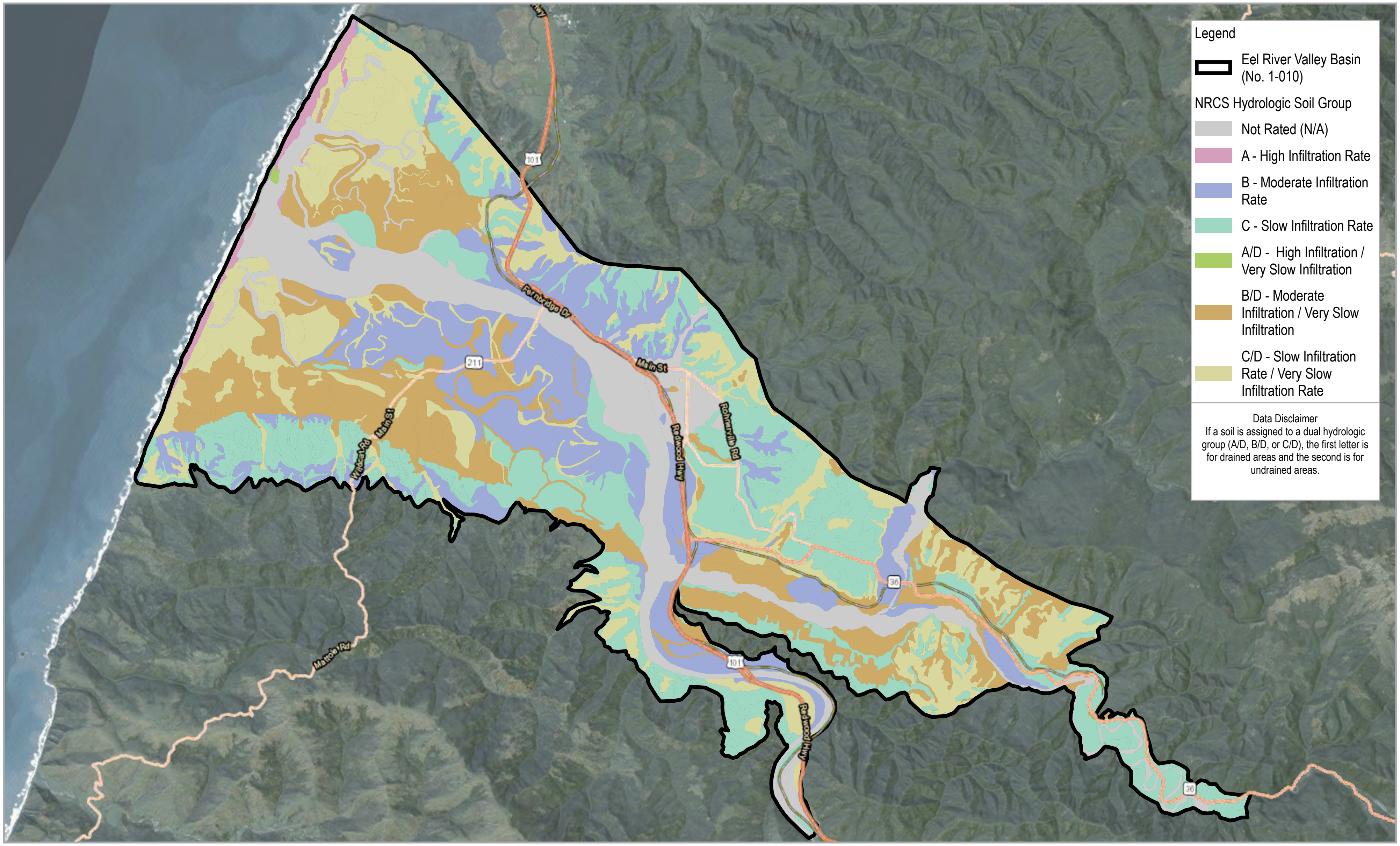

Paper Size ANSI A

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 Department of Public Works
Eel River Valley Groundwater Sustainability Plan

NRCS Mapping by Hydrologic Soil Group

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Date **August 2021**

FIGURE 9

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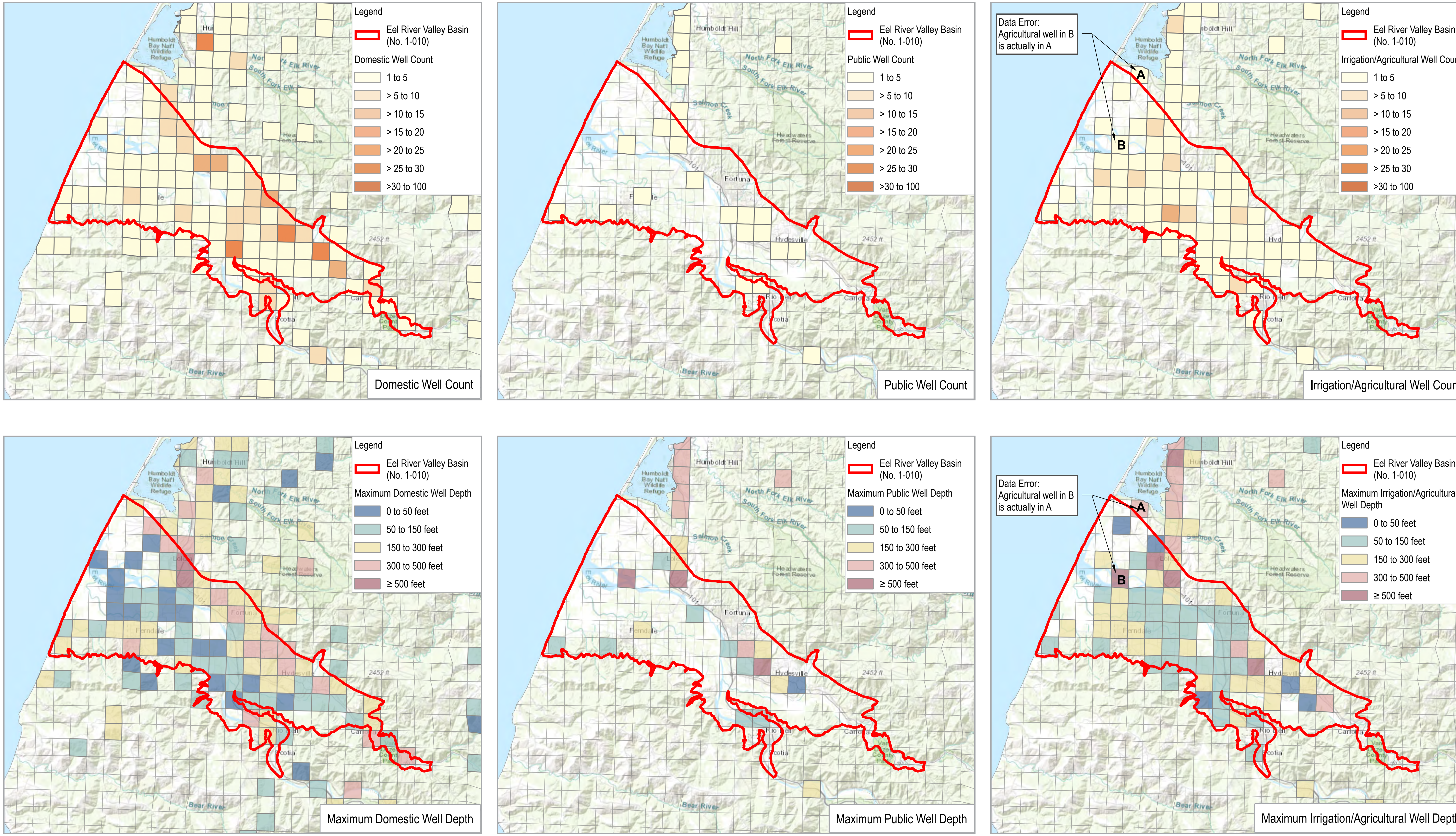
Print date: 17 Aug 2021 - 09:58

Data source: USDA, Natural Resource Conservation Service, 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



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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

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Eel River Valley Groundwater
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Aquifer Use Map

FIGURE 10

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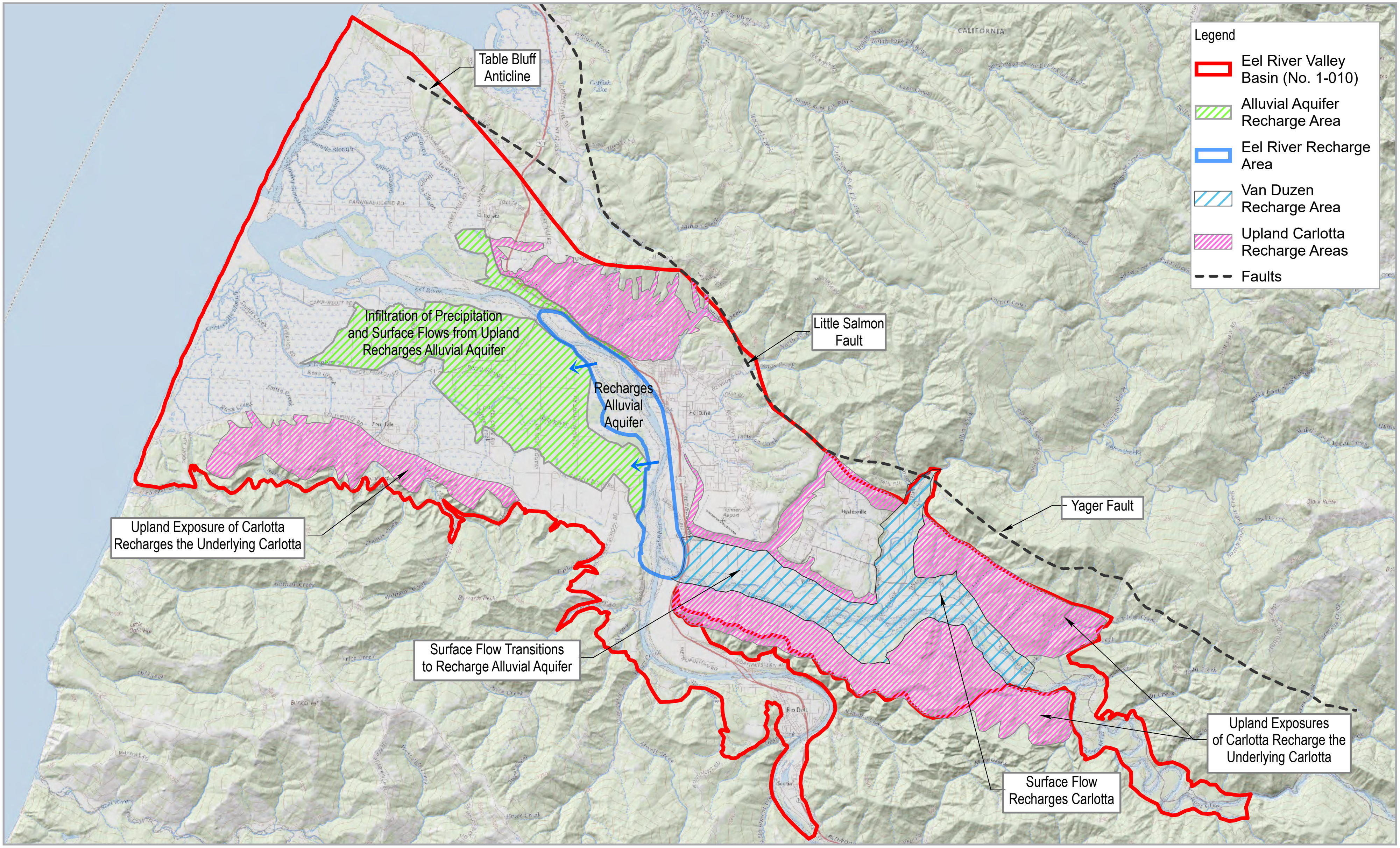
Print date: 17 Aug 2021 - 09:59

Data source: DWR Well Completion Report, 2021;World Topographic Map: Esri, HERE, Garmin, USGS, NGA, EPA, USDA, NPS
World Topographic Map: Bureau of Land Management, Esri, HERE, Garmin, USGS, NGA, EPA, USDA, NPS. 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

N

GHD

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Eel River Valley Groundwater Sustainability Plan

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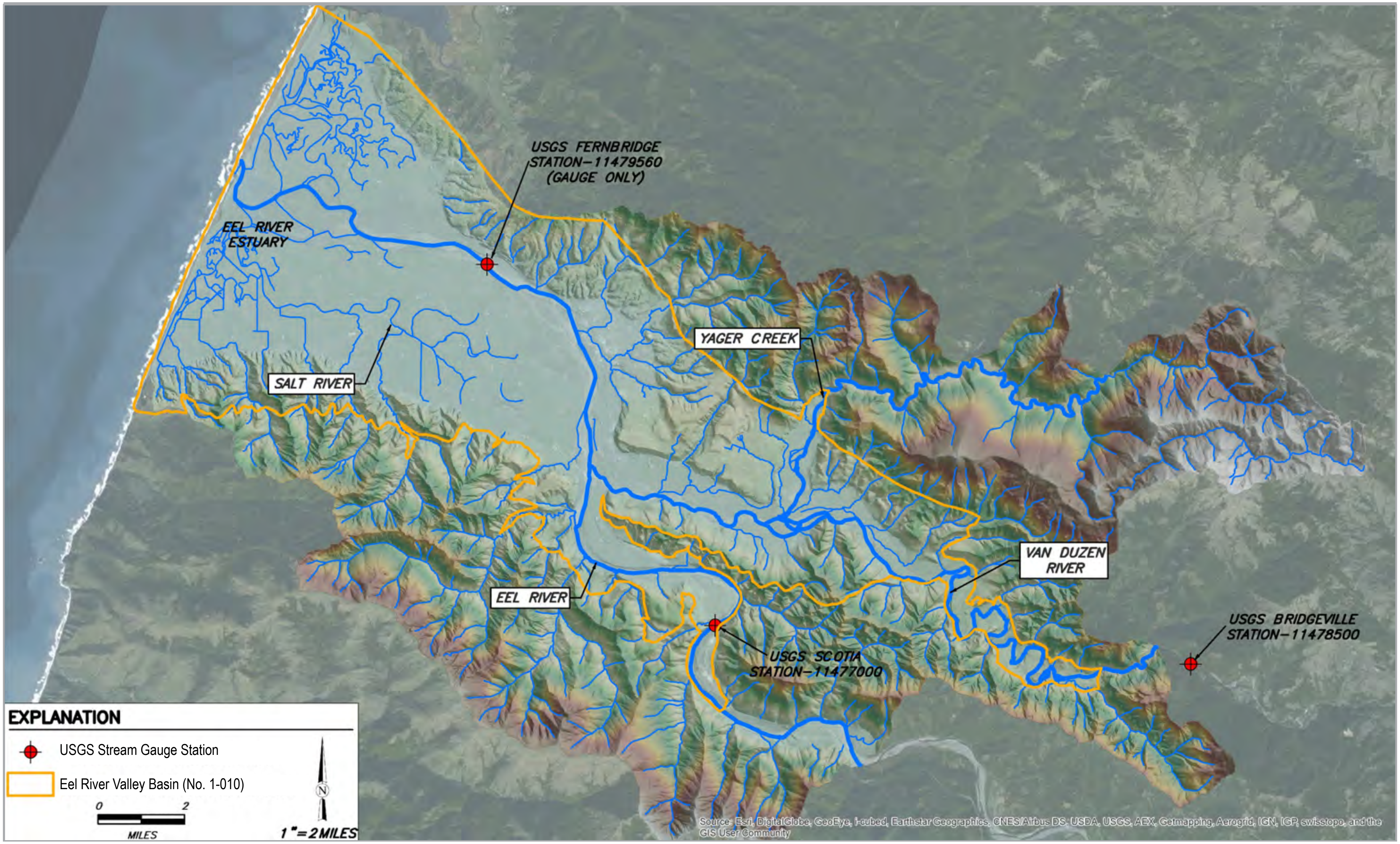
Date **August 2021**

Important Recharge Areas

FIGURE 11

N:\US\Eureka\Projects\561\11217388\GIS\Maps\Deliverables\11217388_HCM_Tech_Memo\11217388_HCM_Tech_Memo_Maps.aprx - 11217388_011_Recharge_areas_RevB
Print date: 17 Aug 2021 - 10:01

Data source: 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



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Eel River Valley Groundwater
Sustainability Plan

Surface Waters

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Revision No. **-**
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FIGURE 12

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Print date: 17 Aug 2021 - 10:03

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Hydrologic Model Technical Memorandum (TM-5)

Hydrologic Model Technical Memorandum

Prepared for: Eel River Valley Groundwater Basin GSP, 2021

Humboldt County Groundwater Sustainability Agency

January 25, 2022

PREPARED BY: GHD, Inc., 718 3rd Street, Eureka, CA 95501

The Power of Commitment

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Attachments

1. Introduction

1.1 Background

The Sustainable Groundwater Management Act (SGMA) requires local governments and water agencies in California's high and medium priority groundwater basins, as defined by the California Department of Water Resources (DWR), to form Groundwater Sustainability Agencies (GSAs) and operate under a Groundwater Sustainability Plan (GSP) by the year 2022.

The Eel River Valley Basin (ERVB), located along the Pacific Coast, was listed as a medium priority basin by DWR in 2018 (**Figure 1.1**, left panel). ERVB has a cool maritime climate and high winter rainfall that recharges the basin aquifers. ERVB is situated within the Eel River watershed and bisected by the Eel and Van Duzen Rivers, which recharge the basin through surface water-groundwater exchange. The river network of the Eel River watershed and corresponding hydrologic response units (HRUs) are shown in the right panel of **Figure 1.1**. An HRU is a land area composed of common watershed attributes, such as land-surface elevation, slope and aspect, vegetation type, soil type, and spatiotemporal climate patterns.

Groundwater in ERVB supports numerous beneficial uses:

– Agricultural water supply
– Municipal and domestic water supply
– Industrial water supply
– Freshwater replenishment of surface water, some of which are used as migration corridors for salmon and Pacific lamprey
– Freshwater supply for groundwater-dependent vegetation (phreatophytes), recreation, sport fishing, and tribal land uses and practices

Avoiding undesirable results associated with groundwater conditions using the best available science and information is the key component of a successful GSP (DWR, 2017). Humboldt County retained GHD to work with their subconsultants SHN Consulting Engineers, Stillwater Sciences, and Thomas Gast & Associates, in collaboration with the United States Geological Survey (USGS), to develop a hydrologic model to represent the groundwater system in the ERVB and evaluate changes in conditions caused by changes in groundwater pumping, climate, and other factors.

1.2 Hydrologic Modeling Purpose

The general purposes of hydrologic modeling within the GSP (DWR, 2016a) are to:

1. Support the development of the water budget
2. Support the establishment of sustainable management criteria (SMC)
3. Support identification and development of potential projects and management actions to address undesirable results (if needed)
4. Support refinement of the monitoring network

Undesirable results comprise one or more of the following effects caused by groundwater conditions occurring through the ERVB:

– Chronic lowering of groundwater levels, indicating a significant and unreasonable depletion of supply
– Significant and unreasonable reduction of groundwater storage
– Significant and unreasonable seawater intrusion

– Significant and unreasonable degraded water quality, including the migration of contaminant plumes that impair water supplies
– Significant and unreasonable land subsidence that substantially interferes with surface land uses
– Depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water

A functional hydrologic model of the ERVB provides a tool to assist the Humboldt County GSA in setting sustainable management criteria at representative monitoring sites.

1.3 Hydrologic Modeling Objectives and Tasks

Hydrologic modeling for this GSP was developed based on ERVB-specific and available regional data, including surface water features, topography, water well records, geological features, and existing precipitation runoff modeling completed by USGS.

The objectives of the model analysis involve:

– Representing observed groundwater/surface water interaction along the Eel River, Van Duzen River, and major tributaries, including seasonal variations, then assessing how groundwater uses (e.g., agricultural, industrial, and municipal pumping) may change groundwater discharge to surface water.
– Evaluating the overall water balance for the ERVB through consideration of all interdependent hydrologic processes, as represented in the numerical model, to determine whether groundwater and surface water uses (e.g., agricultural, industrial, municipal pumping, surface water diversions, etc.) are sustainable currently and into the future.
– Determining if current and future groundwater and surface water uses result in an increased inland extent of the currently observed seawater/fresh groundwater interface at the west end of the ERVB.
– Supporting the establishment of minimum thresholds and associated metrics (e.g., groundwater levels, surface water levels and flows, groundwater pumping rates, inland position of seawater intrusion, etc.) that, if exceeded individually or in combination with other thresholds, may cause an undesirable result in the ERVB.
– Supporting the development of a suitable monitoring network to confirm that minimum thresholds are met and maintained.
– Evaluating any management strategies, if needed, to maintain sustainable yield with the ERVB.

Developing the hydrologic model involves the following steps:

1. Review available ERVB-specific and regional hydrologic, geologic, hydrogeologic, and geochemical data.
2. Develop a hydrogeologic conceptual model (HCM) for the ERVB and surrounding areas based on available ERVB-specific regional and information.
3. Develop a three-dimensional (3D) integrated groundwater/surface water model, representing existing ERVB conditions, based on the HCM.
4. Calibrate the groundwater flow model under transient conditions according to observed groundwater elevations, groundwater flow directions, and surface water flow rates observed in ERVB and surrounding areas.
5. Apply the 3D integrated groundwater/surface water model at key monitoring sites to compare groundwater and surface water conditions to applicable sustainability criteria under current and future conditions.
6. Document the development of the integrated groundwater/surface water model and its applications.

To summarize, the integrated groundwater/surface water model was calibrated to provide a reasonable representation of the groundwater flow system and its interactions with certain surface water features within the ERVB. The calibrated integrated groundwater/surface water and seawater intrusion model then was applied to evaluate groundwater and surface water flow conditions to assist the Humboldt County Groundwater Sustainability Agency determine if the effects of current and future water use are significant and unreasonable.

1.4 Summary of Previous Work

The USGS has been investigating regional groundwater availability in California's coastal basins, including the ERVB, and publications are currently pending final review. USGS was not able to provide a written summary of their investigations prior to the publication of this technical memorandum. USGS staff participated in several verbal discussions about USGS work in the ERVB and provided preliminary data sets for GHD's review and use.

1.5 Technical Memorandum Organization

This technical memorandum (TM) is organized as follows:

– **Section 1 – Introduction**: Presents the introduction, purpose, and scope of work of the integrated groundwater/surface water and seawater intrusion modeling conducted for ERVB

– **Section 2** – **Supporting Data and Information**: Presents a summary of the supporting data and information that this technical memorandum is based on, including the HCM prepared for the ERVB, descriptions of water year type, basin inflow and outflow summaries, and InSAR Land Surveying and Mapping

– **Section 3 – Simulation Program Selection**: Presents a description of the simulation programs selected to conduct the integrated groundwater/surface water modeling

– **Section 4 – Integrated Groundwater/Surface Water and Seawater Intrusion Model Construction**: Presents the details regarding the construction of the numerical groundwater/surface water and seawater intrusion models for the transient conditions across the ERVB

– **Section 5 – Integrated Groundwater/Surface Water Model Calibration**: Presents the calibration of the numerical integrated groundwater/surface water flow models to observed surface water and groundwater flow conditions

– **Section 6 – Applications of the Integrated Groundwater/Surface Water and Seawater Intrusion Models**: Presents the applications of the calibrated models to evaluate flow conditions relative to sustainable management criteria for ERVB under current and future conditions

– **Section 7 – Summary and Conclusions**: Summarizes the assessment of ERVB data and model predictions presented in this TM and provides the conclusions reached based on the assessments

– **Section 8 – References:** Lists the references cited in this TM

2. Supporting Data and Information

2.1 Hydrogeologic Conceptual Model

A detailed hydrogeologic conceptual model (HCM) was developed to characterize the physical components of the ERVB [GHD (2021b)]. The HCM technical memorandum [GHD (2021b)] describes the geologic setting, basin stratigraphy, and aquifer characteristics. The principal water-bearing units of the ERVB are (1) the alluvial deposits that form the lower Eel River Valley and portions of the Van Duzen Valley, and (2) the underlying Carlotta Formation. Coarse gravels near active stream channels (channel deposits) also transmit shallow groundwater but are minor units compared to the depth and extent of the alluvial deposits.

2.2 Basin Inflow and Outflow Summary

The Basin inflow and outflow summaries are based on the Basin water budget. 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 and gaged stream flow. Other components are estimated, such as ungauged stream inflow, unmetered domestic well use, and septic system infiltration. Further water budget components are calculated from the hydrologic model, such as precipitation infiltration, and surface water seepage into groundwater. The Basin inflow and outflow summary presents estimated annual totals of inflows and outflow, measured in acre-feet.

The Basin water budget incorporates historical water uses and conditions that represent the variation in climatic conditions from year to year. The DWR defines five different water year types: wet, above normal, below normal, dry, and critically dry. The historical period used in the water budget represents each of these water year types. The development of the basin water year type uses the DWR methodology with local precipitation data from within the Basin (station in Ferndale) and is described in the next section.

2.2.1 Water Year Type

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 most of the 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.

In January 2021, to support the development of GSPs, DWR presented a methodology for designating water year types for watersheds outside the Sacramento and San Joaquin Valleys. DWR’s methodology is based on selecting a 30-year period and dividing the record into five (5) categories of water year type according to specified weighting percentages (Table 1). 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 1 Water Year Classifications (DWR, January 2021)

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

DWR (January 2021) also published a data set of water year classifications for various hydrologic units around California, including the lower Eel River (HUC 18010105), which encompasses 1,510 square miles and extends upstream to the confluence with the Middle Fork of the Eel River at Dos Rios, in Mendocino County. This hydrologic unit hosts a wide range of climatic conditions (e.g., a combination of coastal and inland areas), but the representation of water year types for the ERVB 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) were obtained from Jerry Lema of the Ferndale Museum (515 Shaw Avenue), where a rain gauge has been operated 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. Rainfall data collected at these Ferndale sites is presumed to be more representative of the ERVB than the regional composite data used by DWR (January 2021).

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

$$\text{Water Year Index} = (0.70 \times \text{current water year precipitation}) + (0.30 \times \text{previous water year precipitation})$$

The equation is applied to each year in the 30-year period to develop index values, which are then ranked from highest to lowest to assign each year to the five (5) water year type categories. The results from applying this methodology to the Ferndale rainfall data for the 30-year period of 1992 to 2021 are summarized in Table 2 and depicted on Figure 1.

Table 2 Water Year Types with Annual Precipitation, Index Values, and Ranking (1992-2021)

Water Year	Annual Precipitation (inches)	Water Year Index	Index Rank (30 is wettest and 1 is driest)	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

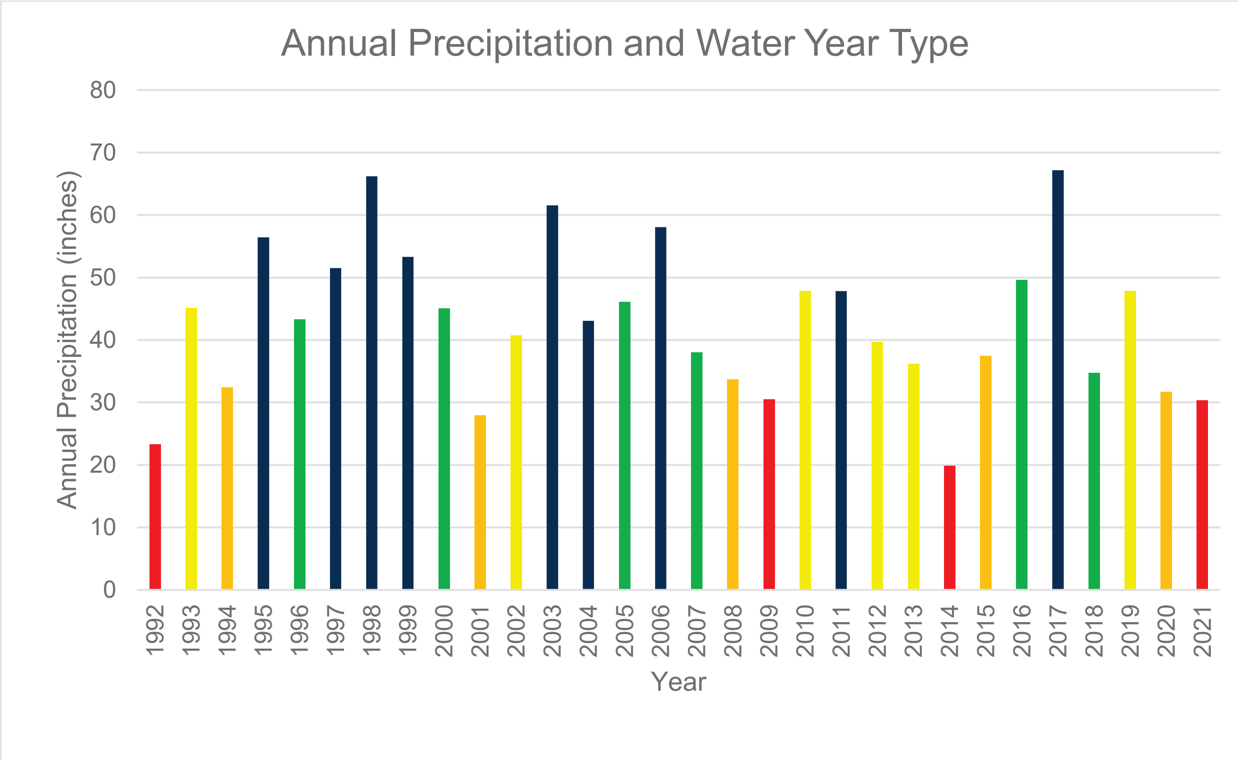

Figure 1 ***Water Year Types (1992-2021), Based on Annual Rainfall Data Collected in Ferndale***

2.2.2 Basin Inflow Summary

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.

– **Streamflow 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 total flow volumes for the period of record.

– **Precipitation Runoff to Streams** – This is a surface water inflow. Precipitation runoff to streams was estimated using the Precipitation Runoff Modeling System (PRMS). 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 streams in the Yager, Salt River, and Price Creek drainages. Precipitation runoff to smaller tributaries in the ERVB, including Reas and Williams Creeks, is accounted for through runoff to the larger surface water feature where these creeks discharge (e.g., Salt River). These creeks gain flows from precipitation runoff. Routing that precipitation runoff directly to the larger surface water feature through application of PRMS is a suitable method for accounting for those flows. It should be noted that the PRMS estimates runoff from areas of these contributing watersheds that are outside of the Basin boundary.

– **Wastewater Effluent Discharge** - This is a surface water inflow. Treated wastewater is directly discharged 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 Discharge to Streams** – This is a surface water inflow. Steams reaches that receive flow from groundwater are known as gaining streams. Stream reaches may vary from gaining to losing 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 the Basin. This process is described in more detail in Section 4.2.3.

- **Precipitation Infiltration** – This is a groundwater inflow. Precipitation infiltration is estimated using PRMS and is described in Section 3.3. The infiltration volumes are estimated on a monthly basis and are used in the water budget and as a groundwater model input.
- **Streamflow to Groundwater** – This is a groundwater inflow. This is calculated the same as groundwater to stream and represents the losing reach condition.
- **Municipal Waste Water Treatment Plant (WWTP) Land Application** - This is a groundwater inflow. 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** - This is a groundwater inflow. 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.

The yearly volume of surface water inflow for each of the components above, along with the yearly total volumes are presented for the 2011 through 2020 water years below in Table 3.

Table 3 Surface Water Inflow for 2011 through 2020 Water Years

Water Year	Type	Water Budget Component				
		Stream Flow (af/yr)	Precipitation Runoff to Steams (af/yr)	WWTP Effluent (af/yr)	Groundwater Discharge to Stream (af/yr)	Yearly Total (af/yr)
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

The yearly volume of groundwater inflow for each of the components above, along with the yearly total volumes are presented for the 2000 through 2020 water years below in Table 4.

Table 4 Groundwater Inflows for 2011 through 2020 Water Years

Water Year	Type	Water Budget Component				
		Precipitation Infiltration (af/yr)	Stream Flow to Groundwater (af/yr)	Municipal WWTP Land Application (af/yr)	Industrial and Domestic Septic System (af/yr)	Yearly Total (af/yr)
2011	Wet	71,383	183,413	1,024	426	256,246
2012	Below Normal	51,015	177,473	919	426	229,833
2013	Below Normal	45,288	171,097	1,235	426	218,045
2014	Critical	8,312	147,646	1,178	426	157,562
2015	Dry	38,181	167,894	1,252	426	207,753
2016	Above Normal	79,360	181,308	858	426	261,953
2017	Wet	116,417	188,665	882	426	306,391
2018	Above Normal	41,591	143,895	999	426	186,911
2019	Below Normal	85,027	169,965	1,019	426	256,437
2020	Dry	27,953	130,016	1,223	426	159,618
Assumptions: no subsurface inflow at upstream boundaries						

2.2.3 Basin Outflow Summary

The Basin outflow summary is estimated in a manner similar to the Basin inflow. The following list describes the water budget component used in the outflow summary and identifies the source of the data.

- **Municipal Drinking Water Diversion** – The is a surface water outflow. The municipalities of Rio Dell and Scotia 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** – This is a surface water outflow. Surface water diversion for irrigation is a relatively small portion of the total water supply for irrigation. 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 Resource Conservation District (HCRCD). The demand rates are presented as a volume of water per land area. A detailed description of the process is presented in the Agriculture Water Use Technical Memorandum (Humboldt County Department of Public Works and HCRCD, 2021).
- **Streamflow to the Pacific Ocean** – This is a surface water outflow. 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 (DWR, 2016b) where all other surface water flows are known or estimated.
- **Streamflow to Groundwater** - This is a surface water outflow and a groundwater inflow. This is calculated the same as groundwater to stream and represents a losing reach condition.
- **Evapotranspiration (open water, riparian, urban landscape)** – This is a surface water outflow. This parameter was estimated using the DWR's 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 an annual rate.

- **Municipal Groundwater Pumping** – This is a groundwater outflow. Municipal groundwater pumping volumes were provided by the nine municipalities or service districts for calendar years 2010 to 2020. For periods where direct pumping volumes were not available, they were estimated based on average monthly rates and water year types. Monthly and annual amounts were tabulated and used for this analysis.
- **Non-Municipal Domestic and Industrial Pumping** – This is a groundwater outflow. 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 or industrial process for the given parcels. Water use for the parcel was based upon land use zoning, parcel improvements, and parcel size.
- **Irrigation Pumping** – This is a groundwater outflow. 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 HCRCD and the County using flow meter data from several irrigated facilities. These rates vary by month and water year type. Water year type was used to apply the appropriate demand in the water balance. The demand rates are presented as a volume of water per land area. A detailed description of the process is presented in the Agriculture Water Use Technical Memorandum (Humboldt County Department of Public Works and HCRCD, 2021).
- **Cannabis Pumping** – This is a groundwater outflow. 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. 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. This was based upon CDFW estimates for other north coast basins.
- **Non-Municipal Commercial and Industrial Pumping** – This is a groundwater outflow that has been estimated for parcels that are outside of municipal water supply systems. The pumping rates per parcel were based upon the number of dwelling units assigned to each parcel, the number of people per dwelling unit, and water demand per person. There were 1498 parcels that had or had the potential to have a domestic dwelling. The number of dwelling units for each parcel was assigned based upon the zoning, zoning description and parcel improvements. Dwelling units per parcel ranged from 1 to 10. It was assumed that there were 2.4 persons per dwelling unit. This value was based upon the US Census website for Humboldt County. The water use per person was assumed to be 100 gallons per day per person. This value is conservative and is consistent with USGS Estimated Use of Water in the United States in 2015 (USGS 2017). This resulted in 240 gallons per dwelling unit per day. The yearly domestic water demand was calculated by multiplying the number of dwelling units per parcel by the water demand per dwelling unit by the number of days in the year. The yearly domestic water demand per parcel ranged from 0.27 to 2.69 acre-feet per year. The total domestic water demand is calculated by summing up the yearly domestic water demand for all selected parcels.
- **Evapotranspiration (irrigated crop, natural vegetation)** – This is a groundwater outflow. 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 HCRCD 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 an annual rate.
- **Groundwater Outflow to Ocean** – This is a groundwater outflow. Groundwater flow to the Pacific 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.
- **Change in Groundwater Storage** – This is a groundwater outflow. The change in groundwater storage is estimated using an integrated groundwater/surface water model described in Section 3.2. Change in groundwater storage is calculated by subtracting the average groundwater volumes for a representative average reference period (March 2003) from March groundwater volumes for each year between water year 2000 and

water year 2020. Selection of the representative average reference period is described in Section 6.1.1 and the process for calculating change in groundwater storage is described in detail in Section 6.2.2.

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 5.

Table 5 Surface Water Outflow for 2011 through 2020 Water Years

		Water Budget Component (af/yr)					
Water Year	**Type**	**Municipal Drinking Water Diversion**	**Irrigation Diversion**	**Streamflow to Pacific**	**Streamflow to Groundwater**	**Evapotranspiration (open water, riparian, urban landscape)**	**Yearly Total**
2011	Wet	847	63	14,630,478	183,413	103,641	14,918,442
2012	Below Normal	857	76	9,707,030	177,473	96,967	9,982,404
2013	Below Normal	893	76	8,597,300	171,097	101,454	8,870,820
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

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 6.

Table 6 Groundwater Outflow for 2011 through 2020 Water Years

Water Year	Type	Water Budget Component (af/yr)								
		Municipal	Non-Municipal Domestic	Irrigation	Cannabis	Non-Municipal Commercial and Industrial	ET (irrigated crop, natural vegetation)	GW Outflow to Ocean	Change in GW Storage	Yearly Total
2011	Wet	1,772	414	10,694	98	34	96,881	131,417	14,936	256,246
2012	Below Normal	1,727	414	12,196	98	34	89,551	118,894	6,919	229,833
2013	Below Normal	1,764	414	12,196	98	34	84,998	130,236	-11,695	218,045
2014	Critical	1,814	414	14,848	98	34	86,118	72,390	-18,154	157,562
2015	Dry	1,599	414	13,522	98	34	82,571	121,312	-11,798	207,753
2016	Above Normal	1,660	414	11,754	98	34	89,666	139,590	18,737	261,953
2017	Wet	1,673	414	10,694	98	34	88,050	161,761	43,667	306,391
2018	Above Normal	1,729	414	11,754	98	34	89,666	98,527	-15,312	186,911
2019	Below Normal	1,758	414	12,196	98	34	88,965	112,024	40,948	256,437
2020	Dry	1,832	414	13,522	98	34	82,884	84,842	-24,009	159,618

2.3 Basin Inflow/Outflow Model Uncertainty

The groundwater model and methods 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 will be recalibrated to maintain accuracy. Table 4 provides an inventory of model assumptions and gaps in model data.

3. Simulation Program Selection

A groundwater flow model simulation is a simplified representation of groundwater flow conditions based on principles of physics and conservation of mass/water. Model simulations are aided by programs for model construction, parameter estimation, uncertainty analysis, graphical visualization, and pre- and post-processing. The selection of a simulation program for groundwater modeling applications is 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

These considerations complement the DWR four (4) Guiding Principles for Models Used in Support of GSPs (DWR, 2016a), described below.

3.1 Summary of DWR Guiding Principles for Models Used in Support of GSPs

As described by DWR (2016a), the intent of the 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. The four (4) 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.

3.2 Integrated Groundwater/Surface Water Flow Model (MODFLOW)

MODFLOW, developed by the USGS, is capable of simulating steady-state or transient groundwater flow in two or three dimensions. MODFLOW uses finite-difference methods, leading to a numerical approximation that allows for a description and solution of complex groundwater flow problems. A rectangular grid is superimposed over the study area to horizontally divide the region of interest into rectangular model cells, while layers are used to vertically divide the study area into units of common hydrogeologic properties. Groundwater flow is formulated as a differential water balance for every model cell; hydraulic head is solved at the center of every model cell. MODFLOW allows for the specification of flows associated with wells, areal groundwater recharge, rivers, drains, streams, and other groundwater sources/sinks.

MODFLOW-2005 (Harbaugh, 2005, 2005) was selected to simulate groundwater flow for model construction, calibration, and applications during this modeling study due to its speed and stability of convergence. MODFLOW-2005 is an update to the original MODFLOW (McDonald and Harbaugh, 1988). MODFLOW is an open-source code, extensively verified and readily accepted by many regulatory agencies throughout North America and Europe. The MODFLOW family of codes—including MODFLOW-2005, SEAWAT (Langevin et al., 2008), and MT3DMS (Zheng and Wang, 1999) for solute transport simulations—operate using a series of human-readable American Standard Code for Information Interchange (ACII) text files, facilitating transparent review by third parties.

MODFLOW-2005 is capable of representing the hydrogeologic components within the ERVB. It is able to account for the effects of pumping on streamflow and to quantifying the depletion of interconnected surface waters when using the streamflow routing package, SFR2, to represent surface water flow conditions.

Each member of the MODFLOW family of codes for model construction, calibration, and application, described in the sections below, used one of two matrix solution solvers: the preconditioned conjugate gradient (PCG2) (Hill, 1990) for MODFLOW-2005 and the geometric multigrid (GMG) (Wilson and Naff, 2004) for SEAWAT. The GMG solver provides a better flow balance under most conditions compared to the PCG2, but can have difficulty converging, particularly for long-term transient models. For this reason, both matrix solvers were used. Regarding convergence of the solvers, the solution technique requires the satisfaction of both hydraulic head change and flow residual criteria, providing a more rigorous and reliable simulated water balance throughout the model domain.

3.2.1 Streamflow Routing (SFR2)

Within MODFLOW, groundwater/surface water interaction is represented using the Streamflow Routing (SFR2) package (Prudic et al., 2004; Niswonger and Prudic, 2005), which calculates flows between streams and groundwater based on stream and groundwater levels. Flow is routed downstream based on the calculated flow in and out of the streams. The SFR2 package includes several options for calculating stream water levels based on stream flow that account for streambed geometry, streambed elevations, channel slope, wetted perimeter, and roughness. Implementation of SFR2 in MODFLOW-2005 was aided through using the Precipitation Runoff Modeling System (PRMS), described in the following section.

3.3 Precipitation Runoff Modeling System (PRMS)

PRMS was developed to evaluate the response of various combinations of climate and land use on streamflow and general watershed hydrology. PRMS simulates hydrologic processes (e.g., evaporation, transpiration, runoff, infiltration, and interflow) 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. Areal recharge of groundwater and runoff that discharges to surface water are estimated based on land use, dominant vegetation covering the soil surface, and surficial soil types. PRMS represents hydrologic responses over HRUs. HRUs that contribute water to ERVB are illustrated as yellow polygons on the right panel of **Figure 1.1**.

On November 12, 2020, the USGS provided GHD a provisional PRMS model for areas contributing to ERVB groundwater flow (e.g., the areas depicted in yellow on the right panel of **Figure 1.1**). The model is provisional in that continued modifications were necessary for it to be able to suitably aid GSP development, and because the USGS does not bear responsibility for modifications made to the model by outside parties. This model is a subset of 183 HRUs and 94 surface water (stream) segments from the National Hydrography Dataset. Parameters for the provisional PRMS model were originally obtained from the National Hydrologic Model (NHM) (Regan et al., 2018) and subsequently modified by USGS[1] to match local conditions. This existing model spans the period of 1980 to 2016. The model has subsequently been updated to include 2017 through 2020 using gridded spatial climate datasets, including precipitation and minimum and maximum temperatures developed by Oregon University's Parameter-elevation Regressions on Independent Slopes Model (PRISM) Climate Group (PRISM Climate Group, 2004).

3.4 Seawater Intrusion Model (SEAWAT)

Density-dependent flow and saltwater intrusion models were developed using SEAWAT-V4 (Langevin et al., 2008), which is an update of SEAWAT-2000 (Langevin et al., 2003). Similar to SEAWAT-2000, SEAWAT-V4 is a coupled version of MODFLOW and MT3DMS (Zheng and Wang, 1999; Zheng, 2006) designed to simulate 3D, variable-density, saturated groundwater flow. SEAWAT-V4 is capable of accounting for the effects of irrigation pumping on seawater intrusion.

SEAWAT-V4 requires aquifer or point water heads[2] as input (i.e., for specification of constant head boundary conditions) and provides point water heads as output, though SEAWAT-V4 performs all internal calculations of groundwater flow and hydraulic head using equivalent freshwater heads with additional terms to account for variations in water density.

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1 USGS matched to observed local conditions by reducing the exchange between groundwater and the gravity reservoir above the water table to be representative of flow systems in the mountains, then adjusting rainfall intensities. The term "gravity reservoir" refers to the slow drainage to the groundwater flow system from the soil profile. Stream segments were also filtered to include only stream segments with arbolate sums (e.g., the length of upstream surface water features) greater than 12.5 miles for perennial streams and 31 miles for intermittent streams.

2 As described in Guo and Langevin (2002), aquifer or point water head at a given point in a saline aquifer is the level to which ambient saline groundwater in the aquifer will rise in a tightly-cased piezometer open to that point (assuming the water column in the piezometer casing contains a uniform density equal to that of the aquifer at that point).

The USGS's GMG solver (Wilson and Naff, 2004) matrix solution method included in SEAWAT-V4 was employed to solve the variable-density groundwater flow equation.

3.5 Parameter Estimation and Uncertainty Analysis (PEST)

The calibration of the coupled seawater intrusion model and integrated groundwater/surface water model was aided by use of the parameter estimation program Parameter Estimation++ (PESTPP) (PEST++ Development Team, 2021), an update to parameter estimation software, PEST (Watermark Numerical Computing, 2021) and written in C++ with several additional capabilities for uncertainty analysis. PEST and PESTPP are model-independent parameter estimators that have become groundwater industry standards for model calibration. PESTPP has a powerful inversion engine which can set bounds on model input parameters such as hydraulic conductivity and groundwater recharge, though combinations of highly correlated input parameters can result in more than one solution that minimizes the error between simulated and observed conditions. When there is more than one solution (as in a combination of input parameter values) that minimizes the error between simulated and observed conditions, the model is said to be non-unique. Non-uniqueness can result in uncertainty in model predictions. An iterative ensemble smoother (IES) methodology, described and demonstrated in White (2018) and based on methods described in Chen and Oliver (2013), has been implemented in PESTPP through the PESTPP-IES mode.

PESTPP collectively conveys input parameters or parameter multipliers at variable values within their bounds to the model codes for the purpose of establishing an ensemble of optimal input parameter values for a set of model realizations. (For example, one model based on one ensemble of parameter input values is a model realization.) For each run of input parameters, PESTPP-IES calculates objective function values (OFV) at model observation points or cells. OFVs represent the error of calculated versus observed groundwater elevations, discharge rates, or concentrations. Of the numerous runs, PESTPP-IES selects a suite of models that each meet model calibration criteria. This approach allows a quantification of model prediction uncertainty that is constrained by model calibration, referred to as a calibration-constrained uncertainty analysis (CCUA) (Doherty, 2015). The application of CCUA for this study is described in Section 5.2

3.6 Graphical User Interface (GUI)

The graphical user interface (GUI) Groundwater Vistas (Rumbaugh and Rumbaugh, 2020) will be employed as the interface between the assembled hydrogeologic data, the required MODFLOW family of codes, and PEST input files. Although the GUI is not an open-source application, input and output files are human-readable and executed using open-source codes described in Sections 3.3 and 3.5. In other words, the GUI is used to create the model files, but the GUI is not the model.

3.7 Pre- and Post-processing

Some pre- and post-processing will be achieved using the 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.

In particular, python will be used extensively with the FloPy library (Bakker et al., 2016) to manage MODFLOW files outside of the GUI and with the pyPRMS library (Norton, 2019) for fine-tuning the existing PRMS input files, which are not supported by a GUI. These libraries are publicly available.

4. Integrated Groundwater/Surface Water and Seawater Intrusion Model Construction

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. The process for model construction, in relation to these aspects of the groundwater flow model, is presented in the following sections.

4.1 Model Spatial Domain and Discretization

The model domain should extend to where reasonably defensible boundary conditions can be established. Where possible, model domain limits, and associated boundary conditions, should be based on natural hydrogeologic features at a regional scale. Boundary conditions must be selected to minimize potentially incorrect biases to model predictions within the area of interest[3].

The selected model domain for this modeling study is shown on **Figure 4.1**., extending approximately 121.5 miles northwest-southeast and approximately 75 miles southwest-northeast. The model domain is oriented with its vertical and horizontal axes arranged northwest-southeast and southwest-northeast respectively to align the average observed groundwater flow directions within the ERVB, which flow predominantly northwest towards the Pacific Coast. Aligning the model domain with the primary flow directions minimizes potential numerical dispersion[4] in subsequent seawater intrusion simulations.

A rectangular finite-difference grid was extended over the groundwater flow model domain, details of which are illustrated in **Figure 4.1**. Horizontally, the model domain is discretized into rows and columns. A minimum finite-difference grid spacing of 1,000 feet by 1,000 feet was assigned to the ERVB to provide sufficient resolution for integrated groundwater/surface water simulations and analysis, as well as for the seawater intrusion simulations. The grid spacing was progressively increased outside the ERVB towards the model domain limits to a maximum of 10,000 feet by 10,000 feet. Horizontally the model is discretized into 103 rows and 291 columns.

The number of model layers varied depending on the application. A total of six (6) and 15 model layers was assigned to the integrated groundwater/surface water and saltwater intrusion models, respectively, with the larger number for the seawater intrusion model layers intended to limit numerical dispersion[5] in the vertical direction. Hydrostratigraphy represented by each model layer is presented below; the structure of the model layers for the integrated groundwater/surface water model is presented on **Figure 4.2** along cross-section A-A'.

Stratigraphy	Integrated Groundwater/Surface Water Model Layers	Seawater Intrusion Model Layers
Coarse Gravels Near Active Stream Channels (Channel Deposits)	1	1
Quaternary Alluvium (Qal)	1 - 2	1 - 11

[3] For example, identifying a river boundary condition with specified stage elevations near a pumping well when the purpose of the analysis is to evaluate the effect of pumping on river flow. Stage elevations could supply an unlimited amount of water to the well, thus introducing a reduced effect (e.g., a potentially incorrect bias) of the pumping on the simulated groundwater flow field.

[4] When groundwater flow models are developed using finite-difference methods, advective flow and mass transport are perpendicular to the finite-difference model cell face. When these faces are not oriented perpendicular to primary flow directions, flow and transport to neighboring cells is only approximated through face-contacting model cells, resulting in gradually dispersive broadening of the transport mass. This dispersive broadening is referred to as numerical dispersion, specifically it is angular-numerical dispersion (Spitz and Moreno, 1996).

[5] The advection dispersion equation is solved at the center of each active finite-difference model cell using finite-difference methods and represents mass throughout the entirety of the model cell. This means that a model cell downgradient of the chloride front will show concentrations even when the actual front has not actually reached the midpoint of the model cell. This is another form of numerical dispersion, specifically it is distance-related numerical dispersion (Spitz and Moreno, 1996) and can be reduced by increasing the vertical discretization.

Stratigraphy	Integrated Groundwater/Surface Water Model Layers	Seawater Intrusion Model Layers
Hookton Formation (Qh)	1 - 2	1 - 11
Upper Carlotta (Qtc upper)	1 - 5	1 - 14
Lower Carlotta (Qtc lower)	1 - 6	1 - 15

Vertical discretization involved assigning the bottom of Model Layer 1 to be a minimum of 10 feet below the static dry water table conditions (i.e., based on historical water levels measured between the months of May and October)[6]. This approach limits the amount of repeated drying and re-wetting of model cells during solution iterations. The thickness of each stratigraphic unit within the ERVB was modified from the thickness rasters[7] provided by the USGS for this project to better reflect the interpretation of field investigation results from 2021[8]. Where the thickness of a stratigraphic deposit was less than 10 feet it was assumed to pinch out and assigned the hydrogeological properties from the model layer below. This resulted in stratigraphic deposits that are represented in a range of model layers. Outside of the ERVB, minimal model layer thicknesses (i.e., 1 ft) were assigned because interaction between surface water and groundwater is limited in these areas due to the competent rock of mountainous regions, but surface water still needed representation in active model cells.

The integrated groundwater/surface water and seawater intrusion models contain a total of 114,948 and 287,370 finite-difference model cells (of which 18,826 and 44,741 are active for flow), respectively.

4.1.1 Time Discretization

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[9] 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 (1) month and timesteps that spanned one (1) day.

4.2 Flow Model Boundary Conditions

Inactive areas of the model domain define the limits of the active areas of the model domain and are depicted by grey fill no-flow cells on **Figure 4.1**. 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

6 See, for example, Figure 3 from SHN (2021a).

7 A raster is a digital method of storing spatial information whereby values that vary across a geographical space, such as stratigraphic thicknesses, are assigned to a matrix of rows and columns.

8 Based on 2021 field investigations (GHD, 2021b) the stratigraphic unit underlying the Quaternary alluvium was interpreted as an upper unit of the Carlotta formation composed of fine-grained silts and clays. The USGS raster for this zone was defined as Hookton formation deposits. Model stratigraphy reflects the 2021 field investigation interpretation (i.e., that this zone is an Upper Carlotta). The thickness of the Upper Carlotta was assumed to be consistent with the USGS-interpreted Hookton formation where the Hookton formation underlies Quaternary alluvium. Hookton Formation is expected to be located along the terraces at the north and northeastern margins of the Basin as illustrated on **Figure 4.6** in Section 4.3.

9 A warm-up period allows any errors associated with the initial representation of the groundwater flow system to work their way through the system so they don't affect simulation targets or model outputs of interest, such as stage elevations or river flows.

– 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

4.2.1 No-Flow Boundary Conditions

No-flow boundary conditions were applied where negligible groundwater flow across a model boundary could be reasonably expected, specifically along the south 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. The northern side of the ERVB is bounded by the axis of the Table Bluff anticline to the west and the Little Salmon fault to the east (illustrated on Hydrologic Conceptual Model TM, Figure 3 of GHD (2021b)). The eastern limit of the ERVB is 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.

In the mountainous regions outside of the ERVB, no-flow boundaries are assigned adjacent to surface water features to represent the limited interaction between groundwater and surface water expected.

At the bottom of the model, a no-flow boundary condition was applied, which is representative of the base of the Carlotta formation and the base of the ERVB as described by GHD (2021b) and Ogle (1953).

4.2.2 Constant Head Boundary Condition

A constant head boundary condition at the northwest (downgradient/discharge) model domain limit represents both the Pacific Ocean and the exchange of groundwater and surface water with the ocean. The elevation was specified as a uniform long-term average (i.e., greater than 1 one [1] month) of 0 feet (NAVD 88). It is recognized that the Pacific Coast is tidally influenced and that tidal changes vary across a period that is less than one (1) day.

4.2.3 Streamflow Routing and River Boundary Conditions

The manners in which the integrated groundwater/surface water and seawater intrusion models represent surface water features vary. The interaction between groundwater and surface water is a primary topic of interest in the ERVB and an accurate representation is required. Of those in the MODFLOW family of codes, the SFR2 package (Prudic et al., 2004; Niswonger and Prudic, 2005) is the most accurate representation of this interaction. However, SEAWAT, the model that was applied to evaluate seawater intrusion in the ERVB, predates development of SFR2 and does not include this more accurate representation of the interaction of groundwater and surface water. Therefore, it was necessary to represent surface water features as SFR boundary condition cells in the integrated groundwater/surface water models and as river boundary condition cells in the seawater intrusion models.

The SFR2 package calculates flows between streams and groundwater based on stream and groundwater levels. Flow is routed downstream based on the calculated flow in and out of the streams. The SFR2 package includes several options for calculating stream water levels based on stream flow that account for streambed geometry, streambed elevations, and channel slope, wetted perimeter, and roughness.

Figure 4.2 shows a representative SFR boundary condition model cell perpendicular to Eel River near Fortuna. As illustrated on **Figure 4.1** SFR boundary condition model cells were assigned to represent natural surface water features throughout the Eel River and Van Duzen watersheds. SFR2 calculates volumetric flow between a section of stream within a boundary condition model cell, using the following formula:

$$Q_L = \frac{KwL}{m}(h_s - h_a) \qquad \text{Equation 4.1}$$

where:

Q_L = volumetric flow between section of stream and volume of aquifer (cubic ft/day)

K = hydraulic conductivity of the streambed sediments (ft/day)

w = width of the stream within the model cell (ft)[10]

L = length of the stream within the finite-difference model cell (ft)

m = thickness of streambed deposits extending from the top to the bottom of the streambed (ft)

h_s = stream stage elevation, calculated by adding the streambed elevation to stream depth (stream depth calculated using Equation 4.3 below) (ft NAVD88)

h_a = head in the aquifer beneath the streambed (ft NAVD88)

The first term on the right-hand side of Equation 4.1 is a conductance term that relates the capacity of the riverbed material to convey water between the groundwater and surface water flow systems. This conductance term is defined as:

$$C=\frac{KwL}{m} \qquad \text{Equation 4.2}$$

where:

C = conductance term (square ft/day)

Values for K and m were adjusted during model calibration.

Streamflow routing is calculated within each SFR boundary condition finite-difference model cell based on the continuity equation so that all volumetric inflow is equal to outflow minus all sources and sinks to the stream. The SFR2 package calculates volumetric flow at the midpoint of each SFR boundary condition cell (Q_{mpt}) as follows:

$$Q_{mdpt}=Q_{trb}+0.5\left(Q_{ro}+Q_{ppt}-Q_{et}-Q_L\right) \qquad \text{Equation 4.3}$$

where:

Q_{trb} = inflow into the SFR boundary cell from upstream SFR boundary cells (cubic ft/day)

Q_{ro} = direct overland runoff (cubic ft/day)

Q_{ppt} = precipitation that falls directly on the stream reach within the finite-difference model cell (cubic ft/day)

Q_{et} = evapotranspiration from a stream reach within the finite-difference model cell (cubic ft/day)

Q_L = leakage through the streambed; positive when flow is from the stream reach to the aquifer, and negative when flow is from the aquifer to the stream reach (cubic ft/day)

Values for Q_{ppt} were obtained from the PRISM (PRISM Climate Group, 2004) data set by assigning monthly average precipitation to the centroid of each HRU that then were assigned to intersecting stream reaches. Values for Q_{et} and Q_{ro} were determined based on output from the calibrated PRMS model that were translated to each stream reach in the SFR model input file. Q_{ro} was adjusted during model calibration.

Stream depth is calculated based on the following:

$$D_{stage}=\left[\frac{Q_{mdpt}n_{Manning's}}{CwS_0^{1/2}}\right]^{3/5} \qquad \text{Equation 4.4}$$

[10] Stream widths were estimated based on the North American River Width Dataset (NARWidth) (Allen and Pavelsky, 2015). Where stream widths were not available within NARWidth they then were estimated based on an empirical power relationship presented in Leaf et al. (2015) and Feinstein (2010).

where:

D_{stage} = stream depth (ft)

$n_{Manning's}$ = Manning's roughness coefficient (standard units) that was modified during the calibration process

C = a constant that is equal to 128,390.4 $ft^{1/3}$/day when volumetric flow is in units of cubic ft/day

S_0 = slope in the stream channel (ft/foot)

For the seawater intrusion models, SFR boundary condition model cells were replaced with river boundary condition cells, which provide a simpler representation of the interactions between groundwater and surface water. If a specified river stage elevation is lower than the simulated groundwater elevation, the river boundary receives discharge from groundwater. If the specified river stage elevation is higher than the simulated groundwater elevation, the river boundary serves as a recharge to groundwater. Regardless, the river package does not itself determine the river stage but must be specified by the user. For seawater intrusion analyses, stage elevations were translated from output from the SFR2 in the integrated groundwater/surface water models to ensure continuity between the two representations of the ERVB.

The quantity of surface and groundwater exchange when using river boundary condition model cells is equal to the difference between the simulated groundwater elevation within the river cell and the specified head within the river cell, multiplied by a conductance term (as expressed in Equation 4.1).

