



Aquifer Parameters

Technical Memorandum Eel River Valley Groundwater Basin

Humboldt County Department of Public Works

Prepared for:

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1. Aquifer Parameters

1.1 Overview

Descriptive hydrogeologic conceptual models (HCM) are required in Groundwater Sustainability Plans (GSP) to characterize the physical components of the subject basin, as well as to describe the occurrence of groundwater and its movement in and out of the basin. The HCM is also the basis for the numerical integrated surface water-groundwater model used to simulate current and future basin conditions. The purpose of this technical memorandum (TM) is to provide a detailed description of the physical properties of the Eel River Valley Basin's (ERVB) aquifers and aquitards in relation to the HCM and to the numerical integrated surface water-groundwater model.

1.2 Principal Aquifers and Aquitards

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

1.2.1 Alluvial Aquifer

The alluvial aquifer is most prominent within the central portions of the lower Eel River Valley, where it is 260 feet thick, or greater. The alluvial aquifer extends up the Van Duzen River Valley thinning to less than 40 feet in the vicinity of the Town of Carlotta.

The alluvial aquifer is generally unconfined, however semi-confined conditions can occur where there are particularly thick fine-grained units near the surface. The surface waters of the Eel and Van Duzen rivers are generally in direct contact with the alluvial aquifer.

The physical characteristics of the alluvial aquifer reflect the dynamic tectonic and geomorphic history in the area and is observed to have significant lateral variation within the ERVB. In general, the alluvium is an accumulation of a variety of materials, tending to be coarser (sands, gravels) in areas where the river channels have migrated and finer (silts, clays) in areas where floodplain processes dominate. There are also thick sequences of fine-grained alluvial material along the base of the Wildcat hills, particularly where major streams have built alluvial fans (generally in the Ferndale area).

1.2.2 Carlotta Formation Aquifer

The Carlotta formation consists of coarse-grained clastic sediments interbedded with fine-grained units of variable thickness, deposited in a near-shore or terrestrial setting. Based on its texture and regional distribution, the Carlotta aquifer represents a principal aquifer in the ERVB. Groundwater within the unit is generally overlain and semi-confined by discontinuous silt and clay interbeds, and alluvium and terrace deposits. In general, it is not as productive as the alluvial aquifer.

The Carlotta formation is known to be in excess of 1,500 feet thick, locally as much as 4,000 feet thick (Ogle 1953; California Department of Water Resources [DWR], U.S. Geological Survey [USGS] 1978). However, only the upper part of the Carlotta formation has been tapped by wells, principally in upland areas such as the slopes flanking the northern and southern boundaries of the ERVB and up on the Hydesville/Rohnerville terrace surfaces.

1.2.3 Aquitards

Virtually all the stratigraphic sections within the ERVB include beds of fine-grained sediments, many of which are thick enough and/or of low enough permeability to act as aquitards. Well-defined, laterally continuous aquitards are not typical of the depositional environments in the ERVB and can be difficult to define with confidence.

Thick fine-grained units have been logged in many of Humboldt County's deeper monitoring wells (MW-5d, MW-7d, MW-8, MW-13d, MW-12d and MW-13d). Groundwater level monitoring in wells screened in aquifers above and below these units often indicate that a confined or semi-confined condition exists below these units. The Carlotta formation is known to contain fine-grained interbeds that form localized aquitards up to 50 feet thick, but these are not well understood because very few wells penetrate deeper than 200 feet.

A significant aquitard was identified recently, in the spring of 2021, during the installation of MW-12d and MW-13d within the lower Van Duzen River Valley. The aquitard was also identified in an exploratory boring installed at the City of Fortuna's well field, off Eel River Drive just south of the City. The approximately 40-foot-thick aquitard is encountered at depths of 100 to 140 feet below grade and is interpreted to be laterally continuous east of the Eel River; it is not known if the aquitard extends beneath the Eel River. This aquitard is believed to separate the alluvial and Carlotta formations, with groundwater levels separated by the aquitard, differing by up to a few feet.

1.3 Aquifer Hydraulic Characteristics

There are two (2) general types of aquifer properties relevant to groundwater management:

1. **Groundwater transmission properties:** control the relationship between hydraulic gradients and the rate of groundwater flow
2. **Aquifer storage properties:** control the relationship between the volume of groundwater stored in the aquifer and the water elevation measured in the aquifer

It is understood that the hydraulic characteristics of the aquifers within the ERVB are generally derived from past DWR/USGS reports (1959, 1965, 1978) and the studies carried out as part of the County's response to the Sustainable Groundwater Management Act (SGMA) (Alternative Plan 2016 and current study). Where hydrogeologic properties have not been measured in the ERVB, aquifer properties have been estimated through model calibration. Aquifer property calibration has been completed for numerous published modeling studies, including by Durbin (1974), Yates (1988), and WRIME (2003).