4.2.4 Groundwater Pumping Wells

As described in Section 2.1.3, municipal water supply wells, industrial supply wells, and irrigation wells are located within the model domain, and are represented in the model as analytical elements. As described in Section 2.1.3, pumping rates were estimated based on Water Year Type, Month of Year, and land use classification (irrigation, industrial, or domestic supply). Where well screen information was available, wells were assigned to the model layer that corresponds to the mid-screen elevation. Where well screen information was not available, wells were assigned to Model Layer 1. Locations of the wells are presented on **Figure 4.3** and ranges of pumping rates assigned to wells are listed in **Table 4.1**.

Two municipal supply wells, Scotia and Rio Dell, obtain their water supply from infiltration galleries and don't pump from the groundwater flow system. These two wells are represented in the groundwater flow model as diversions from the SFR boundary condition model cells at those locations.

4.2.5 Recharge

Recharge from precipitation infiltration was applied as the top boundary condition for the model domain. The amount of precipitation reaching the groundwater table as recharge depends on topography, shallow soil types, ground cover and land use (vegetation or building/pavement coverage), season, weather conditions, etc. Monthly recharge values for 1980 through September 2020 were obtained from a calibrated PRMS simulation output. **Figure 4.4** shows the ranges of recharge rates applied to HRUs within the ERVB between water year 2000 (i.e., after model warm-up) and 2020. Applied recharge varied on a monthly basis so that a representative recharge rate was applied to each HRU for each model stress period. The inset on the right side of **Figure 4.4** shows monthly recharge rates applied to each HRU. These monthly rates also are listed in **Table 4.2**.

4.2.6 Seawater Intrusion Model Groundwater Density

Variations in the densities of groundwater near the coast influence groundwater flow conditions and seawater intrusion, representing the presence of groundwater with such characteristics as:

– Fresh groundwater from precipitation recharge

– Regional fresh groundwater inflow through the ERVB from upgradient locations
– Fresh groundwater from regional rivers and streams
– Fresh groundwater and seawater distributions created by the saltwater present in the Pacific Ocean

In a variable-density groundwater flow model, a groundwater density distribution must be specified. For seawater intrusion model applications, an initial distribution of density was allowed to evolve to simulate, under natural conditions in the absence of pumping, the development of the naturally occurring fresh groundwater and seawater distributions within the groundwater flow system. This initial seawater intrusion simulation was started with the density distribution of fresh groundwater throughout the model domain. The movement of seawater inland from the Pacific Ocean was simulated until an approximately stable distribution of fresh groundwater and seawater was established. For the transient seawater intrusion application models, density distribution was allowed to change through time as the simulation progressed.

Density values are specified in the constant head boundary condition cells representing the Pacific Ocean. In the absence of measured specific gravity near the ERVB, estimated specific gravity values of 1,025,000 mg/L and 1,000,000 mg/L were specified for seawater at the Pacific Coast and fresh groundwater, respectively, based on values presented in Langevin et al. (2008). A constant chloride concentration of 19,400 mg/L was specified for seawater at the constant head boundary condition model cells representing the Pacific Ocean. An equation relating chloride concentration to groundwater density was developed as follows:

$$\rho = 1{,}000{,}000\text{mg/L} + 1.289 \times C_{Cl} \qquad \text{Equation 4.5}$$

where:

ρ = groundwater density (mg/L)

C_{Cl} = groundwater chloride concentration (mg/L)

For the seawater intrusion models, uniform dispersivity values were specified throughout the model domain. Dispersivity is dependent on the scale of the groundwater migration path under consideration. Longitudinal dispersivity values were estimated based on the approximate distance from the coast to the observed 100 mg/L chloride isoconcentration profile delineated by Johnson (1975) and illustrated on **Figure 4.5** and an empirical relationship that relates migration path length with longitudinal dispersivity (Xu and Eckstein, 1995). That empirical relationship is described as follows:

$$\alpha_L = 1.2 \times \log_{10}\left(\frac{L}{3.2808\text{ feet/meter}}\right)^{2.958} \times 3.2808\text{ feet/meter} \qquad \text{Equation 4.6}$$

where:

α_L = longitudinal dispersivity (feet)

$\log_{10}$ = base-10 logarithm

L = migration path length (feet)

Based on Equation 4.5 and a seawater migration path length of 21,000 feet (see **Figure 4.5**) an horizontal dispersivity value of 200 feet was applied to the seawater intrusion model. The horizontal and vertical dispersivity values were specified to be 1/10 of the longitudinal dispersivity. This aligns with observations by Gelhar et al. (1992).

As chloride moves through hydrostratigraphic deposits, it moves through the mobile pore fraction, which corresponds to the segments of an aquifer that have the highest permeability and can be substantially smaller than the drainable fraction (i.e., that of specific yield or effective porosity) (Payne et al., 2008). A mobile fraction of 1 percent was applied uniformly throughout the ERVB. This is consistent with mobile pore fractions reported in other alluvium basins (Payne et al., 2008).

4.3 Model Hydraulic Conductivity Distribution

Hydraulic conductivity zones were assigned in the model to represent each of the major hydrogeologic units in the ERVB (i.e., channel deposits, Quaternary alluvium, Hookton formation, Upper Carlotta, and Lower Carlotta). Hydraulic conductivity zones specified in model layers 1 through 6 in the integrated groundwater/surface water model and in model layers 1 through 15 in the seawater intrusion models are presented on **Figure 4.6**. Specifying hydraulic conductivity zones per hydrogeologic unit permits parameter estimation for each unit and a corresponding uncertainty analysis using PEST. The hydraulic conductivity value for each unit was adjusted during model calibration within reasonable bounds based on the results of the hydraulic conductivity testing performed within each hydrogeologic unit (see Table 1 of GHD (2021a)]) as well as values available in published literature consistent with the geologic materials that make up each unit.

4.4 Model Parameter Specification

As described in the following Section 5, groundwater flow was simulated under transient conditions during model calibration spanning water years 2000 through 2020, with a steady-state initial stress period and subsequent warm-up period that spanned from 1980 through the end of 1999. The model requires specification of uniform specific storage and uniform specific yield. The term “specific storage” refers to the volume of water that is released from storage per unit decrease in groundwater elevation in a fully-saturated model cell. The term “specific yield” refers to the volume of water that drains from interconnected pores per unit decrease in groundwater elevation in a partially-saturated model cell. For this study, a uniform value for specific storage of 1×10^{-4} ft^{-1} was selected based on literature values presented in Spitz and Moreno (1996), which provides ranges of 4×10^{-5} ft^{-1} to 3×10^{-4} ft^{-1} for sandy aquifers. A uniform value for specific yield of 0.21 was applied throughout the ERVB based on average values for fine sand (Johnson, 1967).

Solution of the groundwater flow equation requires iterative methods using numerical solvers. The transient groundwater flow equation was solved using the PCG2 solver implemented in MODFLOW-2005. Each iteration of the numerical solver results in updates to hydraulic head and flow values throughout the model domain. A model converges when updates to these values fall to below specified convergence criteria.. The convergence criteria for the PCG2 solver were specified as 0.001 ft for the maximum hydraulic head change and 8.64 cubic ft per day for the maximum flow residual throughout the model domain. The SFR2 package has its own convergence criteria and values of 1×10^{-6} ft and 1×10^{-6} cubic ft/day (0.0864 cubic feet per second [cfs]) were used for the maximum stream depth change and maximum streamflow residual, respectively. Model convergence was obtained using these criteria to determine a cumulative transient water balance discrepancy of less than 0.2 percent throughout the model domain and model calibration period.

5. Integrated Groundwater/Surface Water Model Calibration

Groundwater flow model calibration is the process of 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 is 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.

5.1 Calibration Targets

Selection of the targets for calibration of the transient models typically considers if groundwater elevation monitoring events:

1. Represent the range of groundwater flow conditions observed throughout the area of interest
2. Feature groundwater stresses and boundary conditions (i.e., extraction rates/stage elevations) represent the range of conditions affecting groundwater elevations and flow directions
3. Provide spatial coverage of the model domain with measurements at the majority of the monitoring well locations
4. Incorporate key areas of interest within the model domain

It is important for the integrated groundwater/surface water model to reasonably represent surface flow conditions (i.e., discharge rates and stage elevations), as they are key features of interest within the ERVB.

Groundwater elevations in California Statewide Groundwater Elevation Monitoring (CASGEM) program monitoring wells in the ERVB have been recorded since 1950. **Figure 5.1** shows CASGEM wells monitored over a substantial length of time (i.e., greater than 20 monitoring events) within the calibration period (i.e., 2000 through 2020). The right panel of **Figure 5.1** also shows measured groundwater elevations in these CASGEM wells since 1992, to align with local water year types presented in Table 2, to illustrate measured groundwater elevation variability, though only water levels from 2000 to 2020 were used for model calibration. Shading behind the right panel of **Figure 5.1** shows the water year types when these water levels were measured, demonstrating that these calibration targets (2000 through 2020) represent a range of flow conditions occurring in the ERVB. Based on **Figure 5.1**, spring groundwater elevations (higher groundwater elevations) show greater variability than fall groundwater elevations (lower groundwater elevations), which are stable historically. **Figure 5.2** shows the groundwater target locations and observation periods used for the calibration. **Table 5.1** lists the observation target values. As illustrated on **Figure 5.1**, observation targets comprise the key areas of interest and provide reasonable coverage across the ERVB. Using transient targets ensures inclusion of a range of groundwater flow conditions representative of wet seasons (March monitoring events) and end of dry season (October monitoring events).

There are two (2) USGS National Water Information System (NWIS) stations near the ERVB: one in the upper Eel River (Station 11477000 Eel River at Scotia, California) and the other in the upper Van Duzen River (Station 11478500 Van Duzen River near Bridgeville, California). River flows and stage elevations for these stations were accessed using tools developed by De Cicco et al. (2021) and are presented on **Figures 5.3** and **5.4**. Stage elevations at Stations 11477000 and 11478500 are available for periods after 2007 and represent each of the five (5) water year types (i.e., wet, above average, below average, dry, and critical). Both flow rates and stage elevations were averaged monthly so that they can be qualitatively compared to simulated flows and stages, which vary according to changes in monthly stress periods. **Table 5.2** lists the monthly average flow and stage targets at each of the Eel River and Van Duzen River station locations.

5.2 Calibration Methodology

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 involves:

1. Manually adjusting the parameters on the USGS provisional PRMS model (see Section 3.4)
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 (see Section 5.1)

Two (2) PRMS parameters from the provisional USGS model were modified during model calibration: ***carea_max***, which is the maximum proportion of each HRU area that contributes to surface runoff, and ***ssr2gw_rate***, which is a coefficient that expresses the rate at which groundwater in the gravity reservoir above the water table recharges. The parameter ***ssr2gw_rate*** originally was adjusted by USGS from the original NHM to reflect the low exchange rate in mountainous areas. Parameter ***ssr2gw_rate*** was increased in the ERVB to reflect the greater exchange in the more permeable deposits (i.e., channel deposits and Quaternary alluvium).

The integrated groundwater/surface water model was then manually calibrated to transiently observed groundwater elevations by adjusting SFR streambed thicknesses and hydraulic conductivity of the streambed sediments. Hydraulic conductivity of major hydrogeologic units in the ERVB was also adjusted during model calibration, aided through applying PESTPP-IES to iteratively adjust hydraulic conductivity values until the error between observed and simulated groundwater elevations was minimized over the model domain. When calibrating a groundwater flow model using the IES as implemented in PESTPP-IES, several realizations of equally valid calibrated groundwater flow models are produced based on ensembles of parameter values so that each provide reasonable matches to observed conditions. These calibrations constrain the uncertainty analysis.

The uncertainty analysis was implemented using 10 model realizations: a base realization that is derived from the initial estimate of parameter values and nine (9) additional calibrated realizations. Calibrating 10 groundwater flow models yields 90 percent confidence intervals for model application predictions.

Model calibration was evaluated both qualitatively and quantitatively. A qualitative evaluation was conducted by visually comparing simulated and observed flow rates and stage elevations at the Eel River and Van Duzen River NWIS station locations. A qualitative evaluation was conducted by visually comparing the simulated to observed transient groundwater elevations at CASGEM wells with long-term monitoring histories. This comparison provided a qualitative measure of the spatial distribution of the calibration error, as well as a way to determine if the calibrated model could reasonably represent observed groundwater flow directions.

The quantitative evaluation was conducted by examining calibration target errors, or residuals, which were calculated by subtracting the simulated from the observed groundwater elevations. The mean residual, absolute mean residual, and residual sum of square statistics, standard deviation, normalized error, etc. were calculated to quantify the discrepancy between observed and simulated groundwater elevations provided by the calibrated model. The objective of the model calibration was to minimize this discrepancy.

A second quantitative evaluation can be found in the simulated cumulative volumetric water budget reported by MODFLOW-2005, indicating the quantities of flow into and out of the model domain via the groundwater flow components specified in the model. The cumulative volumetric budget was reviewed to ensure that the total inflows and outflows were consistent with the HCM. The cumulative volumetric water budget also provided a percent discrepancy between the total simulated inflows and outflows at each timestep. A discrepancy of less than 0.2 percent for each timestep between 2000 and 2020 indicates a satisfactory numerical convergence.

5.3 Integrated Groundwater/Surface Water Model Calibration Results

As presented in **Table 5.3**, 339 groundwater targets from 44 observation wells were used for evaluating groundwater elevation conditions in the ERVB. Calibration target locations and minimum and maximum residual values from the calibrated base realization are plotted spatially on **Figure 5.5**.

Hydraulic conductivity distributions for each model layer are explicitly represented in **Figure 4.6**. Each model layer includes hydraulic conductivity value zones and values applied in the calibrated model representing the stratigraphic units in the ERVB. The ranges of hydraulic conductivity values that produce calibrated model results in the 10 model realizations are summarized as follows:

– **Channel Deposits**: from 385 ft/day to 412 ft/day

– **Quaternary Alluvium**: from 173 ft/day to 191 ft/day

– **Hookton Formation**: from 0.07 ft/day to 0.07 ft/day

– **Carlotta Formation (upper)**: from 0.1 ft/day to 0.1 ft/day

– **Carlotta Formation (lower)**: from 2.1 ft/day to 2.2 ft/day

The limited range of ensemble parameter values indicates that the transient groundwater flow model is reasonably constrained where there are numerous observations, such as near the channel deposits and Quaternary alluvium. Where observations are sparse, such as in the upper and lower Carlotta formation, the limited range of ensemble parameter values indicates that observation targets are not sensitive to parameter adjustments.

Vertical to horizontal hydraulic conductivity anisotropy ratios were applied to the stratigraphic units as follows:

– An anisotropy ratio of 1:10 was applied to the channel deposits and Hookton formation to represent the horizontal stratification (i.e., layering) in these deposits.
– The anisotropy ratio in the Quaternary alluvium was adjusted during the calibration process to reflect the fine-grained bedding in this unit (described in GHD (2021b)]). The vertical to horizontal hydraulic conductivity anisotropy ratios in the 10 calibrated ensembles range from 1:85 to 1:92.
– An anisotropy ratio of 1:1 was applied to the finer-grained deposits where horizontal hydraulic conductivity is limited.

The calibrated hydraulic conductivity values for the model are generally consistent with the hydraulic conductivity values estimated from the single-well response test (GHD, 2021a).

Figure 5.5 shows minimum (in the left panel) and maximum (in the right panel) target residuals for calibration from one (1) of the 10 ensemble calibrated models, referred to as the Base Model. Target residuals are colored based on whether they are positive (blue: indicating that the observed groundwater elevation is underpredicted) or negative (red: indicating that the observed groundwater elevation is over-predicted), and their sizes vary based on the magnitude of the residual. Due to the transient nature of the simulation and the limited number of synoptic monitoring events, a quantitative assessment of simulated and observed hydrographs at regularly monitored CASGEM well locations was prepared based on the Base Model, presented along the bottom of **Figure 5.5**.

Another qualitative evaluation involves the comparison of simulated to observed monthly average stream flows and stage elevations. **Figure 5.6** presents simulated flows in the top panel and stages in the bottom panel for the Eel River (at Station 11477000) and Van Duzen River (at Station 11478500) in the left and right panels, respectively. Simulated values are presented as light blue lines and observed values as orange lines. Vertical axes for the flow plots are logarithmically scaled so that the simulated to observed match can be evaluated for both high and low flow conditions. Flows and stages in the Eel River provide a good match to observed conditions. Flow in the Van Duzen also provides a reasonable match to observed conditions, particularly during high flow conditions. During low flow conditions the model underpredicts flow in the Van Duzen River, though that is typically when flows are less than 10 cfs. Regardless, it is not expected to adversely influence predictions made with the integrated groundwater/surface water model during model application because the magnitude of the mismatch is small (i.e., less than 10 cfs). If specific questions pertaining to low flow conditions are required than additional model investigations involving grid rediscretization can be completed.

Table 5.3 lists targets for Base Model calibration. Calibration target residuals are colored based on whether the residual is positive or negative. **Figure 5.7** presents a scatter plot of Base Model observed versus simulated groundwater elevations for the transient model calibration. The transient calibrated Base Model provides a residual mean of -3.2 ft, an absolute residual mean of 5.9 feet, a residual sum of squared error of 21,070 square ft, and a residual standard deviation of 7.2 ft. The residual standard deviation is 3 percent of the head range. Spitz and Moreno (1996) suggest that the residual standard deviation should normally be less than about 10 percent of the head range, which is satisfied by Base Model calibration.

The scatter plot of the simulated versus observed groundwater elevations presented on **Figure 5.7** includes a line of exact match between the simulated and observed groundwater elevations. Below the observed versus simulated scatter plot is a plot of observed groundwater elevations versus the model residuals. The plotted points appearing above the match line overpredict the observed groundwater elevation (and have a negative residual). The plotted points appearing below the exact match line underpredict the observed groundwater elevation (and have a positive residual). A reasonable distribution of residual points on the bottom panel of **Figure 5.7** occurs above and below the match line across the full range of the measured groundwater elevations throughout the model domain, which further ensures the calibrated model provides a reasonable match to the observed groundwater flow conditions.

Simulated groundwater elevations for spring (March 2003) and fall (October 2003) are presented on left and right panels, respectively, of **Figure 5.8**. The bottom right panel of **Figure 5.8** shows the flows in the Eel and Van Duzen rivers during these periods (highlighted in yellow) as a reference. There is a high hydraulic gradient down the Van Duzen River valley discharging groundwater into the lower Eel River valley. When flows are high in the spring, there is limited exchange with the surface water flow system until below Palmer Creek. This is evidenced by groundwater elevation contours that are approximately perpendicular to Eel River. In the fall, when river flows and groundwater elevations are lower, after entering the lower Eel River valley, groundwater flows towards and discharges to Eel River near Fortuna.

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).

6. Applications of the Integrated Groundwater/Surface Water and Seawater Intrusion Models

6.1 Groundwater Model Scenarios Overview

The calibrated integrated groundwater/surface water and seawater intrusion models were used to support development of the SMC, with the ultimate intention to determine if water uses within the ERVB can be sustained currently and into the future without creating an undesirable result, i.e.:

– Chronic lowering of groundwater levels, indicating a significant and unreasonable depletion of supply
– Significant and unreasonable reduction of groundwater storage
– Significant and unreasonable seawater intrusion
– Depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water

The effect of water use on degradation of water quality—through the migration of contaminant plumes that impair water supply, for example, and land subsidence that substantially interferes with land uses—is evaluated as part of the GSP through monitoring and analytical methods (see Sections 6.2.4 and 6.2.5).

The historical effects of water use in the ERVB were evaluated by comparing the integrated groundwater/surface water and seawater intrusion models that include groundwater pumping to a simulated groundwater flow system that does not include groundwater pumping. Comparing pumped to unpumped (i.e., undisturbed) conditions enables a better understanding of depletions to the groundwater and surface water flow systems that can be attributed to either water use in the ERVB or seasonality and climate. This comparison permits the evaluation of the effect of current water use on the SMC.

Section 5.3 includes a description of the CCUA results, demonstrating that the model is reasonably well constrained and capable of providing predictions with greater reliability where the model can be calibrated to observed groundwater and surface water data. Where observations are sparse across large areas, the model was not sensitive to calibration adjustments. Therefore, application of the integrated groundwater/surface water and seawater intrusion models will focus on the Lower Eel River and Van Duzen River valleys, where there a greater number of observations can constrain the model—which also happens to be where much of the water use is occurring within the ERVB and where predictions can be made with greater reliability.

For much of the analysis presented in Section 6 a reference condition of water levels is necessary. Commonly, this reference is a historical point of comparison (e.g., the date of the implementation of the SGMA). When trends are not evident, as is the case in the ERVB (see for example **Figure 5.1**), selection of an appropriate average condition is necessary. Groundwater levels recorded at the CASGEM program wells provide the best opportunities to evaluate a reference condition. Average spring groundwater levels were calculated for CASGEM program wells 36943, 36942, 23181, and 23183, all located within the Lower Eel River Valley and currently active. The period of record used to develop the average included all measurements available (these generally start in the 1980s) up to 2015. To establish a modeled reference condition, modeled outputs were compared with average groundwater elevations. 2003 was determined to be the best fit. The modeled groundwater levels for Spring 2003 are therefore used as a reference representing average spring conditions. As illustrated on **Figure 5.1** there is not a lot of variability in fall conditions. Fall 2003 was therefore selected as average fall conditions to be consistent with the spring analyses.

6.1.1 Increased Groundwater Extraction Scenarios

The Base Models (of the 10 model realizations) for the calibrated integrated groundwater/surface water and seawater intrusion models were used to investigate future conditions by considering a range of potential future water needs. This was accomplished by simulating increased pumping rates as proportions of historical pumping. To better understand the sustainable yield, additional pumping scenarios were included, up to an 800% increase of current conditions. In total, an additional 13 simulations were completed, encompassing pumping increases of 10 percent, 20 percent, 30 percent, 40 percent, 50 percent, 100 percent, 200 percent, 250 percent, 300 percent, 300 percent, 400 percent, 500 percent, and 800 percent, in addition to the non-pumping conditions and historical conditions described in Section 6.1.

6.1.2 Climate Change Scenarios

The Base Model for the calibrated integrated groundwater/surface water model (Base Model) and the seawater intrusion model were 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 ft) and 45 cm (i.e., 1.48 ft) for the near and late future climate scenarios, respectively. An additional simulation representing conditions where sea level rises by 3 ft also was simulated using the seawater intrusion model to evaluate the effect of this condition on the availability of freshwater in the ERVB. This supplemental model was applied using the late future 2070 climatic conditions. The 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.

6.2 Sustainable Management Criteria (SMC) Modeling Evaluation

6.2.1 Chronic Lowering of Groundwater Levels

As described in SHN (2021a) and presented on the hydrographs therein, there has been no evidence of chronic lowering of groundwater levels observed in the CASGEM monitoring wells. The potential for chronic lowering of groundwater levels was evaluated at select wells screened in alluvium throughout the ERVB, since the alluvium is where most groundwater extraction occurs (see **Figure 4.3)**. **Table 6.1** provides a legend to match Well Identification Keys from **Figure 6.1** with observation well identifications. The model was applied to evaluate if water use (i.e., pumping) in ERVB has the potential to induce chronic groundwater lowering. The amount of groundwater lowering that is attributable to pumping under current conditions was estimated by subtracting groundwater elevations under pumping conditions from groundwater elevations under non-pumping conditions. **Figure 6.2** shows ranges of groundwater lowering attributable to pumping at each of these wells. Wells on **Figure 6.2** are arranged from left to right in order of decreasing median groundwater lowering amounts for the periods between water year 2000 through to the end of water year 2020. The greatest amount of lowering occurs east of Ferndale near the foothills of the Wildcat Range.

Figure 6.3 presents ranges of groundwater lowering based on the 10 CCUA model realizations (described in Sections 5.2 and 5.3) during average spring (March 2003) and fall (September 2003) conditions in the upper left and right panels, respectively. Contours of the minimum and maximum amounts of groundwater lowering, based on the CCUA models, are presented in orange and green, respectively. Simulated groundwater elevations at select groundwater model cells are presented on the bottom panels of **Figure 6.3** to illustrate the water level dynamics in the basin and assess the potential for chronic lowering associated with water use. The bottom panels show that groundwater recovers each year to an equilibrium level, even following critically dry years. Based on historical water use and the seasonal nature of water level recovery, chronic lowering of water levels in the ERVB is not likely.

As described in Section 6.1.1, simulated pumping was modified in the model to better understand potential future conditions and identify the water use rates that would be required to cause a substantial change to water levels and flow directions in the ERVB. **Figures 6.4** and **6.5** show groundwater elevations and groundwater lowering[11], respectively, under a range of increased pumping conditions based on average dry conditions (i.e., September 2003). Flowlines are presented on **Figure 6.4** that show changes to flow under increased pumping. Under most increased pumping scenarios groundwater discharges to Eel River. Only during extreme pumping scenarios (i.e., four [4] and five [5] times current pumping rates [300 percent and 400 percent increases in pumping rates]) does water get drawn from Eel River in towards the center of the valley.

6.2.1.1 Modeling Uncertainties of Chronic Lowering

Figure 6.2 shows the ranges of median groundwater lowering values for each of the 10 model realizations completed during the CCUA. The median values are limited and vary a little under 0.3 feet at the worst-case location (i.e., east of Ferndale near the Wildcats as simulated at E2). **Figure 6.3** shows the ranges of uncertainty related to groundwater lowering in the quaternary alluvium in the ERVB. Although there is some variability in simulated output it is limited and is not significant to the interpretation of the effects of water use on chronic lowering of groundwater levels in the ERVB.

6.2.2 Reduction in Groundwater Storage

The DWR Water Budget BMP (DWR, 2016b) defines the change in storage as “the total change in storage between seasonal high conditions, which typically occurs in the spring” and recommends that the change in storage estimates be based on observed changes in groundwater levels within the Basin. CASGEM monitoring

[11] Note that the upper left panel of **Figure 6.5** shows groundwater elevations under non-pumping conditions as a reference against which the other panels of groundwater lowering are compared.

wells in the Basin typically are measured in March and October. Calculation of change in springtime storage, therefore, is based on March values for spring groundwater storage so that future analyses can be completed using observed changes in groundwater levels within the Basin. Changes in fall storage have been calculated to support Water Balance analysis presented in the GSP based on the storage that is remaining at the end of one water year and the beginning of another. Calculation of fall/end of water year storage is based on September values.

Changes in spring and fall groundwater storage is calculated by subtracting previous year from the same month in the current year groundwater elevations in each Quaternary alluvium model cell for each year between water year 2000 and water year 2020. The initial head differences (i.e., 2000) are compared to March and September 2003, for spring and fall conditions, respectively. The head differences were then converted to volumes by multiplying by the 1,000 ft × 1,000 ft finite-difference model cell area. The volumes of groundwater were then determined by scaling by the specific yield value of 0.21. This approach is summarized in Equation 6.1.

$$\Delta V_{GW} = 1{,}000\text{ ft} \times 1{,}000\text{ ft} \times 0.21 \times \frac{1\text{ acre-ft}}{43{,}560\text{ ft}^3} \sum_{i=1}^{n_{\text{Alluvium Model Cells}}} h_i^{current} - h_i^{previous} \qquad \text{Equation 6.1}$$

where:

ΔV_{GW} = the change in annual groundwater storage volume (acre-ft)

$n_{\text{Alluvium Model Cells}}$ = the number of finite-difference model cells representing Quaternary alluvium

$h_i^{current}$ = the groundwater elevation in model cell (i) during spring (March) or fall (September) in a particular year (ft NAVD88)

$h_i^{previous}$ = the groundwater elevation in model cell (i) during spring (March) or fall (September) in the previous year (feet NAVD88)

The spring and fall changes and cumulative changes in groundwater storage are presented on the upper two panels of **Figure 6.6** for each of the 10 equally calibrated groundwater flow models. Positive changes in storage are represented as green bars and negative changes in storage are represented as red bars on **Figure 6.6**. Interpreting the change in storage in the context of a water year type is complicated because comparing one month to the same month of the previous year does not necessarily reflect the total precipitation that occurred over the duration of the water year, which is how the water year type is determined. The bottom panel of **Figure 6.6** includes simulated estimates of accessible freshwater (i.e., freshwater that is situated in Channel Deposits, Quaternary Alluvium, or Lower Carlotta Formation aquifers) volumes 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.

As described in Section 5.1 and illustrated on **Figure 5.1** spring (March) groundwater elevations are more variable than fall (October) levels. This variability in the spring and stability in the fall also can be observed in the change in storage values illustrated on the upper two panels of **Figure 6.6**.

Figure 6.6 shows that Basin water use is not a major contributor to changes in storage. For example, in situations where there are sequential dry years such as water years 2012 and 2013 (end of water years 2012 and 2013, respectively) there would be potential for an increase in the magnitude in the reduction in fall storage (i.e., more reduction from one water year to the next) if Basin water use were a large contributor to storage reductions. Since these sequential reductions are not observed in fall 2012 and 2013, the data helps show that Basin water use is not a major contributor to storage reductions but rather year over year climatic changes are the primary contributor.

6.2.2.1 Modeling Uncertainties of Reduction in Groundwater Storage Analysis

The ranges of change in storage for each of the 10 model realizations presented on **Figure 6.6** appear to overlay one another. Although there is some variability (this is evident as the lines representing cumulative storage begin to spread towards the end of water year 2020) the variability is not significant to the interpretation of reduction in groundwater storage. That is to say that when the model uncertainty is accounted for reductions in storage in ERVB is neither significant nor unreasonable.

6.2.3 Seawater Intrusion

The seawater intrusion model was used to support the development of protective groundwater level analysis using observed chloride concentration and water level data together with well construction details from the DWR database. Minimum thresholds based on chloride values and the associated 100 mg/L isocontour were developed for specific well locations within the seawater-freshwater transition zone.

There is a natural advance and retreat that occurs with seawater intrusion: 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 move through the surface water and groundwater flow systems. The upper panel of **Figure 6.7** shows the range[12] of advance and retreat of the 100 mg/L chloride concentration isoconcentration contour[13] that would happen under climatic conditions, alone. These frequency contours are compared to the 100 mg/L chloride concentration isocontour estimated by Johnson (1975). The comparison shows that there is a good match between this measured isoconcentration contour and the median simulated 100 mg/L isoconcentration contour. During the seawater intrusion model construction and analysis the advancing chloride distribution near the rivers was investigated. The model indicated that there was an upwelling occurring from the deeper zones. GHD prepared a sensitivity analysis model by removing deep Carlotta Formation constant chloride concentrations from the boundary conditions. The resulting chloride distribution was very close to the Pacific Ocean. This implied that much of the seawater intrusion into the basin is coming from deep formations. Hydraulic heads in the quaternary alluvium are hydraulically connected to the rivers and these heads vary seasonally. During dry seasons, when surface water stage elevations and shallow groundwater elevations are lower, there is an upward head differential between the alluvium and lower Carlotta causing the upward migration of chloride. The seasonal rising and lowering of the Salt and Eel Rivers results in increased summertime hydraulic gradients towards these rivers. This seasonal increase in the hydraulic gradient causes seawater advance along the rivers that is greater than in the surrounding aquifers. Near the middle of the basin the distance that the 100 mg/L isoconcentration profile advances and retreats due to climatic variability alone is 4,750 feet (see the upper left panel of **Figure 6.7**). Under current conditions that include seasonal water usage the advance of the seawater is an additional 700 feet. This is shown in the upper middle plot of **Figure 6.7**[14]. As pumping scenarios increase the stress on the groundwater flow system, freshwater from the Eel and Salt Rivers diffuse the chloride concentrations, lowering them. It is only when pumping is increased to 4× current conditions (a rate that far exceeds the amount that would be required by irrigation to replace evapotranspiration) that 100 mg/L chloride frequencies increase from 5 percent to 95 percent.

The seawater intrusion model also was applied to evaluate various water use scenarios with the purpose of understanding the relationship between the rate of extraction, increases in chloride concentrations, and groundwater level lowering. The model runs 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.

[12] The range represents the range between the 95% and 5% frequency within which chloride concentrations are equal to or greater than 100 mg/L

[13] Chloride concentrations are measured in the upper 60 feet of the aquifer or Model Layer 1, whichever is deeper, to be consistent with most irrigation well screen intervals.

[14] The reference line that appears in the plots that show pumping conditions represents the 5% isocontour for non-pumping conditions

– **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. 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). Preliminary chloride concentrations were established to identify early-notification of significant seawater intrusion. Individual well early-notification concentrations varied across the basin based on the well's proximity to the 100 mg/L chloride isocontour. For each well, the years that the predicted chloride concentration exceeded these key indicators 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 preliminary early-notification concentration 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). 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.

6.2.3.1 Modeling Uncertainties of Seawater Intrusion Analysis

There are two key areas of uncertainty associated with the seawater intrusion model.

– Development of the initial seawater intrusion condition involved simulating the groundwater flow system at steady state for 1,000 years. This was described in Section 4.2.6. By simulating steady-state conditions the regular rising and falling of the rivers was averaged. This potentially underestimated the periodic effect of high flows moving through the flow system that may exaggerate the advance of chloride concentrations along the river channels.
– The MODFLOW package that allows improved representation of groundwater/surface water interactions (i.e., SFR2) is newer than the seawater intrusion model (i.e., SEAWAT4). It was therefore necessary to use another MODFLOW package to represent rivers in the seawater intrusion model (i.e., the river package). Unlike the SFR2 package that calculates stage elevations, the river package needs stage values to be assigned. Assigned stage elevations potentially can provide an infinite source of water into the groundwater flow system. This was mitigated by the Project Team by assigning transient stage elevations based on the SFR-calculated river stages for each of the increased water use scenarios.

Stated another way, there is some uncertainty with the application of the seawater intrusion model; however, the project team applied an approach aimed to reduce this uncertainty. The uncertainty associated with the initial conditions for seawater intrusion that resulted in chloride advances along the Eel and Salt Rivers result in conservative estimates of seawater intrusion and does not adversely affect the associated conclusions.

6.2.4 Degraded Water Quality

Based on evaluation of the historical and current water quality conditions of the ERVB (SHN, 2021b), it has been concluded that water quality generally is good. For example, while there are some constituents with elevated concentrations and some constituents of concern 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. Therefore, it can be concluded that degradation of groundwater associated with use is not likely to have initiated since 2015. Without the identification of degradation conditions related to management or use, the focused application of modeling was not considered useful for the development of the water quality SMC. However, modeling scenarios that evaluate impacts associated with increased pumping scenarios (as described in Sections 6.1.1 and 6.2.1) are informative in that results show that a significant increase in pumping (4x and 5x current rates) is required to induce changes to the regional groundwater gradients and the direction of groundwater flow. The models that have been developed could be used in the future to evaluate potential projects or management actions to ensure that water quality is not inadvertently degraded.

6.2.4.1 Modeling Uncertainties of Degraded Water Quality Analysis

Uncertainty associated with the effects of water use on changing water quality in the ERVB is largely based on the uncertainty of the hydraulic gradient/water level described in Section 6.2.1.1. Although there is some variability in simulated output, it is limited and not significant to the interpretation of the effects of water use on flow patterns, directions, and gradients in the ERVB.

6.2.5 Ground Subsidence

Analyzing conditions in the ERVB related to the potential for ground subsidence were aided by the model's information regarding the maximum groundwater lowering occurring within the basin under historical and current pumping conditions. Since the modeled outputs occurring under the current pumping conditions indicate localized, seasonal groundwater level lowering in the order of 5 ft or less, recovering between October and March each year, it was determined that any measurable subsidence occurring in the ERVB can only be attributed to tectonics related to the Cascadia Subduction Zone. These modeled results and conclusions were then compared to, and confirmed by, the available Interferometric Synthetic Aperture Radar (InSAR) data of the basin, which were plus or minus 0.25 ft for the period of record (2015-2020) (Towill, Inc., 2021).

6.2.5.1 Modeling Uncertainties of Ground Subsidence Analysis

Uncertainty associated with the effects of water use on ground subsidence in the ERVB is largely based on uncertainty with the water level, described in Section 6.2.1.1. Although there is some variability in simulated output, it is limited and not significant to the interpretations of the seasonal recovery of water levels in the ERVB that might affect ground subsidence.

Uncertainties in the vertical ground surface displacement estimations using UnSAR that indicate negligible land subsidence for the basin: quantitative analysis was performed (Towill, Inc., 2021) by comparing Continuous Global Positioning Systems (CGPS) and InSAR time-series data for the reference period. Those results provide strong evidence that the InSAR data accurately models change in ground elevation to an accuracy tested to be a minimum of 18 millimeters (0.71 inches) at 95% confidence.

6.2.6 Depletion of Interconnected Surface Water

This section describes the methods used to evaluate the depletion of interconnected surface waters due to groundwater extraction in the ERVB. The evaluation and quantification of surface water depletion due to groundwater extraction is challenging due to the complexity and variability of groundwater/surface water exchange and the fact that surface water depletion cannot be directly measured. Multiple factors, in addition to groundwater extraction, influence surface water depletion, such as runoff, diversions, evapotranspiration, channel substrate composition and natural seasonal variation in groundwater/surface water exchange. Due to these complexities, the analysis uses a combination of modeling tools, historic flow data, field observations, and stream gages to assess the effects of groundwater extraction on the depletion of interconnected surface water.

The Eel River, Van Duzen River, Salt River, Yager Creek, and other surface waters and GDEs (rivers, streams, and wetlands) are hydraulically connected to the alluvial aquifer. The features of the interconnected surface waters are described in the GHD (2021b) and Stillwater Sciences (2022) technical memoranda. The river conditions generally recharge the aquifer during wet conditions and groundwater discharges into surface waters during dry conditions. However, the specific direction of flow and rate of exchange varies by reach based on the local hydrogeological conditions. The term hyporheic zone refers to the boundary area where there is mixing of groundwater and surface water. The extent of the hyporheic zone is difficult to estimate due the variable thickness and composition of channel deposits. In general, water can flow quickly in surface waters but flows much slower in the porous media of the aquifer. Groundwater extraction may influence the exchange of water between the aquifer and interconnected surface waters.

This study primarily focuses on aquatic beneficial uses related to the depletion of interconnected surface water. The evaluation of terrestrial beneficial uses is discussed in Section 6.3, Terrestrial GDE Assessment. While there are multiple beneficial uses that may be affected by surface water depletion, anadromous fish passage is one of the most important and sufficient information was available to support a framework for impact analysis. Therefore, the primary focus of analysis for beneficial uses is the potential effect on adult anadromous fish migration during the fall (September through November) when low stream flows may adversely affect fish migration.

The analysis examined potential surface water depletion in several discrete reaches of the Eel River, Van Duzen River and Yager Creek, and Salt River. These reaches included: upper Eel River from Scotia to the confluence of the Van Duzen River, Eel River from the confluence of the Van Duzen River to the tidally influenced section of the Eel River, tidally influenced section and estuary of the Eel River, Van Duzen River and Yager Creek from Bridgeville to the Eel River confluence, and Salt River. In review of the modeling results, a change in stream flow rates due to groundwater extraction results in variable potential for depletion of surface water for each reach. The model results indicate minimal changes in stream flow through upper Eel River, Van Duzen River and Yager Creek due to groundwater extraction. Most of these reaches are up-stream of the majority of the groundwater extraction in the basin. River conditions in the tidally influenced and estuary reaches are governed by the sea level and are not likely to exhibit shallow depth limitations that would impede anadromous fish passage. Based on evaluation of the modeling results and field monitoring data, the Eel River from the confluence of the Van Duzen River to the tidally influenced reach exhibits the highest potential for surface water depletion due to groundwater extraction.

The analysis of interconnected surface water depletion in the Eel River has four components:

1. Identification of focused study locations where the river geomorphology creates critical passage conditions (Section 6.2.6.1)
2. Evaluation of the changes in river flow due to groundwater extraction at the focused study locations (Section 6.2.6.2)
3. Evaluation of the change in river stage at the focused study locations resulting from the change in river flow due to groundwater extraction (Section 6.2.6.3)
4. Evaluation of the change in groundwater levels at monitoring wells near the focused study areas (Section 6.2.6.4)

6.2.6.1 Surface Water Depletion Locations of Interest Identification

This study investigated the potential effects from depletion of surface waters through groundwater use on the upstream migration of adult salmon and steelhead (salmonids). Between 2006 and 2020, shallow riffles have been observed blocking adult salmonid passage until the first high flows during the fall (September–November) (Stillwater Sciences 2022). A review of riffle depths and adult Chinook salmon holding location collected from 2010 to 2020 (Stillwater Sciences 2011-2021) showed that upstream migration by adult Chinook salmon in the Lower Eel River during the early fall is inhibited by riffles that are 0.5–0.6 ft deep and is blocked by riffle depths 0.4 ft or less. Adult Chinook salmon have generally been observed in the pool at the confluence of the Eel/Van Duzen rivers when riffle depths downstream of the confluence met or exceeded 0.7 ft deep. Based upon these observations and for this analysis, a riffle crest depth of 0.7 feet is defined as Minimum Fish Passage Depth, which is the minimum depth required over riffles for unimpeded fish passage (i.e., fish passage is not blocked or impeded).

Figure 6.8 presents riffle depths within the lower Eel River measured by Stillwater Sciences from 2010 through 2020 compared to daily average flows (cfs) at the Eel River Scotia gage [USGS 11477000]. According to Stillwater Sciences (Dennis Halligan, personal communication), the Minimum Fish Passage Depth of 0.7 ft occurs when river flows, as monitored at Scotia, are between 130 and 310 cfs. The exact location of the shallowest riffles within the Eel River will vary from year to year due to geomorphic changes in the river channel. While the exact locations of these individual riffles may vary, historically they have occurred in the same general areas. These shallow riffle areas are included within the locations of interest in this study and are shown on **Figure 6.9**. An individual location of interest may incorporate multiple model grid cells. Table 3 summarizes the locations of interest and the number of model grid cells.

A more detailed description of minimum riffles depth and locations is presented in Stillwater Sciences (2022).

Table 7 Surface Water Depletion Locations of Interest and Model Grid Cells

Surface Water Depletion Location of Interest	Number of Model Grid Cells
ME-1	5
ME-2	4
ME-3	4
ME-4	5
ME-5	5
ME-6	3
ME-7	2

6.2.6.2 Groundwater/Surface Water Model River Flow Estimates

The effect of groundwater extraction on surface water depletion is evaluated by comparing stream flow estimates from a no groundwater extraction scenario and various groundwater extraction scenarios. The rate of streamflow depletion due to groundwater extraction is the difference between the streamflow rates of the extraction and no-extraction scenarios.

The groundwater/surface water model incorporates the historical and seasonal variations in hydrologic conditions as well as the hydrogeologic conditions of the groundwater/surface water exchange. The model simulates monthly average river flow rates over a time period ranging from 2000 through 2020. This time period incorporates historical climate data, and all water year types are represented in the dataset.

The resulting monthly average change in streamflow rates vary from month to month due to seasonal weather and water use variations. The monthly average change in flow rates and percent changes in flow rates at each of the surface water depletion locations of interest along the Eel River are shown on **Figure 6.10**. The change in flow rate due to groundwater extraction ranged from 0 to 16.2 cfs (i.e., as simulated for June 2014 at ME 7). The greatest changes in flow rates occur in the summer irrigation season when the river flows are decreasing. As the irrigation season ends and stream flows increase, the change in stream flow due to groundwater extraction decreases. The change in stream flow due to groundwater extraction remains low when the flow in the river is high.

The monthly average change in flow rate for a given month will vary from year to year due to climate conditions reflective of the water year type. Grouping the model results from the 2000 through 2020 time period of the monthly average change in flow rate by month shows the distribution of change in flow rate for each month and illustrates the year-to-year variation, as shown on **Figure 6.11**.

The change in flow rates due to groundwater extraction varies for each surface depletion location with the lowest change in flow rate at the upper reach of the Eel River and gradually increasing by location moving down river.

The next step in the evaluation focuses on the time period when there is upstream fish migration, September through November. As a worst-case scenario, the maximum observed flow difference for the time period (2000-2020) is selected as the maximum potential flow difference due to groundwater extraction at each surface water depletion location. Under current groundwater extraction conditions, the value of the maximum September through November flow change ranged from 6.6 cfs at the upper reach near the confluence of the Van Duzen River to 14.6 cfs just below Fernbridge.

The model results of the maximum, average, and minimum September through November change in stream flow at each of the surface water depletion locations of interest due to groundwater extraction for the current conditions and for the increased groundwater extraction scenarios are presented in Tables 8 through 14.

Table A.1 in Attachment A includes the change in stream flows at each of these locations for each of the increased groundwater scenarios between Water Years 2000 and 2020, inclusively. As described in Section 6.2.6.1, an individual location of interest may incorporate multiple model grid cells. Table A.1 includes flows, flow differences, and percent reductions of flows at each of the model grid cells representing the locations of interest. Table A.1 first presents flows for existing conditions through to 50% increase in pumping for each location, then 75%[15] through to 300% increase in pumping for each location, then 400% through 800% increase in pumping for each location.

Table 8 Change in ME-1 Monthly Average Stream Flow Due to Groundwater Extraction, September through November, 2000-2020

	ME-1					
	Maximum Change in Flow		Average Change in Flow		Minimum Change in Flow (cfs)	
Scenario	**cfs**	**% Of Total Flow**	**cfs**	**% Of Total Flow**	**cfs**	**% Of Total Flow**
Current Conditions	7	9%	2	1%	1	0.01%
10% Increase	7	10%	3	2%	1	0.01%
20% Increase	8	11%	3	2%	1	0.01%
30% Increase	9	11%	3	2%	1	0.01%
40% Increase	9	12%	3	2%	1	0.01%
50% Increase	10	13%	3	2%	1	0.02%
100% Increase	13	17%	5	3%	2	0.03%
150% Increase	16	22%	6	4%	2	0.03%
200% Increase	20	26%	7	5%	3	0.04%
250% Increase	23	31%	8	5%	3	0.04%
300% Increase	27	35%	9	6%	4	0.05%
400% Increase	33	44%	12	8%	5	0.06%
500% Increase	40	53%	14	9%	6	0.08%
800% Increase	59	77%	21	14%	9	0.12%

15 The 75% increase in pumping evaluation is an evaluation that occurred in the development and evaluation of the sustainable yield, which was completed following the development of the SMCs reported in this technical memorandum. Flows and flow differences under a 75% pumping increase scenario are included in Table A.1 as a reference for the sustainable yield analysis provided under separate cover.

Table 9 Change in ME-2 Monthly Average Stream Flow Due to Groundwater Extraction, September through November, 2000-2020

Scenario	ME-2					
	Maximum Change in Flow		Average Change in Flow		Minimum Change in Flow (cfs)	
	cfs	% Of Total Flow	cfs	% Of Total Flow	cfs	% Of Total Flow
Current Conditions	9	10%	5	1%	3	0.02%
10% Increase	10	11%	6	2%	3	0.02%
20% Increase	11	12%	7	2%	3	0.02%
30% Increase	12	13%	7	2%	3	0.02%
40% Increase	13	14%	8	2%	4	0.02%
50% Increase	14	15%	8	2%	5	0.02%
100% Increase	19	20%	11	3%	6	0.04%
150% Increase	23	24%	14	4%	8	0.05%
200% Increase	28	29%	16	5%	9	0.06%
250% Increase	33	34%	19	5%	11	0.07%
300% Increase	38	39%	22	6%	13	0.07%
400% Increase	47	49%	28	8%	16	0.10%
500% Increase	56	59%	33	9%	19	0.12%
800% Increase	84	87%	50	14%	29	0.17%

Table 10 Change in ME-3 Monthly Average Stream Flow Due to Groundwater Extraction, September through November, 2000-2020

Scenario	ME-3					
	Maximum Change in Flow		Average Change in Flow		Minimum Change in Flow (cfs)	
	cfs	% Of Total Flow	cfs	% Of Total Flow	cfs	% Of Total Flow
Current Conditions	11	11%	7	2%	4	0.02%
10% Increase	13	12%	8	2%	5	0.03%
20% Increase	14	14%	9	2%	5	0.03%
30% Increase	15	15%	10	3%	6	0.04%
40% Increase	16	16%	10	3%	6	0.04%
50% Increase	17	17%	11	3%	7	0.04%
100% Increase	23	23%	15	4%	9	0.06%
150% Increase	29	28%	19	5%	11	0.07%
200% Increase	34	34%	22	6%	13	0.08%
250% Increase	40	40%	26	7%	16	0.09%
300% Increase	46	45%	30	8%	18	0.11%
400% Increase	58	57%	37	10%	23	0.13%
500% Increase	69	68%	45	12%	27	0.16%
800% Increase	104	97%	68	18%	41	0.24%

Table 11 Change in ME-4 Monthly Average Stream Flow Due to Groundwater Extraction, September through November, 2000-2020

	ME-4					
	Maximum Change in Flow		Average Change in Flow		Minimum Change in Flow (cfs)	
Scenario	**cfs**	**% Of Total Flow**	**cfs**	**% Of Total Flow**	**cfs**	**% Of Total Flow**
Current Conditions	13	12%	8	2%	6	0.03%
10% Increase	14	13%	9	2%	6	0.03%
20% Increase	15	15%	10	3%	7	0.04%
30% Increase	16	16%	11	3%	7	0.04%
40% Increase	18	17%	12	3%	8	0.04%
50% Increase	19	18%	13	3%	8	0.04%
100% Increase	25	24%	17	4%	11	0.06%
150% Increase	31	30%	21	5%	14	0.07%
200% Increase	38	37%	25	7%	17	0.09%
250% Increase	44	43%	30	8%	20	0.11%
300% Increase	50	49%	34	9%	23	0.12%
400% Increase	63	61%	42	11%	28	0.16%
500% Increase	76	73%	51	13%	34	0.19%
800% Increase	114	98%	77	20%	52	0.29%

Table 12 Change in ME-5 Monthly Average Stream Flow Due to Groundwater Extraction, September through November, 2000-2020

	ME-5					
	Maximum Change in Flow		Average Change in Flow		Minimum Change in Flow (cfs)	
Scenario	**cfs**	**% Of Total Flow**	**cfs**	**% Of Total Flow**	**cfs**	**% Of Total Flow**
Current Conditions	13	12%	9	2%	6	0.03%
10% Increase	15	13%	10	3%	7	0.04%
20% Increase	16	15%	11	3%	7	0.04%
30% Increase	17	16%	12	3%	8	0.04%
40% Increase	19	17%	13	3%	9	0.05%
50% Increase	20	18%	14	3%	9	0.05%
100% Increase	27	24%	18	5%	13	0.07%
150% Increase	33	31%	23	6%	16	0.09%
200% Increase	40	37%	28	7%	19	0.10%
250% Increase	47	43%	32	8%	23	0.12%
300% Increase	53	49%	37	9%	26	0.14%
400% Increase	67	61%	46	12%	32	0.18%
500% Increase	81	73%	56	14%	39	0.21%
800% Increase	120	100%	83	21%	59	0.32%

Table 13 Change in ME-6 Monthly Average Stream Flow Due to Groundwater Extraction, September through November, 2000-2020

	ME-6					
	Maximum Change in Flow		Average Change in Flow		Minimum Change in Flow (cfs)	
Scenario	**cfs**	**% Of Total Flow**	**cfs**	**% Of Total Flow**	**cfs**	**% Of Total Flow**
Current Conditions	14	12%	9	2%	7	0.04%
10% Increase	15	13%	10	3%	7	0.04%
20% Increase	16	15%	11	3%	8	0.04%
30% Increase	18	16%	12	3%	8	0.04%
40% Increase	19	17%	13	3%	9	0.05%
50% Increase	20	18%	14	3%	10	0.05%
100% Increase	27	24%	19	5%	13	0.07%
150% Increase	34	30%	24	6%	17	0.09%
200% Increase	41	36%	28	7%	20	0.11%
250% Increase	48	42%	33	8%	23	0.13%
300% Increase	55	48%	38	9%	27	0.15%
400% Increase	68	60%	48	12%	34	0.18%
500% Increase	82	73%	57	14%	41	0.23%
800% Increase	123	100%	86	21%	62	0.34%

Table 14 Change in ME-7 Monthly Average Stream Flow Due to Groundwater Extraction, September through November, 2000-2020

	ME-7					
	Maximum Change in Flow		Average Change in Flow		Minimum Change in Flow (cfs)	
Scenario	**cfs**	**% Of Total Flow**	**cfs**	**% Of Total Flow**	**cfs**	**% Of Total Flow**
Current Conditions	15	12%	10	2%	7	0.04%
10% Increase	16	13%	11	3%	8	0.04%
20% Increase	17	15%	12	3%	8	0.04%
30% Increase	19	16%	13	3%	9	0.05%
40% Increase	20	17%	14	3%	10	0.05%
50% Increase	22	18%	15	4%	10	0.05%
100% Increase	29	25%	21	5%	14	0.08%
150% Increase	37	31%	26	6%	18	0.10%
200% Increase	44	37%	31	7%	22	0.12%
250% Increase	52	43%	36	9%	25	0.14%
300% Increase	59	49%	41	10%	29	0.16%
400% Increase	74	61%	52	12%	37	0.20%
500% Increase	89	74%	62	15%	44	0.24%
800% Increase	133	100%	94	22%	67	0.37%

6.2.6.3 Modeled Changes in River Stage at Surface Water Depletion Locations of Interest

The next step in the analysis of surface water depletion examines the effect of the change in flow on river stage. The shape and size of the river channel varies by location and is dynamic due to active migration of sediments. To evaluate the variation of the channel geometry and flow rates throughout the basin, several low flow stream gages were installed along the Eel and Van Duzen rivers. The gage station locations are shown in **Figure 6.12**. Each station recorded flow data over the low flow period and stage/discharge relationships were developed for each gage location. The measured flow data is shown on **Figures 6.13** through **Figure 6.15**, with **Figure 6.13** showing the Upper Eel River gages above the Van Duzen confluence, **Figure 6.14** showing Main Eel River gages below the confluence, and **Figure 6.15** showing gages on the Van Duzen River. The stage/discharge curve for each gage station is shown on **Figure 6.16.**

The analysis of the change in stage at each surface water depletion locations utilizes the stage/discharge relationship from the closest gage station. The stream gage station associated with each surface water depletion location is shown in Table 5.

Table 15 Stream Gages Associated with Surface Water Depletion Location

Surface Water Depletion Location of Interest	Closest Stream Gage
ME-1	SW-7
ME-2	SW-7 and SW-5
ME-3	SW-5
ME-4	R-2
ME-5	R-2 and R-5
ME-6	R-2 and R-5
ME-7	R-5

The stage/discharge relationship provides the depth of the river for a given flow rate. The relationship varies with the flow rate: changes in the stage are greater at the lower flow rates, and changes in the stage decrease as flows increase. Therefore, it is important to consider the flow rate when fish are migrating when evaluating the effects of flow depletion on river stage. The monthly average stream flows in the fall are typically below the minimum fish passage flows of 130 cfs. The monthly average flow rates typically increase in October and November. Increased river flows that allow for fish passage are typically caused by rainfall events. These events increase stream flows to greater than 130 cfs for periods of time in the order of a few days and then flows decrease below 130 cfs. The increase of flow in the river to greater than 130 cfs may only persist for a few days. The period when flow conditions permit fish migration may be obscured in the monthly average flow rates calculated by the model. To evaluate the effect of the change in flow due to groundwater extraction the stage/discharge relationship is used to calculate the change in stage that would occur due to groundwater extraction when the river stage was at the minimum fish passage flow of 130 cfs (see Section 6.2.6.1). The stage at 130 cfs is compared to what the stage would be without the change in flow due to the groundwater extraction scenario. That is to say that 130 cfs is the entry point for reviewing the stage/discharge relationship.

The evaluation of the change in river stage uses the stage/discharge relationship to determine the river depth at the minimum fish passage flow of 130 cfs and then what the stage would have been without the flow decrease due to the groundwater extraction for a given scenario. This stage is calculated using minimum fish passage flow (130 cfs) plus maximum scenario flow depletion. The difference between the river stage at 130 cfs and what the stage would have been without the flow depletion indicates the effect on the river stage due to groundwater extraction. As an example, the stage/discharge relationship from SW-7 is used for ME-1. Based on the SW-7 stage/discharge relationship, a flow of 130 cfs would result in a stage of 1.64 ft. Under the 800% groundwater extraction scenario the reduction in flow would be 53 cfs. Using the stage/discharge relationship, a flow of 183 (130 cfs plus the change in flow of 53 cfs) would result in a stage of 1.76, indicating a change in river stage of

0.12 ft. **Figure 6.17** shows the stage/discharge curve for SW-7. The vertical red line shows the flow rates of 130 and 183 cfs. The horizontal yellow line intersecting the discharge curve at the red lines indicate the stage of 1.64 ft and 1.76 ft, at the respective flow rates.

The model results indicate a negligible change in stage resulting from groundwater extraction under current conditions, and incrementally larger changes with scenarios of increased pumping rates. A summary of the change in stage at each surface water depletion location for each scenario is presented in **Table 16**.

Table 16 Change in Stream Stage at Minimum Fish Passage Flow (130 cfs) Due to Groundwater Extraction

Scenario	Change in River Stage Due to Groundwater Extraction (ft)						
	ME-1	ME-2	ME-3	ME-4	ME-5	ME-6	ME-7
Current Conditions	0.02	0.02	0.03	0.04	0.04	0.04	0.05
10% Increase	0.02	0.03	0.03	0.04	0.05	0.05	0.05
20% Increase	0.02	0.03	0.04	0.05	0.05	0.05	0.06
30% Increase	0.02	0.03	0.04	0.05	0.05	0.06	0.06
40% Increase	0.02	0.03	0.04	0.06	0.06	0.06	0.06
50% Increase	0.03	0.04	0.04	0.06	0.06	0.06	0.07
100% Increase	0.03	0.05	0.06	0.08	0.08	0.08	0.09
150% Increase	0.04	0.06	0.07	0.10	0.10	0.10	0.11
200% Increase	0.05	0.07	0.09	0.11	0.12	0.12	0.13
250% Increase	0.06	0.08	0.10	0.13	0.14	0.14	0.16
300% Increase	0.07	0.09	0.11	0.15	0.16	0.16	0.18
400% Increase	0.08	0.11	0.14	0.19	0.20	0.20	0.22
500% Increase	0.09	0.13	0.16	0.22	0.23	0.24	0.26
800% Increase	0.13	0.19	0.23	0.31	0.33	0.34	0.36

6.2.6.4 Groundwater Levels as a Proxy for Surface Water Depletion

The groundwater model can produce estimates of the monthly average groundwater elevations at monitoring well locations. To aid in selection of monitoring wells useful for the Impacts to Interconnected Surface Waters SMCs, modeled water level lowering associated with the extraction scenarios in candidate wells near the river were reviewed. Predicted lowering of groundwater levels associated with extraction is greatest in the immediate vicinity of the source of extraction itself, with a diminishing magnitude of impact as you move away from that source. In general, groundwater levels in wells adjacent to the river under any of the given increased groundwater pumping scenarios indicate the smallest range of groundwater level lowering, including current pumping conditions (i.e., 0.5 feet or less of change). Conversely, monitoring wells further away from the river exhibit a greater fluctuation of groundwater levels under increased pumping scenarios, likely due to closer proximity to the location of the groundwater extraction and reduced groundwater recharging influence of the river (i.e., losing stream conditions encountered in the summer and fall). Monitoring wells adjacent to the river are not sufficiently responsive to modelled increased pumping scenarios for setting water level minimum thresholds, while the groundwater levels in a selected set of 2021 County Monitoring Wells and a CASGEM Well have been identified as being a sufficient distance from the Eel River for use as Representative Monitoring Sites for evaluating impacts to surface waters and in the establishment of groundwater level proxies.

The evaluation of change in river stage due to groundwater extraction resulted in relatively small changes. The field measurement of river stage is typically +/- 0.1 ft. Therefore, modeled extraction scenarios that result in this 0.1 foot river stage depletion can be used by the model to correlate an associated groundwater level lowering in a given well in the vicinity of the river relative to that given well’s specific fall baseline water level (Note the newly installed

2021 County Monitoring Wells do not yet have an adequate period of record). As an example, **Figure 6.18** depicts the modeled monthly average groundwater levels of CASGEM Well 36942 from 2000 through 2020 for the existing condition and increased groundwater extraction scenarios including the resulting 0.1 foot, or greater, of associated river stage depletion. The monthly average groundwater levels may also be grouped by month to provide a distribution of groundwater levels for each pumping scenario month. Using this methodology, river stage depletion can now be attributed to each individual Representative Monitoring Site now utilizing an appropriately established groundwater level proxy as the Minimum Threshold for surface water depletion. Table 17 presents the potential RMS proxy wells and their associated monthly average groundwater level plot.

Table 17 Potential Surface Water Deletion RMS Proxy Wells

Potential RMS Proxy Well	Time Series Plot Figure
CASGEM 36942	**Figure 6.19**
MW-2s	**Figure 6.20**
MW-13	**Figure 6.21**
MW-20	**Figure 6.22**
MW-21	**Figure 6.23**
MW-22	**Figure 6.24**
MW-25	**Figure 6.25**
MW-30	**Figure 6.26**

6.2.6.5 Modeling Uncertainties of Depletion of Groundwater Analysis

The evaluation and quantification surface water depletion due to groundwater extraction is challenging due to the complexity and variability of the groundwater/surface water interchange. There is not a method to directly measure surface water depletion and using multiple models and monitoring data has some limitations and uncertainties.

The groundwater model uses a finite-difference grid cell of 1,000 ft by 1,000 ft and values used to define the physical characteristics, model inputs, and outputs represent the average values for a model grid cell. The complex nature of the river channel where critical riffles occur are not represented in the model. The model does accurately simulate the average flow and groundwater level for the model grid cell but the assessment of effect of the change in flow on the change in stage relies upon monitored data and a local stage/discharge relationship. Each individual surface water depletion location is comprised of several model gird cells. The river channel geometry is constantly changing. The analysis assumes that a critical riffle will form within a surface water depletion location. The modeled values for cells within a surface water depletion location are similar but there is variation. To be conservative, the analysis selected the highest value from the cells within a surface water depletion location.

Another factor that effects the uncertainty of the analysis is time step of the physical process. The rate of flow of surface waters is relatively quick, reported in feet per second, compared to groundwater, reported in feet per day. Dynamic changes in the river flow occur rapidly and changes in groundwater take much longer. The river flow measurements are reported as daily average values and the groundwater model reports monthly average values. The disparity of the time rates of the physical processes and reporting periods may introduce uncertainty to the analysis.

Unlike flow in the Eel and Van Duzen Rivers, long term flow in Salt River has not been monitored and therefore there is not a direct set of calibration targets that can be used to evaluate the goodness of fit of Salt River flow model predictions. Currently there has not been an investigation to determine the flow/stage relationships in Salt River. These factors introduce uncertainty to the Salt River depletion of interconnected surface water analysis. There are currently many ongoing or planned landscape-scale multi-benefit projects in the lower ERVB that may affect the analysis of surface water groundwater interactions in the lower basin. These including the Salt River Ecosystem Restoration Project, the Centerville Slough Restoration Project, Ocean Ranch Restoration, and Cannibal Island Restoration. Each of the landscape-scale projects are required to evaluate the associated environmental impacts following the California Environmental Quality Act (CEQA). Should future analysis require application of the model with landscape-scale accuracy, collection of data including surface water flows, bathymetry, shallow groundwater elevations, chloride concentrations, and/or total dissolved solids, among others, would be required to refine and calibrate the model locally.

SGMA requires that GSPs and the corresponding groundwater sustainability programs are reviewed at least every 5 years after initial submission. If, during one of those review periods, further predictive analysis that includes application of modeling is required or found to be warranted, the integrated groundwater/surface water flow and seawater intrusion models can be updated to include data collected as part of the landscape-scale multi-benefit projects in the lower ERVB.

6.3 Terrestrial GDE Assessment

To assess the impact of the SMCs on terrestrial GDEs we compared the modeled groundwater elevations for the 2003 water year with the 2003 pumping rates (historical pumping) with the groundwater elevations with pumping increased by 150 percent (increased pumping) while all other variables are held constant. A 150% increase in pumping corresponds to the SMC for basin. The modeled groundwater elevations for the historical and increased pumping periods were differenced to assess the effects of increased pumping on groundwater elevations in March (spring) and September (fall). Changes to the spring 2003 groundwater elevation were generally 0-2 ft for the basin with the exception of the upper portions of the Salt River near Waddington where spring groundwater elevations declined by up to 6 ft and near Loleta, where spring groundwater elevation declined by up to 4 ft. The decline in groundwater elevation was greater for September. The magnitude and extent of groundwater decline was greater in the fall for the coastal plain near the Salt River in the Middle Eel GDE unit, with groundwater declines from 2-6 ft. The GDEs along this portion of the basin are typically limited to the areas along channels and oxbows of the Salt River, where vegetation grows along the channel margins. GDE units along these channels were typically river/stream/canal, which includes emergent herbaceous species with rooting depths of up to 1-2 ft. Groundwater declines of 2-4 ft extend toward the Eel River in the Middle Eel GDE unit, potentially affecting willow and cottonwood forests along the channel comprised of red alder, various willow species, and black cottonwood. This vegetation can have relatively deep roots (up to 7-15 ft, depending on the species). Declines in groundwater of 2-4 ft have been documented seasonally and during droughts in the Middle Eel River. Near Loleta the fall groundwater elevation decreased by 2-4 ft potentially affecting small channels and willows in the Intertidal Zone and Tributaries GDE. For the remainder of the basin groundwater declines by 0-2 ft.

The effects of a long-term decline in groundwater of 2-4 ft in the ERVB are uncertain. There is limited data to correlate groundwater elevation changes with vegetation health because long-term groundwater data is somewhat limited (Stillwater Sciences, 2022). Historically, GDEs were resilient through droughts with little sustained decline in NDVI through time (Stillwater Sciences, 2022). However, a sustained decline of 2-4 ft could impact GDEs, particularly for plants at higher elevation within a particular GDE (and hence further from groundwater). In addition, vegetation that was able to survive droughts at historical pumping levels may become more stressed during droughts if pumping was increased by 150%. Where groundwater declines are small (the remainder of the basin outside of the Loleta and Salt River areas), the decline is likely to have limited effects on more deeply rooted GDEs, provided surface waters continue to be connected with groundwater, although vegetation at higher elevation relative to existing groundwater may become stressed during even modest declines in groundwater.

6.4 Effects of Climate Change Scenarios

Section 6.1.2 describes the implementation of the climate change scenarios in the integrated groundwater/surface water and seawater intrusion models. Evaluation of the effects of climate change on the basin have been prepared by comparing average groundwater levels in the quaternary alluvium, changes in storage, stream flow at critical riffle locations, and volumes of accessible freshwater.

Figure 6.27 shows average quaternary alluvium groundwater elevations in both the near future (i.e., 2030) and late future (i.e., 2070) climate conditions on the left and right panels, respectively. A yellow horizontal line is presented to show the average groundwater elevations for the reference period of March 2003. Horizontal green lines are presented to show the average March groundwater elevations in each of the two climate change scenarios. The average March climate change scenarios show increases to average alluvium water levels. The climate change scenarios show average March groundwater elevations as rising by 0.9 ft and 1.2 feet in the near and late future scenarios, respectively. As discussed in Section 6.2.1 chronic lowering of water levels is not expected to be a factor for ERVB. The climate change scenarios indicate that chronic lowering also is not expected into the near and late future. This is attributable to the climate forecast models for this area of California that show wetter average conditions (i.e., more precipitation) that the DWR (2018) datasets are based upon. Those same forecasts show warmer average minimum and maximum temperatures; however, these warmer conditions are not warm enough to counteract the effect of the increased precipitation, resulting in greater recharge and increased groundwater elevations.

These increased water levels do not result in long-term decreasing storage levels as illustrated on **Figure 6.28**. Cumulative changes in storage show increasing trends towards the ends of the simulation timeframes (i.e., beginning in water year 2044 in the near future model and 2084 in the late future model) resulting from the wetter conditions compared throughout the simulation period. **Figure 6.28** shows climate model changes in storage that align with current/recent times. These changes in storage have been greyed-out on **Figure 6.28** to reflect they do not reflect actual conditions but rather conditions simulated through the climate forecast models. These scenarios imply that ERVB will experience fewer reductions in groundwater storage due to changing climate conditions when compared to current conditions, as presented on **Figure 6.6**.

The effect of these future climate scenarios on stream flows and stage elevations at the seven focused study locations on the Main Eel River are illustrated on **Figures 6.29** and **6.30**, respectively. Each of the boxplots[16] shows the Near Future, Late Future, and current conditions presented as a reference. **Figures 6.29** and **6.30** show that flows and stage elevations in the Eel River are not expected to lower and climate change is not expected to negatively affect streamflow depletion.

The effects sea level rising to 0.49 ft in the near future (2030) and to 1.49 ft and 3 ft in late future (2070) have on the volume of accessible freshwater in the basin were evaluated using the saltwater intrusion model. **Figure 6.33** shows each of these three scenarios and provides summary statistics that include minimum, average, and maximum freshwater volumes. The difference between current conditions and the climate change scenarios is the expected increase in wetness under future conditions. This results in greater volumes of freshwater in the basin. Despite the 1.48 feet of sea level rise represented by the Late Future (2070) model, the additional wetness under the 2070 model compared to the 2030 model results in more freshwater volume in the basin. Under the 3-foot sea level rise scenario, there is a reduction in freshwater volume compared to the 1.48-foot sea level rise condition that ranges from 1,000-acre-feet to 31,000-acre-feet.

6.4.1 Modeling Uncertainties of Climate Change Analysis

The integrated groundwater/surface water and seawater intrusion models were developed using climate data obtained from the PRISM dataset that formed key inputs to the PRMS model that then generated the boundary conditions of the MODFLOW and SEAWAT models. However, the climate change dataset was developed by DWR using different methodologies than the historical datasets. These differences are documented in DWR (2018). As a result, changes between current conditions and future conditions are not directly comparable. However, the forecast models tend to show an increasing water level in the ERVB (compare, for example, the 2030 and 2070 model scenarios). These forecasted wet conditions and the corresponding rising levels will make the basin more resilient to chronic lowering of water levels, storage loss, and seawater intrusion.

[16] A boxplot is a simplified way of evaluating the spread of data in which a box represents the range between the 25th and 75th percentiles, an horizontal line represents the median value, whiskers (vertical lines) represent 1.5× the range from 25th percentile to the median and 1.5× the range from the median to the 75th percentile. Values outside of the range of upper and lower box plot whiskers are presented as symbols.

7. Summary and Conclusions

SGMA requires local governments and water agencies in California's high and medium priority groundwater basins to form GSAs and operate under a GSP by 2022. Groundwater in the ERVB supports several beneficial uses.

A key component of a GSP is avoidance of a range of undesirable results as defined in SGMA.

The Humboldt County Groundwater Sustainability Agency retained a project team consisting of GHD, SHN Consulting Engineers, Stillwater Sciences, and Thomas Gast & Associates, in collaboration with USGS to develop integrated groundwater/surface water and seawater intrusion models to represent the hydrologic, geologic, and hydrogeologic conditions in the ERVB. 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 10 equally calibrated model realizations. The model uncertainty analysis indicated the transient groundwater flow model is reasonably constrained where there are numerous observations, such as near the Channel Deposits and Quaternary Alluvium. These areas provide greater reliability in model predictions. This area also is where much of the water use is occurring within the ERVB and therefore is the area of focus for application of the model.

The integrated groundwater/surface water and seawater intrusion models were applied to evaluate the key sustainability management criteria to understand whether water uses in ERVB can be sustained currently and into the future without creating undesirable results. Models were developed to represent current and historical conditions. The integrated groundwater/surface water model also was applied to represent near (2030) and late (2070) future conditions. To evaluate undesirable results a reference condition of the groundwater flow system is necessary. Commonly this reference is a historical comparison, such as the date of the implementation of SGMA, to evaluate trends. When trends are not evident, as is the case in ERVB, selection of an appropriate average conditions is required. Historical trends in the CASGEM program monitoring wells were evaluated because these wells currently are active, are located in the ERVB, and have a long period of record. Based on this review March 2003 provides a reasonable average groundwater system condition representing wet conditions for model output comparisons. As there is not a lot of variability in fall water level conditions Fall 2003 was selected as average fall conditions to be consistent with spring analyses.

Based on those analyses the following conclusions are made:

– **Chronic Lowering of Groundwater Levels**
  - Current and historical conditions: 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.
  - Near and late future conditions: Average March water level conditions in near and late future are expected to be higher than March 2003 reference conditions indicating that chronic lowering of water levels is not expected in ERVB. This is a result of the generally wetter conditions predicted through the climate forecast models that these analyses are based on.

– **Reduction in Groundwater Storage**
  - Current and historical conditions: The change in storage in the ERVB was developed by subtracting previous from current March and September water volumes in the alluvium, for spring and fall analyses, respectively. From 2000 through to 2020 the net change in volume and cumulative net change in volume are stable and decreasing trends are not evident.
  - Near and late future conditions: In near and late future conditions groundwater storage is anticipated to be stable and with increasing cumulative groundwater storage arising in the latter part of the near and late future simulations. Reduction in groundwater storage is not expected in ERVB.

- **Seawater Intrusion**
  - Current and historical conditions: 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. Near the middle of the basin that advance and retreat spans approximately 4,750 feet due to climatic conditions, alone (i.e., without pumping). The advance due to pumping is on the order of approximately 700 feet. Under extreme 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.
  - Near and late future conditions: The near and late future forecasted wet conditions are predicted to provide enough freshwater into the basin to prevent a reduction of accessible freshwater under 0.49 ft, 1.48 ft, and 3 ft of sea level rise.
- **Depletion of Interconnected Surface Water**
  - Current and historical conditions: Streamflow depletions is a sustainability indicator that is of key interest in the Basin. One of the key questions with the depletion of surface waters is the potential effects on the upstream migration of adult salmon and steelhead. The time period when this occurs is generally in the fall (September through November). Reviews of migration timing and riffle depth data collected from 2010 to 2020 showed upstream migration by adult Chinook salmon in the Lower Eel River during the early fall is inhibited by riffles that are 0.5 – 0.6 feet deep and is blocked by rifle depths 0.4 feet or less. The model was applied to evaluate the effects of water use, current and increased pumping rates, on flow and depth of water (stage elevations) at critical riffle locations. Salt River flows also were evaluated; however, these analyses should be considered preliminary because the integrated groundwater/surface water model was not calibrated to surface water flows in Salt River.
  - Near and late future conditions: near and late future flows and stage elevations are expected to be greater than current and historical conditions owing to the generally wetter conditions predicted by the climate forecast models for this area.

Each of the sustainability indicators were evaluated under current and future climatic conditions using current and enhanced water use conditions. The enhanced water use conditions ranged from moderate to extreme [nine (9) times current conditions]. Only during extreme water use conditions, when water use is much greater than the evaporative demand, are there undesirable results.

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Tables

Table 4.1

Well Locations and Pumping Rates Assigned to Transient Models
Eel River Valley Groundwater Sustainability Plan
Humboldt County Groundwater Sustainability Agency

Well Identification	State Plane Coordinate X	State Plane Coordinate Y	Screen Elevation (NAVD88) Top	Screen Elevation (NAVD88) Bottom	Well Type	Pumping Rate (GPM) Minimum	Pumping Rate (GPM) Maximum
Municipality							
Bear River	5,949,073	2,120,296	-346	-366	Municipal Supply	18	46
Ferndale	5,936,329	2,105,461	-114	-134	Municipal Supply	79	161
Fortuna	5,965,286	2,098,507	-27	-55	Municipal Supply	602	1,191
Hydesville	5,986,520	2,087,832	111	84	Municipal Supply	18	133
Loleta	5,945,641	2,126,820	-190	-195	Municipal Supply	24	70
Palmer Creek	5,956,866	2,110,863	-11	-21	Municipal Supply	0	28
Rio Dell(1)	5,974,639	2,073,583	--	--	Municipal Supply	127	279
Riverside	5,928,114	2,103,168	-18	-28	Municipal Supply	12	28
Scotia(1)	5,975,178	2,063,310	--	--	Municipal Supply	263	475
Land Classification Code							
100-101-001-000	5,926,215	2,116,777	--	--	Agriculture	0	105
100-101-002-000	5,927,952	2,116,267	--	--	Agriculture	0	155
100-101-003-000	5,929,738	2,116,430	--	--	Agriculture	0	56
100-101-004-000	5,929,242	2,113,535	--	--	Agriculture	0	278
100-101-005-000	5,928,347	2,114,468	--	--	Agriculture	0	89
100-101-006-000	5,926,376	2,114,526	--	--	Agriculture	0	196
100-101-007-000	5,926,224	2,113,201	--	--	Agriculture	0	201
100-102-002-000	5,931,780	2,116,813	--	--	Agriculture	0	35
100-102-003-000	5,931,975	2,115,097	--	--	Agriculture	0	262
100-102-004-000	5,933,804	2,117,178	--	--	Agriculture	0	75
100-102-005-000	5,933,431	2,116,313	--	--	Agriculture	0	16
100-102-006-000	5,934,080	2,116,298	--	--	Agriculture	0	25
100-102-007-000	5,933,730	2,115,310	--	--	Agriculture	0	47
100-102-008-000	5,933,712	2,114,647	--	--	Agriculture	0	44
100-102-009-000	5,933,690	2,113,987	--	--	Agriculture	0	45
100-102-010-000	5,935,047	2,115,704	--	--	Agriculture	0	220
100-102-011-000	5,935,337	2,113,204	--	--	Agriculture	0	71
100-102-012-000	5,934,664	2,113,228	--	--	Agriculture	0	321
100-102-013-000	5,933,993	2,112,968	--	--	Agriculture	0	47
100-102-014-000	5,933,338	2,112,996	--	--	Agriculture	0	45
100-102-015-000	5,932,510	2,113,067	--	--	Agriculture	0	76
100-102-016-000	5,931,090	2,113,491	--	--	Agriculture	0	185
100-111-002-000	5,925,450	2,110,775	--	--	Agriculture	0	262
100-111-009-000	5,928,239	2,111,610	--	--	Agriculture	0	333
100-111-013-000	5,926,952	2,109,982	--	--	Agriculture	0	360
100-111-014-000	5,929,008	2,109,872	--	--	Agriculture	0	214
100-112-003-000	5,930,579	2,108,684	--	--	Agriculture	0	21
100-112-004-000	5,930,554	2,109,379	--	--	Agriculture	0	21
100-112-005-000	5,931,871	2,109,027	--	--	Agriculture	0	132
100-112-006-000	5,930,933	2,111,054	--	--	Agriculture	0	182
100-112-007-000	5,932,260	2,111,016	--	--	Agriculture	0	179
100-112-008-000	5,933,619	2,111,641	--	--	Agriculture	0	94
100-112-009-000	5,934,531	2,111,609	--	--	Agriculture	0	38
100-112-010-000	5,934,911	2,111,591	--	--	Agriculture	0	19
100-112-011-000	5,935,324	2,111,570	--	--	Agriculture	0	41
100-112-012-000	5,935,146	2,110,254	--	--	Agriculture	0	58
100-112-014-000	5,934,025	2,109,047	--	--	Agriculture	0	67
100-112-015-000	5,933,811	2,110,304	--	--	Agriculture	0	109
100-142-008-000	5,915,513	2,105,403	--	--	Agriculture	0	59
100-142-009-000	5,915,490	2,104,049	--	--	Agriculture	0	62
100-142-011-000	5,915,582	2,106,735	--	--	Agriculture	0	171
100-142-019-000	5,916,441	2,104,733	--	--	Agriculture	0	219
100-142-021-000	5,914,281	2,102,889	--	--	Agriculture	0	98
100-142-021-000	5,914,739	2,104,737	--	--	Agriculture	0	98
100-143-004-000	5,912,782	2,103,183	--	--	Agriculture	0	191
100-152-021-000	5,928,794	2,105,023	--	--	Agriculture	0	238
100-161-007-000	5,934,444	2,108,301	--	--	Agriculture	0	82
100-191-009-000	5,937,976	2,107,514	--	--	Agriculture	0	102
100-191-014-000	5,938,843	2,109,002	--	--	Agriculture	0	85
100-201-004-000	5,940,161	2,104,999	--	--	Agriculture	0	284
100-201-005-000	5,940,159	2,104,304	--	--	Agriculture	0	27
100-201-006-000	5,938,800	2,104,712	--	--	Agriculture	0	352
100-201-034-000	5,936,554	2,106,442	--	--	Agriculture	0	30
100-201-038-000	5,935,952	2,106,094	--	--	Agriculture	0	19
100-201-050-000	5,937,319	2,106,198	--	--	Agriculture	0	87

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Humboldt County Groundwater Sustainability Agency

Well Identification	State Plane Coordinate X	State Plane Coordinate Y	Screen Elevation (NAVD88) Top	Screen Elevation (NAVD88) Bottom	Well Type	Pumping Rate (GPM) Minimum	Pumping Rate (GPM) Maximum
100-211-001-000	5,939,458	2,103,789	--	--	Agriculture	0	54
100-211-002-000	5,940,153	2,102,925	--	--	Agriculture	0	227
100-211-003-000	5,940,138	2,101,930	--	--	Agriculture	0	348
100-211-004-000	5,938,767	2,101,716	--	--	Agriculture	0	18
100-211-007-000	5,938,786	2,103,207	--	--	Agriculture	0	31
100-212-005-000	5,936,456	2,102,550	--	--	Agriculture	0	21
100-212-008-000	5,935,807	2,102,559	--	--	Agriculture	0	7
100-212-009-000	5,936,115	2,103,046	--	--	Agriculture	0	23
100-212-012-000	5,937,508	2,103,821	--	--	Agriculture	0	41
100-212-021-000	5,936,297	2,102,058	--	--	Agriculture	0	8
100-212-028-000	5,936,095	2,103,697	--	--	Agriculture	0	36
100-221-001-000	5,940,098	2,100,703	--	--	Agriculture	0	103
100-221-002-000	5,938,985	2,100,615	--	--	Agriculture	0	80
100-221-003-000	5,938,177	2,101,162	--	--	Agriculture	0	16
100-221-004-000	5,938,189	2,100,275	--	--	Agriculture	0	52
100-222-001-000	5,940,053	2,099,344	--	--	Agriculture	0	331
100-241-001-000	5,931,377	2,107,667	--	--	Agriculture	0	13
101-011-005-000	5,915,526	2,102,264	--	--	Agriculture	0	18
101-011-014-000	5,914,690	2,103,165	--	--	Agriculture	0	14
101-011-016-000	5,916,006	2,103,211	--	--	Agriculture	0	11
106-011-001-000	5,936,364	2,115,050	--	--	Agriculture	0	250
106-011-002-000	5,936,357	2,112,549	--	--	Agriculture	0	46
106-011-003-000	5,938,338	2,112,711	--	--	Agriculture	0	156
106-011-004-000	5,939,273	2,113,753	--	--	Agriculture	0	394
106-011-006-000	5,943,044	2,114,017	--	--	Agriculture	0	94
106-011-007-000	5,944,369	2,114,015	--	--	Agriculture	0	63
106-011-008-000	5,945,606	2,113,805	--	--	Agriculture	0	83
106-011-009-000	5,947,528	2,112,374	--	--	Agriculture	0	329
106-011-011-000	5,941,582	2,115,323	--	--	Agriculture	0	38
106-011-013-000	5,939,755	2,117,126	--	--	Agriculture	0	84
106-011-016-000	5,937,747	2,115,471	--	--	Agriculture	0	36
106-011-020-000	5,947,775	2,112,982	--	--	Agriculture	0	31
106-011-022-000	5,941,659	2,112,751	--	--	Agriculture	0	423
106-011-023-000	5,941,688	2,114,060	--	--	Agriculture	0	91
106-011-024-000	5,945,562	2,113,288	--	--	Agriculture	0	359
106-021-001-000	5,936,295	2,111,876	--	--	Agriculture	0	48
106-021-002-000	5,936,272	2,111,205	--	--	Agriculture	0	49
106-021-003-000	5,936,242	2,110,220	--	--	Agriculture	0	93
106-021-007-000	5,937,568	2,109,827	--	--	Agriculture	0	38
106-021-011-000	5,940,287	2,111,108	--	--	Agriculture	0	143
106-021-012-000	5,940,231	2,109,146	--	--	Agriculture	0	127
106-021-013-000	5,941,628	2,111,270	--	--	Agriculture	0	107
106-021-020-000	5,941,197	2,107,426	--	--	Agriculture	0	45
106-021-024-000	5,942,829	2,106,018	--	--	Agriculture	0	100
106-021-025-000	5,942,852	2,107,386	--	--	Agriculture	0	94
106-021-028-000	5,942,930	2,110,057	--	--	Multi Family Residential	0	89
106-021-030-000	5,943,232	2,111,297	--	--	Agriculture	0	54
106-021-032-000	5,944,274	2,111,374	--	--	Agriculture	0	91
106-021-033-000	5,945,749	2,111,505	--	--	Agriculture	0	110
106-021-036-000	5,946,844	2,108,629	--	--	Agriculture	0	84
106-021-037-000	5,945,367	2,108,075	--	--	Agriculture	0	186
106-021-038-000	5,944,173	2,107,384	--	--	Agriculture	0	78
106-021-039-000	5,944,114	2,105,400	--	--	Agriculture	0	155
106-021-040-000	5,945,408	2,105,810	--	--	Agriculture	0	95
106-021-046-000	5,943,972	2,108,712	--	--	Agriculture	0	45
106-021-048-000	5,944,581	2,110,006	--	--	Agriculture	0	154
106-021-050-000	5,941,638	2,109,748	--	--	Agriculture	0	64
106-021-056-000	5,945,984	2,110,134	--	--	Agriculture	0	63
106-021-061-000	5,938,971	2,111,470	--	--	Agriculture	0	95
106-021-062-000	5,937,682	2,111,069	--	--	Agriculture	0	122
106-021-063-000	5,947,016	2,110,844	--	--	Agriculture	0	110
106-021-066-000	5,942,619	2,111,551	--	--	Agriculture	0	35
106-021-068-000	5,942,949	2,108,624	--	--	Agriculture	0	55
106-021-071-000	5,941,883	2,107,421	--	--	Agriculture	0	38
106-021-073-000	5,938,926	2,110,389	--	--	Agriculture	0	57
106-021-076-000	5,936,195	2,108,875	--	--	Agriculture	0	21
106-021-077-000	5,937,442	2,108,881	--	--	Agriculture	0	54

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Well Identification	State Plane Coordinate X	Y	Screen Elevation (NAVD88) Top	Bottom	Well Type	Pumping Rate (GPM) Minimum	Maximum
106-021-078-000	5,941,213	2,108,919	--	--	Agriculture	0	36
106-021-081-000	5,940,526	2,107,448	--	--	Agriculture	0	42
106-021-083-000	5,939,028	2,109,766	--	--	Agriculture	0	33
106-021-086-000	5,942,781	2,104,778	--	--	Agriculture	0	68
106-021-087-000	5,943,273	2,104,310	--	--	Agriculture	0	4
106-031-001-000	5,948,720	2,113,443	--	--	Agriculture	0	56
106-031-010-000	5,948,828	2,108,374	--	--	Agriculture	0	110
106-031-011-000	5,947,480	2,107,284	--	--	Agriculture	0	188
106-031-012-000	5,947,831	2,105,146	--	--	Agriculture	0	264
106-031-013-000	5,949,339	2,104,312	--	--	Agriculture	0	299
106-031-014-000	5,949,877	2,105,230	--	--	Agriculture	0	113
106-031-015-000	5,949,470	2,107,199	--	--	Agriculture	0	90
106-031-016-000	5,950,579	2,103,948	--	--	Agriculture	0	57
106-031-018-000	5,950,794	2,105,981	--	--	Agriculture	0	65
106-031-019-000	5,952,771	2,104,045	--	--	Agriculture	0	376
106-031-020-000	5,952,799	2,105,620	--	--	Agriculture	0	60
106-031-021-000	5,952,793	2,106,145	--	--	Agriculture	0	77
106-031-023-000	5,952,177	2,107,768	--	--	Agriculture	0	175
106-031-024-000	5,951,016	2,109,066	--	--	Agriculture	0	102
106-031-026-000	5,950,812	2,107,159	--	--	Agriculture	0	86
106-031-027-000	5,947,824	2,111,306	--	--	Agriculture	0	36
106-031-034-000	5,949,140	2,109,497	--	--	Agriculture	0	215
106-031-036-000	5,948,654	2,112,400	--	--	Agriculture	0	57
106-031-040-000	5,949,983	2,111,501	--	--	Agriculture	0	401
106-031-041-000	5,952,529	2,111,102	--	--	Agriculture	0	559
106-031-043-000	5,953,509	2,107,709	--	--	Agriculture	0	164
106-031-045-000	5,952,858	2,109,564	--	--	Agriculture	0	135
106-041-003-000	5,954,986	2,108,069	--	--	Agriculture	0	535
106-041-005-000	5,955,511	2,105,811	--	--	Agriculture	0	121
106-041-007-000	5,954,757	2,104,618	--	--	Agriculture	0	89
106-051-001-000	5,941,417	2,104,249	--	--	Agriculture	0	74
106-051-002-000	5,941,467	2,103,035	--	--	Agriculture	0	71
106-051-003-000	5,941,447	2,101,938	--	--	Agriculture	0	324
106-051-004-000	5,942,721	2,103,299	--	--	Agriculture	0	76
106-051-005-000	5,943,692	2,102,650	--	--	Agriculture	0	239
106-051-006-000	5,945,432	2,102,211	--	--	Agriculture	0	104
106-051-007-000	5,945,564	2,103,994	--	--	Agriculture	0	148
106-051-008-000	5,947,069	2,104,177	--	--	Agriculture	0	161
106-051-009-000	5,947,309	2,102,244	--	--	Agriculture	0	177
106-051-010-000	5,949,480	2,102,205	--	--	Agriculture	0	87
106-051-013-000	5,950,444	2,102,109	--	--	Agriculture	0	41
106-051-015-000	5,951,115	2,103,128	--	--	Agriculture	0	148
106-061-001-000	5,941,444	2,100,733	--	--	Agriculture	0	433
106-061-002-000	5,940,836	2,099,419	--	--	Agriculture	0	134
106-061-006-000	5,945,410	2,100,907	--	--	Agriculture	0	85
106-061-007-000	5,945,392	2,099,873	--	--	Agriculture	0	50
106-061-012-000	5,946,987	2,097,096	--	--	Agriculture	0	41
106-061-013-000	5,946,787	2,098,974	--	--	Agriculture	0	139
106-061-014-000	5,946,735	2,100,298	--	--	Agriculture	0	56
106-061-015-000	5,946,731	2,101,119	--	--	Agriculture	0	57
106-061-016-000	5,948,091	2,100,233	--	--	Agriculture	0	171
106-061-017-000	5,949,375	2,100,919	--	--	Agriculture	0	75
106-061-024-000	5,949,360	2,099,238	--	--	Agriculture	0	33
106-061-028-000	5,950,720	2,100,252	--	--	Agriculture	0	23
106-061-036-000	5,951,026	2,097,084	--	--	Agriculture	0	17
106-061-037-000	5,950,463	2,096,625	--	--	Agriculture	0	75
106-061-038-000	5,950,669	2,095,296	--	--	Agriculture	0	106
106-061-039-000	5,950,654	2,094,020	--	--	Agriculture	0	50
106-061-041-000	5,949,288	2,095,513	--	--	Agriculture	0	87
106-061-046-000	5,950,699	2,099,415	--	--	Agriculture	0	92
106-061-047-000	5,950,868	2,098,093	--	--	Agriculture	0	65
106-061-052-000	5,945,631	2,097,303	--	--	Agriculture	0	188
106-061-053-000	5,945,473	2,099,025	--	--	Agriculture	0	67
106-061-054-000	5,949,550	2,094,730	--	--	Agriculture	0	88
106-061-066-000	5,950,588	2,100,857	--	--	Agriculture	0	46
106-061-067-000	5,943,487	2,100,519	--	--	Agriculture	0	256
106-061-069-000	5,944,049	2,097,963	--	--	Agriculture	0	149

Table 4.1

Well Locations and Pumping Rates Assigned to Transient Models
Eel River Valley Groundwater Sustainability Plan
Humboldt County Groundwater Sustainability Agency

Well Identification	State Plane Coordinate X	Y	Screen Elevation (NAVD88) Top	Bottom	Well Type	Pumping Rate (GPM) Minimum	Maximum
106-071-002-000	5,947,617	2,097,849	--	--	Rural Residential	0	15
106-071-013-000	5,949,495	2,098,328	--	--	Agriculture	0	20
106-071-016-000	5,949,125	2,096,842	--	--	Agriculture	0	23
106-071-017-000	5,948,790	2,096,854	--	--	Agriculture	0	23
106-071-018-000	5,948,422	2,096,867	--	--	Agriculture	0	22
106-071-019-000	5,947,930	2,096,881	--	--	Agriculture	0	33
106-071-020-000	5,947,470	2,096,910	--	--	Agriculture	0	24
106-071-022-000	5,947,736	2,098,443	--	--	Rural Residential - Vacant	0	26
106-071-023-000	5,949,604	2,096,766	--	--	Agriculture	0	200
106-081-003-000	5,947,201	2,095,620	--	--	Agriculture	0	71
106-081-005-000	5,948,339	2,095,389	--	--	Agriculture	0	47
106-091-001-000	--	--	--	--	--	0	85
106-091-002-000	5,953,492	2,102,016	--	--	Agriculture	0	79
106-091-003-000	--	--	--	--	--	0	304
106-091-004-000	5,952,013	2,098,706	--	--	Agriculture	0	177
106-091-005-000	5,953,303	2,097,837	--	--	Agriculture	0	111
106-091-006-000	5,954,410	2,101,987	--	--	Agriculture	0	46
106-091-007-000	5,955,070	2,101,966	--	--	Agriculture	0	46
106-091-008-000	5,956,288	2,101,671	--	--	Agriculture	0	228
106-091-009-000	5,956,453	2,100,057	--	--	Agriculture	0	752
106-091-012-000	5,955,392	2,097,475	--	--	Agriculture	0	143
106-091-013-000	5,956,274	2,097,317	--	--	Agriculture	0	87
106-091-014-000	5,957,122	2,097,976	--	--	Agriculture	0	138
106-091-015-000	5,957,320	2,096,194	--	--	Agriculture	0	46
106-091-018-000	5,957,666	2,097,907	--	--	Agriculture	0	215
106-091-020-000	5,958,163	2,096,449	--	--	Agriculture	0	32
106-091-023-000	5,958,837	2,096,393	--	--	Agriculture	0	70
106-091-024-000	5,959,888	2,096,522	--	--	Agriculture	0	85
106-091-025-000	5,960,722	2,097,805	--	--	Agriculture	0	271
106-091-046-000	5,954,425	2,097,632	--	--	Agriculture	0	81
106-101-001-000	5,951,975	2,096,754	--	--	Agriculture	0	67
106-101-002-000	5,951,954	2,095,800	--	--	Agriculture	0	43
106-101-003-000	5,951,909	2,095,134	--	--	Agriculture	0	45
106-101-007-000	5,953,584	2,094,747	--	--	Agriculture	0	135
106-101-009-000	5,953,118	2,095,917	--	--	Agriculture	0	231
106-101-012-000	5,954,647	2,095,654	--	--	Agriculture	0	73
106-101-014-000	5,954,719	2,093,719	--	--	Agriculture	0	66
106-101-018-000	5,956,925	2,094,915	--	--	Agriculture	0	21
106-101-021-000	5,956,740	2,095,585	--	--	Agriculture	0	9
106-101-022-000	5,957,063	2,095,533	--	--	Agriculture	0	9
106-101-028-000	5,957,367	2,092,039	--	--	Agriculture	0	120
106-101-029-000	5,957,172	2,090,939	--	--	Agriculture	0	45
106-101-030-000	5,957,848	2,089,955	--	--	Agriculture	0	187
106-101-031-000	5,958,638	2,091,801	--	--	Agriculture	0	79
106-101-033-000	5,959,746	2,094,353	--	--	Agriculture	0	258
106-101-034-000	5,958,779	2,094,992	--	--	Agriculture	0	41
106-101-036-000	5,961,223	2,095,204	--	--	Agriculture	0	86
106-101-054-000	5,954,094	2,096,029	--	--	Agriculture	0	19
106-101-056-000	5,956,166	2,095,839	--	--	Agriculture	0	20
106-101-059-000	5,951,418	2,094,087	--	--	Agriculture	0	27
106-101-060-000	5,955,479	2,095,054	--	--	Agriculture	0	118
106-101-064-000	5,956,071	2,094,080	--	--	Agriculture	0	81
106-101-071-000	5,957,124	2,093,929	--	--	Agriculture	0	77
106-101-073-000	5,957,863	2,094,609	--	--	Agriculture	0	102
106-111-002-000	5,954,012	2,093,412	--	--	Agriculture	0	8
106-111-004-000	5,955,962	2,092,432	--	--	Agriculture	0	254
106-221-003-000	5,961,178	2,090,195	--	--	Agriculture	0	9
106-221-005-000	5,960,463	2,088,606	--	--	Agriculture	0	329
106-221-007-000	5,959,813	2,089,630	--	--	Agriculture	0	11
106-221-008-000	5,959,772	2,090,029	--	--	Agriculture	0	39
106-221-009-000	5,959,780	2,090,436	--	--	Agriculture	0	14
106-221-012-000	5,959,813	2,091,546	--	--	Agriculture	0	45
106-221-013-000	5,960,424	2,092,500	--	--	Agriculture	0	72
201-172-001-000	5,964,678	2,097,144	--	--	Agriculture	0	28
201-172-003-000	5,964,830	2,096,166	--	--	Agriculture	0	7
201-201-003-000	5,964,805	2,094,225	--	--	Agriculture	0	243
201-201-005-000	5,963,924	2,093,176	--	--	Agriculture	0	18

Table 4.1

Well Locations and Pumping Rates Assigned to Transient Models
Eel River Valley Groundwater Sustainability Plan
Humboldt County Groundwater Sustainability Agency

Well Identification	State Plane Coordinate X	Y	Screen Elevation (NAVD88) Top	Bottom	Well Type	Pumping Rate (GPM) Minimum	Maximum
201-201-008-000	5,964,050	2,094,440	--	--	Agriculture	0	132
201-201-009-000	5,962,685	2,094,540	--	--	Open Space/Parks	0	37
201-211-003-000	5,963,941	2,092,420	--	--	Agriculture	0	453
201-221-009-000	5,963,963	2,091,140	--	--	Agriculture	0	12
201-221-010-000	5,964,702	2,090,916	--	--	Agriculture	0	11
201-221-010-000	5,965,113	2,090,813	--	--	Agriculture	0	11
201-261-001-000	5,963,845	2,088,998	--	--	Agriculture	0	44
201-261-003-000	5,964,902	2,089,663	--	--	Agriculture	0	13
201-261-008-000	5,964,961	2,088,416	--	--	Agriculture	0	82
201-262-004-000	5,966,521	2,088,358	--	--	Agriculture	0	47
201-311-004-000	5,968,993	2,087,012	--	--	Grazing/Timber	0	151
201-311-013-000	5,968,680	2,088,715	--	--	Rural Residential	0	239
201-311-017-000	5,967,634	2,088,615	--	--	Agriculture	0	419
201-322-008-000	5,970,233	2,088,573	--	--	Grazing/Timber	0	78
201-322-020-000	5,969,793	2,086,325	--	--	Agriculture	0	20
201-322-021-000	5,970,197	2,086,297	--	--	Grazing/Timber	0	23
201-322-022-000	5,970,596	2,086,297	--	--	Grazing/Timber	0	41
204-051-008-000	5,986,970	2,078,812	--	--	--	0	22
204-071-011-000	5,987,328	2,080,584	--	--	--	0	53
204-072-003-000	5,991,896	2,082,418	--	--	Timber Production	0	38
204-072-006-000	5,988,964	2,081,300	--	--	--	0	50
204-081-002-000	5,973,431	2,088,105	--	--	Agriculture	0	418
204-081-005-000	5,973,512	2,086,209	--	--	Agriculture	0	257
204-091-008-000	5,978,566	2,085,669	--	--	Grazing/Timber	0	76
204-091-015-000	5,976,547	2,086,244	--	--	Rural Residential	0	675
204-091-022-000	5,975,249	2,087,192	--	--	Rural Residential - Vacant	0	137
204-091-023-000	5,975,471	2,085,642	--	--	Rural Residential - Vacant	0	477
204-101-001-000	5,975,497	2,084,191	--	--	Agriculture	0	225
204-111-008-000	5,980,994	2,084,244	--	--	--	0	30
204-171-012-000	5,975,237	2,087,719	--	--	Rural Residential	0	34
204-181-023-000	5,979,525	2,088,206	--	--	Grazing/Timber	0	200
204-211-044-000	5,986,702	2,089,385	--	--	Grazing/Timber	0	69
204-211-044-000	5,987,791	2,089,341	--	--	Grazing/Timber	0	69
204-211-045-000	5,986,363	2,088,201	--	--	Grazing/Timber	0	185
204-231-001-000	5,987,039	2,087,421	--	--	Agriculture	0	414
204-231-001-000	5,987,681	2,088,419	--	--	Agriculture	0	414
204-231-013-000	5,986,954	2,086,547	--	--	Agriculture	0	349
204-231-013-000	5,988,215	2,086,264	--	--	Agriculture	0	349
204-251-005-000	5,986,435	2,083,926	--	--	Agriculture	0	56
204-262-001-000	5,977,648	2,089,923	--	--	Rural Residential	0	6
204-381-023-000	5,986,792	2,090,169	--	--	Grazing/Timber	0	92
204-381-027-000	5,987,023	2,090,688	--	--	Agriculture	0	82
205-091-001-000	5,963,662	2,079,216	--	--	Rural Residential	0	209
205-091-004-000	5,965,961	2,078,908	--	--	Rural Residential	0	68
205-091-009-000	5,965,968	2,077,294	--	--	Rural Residential	0	93
205-091-011-000	5,964,181	2,077,909	--	--	Rural Residential	0	124
205-101-004-000	5,962,964	2,082,462	--	--	Agriculture	0	370
205-101-012-000	5,964,729	2,080,279	--	--	Grazing/Timber	0	279
205-101-014-000	5,963,160	2,080,541	--	--	Rural Residential	0	573
205-101-016-000	5,963,125	2,084,519	--	--	Rural Residential - Vacant	0	220
205-111-035-000	5,967,754	2,076,889	--	--	Rural Residential - Vacant	0	89
205-111-036-000	5,968,740	2,077,690	--	--	Rural Residential	0	485
205-121-001-000	5,963,568	2,086,397	--	--	Agriculture	0	37
206-101-052-000	5,988,990	2,088,696	--	--	Timber Production	0	21
206-321-007-000	--	--	--	--	--	0	17
206-331-028-000	5,991,968	2,085,196	--	--	Rural Residential	0	170
206-331-038-000	5,991,360	2,085,120	--	--	Rural Residential - Vacant	0	136
206-351-003-000	5,987,641	2,082,993	--	--	Agriculture	0	108
206-361-005-000	5,990,356	2,085,062	--	--	Rural Residential	0	245
206-371-001-000	5,988,576	2,083,862	--	--	Rural Residential	0	46
206-371-010-000	5,988,851	2,082,501	--	--	Agriculture	0	20
206-371-019-000	5,990,952	2,083,787	--	--	Rural Residential	0	232
308-141-020-000	5,936,162	2,133,959	--	--	Agriculture	0	116
308-141-020-000	5,937,427	2,134,251	--	--	Agriculture	0	116
309-171-003-000	5,939,922	2,128,259	--	--	Agriculture	0	162
309-171-004-000	5,939,537	2,127,206	--	--	Agriculture	0	167
309-181-003-000	5,937,004	2,126,250	--	--	Agriculture	0	90

Table 4.1

Well Locations and Pumping Rates Assigned to Transient Models
Eel River Valley Groundwater Sustainability Plan
Humboldt County Groundwater Sustainability Agency

Well Identification	State Plane Coordinate X	Y	Screen Elevation (NAVD88) Top	Bottom	Well Type	Pumping Rate (GPM) Minimum	Maximum
309-191-001-000	5,939,628	2,126,444	--	--	Agriculture	0	67
309-191-002-000	5,939,598	2,125,824	--	--	Agriculture	0	55
309-191-003-000	5,941,286	2,126,167	--	--	Agriculture	0	92
309-191-008-000	5,941,085	2,125,296	--	--	Agriculture	0	10
309-191-009-000	5,939,871	2,124,754	--	--	Agriculture	0	168
309-191-010-000	5,941,176	2,124,327	--	--	Agriculture	0	14
309-191-012-000	5,942,709	2,124,860	--	--	Agriculture	0	126
309-201-002-000	5,937,331	2,124,162	--	--	Agriculture	0	368
309-201-003-000	5,940,073	2,123,563	--	--	Agriculture	0	264
309-201-004-000	5,939,650	2,123,003	--	--	Agriculture	0	19
309-211-007-000	5,942,809	2,123,834	--	--	Agriculture	0	113
309-221-003-000	5,944,661	2,120,447	--	--	Agriculture	0	36
309-221-005-000	5,944,340	2,121,834	--	--	Agriculture	0	57
309-231-001-000	5,933,900	2,121,526	--	--	Agriculture	0	144
309-231-002-000	5,935,227	2,121,498	--	--	Agriculture	0	163
309-231-003-000	5,937,172	2,121,581	--	--	Agriculture	0	166
309-251-001-000	5,939,877	2,121,400	--	--	Agriculture	0	22
309-251-002-000	5,942,549	2,121,328	--	--	Agriculture	0	255
309-261-003-000	5,944,074	2,117,692	--	--	Agriculture	0	55
309-271-001-000	5,944,391	2,116,597	--	--	Agriculture	0	13
309-271-002-000	5,944,281	2,115,897	--	--	Gravel Mining	0	29
310-061-009-000	5,935,296	2,124,202	--	--	Agriculture	0	189
310-091-001-000	5,932,921	2,121,802	--	--	Agriculture	0	59

Note:

(1) Water is supplied through an infiltration gallery. This is represented in the model by removing surface water flows from SFR boundary condition cells at these locations.

Table 4.2

Model-Assigned Recharge Rates
Eel River Valley Groundwater Sustainability Plan
Humboldt County Groundwater Sustainability Agency

	Model-Applied Recharge Rates in Each HRU (inches/month)														
Date	**109325**	**109326**	**109337**	**109341**	**109348**	**109349**	**109350**	**109351**	**109355**	**109377**	**109378**	**109380**	**109390**	**109911**	**109912**
October 1999	0.0029	0.0016	0.0015	0.0085	0.00079	0.000000011	0.001	0.003	0.000000011	0.000000011	0.000000011	0.0066	0.00000001	0.000000011	0.000000023
November 1999	0.012	0.0011	0.001	0.0057	0.00054	0.089	0.00072	0.002	0.17	2.3	4.1E-09	0.0045	1.6	0.000000004	2.4
December 1999	1.1	0.15	0.00077	0.21	0.0004	2.3	0.2	0.51	1.7	1.6	1.4	0.8	1.1	0.41	1.8
January 2000	2	0.75	2.7	1.6	1.9	6.2	0.9	3.8	4.7	4	7	1.9	3.2	6.8	4.5
February 2000	1.8	0.54	2.6	1.7	1.5	6	0.63	3.2	5.2	3.7	3.9	1.7	2.3	3	3.7
March 2000	1	0.32	1.5	1.1	0.63	1.7	0.38	1.9	1.7	1.3	1.1	1.2	0.85	0.84	1.1
April 2000	0.22	0.022	0.17	0.19	0.009	0.00013	0.014	0.041	0.17	0.54	0.00015	0.097	0.17	0.00021	0.38
May 2000	0.39	0.0098	0.26	0.063	0.0044	0.0000045	0.0064	0.019	0.13	0.06	0.0000048	0.044	0.022	0.0000057	0.015
June 2000	0.022	0.0053	0.0079	0.033	0.0025	0.00000051	0.0034	0.01	0.000052	0.0000099	0.00000053	0.023	0.00000027	0.00000059	0.0000083
July 2000	0.0099	0.0034	0.0047	0.021	0.0016	0.00000011	0.0022	0.0065	0.0000026	0.00000094	0.00000011	0.015	0.000000066	0.00000012	0.00000084
August 2000	0.0055	0.0022	0.0029	0.013	0.0011	0.000000029	0.0015	0.0042	0.00000035	0.00000016	0.00000003	0.0096	0.000000019	0.000000032	0.00000015
September 2000	0.0034	0.0015	0.0019	0.0086	0.0007	9.6E-09	0.00098	0.0028	0.000000075	0.000000041	9.9E-09	0.0063	6.7E-09	0.00000001	0.000000038
October 2000	0.0045	0.0011	0.0014	0.0061	0.00052	3.9E-09	0.00073	0.002	0.000000023	0.29	0.000000004	0.0045	2.8E-09	4.2E-09	0.38
November 2000	0.0092	0.00077	0.00094	0.0042	0.00036	1.6E-09	0.00051	0.0014	7.7E-09	0.88	1.7E-09	0.0031	0.75	1.7E-09	0.85
December 2000	0.0094	0.00058	0.0007	0.0031	0.00027	8E-10	0.00039	0.0011	3.2E-09	1.1	8.3E-10	0.25	0.86	8.3E-10	1.1
January 2001	1.1	0.3	1	0.32	0.36	2.9	0.37	1.9	2.1	2.1	2.2	0.98	1.5	1.3	2.2
February 2001	1.2	0.38	1.8	1.1	0.99	3	0.42	2.3	2.6	1.9	1.9	1.3	1.1	1.2	1.6
March 2001	0.46	0.14	0.61	0.61	0.24	1.2	0.12	0.84	1.2	0.65	0.73	0.6	0.36	0.45	0.61
April 2001	0.72	0.018	0.97	0.49	0.0094	0.000077	0.012	0.82	0.79	0.41	0.000075	0.47	0.41	0.000072	0.15
May 2001	0.032	0.0088	0.017	0.11	0.0045	0.0000033	0.0056	0.028	0.0015	0.00093	0.0000033	0.079	0.0000027	0.0000032	0.0000032
June 2001	0.013	0.0049	0.0079	0.048	0.0025	0.00000041	0.0031	0.014	0.000012	0.00001	0.00000041	0.036	0.00000035	0.00000039	0.00000039
July 2001	0.0078	0.0032	0.0047	0.028	0.0016	0.00000009	0.002	0.0083	0.0000011	0.00000097	0.00000009	0.021	0.000000079	0.000000088	0.000000088
August 2001	0.004	0.0021	0.0029	0.017	0.0011	0.000000025	0.0014	0.0053	0.00000018	0.00000017	0.000000025	0.013	0.000000023	0.000000025	0.000000025
September 2001	0.0025	0.0014	0.0019	0.011	0.00071	8.5E-09	0.00092	0.0034	0.000000044	0.000000041	8.5E-09	0.0084	7.7E-09	8.2E-09	8.4E-09
October 2001	0.0021	0.001	0.0014	0.0077	0.00052	3.5E-09	0.00068	0.0025	0.000000015	0.000000014	3.5E-09	0.0059	3.2E-09	3.4E-09	3.5E-09
November 2001	0.01	0.00073	0.00094	0.0052	0.00036	1.5E-09	0.00048	0.0017	5.3E-09	0.93	1.5E-09	0.004	0.4	1.4E-09	0.84
December 2001	2.2	0.61	2	1.4	1.4	5.9	0.55	3.3	4.3	4.2	4.2	2	2.9	1.5	4.6
January 2002	1.2	0.46	1.7	1.1	1.2	3.6	0.55	2.2	2.8	2.1	3.9	1.4	1.7	3.5	2.2
February 2002	0.9	0.3	1.3	0.86	0.71	2.8	0.38	1.7	2.4	1.5	1.6	0.92	0.92	1.4	1.6
March 2002	1.2	0.34	1.8	1.1	0.79	2.1	0.37	2.1	2.3	1.7	1.3	1.2	1.2	0.95	1.4
April 2002	0.048	0.03	0.031	0.17	0.0079	0.0025	0.017	0.052	0.003	0.0023	0.0025	0.13	0.00029	0.0024	0.00059
May 2002	0.018	0.012	0.012	0.069	0.004	0.000017	0.0072	0.022	0.000018	0.000016	0.000017	0.053	0.0000067	0.000017	0.0000094
June 2002	0.0073	0.0061	0.006	0.035	0.0023	0.0000012	0.0038	0.011	0.0000013	0.0000012	0.0000012	0.027	0.00000066	0.0000012	0.00000084
July 2002	0.0045	0.0038	0.0037	0.022	0.0015	0.00000021	0.0024	0.0071	0.00000022	0.00000021	0.00000021	0.017	0.00000013	0.00000021	0.00000016
August 2002	0.0028	0.0025	0.0024	0.014	0.001	0.000000051	0.0016	0.0046	0.000000052	0.000000051	0.000000051	0.011	0.000000034	0.00000005	0.00000004
September 2002	0.0019	0.0016	0.0016	0.0089	0.00067	0.000000015	0.0011	0.003	0.000000016	0.000000015	0.000000015	0.0069	0.000000011	0.000000015	0.000000013
October 2002	0.0014	0.0012	0.0012	0.0064	0.00049	5.9E-09	0.00077	0.0022	0.000000006	5.9E-09	5.9E-09	0.0049	4.4E-09	5.8E-09	0.000000005
November 2002	0.0052	0.00084	0.00081	0.0044	0.00034	2.4E-09	0.00054	0.0015	2.4E-09	2.4E-09	2.4E-09	0.0034	1.8E-09	2.3E-09	2.1E-09
December 2002	1.4	0.43	1.4	1.2	0.98	8.1	0.51	2.3	7.1	5.2	6.8	1.5	4.5	5.4	5.1
January 2003	1.4	0.51	2	1.4	1.3	3	0.57	2.6	2.3	1.9	3.3	1.5	1.4	2.7	1.9
February 2003	0.7	0.21	1.2	0.65	0.56	1.7	0.25	1.3	1.5	1.2	1.1	0.71	0.72	0.8	1
March 2003	1.3	0.32	1.8	1.1	0.62	2.9	0.24	2.1	3.2	1.9	1.6	1.2	1.1	1.2	1.5
April 2003	2.1	0.58	3.2	1.9	1.6	7.1	0.64	3.9	7.7	4.8	4.6	2.2	3	3	4.4
May 2003	0.48	0.19	0.65	0.61	0.35	0.74	0.16	0.43	0.66	0.44	0.44	0.46	0.23	0.32	0.37
June 2003	0.023	0.02	0.017	0.1	0.0092	0.000098	0.012	0.032	0.000089	0.000084	0.000081	0.077	0.000029	0.000095	0.000053
July 2003	0.01	0.0093	0.0083	0.05	0.0045	0.0000038	0.0059	0.016	0.0000036	0.0000035	0.0000034	0.038	0.0000018	0.0000037	0.0000027
August 2003	0.0056	0.0052	0.0047	0.028	0.0025	0.00000046	0.0033	0.0092	0.00000044	0.00000043	0.00000042	0.021	0.00000027	0.00000045	0.00000036
September 2003	0.0034	0.0032	0.0029	0.017	0.0015	0.000000092	0.002	0.0056	0.000000089	0.000000089	0.000000087	0.013	0.00000006	0.00000009	0.000000076
October 2003	0.0023	0.0022	0.002	0.011	0.0011	0.000000027	0.0014	0.0039	0.000000026	0.000000026	0.000000026	0.0087	0.000000019	0.000000026	0.000000023
November 2003	0.0078	0.0014	0.0013	0.0075	0.00071	0.000000009	0.00095	0.0026	8.8E-09	0.49	8.7E-09	0.0058	0.29	8.8E-09	0.51
December 2003	1.3	0.38	0.88	0.88	0.53	5.7	0.41	2	4.2	4.5	4.1	1.3	3.3	2.5	4.9
January 2004	1.9	0.72	2.7	1.7	2	4.9	0.87	3.3	3.6	3.2	5.3	1.9	2.4	5.4	3.4
February 2004	1.5	0.48	2.3	1.5	1.3	5.9	0.53	3	5.3	3.2	3.9	1.6	2	2.9	3.2
March 2004	0.26	0.084	0.45	0.39	0.094	0.19	0.074	0.4	0.18	0.17	0.094	0.41	0.05	0.078	0.083

Table 4.2

Model-Assigned Recharge Rates
Eel River Valley Groundwater Sustainability Plan
Humboldt County Groundwater Sustainability Agency