Recent data collection and analysis from the County's 2016 Alternative Plan, as well as through the development of this 2021 GSP and related numerical modeling, offer insight to the ERVB's physical characteristics. Still, ERVB geometry and hydrogeological components are complex, so future data and monitoring integrated with numerical modeling will significantly improve understanding of the basin. Data gaps and important uncertainties are discussed in Section 2.1 of this TM.

1.3.1 Groundwater Transmission Properties

To evaluate the alluvial and Carlotta formations aquifers' parameters, aquifer testing has been conducted on 36 County monitoring wells, installed at key locations in the ERVB in 2016 and 2021, shown in Figure 1. Hydraulic conductivity within the screened aquifers of the wells was evaluated by analyzing data from pneumatic slug tests performed following the wells' initial construction and development. Wells MW-1s/d, MW-2s/d, MW-3d, MW-7s/d, MW-9s/d, MW-10, and MW-11 were tested between November 1, 2016 and November 15, 2016, while wells MW-12 through MW-30 were tested between June 17, 2021 and July 2, 2021. Depths of the wells range from 20 to 250 feet below the ground surface (bgs).

The method for pneumatic slug testing involves:

1. Attaching a valve cluster and regulator to the well head
2. Installing a pressure transducer in the well

3. Determining the pre-test equilibrium water level
4. Pressurizing to between 30 and 40 pounds per square inch (psi)
5. Releasing the pressure and recording data until the water level returns to the pre-test level

At least three (3) tests were performed to ensure stable results. The test data was then analyzed using either Bouwer and Rice (1976) or the van der Kamp (1976) methods. The Bouwer and Rice method is used for water levels that smoothly and gradually returned to the pre-test level, and the van der Kamp method is used when the water level oscillated back to the pre-test level. Results of the analysis are included in Appendix 1, Table 1.

Hydraulic conductivities of the alluvial aquifer, as measured in County wells, range from 0.1 feet per day (ft/day) in the shallow fine-grained sediments west of Fortuna to as high as 420 ft/day in the channel alluvium adjacent to the active Eel River channel.

Monitoring wells MW-1s/d, MW-2s/d, MW-3d, MW-7d, MW-8, MW-12s, MW-14d, MW-24, and MW-26 had the highest hydraulic conductivities, ranging from 110 to 420 ft/day. These values, with exception to MW-8, correspond to the alluvial aquifer adjacent to the Eel River, which is composed of relatively shallow channel deposits of unconsolidated sand and gravel. MW-8 is screened in the gravelly alluvium below a 120-foot-thick deposit of silt.

Monitoring wells MW-5d, MW-9s/d, MW-10, MW-11, MW-13s/d, MW-14s, MW-15s/d, MW-18, MW-19, MW 25, MW-28, and MW-30 had low to moderate hydraulic conductivities, between 10 and 100 ft/day. These values correspond to older (deeper) alluvium deposits and/or Carlotta deposits.

Monitoring wells MW-7s, MW-12d, MW-16, MW-17, MW-20, MW-21, MW-22, MW-23, MW-27, and MW-29 had low hydraulic conductivities, between 0.1 and 8.3 ft/day, which correspond to relatively consolidated alluvium or areas with a higher percentage of fine-grained soils, predominantly silt.

Vertical hydraulic conductivities throughout the ERVB, particularly between the contacts of the alluvial aquifer and the Carlota formation, have not been previously studied, though they have been estimated through finite-difference flow modeling calibration in this GSP. In general, estimated vertical hydraulic conductivities range from 6 to 10 percent of lateral hydraulic conductivities.

1.3.2 Aquifer Storage Properties

The alluvial aquifer is a high production unit that is widely used for agricultural irrigation and municipal water. The depth to groundwater is generally shallow, with the water table measuring a few feet to as many as 40 feet bgs. This indicates a relatively high specific yield for the alluvial aquifer and high specific capacities of production wells completed in this unit, with water levels responding quickly to recharge rain events. Specific well capacities are typically 20 to 350 gallons per minute (GPM) per foot (GPM/ft) of drawdown (Johnson 1978), although they may locally be as high as 600 GPM/ft of drawdown (DWR 1965).