	Model-Applied Recharge Rates in Each HRU (inches/month)														
Date	**109325**	**109326**	**109337**	**109341**	**109348**	**109349**	**109350**	**109351**	**109355**	**109377**	**109378**	**109380**	**109390**	**109911**	**109912**
April 2004	0.22	0.016	0.16	0.092	0.0081	0.000029	0.01	0.031	0.12	0.26	0.000028	0.071	0.22	0.000032	0.028
May 2004	0.033	0.008	0.016	0.046	0.0041	0.0000019	0.0051	0.016	0.000002	0.0016	0.0000019	0.036	0.00049	0.000002	0.0000018
June 2004	0.012	0.0045	0.0075	0.026	0.0023	0.00000027	0.0029	0.0087	0.00000028	0.000013	0.00000027	0.02	0.0000078	0.00000028	0.00000026
July 2004	0.0065	0.0029	0.0045	0.017	0.0015	0.000000065	0.0019	0.0057	0.000000068	0.0000011	0.000000065	0.013	0.00000079	0.000000067	0.000000064
August 2004	0.0039	0.002	0.0028	0.011	0.001	0.000000019	0.0013	0.0038	0.00000002	0.00000019	0.000000019	0.0084	0.00000014	0.00000002	0.000000019
September 2004	0.0025	0.0013	0.0018	0.0072	0.00068	6.7E-09	0.00088	0.0025	6.9E-09	0.000000045	6.7E-09	0.0056	0.000000036	6.8E-09	6.7E-09
October 2004	0.0098	0.00098	0.0013	0.0052	0.0005	2.8E-09	0.00065	0.0019	2.9E-09	1.1	2.9E-09	0.0041	0.39	2.9E-09	1.2
November 2004	0.0086	0.00069	0.00091	0.0036	0.00035	1.2E-09	0.00046	0.0013	1.3E-09	0.0059	1.2E-09	0.0028	0.0018	1.2E-09	0.0053
December 2004	0.9	0.3	1.4	0.31	0.66	3.6	0.25	1.5	2.9	2.7	2.2	0.61	2.3	1.3	2.9
January 2005	1.2	0.48	1.7	1.1	1.3	4.6	0.56	2.2	3.4	2.7	4.8	1.3	2	5.4	3.3
February 2005	0.71	0.21	1.1	0.7	0.3	1	0.12	1.3	0.84	0.48	0.29	0.53	0.33	0.35	0.27
March 2005	1.2	0.35	1.7	1.2	0.9	4.4	0.39	2.4	4.4	2.7	2.4	1.2	1.5	2.3	2.7
April 2005	0.86	0.25	1.3	1	0.56	2.9	0.27	1.6	3.1	1.8	1.8	1	1.1	1.3	1.8
May 2005	0.67	0.22	0.75	0.35	0.24	1.3	0.11	0.42	1.8	0.93	0.64	0.52	0.23	0.00027	1.3
June 2005	0.28	0.13	0.34	0.13	0.059	1.1	0.11	0.034	1	1.2	0.00084	0.21	0.39	0.39	1.5
July 2005	0.043	0.037	0.027	0.058	0.0061	0.0013	0.02	0.017	0.0013	0.0012	0.000011	0.075	0.00078	0.0012	0.0013
August 2005	0.014	0.013	0.011	0.032	0.0032	0.000012	0.0076	0.0094	0.000012	0.000012	0.00000094	0.036	0.0000095	0.000011	0.000012
September 2005	0.0069	0.0065	0.0055	0.019	0.0019	0.00000096	0.004	0.0057	0.00000096	0.00000096	0.00000016	0.02	0.00000084	0.00000095	0.00000097
October 2005	0.0053	0.004	0.0035	0.013	0.0013	0.00000018	0.0025	0.0039	0.00000018	0.00000018	0.000000043	0.013	0.00000016	0.00000017	0.00000018
November 2005	0.012	0.0025	0.0022	0.0082	0.00084	0.000000043	0.0016	0.0026	0.000000043	1.5	0.000000013	0.0082	0.98	0.000000042	1.4
December 2005	1.7	0.43	1.8	0.94	1.2	7.8	0.5	2.2	6	4.3	6.1	1.2	3.2	5.3	4.6
January 2006	2.2	0.79	3.5	2	2.5	8.6	1	4.4	6.4	5.6	9	2.3	3.8	9	6.3
February 2006	0.58	0.22	0.81	0.72	0.57	3	0.25	1.1	2.7	1.4	1.9	0.71	1	1.7	1.8
March 2006	2.5	0.77	3.7	2.3	2.1	8.7	1	4.7	8.3	5.6	5.8	2.5	3.6	4.6	5.5
April 2006	1.2	0.35	1.8	1.3	0.81	3.5	0.33	2.2	3.6	2.2	2.1	1.4	1.3	1.4	1.8
May 2006	0.044	0.03	0.03	0.17	0.013	0.0007	0.019	0.058	0.00072	0.17	0.00067	0.13	0.00032	0.00065	0.36
June 2006	0.016	0.011	0.011	0.066	0.0052	0.0000091	0.0071	0.022	0.0000092	0.0027	0.0000089	0.051	0.0000063	0.0000087	0.0024
July 2006	0.0069	0.0062	0.006	0.036	0.003	0.00000088	0.004	0.012	0.00000089	0.000017	0.00000088	0.028	0.00000069	0.00000086	0.000017
August 2006	0.0041	0.0037	0.0036	0.021	0.0018	0.00000016	0.0024	0.0073	0.00000016	0.0000013	0.00000016	0.016	0.00000013	0.00000015	0.0000012
September 2006	0.0026	0.0024	0.0023	0.013	0.0012	0.000000039	0.0015	0.0046	0.000000039	0.0000002	0.000000039	0.01	0.000000033	0.000000038	0.0000002
October 2006	0.0019	0.0017	0.0016	0.0092	0.00081	0.000000013	0.0011	0.0032	0.000000013	0.000000052	0.000000013	0.0071	0.000000011	0.000000013	0.000000051
November 2006	0.011	0.0011	0.0011	0.0061	0.00055	4.8E-09	0.00075	0.0022	4.8E-09	1.2	4.8E-09	0.0048	0.75	4.7E-09	1.2
December 2006	1.1	0.27	0.3	0.55	0.22	4.1	0.21	0.97	3	2.9	2.5	1	2.1	0.84	3.2
January 2007	0.43	0.2	0.51	0.52	0.45	0.94	0.22	0.76	0.73	0.74	1.2	0.63	0.55	1.2	0.8
February 2007	1.5	0.45	2.3	1.3	1.5	6.6	0.65	3.3	6.1	4.1	4.7	1.6	2.6	3.7	4.3
March 2007	0.55	0.18	0.77	0.72	0.22	0.66	0.13	0.83	0.7	0.52	0.51	0.58	0.46	0.45	0.5
April 2007	0.7	0.018	0.88	0.65	0.009	0.2	0.012	0.9	1	0.38	0.000046	0.51	0.34	0.000047	0.21
May 2007	0.23	0.0087	0.098	0.16	0.0044	0.0014	0.0056	0.063	0.061	0.0024	0.0000025	0.13	0.0013	0.0000025	0.0015
June 2007	0.016	0.0048	0.011	0.064	0.0025	0.000012	0.0031	0.023	0.000016	0.000015	0.00000033	0.05	0.000012	0.00000033	0.000012
July 2007	0.0087	0.0031	0.0061	0.035	0.0016	0.0000011	0.0021	0.013	0.0000013	0.0000012	0.000000077	0.028	0.000001	0.000000076	0.0000011
August 2007	0.0048	0.0021	0.0037	0.021	0.0011	0.00000018	0.0014	0.0075	0.0000002	0.0000002	0.000000022	0.016	0.00000018	0.000000022	0.00000018
September 2007	0.003	0.0014	0.0023	0.013	0.0007	0.000000044	0.00092	0.0047	0.000000049	0.000000048	7.6E-09	0.01	0.000000043	7.4E-09	0.000000045
October 2007	0.0073	0.001	0.0016	0.0091	0.00052	0.000000014	0.00068	0.0033	0.000000016	0.31	3.2E-09	0.0071	0.000000014	3.1E-09	0.23
November 2007	0.0051	0.00072	0.0011	0.0061	0.00036	5.2E-09	0.00048	0.0022	5.6E-09	0.045	1.4E-09	0.0048	0.14	1.3E-09	0.00015
December 2007	1	0.31	1.5	0.75	0.9	3.8	0.43	2.2	3	3.5	3.2	1.1	2.8	1.8	3.8
January 2008	1.8	0.67	2.7	1.6	2	6.9	0.83	3.4	5.1	3.4	6.6	1.8	2.3	5.5	3.6
February 2008	0.85	0.29	1.3	0.95	0.55	2.3	0.29	1.5	1.9	1.2	1.3	0.8	0.7	1	1.2
March 2008	0.29	0.042	0.45	0.42	0.018	0.01	0.027	0.38	0.22	0.048	0.0082	0.43	0.24	0.0089	0.0059
April 2008	0.25	0.013	0.3	0.22	0.0064	0.000023	0.0086	0.21	0.45	0.24	0.000022	0.22	0.23	0.000022	0.13
May 2008	0.035	0.0071	0.022	0.1	0.0035	0.0000016	0.0046	0.019	0.0034	0.0027	0.0000016	0.064	0.0000013	0.0000016	0.0000015
June 2008	0.012	0.0041	0.0093	0.046	0.002	0.00000024	0.0027	0.01	0.000017	0.000015	0.00000024	0.031	0.00000021	0.00000024	0.00000023
July 2008	0.0067	0.0027	0.0053	0.027	0.0013	0.00000006	0.0018	0.0065	0.0000013	0.0000013	0.000000059	0.019	0.000000053	0.000000058	0.000000057
August 2008	0.004	0.0018	0.0033	0.017	0.0009	0.000000018	0.0012	0.0043	0.00000021	0.0000002	0.000000018	0.012	0.000000016	0.000000018	0.000000017
September 2008	0.0025	0.0012	0.0021	0.011	0.00061	6.3E-09	0.00082	0.0028	0.00000005	0.000000049	6.3E-09	0.0076	5.7E-09	6.1E-09	6.1E-09

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October 2008	0.0059	0.00092	0.0015	0.0076	0.00045	2.7E-09	0.00061	0.0021	0.000000016	0.000000016	2.7E-09	0.0054	2.5E-09	2.6E-09	2.6E-09
November 2008	0.0094	0.00065	0.001	0.0051	0.00031	1.2E-09	0.00043	0.0014	5.8E-09	0.61	1.2E-09	0.0037	0.25	1.1E-09	0.53
December 2008	0.5	0.033	0.00076	0.0038	0.00024	1	0.00033	0.0011	0.82	2.2	5.9E-10	0.065	1.8	5.7E-10	2.3
January 2009	0.92	0.33	0.92	0.59	0.00018	1.2	0.39	1.6	0.65	0.42	0.94	0.83	0.36	2.9E-10	0.38
February 2009	1.8	0.57	2.6	1.6	1.5	5.6	0.75	3.5	4.2	2.8	3	1.8	1.5	2.6	2.6
March 2009	0.94	0.32	1.3	1.1	0.73	3	0.39	2.2	2.9	1.7	1.8	1.4	1	1.6	1.5
April 2009	0.45	0.03	0.69	0.59	0.0097	0.0017	0.02	0.88	0.2	0.0013	0.001	0.68	0.00033	0.0012	0.00046
May 2009	0.48	0.17	0.68	0.56	0.12	1.2	0.0078	0.77	1.6	0.000013	0.000012	0.65	0.0000071	0.000013	0.0000084
June 2009	0.024	0.021	0.021	0.11	0.0059	0.000088	0.004	0.041	0.000088	0.000001	0.00000097	0.092	0.00000069	0.000001	0.00000077
July 2009	0.01	0.0097	0.0093	0.053	0.0033	0.0000036	0.0025	0.019	0.0000036	0.00000019	0.00000018	0.042	0.00000014	0.00000018	0.00000015
August 2009	0.0057	0.0054	0.0051	0.029	0.002	0.00000044	0.0016	0.01	0.00000044	0.000000047	0.000000044	0.023	0.000000035	0.000000045	0.000000039
September 2009	0.0035	0.0032	0.0031	0.017	0.0012	0.000000089	0.0011	0.0062	0.000000089	0.000000014	0.000000014	0.014	0.000000011	0.000000014	0.000000012
October 2009	0.011	0.0022	0.0021	0.012	0.00087	0.000000026	0.0008	0.0042	0.000000026	5.6E-09	5.4E-09	0.0094	4.5E-09	5.3E-09	4.8E-09
November 2009	0.0097	0.0015	0.0014	0.0077	0.00059	8.7E-09	0.00056	0.0028	8.8E-09	2.3E-09	2.2E-09	0.0062	1.8E-09	2.2E-09	0.000000002
December 2009	0.86	0.16	1.1	0.43	0.00043	1.1	0.14	2	0.2	1.3	0.000000001	0.82	0.89	0.000000001	1.5
January 2010	2	0.74	2.7	1.8	1.5	7.7	0.86	3.6	5.9	3.4	5.7	2.2	2.3	5	3.9
February 2010	1.6	0.48	2.3	1.5	1	3.5	0.63	3.2	2.8	1.5	1.7	1.8	0.79	1.5	1.4
March 2010	1.2	0.29	1.9	1.4	0.66	2.9	0.21	2.6	3.2	1.1	1.3	1.5	0.59	0.77	0.88
April 2010	1.5	0.43	2.2	1.7	0.89	5.1	0.31	3	5.3	2	2.5	2	1.1	1.5	1.8
May 2010	0.75	0.26	1	0.76	0.36	1.3	0.19	0.59	1.5	1.1	1.1	0.84	0.62	0.72	0.99
June 2010	0.36	0.17	0.39	0.35	0.31	1.2	0.17	0.36	1.1	0.88	1.2	0.47	0.42	1.4	1.2
July 2010	0.022	0.021	0.017	0.075	0.01	0.000079	0.014	0.026	0.000079	0.000077	0.00008	0.078	0.000061	0.000088	0.000078
August 2010	0.0097	0.0093	0.008	0.039	0.0046	0.0000031	0.0061	0.013	0.0000031	0.0000031	0.0000031	0.037	0.0000027	0.0000033	0.0000031
September 2010	0.0064	0.005	0.0044	0.022	0.0025	0.00000039	0.0033	0.0076	0.00000039	0.00000039	0.00000039	0.02	0.00000035	0.0000004	0.00000039
October 2010	0.0088	0.0033	0.0029	0.015	0.0016	0.000000087	0.0022	0.0051	0.000000087	0.61	0.000000088	0.013	0.00000008	0.000000089	0.63
November 2010	0.49	0.025	0.72	0.0094	0.0011	0.23	0.0014	0.7	0.29	1.1	0.000000024	0.57	0.89	0.000000025	1
December 2010	2.2	0.82	3.2	1.6	2	8.2	0.91	4.2	6	4.6	6	2.4	3.3	7	5.1
January 2011	0.79	0.32	0.95	0.83	0.7	1.2	0.33	1.4	0.71	0.69	1.3	0.92	0.57	1.3	0.67
February 2011	0.95	0.32	1.5	0.94	0.73	2.9	0.37	2	2.3	1.1	1.4	1.1	0.62	0.97	0.81
March 2011	2.5	0.8	3.7	2.4	2.3	9.5	1.1	5	8.2	4.1	4.9	2.8	2.4	3.7	3.6
April 2011	1.2	0.15	1.4	1.2	0.27	1.6	0.12	2.2	2.1	0.55	0.77	1.4	0.44	0.16	0.23
May 2011	0.47	0.099	0.57	0.25	0.011	0.00094	0.018	0.064	0.00098	0.00057	0.00086	0.24	0.00038	0.00048	0.00043
June 2011	0.45	0.14	0.39	0.24	0.0048	0.00001	0.007	0.023	0.00001	0.0000083	0.0000099	0.31	0.0000068	0.0000077	0.0000073
July 2011	0.019	0.017	0.012	0.053	0.0028	0.00000096	0.004	0.013	0.00000097	0.00000084	0.00000094	0.052	0.00000073	0.00000079	0.00000077
August 2011	0.0085	0.008	0.0061	0.029	0.0017	0.00000017	0.0024	0.0075	0.00000017	0.00000015	0.00000016	0.027	0.00000013	0.00000014	0.00000014
September 2011	0.0048	0.0045	0.0036	0.018	0.0011	0.000000041	0.0015	0.0047	0.000000041	0.000000038	0.000000041	0.016	0.000000034	0.000000036	0.000000036
October 2011	0.0097	0.0029	0.0024	0.012	0.00077	0.000000014	0.0011	0.0033	0.000000014	0.13	0.000000014	0.011	0.000000012	0.000000012	0.13
November 2011	0.0073	0.0019	0.0016	0.0078	0.00053	0.000000005	0.00075	0.0022	0.000000005	0.55	0.000000005	0.0069	0.31	4.5E-09	0.62
December 2011	0.0057	0.0014	0.0012	0.0056	0.00039	2.2E-09	0.00056	0.0016	2.2E-09	0.22	2.2E-09	0.0049	0.34	0.000000002	0.2
January 2012	0.69	0.28	0.87	0.51	0.5	3.4	0.4	1.4	2	2.2	2.4	0.82	2	4.6	2.5
February 2012	0.79	0.27	1.1	0.86	0.46	1.8	0.31	1.7	1.5	0.87	0.94	1.1	0.49	1	0.84
March 2012	1.9	0.61	2.7	1.9	1.4	8.1	0.8	4.1	7.3	3.7	4.6	2.2	2.5	4.6	3.6
April 2012	0.9	0.29	1.2	1.2	0.59	2.7	0.3	1.8	2.6	1.5	1.6	1.4	0.88	1.3	1.4
May 2012	0.039	0.027	0.027	0.16	0.013	0.00035	0.017	0.054	0.00036	0.00033	0.00034	0.31	0.00026	0.00033	0.00032
June 2012	0.014	0.011	0.01	0.063	0.0053	0.0000067	0.0068	0.021	0.0000067	0.0000065	0.0000066	0.058	0.0000057	0.0000065	0.0000064
July 2012	0.0075	0.0059	0.0058	0.035	0.003	0.00000072	0.0038	0.012	0.00000072	0.00000071	0.00000071	0.031	0.00000064	0.0000007	0.0000007
August 2012	0.004	0.0036	0.0035	0.021	0.0018	0.00000013	0.0024	0.0071	0.00000013	0.00000013	0.00000013	0.018	0.00000012	0.00000013	0.00000013
September 2012	0.0025	0.0023	0.0022	0.013	0.0012	0.000000034	0.0015	0.0045	0.000000034	0.000000034	0.000000034	0.011	0.000000032	0.000000033	0.000000034
October 2012	0.0041	0.0016	0.0016	0.009	0.00082	0.000000012	0.0011	0.0031	0.000000012	0.000000012	0.000000012	0.0076	0.000000011	0.000000011	0.000000012
November 2012	0.095	0.024	0.0011	0.006	0.00056	0.6	0.039	0.0021	0.2	1.3	4.4E-09	0.077	0.73	4.2E-09	1.2
December 2012	2	0.74	2.6	1.8	1.9	8.1	0.95	3.8	5.8	4	6.3	2.1	2.9	7	4.3
January 2013	0.96	0.37	1.2	0.95	1	1.8	0.46	1.5	1.1	1.2	1.9	1	0.89	2	1.3
February 2013	0.49	0.12	0.75	0.52	0.17	0.48	0.18	1.2	0.51	0.66	0.49	0.72	0.45	0.5	0.6
March 2013	0.27	0.11	0.36	0.42	0.24	1.3	0.12	0.52	1.2	0.48	0.81	0.46	0.39	0.95	0.66

Table 4.2

Model-Assigned Recharge Rates
Eel River Valley Groundwater Sustainability Plan
Humboldt County Groundwater Sustainability Agency

Date	Model-Applied Recharge Rates in Each HRU (inches/month)														
	109325	109326	109337	109341	109348	109349	109350	109351	109355	109377	109378	109380	109390	109911	109912
April 2013	0.42	0.019	0.62	0.43	0.0096	0.084	0.013	0.71	0.4	0.12	0.000095	0.47	0.18	0.3	0.000087
May 2013	0.023	0.009	0.017	0.09	0.0046	0.0000038	0.006	0.032	0.00013	0.000049	0.0000037	0.075	0.000086	0.00013	0.0000036
June 2013	0.01	0.005	0.0079	0.043	0.0025	0.00000045	0.0033	0.015	0.0000041	0.0000024	0.00000045	0.035	0.0000032	0.000004	0.00000043
July 2013	0.0056	0.0032	0.0047	0.026	0.0016	0.000000098	0.0021	0.009	0.00000051	0.00000035	0.000000097	0.021	0.00000043	0.0000005	0.000000095
August 2013	0.0035	0.0021	0.0029	0.016	0.0011	0.000000027	0.0014	0.0057	0.0000001	0.000000076	0.000000027	0.013	0.000000089	0.0000001	0.000000027
September 2013	0.0045	0.0014	0.0019	0.01	0.00072	0.000000009	0.00096	0.0037	0.000000028	0.000000022	0.000000009	0.0082	0.000000024	0.000000027	8.9E-09
October 2013	0.0057	0.001	0.0014	0.0072	0.00053	3.7E-09	0.00071	0.0026	9.7E-09	7.9E-09	3.7E-09	0.0058	8.8E-09	9.6E-09	3.6E-09
November 2013	0.0023	0.00074	0.00094	0.0049	0.00037	1.5E-09	0.0005	0.0018	3.7E-09	3.1E-09	1.6E-09	0.0039	3.4E-09	3.6E-09	1.5E-09
December 2013	0.0029	0.00056	0.0007	0.0036	0.00028	7.6E-10	0.00038	0.0013	1.7E-09	1.4E-09	7.7E-10	0.0029	1.5E-09	1.6E-09	7.6E-10
January 2014	0.0019	0.00042	0.00052	0.0026	0.0002	3.8E-10	0.00028	0.00098	7.8E-10	6.8E-10	3.8E-10	0.0021	7.2E-10	7.6E-10	3.8E-10
February 2014	0.18	0.00029	0.00035	0.14	0.00014	0.37	0.0002	0.71	0.36	1.3	1.9E-10	0.52	0.74	3.5E-10	0.97
March 2014	1.4	0.075	1.8	1.2	0.00012	3.6	0.17	2.5	3.1	1.1	1.2E-10	1.4	0.45	2.1E-10	0.56
April 2014	0.19	0.11	0.21	0.4	0.000085	0.63	0.085	0.34	0.58	0.45	6.6E-11	0.37	0.24	1.1E-10	0.46
May 2014	0.022	0.017	0.017	0.099	0.000067	0.000052	0.012	0.034	0.000052	0.000049	4.1E-11	0.076	0.00004	6.7E-11	0.000048
June 2014	0.009	0.0078	0.0077	0.046	0.00005	0.0000024	0.0053	0.016	0.0000024	0.0000024	2.4E-11	0.035	0.0000021	3.8E-11	0.0000023
July 2014	0.0053	0.0047	0.0046	0.027	0.000039	0.00000035	0.0032	0.0093	0.00000035	0.00000035	1.6E-11	0.021	0.00000031	2.4E-11	0.00000034
August 2014	0.0033	0.003	0.0029	0.017	0.00003	0.000000076	0.002	0.0058	0.000000076	0.000000076	9.9E-12	0.013	0.000000069	1.5E-11	0.000000075
September 2014	0.004	0.0019	0.0019	0.011	0.000023	0.000000022	0.0013	0.0038	0.000000022	0.000000022	6.2E-12	0.0083	0.00000002	9.1E-12	0.000000021
October 2014	0.01	0.0014	0.0013	0.0075	0.000018	7.9E-09	0.00094	0.0027	7.9E-09	0.43	4.3E-12	0.0058	7.3E-09	6.1E-12	0.33
November 2014	0.11	0.00096	0.43	0.0051	0.000014	3.1E-09	0.061	0.19	3.1E-09	0.74	2.8E-12	0.077	0.51	3.9E-12	0.74
December 2014	1.9	0.7	2.7	1.1	1.4	6.2	0.92	3.3	4.1	3.3	4.1	1.6	2.5	7.3	3.8
January 2015	0.35	0.16	0.44	0.42	0.35	0.75	0.17	0.58	0.37	0.33	0.68	0.45	0.21	1.2	0.32
February 2015	0.84	0.3	1.3	1	0.74	4.1	0.29	1.7	3.6	1.2	1.9	1	0.6	1.3	1.1
March 2015	0.038	0.027	0.19	0.16	0.014	0.00024	0.017	0.32	0.00024	0.00022	0.00023	0.12	0.13	0.00021	0.00019
April 2015	0.21	0.011	0.26	0.32	0.0055	0.61	0.0068	0.36	1.2	0.35	0.0000054	0.31	0.34	0.33	0.58
May 2015	0.024	0.0059	0.02	0.095	0.0031	0.00012	0.0039	0.037	0.00013	0.00011	0.00000062	0.072	0.00011	0.00011	0.00012
June 2015	0.0099	0.0035	0.0088	0.044	0.0018	0.0000039	0.0023	0.017	0.000004	0.0000037	0.00000012	0.034	0.0000036	0.0000038	0.0000039
July 2015	0.0058	0.0024	0.0051	0.026	0.0012	0.00000049	0.0016	0.0098	0.0000005	0.00000048	0.000000033	0.02	0.00000047	0.00000048	0.0000005
August 2015	0.0036	0.0016	0.0031	0.016	0.00084	0.000000099	0.0011	0.0061	0.0000001	0.000000097	0.000000011	0.013	0.000000095	0.000000097	0.0000001
September 2015	0.0028	0.0011	0.002	0.01	0.00057	0.000000027	0.00074	0.0039	0.000000027	0.000000027	4.1E-09	0.0081	0.000000026	0.000000026	0.000000027
October 2015	0.0017	0.00083	0.0014	0.0074	0.00042	9.5E-09	0.00055	0.0028	9.7E-09	9.5E-09	1.8E-09	0.0057	9.2E-09	9.3E-09	9.7E-09
November 2015	0.0052	0.00059	0.00099	0.005	0.0003	3.6E-09	0.0004	0.0019	3.7E-09	0.48	8.3E-10	0.0039	0.27	3.5E-09	0.52
December 2015	1.5	0.57	1.2	1.1	1	7.2	0.86	2.5	4.6	4.6	4.7	1.6	3.2	6.9	5
January 2016	2.3	0.89	3.2	2.1	2.5	9.5	1.1	4.3	6.4	4.1	7.9	2.4	2.8	12	4.8
February 2016	0.69	0.23	0.96	0.78	0.36	1.2	0.25	1.3	0.9	0.71	0.48	0.78	0.55	1	0.53
March 2016	1.5	0.46	2.2	1.6	1.1	6.7	0.54	2.8	5.8	2.2	2.5	1.7	1.1	3.9	1.9
April 2016	0.057	0.036	0.037	0.21	0.017	0.0021	0.021	0.073	0.0022	0.13	0.0011	0.16	0.00018	0.0004	0.0033
May 2016	0.02	0.013	0.013	0.078	0.0065	0.000016	0.0081	0.026	0.000016	0.000011	0.000012	0.059	0.0000052	0.0000078	0.0000068
June 2016	0.0074	0.0066	0.0065	0.039	0.0033	0.0000012	0.0041	0.013	0.0000012	0.00000092	0.00000099	0.029	0.00000056	0.00000073	0.00000068
July 2016	0.0045	0.0041	0.004	0.024	0.0021	0.0000002	0.0026	0.008	0.00000021	0.00000017	0.00000018	0.018	0.00000012	0.00000014	0.00000013
August 2016	0.0029	0.0026	0.0026	0.015	0.0013	0.000000049	0.0017	0.0051	0.00000005	0.000000043	0.000000045	0.011	0.000000031	0.000000037	0.000000035
September 2016	0.0019	0.0017	0.0017	0.0096	0.00087	0.000000015	0.0011	0.0033	0.000000015	0.000000013	0.000000014	0.0073	0.00000001	0.000000012	0.000000011
October 2016	0.38	0.025	0.7	0.0068	0.1	0.98	0.037	0.37	0.82	1.1	5.4E-09	0.39	0.33	4.6E-09	1
November 2016	0.98	0.46	1.6	0.4	1.2	3.1	0.58	2	1.9	2	0.51	0.89	1.5	3.5	2.2
December 2016	1.1	0.47	1.5	1	1.2	4.6	0.53	2	3.3	2.2	4.2	1.3	1.6	7.4	2.6
January 2017	1.4	0.65	2.4	1.7	0.95	11	0.76	1.4	9.2	5.3	10	1.9	5.2	13	6.2
February 2017	2.1	0.66	2.5	1.9	2.2	8.1	0.72	2.6	7.4	5	5.7	1.8	3.3	5	4.7
March 2017	1.3	0.35	1.2	0.88	2.6	1.9	0.22	2.5	2.2	1.8	1.1	0.81	1.1	0.98	1.9
April 2017	0.97	0.66	1.4	1.1	1.8	2.6	0.26	4.1	2.9	2.1	1.4	0.98	1.2	1.2	1.4
May 2017	0.039	0.81	0.03	0.17	0.02	0.0013	0.016	4	0.0015	0.0013	0.0011	0.12	0.00051	0.0012	0.00059
June 2017	0.013	0.051	0.011	0.065	0.0067	0.000012	0.0066	0.056	0.000012	0.000012	0.000011	0.049	0.0000079	0.000011	0.0000085
July 2017	0.007	0.016	0.0061	0.036	0.0036	0.0000011	0.0038	0.023	0.0000011	0.0000011	0.000001	0.027	0.0000008	0.000001	0.00000085
August 2017	0.0042	0.0076	0.0036	0.021	0.0021	0.00000018	0.0023	0.012	0.00000018	0.00000018	0.00000017	0.016	0.00000014	0.00000017	0.00000015
September 2017	0.0026	0.0043	0.0023	0.013	0.0013	0.000000043	0.0015	0.007	0.000000044	0.000000044	0.000000042	0.01	0.000000036	0.000000042	0.000000038

Table 4.2

Model-Assigned Recharge Rates
Eel River Valley Groundwater Sustainability Plan
Humboldt County Groundwater Sustainability Agency

	Model-Applied Recharge Rates in Each HRU (inches/month)														
Date	**109325**	**109326**	**109337**	**109341**	**109348**	**109349**	**109350**	**109351**	**109355**	**109377**	**109378**	**109380**	**109390**	**109911**	**109912**
October 2017	0.0022	0.0029	0.0016	0.0091	0.00093	0.000000014	0.0011	0.0047	0.000000015	0.000000015	0.000000014	0.007	0.000000012	0.000000014	0.000000013
November 2017	0.0079	0.0019	0.0011	0.0061	0.11	5.2E-09	0.00073	0.0031	5.3E-09	1.9	5.1E-09	0.0047	1.1	0.000000005	1.1
December 2017	0.0049	0.0013	0.00082	0.0045	0.23	2.3E-09	0.00055	0.18	2.3E-09	0.056	2.2E-09	0.0034	0.09	2.2E-09	0.0084
January 2018	0.51	0.48	0.38	0.35	1.6	4.4	0.29	1.6	3.6	2.7	3.1	0.48	2.4	2.1	3.2
February 2018	0.37	0.41	0.1	0.16	1.6	0.0082	0.034	0.96	0.0079	0.0073	0.0085	0.17	0.0058	0.011	0.0079
March 2018	1.9	0.42	2.2	1.3	2.6	4.5	0.58	2.4	4.5	3.3	2.7	1.4	2	2.3	3.8
April 2018	0.73	0.72	0.91	0.94	0.87	2.7	0.2	3.6	3.2	2.4	1.7	0.85	1.5	2	0.37
May 2018	0.032	0.14	0.026	0.16	0.014	0.00052	0.015	1.1	0.00055	0.00056	0.00048	0.11	0.0003	0.00052	0.00011
June 2018	0.011	0.017	0.01	0.062	0.0056	0.000008	0.0064	0.029	0.0000082	0.0000082	0.0000077	0.046	0.0000062	0.0000079	0.0000037
July 2018	0.0064	0.0083	0.0057	0.035	0.0031	0.00000081	0.0037	0.015	0.00000082	0.00000083	0.00000079	0.026	0.00000068	0.0000008	0.00000048
August 2018	0.0039	0.0047	0.0035	0.021	0.0019	0.00000015	0.0023	0.0085	0.00000015	0.00000015	0.00000014	0.015	0.00000013	0.00000014	0.000000098
September 2018	0.0025	0.0029	0.0022	0.013	0.0012	0.000000037	0.0015	0.0053	0.000000037	0.000000038	0.000000037	0.0097	0.000000033	0.000000036	0.000000027
October 2018	0.0029	0.002	0.0016	0.0089	0.00085	0.000000013	0.001	0.0036	0.000000013	0.000000013	0.000000012	0.0068	0.000000011	0.000000012	9.5E-09
November 2018	0.004	0.0014	0.0011	0.006	0.00057	4.6E-09	0.00072	0.0024	4.6E-09	1.1	4.6E-09	0.0045	0.63	4.5E-09	0.94
December 2018	0.012	0.15	0.00079	0.061	0.69	2.4	0.05	1.1	2	2.4	0.78	0.35	1.9	0.000000002	1.9
January 2019	1.3	0.7	1.5	1.1	1.9	6.5	0.58	2.4	5.4	3.8	6.4	1.4	2.9	6.5	4.8
February 2019	1.1	0.32	2.5	1.6	1.2	8.6	0.83	1.3	7.6	5	5.7	1.7	3.5	5	6.8
March 2019	2.5	0.52	2.1	1.5	2.7	4.3	0.51	3	4.3	3.3	2.8	1.5	2.1	2.2	3.9
April 2019	0.87	0.8	0.77	0.65	1	1.1	0.11	3.8	1.2	0.85	0.42	0.56	0.53	0.44	0.039
May 2019	0.42	0.81	0.62	0.13	0.12	1.9	0.098	5	2	2.2	1.4	0.17	0.88	0.038	2
June 2019	0.03	0.046	0.031	0.051	0.0091	0.0021	0.019	2	0.0021	0.0021	0.0022	0.058	0.0012	0.00013	0.0016
July 2019	0.012	0.015	0.012	0.03	0.0044	0.000016	0.0078	0.044	0.000016	0.000016	0.000016	0.031	0.000013	0.0000044	0.000014
August 2019	0.0062	0.0073	0.0062	0.018	0.0025	0.0000012	0.0041	0.019	0.0000012	0.0000012	0.0000012	0.018	0.000001	0.0000005	0.0000011
September 2019	0.0037	0.0042	0.0036	0.011	0.0015	0.00000019	0.0024	0.01	0.00000019	0.00000019	0.00000019	0.011	0.00000017	0.000000098	0.00000018
October 2019	0.0025	0.0028	0.0024	0.008	0.0011	0.000000049	0.0016	0.0065	0.000000049	0.00000005	0.00000005	0.0076	0.000000045	0.000000028	0.000000048
November 2019	0.0017	0.0018	0.0016	0.0054	0.00071	0.000000015	0.0011	0.0042	0.000000015	0.000000015	0.000000015	0.0051	0.000000014	9.3E-09	0.000000015
December 2019	0.11	0.13	0.0012	0.004	1.2	2.2	0.0008	1.9	1.6	3	0.38	0.46	2.2	3.8E-09	4
January 2020	1.4	0.75	1.1	0.99	2.1	4.9	0.72	2.8	3.7	3	4.5	1.5	2.3	3.2	3.5
February 2020	0.083	0.56	0.041	0.2	1.6	0.013	0.037	0.39	0.012	0.0096	0.014	0.19	0.0068	0.017	0.0077
March 2020	0.19	0.3	0.41	0.079	1	0.000032	0.011	1.5	0.000031	0.27	0.000032	0.068	0.066	0.000034	0.13
April 2020	0.32	0.36	0.38	0.26	0.33	0.21	0.0051	2.9	0.79	0.49	0.0000018	0.033	0.37	0.13	0.27
May 2020	0.023	0.027	0.017	0.072	0.011	0.00000028	0.0031	0.69	0.000095	0.37	0.00000029	0.02	0.000078	0.00007	0.099
June 2020	0.0094	0.011	0.0078	0.036	0.0048	0.000000063	0.0019	0.039	0.0000034	0.00068	0.000000064	0.012	0.000003	0.0000029	0.0000025
July 2020	0.0053	0.0059	0.0047	0.022	0.0028	0.00000002	0.0013	0.018	0.00000045	0.00001	0.00000002	0.0082	0.00000041	0.00000039	0.00000036
August 2020	0.0033	0.0036	0.0029	0.014	0.0017	0.000000007	0.00092	0.01	0.000000092	0.00000088	7.1E-09	0.0056	0.000000086	0.000000083	0.000000078
September 2020	0.0021	0.0023	0.0019	0.0092	0.0011	2.7E-09	0.00064	0.0061	0.000000025	0.00000015	2.8E-09	0.0038	0.000000024	0.000000023	0.000000022

Table 5.1

Groundwater Observation Targets and Weights
Eel River Valley Groundwater Sustainability Plan
Humboldt County Groundwater Sustainability Agency

Well Identification	Observation Date	State Plane Coordinate X	State Plane Coordinate Y	Observed Groundwater Elevation (NAVD88)	Target Observation Weight
02N01W08B001H	March 2000	5,949,810	2,100,915	25.04	0.029
02N01W08B001H	October 2000	5,949,810	2,100,915	10.44	0.029
02N01W08B001H	March 2001	5,949,810	2,100,915	18.94	0.029
02N01W08B001H	October 2001	5,949,810	2,100,915	11.84	0.029
02N01W08B001H	March 2002	5,949,810	2,100,915	21.74	0.029
02N01W08B001H	March 2003	5,949,810	2,100,915	22.04	0.029
02N01W08B001H	October 2003	5,949,810	2,100,915	13.14	0.029
02N01W08B001H	April 2004	5,949,810	2,100,915	19.34	0.029
02N01W08B001H	October 2004	5,949,810	2,100,915	8.04	0.029
02N01W08B001H	April 2005	5,949,810	2,100,915	22.44	0.029
02N01W08B001H	October 2005	5,949,810	2,100,915	13.14	0.029
02N01W08B001H	May 2006	5,949,810	2,100,915	20.44	0.029
02N01W08B001H	October 2006	5,949,810	2,100,915	13.04	0.029
02N01W08B001H	March 2007	5,949,810	2,100,915	22.64	0.029
02N01W08B001H	October 2007	5,949,810	2,100,915	13.04	0.029
02N01W08B001H	April 2008	5,949,810	2,100,915	20.84	0.029
02N01W08B001H	October 2008	5,949,810	2,100,915	12.64	0.029
02N01W08B001H	April 2009	5,949,810	2,100,915	20.34	0.029
02N01W08B001H	October 2009	5,949,810	2,100,915	10.74	0.029
02N01W08B001H	March 2010	5,949,810	2,100,915	19.64	0.029
02N01W08B001H	October 2010	5,949,810	2,100,915	13.04	0.029
02N01W08B001H	April 2011	5,949,810	2,100,915	25.54	0.029
02N01W08B001H	October 2011	5,949,810	2,100,915	13.14	0.029
02N01W08B001H	April 2012	5,949,810	2,100,915	25.04	0.029
02N01W08B001H	October 2012	5,949,810	2,100,915	12.44	0.029
02N01W08B001H	March 2013	5,949,810	2,100,915	18.94	0.029
02N01W08B001H	October 2013	5,949,810	2,100,915	12.14	0.029
02N01W08B001H	March 2014	5,949,810	2,100,915	16.04	0.029
02N01W08B001H	October 2014	5,949,810	2,100,915	10.54	0.029
02N01W08B001H	April 2015	5,949,810	2,100,915	20.84	0.029
02N01W08B001H	October 2015	5,949,810	2,100,915	11.24	0.029
02N01W08B001H	March 2016	5,949,810	2,100,915	29.54	0.029
02N01W08B001H	October 2016	5,949,810	2,100,915	10.94	0.029
02N01W08B001H	March 2017	5,949,810	2,100,915	26.54	0.029
02N01W08B001H	October 2017	5,949,810	2,100,915	9.04	0.029
02N01W09G001H	March 2000	5,954,198	2,098,582	25.01	0.027
02N01W09G001H	October 2000	5,954,198	2,098,582	13.41	0.027
02N01W09G001H	March 2001	5,954,198	2,098,582	17.51	0.027
02N01W09G001H	October 2001	5,954,198	2,098,582	13.11	0.027
02N01W09G001H	March 2002	5,954,198	2,098,582	21.51	0.027
02N01W09G001H	October 2002	5,954,198	2,098,582	12.91	0.027
02N01W09G001H	March 2003	5,954,198	2,098,582	21.91	0.027
02N01W09G001H	October 2003	5,954,198	2,098,582	14.11	0.027
02N01W09G001H	April 2004	5,954,198	2,098,582	21.91	0.027
02N01W09G001H	October 2004	5,954,198	2,098,582	13.61	0.027
02N01W09G001H	April 2005	5,954,198	2,098,582	22.21	0.027
02N01W09G001H	October 2005	5,954,198	2,098,582	14.01	0.027
02N01W09G001H	May 2006	5,954,198	2,098,582	24.81	0.027
02N01W09G001H	October 2006	5,954,198	2,098,582	14.21	0.027
02N01W09G001H	March 2007	5,954,198	2,098,582	21.81	0.027
02N01W09G001H	October 2007	5,954,198	2,098,582	14.51	0.027
02N01W09G001H	April 2008	5,954,198	2,098,582	21.01	0.027
02N01W09G001H	October 2008	5,954,198	2,098,582	13.91	0.027
02N01W09G001H	April 2009	5,954,198	2,098,582	20.81	0.027
02N01W09G001H	October 2009	5,954,198	2,098,582	14.21	0.027

Table 5.1

Groundwater Observation Targets and Weights
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Humboldt County Groundwater Sustainability Agency

Well Identification	Observation Date	State Plane Coordinate X	State Plane Coordinate Y	Observed Groundwater Elevation (NAVD88)	Target Observation Weight
02N01W09G001H	March 2010	5,954,198	2,098,582	21.71	0.027
02N01W09G001H	October 2010	5,954,198	2,098,582	14.11	0.027
02N01W09G001H	April 2011	5,954,198	2,098,582	25.51	0.027
02N01W09G001H	October 2011	5,954,198	2,098,582	15.56	0.027
02N01W09G001H	April 2012	5,954,198	2,098,582	24.55	0.027
02N01W09G001H	October 2012	5,954,198	2,098,582	13.21	0.027
02N01W09G001H	March 2013	5,954,198	2,098,582	18.71	0.027
02N01W09G001H	October 2013	5,954,198	2,098,582	13.01	0.027
02N01W09G001H	March 2014	5,954,198	2,098,582	16.71	0.027
02N01W09G001H	October 2014	5,954,198	2,098,582	12.51	0.027
02N01W09G001H	April 2015	5,954,198	2,098,582	18.20	0.027
02N01W09G001H	October 2015	5,954,198	2,098,582	12.10	0.027
02N01W09G001H	March 2016	5,954,198	2,098,582	26.36	0.027
02N01W09G001H	October 2016	5,954,198	2,098,582	12.77	0.027
02N01W09G001H	March 2017	5,954,198	2,098,582	25.91	0.027
02N01W09G001H	October 2017	5,954,198	2,098,582	13.41	0.027
02N01W09G001H	March 2018	5,954,198	2,098,582	19.91	0.027
02N02W02G001H	March 2000	5,932,962	2,104,842	14.89	0.031
02N02W02G001H	October 2000	5,932,962	2,104,842	7.09	0.031
02N02W02G001H	March 2001	5,932,962	2,104,842	11.79	0.031
02N02W02G001H	October 2001	5,932,962	2,104,842	7.49	0.031
02N02W02G001H	March 2002	5,932,962	2,104,842	13.49	0.031
02N02W02G001H	October 2002	5,932,962	2,104,842	5.89	0.031
02N02W02G001H	March 2003	5,932,962	2,104,842	13.89	0.031
02N02W02G001H	October 2003	5,932,962	2,104,842	8.29	0.031
02N02W02G001H	April 2004	5,932,962	2,104,842	12.99	0.031
02N02W02G001H	October 2004	5,932,962	2,104,842	7.69	0.031
02N02W02G001H	April 2005	5,932,962	2,104,842	14.69	0.031
02N02W02G001H	October 2005	5,932,962	2,104,842	8.19	0.031
02N02W02G001H	May 2006	5,932,962	2,104,842	14.49	0.031
02N02W02G001H	October 2006	5,932,962	2,104,842	7.69	0.031
02N02W02G001H	March 2007	5,932,962	2,104,842	14.39	0.031
02N02W02G001H	October 2007	5,932,962	2,104,842	7.99	0.031
02N02W02G001H	April 2008	5,932,962	2,104,842	12.49	0.031
02N02W02G001H	October 2008	5,932,962	2,104,842	7.69	0.031
02N02W02G001H	April 2009	5,932,962	2,104,842	12.59	0.031
02N02W02G001H	October 2009	5,932,962	2,104,842	8.09	0.031
02N02W02G001H	March 2010	5,932,962	2,104,842	13.59	0.031
02N02W02G001H	October 2010	5,932,962	2,104,842	8.59	0.031
02N02W02G001H	April 2011	5,932,962	2,104,842	14.79	0.031
02N02W02G001H	October 2011	5,932,962	2,104,842	8.49	0.031
02N02W02G001H	October 2012	5,932,962	2,104,842	8.19	0.031
02N02W02G001H	March 2013	5,932,962	2,104,842	11.89	0.031
02N02W02G001H	March 2014	5,932,962	2,104,842	10.89	0.031
02N02W02G001H	October 2014	5,932,962	2,104,842	8.99	0.031
02N02W02G001H	April 2015	5,932,962	2,104,842	11.79	0.031
02N02W02G001H	March 2017	5,932,962	2,104,842	14.79	0.031
02N02W02G001H	October 2017	5,932,962	2,104,842	7.19	0.031
02N02W02G001H	March 2018	5,932,962	2,104,842	12.79	0.031
03N01W30N001H	March 2000	5,941,781	2,112,961	13.64	0.028
03N01W30N001H	October 2000	5,941,781	2,112,961	6.14	0.028
03N01W30N001H	March 2001	5,941,781	2,112,961	11.14	0.028
03N01W30N001H	October 2001	5,941,781	2,112,961	5.84	0.028
03N01W30N001H	March 2002	5,941,781	2,112,961	12.14	0.028
03N01W30N001H	October 2002	5,941,781	2,112,961	5.74	0.028

Table 5.1

Groundwater Observation Targets and Weights
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Well Identification	Observation Date	State Plane Coordinate X	State Plane Coordinate Y	Observed Groundwater Elevation (NAVD88)	Target Observation Weight
03N01W30N001H	March 2003	5,941,781	2,112,961	12.04	0.028
03N01W30N001H	October 2003	5,941,781	2,112,961	6.24	0.028
03N01W30N001H	April 2004	5,941,781	2,112,961	11.24	0.028
03N01W30N001H	October 2004	5,941,781	2,112,961	5.94	0.028
03N01W30N001H	April 2005	5,941,781	2,112,961	13.74	0.028
03N01W30N001H	October 2005	5,941,781	2,112,961	6.34	0.028
03N01W30N001H	May 2006	5,941,781	2,112,961	13.04	0.028
03N01W30N001H	October 2006	5,941,781	2,112,961	6.94	0.028
03N01W30N001H	October 2007	5,941,781	2,112,961	7.34	0.028
03N01W30N001H	April 2008	5,941,781	2,112,961	11.54	0.028
03N01W30N001H	October 2008	5,941,781	2,112,961	8.34	0.028
03N01W30N001H	April 2009	5,941,781	2,112,961	11.64	0.028
03N01W30N001H	October 2009	5,941,781	2,112,961	7.04	0.028
03N01W30N001H	March 2010	5,941,781	2,112,961	12.34	0.028
03N01W30N001H	October 2010	5,941,781	2,112,961	7.44	0.028
03N01W30N001H	April 2011	5,941,781	2,112,961	13.94	0.028
03N01W30N001H	October 2011	5,941,781	2,112,961	6.54	0.028
03N01W30N001H	April 2012	5,941,781	2,112,961	14.24	0.028
03N01W30N001H	October 2012	5,941,781	2,112,961	6.64	0.028
03N01W30N001H	March 2013	5,941,781	2,112,961	10.54	0.028
03N01W30N001H	October 2013	5,941,781	2,112,961	6.44	0.028
03N01W30N001H	March 2014	5,941,781	2,112,961	11.14	0.028
03N01W30N001H	October 2014	5,941,781	2,112,961	6.94	0.028
03N01W30N001H	April 2015	5,941,781	2,112,961	10.24	0.028
03N01W30N001H	October 2015	5,941,781	2,112,961	6.44	0.028
03N01W30N001H	March 2016	5,941,781	2,112,961	15.04	0.028
03N01W30N001H	October 2016	5,941,781	2,112,961	6.74	0.028
03N01W30N001H	March 2017	5,941,781	2,112,961	15.34	0.028
03N01W30N001H	October 2017	5,941,781	2,112,961	5.74	0.028
03N01W30N001H	March 2018	5,941,781	2,112,961	13.64	0.028
03N01W34J001H	March 2000	5,961,994	2,107,979	25.49	0.030
03N01W34J001H	October 2000	5,961,994	2,107,979	21.99	0.030
03N01W34J001H	March 2001	5,961,994	2,107,979	23.39	0.030
03N01W34J001H	October 2001	5,961,994	2,107,979	20.69	0.030
03N01W34J001H	March 2002	5,961,994	2,107,979	24.49	0.030
03N01W34J001H	October 2002	5,961,994	2,107,979	20.79	0.030
03N01W34J001H	March 2003	5,961,994	2,107,979	25.39	0.030
03N01W34J001H	October 2003	5,961,994	2,107,979	21.69	0.030
03N01W34J001H	April 2004	5,961,994	2,107,979	24.69	0.030
03N01W34J001H	October 2004	5,961,994	2,107,979	21.19	0.030
03N01W34J001H	April 2005	5,961,994	2,107,979	25.29	0.030
03N01W34J001H	October 2005	5,961,994	2,107,979	21.79	0.030
03N01W34J001H	May 2006	5,961,994	2,107,979	26.69	0.030
03N01W34J001H	October 2006	5,961,994	2,107,979	22.29	0.030
03N01W34J001H	March 2007	5,961,994	2,107,979	24.89	0.030
03N01W34J001H	October 2007	5,961,994	2,107,979	22.39	0.030
03N01W34J001H	April 2008	5,961,994	2,107,979	24.79	0.030
03N01W34J001H	October 2008	5,961,994	2,107,979	21.89	0.030
03N01W34J001H	April 2009	5,961,994	2,107,979	24.19	0.030
03N01W34J001H	October 2009	5,961,994	2,107,979	21.79	0.030
03N01W34J001H	March 2010	5,961,994	2,107,979	23.09	0.030
03N01W34J001H	October 2010	5,961,994	2,107,979	21.29	0.030
03N01W34J001H	April 2011	5,961,994	2,107,979	25.47	0.030
03N01W34J001H	April 2012	5,961,994	2,107,979	25.30	0.030
03N01W34J001H	October 2012	5,961,994	2,107,979	24.39	0.030

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Well Identification	Observation Date	State Plane Coordinate X	State Plane Coordinate Y	Observed Groundwater Elevation (NAVD88)	Target Observation Weight
03N01W34J001H	March 2013	5,961,994	2,107,979	24.09	0.030
03N01W34J001H	April 2015	5,961,994	2,107,979	22.88	0.030
03N01W34J001H	October 2015	5,961,994	2,107,979	20.40	0.030
03N01W34J001H	March 2016	5,961,994	2,107,979	25.89	0.030
03N01W34J001H	October 2016	5,961,994	2,107,979	21.56	0.030
03N01W34J001H	March 2017	5,961,994	2,107,979	26.89	0.030
03N01W34J001H	October 2017	5,961,994	2,107,979	21.79	0.030
03N01W34J001H	March 2018	5,961,994	2,107,979	25.79	0.030
03N01W34J001H	March 2000	5,961,994	2,107,979	25.49	0.030
03N01W34J001H	October 2000	5,961,994	2,107,979	21.99	0.030
03N01W34J001H	March 2001	5,961,994	2,107,979	23.39	0.030
03N01W34J001H	October 2001	5,961,994	2,107,979	20.69	0.030
03N01W34J001H	March 2002	5,961,994	2,107,979	24.49	0.030
03N01W34J001H	October 2002	5,961,994	2,107,979	20.79	0.030
03N01W34J001H	March 2003	5,961,994	2,107,979	25.39	0.030
03N01W34J001H	October 2003	5,961,994	2,107,979	21.69	0.030
03N01W34J001H	April 2004	5,961,994	2,107,979	24.69	0.030
03N01W34J001H	October 2004	5,961,994	2,107,979	21.19	0.030
03N01W34J001H	April 2005	5,961,994	2,107,979	25.29	0.030
03N01W34J001H	October 2005	5,961,994	2,107,979	21.79	0.030
03N01W34J001H	May 2006	5,961,994	2,107,979	26.69	0.030
03N01W34J001H	October 2006	5,961,994	2,107,979	22.29	0.030
03N01W34J001H	March 2007	5,961,994	2,107,979	24.89	0.030
03N01W34J001H	October 2007	5,961,994	2,107,979	22.39	0.030
03N01W34J001H	April 2008	5,961,994	2,107,979	24.79	0.030
03N01W34J001H	October 2008	5,961,994	2,107,979	21.89	0.030
03N01W34J001H	April 2009	5,961,994	2,107,979	24.19	0.030
03N01W34J001H	October 2009	5,961,994	2,107,979	21.79	0.030
03N01W34J001H	March 2010	5,961,994	2,107,979	23.09	0.030
03N01W34J001H	October 2010	5,961,994	2,107,979	21.29	0.030
03N01W34J001H	April 2011	5,961,994	2,107,979	25.47	0.030
03N01W34J001H	April 2012	5,961,994	2,107,979	25.30	0.030
03N01W34J001H	October 2012	5,961,994	2,107,979	24.39	0.030
03N01W34J001H	March 2013	5,961,994	2,107,979	24.09	0.030
03N01W34J001H	April 2015	5,961,994	2,107,979	22.88	0.030
03N01W34J001H	October 2015	5,961,994	2,107,979	20.40	0.030
03N01W34J001H	March 2016	5,961,994	2,107,979	25.89	0.030
03N01W34J001H	October 2016	5,961,994	2,107,979	21.56	0.030
03N01W34J001H	March 2017	5,961,994	2,107,979	26.89	0.030
03N01W34J001H	October 2017	5,961,994	2,107,979	21.79	0.030
03N01W34J001H	March 2018	5,961,994	2,107,979	25.79	0.030
03N02W13J001H	March 2000	5,939,865	2,124,890	8.97	0.037
03N02W13J001H	March 2001	5,939,865	2,124,890	5.27	0.037
03N02W13J001H	October 2001	5,939,865	2,124,890	2.97	0.037
03N02W13J001H	March 2002	5,939,865	2,124,890	7.57	0.037
03N02W13J001H	October 2002	5,939,865	2,124,890	6.07	0.037
03N02W13J001H	March 2003	5,939,865	2,124,890	8.67	0.037
03N02W13J001H	October 2003	5,939,865	2,124,890	4.87	0.037
03N02W13J001H	April 2004	5,939,865	2,124,890	6.77	0.037
03N02W13J001H	April 2005	5,939,865	2,124,890	10.87	0.037
03N02W13J001H	October 2005	5,939,865	2,124,890	4.77	0.037
03N02W13J001H	May 2006	5,939,865	2,124,890	7.67	0.037
03N02W13J001H	October 2006	5,939,865	2,124,890	4.57	0.037
03N02W13J001H	March 2007	5,939,865	2,124,890	6.87	0.037
03N02W13J001H	October 2007	5,939,865	2,124,890	4.87	0.037

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Well Identification	Observation Date	State Plane Coordinate X	State Plane Coordinate Y	Observed Groundwater Elevation (NAVD88)	Target Observation Weight
03N02W13J001H	April 2008	5,939,865	2,124,890	6.17	0.037
03N02W13J001H	October 2008	5,939,865	2,124,890	4.47	0.037
03N02W13J001H	April 2009	5,939,865	2,124,890	6.47	0.037
03N02W13J001H	October 2009	5,939,865	2,124,890	4.77	0.037
03N02W13J001H	March 2010	5,939,865	2,124,890	7.07	0.037
03N02W13J001H	October 2010	5,939,865	2,124,890	5.47	0.037
03N02W13J001H	October 2011	5,939,865	2,124,890	5.37	0.037
03N02W13J001H	April 2012	5,939,865	2,124,890	8.97	0.037
03N02W13J001H	October 2012	5,939,865	2,124,890	4.77	0.037
03N02W13J001H	March 2013	5,939,865	2,124,890	6.27	0.037
03N02W13J001H	October 2013	5,939,865	2,124,890	4.67	0.037
03N02W13J001H	October 2014	5,939,865	2,124,890	6.47	0.037
03N02W13J001H	April 2015	5,939,865	2,124,890	6.07	0.037
03N02W13J002H	March 2016	5,939,865	2,124,890	8.64	1.000
03N02W35M002H	March 2000	5,931,405	2,109,073	16.00	0.028
03N02W35M002H	October 2000	5,931,405	2,109,073	8.60	0.028
03N02W35M002H	March 2001	5,931,405	2,109,073	13.30	0.028
03N02W35M002H	October 2001	5,931,405	2,109,073	8.60	0.028
03N02W35M002H	March 2002	5,931,405	2,109,073	14.90	0.028
03N02W35M002H	October 2002	5,931,405	2,109,073	8.60	0.028
03N02W35M002H	March 2003	5,931,405	2,109,073	15.70	0.028
03N02W35M002H	October 2003	5,931,405	2,109,073	9.50	0.028
03N02W35M002H	April 2004	5,931,405	2,109,073	14.40	0.028
03N02W35M002H	October 2004	5,931,405	2,109,073	8.50	0.028
03N02W35M002H	April 2005	5,931,405	2,109,073	17.00	0.028
03N02W35M002H	October 2005	5,931,405	2,109,073	9.10	0.028
03N02W35M002H	May 2006	5,931,405	2,109,073	14.50	0.028
03N02W35M002H	October 2006	5,931,405	2,109,073	8.90	0.028
03N02W35M002H	March 2007	5,931,405	2,109,073	14.80	0.028
03N02W35M002H	October 2007	5,931,405	2,109,073	9.00	0.028
03N02W35M002H	April 2008	5,931,405	2,109,073	13.80	0.028
03N02W35M002H	October 2008	5,931,405	2,109,073	8.60	0.028
03N02W35M002H	April 2009	5,931,405	2,109,073	14.10	0.028
03N02W35M002H	October 2009	5,931,405	2,109,073	9.00	0.028
03N02W35M002H	March 2010	5,931,405	2,109,073	15.10	0.028
03N02W35M002H	October 2010	5,931,405	2,109,073	10.00	0.028
03N02W35M002H	April 2011	5,931,405	2,109,073	16.10	0.028
03N02W35M002H	October 2011	5,931,405	2,109,073	9.70	0.028
03N02W35M002H	April 2012	5,931,405	2,109,073	16.30	0.028
03N02W35M002H	October 2012	5,931,405	2,109,073	9.60	0.028
03N02W35M002H	March 2013	5,931,405	2,109,073	13.90	0.028
03N02W35M002H	October 2013	5,931,405	2,109,073	8.90	0.028
03N02W35M002H	March 2014	5,931,405	2,109,073	12.20	0.028
03N02W35M002H	October 2014	5,931,405	2,109,073	8.90	0.028
03N02W35M002H	April 2015	5,931,405	2,109,073	13.50	0.028
03N02W35M002H	October 2015	5,931,405	2,109,073	9.00	0.028
03N02W35M002H	March 2016	5,931,405	2,109,073	15.83	0.028
03N02W35M002H	October 2016	5,931,405	2,109,073	9.00	0.028
03N02W35M002H	October 2017	5,931,405	2,109,073	9.10	0.028
03N02W35M002H	March 2018	5,931,405	2,109,073	15.80	0.028
1	March 2017	5,925,192	2,105,190	15.01	1.000
10	October 2016	5,939,340	2,115,246	5.85	0.500
10	March 2017	5,939,340	2,115,246	10.12	0.500
11	March 2017	5,937,561	2,110,846	15.16	0.500
11	October 2016	5,937,561	2,110,846	6.70	0.500

Groundwater Observation Targets and Weights
Eel River Valley Groundwater Sustainability Plan
Humboldt County Groundwater Sustainability Agency

Well Identification	Observation Date	State Plane Coordinate X	State Plane Coordinate Y	Observed Groundwater Elevation (NAVD88)	Target Observation Weight
12	March 2017	5,938,042	2,107,919	18.19	0.500
12	October 2016	5,938,042	2,107,919	7.96	0.500
13	October 2016	5,945,462	2,104,778	-1.53	0.500
13	March 2017	5,945,462	2,104,778	12.37	0.500
14	October 2016	5,949,643	2,105,328	13.90	0.500
14	March 2017	5,949,643	2,105,328	25.87	0.500
15	October 2016	5,953,588	2,107,525	11.98	0.500
15	March 2017	5,953,588	2,107,525	20.98	0.500
16	October 2016	5,949,707	2,096,799	14.18	0.500
16	March 2017	5,949,707	2,096,799	31.30	0.500
17	October 2016	5,953,393	2,099,732	15.07	0.500
17	March 2017	5,953,393	2,099,732	27.68	0.500
18	March 2017	5,946,760	2,101,174	25.81	0.500
18	October 2016	5,946,760	2,101,174	10.93	0.500
19	March 2017	5,956,006	2,093,107	30.63	0.500
19	October 2016	5,956,006	2,093,107	18.73	0.500
2	October 2016	5,928,336	2,108,570	8.01	1.000
20	March 2017	5,960,894	2,088,431	34.58	0.500
20	October 2016	5,960,894	2,088,431	28.00	0.500
21	March 2017	5,963,173	2,079,374	44.77	0.500
21	October 2016	5,963,173	2,079,374	34.90	0.500
22	March 2017	5,967,573	2,088,741	49.48	0.500
22	October 2016	5,967,573	2,088,741	43.45	0.500
24	October 2016	5,942,291	2,122,058	6.21	1.000
25	March 2017	5,944,004	2,123,910	18.13	0.500
25	October 2016	5,944,004	2,123,910	13.65	0.500
26	October 2016	5,935,929	2,133,737	5.37	1.000
28	October 2016	5,953,850	2,095,785	15.10	1.000
3	October 2016	5,928,640	2,109,546	5.83	0.500
3	March 2017	5,928,640	2,109,546	10.55	0.500
4	March 2017	5,930,312	2,109,758	10.98	0.500
4	October 2016	5,930,312	2,109,758	5.28	0.500
403358124063701	July 2010	5,975,454	2,096,611	223.45	0.500
403358124063701	July 2011	5,975,454	2,096,611	225.87	0.500
403421124155801	July 2011	5,932,213	2,100,050	72.84	1.000
403544124131501	July 2010	5,944,976	2,108,124	12.41	0.200
403544124131501	July 2011	5,944,976	2,108,124	12.27	0.200
403544124131501	May 2012	5,944,976	2,108,124	16.86	0.200
403544124131501	May 2014	5,944,976	2,108,124	12.23	0.200
403544124131501	June 2016	5,944,976	2,108,124	11.19	0.200
403825124123301	August 2009	5,948,360	2,124,211	66.15	0.167
403825124123301	July 2010	5,948,360	2,124,211	69.05	0.167
403825124123301	July 2011	5,948,360	2,124,211	69.30	0.167
403825124123301	May 2012	5,948,360	2,124,211	69.17	0.167
403825124123301	May 2014	5,948,360	2,124,211	68.21	0.167
403825124123301	June 2016	5,948,360	2,124,211	68.62	0.167
5	March 2017	5,929,435	2,108,104	10.96	0.500
5	October 2016	5,929,435	2,108,104	5.34	0.500
6	October 2016	5,933,416	2,111,645	7.29	0.500
6	March 2017	5,933,416	2,111,645	14.34	0.500
7	March 2017	5,933,173	2,113,000	14.18	0.500
7	October 2016	5,933,173	2,113,000	7.83	0.500
8	October 2016	5,932,949	2,115,083	6.26	0.500
8	March 2017	5,932,949	2,115,083	11.21	0.500
A	November 2016	5,989,976	2,083,905	111.38	1.000

Table 5.1

Groundwater Observation Targets and Weights
Eel River Valley Groundwater Sustainability Plan
Humboldt County Groundwater Sustainability Agency

Well Identification	Observation Date	State Plane Coordinate X	State Plane Coordinate Y	Observed Groundwater Elevation (NAVD88)	Target Observation Weight
Add-29	November 2016	5,929,452	2,119,437	7.03	0.500
Add-29	March 2017	5,929,452	2,119,437	15.83	0.500
B	November 2016	5,975,815	2,084,679	70.00	0.500
B	March 2017	5,975,815	2,084,679	72.59	0.500
C-23	October 2016	5,974,763	2,087,182	63.05	0.500
C-23	March 2017	5,974,763	2,087,182	69.52	0.500
D	March 2017	5,958,167	2,090,576	30.44	0.500
D	November 2016	5,958,167	2,090,576	21.40	0.500
1	March 2017	5,965,284	2,098,690	15.01	1.000

Table 5.2

Surface Water Observation Qualitative Targets
Eel River Valley Groundwater Sustainability Plan
Humboldt County Groundwater Sustainability Agency

Date	Eel River Station 11477000 Monthly Average Flow Rate (cfs)	Eel River Station 11477000 Monthly Average Stage Elevation (NAVD88)	Van Duzen River Station 11478500 Monthly Average Flow Rate (cfs)	Van Duzen River Station 11478500 Monthly Average Stage Elevation (NAVD88)
January 2000	12,386.9	--	2,488.5	--
February 2000	26,453.3	--	2,831.3	--
March 2000	26,406.7	--	2,153.7	--
April 2000	5,171.0	--	457.8	--
May 2000	3,634.8	--	448.8	--
June 2000	1,500.5	--	174.8	--
July 2000	403.5	--	42.7	--
August 2000	156.9	--	14.7	--
September 2000	88.6	--	9.0	--
October 2000	76.6	--	8.6	--
November 2000	482.0	--	66.5	--
December 2000	1,070.6	--	232.1	--
January 2001	2,234.3	--	380.4	--
February 2001	4,061.7	--	485.3	--
March 2001	15,686.7	--	1,365.5	--
April 2001	4,362.7	--	634.1	--
May 2001	2,398.4	--	380.8	--
June 2001	623.9	--	77.2	--
July 2001	254.0	--	40.9	--
August 2001	78.2	--	10.9	--
September 2001	48.6	--	5.9	--
October 2001	54.7	--	4.7	--
November 2001	257.4	--	54.2	--
December 2001	20,115.8	--	2,779.7	--
January 2002	32,348.1	--	3,374.1	--
February 2002	7,088.6	--	1,049.1	--
March 2002	11,553.0	--	1,348.7	--
April 2002	5,312.0	--	580.1	--
May 2002	2,019.4	--	207.5	--
June 2002	940.8	--	84.1	--
July 2002	283.2	--	24.4	--
August 2002	99.4	--	7.7	--
September 2002	52.4	--	4.6	--
October 2002	41.6	--	3.9	--
November 2002	1,142.9	--	188.0	--
December 2002	13,557.4	--	1,744.0	--
January 2003	51,935.5	--	4,455.2	--
February 2003	11,706.2	--	1,053.0	--
March 2003	11,441.3	--	1,364.9	--
April 2003	14,875.7	--	1,803.1	--
May 2003	25,056.1	--	2,143.8	--
June 2003	3,684.0	--	326.9	--
July 2003	809.3	--	65.1	--
August 2003	248.1	--	18.8	--
September 2003	148.4	--	10.0	--
October 2003	104.9	--	6.7	--
November 2003	325.4	--	30.6	--
December 2003	11,937.1	--	1,685.9	--
January 2004	25,477.1	--	2,700.6	--
February 2004	12,011.7	--	1,352.7	--
March 2004	32,823.7	--	2,913.8	--
April 2004	4,864.7	--	464.5	--
May 2004	2,995.8	--	412.0	--
June 2004	1,006.1	--	84.2	--
July 2004	323.6	--	27.4	--
August 2004	130.4	--	10.6	--
September 2004	96.7	--	6.4	--
October 2004	76.2	--	6.4	--

Table 5.2

Surface Water Observation Qualitative Targets
Eel River Valley Groundwater Sustainability Plan
Humboldt County Groundwater Sustainability Agency

	Eel River Station 11477000		Van Duzen River Station 11478500	
Date	**Monthly Average Flow Rate (cfs)**	**Monthly Average Stage Elevation (NAVD88)**	**Monthly Average Flow Rate (cfs)**	**Monthly Average Stage Elevation (NAVD88)**
November 2004	843.7	--	151.9	--
December 2004	5,270.8	--	885.6	--
January 2005	11,783.2	--	966.7	--
February 2005	10,823.8	--	1,325.4	--
March 2005	10,154.7	--	788.0	--
April 2005	23,169.0	--	2,332.4	--
May 2005	8,367.1	--	1,090.6	--
June 2005	10,788.3	--	937.9	--
July 2005	3,722.3	--	479.7	--
August 2005	555.8	--	49.4	--
September 2005	223.0	--	14.6	--
October 2005	174.9	--	14.4	--
November 2005	1,382.8	--	211.2	--
December 2005	7,073.6	--	1,158.9	--
January 2006	64,757.7	--	5,743.0	--
February 2006	29,541.4	--	2,937.9	--
March 2006	24,693.0	--	1,977.5	--
April 2006	28,206.7	--	2,349.7	--
May 2006	14,191.9	--	1,200.6	--
June 2006	2,718.3	--	266.3	--
July 2006	640.1	--	64.2	--
August 2006	223.9	--	18.7	--
September 2006	142.9	--	9.4	--
October 2006	130.9	--	9.7	--
November 2006	373.1	--	107.7	--
December 2006	5,385.4	--	1,212.8	--
January 2007	10,863.2	--	1,485.0	--
February 2007	7,341.4	--	742.1	--
March 2007	17,814.3	--	2,105.9	--
April 2007	3,902.7	--	604.6	--
May 2007	3,390.6	--	519.0	--
June 2007	894.4	--	111.2	--
July 2007	291.8	--	33.3	--
August 2007	159.9	--	17.1	--
September 2007	86.3	--	6.6	--
October 2007	124.5	45.4	16.0	358.8
November 2007	791.7	46.0	151.3	359.2
December 2007	2,431.0	46.8	387.3	359.7
January 2008	19,609.4	52.0	2,509.5	361.9
February 2008	18,761.3	52.1	1,730.8	361.4
March 2008	9,737.0	49.9	1,209.0	361.1
April 2008	4,276.7	48.0	614.9	360.4
May 2008	3,049.7	47.5	401.7	360.1
June 2008	1,317.2	46.5	137.3	359.5
July 2008	272.1	45.5	33.7	359.0
August 2008	98.2	45.1	9.9	358.7
September 2008	55.4	44.9	5.3	358.6
October 2008	116.0	45.1	14.2	358.7
November 2008	962.9	45.9	223.3	359.4
December 2008	423.7	45.6	63.8	359.2
January 2009	6,880.7	48.7	1,566.9	361.2
February 2009	2,875.2	47.0	302.6	359.9
March 2009	19,911.7	52.4	2,749.4	362.0
April 2009	6,476.0	48.9	882.9	360.8
May 2009	5,818.4	48.3	841.9	360.5
June 2009	1,543.8	46.6	161.6	359.7
July 2009	421.3	45.6	42.1	359.2
August 2009	135.1	45.2	11.3	359.0

Table 5.2

Surface Water Observation Qualitative Targets
Eel River Valley Groundwater Sustainability Plan
Humboldt County Groundwater Sustainability Agency

Date	Eel River Station 11477000 Monthly Average Flow Rate (cfs)	Eel River Station 11477000 Monthly Average Stage Elevation (NAVD88)	Van Duzen River Station 11478500 Monthly Average Flow Rate (cfs)	Van Duzen River Station 11478500 Monthly Average Stage Elevation (NAVD88)
September 2009	60.1	45.0	5.1	358.9
October 2009	214.7	45.1	42.3	359.0
November 2009	390.9	45.6	59.9	359.3
December 2009	1,492.8	46.3	415.6	359.9
January 2010	7,561.9	49.1	1,296.5	361.0
February 2010	26,779.3	54.0	2,635.5	362.1
March 2010	13,902.0	51.1	1,616.0	361.4
April 2010	15,489.0	51.5	1,497.4	361.3
May 2010	12,850.3	50.8	1,323.5	361.1
June 2010	5,785.0	48.6	662.9	360.5
July 2010	1,475.6	46.4	152.7	359.5
August 2010	354.2	45.3	36.4	359.0
September 2010	170.4	45.0	14.4	358.8
October 2010	150.8	44.9	13.6	358.8
November 2010	4,246.6	47.4	543.5	359.9
December 2010	10,909.0	50.0	1,511.3	361.1
January 2011	24,144.5	53.6	2,472.8	361.8
February 2011	4,993.4	48.6	458.7	360.1
March 2011	21,160.3	52.9	2,428.5	361.9
April 2011	35,857.3	56.1	2,662.5	362.2
May 2011	7,418.7	49.6	1,203.5	361.1
June 2011	3,715.0	48.0	558.2	360.4
July 2011	1,419.2	46.4	205.0	359.6
August 2011	409.3	45.2	56.7	359.0
September 2011	160.8	44.7	13.3	358.7
October 2011	444.5	45.1	52.8	358.9
November 2011	340.5	45.1	36.8	359.0
December 2011	1,118.2	46.0	224.9	359.5
January 2012	548.8	45.5	109.0	359.2
February 2012	10,134.4	49.7	1,644.3	361.1
March 2012	6,304.3	48.6	1,136.6	360.7
April 2012	29,449.7	55.1	3,472.7	362.7
May 2012	6,844.8	49.3	845.5	360.7
June 2012	1,459.4	46.4	165.6	359.5
July 2012	492.0	45.4	58.3	359.1
August 2012	176.3	44.7	22.4	358.9
September 2012	78.6	44.4	8.0	358.7
October 2012	62.2	44.3	6.4	358.6
November 2012	233.7	44.9	37.4	359.0
December 2012	19,875.1	51.6	2,564.4	361.3
January 2013	21,124.5	52.8	1,910.3	361.0
February 2013	4,131.4	48.1	735.1	359.8
March 2013	3,710.0	47.7	575.1	359.6
April 2013	4,766.3	48.4	721.2	359.8
May 2013	1,764.9	46.7	183.8	358.9
June 2013	601.1	45.5	59.1	358.5
July 2013	323.9	45.0	33.6	358.3
August 2013	98.3	44.4	7.9	358.1
September 2013	57.8	44.2	4.7	358.0
October 2013	210.4	44.7	69.3	358.4
November 2013	137.1	44.5	16.0	358.2
December 2013	330.5	45.0	43.8	358.4
January 2014	196.0	44.7	26.8	358.3
February 2014	2,589.4	46.0	378.1	358.9
March 2014	11,238.3	50.3	1,662.6	360.7
April 2014	10,008.7	49.8	1,262.7	360.3
May 2014	1,677.4	46.5	172.3	359.1
June 2014	451.8	45.1	50.1	358.6

Table 5.2

Surface Water Observation Qualitative Targets
Eel River Valley Groundwater Sustainability Plan
Humboldt County Groundwater Sustainability Agency

	Eel River Station 11477000		Van Duzen River Station 11478500	
Date	Monthly Average Flow Rate (cfs)	Monthly Average Stage Elevation (NAVD88)	Monthly Average Flow Rate (cfs)	Monthly Average Stage Elevation (NAVD88)
July 2014	134.4	44.4	15.1	358.3
August 2014	47.1	44.1	4.3	358.1
September 2014	32.1	44.0	2.3	358.0
October 2014	98.9	44.3	7.9	358.1
November 2014	732.8	45.4	237.6	359.0
December 2014	14,440.2	50.6	1,690.8	360.8
January 2015	12,018.1	50.4	1,458.6	360.6
February 2015	16,644.1	50.9	2,247.1	361.0
March 2015	3,523.3	47.8	306.0	359.4
April 2015	1,918.3	46.9	323.5	359.4
May 2015	994.6	46.1	96.8	358.8
June 2015	485.5	45.5	40.8	358.5
July 2015	125.0	44.8	13.6	358.3
August 2015	66.5	44.6	4.5	358.2
September 2015	33.7	44.5	3.5	358.1
October 2015	57.4	44.6	4.7	358.2
November 2015	87.8	44.7	9.4	358.3
December 2015	5,154.4	47.4	1,061.5	359.8
January 2016	23,496.1	53.4	3,439.6	362.3
February 2016	31,193.3	55.2	3,257.8	362.0
March 2016	30,071.0	54.4	3,026.9	361.8
April 2016	12,724.7	50.9	1,153.6	360.5
May 2016	2,924.5	47.4	313.7	359.4
June 2016	1,050.2	46.0	90.8	358.8
July 2016	356.3	45.0	33.0	358.5
August 2016	123.0	44.5	11.6	358.3
September 2016	56.3	44.2	4.6	358.3
October 2016	200.6	44.4	83.7	358.4
November 2016	7,051.2	48.8	1,199.2	360.5
December 2016	22,517.7	52.6	2,563.1	361.7
January 2017	36,660.6	55.6	3,093.8	362.0
February 2017	53,689.7	59.1	5,076.8	363.2
March 2017	27,340.0	54.1	2,830.0	362.0
April 2017	18,826.0	52.1	2,112.5	361.5
May 2017	10,510.3	49.7	1,165.7	360.6
June 2017	2,177.3	46.4	186.2	359.2
July 2017	614.5	45.3	59.4	358.7
August 2017	215.8	44.3	18.7	358.4
September 2017	128.7	44.1	9.0	358.3
October 2017	123.4	44.1	13.3	358.4
November 2017	462.3	44.6	211.6	359.0
December 2017	4,781.4	47.4	933.0	360.4
January 2018	1,913.5	45.9	352.7	359.5
February 2018	10,899.3	49.6	1,349.7	360.8
March 2018	7,285.7	48.4	1,078.9	360.4
April 2018	19,204.7	52.4	2,081.9	361.5
May 2018	4,570.6	47.8	558.2	360.0
June 2018	1,161.1	45.7	128.0	359.2
July 2018	364.2	44.7	39.9	358.7
August 2018	141.8	44.2	9.5	358.4
September 2018	77.7	44.1	5.4	358.3
October 2018	64.2	44.1	6.8	358.3
November 2018	72.6	44.2	9.3	358.4
December 2018	1,914.1	45.9	336.9	359.4
January 2019	9,271.6	49.3	1,241.2	360.7
February 2019	23,656.9	52.8	2,729.7	361.7
March 2019	41,450.0	57.0	3,569.3	362.4
April 2019	18,488.3	52.4	1,709.0	361.1

Table 5.2

Surface Water Observation Qualitative Targets
Eel River Valley Groundwater Sustainability Plan
Humboldt County Groundwater Sustainability Agency

	Eel River Station 11477000		Van Duzen River Station 11478500	
Date	Monthly Average Flow Rate (cfs)	Monthly Average Stage Elevation (NAVD88)	Monthly Average Flow Rate (cfs)	Monthly Average Stage Elevation (NAVD88)
May 2019	6,286.1	48.5	400.6	359.6
June 2019	7,879.0	48.9	648.3	359.8
July 2019	1,223.6	45.6	69.6	358.6
August 2019	344.6	44.5	22.2	358.3
September 2019	140.2	43.9	9.8	358.2
October 2019	161.6	44.0	17.7	358.3
November 2019	150.7	44.0	18.5	358.3
December 2019	1,893.8	45.5	415.9	359.2
January 2020	3,316.8	47.0	817.0	360.1
February 2020	9,264.7	49.3	1,408.9	360.8
March 2020	1,311.1	45.7	130.6	359.1
April 2020	3,149.7	46.9	589.0	359.9
May 2020	1,457.5	45.8	216.7	359.3
June 2020	2,141.3	46.2	441.7	359.7
July 2020	369.6	44.4	64.3	358.6
August 2020	100.0	43.7	16.2	358.3
September 2020	60.5	43.5	6.7	358.1
October 2020	60.8	43.5	6.5	358.1

Note:

-- Stage elevations were not recorded this month

Table 5.3

Groundwater Elevation Target Residuals
Eel River Valley Groundwater Sustainability Plan
Humboldt County Groundwater Sustainability Agency

		State Plane Coordinates		Groundwater Elevations (NAVD88)		
Well Identification	**Observation Date**	**X**	**Y**	**Observed**	**Simulated**	**Residuals**
02N01W08B001H	March 2000	5949810.16	2100914.61	25.0	26.6	**-1.55**
02N01W08B001H	October 2000	5949810.16	2100914.61	10.4	21.9	**-11.46**
02N01W08B001H	March 2001	5949810.16	2100914.61	18.9	24.4	**-5.48**
02N01W08B001H	October 2001	5949810.16	2100914.61	11.8	19.8	**-8.00**
02N01W08B001H	March 2002	5949810.16	2100914.61	21.7	24.8	**-3.10**
02N01W08B001H	March 2003	5949810.16	2100914.61	22.0	25.0	**-2.95**
02N01W08B001H	October 2003	5949810.16	2100914.61	13.1	20.9	**-7.74**
02N01W08B001H	April 2004	5949810.16	2100914.61	19.3	25.8	**-6.48**
02N01W08B001H	October 2004	5949810.16	2100914.61	8.0	21.2	**-13.11**
02N01W08B001H	April 2005	5949810.16	2100914.61	22.4	25.4	**-3.01**
02N01W08B001H	October 2005	5949810.16	2100914.61	13.1	22.0	**-8.86**
02N01W08B001H	May 2006	5949810.16	2100914.61	20.4	27.8	**-7.33**
02N01W08B001H	October 2006	5949810.16	2100914.61	13.0	21.5	**-8.47**
02N01W08B001H	March 2007	5949810.16	2100914.61	22.6	25.5	**-2.85**
02N01W08B001H	October 2007	5949810.16	2100914.61	13.0	21.4	**-8.32**
02N01W08B001H	April 2008	5949810.16	2100914.61	20.8	24.9	**-4.10**
02N01W08B001H	October 2008	5949810.16	2100914.61	12.6	20.4	**-7.74**
02N01W08B001H	April 2009	5949810.16	2100914.61	20.3	24.0	**-3.69**
02N01W08B001H	October 2009	5949810.16	2100914.61	10.7	20.3	**-9.56**
02N01W08B001H	March 2010	5949810.16	2100914.61	19.6	24.8	**-5.17**
02N01W08B001H	October 2010	5949810.16	2100914.61	13.0	23.3	**-10.25**
02N01W08B001H	April 2011	5949810.16	2100914.61	25.5	26.1	-0.60
02N01W08B001H	October 2011	5949810.16	2100914.61	13.1	22.7	**-9.60**
02N01W08B001H	April 2012	5949810.16	2100914.61	25.0	26.0	-0.94
02N01W08B001H	October 2012	5949810.16	2100914.61	12.4	22.8	**-10.32**
02N01W08B001H	March 2013	5949810.16	2100914.61	18.9	25.4	**-6.48**
02N01W08B001H	October 2013	5949810.16	2100914.61	12.1	21.6	**-9.48**
02N01W08B001H	March 2014	5949810.16	2100914.61	16.0	23.5	**-7.41**
02N01W08B001H	October 2014	5949810.16	2100914.61	10.5	21.7	**-11.11**
02N01W08B001H	April 2015	5949810.16	2100914.61	20.8	24.5	**-3.66**
02N01W08B001H	October 2015	5949810.16	2100914.61	11.2	21.7	**-10.47**
02N01W08B001H	March 2016	5949810.16	2100914.61	29.5	27.1	**2.42**
02N01W08B001H	October 2016	5949810.16	2100914.61	10.9	22.4	**-11.41**
02N01W08B001H	March 2017	5949810.16	2100914.61	26.5	29.3	**-2.76**
02N01W08B001H	October 2017	5949810.16	2100914.61	9.0	22.1	**-13.02**
02N01W09G001H	March 2000	5954197.59	2098581.83	25.0	26.8	**-1.75**
02N01W09G001H	October 2000	5954197.59	2098581.83	13.4	21.8	**-8.41**
02N01W09G001H	March 2001	5954197.59	2098581.83	17.5	24.2	**-6.71**
02N01W09G001H	October 2001	5954197.59	2098581.83	13.1	19.6	**-6.50**
02N01W09G001H	March 2002	5954197.59	2098581.83	21.5	24.9	**-3.37**
02N01W09G001H	October 2002	5954197.59	2098581.83	12.9	19.7	**-6.78**
02N01W09G001H	March 2003	5954197.59	2098581.83	21.9	24.9	**-3.02**
02N01W09G001H	October 2003	5954197.59	2098581.83	14.1	21.6	**-7.48**
02N01W09G001H	April 2004	5954197.59	2098581.83	21.9	26.9	**-4.96**
02N01W09G001H	October 2004	5954197.59	2098581.83	13.6	20.8	**-7.16**
02N01W09G001H	April 2005	5954197.59	2098581.83	22.2	25.3	**-3.06**
02N01W09G001H	October 2005	5954197.59	2098581.83	14.0	22.4	**-8.37**
02N01W09G001H	May 2006	5954197.59	2098581.83	24.8	29.8	**-4.99**

Table 5.3

Groundwater Elevation Target Residuals
Eel River Valley Groundwater Sustainability Plan
Humboldt County Groundwater Sustainability Agency

02N01W09G001H	October 2006	5954197.59	2098581.83	14.2	23.3	**-9.07**
02N01W09G001H	March 2007	5954197.59	2098581.83	21.8	25.8	**-3.98**
02N01W09G001H	October 2007	5954197.59	2098581.83	14.5	20.7	**-6.15**
02N01W09G001H	April 2008	5954197.59	2098581.83	21.0	25.4	**-4.41**
02N01W09G001H	October 2008	5954197.59	2098581.83	13.9	19.3	**-5.38**
02N01W09G001H	April 2009	5954197.59	2098581.83	20.8	23.5	**-2.72**
02N01W09G001H	October 2009	5954197.59	2098581.83	14.2	19.6	**-5.35**
02N01W09G001H	March 2010	5954197.59	2098581.83	21.7	24.4	**-2.73**
02N01W09G001H	October 2010	5954197.59	2098581.83	14.1	22.5	**-8.43**
02N01W09G001H	April 2011	5954197.59	2098581.83	25.5	26.9	**-1.40**
02N01W09G001H	October 2011	5954197.59	2098581.83	15.6	22.3	**-6.78**
02N01W09G001H	April 2012	5954197.59	2098581.83	24.6	25.8	**-1.30**
02N01W09G001H	October 2012	5954197.59	2098581.83	13.2	22.1	**-8.86**
02N01W09G001H	March 2013	5954197.59	2098581.83	18.7	26.1	**-7.37**
02N01W09G001H	October 2013	5954197.59	2098581.83	13.0	21.0	**-7.95**
02N01W09G001H	March 2014	5954197.59	2098581.83	16.7	22.1	**-5.39**
02N01W09G001H	October 2014	5954197.59	2098581.83	12.5	19.4	**-6.90**
02N01W09G001H	April 2015	5954197.59	2098581.83	18.2	24.5	**-6.29**
02N01W09G001H	October 2015	5954197.59	2098581.83	12.1	20.1	**-7.98**
02N01W09G001H	March 2016	5954197.59	2098581.83	26.4	27.2	-0.88
02N01W09G001H	October 2016	5954197.59	2098581.83	12.8	21.8	**-9.02**
02N01W09G001H	March 2017	5954197.59	2098581.83	25.9	31.1	**-5.17**
02N01W09G001H	October 2017	5954197.59	2098581.83	13.4	23.4	**-9.94**
02N01W09G001H	March 2018	5954197.59	2098581.83	19.9	24.8	**-4.84**
02N02W02G001H	March 2000	5932962.22	2104842.47	14.9	22.1	**-7.24**
02N02W02G001H	October 2000	5932962.22	2104842.47	7.1	15.5	**-8.39**
02N02W02G001H	March 2001	5932962.22	2104842.47	11.8	18.1	**-6.34**
02N02W02G001H	October 2001	5932962.22	2104842.47	7.5	14.2	**-6.70**
02N02W02G001H	March 2002	5932962.22	2104842.47	13.5	19.5	**-5.96**
02N02W02G001H	October 2002	5932962.22	2104842.47	5.9	13.8	**-7.89**
02N02W02G001H	March 2003	5932962.22	2104842.47	13.9	19.8	**-5.87**
02N02W02G001H	October 2003	5932962.22	2104842.47	8.3	14.9	**-6.56**
02N02W02G001H	April 2004	5932962.22	2104842.47	13.0	20.7	**-7.69**
02N02W02G001H	October 2004	5932962.22	2104842.47	7.7	14.6	**-6.89**
02N02W02G001H	April 2005	5932962.22	2104842.47	14.7	20.1	**-5.37**
02N02W02G001H	October 2005	5932962.22	2104842.47	8.2	15.7	**-7.55**
02N02W02G001H	May 2006	5932962.22	2104842.47	14.5	23.8	**-9.26**
02N02W02G001H	October 2006	5932962.22	2104842.47	7.7	15.7	**-8.03**
02N02W02G001H	March 2007	5932962.22	2104842.47	14.4	19.7	**-5.30**
02N02W02G001H	October 2007	5932962.22	2104842.47	8.0	14.7	**-6.69**
02N02W02G001H	April 2008	5932962.22	2104842.47	12.5	19.5	**-7.04**
02N02W02G001H	October 2008	5932962.22	2104842.47	7.7	14.1	**-6.39**
02N02W02G001H	April 2009	5932962.22	2104842.47	12.6	18.2	**-5.64**
02N02W02G001H	October 2009	5932962.22	2104842.47	8.1	14.0	**-5.86**
02N02W02G001H	March 2010	5932962.22	2104842.47	13.6	19.4	**-5.85**
02N02W02G001H	October 2010	5932962.22	2104842.47	8.6	16.4	**-7.79**
02N02W02G001H	April 2011	5932962.22	2104842.47	14.8	20.9	**-6.07**
02N02W02G001H	October 2011	5932962.22	2104842.47	8.5	15.5	**-7.03**
02N02W02G001H	October 2012	5932962.22	2104842.47	8.2	15.8	**-7.61**
02N02W02G001H	March 2013	5932962.22	2104842.47	11.9	19.8	**-7.90**

Groundwater Elevation Target Residuals
Eel River Valley Groundwater Sustainability Plan
Humboldt County Groundwater Sustainability Agency

02N02W02G001H	March 2014	5932962.22	2104842.47	10.9	16.2	-5.34
02N02W02G001H	October 2014	5932962.22	2104842.47	9.0	14.6	-5.65
02N02W02G001H	April 2015	5932962.22	2104842.47	11.8	19.0	-7.20
02N02W02G001H	March 2017	5932962.22	2104842.47	14.8	27.3	-12.53
02N02W02G001H	October 2017	5932962.22	2104842.47	7.2	15.8	-8.59
02N02W02G001H	March 2018	5932962.22	2104842.47	12.8	18.6	-5.79
03N01W30N001H	March 2000	5941781.5	2112961.05	13.6	20.2	-6.55
03N01W30N001H	October 2000	5941781.5	2112961.05	6.1	11.2	-5.09
03N01W30N001H	March 2001	5941781.5	2112961.05	11.1	16.4	-5.22
03N01W30N001H	October 2001	5941781.5	2112961.05	5.8	10.5	-4.61
03N01W30N001H	March 2002	5941781.5	2112961.05	12.1	18.2	-6.09
03N01W30N001H	October 2002	5941781.5	2112961.05	5.7	10.1	-4.33
03N01W30N001H	March 2003	5941781.5	2112961.05	12.0	18.3	-6.27
03N01W30N001H	October 2003	5941781.5	2112961.05	6.2	11.2	-4.98
03N01W30N001H	April 2004	5941781.5	2112961.05	11.2	18.8	-7.58
03N01W30N001H	October 2004	5941781.5	2112961.05	5.9	10.7	-4.71
03N01W30N001H	April 2005	5941781.5	2112961.05	13.7	18.1	-4.35
03N01W30N001H	October 2005	5941781.5	2112961.05	6.3	12.0	-5.61
03N01W30N001H	May 2006	5941781.5	2112961.05	13.0	21.5	-8.47
03N01W30N001H	October 2006	5941781.5	2112961.05	6.9	11.4	-4.45
03N01W30N001H	October 2007	5941781.5	2112961.05	7.3	10.9	-3.54
03N01W30N001H	April 2008	5941781.5	2112961.05	11.5	17.6	-6.09
03N01W30N001H	October 2008	5941781.5	2112961.05	8.3	10.2	-1.89
03N01W30N001H	April 2009	5941781.5	2112961.05	11.6	17.0	-5.40
03N01W30N001H	October 2009	5941781.5	2112961.05	7.0	11.2	-4.12
03N01W30N001H	March 2010	5941781.5	2112961.05	12.3	18.7	-6.38
03N01W30N001H	October 2010	5941781.5	2112961.05	7.4	12.8	-5.35
03N01W30N001H	April 2011	5941781.5	2112961.05	13.9	20.3	-6.35
03N01W30N001H	October 2011	5941781.5	2112961.05	6.5	11.9	-5.33
03N01W30N001H	April 2012	5941781.5	2112961.05	14.2	19.6	-5.40
03N01W30N001H	October 2012	5941781.5	2112961.05	6.6	11.9	-5.24
03N01W30N001H	March 2013	5941781.5	2112961.05	10.5	16.7	-6.18
03N01W30N001H	October 2013	5941781.5	2112961.05	6.4	11.5	-5.11
03N01W30N001H	March 2014	5941781.5	2112961.05	11.1	15.1	-3.99
03N01W30N001H	October 2014	5941781.5	2112961.05	6.9	11.7	-4.78
03N01W30N001H	April 2015	5941781.5	2112961.05	10.2	16.8	-6.56
03N01W30N001H	October 2015	5941781.5	2112961.05	6.4	10.6	-4.14
03N01W30N001H	March 2016	5941781.5	2112961.05	15.0	20.3	-5.26
03N01W30N001H	October 2016	5941781.5	2112961.05	6.7	11.6	-4.88
03N01W30N001H	March 2017	5941781.5	2112961.05	15.3	23.0	-7.68
03N01W30N001H	October 2017	5941781.5	2112961.05	5.7	11.2	-5.44
03N01W30N001H	March 2018	5941781.5	2112961.05	13.6	16.3	-2.68
03N01W34J001H	March 2000	5961994.29	2107979.43	25.5	24.1	1.39
03N01W34J001H	October 2000	5961994.29	2107979.43	22.0	17.4	4.56
03N01W34J001H	March 2001	5961994.29	2107979.43	23.4	21.0	2.41
03N01W34J001H	October 2001	5961994.29	2107979.43	20.7	16.9	3.83
03N01W34J001H	March 2002	5961994.29	2107979.43	24.5	22.4	2.11
03N01W34J001H	October 2002	5961994.29	2107979.43	20.8	16.5	4.32
03N01W34J001H	March 2003	5961994.29	2107979.43	25.4	23.1	2.29
03N01W34J001H	October 2003	5961994.29	2107979.43	21.7	17.2	4.44

Table 5.3

Groundwater Elevation Target Residuals
Eel River Valley Groundwater Sustainability Plan
Humboldt County Groundwater Sustainability Agency

03N01W34J001H	April 2004	5961994.29	2107979.43	24.7	22.3	**2.43**
03N01W34J001H	October 2004	5961994.29	2107979.43	21.2	17.7	**3.52**
03N01W34J001H	April 2005	5961994.29	2107979.43	25.3	22.9	**2.42**
03N01W34J001H	October 2005	5961994.29	2107979.43	21.8	17.2	**4.61**
03N01W34J001H	May 2006	5961994.29	2107979.43	26.7	24.7	**1.98**
03N01W34J001H	October 2006	5961994.29	2107979.43	22.3	17.1	**5.14**
03N01W34J001H	March 2007	5961994.29	2107979.43	24.9	22.0	**2.88**
03N01W34J001H	October 2007	5961994.29	2107979.43	22.4	17.3	**5.12**
03N01W34J001H	April 2008	5961994.29	2107979.43	24.8	21.5	**3.29**
03N01W34J001H	October 2008	5961994.29	2107979.43	21.9	16.8	**5.09**
03N01W34J001H	April 2009	5961994.29	2107979.43	24.2	21.5	**2.70**
03N01W34J001H	October 2009	5961994.29	2107979.43	21.8	17.9	**3.85**
03N01W34J001H	March 2010	5961994.29	2107979.43	23.1	23.9	-0.83
03N01W34J001H	October 2010	5961994.29	2107979.43	21.3	18.9	**2.39**
03N01W34J001H	April 2011	5961994.29	2107979.43	25.5	25.0	0.49
03N01W34J001H	April 2012	5961994.29	2107979.43	25.3	24.1	**1.19**
03N01W34J001H	October 2012	5961994.29	2107979.43	24.4	17.9	**6.48**
03N01W34J001H	March 2013	5961994.29	2107979.43	24.1	20.6	**3.52**
03N01W34J001H	April 2015	5961994.29	2107979.43	22.9	20.9	**1.98**
03N01W34J001H	October 2015	5961994.29	2107979.43	20.4	16.2	**4.23**
03N01W34J001H	March 2016	5961994.29	2107979.43	25.9	24.3	**1.59**
03N01W34J001H	October 2016	5961994.29	2107979.43	21.6	18.9	**2.62**
03N01W34J001H	March 2017	5961994.29	2107979.43	26.9	26.5	0.35
03N01W34J001H	October 2017	5961994.29	2107979.43	21.8	17.1	**4.68**
03N01W34J001H	March 2018	5961994.29	2107979.43	25.8	21.5	**4.28**
03N01W34J001H	March 2000	5961994.29	2107979.43	25.5	24.1	**1.39**
03N01W34J001H	October 2000	5961994.29	2107979.43	22.0	17.4	**4.56**
03N01W34J001H	March 2001	5961994.29	2107979.43	23.4	21.0	**2.41**
03N01W34J001H	October 2001	5961994.29	2107979.43	20.7	16.9	**3.83**
03N01W34J001H	March 2002	5961994.29	2107979.43	24.5	22.4	**2.11**
03N01W34J001H	October 2002	5961994.29	2107979.43	20.8	16.5	**4.32**
03N01W34J001H	March 2003	5961994.29	2107979.43	25.4	23.1	**2.29**
03N01W34J001H	October 2003	5961994.29	2107979.43	21.7	17.2	**4.44**
03N01W34J001H	April 2004	5961994.29	2107979.43	24.7	22.3	**2.43**
03N01W34J001H	October 2004	5961994.29	2107979.43	21.2	17.7	**3.52**
03N01W34J001H	April 2005	5961994.29	2107979.43	25.3	22.9	**2.42**
03N01W34J001H	October 2005	5961994.29	2107979.43	21.8	17.2	**4.61**
03N01W34J001H	May 2006	5961994.29	2107979.43	26.7	24.7	**1.98**
03N01W34J001H	October 2006	5961994.29	2107979.43	22.3	17.1	**5.14**
03N01W34J001H	March 2007	5961994.29	2107979.43	24.9	22.0	**2.88**
03N01W34J001H	October 2007	5961994.29	2107979.43	22.4	17.3	**5.12**
03N01W34J001H	April 2008	5961994.29	2107979.43	24.8	21.5	**3.29**
03N01W34J001H	October 2008	5961994.29	2107979.43	21.9	16.8	**5.09**
03N01W34J001H	April 2009	5961994.29	2107979.43	24.2	21.5	**2.70**
03N01W34J001H	October 2009	5961994.29	2107979.43	21.8	17.9	**3.85**
03N01W34J001H	March 2010	5961994.29	2107979.43	23.1	23.9	-0.83
03N01W34J001H	October 2010	5961994.29	2107979.43	21.3	18.9	**2.39**
03N01W34J001H	April 2011	5961994.29	2107979.43	25.5	25.0	0.49
03N01W34J001H	April 2012	5961994.29	2107979.43	25.3	24.1	**1.19**
03N01W34J001H	October 2012	5961994.29	2107979.43	24.4	17.9	**6.48**

Table 5.3

Groundwater Elevation Target Residuals
Eel River Valley Groundwater Sustainability Plan
Humboldt County Groundwater Sustainability Agency

03N01W34J001H	March 2013	5961994.29	2107979.43	24.1	20.6	**3.52**
03N01W34J001H	April 2015	5961994.29	2107979.43	22.9	20.9	**1.98**
03N01W34J001H	October 2015	5961994.29	2107979.43	20.4	16.2	**4.23**
03N01W34J001H	March 2016	5961994.29	2107979.43	25.9	24.3	**1.59**
03N01W34J001H	October 2016	5961994.29	2107979.43	21.6	18.9	**2.62**
03N01W34J001H	March 2017	5961994.29	2107979.43	26.9	26.5	0.35
03N01W34J001H	October 2017	5961994.29	2107979.43	21.8	17.1	**4.68**
03N01W34J001H	March 2018	5961994.29	2107979.43	25.8	21.5	**4.28**
03N02W13J001H	March 2000	5939864.86	2124889.71	9.0	17.4	**-8.40**
03N02W13J001H	March 2001	5939864.86	2124889.71	5.3	12.6	**-7.30**
03N02W13J001H	October 2001	5939864.86	2124889.71	3.0	8.2	**-5.21**
03N02W13J001H	March 2002	5939864.86	2124889.71	7.6	14.0	**-6.43**
03N02W13J001H	October 2002	5939864.86	2124889.71	6.1	8.4	**-2.31**
03N02W13J001H	March 2003	5939864.86	2124889.71	8.7	14.3	**-5.61**
03N02W13J001H	October 2003	5939864.86	2124889.71	4.9	9.5	**-4.62**
03N02W13J001H	April 2004	5939864.86	2124889.71	6.8	15.0	**-8.28**
03N02W13J001H	April 2005	5939864.86	2124889.71	10.9	13.9	**-3.01**
03N02W13J001H	October 2005	5939864.86	2124889.71	4.8	9.7	**-4.90**
03N02W13J001H	May 2006	5939864.86	2124889.71	7.7	18.0	**-10.33**
03N02W13J001H	October 2006	5939864.86	2124889.71	4.6	9.9	**-5.34**
03N02W13J001H	March 2007	5939864.86	2124889.71	6.9	14.4	**-7.57**
03N02W13J001H	October 2007	5939864.86	2124889.71	4.9	8.8	**-3.93**
03N02W13J001H	April 2008	5939864.86	2124889.71	6.2	13.5	**-7.29**
03N02W13J001H	October 2008	5939864.86	2124889.71	4.5	8.0	**-3.54**
03N02W13J001H	April 2009	5939864.86	2124889.71	6.5	11.9	**-5.48**
03N02W13J001H	October 2009	5939864.86	2124889.71	4.8	8.2	**-3.43**
03N02W13J001H	March 2010	5939864.86	2124889.71	7.1	13.4	**-6.38**
03N02W13J001H	October 2010	5939864.86	2124889.71	5.5	9.4	**-3.96**
03N02W13J001H	October 2011	5939864.86	2124889.71	5.4	9.3	**-3.98**
03N02W13J001H	April 2012	5939864.86	2124889.71	9.0	15.1	**-6.15**
03N02W13J001H	October 2012	5939864.86	2124889.71	4.8	9.1	**-4.34**
03N02W13J001H	March 2013	5939864.86	2124889.71	6.3	12.7	**-6.44**
03N02W13J001H	October 2013	5939864.86	2124889.71	4.7	8.5	**-3.83**
03N02W13J001H	October 2014	5939864.86	2124889.71	6.5	7.6	**-1.10**
03N02W13J001H	April 2015	5939864.86	2124889.71	6.1	11.4	**-5.38**
03N02W13J002H	March 2016	5939864.86	2124889.71	8.6	14.3	**-5.67**
03N02W35M002H	March 2000	5931404.93	2109073.48	16.0	17.3	**-1.29**
03N02W35M002H	October 2000	5931404.93	2109073.48	8.6	12.7	**-4.08**
03N02W35M002H	March 2001	5931404.93	2109073.48	13.3	14.9	**-1.58**
03N02W35M002H	October 2001	5931404.93	2109073.48	8.6	11.2	**-2.60**
03N02W35M002H	March 2002	5931404.93	2109073.48	14.9	16.0	**-1.14**
03N02W35M002H	October 2002	5931404.93	2109073.48	8.6	10.5	**-1.86**
03N02W35M002H	March 2003	5931404.93	2109073.48	15.7	17.1	**-1.45**
03N02W35M002H	October 2003	5931404.93	2109073.48	9.5	12.0	**-2.46**
03N02W35M002H	April 2004	5931404.93	2109073.48	14.4	15.5	**-1.09**
03N02W35M002H	October 2004	5931404.93	2109073.48	8.5	13.4	**-4.90**
03N02W35M002H	April 2005	5931404.93	2109073.48	17.0	17.7	-0.69
03N02W35M002H	October 2005	5931404.93	2109073.48	9.1	12.2	**-3.10**
03N02W35M002H	May 2006	5931404.93	2109073.48	14.5	18.1	**-3.56**
03N02W35M002H	October 2006	5931404.93	2109073.48	8.9	10.9	**-2.00**

Table 5.3

Groundwater Elevation Target Residuals
Eel River Valley Groundwater Sustainability Plan
Humboldt County Groundwater Sustainability Agency

03N02W35M002H	March 2007	5931404.93	2109073.48	14.8	16.0	**-1.19**
03N02W35M002H	October 2007	5931404.93	2109073.48	9.0	12.6	**-3.61**
03N02W35M002H	April 2008	5931404.93	2109073.48	13.8	14.7	-0.86
03N02W35M002H	October 2008	5931404.93	2109073.48	8.6	12.2	**-3.61**
03N02W35M002H	April 2009	5931404.93	2109073.48	14.1	14.7	-0.63
03N02W35M002H	October 2009	5931404.93	2109073.48	9.0	11.3	**-2.34**
03N02W35M002H	March 2010	5931404.93	2109073.48	15.1	17.0	**-1.89**
03N02W35M002H	October 2010	5931404.93	2109073.48	10.0	14.8	**-4.82**
03N02W35M002H	April 2011	5931404.93	2109073.48	16.1	17.0	-0.94
03N02W35M002H	October 2011	5931404.93	2109073.48	9.7	13.8	**-4.08**
03N02W35M002H	April 2012	5931404.93	2109073.48	16.3	17.7	**-1.35**
03N02W35M002H	October 2012	5931404.93	2109073.48	9.6	14.7	**-5.12**
03N02W35M002H	March 2013	5931404.93	2109073.48	13.9	15.5	**-1.63**
03N02W35M002H	October 2013	5931404.93	2109073.48	8.9	11.8	**-2.95**
03N02W35M002H	March 2014	5931404.93	2109073.48	12.2	15.6	**-3.36**
03N02W35M002H	October 2014	5931404.93	2109073.48	8.9	14.9	**-6.02**
03N02W35M002H	April 2015	5931404.93	2109073.48	13.5	15.2	**-1.68**
03N02W35M002H	October 2015	5931404.93	2109073.48	9.0	11.9	**-2.92**
03N02W35M002H	March 2016	5931404.93	2109073.48	15.8	19.1	**-3.30**
03N02W35M002H	October 2016	5931404.93	2109073.48	9.0	16.0	**-6.98**
03N02W35M002H	October 2017	5931404.93	2109073.48	9.1	11.9	**-2.78**
03N02W35M002H	March 2018	5931404.93	2109073.48	15.8	17.7	**-1.89**
1	March 2017	5925192.3	2105190.27	15.0	21.6	**-6.63**
10	October 2016	5939340.48	2115246.29	5.9	11.5	**-5.68**
10	March 2017	5939340.48	2115246.29	10.1	18.6	**-8.50**
11	March 2017	5937561.37	2110846.1	15.2	22.8	**-7.63**
11	October 2016	5937561.37	2110846.1	6.7	15.4	**-8.75**
12	March 2017	5938041.82	2107918.5	18.2	23.1	**-4.92**
12	October 2016	5938041.82	2107918.5	8.0	22.0	**-14.02**
13	October 2016	5945462.31	2104777.71	-1.5	25.4	**-26.92**
13	March 2017	5945462.31	2104777.71	12.4	24.6	**-12.28**
14	October 2016	5949643.34	2105328.09	13.9	18.9	**-4.98**
14	March 2017	5949643.34	2105328.09	25.9	26.5	-0.63
15	October 2016	5953587.51	2107524.92	12.0	15.8	**-3.81**
15	March 2017	5953587.51	2107524.92	21.0	27.1	**-6.15**
16	October 2016	5949706.67	2096799.47	14.2	22.7	**-8.48**
16	March 2017	5949706.67	2096799.47	31.3	32.1	-0.80
17	October 2016	5953392.69	2099731.59	15.1	21.8	**-6.77**
17	March 2017	5953392.69	2099731.59	27.7	30.3	**-2.60**
18	March 2017	5946760.3	2101173.7	25.8	29.8	**-3.97**
18	October 2016	5946760.3	2101173.7	10.9	21.3	**-10.35**
19	March 2017	5956006.5	2093107.18	30.6	36.1	**-5.49**
19	October 2016	5956006.5	2093107.18	18.7	23.3	**-4.60**
2	October 2016	5928336.31	2108570.13	8.0	15.0	**-7.00**
20	March 2017	5960894.01	2088431.08	34.6	37.0	**-2.41**
20	October 2016	5960894.01	2088431.08	28.0	31.5	**-3.47**
21	March 2017	5963173.34	2079374.34	44.8	61.8	**-17.07**
21	October 2016	5963173.34	2079374.34	34.9	44.4	**-9.47**
22	March 2017	5967573.31	2088740.88	49.5	58.2	**-8.73**
22	October 2016	5967573.31	2088740.88	43.5	44.3	-0.81

Table 5.3

Groundwater Elevation Target Residuals
Eel River Valley Groundwater Sustainability Plan
Humboldt County Groundwater Sustainability Agency

24	October 2016	5942291	2122058.27	6.2	9.8	**-3.57**
25	March 2017	5944003.75	2123909.61	18.1	19.5	**-1.42**
25	October 2016	5944003.75	2123909.61	13.6	11.1	**2.55**
26	October 2016	5935928.86	2133736.59	5.4	6.0	-0.60
28	October 2016	5953849.84	2095784.63	15.1	22.6	**-7.47**
3	October 2016	5928639.5	2109546.14	5.8	18.1	**-12.31**
3	March 2017	5928639.5	2109546.14	10.5	16.1	**-5.59**
4	March 2017	5930311.6	2109757.77	11.0	19.3	**-8.35**
4	October 2016	5930311.6	2109757.77	5.3	14.4	**-9.17**
403358124063701	July 2010	5975453.72	2096611	223.4	223.5	-0.03
403358124063701	July 2011	5975453.72	2096611	225.9	223.0	**2.85**
403421124155801	July 2011	5932213.13	2100049.6	72.8	33.9	**38.97**
403544124131501	July 2010	5944976.09	2108124.34	12.4	19.1	**-6.70**
403544124131501	July 2011	5944976.09	2108124.34	12.3	18.1	**-5.86**
403544124131501	May 2012	5944976.09	2108124.34	16.9	21.4	**-4.59**
403544124131501	May 2014	5944976.09	2108124.34	12.2	18.1	**-5.82**
403544124131501	June 2016	5944976.09	2108124.34	11.2	20.3	**-9.10**
403825124123301	August 2009	5948360.06	2124210.69	66.2	37.9	**28.25**
403825124123301	July 2010	5948360.06	2124210.69	69.1	36.9	**32.10**
403825124123301	July 2011	5948360.06	2124210.69	69.3	36.8	**32.48**
403825124123301	May 2012	5948360.06	2124210.69	69.2	36.5	**32.66**
403825124123301	May 2014	5948360.06	2124210.69	68.2	33.0	**35.17**
403825124123301	June 2016	5948360.06	2124210.69	68.6	31.7	**36.90**
5	March 2017	5929435.33	2108104.25	11.0	19.5	**-8.54**
5	October 2016	5929435.33	2108104.25	5.3	15.7	**-10.31**
6	October 2016	5933415.77	2111645.21	7.3	11.7	**-4.39**
6	March 2017	5933415.77	2111645.21	14.3	21.6	**-7.26**
7	March 2017	5933173.03	2112999.8	14.2	21.0	**-6.87**
7	October 2016	5933173.03	2112999.8	7.8	10.6	**-2.73**
8	October 2016	5932949.16	2115082.73	6.3	11.0	**-4.73**
8	March 2017	5932949.16	2115082.73	11.2	18.9	**-7.64**
A	November 2016	5989975.93	2083904.69	111.4	117.3	**-5.87**
Add-29	November 2016	5929452.23	2119437.02	7.0	10.5	**-3.47**
Add-29	March 2017	5929452.23	2119437.02	15.8	14.8	0.98
B	November 2016	5975815	2084678.58	70.0	74.3	**-4.31**
B	March 2017	5975815	2084678.58	72.6	97.6	**-25.01**
C-23	October 2016	5974763.25	2087181.78	63.1	67.8	**-4.71**
C-23	March 2017	5974763.25	2087181.78	69.5	82.6	**-13.12**
D	March 2017	5958167.25	2090575.59	30.4	39.5	**-9.03**
D	November 2016	5958167.25	2090575.59	21.4	27.2	**-5.81**
1	March 2017	5965284.44	2098690.21	15.0	36.6	**-21.58**

Table 6.1

Chronic Lowering Of Groundwater Levels Observation Locations
Eel River Valley Groundwater Sustainability Plan
Humboldt County Groundwater Sustainability Agency

Well Identification	State Plane Coordinate *X*	State Plane Coordinate *Y*	*Figure 6.1 Well Identification Key*
1	5,925,179	2,105,211	1
2	5,928,233	2,108,573	2
3	5,928,671	2,109,526	3
4	5,930,188	2,109,772	4
5	5,929,388	2,108,100	5
6	5,933,532	2,111,625	6
7	5,933,042	2,112,987	7
8	5,933,084	2,115,062	8
9	5,936,944	2,114,201	9
10	5,939,245	2,115,102	10
11	5,937,615	2,110,826	11
12	5,938,024	2,107,938	12
13	5,945,465	2,103,695	13
14	5,949,737	2,105,319	14
15	5,953,502	2,107,539	15
16	5,949,617	2,096,793	16
17	5,953,357	2,099,748	17
18	5,946,766	2,101,173	18
19	5,956,028	2,093,117	19
20	5,960,982	2,088,419	20
21	5,963,120	2,079,385	21
22	5,967,621	2,088,700	22
24	5,942,199	2,122,053	23
25	5,943,912	2,123,923	24
26	5,935,824	2,133,750	25
28	5,953,953	2,095,865	26
29	5,929,391	2,119,453	27
30	5,954,146	2,105,309	28
31	5,952,765	2,103,974	29
33	5,955,405	2,101,065	30
34	5,930,671	2,125,754	31
36	5,962,625	2,083,216	32
38	5,960,865	2,095,371	33
39	5,959,889	2,096,744	34
41	5,948,530	2,108,381	35
42	5,946,815	2,108,578	36
43	5,948,437	2,109,406	37
44	5,950,157	2,111,234	38
45	5,965,847	2,088,717	39
46	5,963,971	2,094,227	40
47	5,938,833	2,102,698	41
48	5,937,228	2,103,521	42
51	5,927,602	2,113,776	43
52	5,918,119	2,104,150	44
53	5,916,152	2,110,076	45
54	5,941,575	2,109,413	46

Table 6.1

Chronic Lowering Of Groundwater Levels Observation Locations
Eel River Valley Groundwater Sustainability Plan
Humboldt County Groundwater Sustainability Agency

Well Identification	State Plane Coordinate *X*	*Y*	*Figure 6.1 Well Identification Key*
57	5,941,620	2,111,242	47
58	5,938,968	2,111,463	48
59	5,937,635	2,114,203	49
17A	5,952,066	2,100,930	50
41A	5,948,543	2,108,373	51
A	5,990,094	2,083,900	52
Bear River #1 (090605125)	5,948,992	2,119,691	53
Bear River #2 (090605119)	5,949,076	2,120,284	54
C-23	5,974,643	2,087,094	55
City of Fortuna Well 1	5,965,276	2,098,658	56
City of Fortuna Well 2	5,965,382	2,098,532	57
City of Fortuna Well 4	5,965,219	2,098,497	58
City of Fortuna Well 5	5,965,320	2,098,430	59
D	5,958,128	2,090,556	60
Del Oro Water Company	5,936,336	2,105,436	61
E	5,951,966	2,096,882	62
E2	5,951,909	2,095,750	63
FDMW 1	5,958,170	2,102,173	64
FDMW 2	5,958,425	2,102,498	65
FDMW 3	5,958,821	2,102,772	66
FDMW 4	5,959,242	2,103,000	67
FDMW 5	5,957,664	2,103,316	68
FDMW 6	5,959,549	2,101,652	69
FDMW 7	5,959,229	2,102,487	70
G	5,927,313	2,104,581	71
H	5,925,780	2,108,790	72
Hydesville CSD Well# 1	5,986,540	2,087,841	73
Hydesville CSD Well# 2	5,986,740	2,087,834	74
I	5,914,495	2,104,720	75
J	5,945,746	2,111,413	76
L	5,931,705	2,114,523	77
M	5,940,076	2,123,568	78
M2	5,940,076	2,123,555	79
MW-10	5,988,306	2,091,199	80
MW-11	5,994,302	2,084,729	81
MW-1s	5,994,302	2,084,729	82
MW-1d	5,949,527	2,113,094	83
MW-2s	5,961,651	2,096,148	84
MW-2d	5,961,651	2,096,148	85
MW-3s	5,960,531	2,089,098	86
MW-3d	5,960,531	2,089,098	87
MW-5s	5,930,282	2,112,001	88
MW-5d	5,930,282	2,112,001	89
MW-7s	5,927,441	2,105,966	90
MW-7d	5,927,441	2,105,966	91
MW-9s	5,976,155	2,084,927	92

Table 6.1

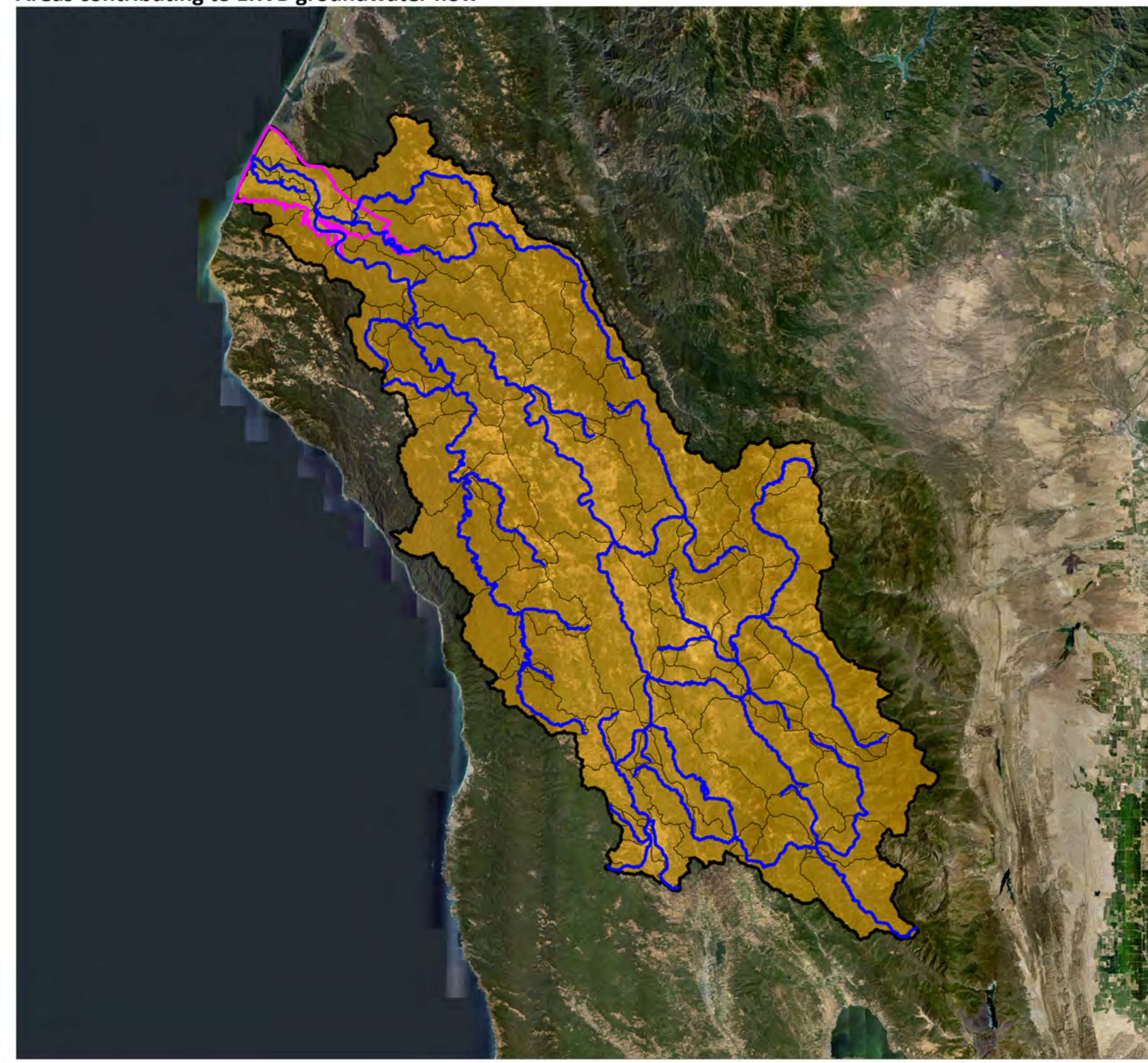
Chronic Lowering Of Groundwater Levels Observation Locations
Eel River Valley Groundwater Sustainability Plan
Humboldt County Groundwater Sustainability Agency

Well Identification	State Plane Coordinate X	State Plane Coordinate Y	*Figure 6.1 Well Identification Key*
MW-9d	5,976,155	2,084,927	93
N	5,941,130	2,128,132	94
Palmer Creek #2	5,956,872	2,110,870	95
Q	5,928,407	2,115,070	96
R	5,937,514	2,124,093	97
R_Shop	5,937,505	2,124,090	98
Rio Dell Infiltration MW 1	5,969,841	2,077,383	99
Rio Dell Infiltration MW 2	5,970,353	2,077,210	100
Rio Dell Infiltration MW 3	5,970,500	2,076,578	101
Rio Dell Well 1	5,971,279	2,077,481	102
Rio Dell Well 3	5,971,281	2,077,390	103
CASGEM 23182	5,939,844	2,125,324	104
CASGEM 36943	5,932,994	2,104,855	105
CASGEM 23178	5,949,889	2,100,880	106
CASGEM 36942	5,954,097	2,098,577	107
CASGEM 23181	5,941,647	2,112,944	108
CASGEM 23183	5,931,514	2,109,076	109
CASGEM 36944	5,961,956	2,107,949	110
CASGEM 23179	5,960,020	2,094,011	111
CASGEM 23180	5,943,401	2,127,535	112
City of Fortuna Well 3	5,965,286	2,098,418	113
Palmer Creek CSD 1	5,956,818	2,110,894	114
MW-16	5,989,635	2,084,565	115
MW-17	5,979,383	2,084,217	116
MW-12s	5,974,842	2,087,034	117
MW-12d	5,974,842	2,087,034	118
MW-13s	5,964,857	2,090,812	119
MW-13d	5,964,857	2,090,812	120
MW-19	5,960,436	2,090,990	121
MW-21	5,963,287	2,094,917	122
MW-22	5,965,194	2,097,679	123
MW-20	5,956,832	2,095,889	124
MW-30	5,952,137	2,097,299	125
MW-22	5,965,194	2,097,679	126
MW-24	5,963,845	2,100,901	127
MW-23	5,960,172	2,108,790	128
MW-25	5,953,830	2,106,090	129
MW-28	5,932,206	2,107,960	130
MW-14s	5,939,094	2,112,139	131
MW-14d	5,939,094	2,112,139	132
MW-26	5,941,585	2,125,434	133
MW-27	5,934,787	2,125,601	134
MW-15s	5,947,471	2,109,285	135
MW-15d	5,947,471	2,109,285	136

Figures

Eel River Valley Basin (ERVB) (Groundwater Basin 1-010 Eel River Valley)

Areas contributing to ERVB groundwater flow



Legend

- Hydrologic Response Unit (HRU) contributing flow to Eel River Valley Basin (ERVB) (Groundwater Basin 1-010 Eel River Valley)
- River network contributing flow to ERVB
- ERVB

N

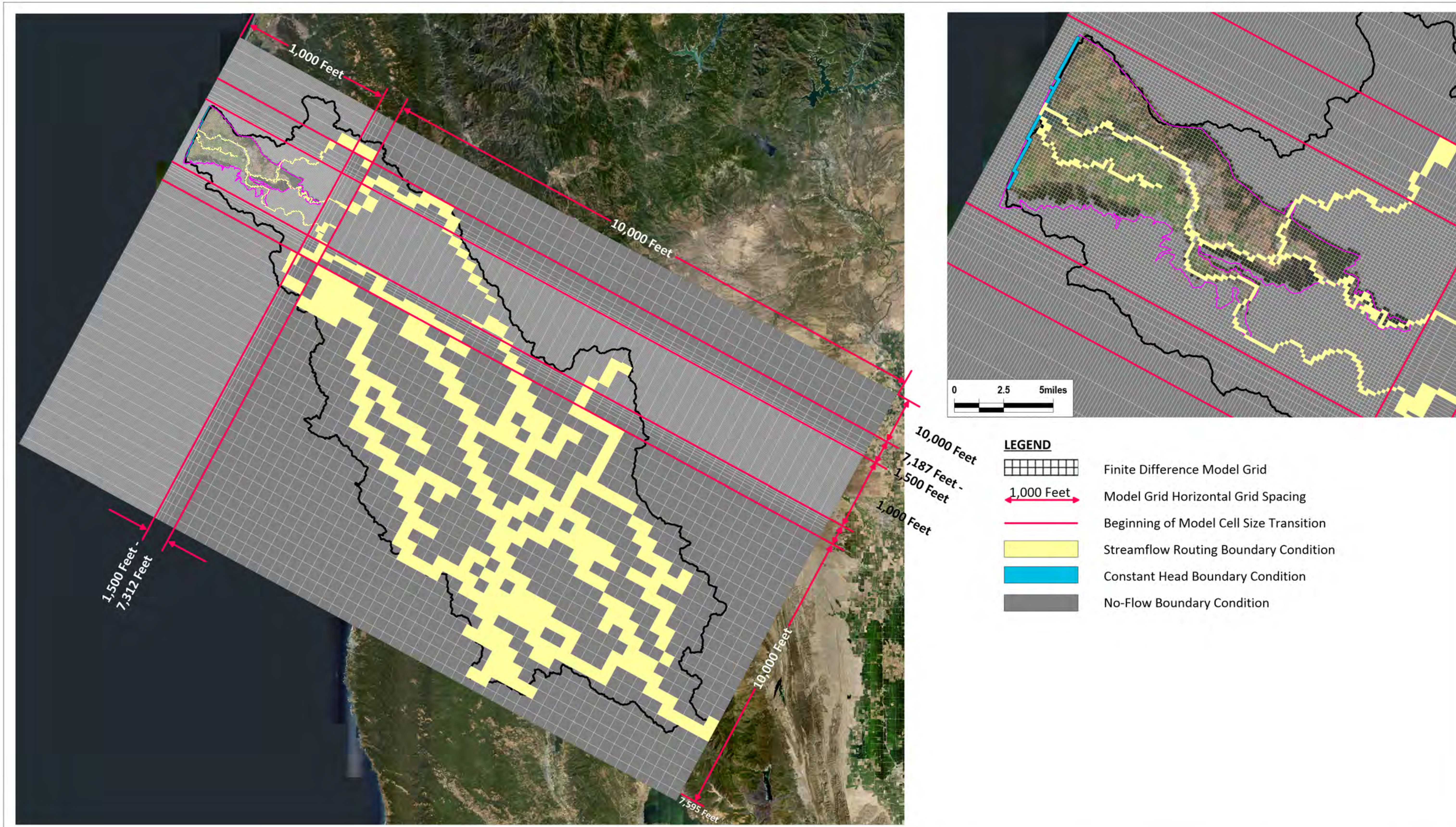
HUMBOLDT COUNTY GROUNDWATER SUSTAINABILITY AGENCY
EEL RIVER VALLEY GROUNDWATER SUSTAINABILITY PLAN

ERVB LOCATION AND HRU AREAS CONTRIBUTING TO GROUNDWATER FLOW

Project No. 11217388
Date November 2021

FIGURE 1.1

Filename:\\ghdnet\ghd\US\Eureka\Projects\561\11217388\Tech\Model Predictions\Figures\FigureFiles\Figure 1.1 ERVB.srf
Plot Date: November 19 2021 8:11 AM



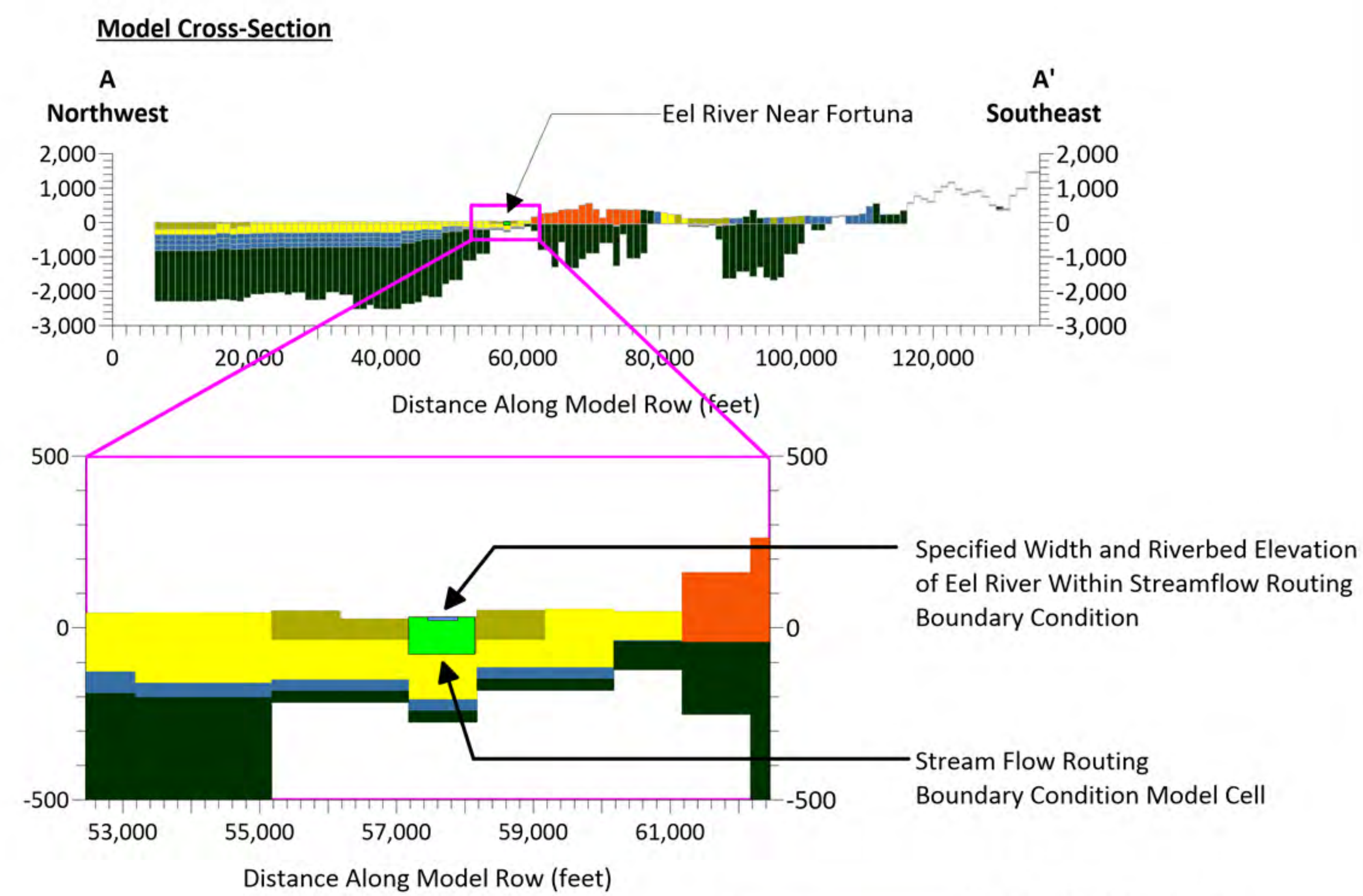
HUMBOLDT COUNTY GROUNDWATER SUSTAINABILITY AGENCY
EEL RIVER VALLEY GROUNDWATER SUSTAINABILITY PLAN

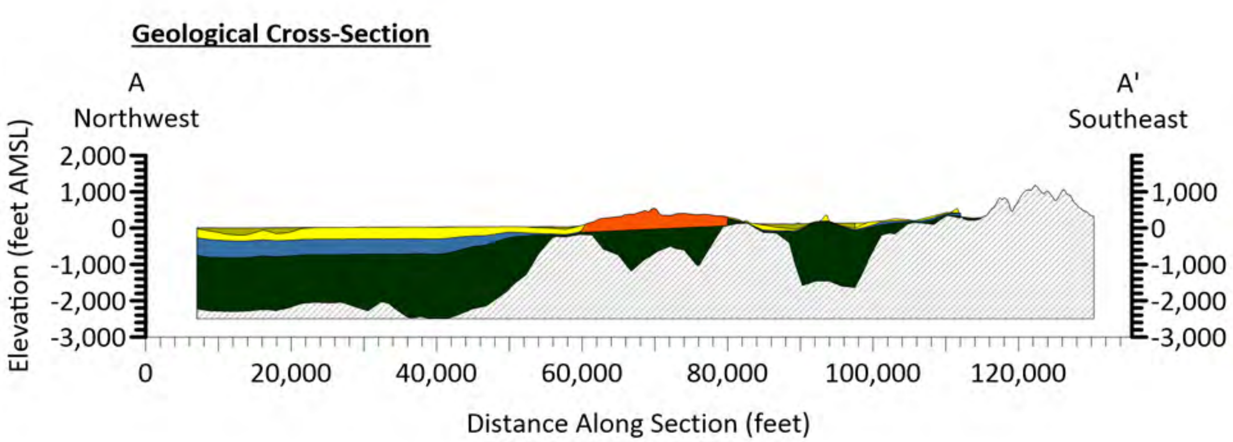
FINITE DIFFERENCE GRID AND BOUNDARY CONDITIONS

Project No. 11217388
Date October 2021

FIGURE 4.1

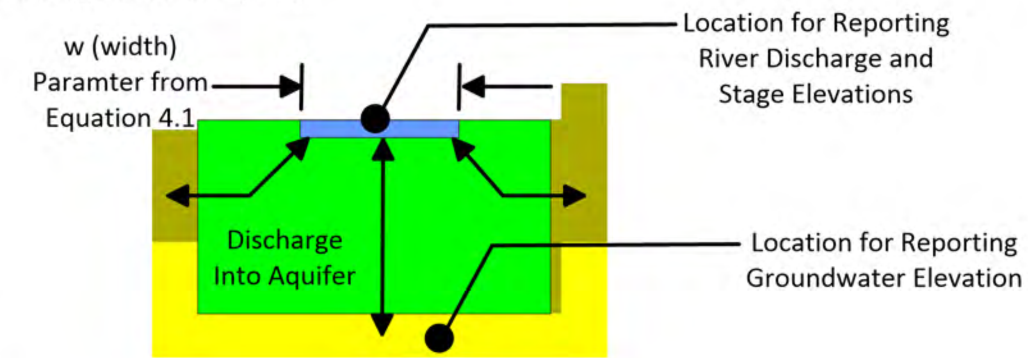
Filename:\\ghdnet\ghd\US\Eureka\Projects\561\11217388\Tech\Model Predictions\Figures\FigureFiles\Figure 4.1 Finite Difference Grid and Boundary Conditions.srf
Plot Date: October 29 2021 12:10 PM





Stratigraphy

- Channel Deposits
- Qal - Alluvium
- Qh - Hookton Formation
- Qtc - Carlotta Formation (upper)
- Qtc - Carlotta Formation (lower)
- Boundary representing base of Carlotta Formation and base of ERVB



0 2 4miles

N

GHD

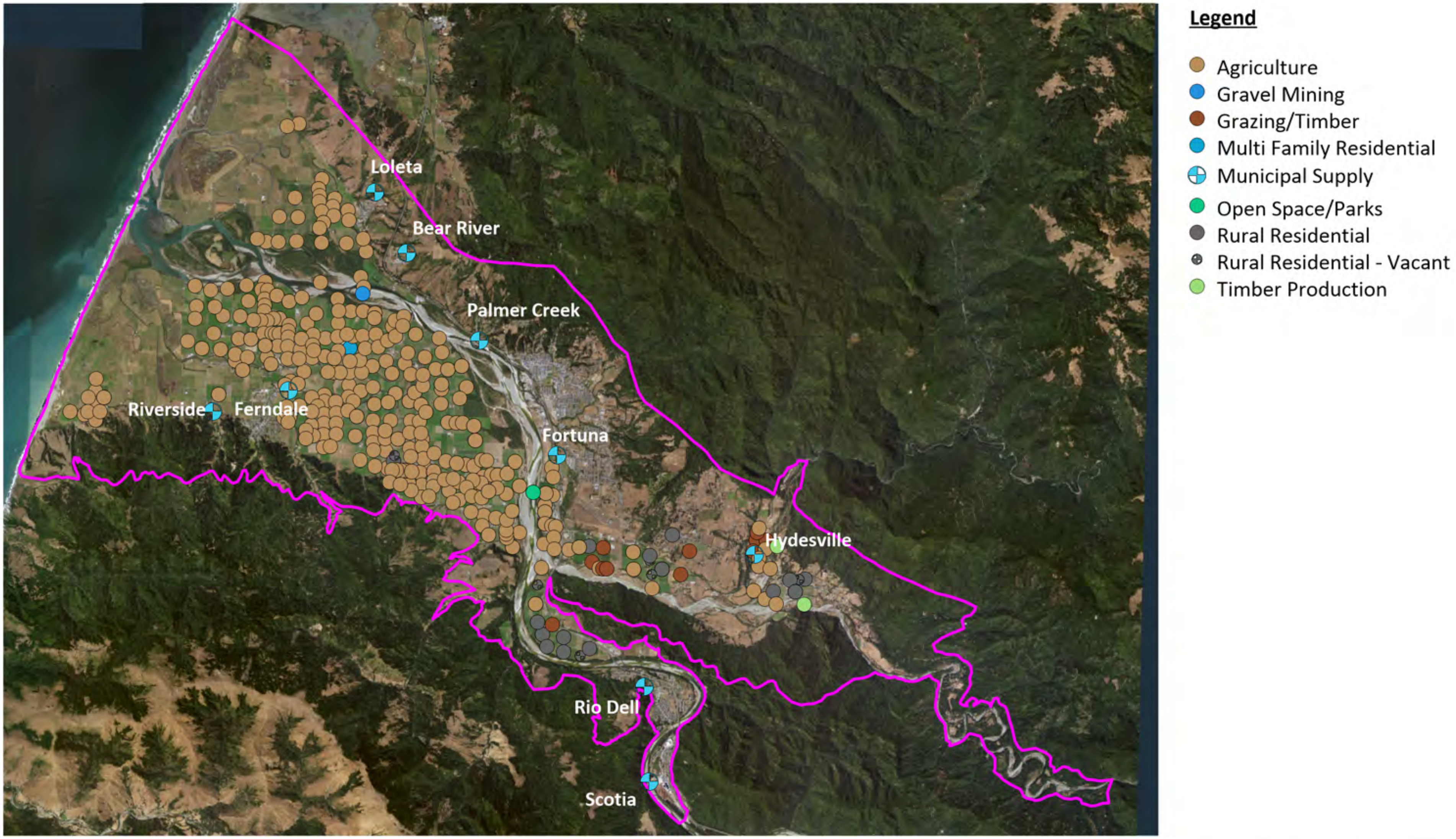
HUMBOLDT COUNTY GROUNDWATER SUSTAINABILITY AGENCY
EEL RIVER VALLEY GROUNDWATER SUSTAINABILITY PLAN

MODEL VERTICAL DISCRETIZATION AND STREAMFLOW BOUNDARY

Project No. 11182028
Date November 2021

FIGURE 4.2

Filename:\\ghdnet\ghd\US\Eureka\Projects\561\11217388\Tech\Model Predictions\Figures\FigureFiles\Figure 4.2 Cross-Section AAprime and BCs.srf
Plot Date: November 16 2021 6:11 PM



GHD

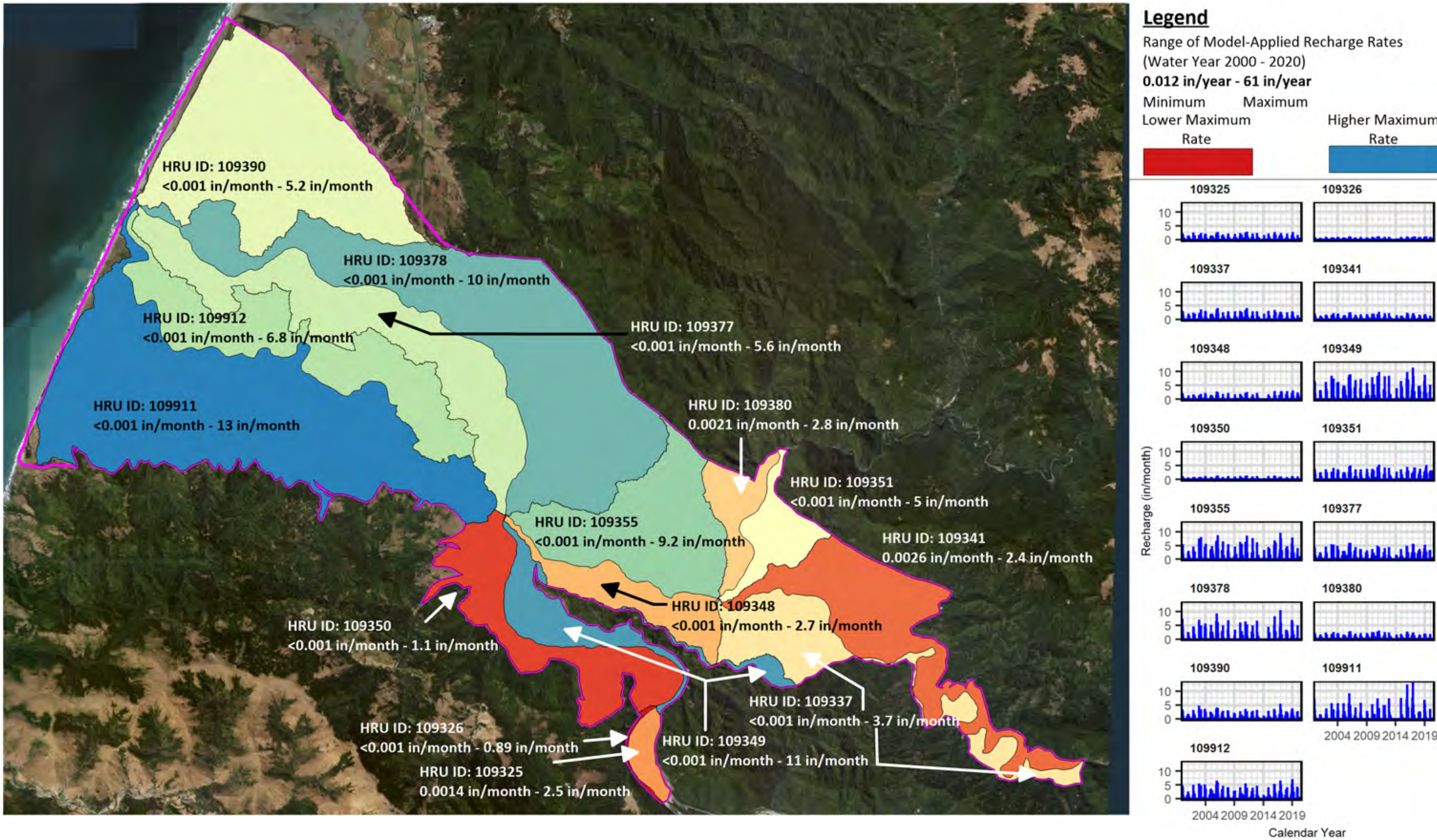
HUMBOLDT COUNTY GROUNDWATER SUSTAINABILITY AGENCY
EEL RIVER VALLEY GROUNDWATER SUSTAINABILITY PLAN

ERVB GROUNDWATER EXTRACTION WELL LOCATIONS

Project No. 11217388
Date November 2021

FIGURE 4.3

Filename:\\ghdnet\ghd\US\Eureka\Projects\561\11217388\Tech\Model Predictions\Figures\FigureFiles\Figure 4.3 WellLocations.srf
Plot Date: November 06 2021 4:11 PM



HUMBOLDT COUNTY GROUNDWATER SUSTAINABILITY AGENCY
EEL RIVER VALLEY GROUNDWATER SUSTAINABILITY PLAN

ERVB GROUNDWATER RECHARGE ZONES AND RATES

Project No. 11217388
Date November 2021

FIGURE 4.4

Filename:\\ghdnet\ghd\US\Eureka\Projects\561\11217388\Tech\Model Predictions\Figures\FigureFiles\Figure 4.4 Recharge Zones.srf
Plot Date: November 02 2021 1:11 PM

Legend

100 mg/L Chloride Isoconcentration Contour Based on Johnson (1975)

0 0.5 1mile

N

GHD

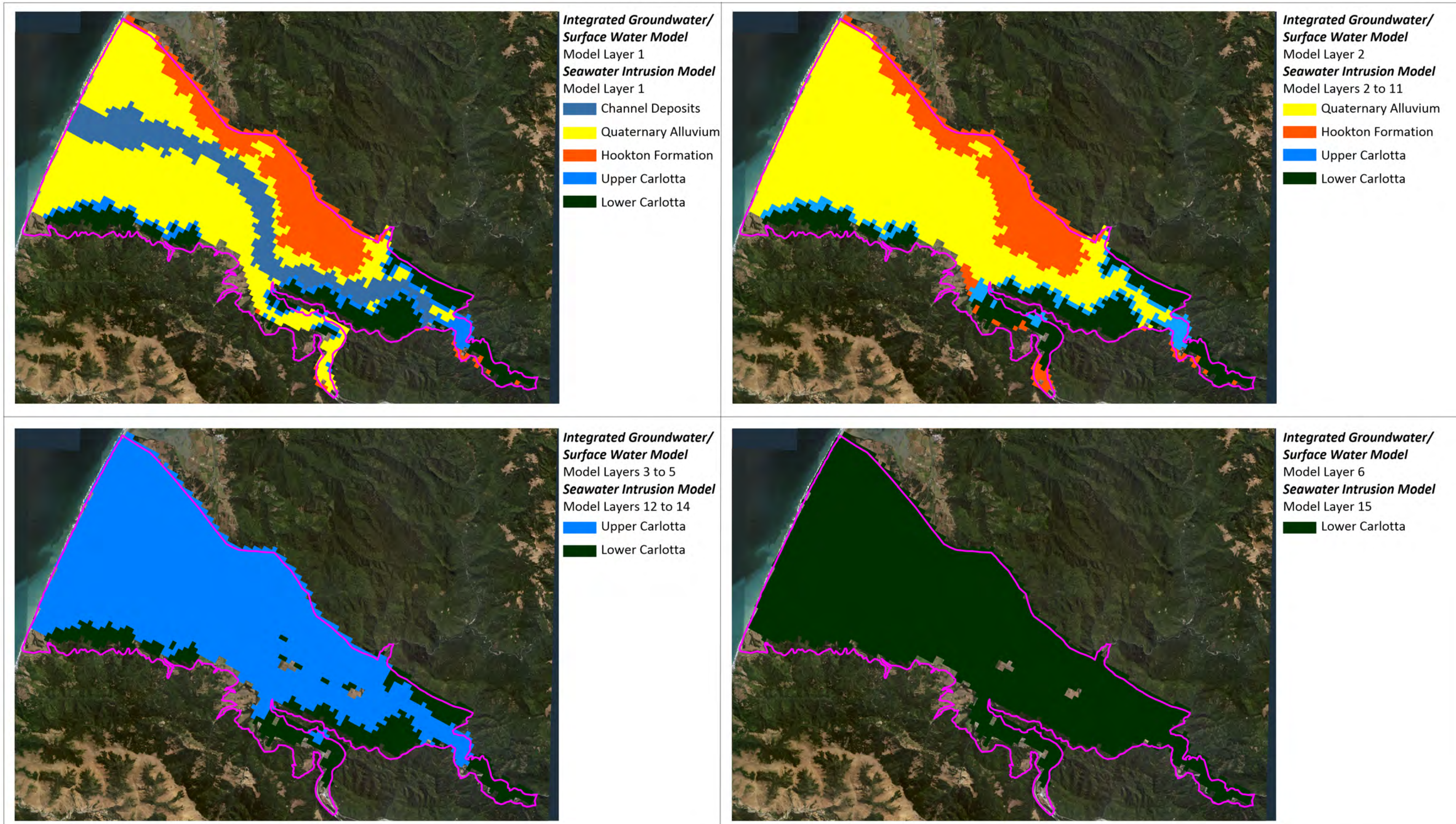
HUMBOLDT COUNTY GROUNDWATER SUSTAINABILITY AGENCY
EEL RIVER VALLEY GROUNDWATER SUSTAINABILITY PLAN

SEAWATER INTRUSION 100 mg/L ISOCONCENTRATION CONTOUR

Project No. 11217388
Date November 2021

FIGURE 4.5

Filename:\\ghdnet\ghd\US\Eureka\Projects\561\11217388\Tech\Model Predictions\Figures\FigureFiles\Figure 4.5 SeawaterIntrusion.srf
Plot Date: November 06 2021 3:11 PM



0 2 4miles

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GHD

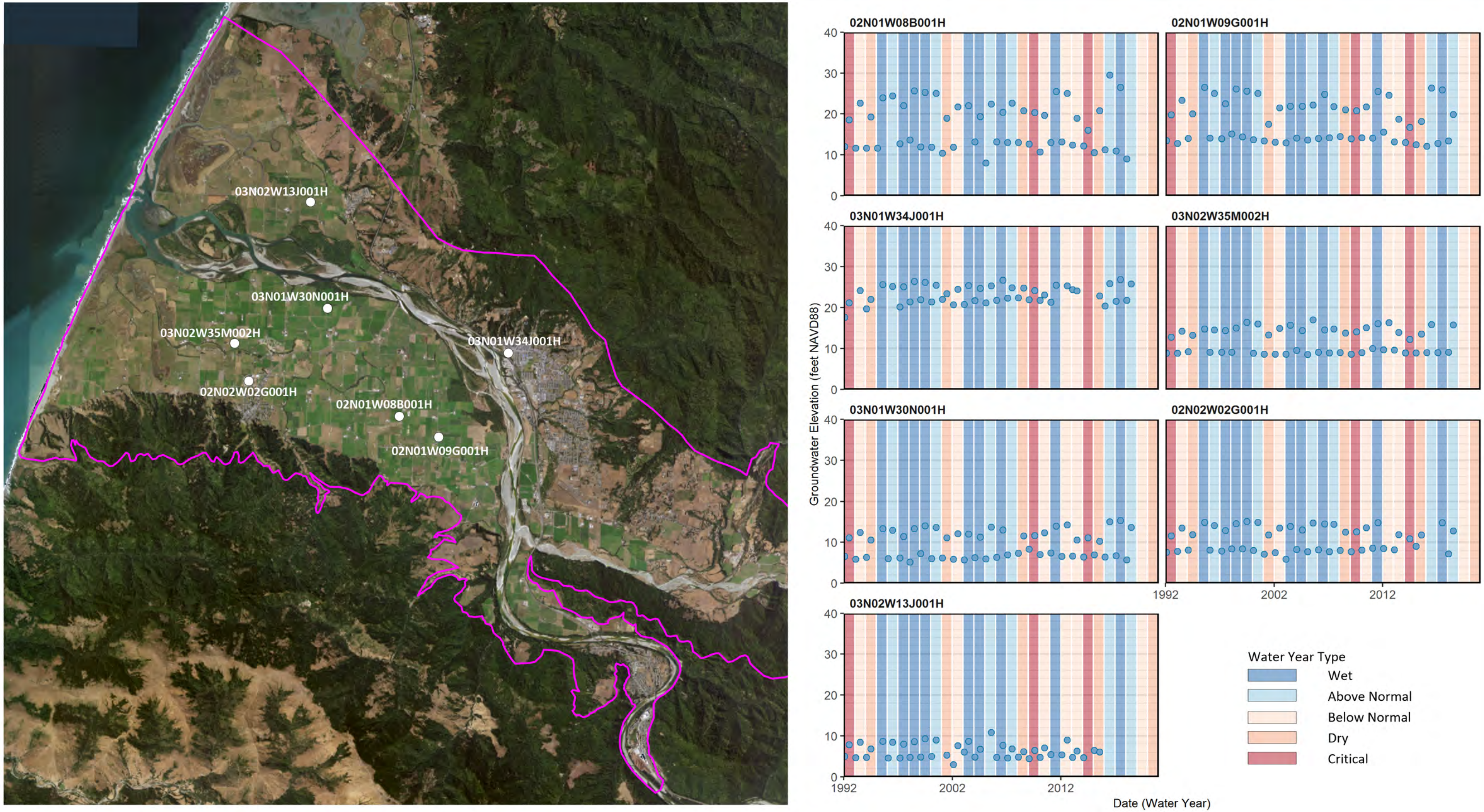
HUMBOLDT COUNTY GROUNDWATER SUSTAINABILITY AGENCY
EEL RIVER VALLEY GROUNDWATER SUSTAINABILITY PLAN

DISTRIBUTION OF MODEL-ASSIGNED HYDRAULIC CONDUCTIVITY ZONES

Project No. **11217388**
Date **November 2021**

FIGURE 4.6

Filename:\\ghdnet\ghd\US\Eureka\Projects\561\11217388\Tech\Model Predictions\Figures\FigureFiles\Figure 4.6 K Zones.srf
Plot Date: November 06 2021 4:11 PM



0 1 2miles

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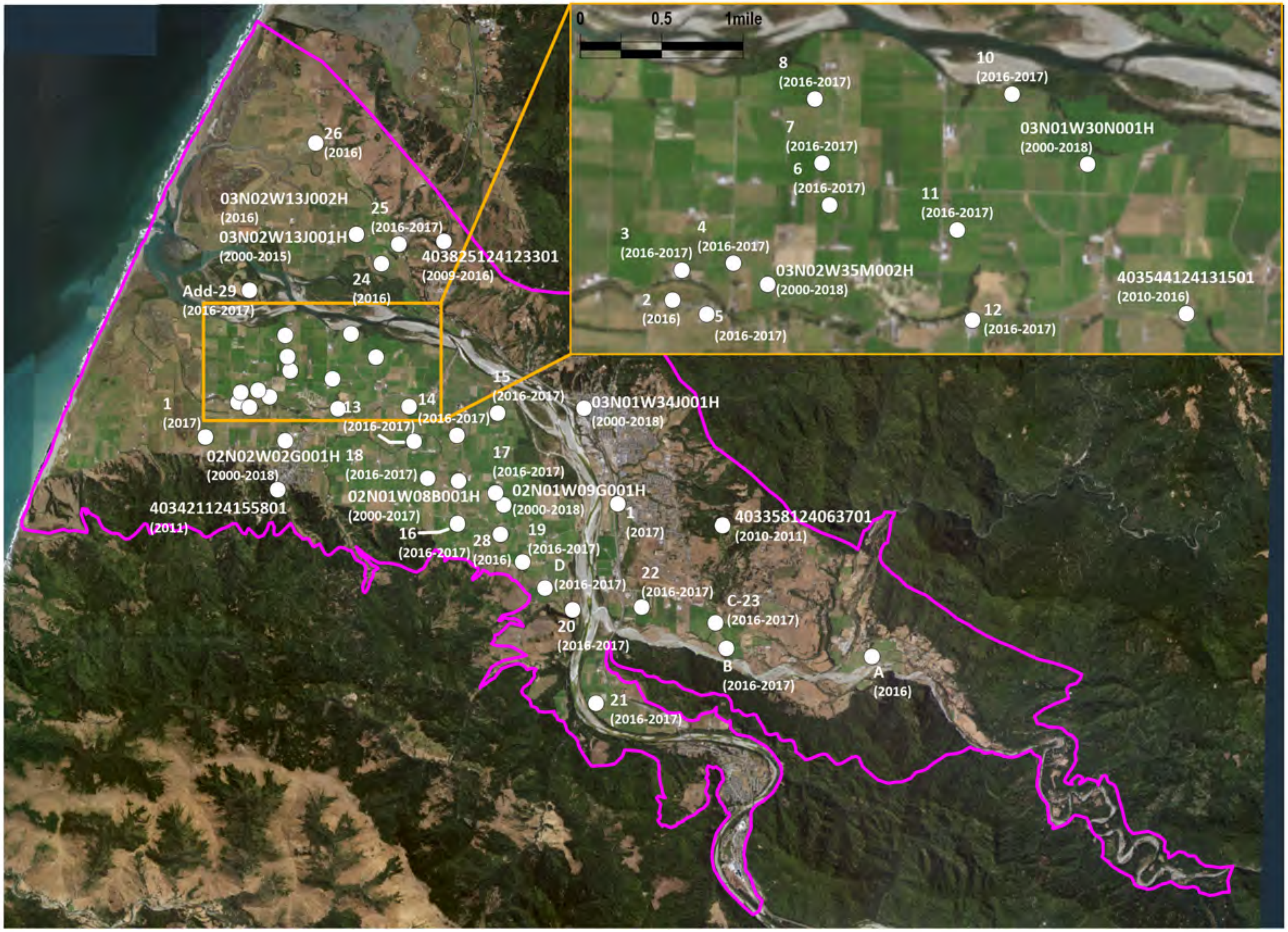
HUMBOLDT COUNTY GROUNDWATER SUSTAINABILITY AGENCY
EEL RIVER VALLEY GROUNDWATER SUSTAINABILITY PLAN

LONGTERM CASGEM MONITORING WELL LOCATIONS AND WATER LEVELS

Project No. 11182028
Date January 2022

FIGURE 5.1

Filename:\\ghdnet\ghd\US\Eureka\Projects\561\11217388\Tech\Model Predictions\Figures\FigureFiles\Figure 5.1 CASGEM MonitoringWellLocations.srf
Plot Date: January 10 2022 10:01 AM



Legend

25	Well Identification(1)
(2016-2017)	Observation Period

Note:

(1) Some well identification numbers have been anonymized

0 1.5 3miles

N

GHD

HUMBOLDT COUNTY GROUNDWATER SUSTAINABILITY AGENCY
EEL RIVER VALLEY GROUNDWATER SUSTAINABILITY PLAN

ERVB GROUNDWATER TARGET LOCATIONS AND OBSERVATION PERIOD

Project No. 11217388
Date November 2021

FIGURE 5.2

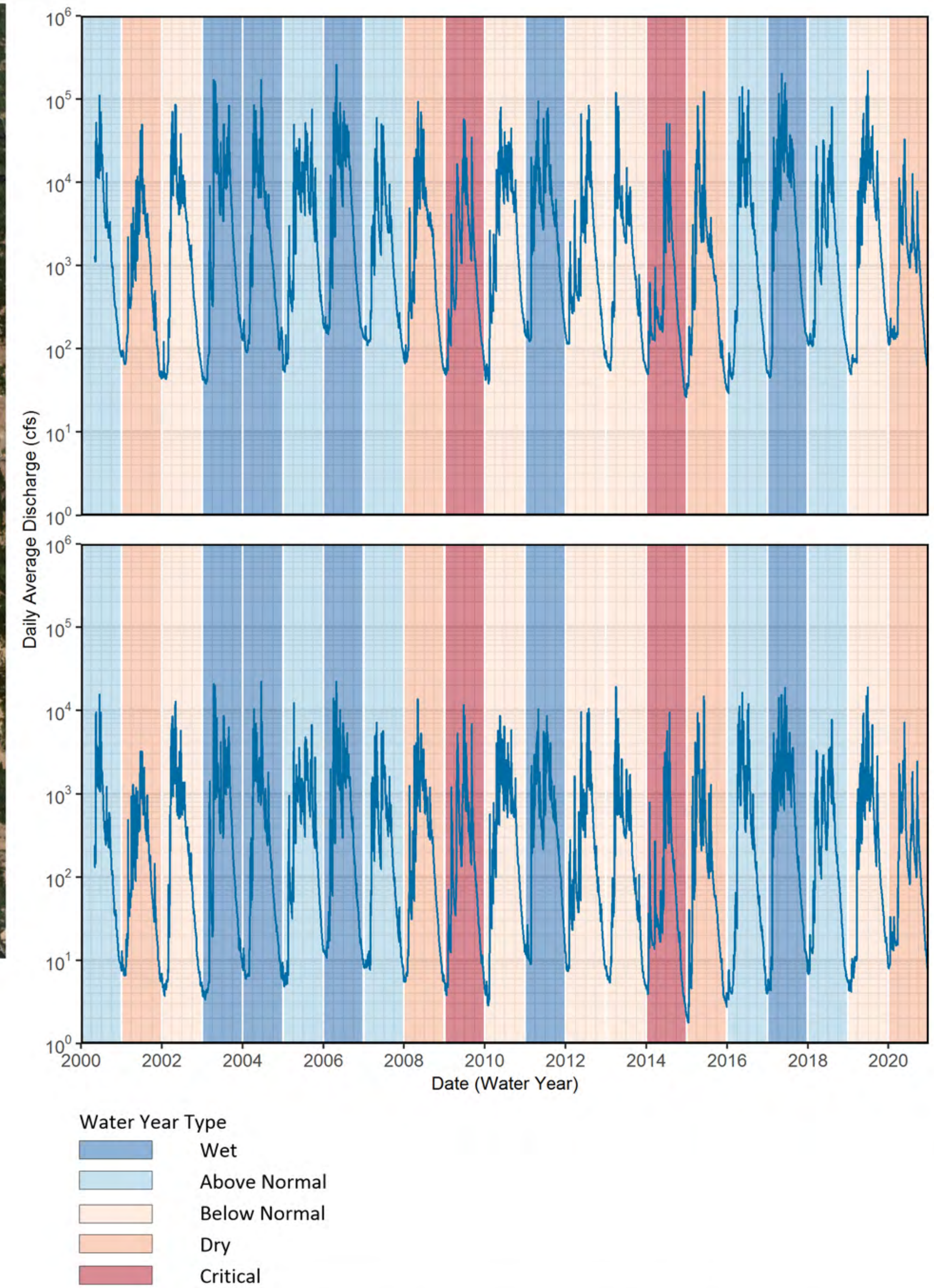
Filename:\\ghdnet\ghd\US\Eureka\Projects\561\11217388\Tech\Model Predictions\Figures\FigureFiles\Figure 5.2 Target Locations.srf
Plot Date: November 03 2021 2:11 PM

Legend

Eel River Valley Basin

11478500 USGS Surface Water Monitoring Station Target Identification

USGS Surface Water Monitoring Station Target Locations



Sources: Orthoimagery: USDA, 2021. National Agriculture Image Program (NAIP)

0 1.5 3miles

N

GHD

HUMBOLDT COUNTY GROUNDWATER SUSTAINABILITY AGENCY
EEL RIVER VALLEY GROUNDWATER SUSTAINABILITY PLAN

HISTORICAL RIVER TARGET FLOW RATES

Project No. 11217388
Date January 2022

FIGURE 5.3

Filename:\\ghdnet\ghd\US\Eureka\Projects\561\11217388\Tech\Model Predictions\Figures\FigureFiles\Figure 5.3 LocalSurfaceWater.srf
Plot Date: January 10 2022 10:01 AM

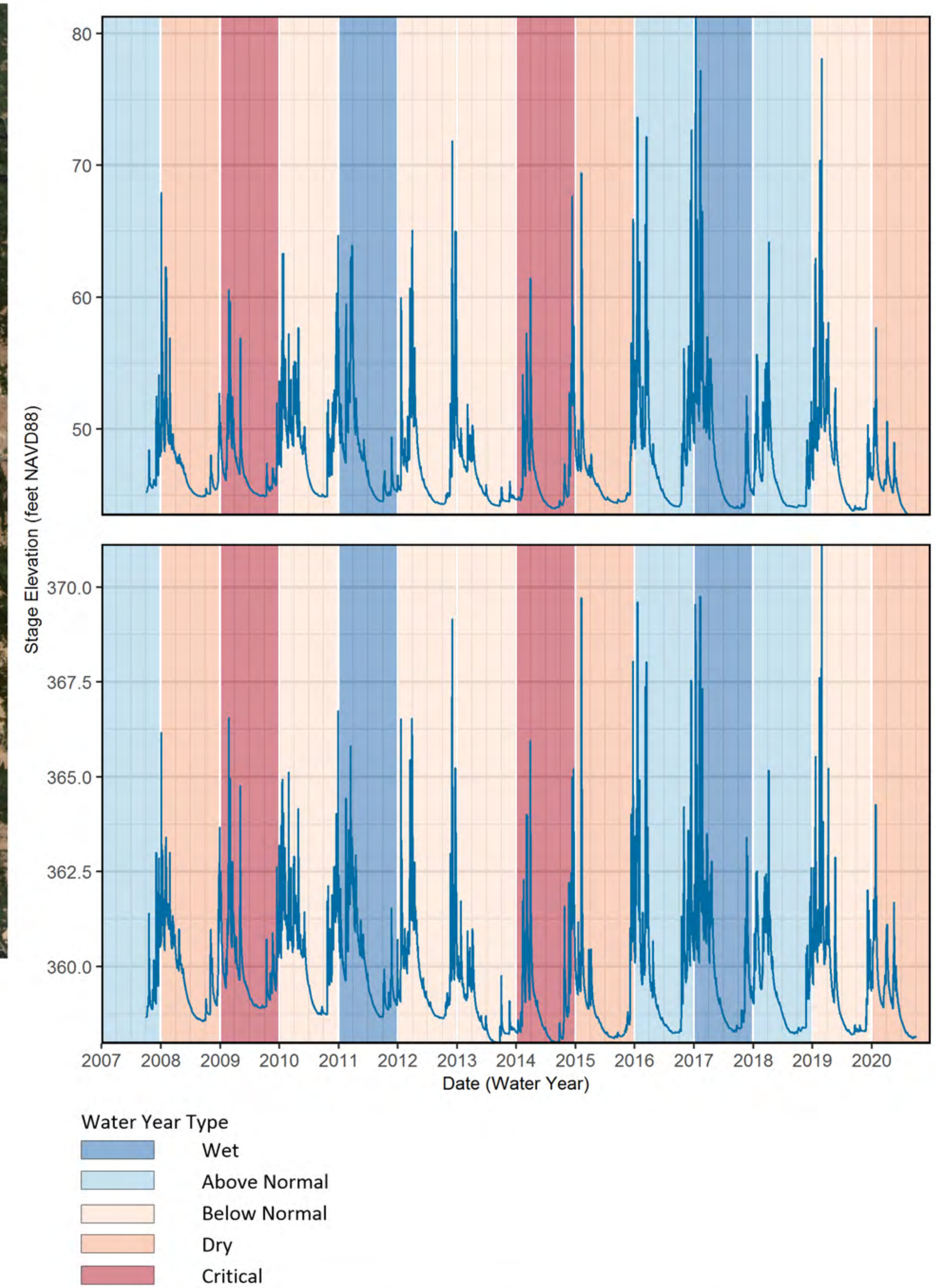
Legend

Eel River Valley Basin

11478500 USGS Surface Water Monitoring Station Target Identification

USGS Surface Water Monitoring Station Target Locations

Sources: Orthoimagery: USDA, 2021. National Agriculture Image Program (NAIP)



0 1.5 3miles

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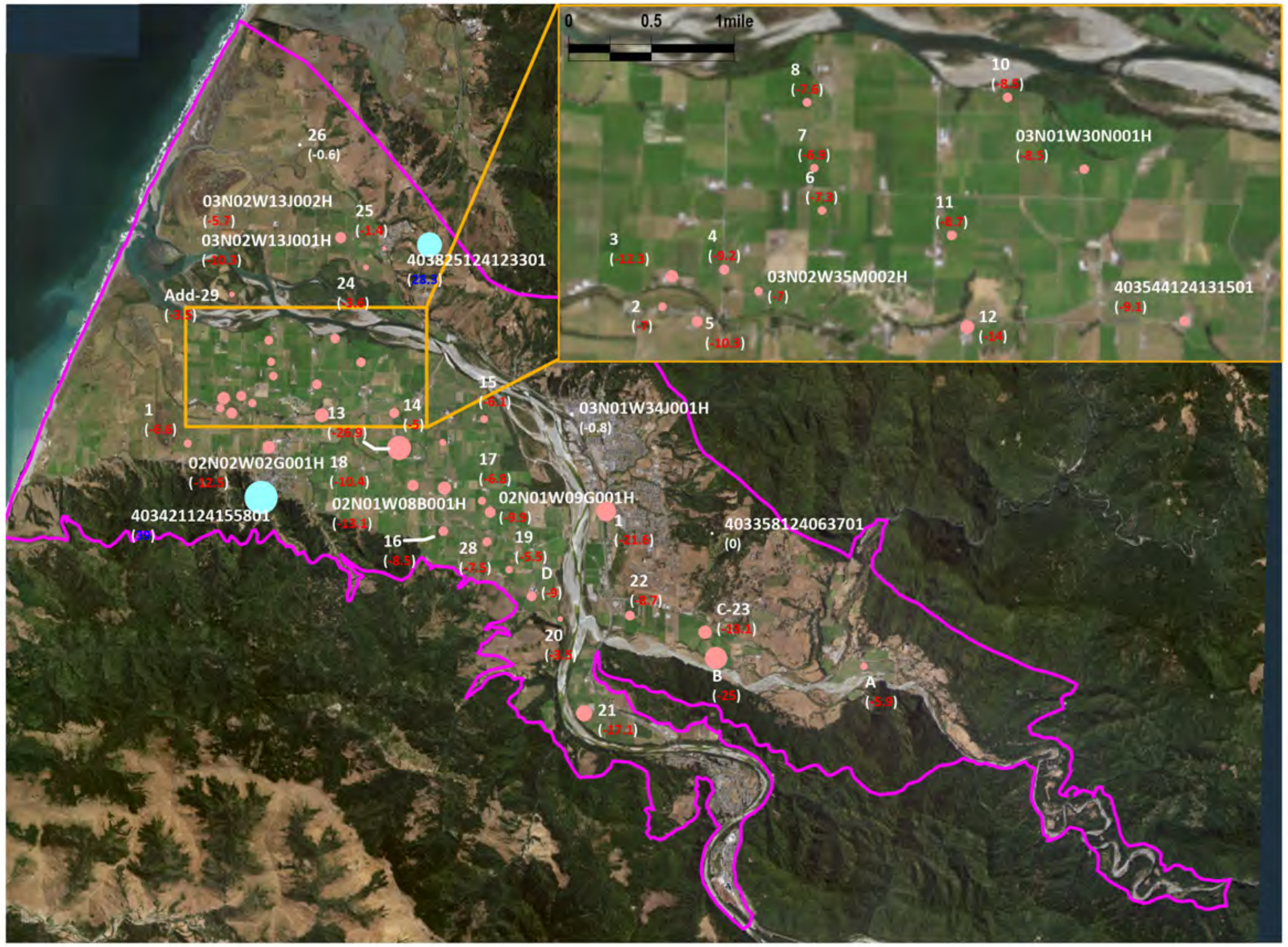
HUMBOLDT COUNTY GROUNDWATER SUSTAINABILITY AGENCY
EEL RIVER VALLEY GROUNDWATER SUSTAINABILITY PLAN

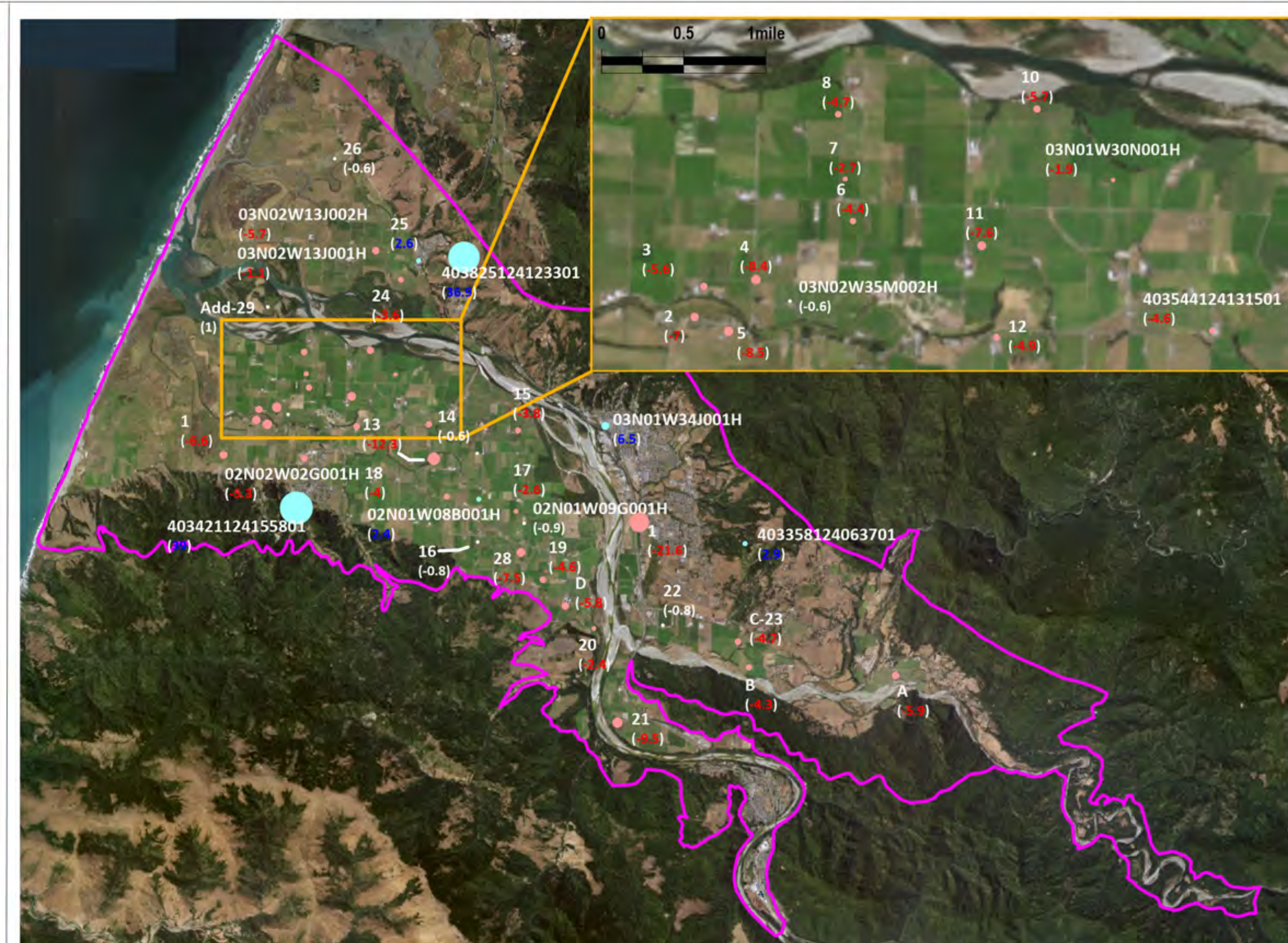
HISTORICAL RIVER STAGE TARGET ELEVATIONS

Project No. 11217388
Date January 2022

FIGURE 5.4

Filename:\\ghdnet\ghd\US\Eureka\Projects\561\11217388\Tech\Model Predictions\Figures\FigureFiles\Figure 5.4 LocalSurfaceWater_StageElevations.srf
Plot Date: January 10 2022 10:01 AM





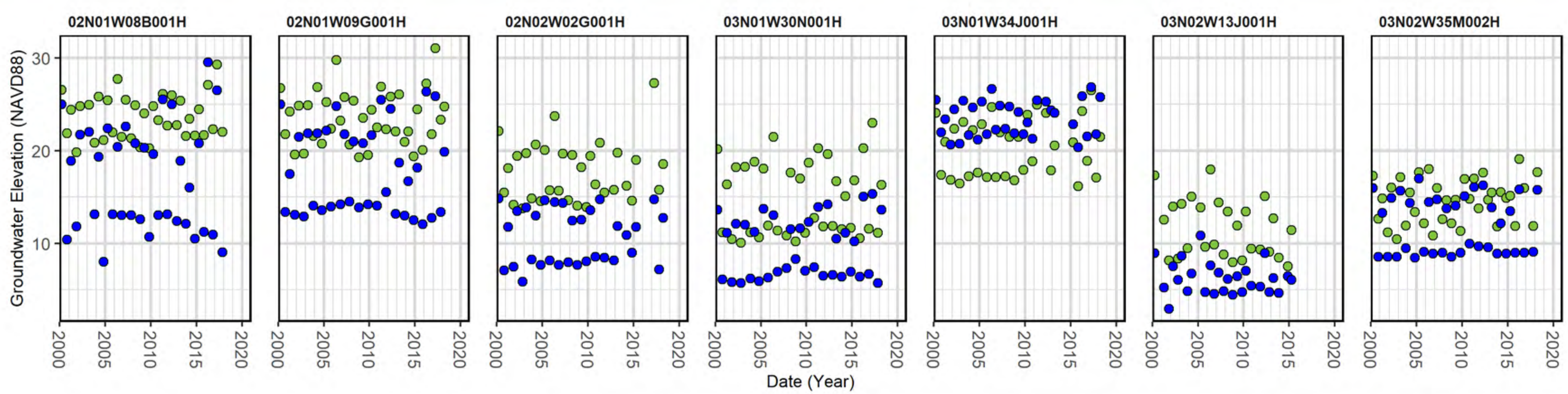
Legend

7	Monitoring Well Identification
(-6.9)	Groundwater Elevation Residual[1]
2.4	Postitive Calibration Residual (Under-predicted)
-6.9	Negative Calibration Residual (Over-predicted)
-0.4	Residual within +/- 1 foot
●	Postive Residual Circles
●	Negative Residual Circles
●	Residual Circle within +/- 1 foot

Transient Targets

(More than 20 Observations)

●	Observed Groundwater Elevation (NAVD88)
●	Simulated Groundwater Elevation (NAVD88)



0 1.5 3miles

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GHD

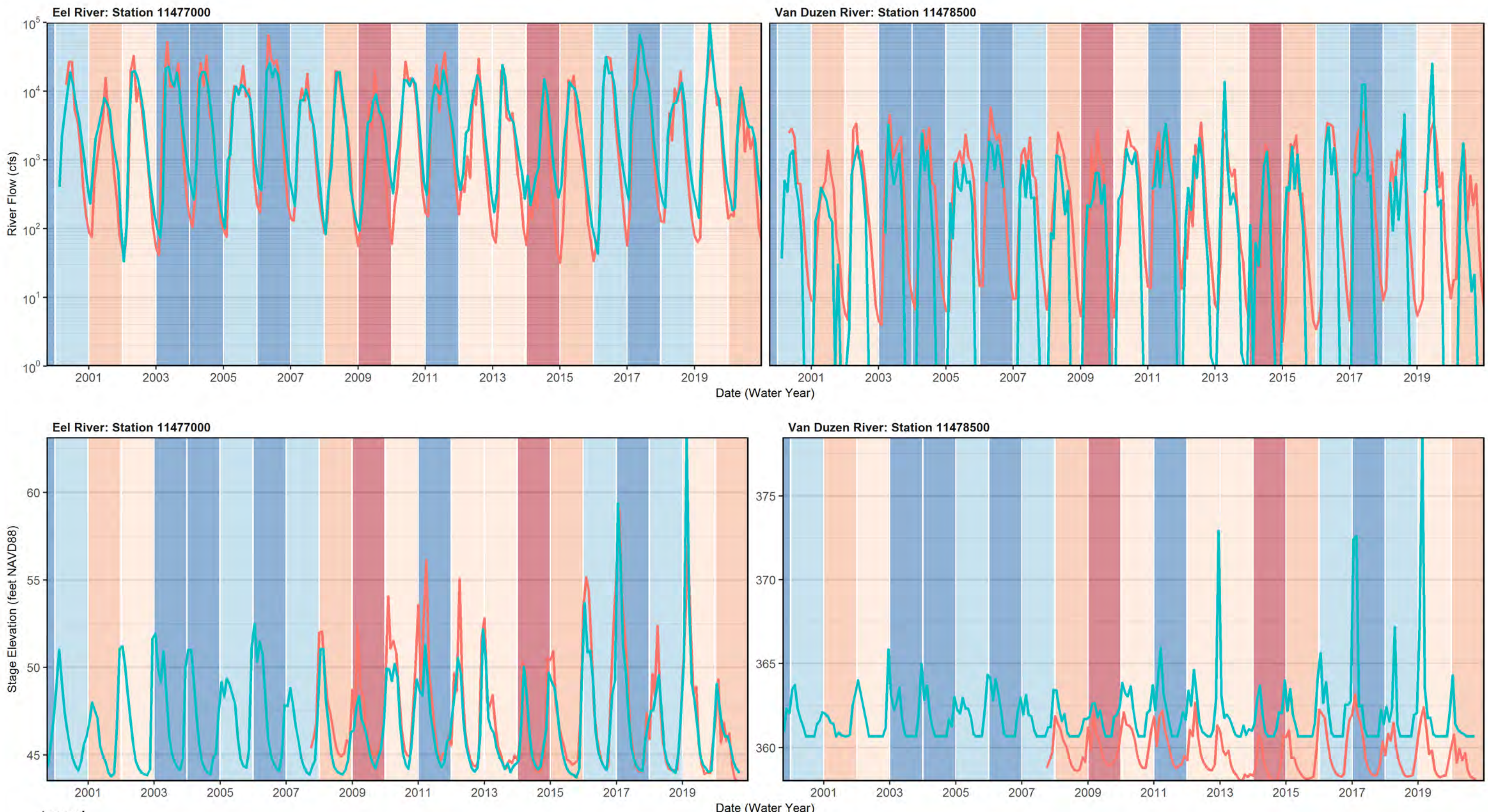
HUMBOLDT COUNTY GROUNDWATER SUSTAINABILITY AGENCY
EEL RIVER VALLEY GROUNDWATER SUSTAINABILITY PLAN

Project No. 11217388
Date November 2021

TRANSIENT TARGET RESIDUALS

FIGURE 5.5

Filename:\\ghdnet\ghd\US\Eureka\Projects\561\11217388\Tech\Model Predictions\Figures\FigureFiles\Figure 5.5 Target Residuals.srf
Plot Date: November 06 2021 3:11 PM



Legend

Observed Flow (cfs)/Groundwater Elevation (feet NAVD88)

Simulated Flow (cfs)/Groundwater Elevation (feet NAVD88)

Water Year Type

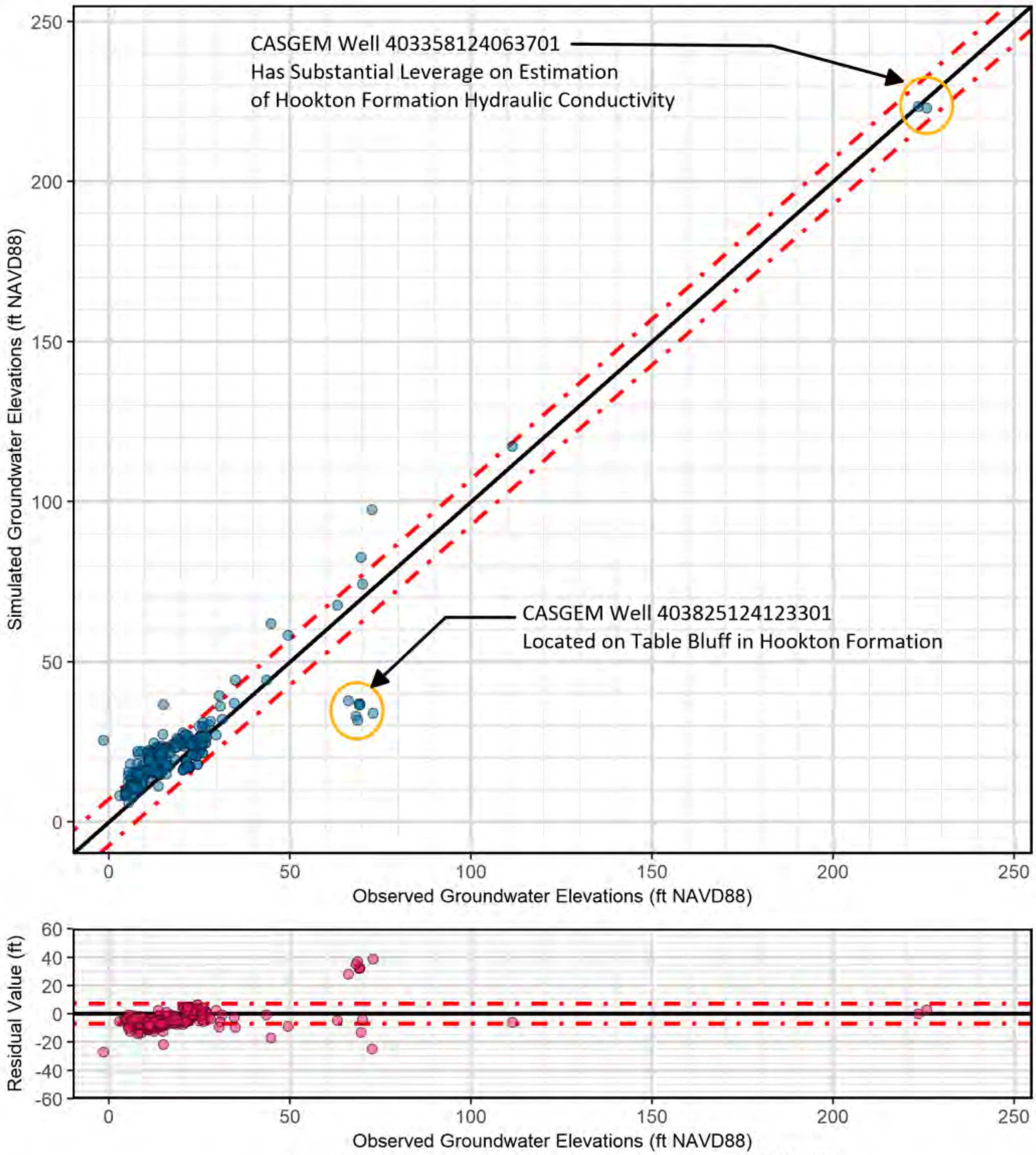
- Wet
- Above Normal
- Below Normal
- Dry
- Critical

HUMBOLDT COUNTY GROUNDWATER SUSTAINABILITY AGENCY
EEL RIVER VALLEY GROUNDWATER SUSTAINABILITY PLAN

EEL AND VAN DUZEN RIVERS SIMULATED AND OBSERVED FLOW AND STAGE

Project No. 11217388
Date January 2022

FIGURE 5.6



Calibration Statistics	Statistic Value
Number of Observations =	339
Residual Mean (feet) =	-3.2
Absolute Residual Mean (feet) =	5.9
Residual Standard Deviation (feet) =	7.2
Residual Sum of Square (feet^2) =	21,070
Minimum Residual (feet) =	-27
Maximum Residual (feet) =	39
Observation Head Range (feet) =	227
Standard Deviation / Head Range (Standard Units) =	0.03

LEGEND

- Groundwater Elevation Target
- Observed - Simulated Groundwater Elevation Residual
- Line of Exact Match
- +/- Standard Deviation

HUMBOLDT COUNTY GROUNDWATER SUSTAINABILITY AGENCY
EEL RIVER VALLEY GROUNDWATER SUSTAINABILITY PLAN

SCATTER PLOT OF OBSERVED VERSUS SIMULATED GROUNDWATER ELEVATIONS

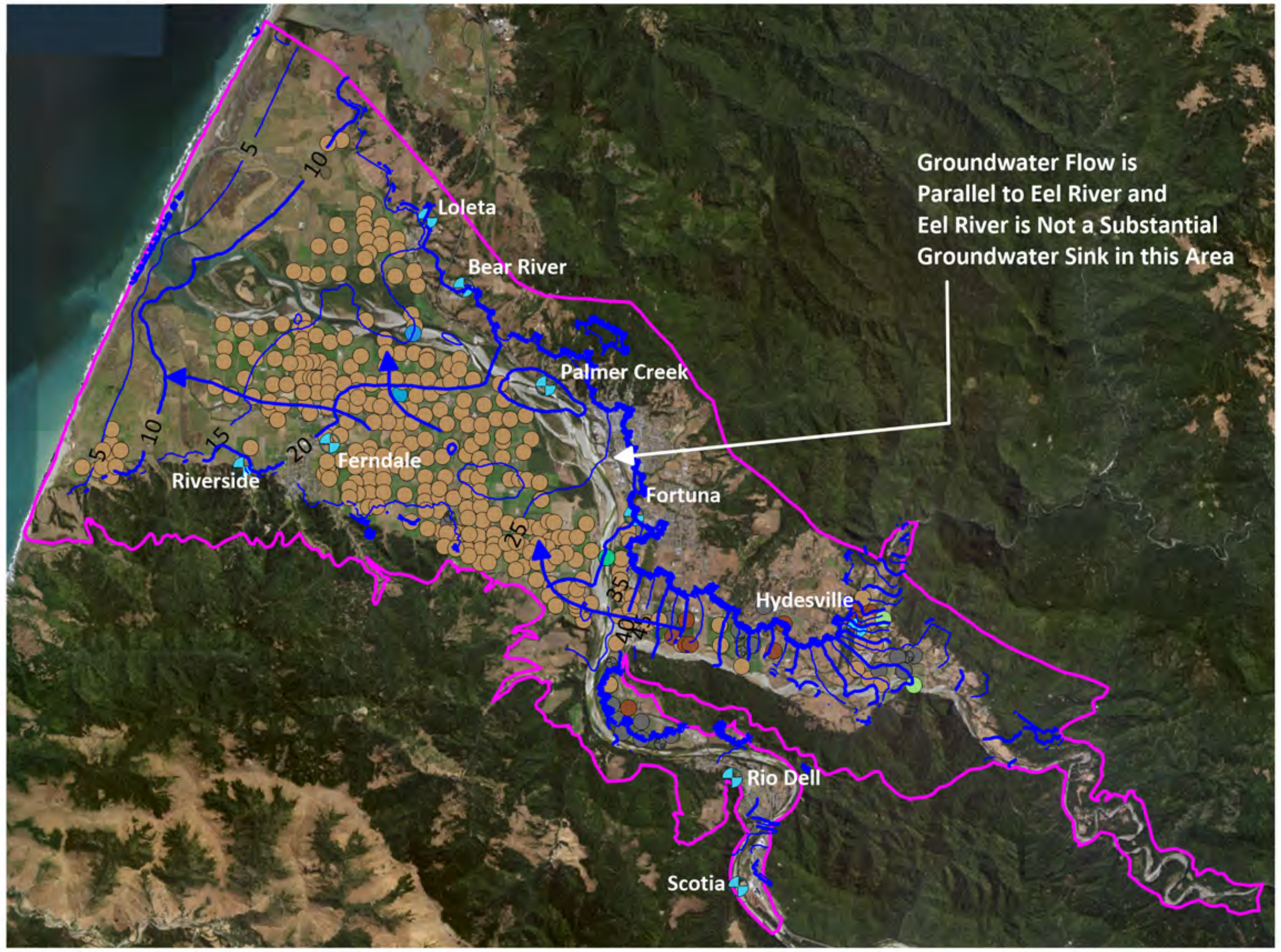
Project No. **11217388**
Date **November 2021**

FIGURE 5.7

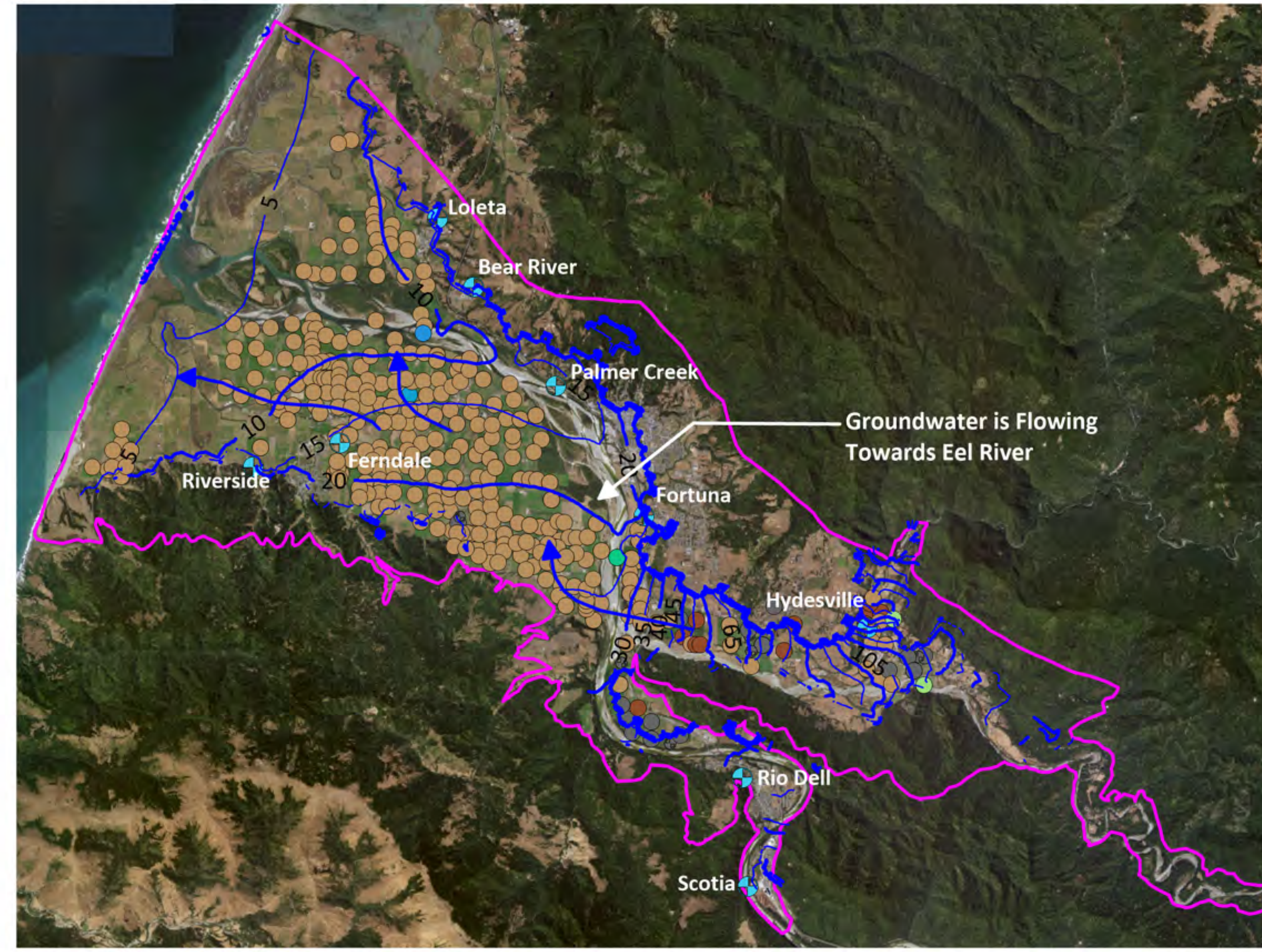
Filename:\\ghdnet\ghd\US\Eureka\Projects\561\11217388\Tech\Model Predictions\Figures\FigureFiles\Figure 5.7 ObservedVsSimulatedScatterPlot.srf
Plot Date: November 06 2021 4:11 PM

Data Source

Spring (March) 2003



Fall (October) 2003



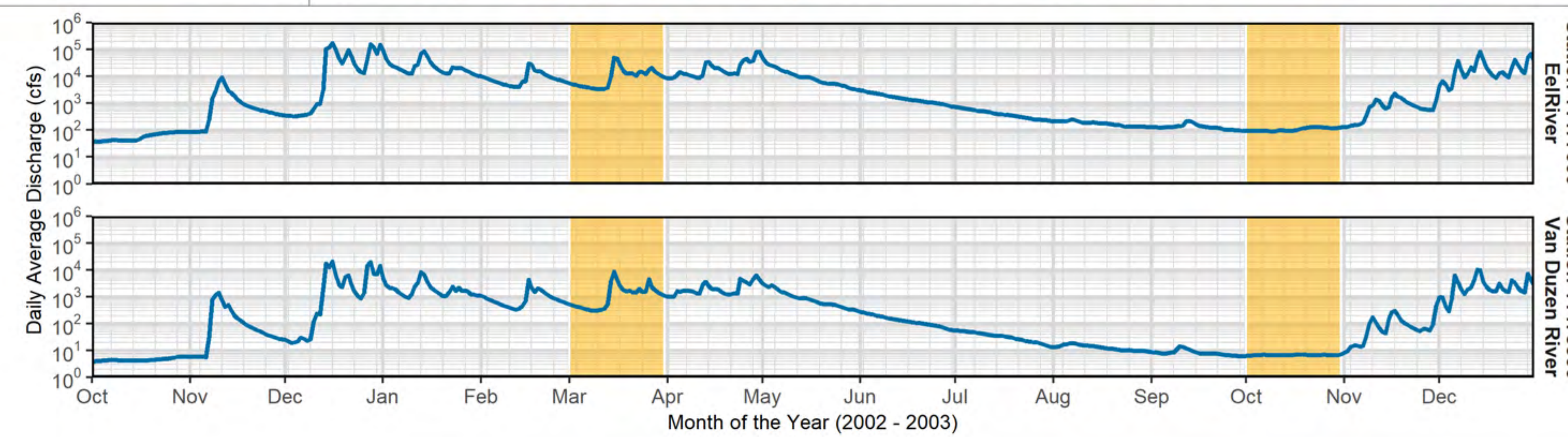
Legend

Simulated Groundwater Elevation Contour (feet NAVD88) in Alluvium Deposits

Groundwater Flow Directions

Extraction Well

- Agriculture
- Gravel Mining
- Grazing/Timber
- Multi Family Residential
- Municipal Supply
- Open Space/Parks
- Rural Residential
- Rural Residential - Vacant
- Timber Production



0 1.5 3miles

N

GHD

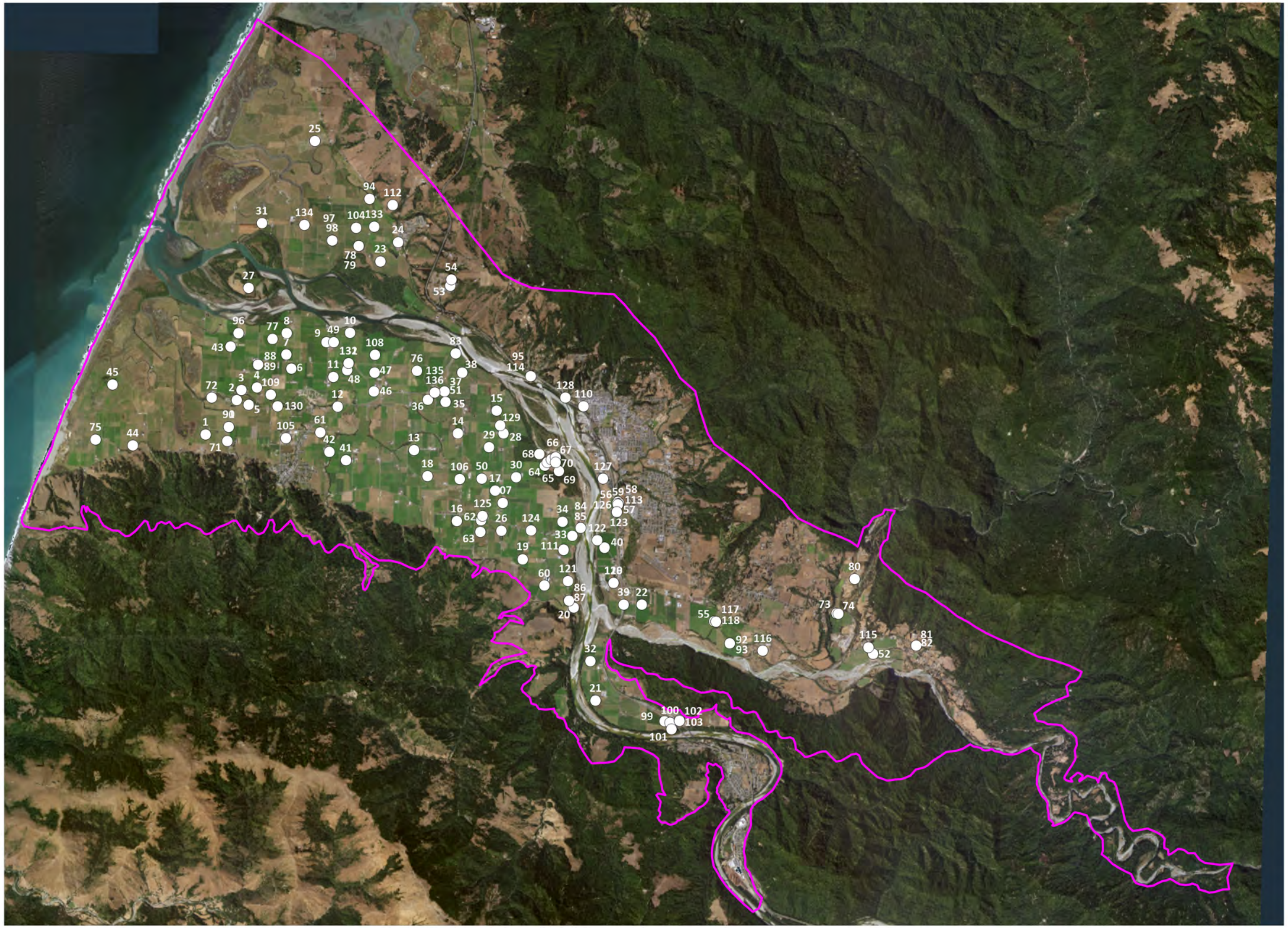
HUMBOLDT COUNTY GROUNDWATER SUSTAINABILITY AGENCY
EEL RIVER VALLEY GROUNDWATER SUSTAINABILITY PLAN

SPRING AND FALL 2003 SIMULATED GROUNDWATER ELEVATIONS

Project No. 11217388
Date November 2021

FIGURE 5.8

Filename:\\ghdnet\ghd\US\Eureka\Projects\561\11217388\Tech\Model Predictions\Figures\FigureFiles\Figure 5.8 SpringAndFallSimulatedGroundwaterElevations.srf
Plot Date: November 07 2021 1:11 PM



Legend

10 Well Identification Key[(1)]

◯ Chrinic Groundwater Lowering Evaluation Location

Note:

(1) Table 6.1 Relates Well Identification Key Value with Well Identification

0 700 1400ft

N

GHD

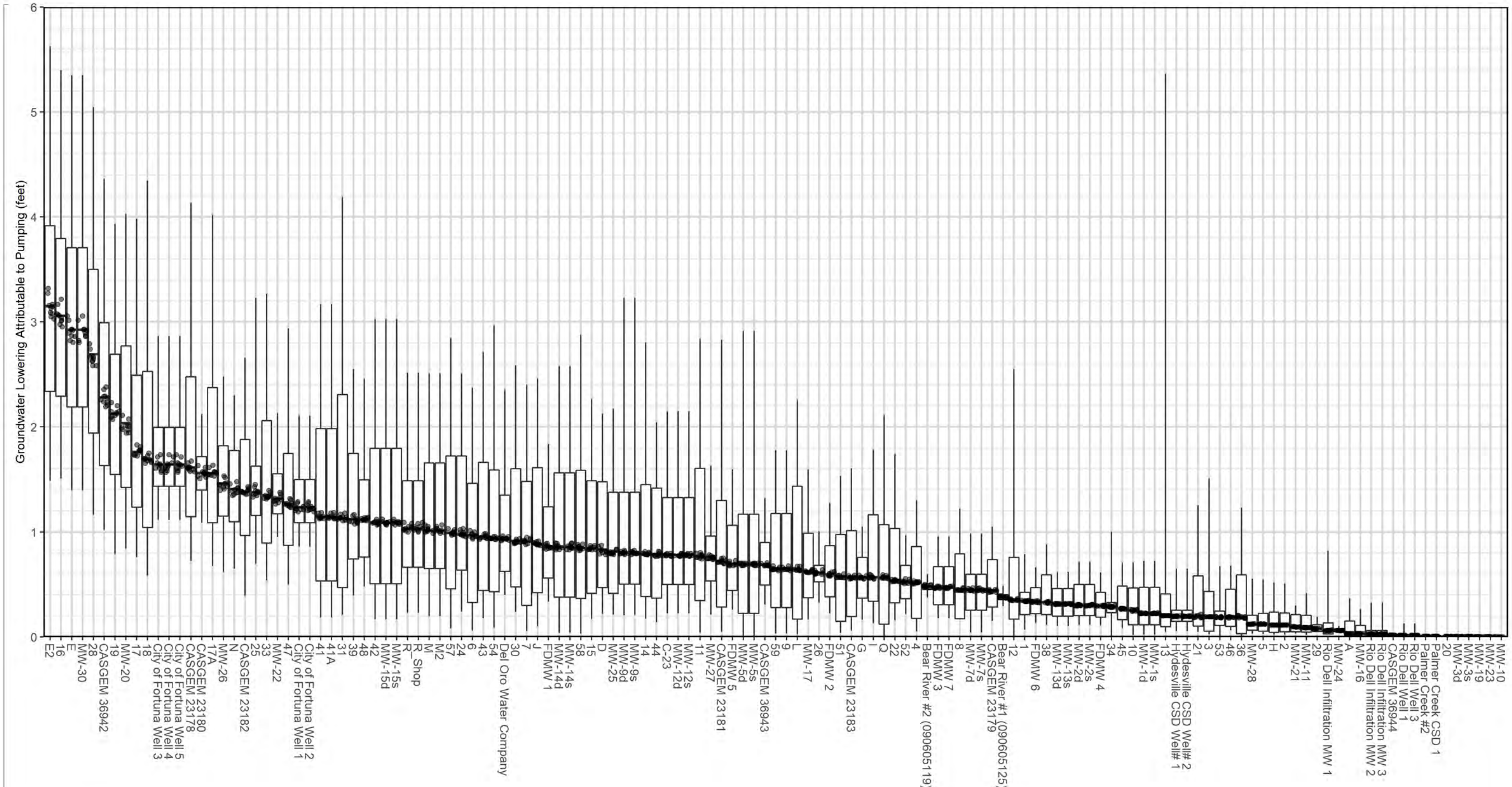
HUMBOLDT COUNTY GROUNDWATER SUSTAINABILITY AGENCY
EEL RIVER VALLEY GROUNDWATER SUSTAINABILITY PLAN

CHRONIC GROUNDWATER LOWERING EVALUATION LOCATIONS

Project No. 11217388
Date November 2021

FIGURE 6.1

Filename:\\ghdnet\ghd\US\Eureka\Projects\561\11217388\Tech\Model Predictions\Figures\FigureFiles\Figure 6.1 Chronic Lowering Evaluation Locations.srf
Plot Date: November 07 2021 5:11 PM



Legend

Global Upper Range of Groundwater Displacement for 10 Calibrated Models (feet)

Global 75th Percentile of Groundwater Displacement for 10 Calibrated Models (feet)

Global Median of Groundwater Displacement for 10 Calibrated Models (feet)

Global 25th Percentile of Groundwater Displacement for 10 Calibrated Models (feet)

Global Lower Range of Groundwater Displacement for 10 Calibrated Models (feet)

Median Displacement for each Calibrated Model (feet)

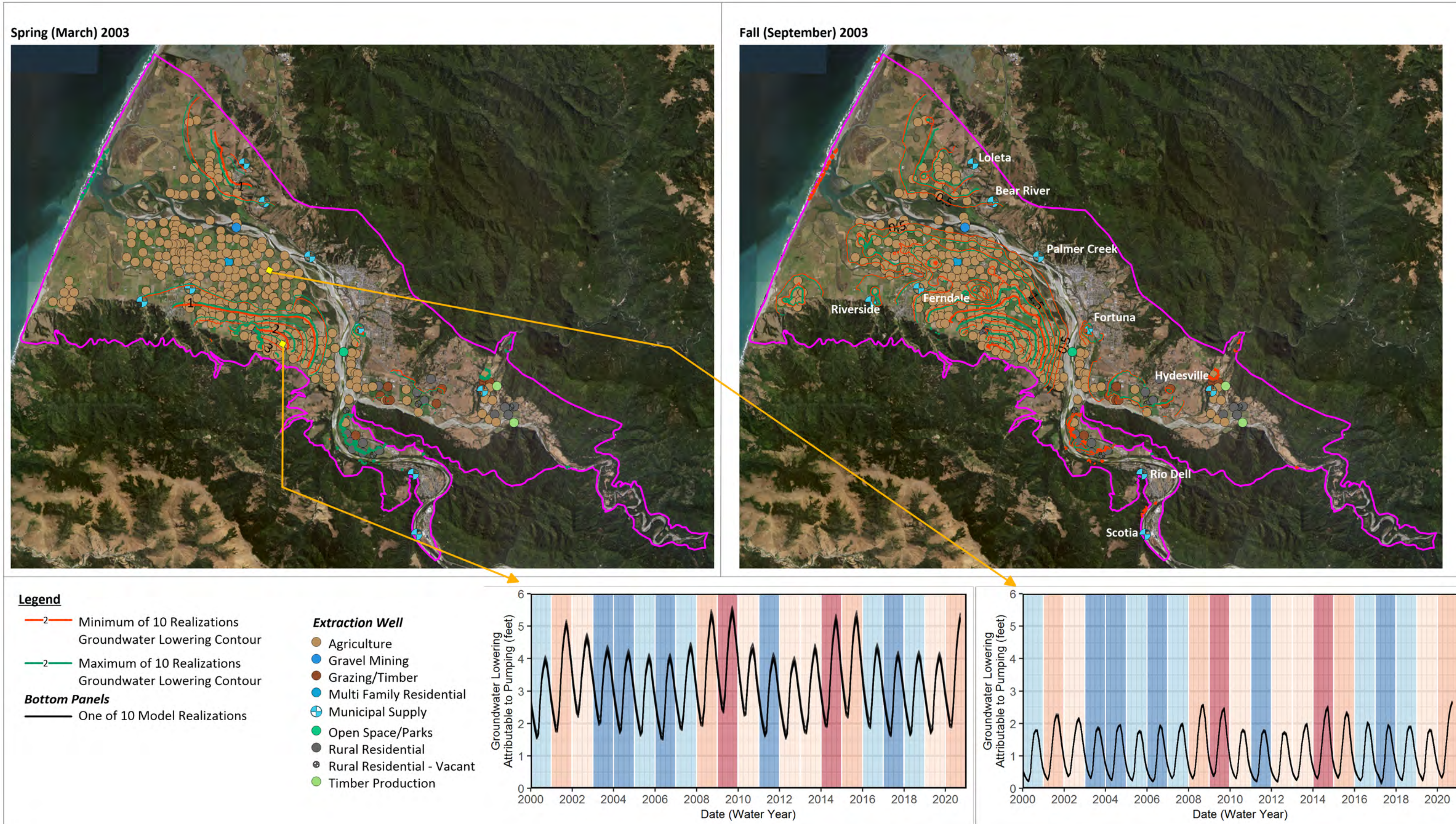
HUMBOLDT COUNTY GROUNDWATER SUSTAINABILITY AGENCY
EEL RIVER VALLEY GROUNDWATER SUSTAINABILITY PLAN

GROUNDWATER LOWERING ATTRIBUTABLE TO PUMPING

Project No. 11217388
Date November 2021

FIGURE 6.2

Filename: \\ghdnet\ghd\US\Eureka\Projects\561\11217388\Tech\Model Predictions\Figures\FigureFiles\Figure 6.2 Chronic Lowering Evaluation.srf
Plot Date: November 08 2021 8:11 AM



0 1.5 3miles

N

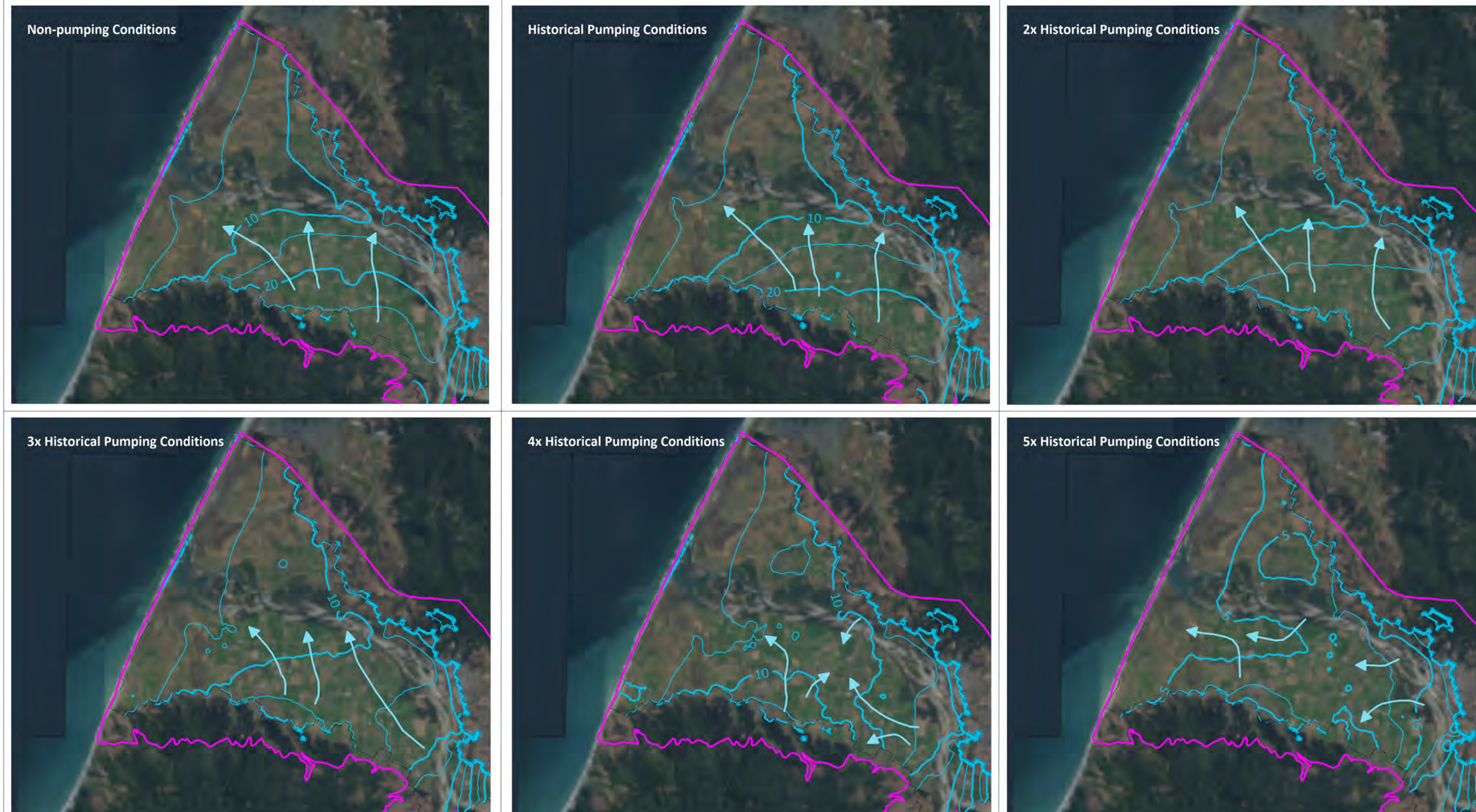
HUMBOLDT COUNTY GROUNDWATER SUSTAINABILITY AGENCY
EEL RIVER VALLEY GROUNDWATER SUSTAINABILITY PLAN

SPRING AND FALL 2003 SIMULATED GROUNDWATER LOWERING

Project No. 11217388
Date January 2022

FIGURE 6.3

Filename:\\ghdnet\ghd\US\Eureka\Projects\561\11217388\Tech\Model Predictions\Figures\FigureFiles\Figure 6.3 March and September 2003 Groundwater Lowering.srf
Plot Date: January 10 2022 11:01 AM



Legend

—10— 5 foot Interval Groundwater Elevation Contour (feet NAVD88)

Groundwater Flow Direction

Note:

Groundwater elevations represent average dry conditions from September 2003 with a range of increased pumping conditions to represent potential future demand and evaluate sustainable yield.

0 7,500 15,000ft

N

GHD

HUMBOLDT COUNTY GROUNDWATER SUSTAINABILITY AGENCY
EEL RIVER VALLEY GROUNDWATER SUSTAINABILITY PLAN

INCREASED PUMPING GROUNDWATER ELEVATION CONTOURS

Project No. 11217388
Date November 2021

FIGURE 6.4

Filename:\\ghdnet\ghd\US\Eureka\Projects\561\11217388\Tech\Model Predictions\Figures\FigureFiles\Figure 6.4 GWE IncreasedPumping.srf
Plot Date: November 17 2021 7:11 PM

Legend

—10— 1 foot Interval Groundwater Elevation Lowering Contour (feet)/ 5 foot Interval Groundwater Elevation Contour - Non-Pumping Conditions (feet NAVD88)

Non-Pumping Conditions Groundwater Flow Direction

Note:

Groundwater elevation lowering represent average dry conditions from September 2003 with a range of increased pumping conditions to represent potential future demand and evaluate sustainable yield.

0 7,500 15,000ft

N

GHD

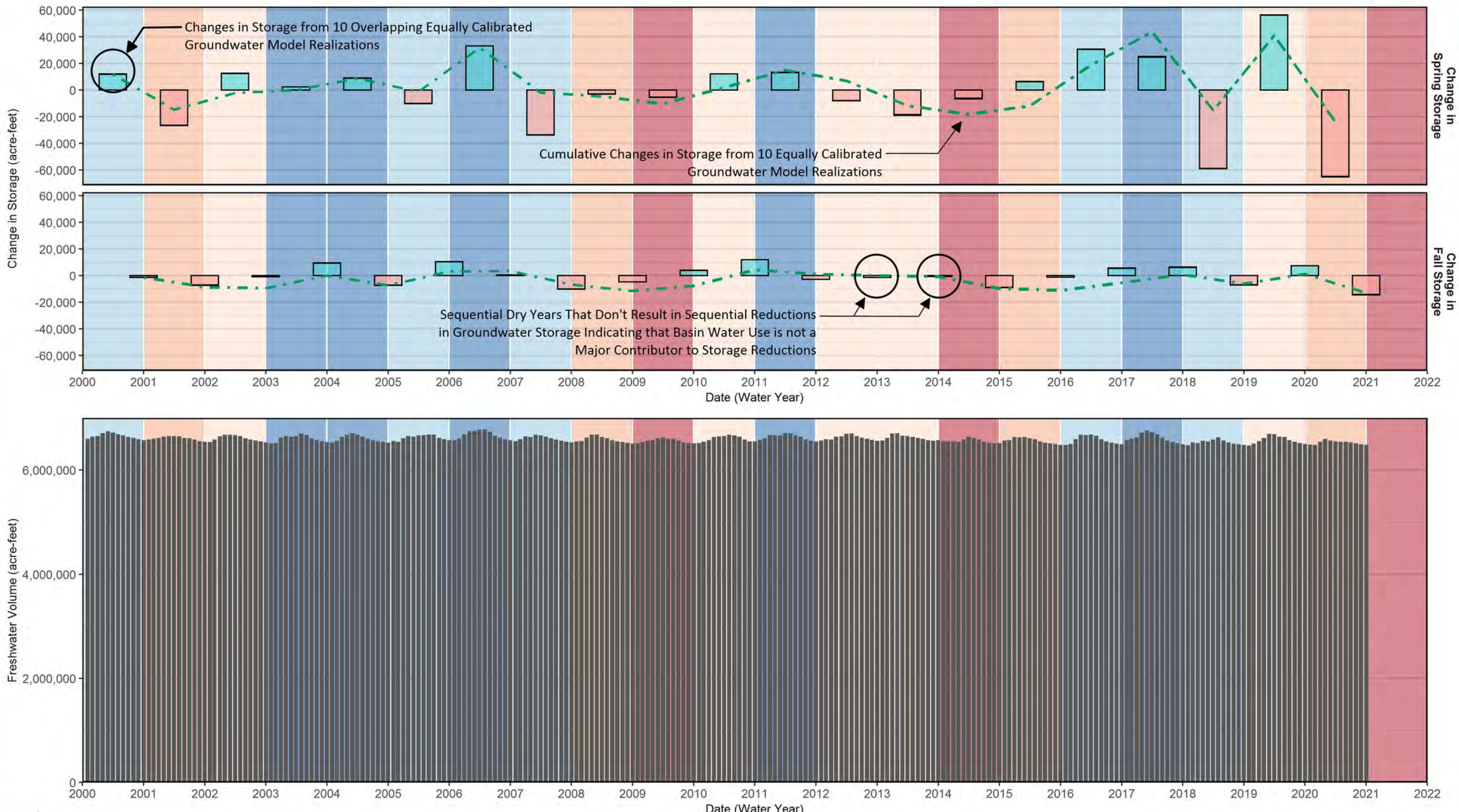
HUMBOLDT COUNTY GROUNDWATER SUSTAINABILITY AGENCY
EEL RIVER VALLEY GROUNDWATER SUSTAINABILITY PLAN

INCREASED PUMPING
GROUNDWATER LOWERING CONTOURS

Project No. 11217388
Date November 2021

FIGURE 6.5

Filename:\\ghdnet\ghd\US\Eureka\Projects\561\11217388\Tech\Model Predictions\Figures\FigureFiles\Figure 6.5 GWE Lowering IncreasedPumping.srf
Plot Date: November 17 2021 7:11 PM



Legend

Positive Change in Storage
Negative Change in Storage
Cumulative Change in Storage

Water Year Type

- Wet
- Above Normal
- Below Normal
- Dry
- Critical

Note:

Storage is calculated for groundwater in Quaternary alluvium

Freshwater volume is calculated for groundwater in transmissive water-bearing units including channel deposits, Quaternary alluvium, and Carlotta Formation

GHD

HUMBOLDT COUNTY GROUNDWATER SUSTAINABILITY AGENCY
EEL RIVER VALLEY GROUNDWATER SUSTAINABILITY PLAN
CHANGE AND CUMULATIVE CHANGE IN GROUNDWATER STORAGE AND TOTAL FRESHWATER VOLUME

Project No. 11217388
Date January 2022

FIGURE 6.6

Legend

Isocontours representing 95% and 5% frequency within which chloride concentrations are equal to or greater than 100 mg/L

Isocontour representing 50% frequency within which chloride concentrations are equal to or greater than 100 mg/L

Note:
Black contour under pumping conditions represents 5% isocontour for non-pumping conditions. This is included as a reference line.

0 7,500 15,000ft

N

GHD

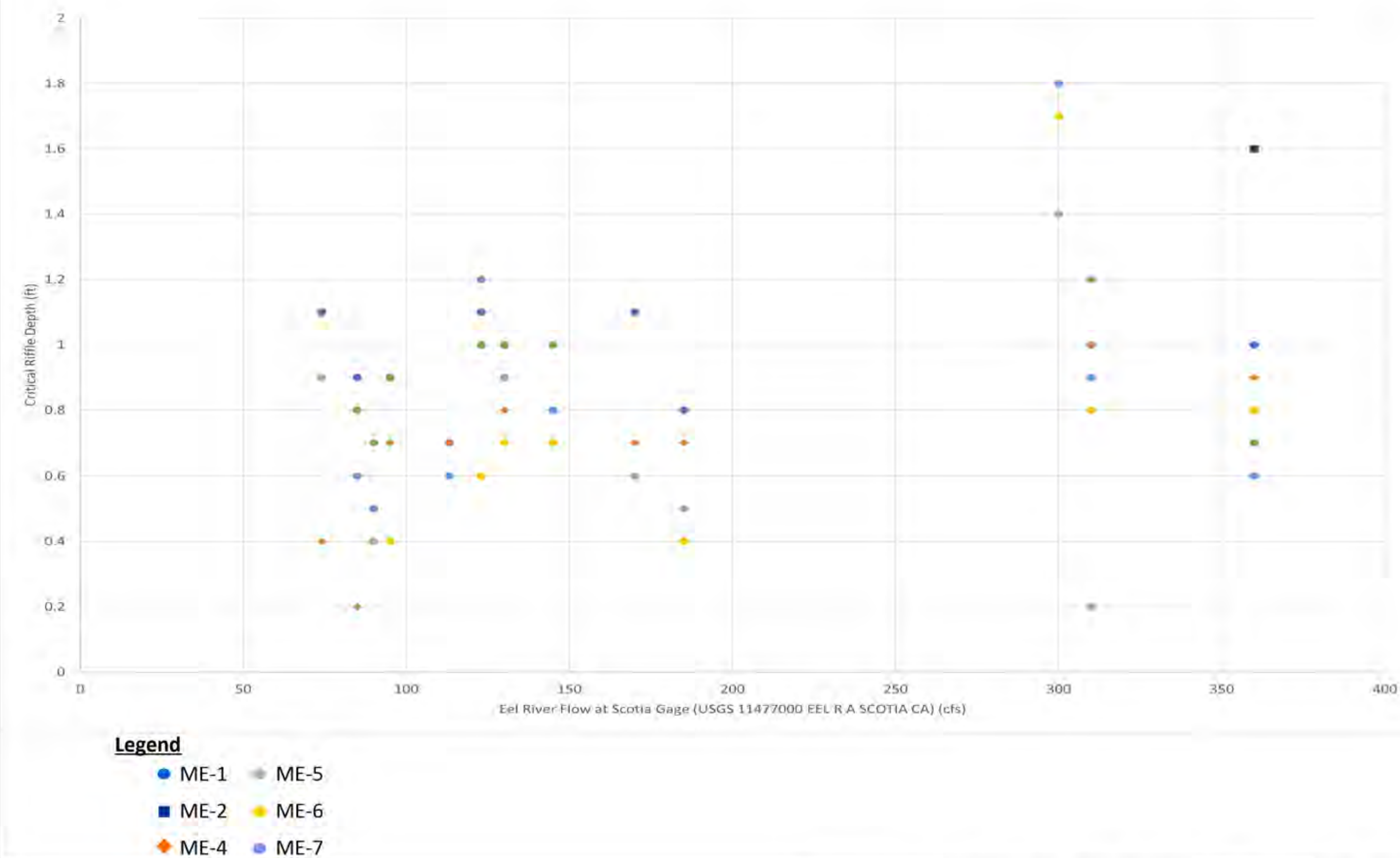
HUMBOLDT COUNTY GROUNDWATER SUSTAINABILITY AGENCY
EEL RIVER VALLEY GROUNDWATER SUSTAINABILITY PLAN

SEAWATER INTRUSION UNDER INCREASED WATER USE

Project No. 11217388
Date November 2021

FIGURE 6.7

Filename:\\ghdnet\ghd\US\Eureka\Projects\561\11217388\Tech\Model Predictions\Figures\FigureFiles\Figure 6.7 SaltwaterIntrusionIncreasedPumping.srf
Plot Date: November 17 2021 7:11 PM



HUMBOLDT COUNTY GROUNDWATER SUSTAINABILITY AGENCY
EEL RIVER VALLEY GROUNDWATER SUSTAINABILITY PLAN

EEL RIVER CRITICAL RIFFLE DEPTH BY FLOW 2006-2020 (STILLWATER SCIENCES 2021)

Project No. 11217388
Date November 2021

FIGURE 6.8

Filename:\\ghdnet\ghd\US\Eureka\Projects\561\11217388\Tech\Model Predictions\Figures\FigureFiles\Figure 6.8 Critical Riffle Data.srf
Plot Date: November 17 2021 7:11 PM

0 1 2miles

N

GHD

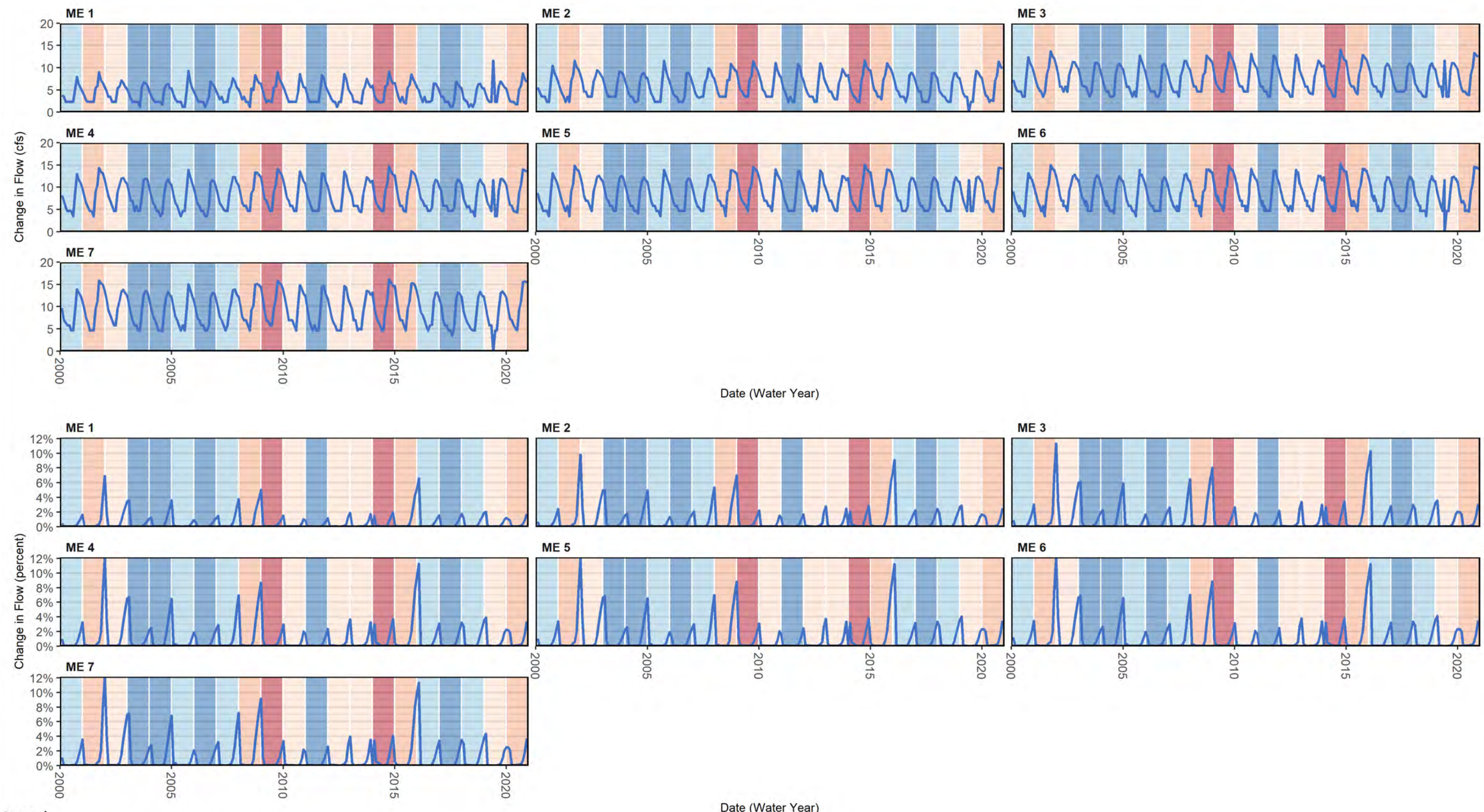
HUMBOLDT COUNTY GROUNDWATER SUSTAINABILITY AGENCY
EEL RIVER VALLEY GROUNDWATER SUSTAINABILITY PLAN

SURFACE WATER DEPLETION LOCATIONS OF INTEREST

Project No. 11217388
Date November 2021

FIGURE 6.9

Filename:\\ghdnet\ghd\US\Eureka\Projects\561\11217388\Tech\Model Predictions\Figures\FigureFiles\Figure 6.9 Surface Water Depletion.srf
Plot Date: November 17 2021 7:11 PM



Legend

Change and Percent Change in Flow Compared to Non-Pumping Conditions

Water Year Type

- Wet
- Above Normal
- Below Normal
- Dry
- Critical

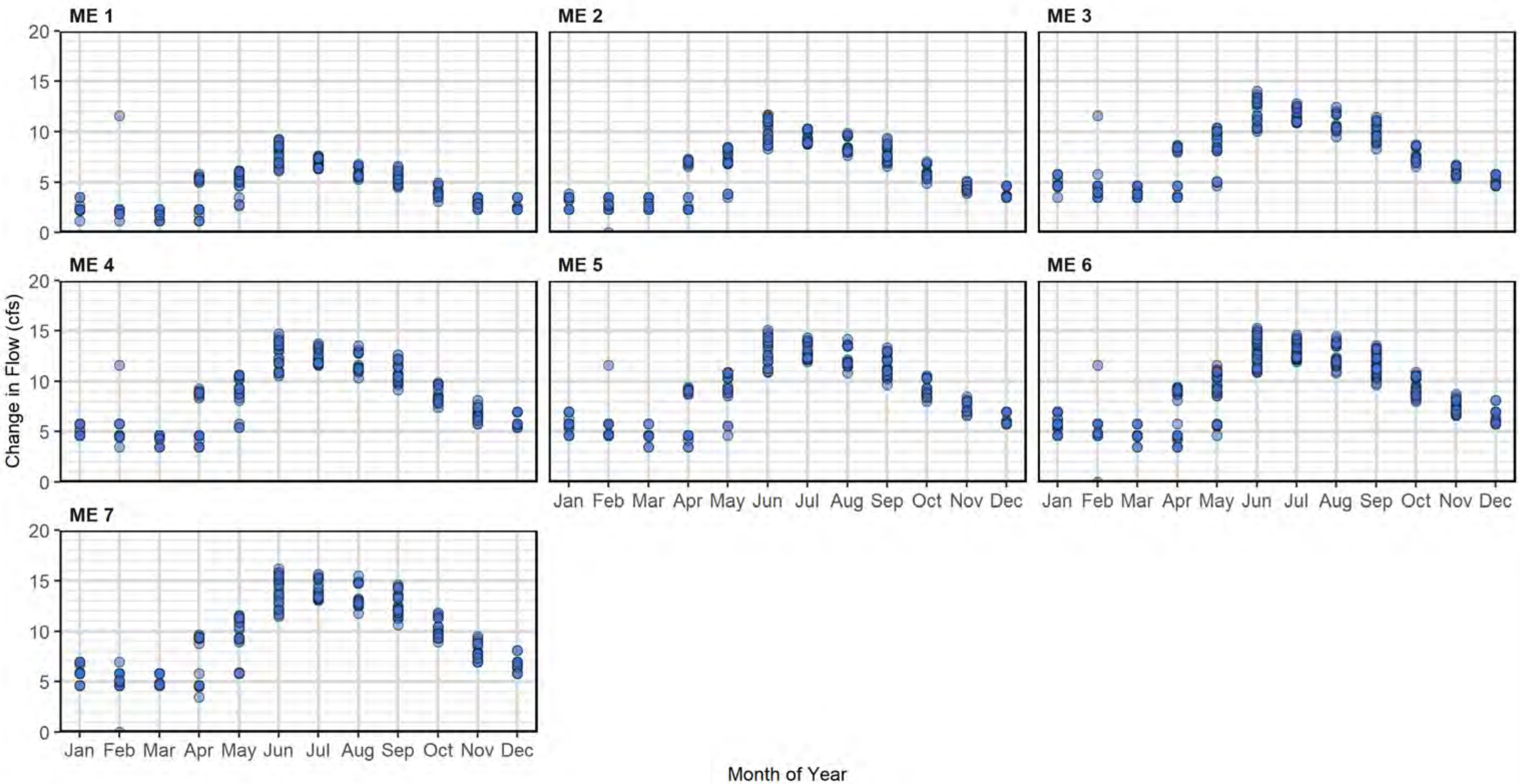
GHD

HUMBOLDT COUNTY GROUNDWATER SUSTAINABILITY AGENCY
EEL RIVER VALLEY GROUNDWATER SUSTAINABILITY PLAN
MONTHLY AVERAGE CHANGE AND PERCENT CHANGE IN EEL RIVER FLOW RATES

Project No. 11217388
Date January 2022

FIGURE 6.10

Filename:\\ghdnet\ghd\US\Eureka\Projects\561\11217388\Tech\Model Predictions\Figures\FigureFiles\Figure 6.10 Monthly Average and Percent Change in Eel River Flow Rates.srf
Plot Date: January 06 2022 9:01 AM



Legend

Change in Flow from Non-Pumping Conditions

HUMBOLDT COUNTY GROUNDWATER SUSTAINABILITY AGENCY
EEL RIVER VALLEY GROUNDWATER SUSTAINABILITY PLAN

EEL RIVER CHANGE IN FLOW WITH AND WITHOUT EXTRACTION

Project No. **11217388**
Date **January 2022**

FIGURE 6.11

Filename:\\ghdnet\ghd\US\Eureka\Projects\561\11217388\Tech\Model Predictions\Figures\FigureFiles\Figure 6.11 Year to Year Monthly Average Change in Eel River Flow.srf
Plot Date: January 06 2022 7:01 AM

GHD

HUMBOLDT COUNTY GROUNDWATER SUSTAINABILITY AGENCY
EEL RIVER VALLEY GROUNDWATER SUSTAINABILITY PLAN

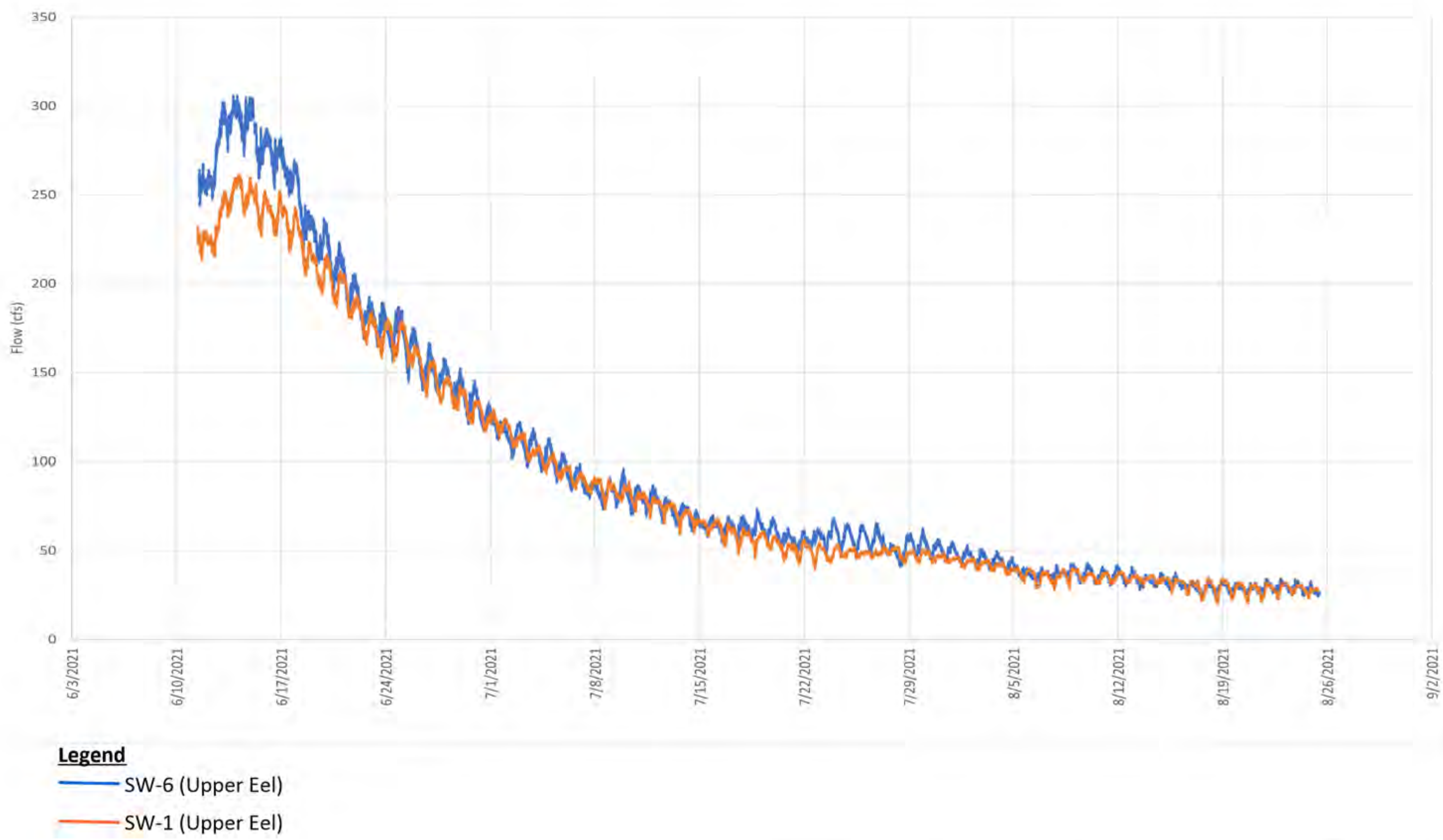
EEL RIVER GROUNDWATER ASSESSMENT SURFACE WATER MONITORING SITES

Project No. **11217388**
Date **November 2021**

FIGURE 6.12

Filename:\\ghdnet\ghd\US\Eureka\Projects\561\11217388\Tech\Model Predictions\Figures\FigureFiles\Figure 6.12 Stream Gage Locations.srf
Plot Date: November 17 2021 7:11 PM

Data Source



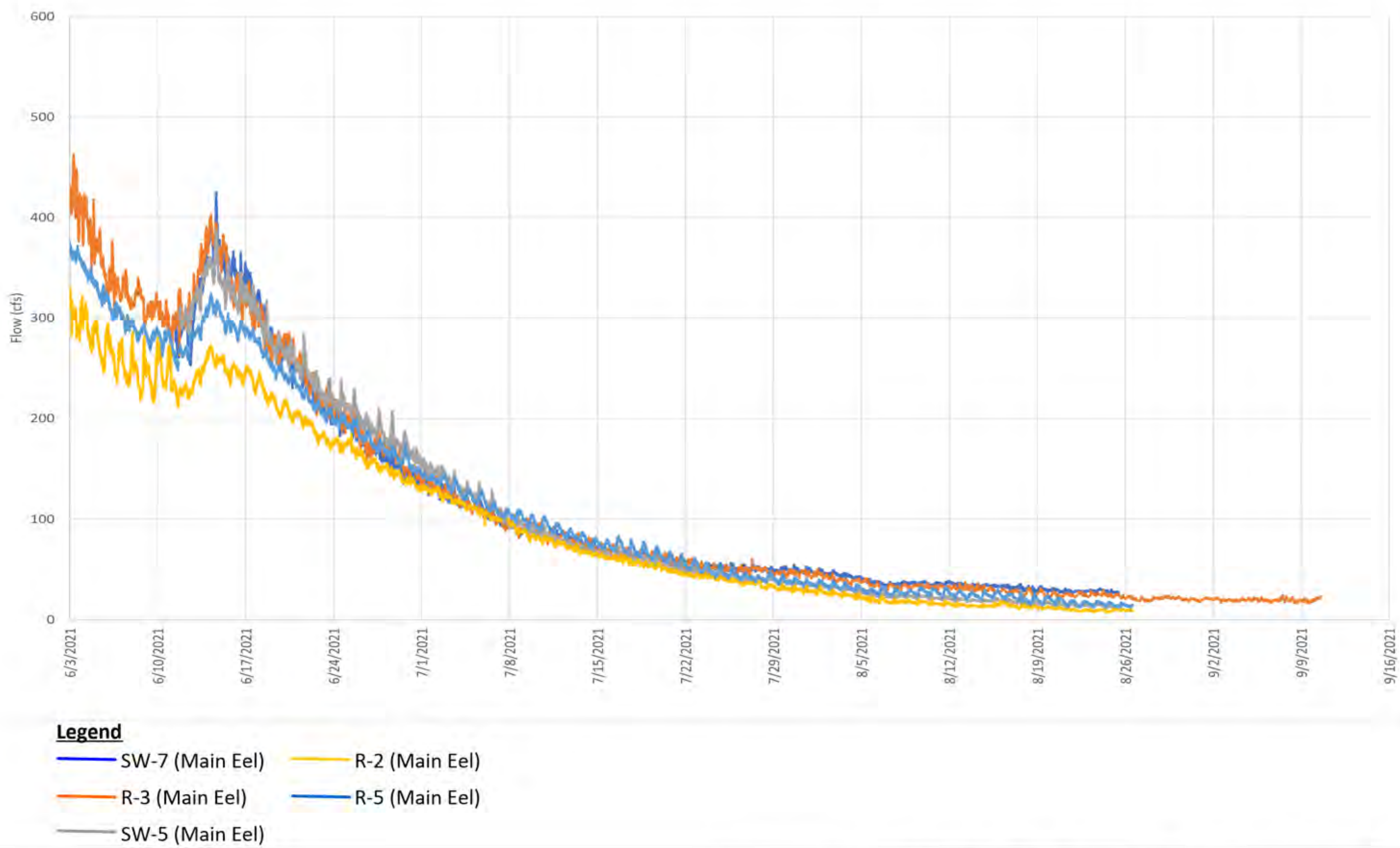
HUMBOLDT COUNTY GROUNDWATER SUSTAINABILITY AGENCY
EEL RIVER VALLEY GROUNDWATER SUSTAINABILITY PLAN

EEL RIVER FLOW MEASUREMENTS
(UPPER EEL ABOVE VAN DUZEN CONFLUENCE)

Project No. 11217388
Date November 2021

FIGURE 6.13

Filename:\\ghdnet\ghd\US\Eureka\Projects\561\11217388\Tech\Model Predictions\Figures\FigureFiles\Figure 6.13 Upper Eel Monitored Stream Flow.srf
Plot Date: November 17 2021 7:11 PM



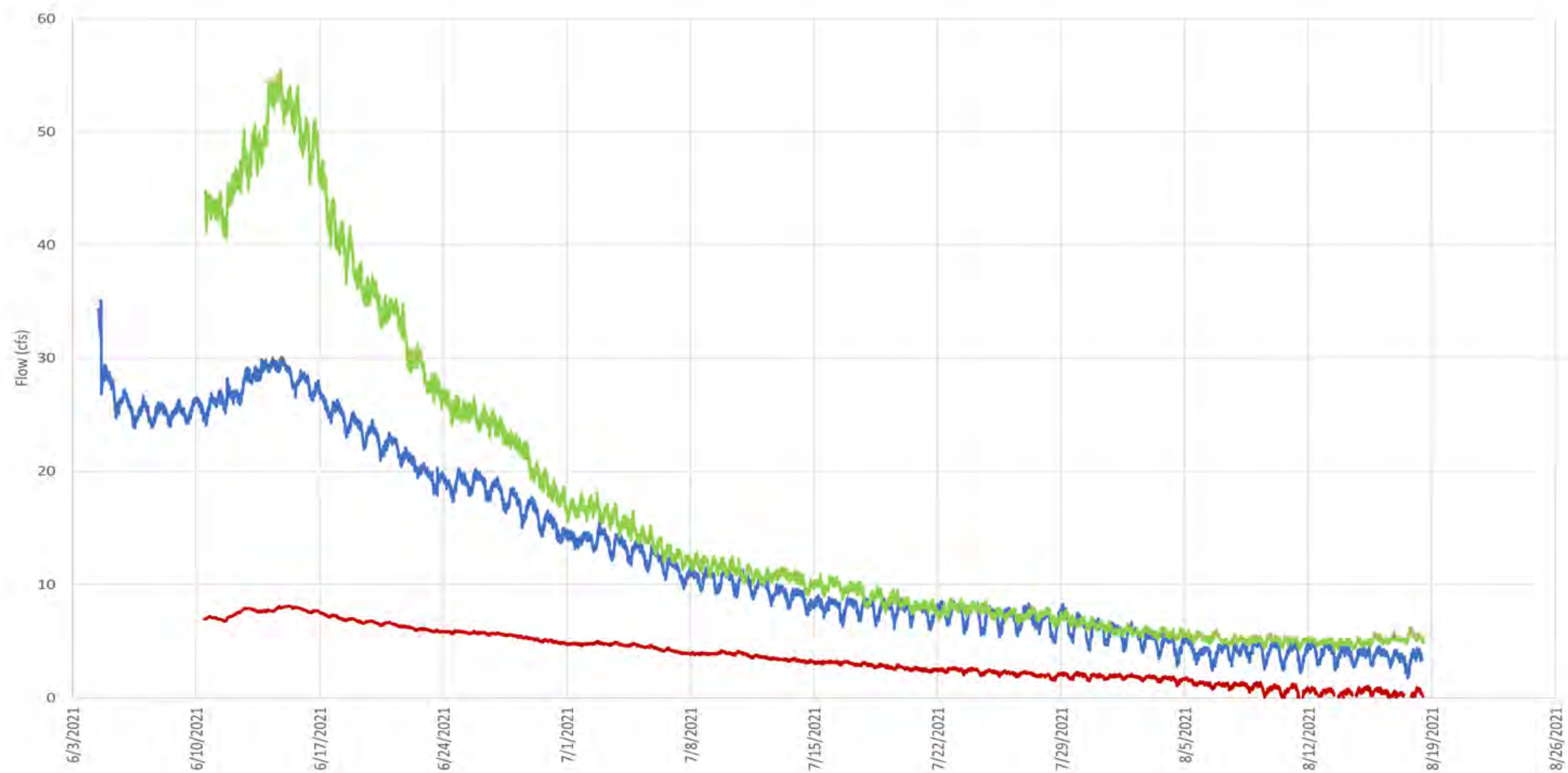
HUMBOLDT COUNTY GROUNDWATER SUSTAINABILITY AGENCY
EEL RIVER VALLEY GROUNDWATER SUSTAINABILITY PLAN

EEL RIVER FLOW MEASUREMENTS
(MAIN EEL BELOW VAN DUZEN CONFUENCE)

Project No. 11217388
Date November 2021

FIGURE 6.14

Filename:\\ghdnet\ghd\US\Eureka\Projects\561\11217388\Tech\Model Predictions\Figures\FigureFiles\Figure 6.14 Main Eel Monitored Stream Flow.srf
Plot Date: November 17 2021 7:11 PM



Legend

- SW-3 (Van Duzen)
- SW-2 (Yager Creek)
- SW-4 (Van Duzen)

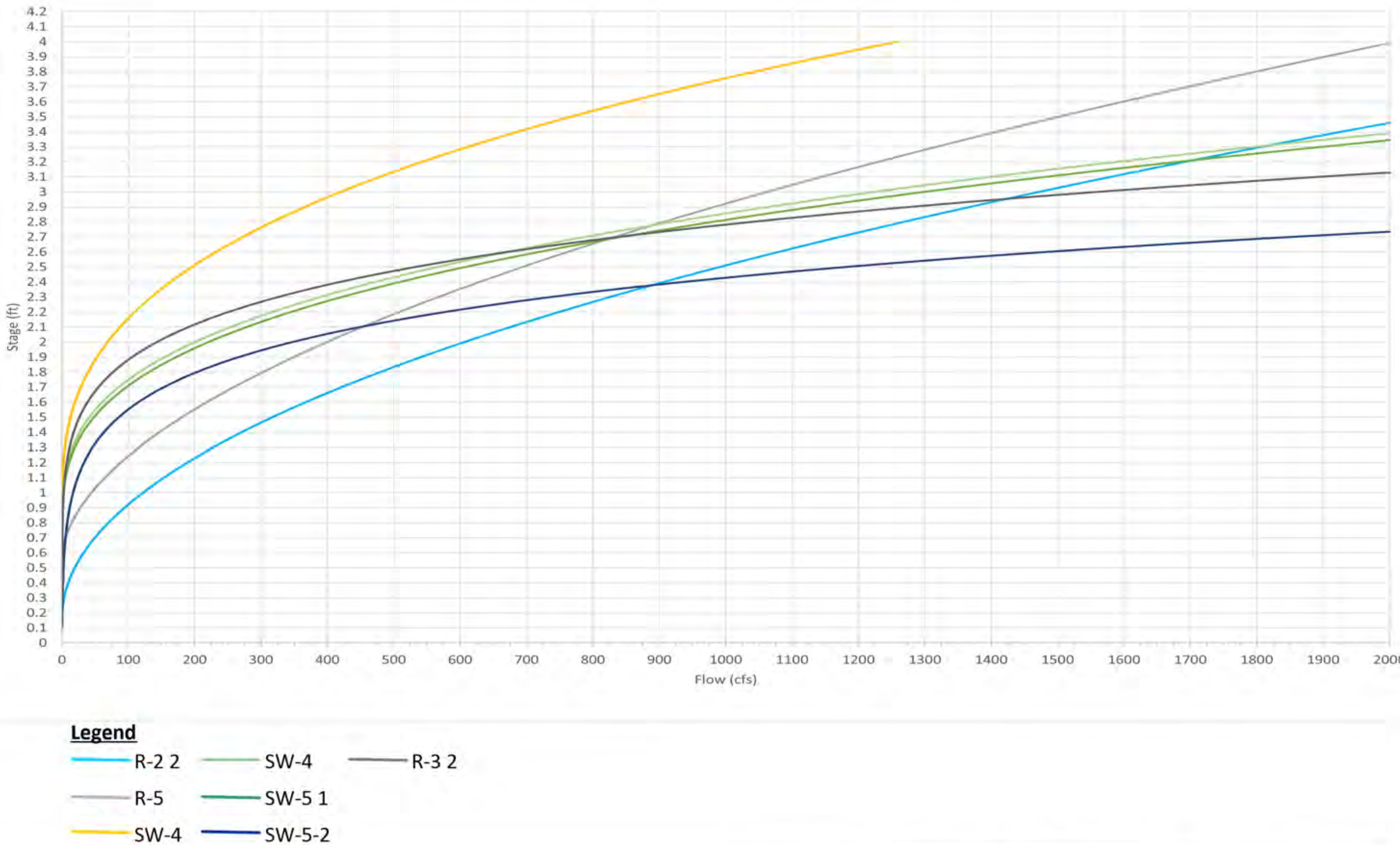
HUMBOLDT COUNTY GROUNDWATER SUSTAINABILITY AGENCY
EEL RIVER VALLEY GROUNDWATER SUSTAINABILITY PLAN

VAN DUZEN RIVER AND YAGER CREEK FLOW MEASUREMENTS

Project No. **11217388**
Date **November 2021**

FIGURE 6.15

Filename:\\ghdnet\ghd\US\Eureka\Projects\561\11217388\Tech\Model Predictions\Figures\FigureFiles\Figure 6.15 Van Duzen Monitored Stream Flow.srf
Plot Date: November 17 2021 7:11 PM



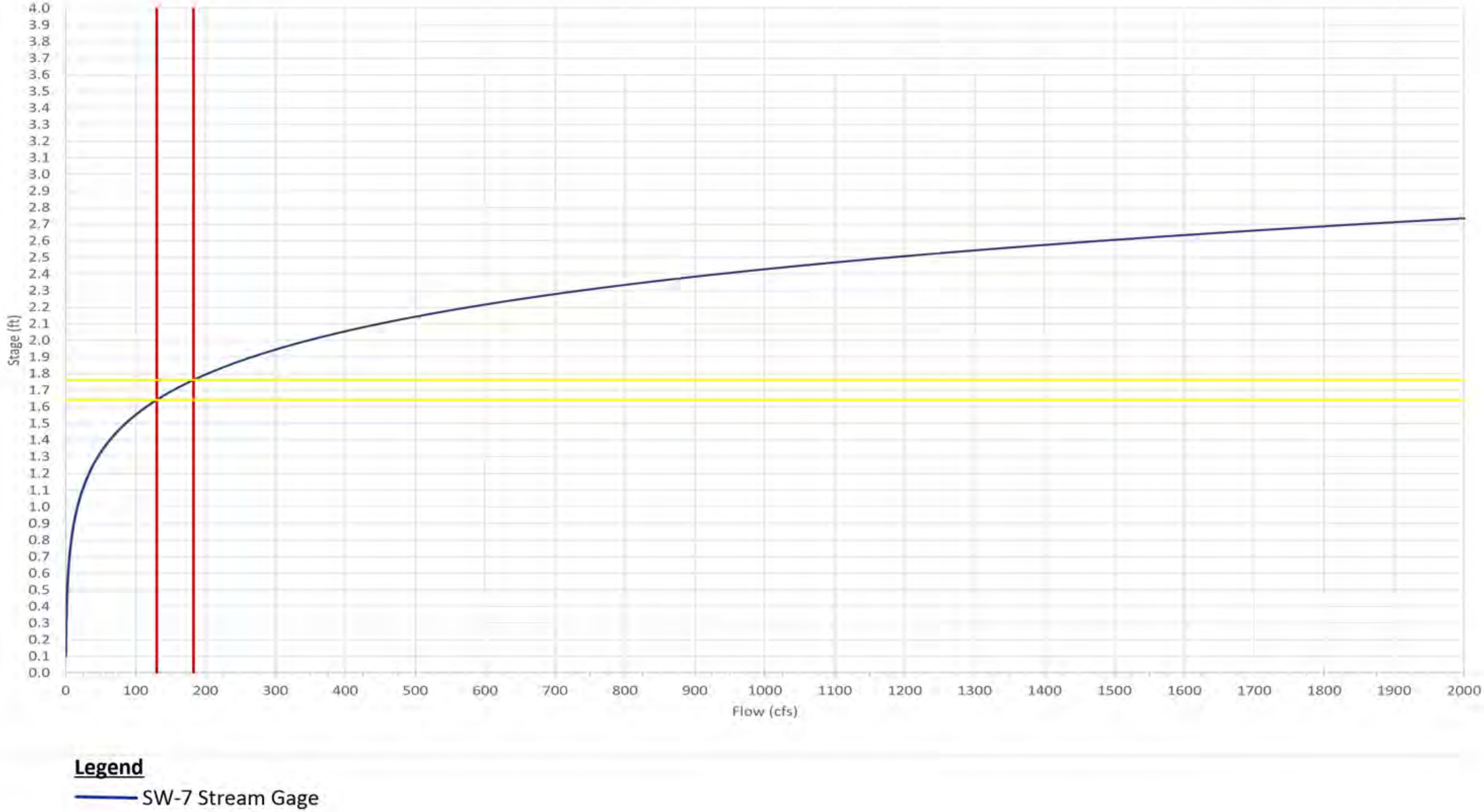
HUMBOLDT COUNTY GROUNDWATER SUSTAINABILITY AGENCY
EEL RIVER VALLEY GROUNDWATER SUSTAINABILITY PLAN

EEL RIVER DISCHARGE CURVES BY GAGE STATION

Project No. **11217388**
Date **November 2021**

FIGURE 6.16

Filename:\\ghdnet\ghd\US\Eureka\Projects\561\11217388\Tech\Model Predictions\Figures\FigureFiles\Figure 6.16 Stage Dischagre Curve.srf
Plot Date: November 17 2021 7:11 PM



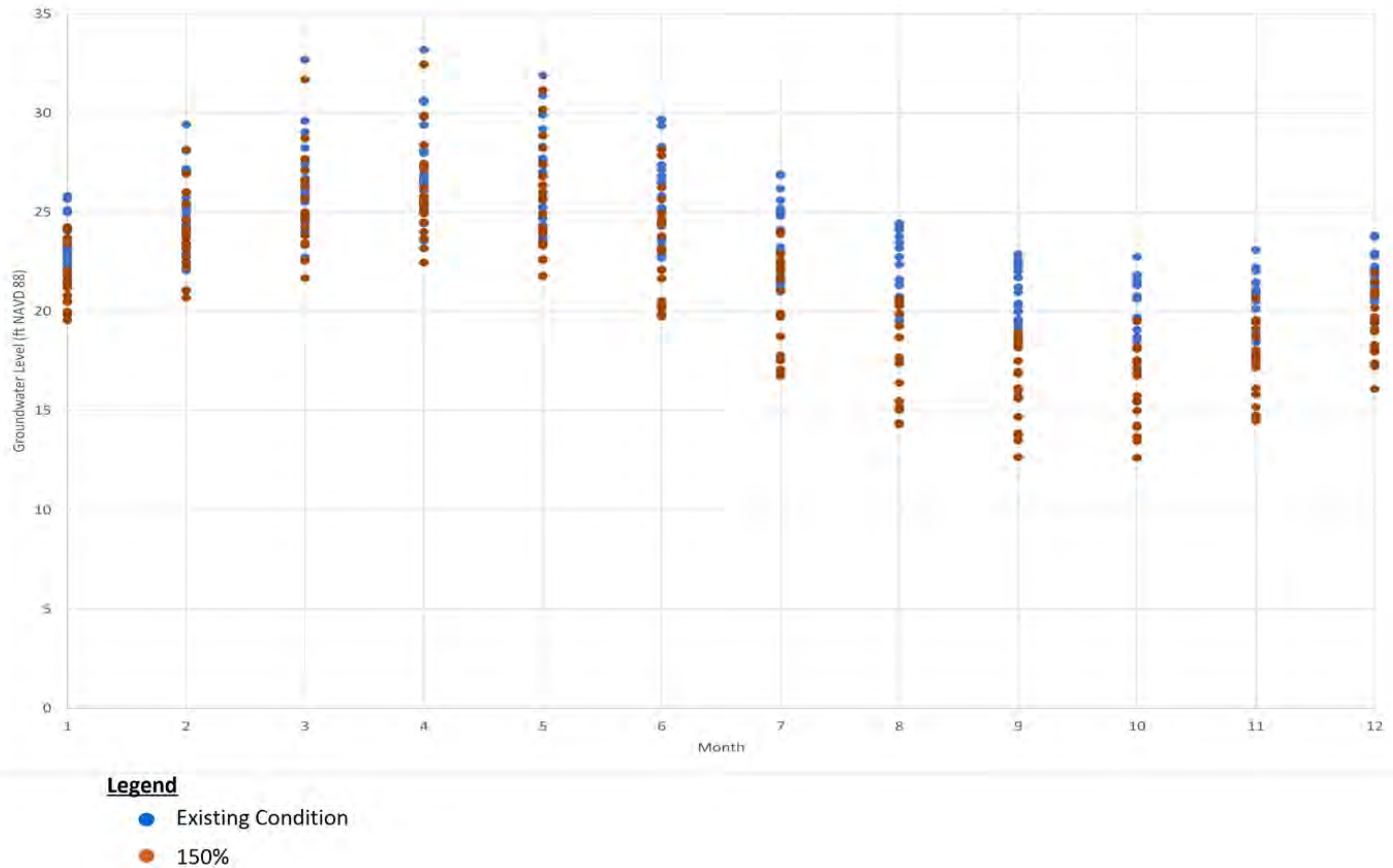
HUMBOLDT COUNTY GROUNDWATER SUSTAINABILITY AGENCY
EEL RIVER VALLEY GROUNDWATER SUSTAINABILITY PLAN

EEL RIVER ME-1
SW-7 STAGE DISCHARGE CURVE

Project No. 11217388
Date November 2021

FIGURE 6.17

Filename:\\ghdnet\ghd\US\Eureka\Projects\561\11217388\Tech\Model Predictions\Figures\FigureFiles\Figure 6.17 Stage Dischage Curve for SW-7.srf
Plot Date: November 17 2021 7:11 PM



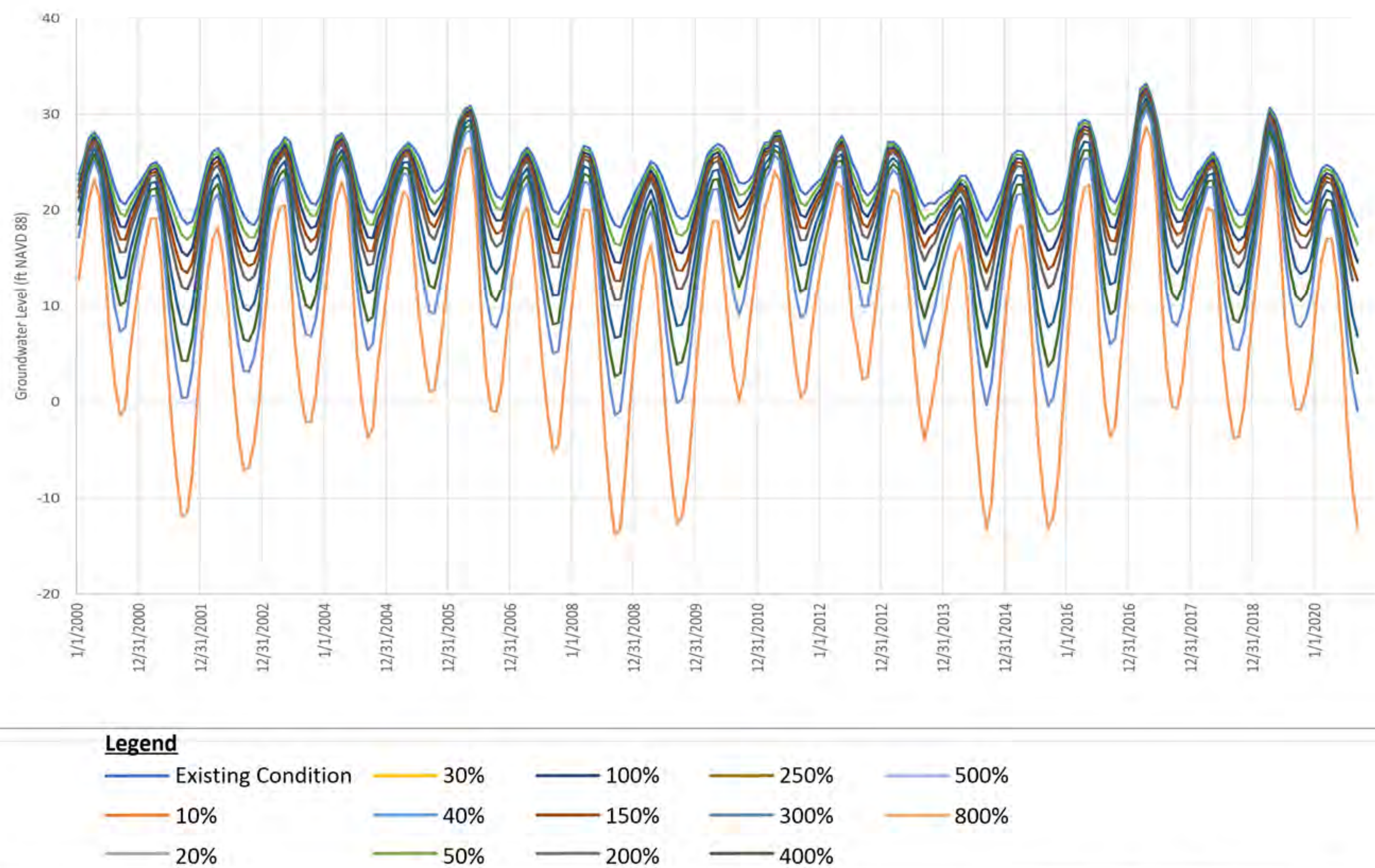
HUMBOLDT COUNTY GROUNDWATER SUSTAINABILITY AGENCY
EEL RIVER VALLEY GROUNDWATER SUSTAINABILITY PLAN

CASGEM 36942
MODELED HEAD BY MONTH

Project No. **11217388**
Date **November 2021**

FIGURE 6.18

Filename:\\ghdnet\ghd\US\Eureka\Projects\561\11217388\Tech\Model Predictions\Figures\FigureFiles\Figure 6.18 Modeled Monthly Average Groundwater Levels by Month of CASGEM Well 36942.srf
Plot Date: November 17 2021 7:11 PM



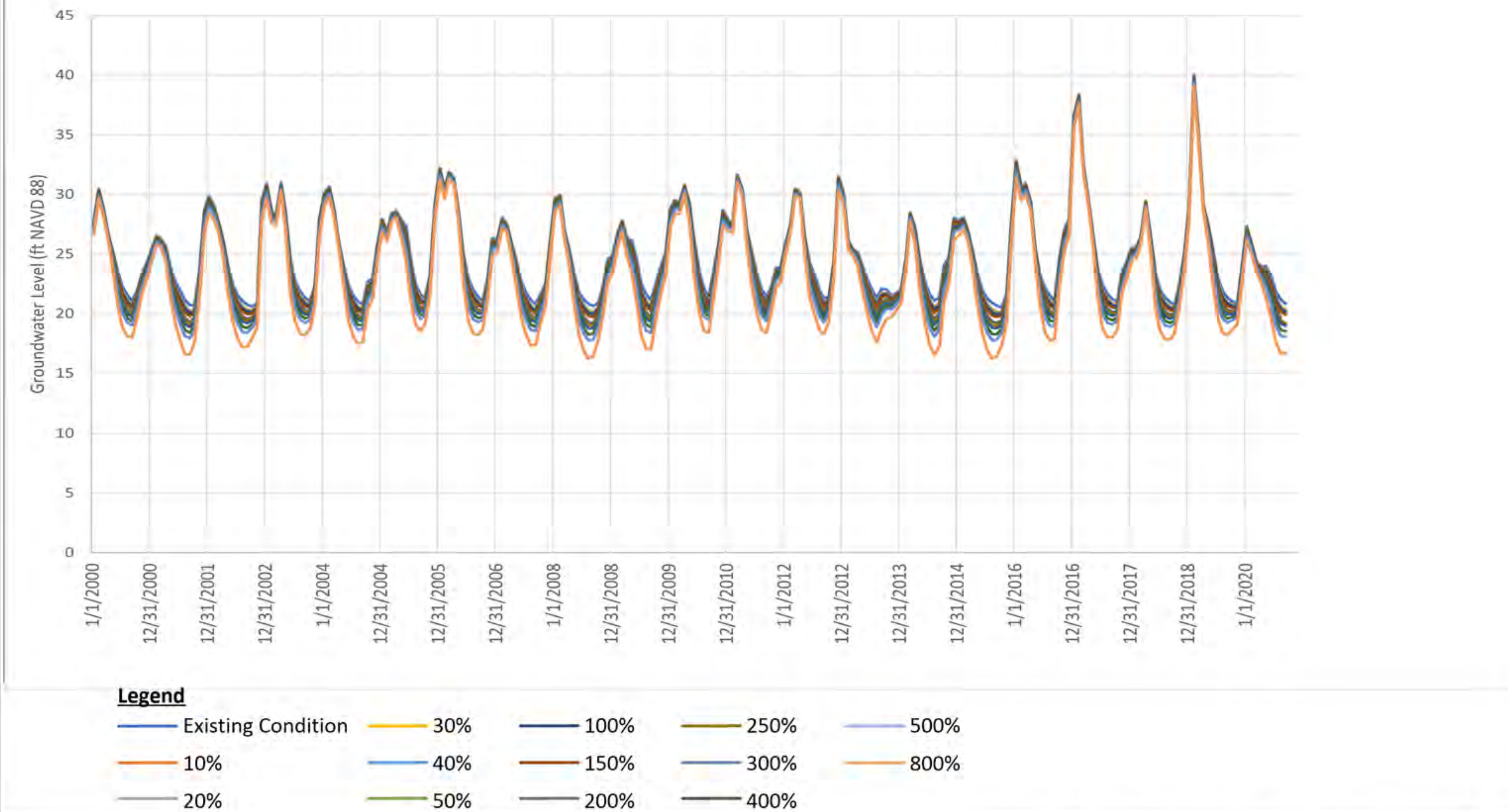
HUMBOLDT COUNTY GROUNDWATER SUSTAINABILITY AGENCY
EEL RIVER VALLEY GROUNDWATER SUSTAINABILITY PLAN

MONTHLY AVERAGE GROUNDWATER LEVELS CASGEM 36942

Project No. **11217388**
Date **November 2021**

FIGURE 6.19

Filename:\\ghdnet\ghd\US\Eureka\Projects\561\11217388\Tech\Model Predictions\Figures\FigureFiles\Figure 6.19 Modeled Monthly Average Groundwater Levels of CASGEM Well 36942.srf
Plot Date: November 17 2021 8:11 PM



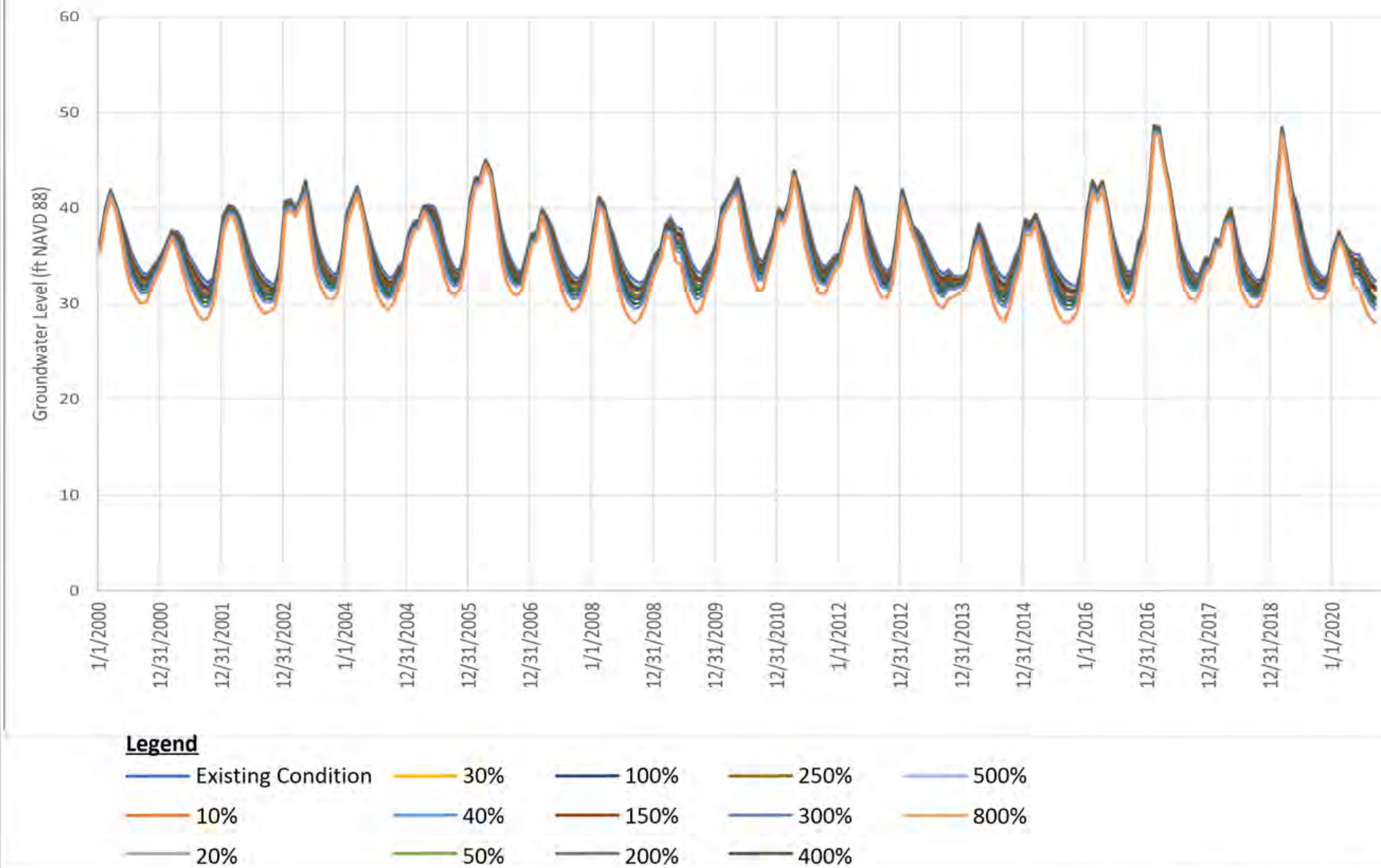
HUMBOLDT COUNTY GROUNDWATER SUSTAINABILITY AGENCY
EEL RIVER VALLEY GROUNDWATER SUSTAINABILITY PLAN

MONTHLY AVERAGE GROUNDWATER LEVELS MW-2s

Project No. **11217388**
Date **November 2021**

FIGURE 6.20

Filename:\\ghdnet\ghd\US\Eureka\Projects\561\11217388\Tech\Model Predictions\Figures\FigureFiles\Figure 6.20 Modeled Monthly Average Groundwater Levels of Well MW-2s.srf
Plot Date: November 17 2021 8:11 PM



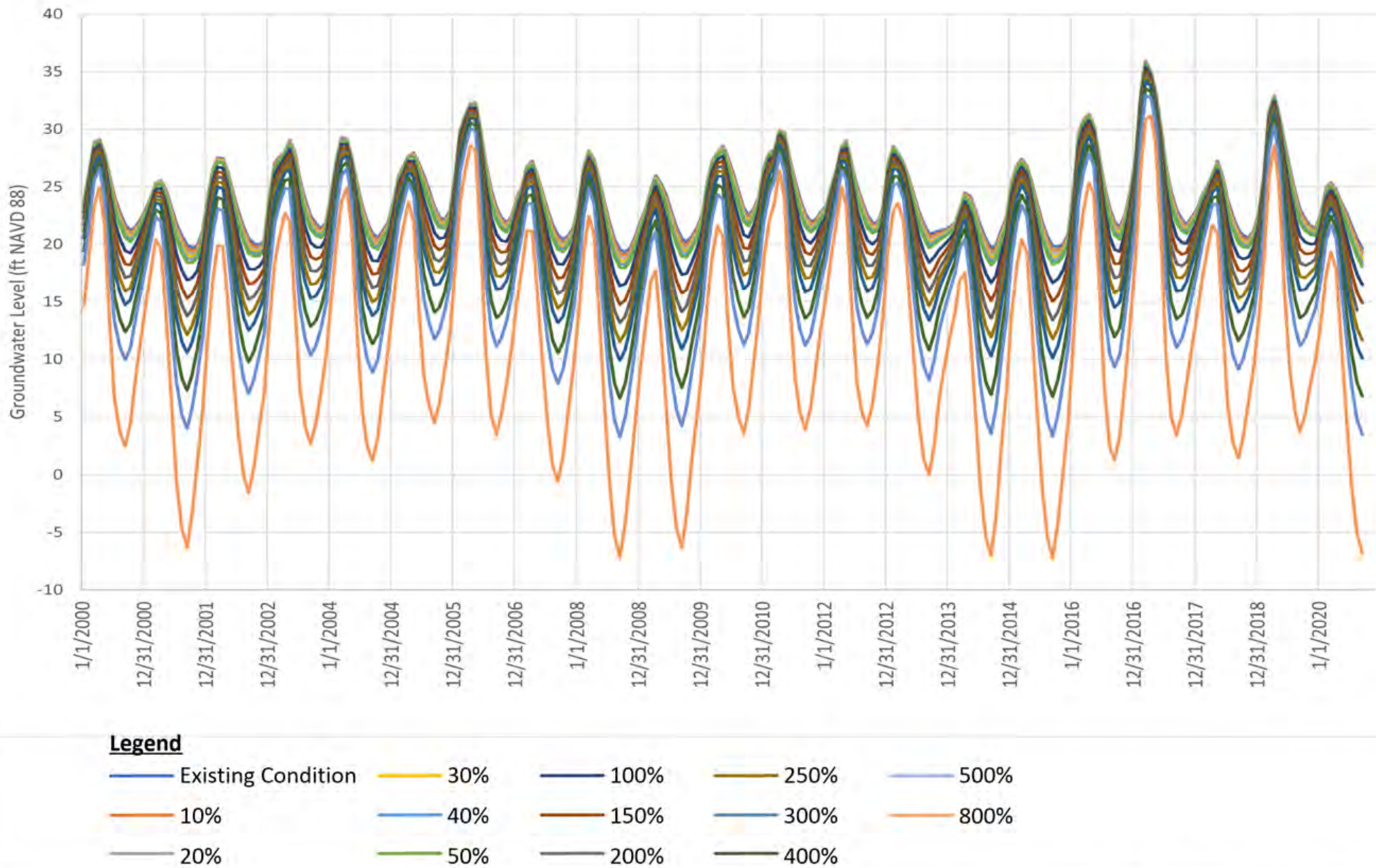
GHD

HUMBOLDT COUNTY GROUNDWATER SUSTAINABILITY AGENCY
EEL RIVER VALLEY GROUNDWATER SUSTAINABILITY PLAN

MONTHLY AVERAGE GROUNDWATER LEVELS MW-13

Project No. **11217388**
Date **November 2021**

FIGURE 6.21



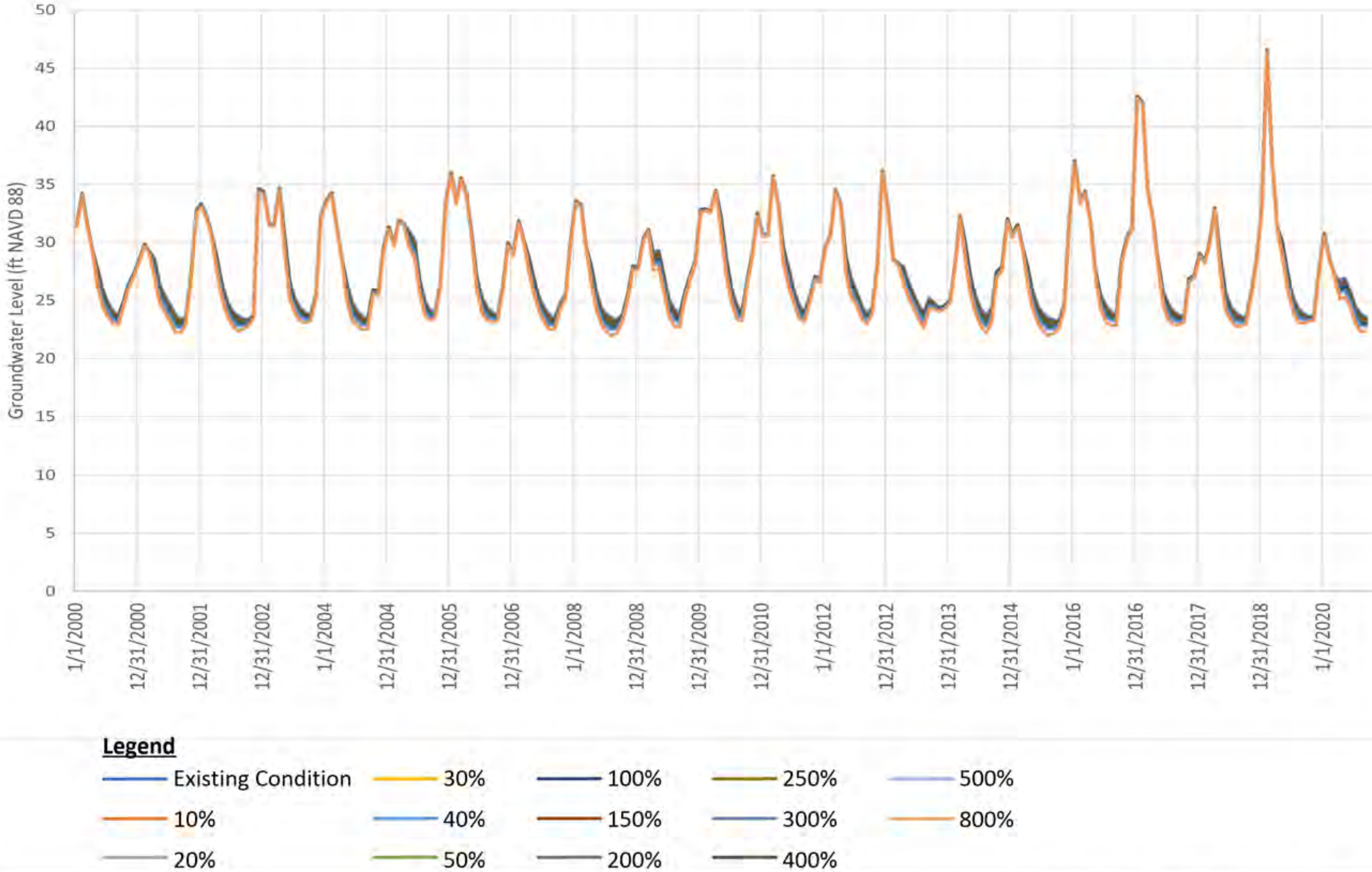
HUMBOLDT COUNTY GROUNDWATER SUSTAINABILITY AGENCY
EEL RIVER VALLEY GROUNDWATER SUSTAINABILITY PLAN

MONTHLY AVERAGE GROUNDWATER LEVELS MW-20

Project No. **11217388**
Date **November 2021**

FIGURE 6.22

Filename:\\ghdnet\ghd\US\Eureka\Projects\561\11217388\Tech\Model Predictions\Figures\FigureFiles\Figure 6.22 Modeled Monthly Average Groundwater Levels of Well MW-20.srf
Plot Date: November 17 2021 8:11 PM



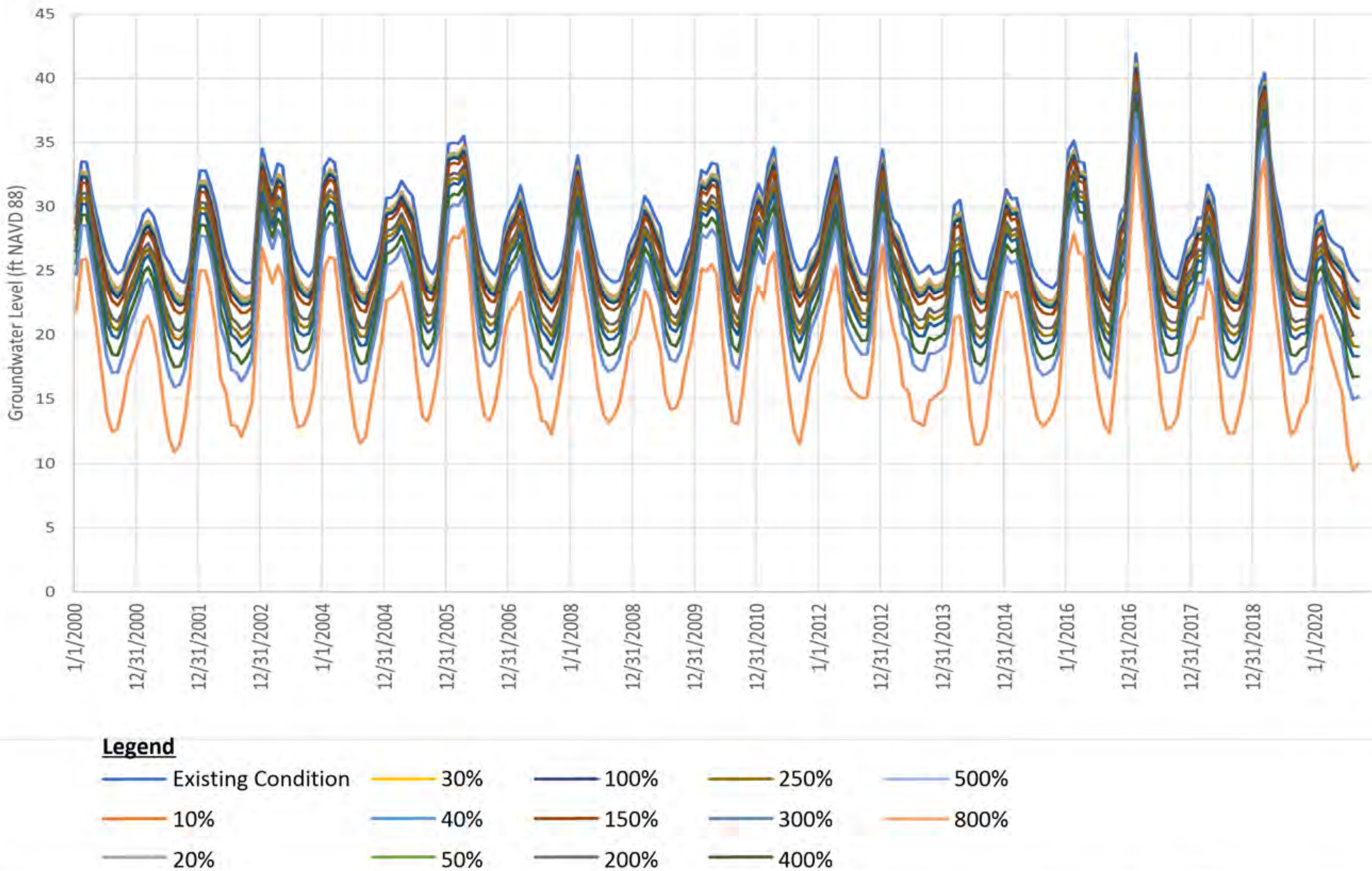
HUMBOLDT COUNTY GROUNDWATER SUSTAINABILITY AGENCY
EEL RIVER VALLEY GROUNDWATER SUSTAINABILITY PLAN

MONTHLY AVERAGE GROUNDWATER LEVELS MW-21

Project No. 11217388
Date November 2021

FIGURE 6.23

Filename:\\ghdnet\ghd\US\Eureka\Projects\561\11217388\Tech\Model Predictions\Figures\FigureFiles\Figure 6.23 Modeled Monthly Average Groundwater Levels of Well MW-21.srf
Plot Date: November 17 2021 8:11 PM

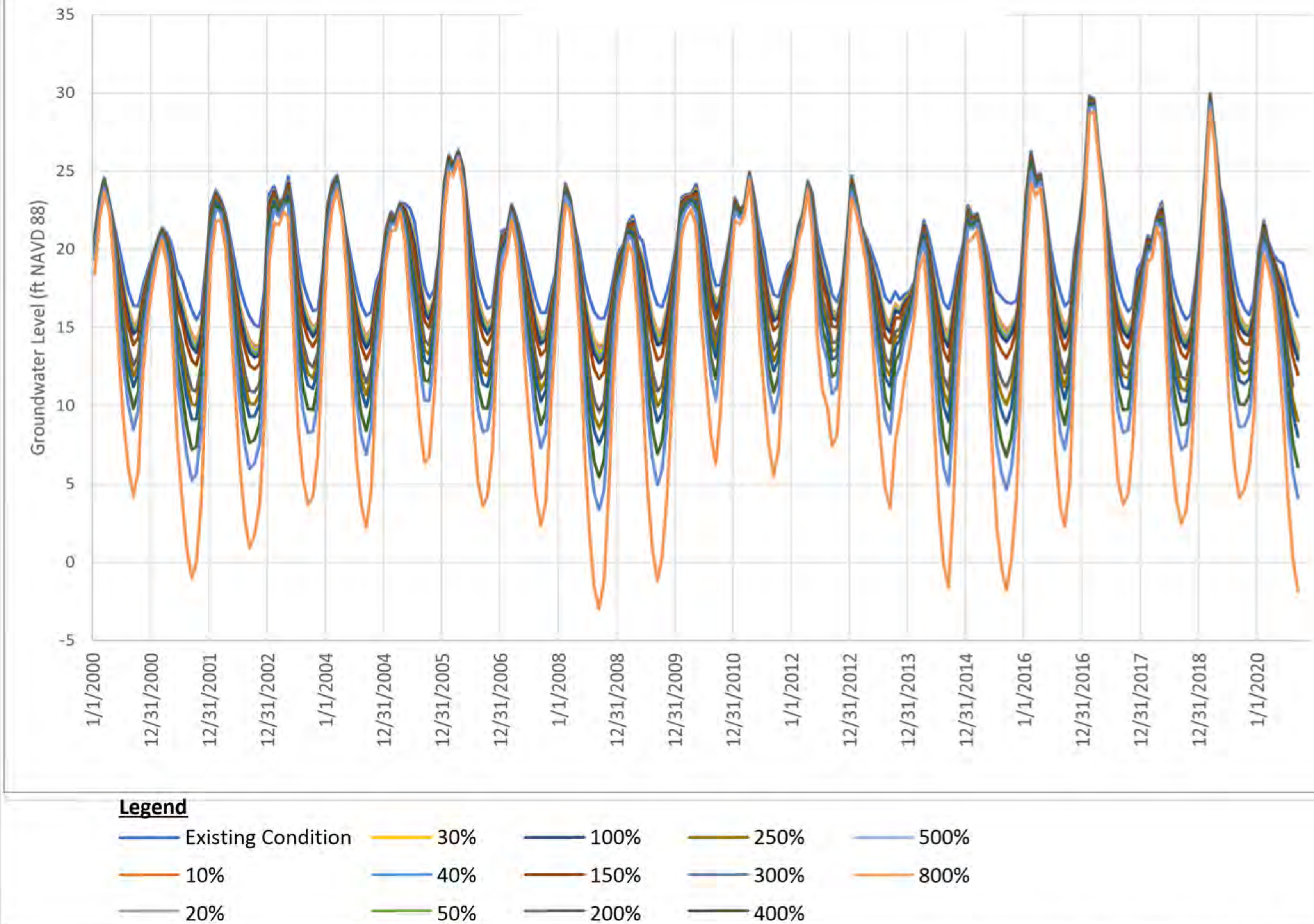


HUMBOLDT COUNTY GROUNDWATER SUSTAINABILITY AGENCY
EEL RIVER VALLEY GROUNDWATER SUSTAINABILITY PLAN

MONTHLY AVERAGE GROUNDWATER LEVELS MW-22

Project No. **11217388**
Date **November 2021**

FIGURE 6.24



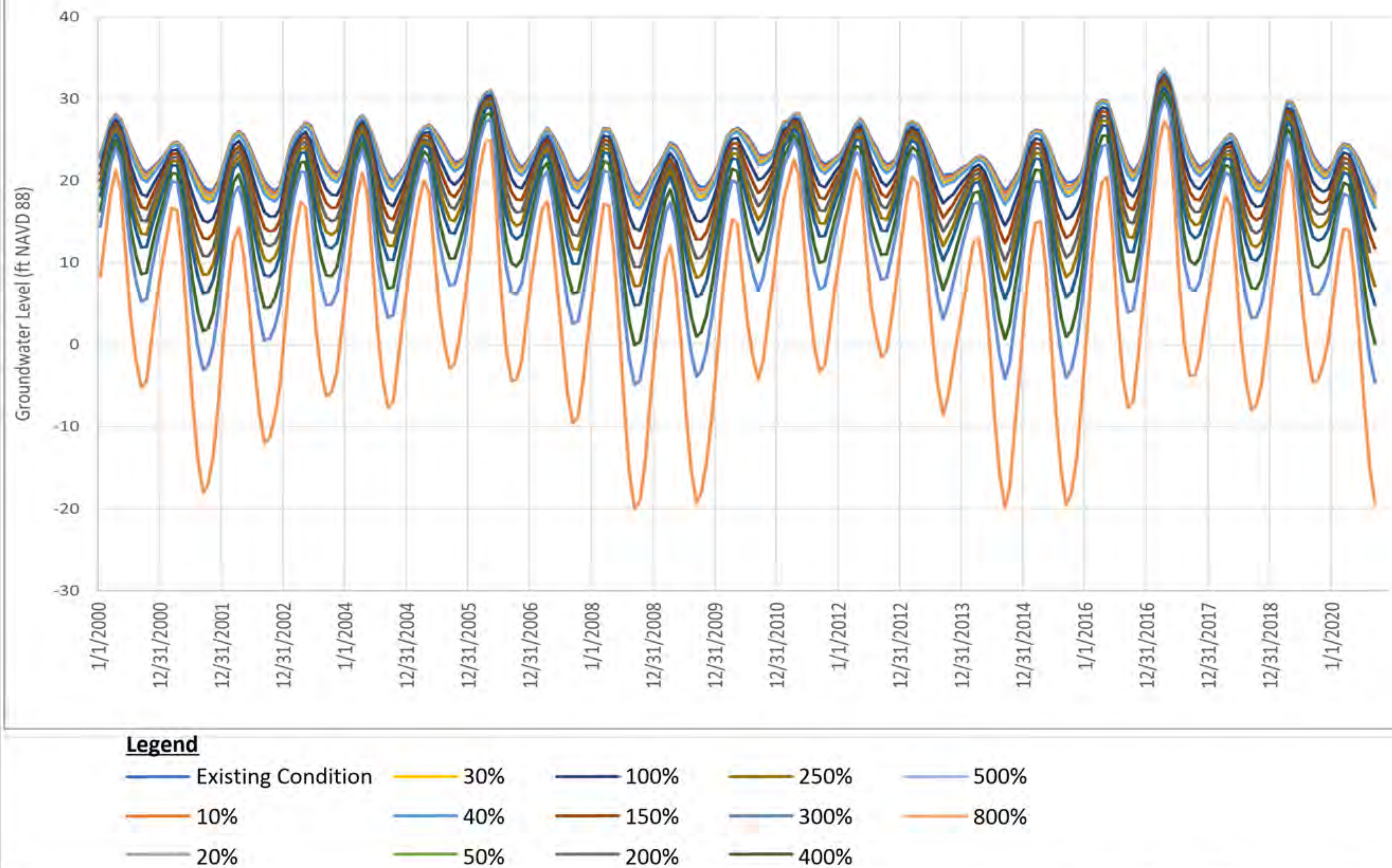
HUMBOLDT COUNTY GROUNDWATER SUSTAINABILITY AGENCY
EEL RIVER VALLEY GROUNDWATER SUSTAINABILITY PLAN

MONTHLY AVERAGE GROUNDWATER LEVELS MW-25

Project No. **11217388**
Date **November 2021**

FIGURE 6.25

Filename:\\ghdnet\ghd\US\Eureka\Projects\561\11217388\Tech\Model Predictions\Figures\FigureFiles\Figure 6.25 Modeled Monthly Average Groundwater Levels of Well MW-25.srf
Plot Date: November 17 2021 8:11 PM



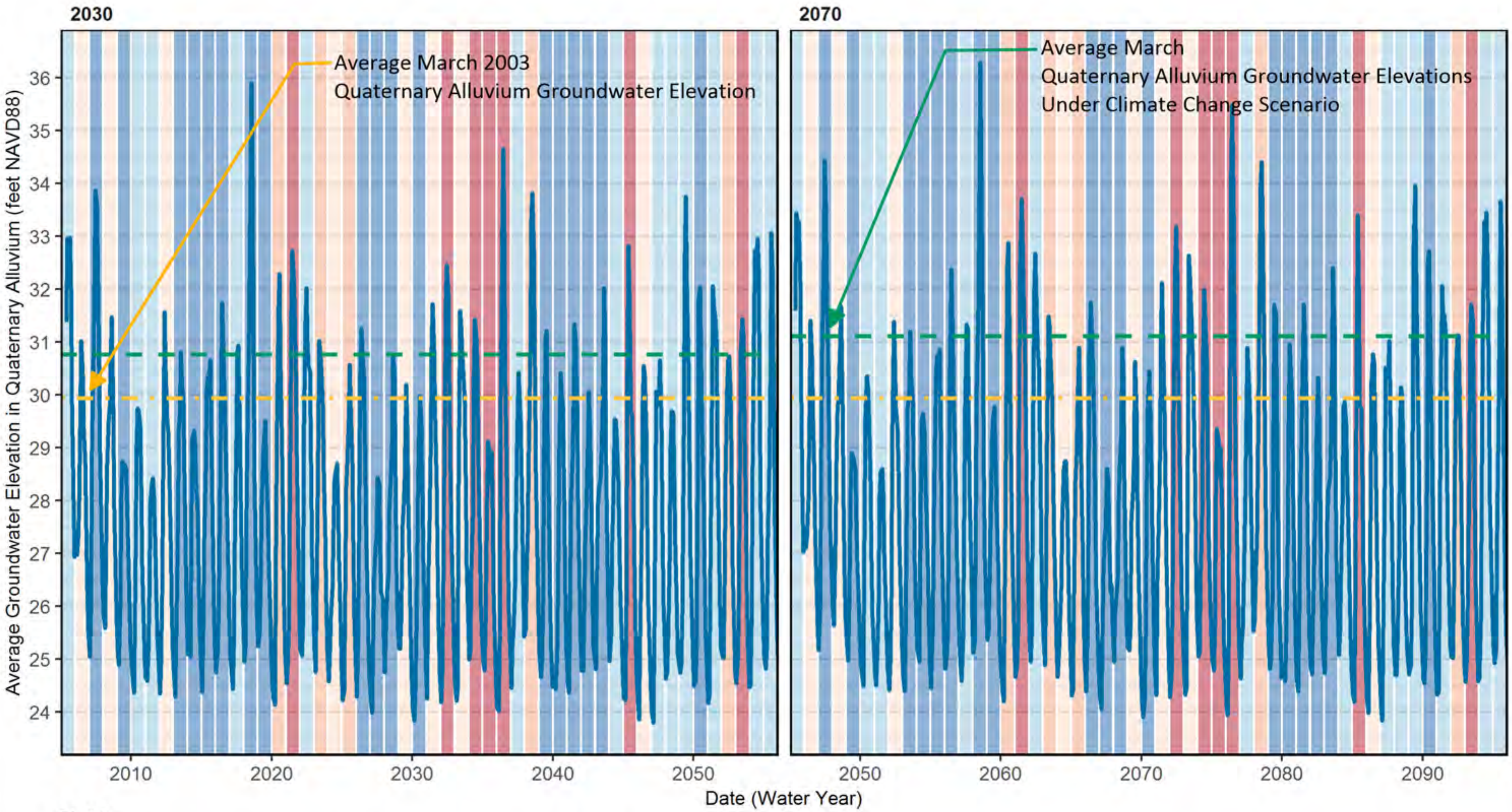
HUMBOLDT COUNTY GROUNDWATER SUSTAINABILITY AGENCY
EEL RIVER VALLEY GROUNDWATER SUSTAINABILITY PLAN

MONTHLY AVERAGE GROUNDWATER LEVELS MW-30

Project No. 11217388
Date November 2021

FIGURE 6.26

Filename:\\ghdnet\ghd\US\Eureka\Projects\561\11217388\Tech\Model Predictions\Figures\FigureFiles\Figure 6.26 Modeled Monthly Average Groundwater Levels of Well MW-30.srf
Plot Date: November 17 2021 8:11 PM



Note:
All averages represent average groundwater elevations in the Quaternary Alluvium

Water Year Type: Wet; Above Normal; Below Normal; Dry; Critical

HUMBOLDT COUNTY GROUNDWATER SUSTAINABILITY AGENCY
EEL RIVER VALLEY GROUNDWATER SUSTAINABILITY PLAN

AVERAGE GROUNDWATER ELEVATIONS UNDER CLIMATE CHANGE SCENARIOS

Project No. **11217388**
Date **January 2022**

FIGURE 6.27

Filename:\\ghdnet\ghd\US\Eureka\Projects\561\11217388\Tech\Model Predictions\Figures\FigureFiles\Figure 6.27 ClimateChangeGWE.srf
Plot Date: January 19 2022 5:01 PM