Specific storage values for partially or completely confined areas of the ERVB have been previously measured, with the primary data provided by Evenson (1959), who estimated an average specific yield of 22 percent. Due to the nature of the ERVB abutting the Pacific Ocean, a fixed head boundary influences the available aquifer storage. Therefore, it is important to look at the volume of water in the aquifer as storage fluxing annually, where years of above average precipitation increase aquifer storage and years of below average precipitation decrease aquifer storage.

1.4 Eel River Valley Basin Boundaries

The boundaries of the ERVB influence the hydraulic transmission properties of the aquifer's groundwater flow direction and are currently unquantified. The ERVB is bounded on the south side by the Wildcat Range, a mountainous area formed by north-dipping sediments of the Wildcat Group in the southern limb of the Eel River syncline. Specifically, the ERVB includes the portions of the Wildcat Range underlain by the uppermost, coarse-grained member of the Wildcat Group (the Carlotta formation).

The northern side of the Basin is bounded by the axis of the Table Bluff anticline to the west and the mapped main trace of the Little Salmon fault to the east. The Little Salmon fault is a prominent, active, northwest-trending, northeast-dipping thrust fault that accommodates triple-junction related crustal shortening and is generally believed to be the confining boundary to groundwater flow to the north side of the ERVB. This boundary is generally considered and assumed here to be a groundwater flow boundary.

The western boundary of the ERVB abuts the Pacific Ocean, where the Eel River and underlying aquifers flow and mix with seawater.

The eastern limits of the ERVB are defined by the extent of the mapped Carlotta formation with some extensions to include the terraces and shallow alluvial materials of the Eel and Van Duzen rivers. Bedrock inflows from the southern and eastern limits of the basin have been relatively unstudied and are preliminarily considered to contribute a negligible amount of groundwater on a year-to-year basis, until more information is collected.

The ERVB bottom is defined by the base of the Carlotta formation where it is in contact with the Scotia Bluffs Sandstone and other finer-grained units of the Wildcat Group. The base of the ERVB is not well constrained, as the Carlotta formation is several thousand feet thick in places and exploration of groundwater potential, flow characteristics, and aquifer parameters has not penetrated to those depths.

Due to the uncertainty of the ERVB bottom and the fact that no wells tap into the middle or lower portions of the Carlotta formation, the ERVB bottom has been initially modeled in this GSP, using geologic cross-sections and lithological descriptions of the exposed sections of the Wildcat Group south and north of the Basin (Ogle 1953), to terminate at 1,500 feet with no vertical conductivity between the Carlotta formation and the underlying Wildcat Group.

2. Conclusions

The vast majority of groundwater use in the ERVB occurs in the alluvial aquifer channel deposits, where the range of hydraulic conductivities and specific yield are relatively high, and the overall aquifer depth to water from the ground surface is relatively shallow. Thus, the following conclusions apply:

1. Water supply wells generally have a limited radius of influence and minimal interference with near vicinity wells.
2. Annual aquifer recharge occurs rapidly.
3. The volume of water in the aquifer as storage within any given year occurs as with an annual flux, not as a closed system, and likely cannot be used for groundwater banking as a specific management approach.

2.1 Aquifer Parameters Data Gaps and Uncertainty

Data gaps within the current aquifer parameters include:

- The stratigraphy within the surficial alluvium is complex. Lateral and vertical stratigraphic variations are the result of a dynamic geologic history influenced by tectonics, sea level fluctuations, and large river systems with high sedimentation rates. The size and geometric configuration of the aquifer(s) associated with the alluvial unit, particularly at depth, are not entirely understood. Similarly, the thicknesses and continuity of silt/clay layers (aquitards) across the ERVB are not fully delineated.
- Although the 2016 Alternative Plan and this 2021 GSP have generally defined the uppermost portions of the Carlotta formation aquifer, little is known about the hydrogeologic characteristics of the lower underlying Carlotta formation aquifers. The aquifer transmission and storage relationship between the base of the alluvial aquifer and top of the Carlotta aquifer is not well understood, particularly in the central and westernmost portion of the ERVB. Further, there

is little available information about lower aquitards within the Carlotta formation; multiple aquifers likely exist within the unit. Additionally, there are no data in relation to the thickness of the water-bearing part of the unit; the unit is up to 4,000 feet thick in places.

- The stratigraphy and aquifer characteristics associated with the Rohnerville and Hydesville terraces have not been studied in detail. These areas are unique in their setting, but do not play a significant role in overall water use in the ERVB.
- The fault zone associated with the Little Salmon fault and secondary faults within the ERVB are not well understood in terms of their impact and control of groundwater flow dynamics at the boundaries of and internally within the ERVB.

3. References

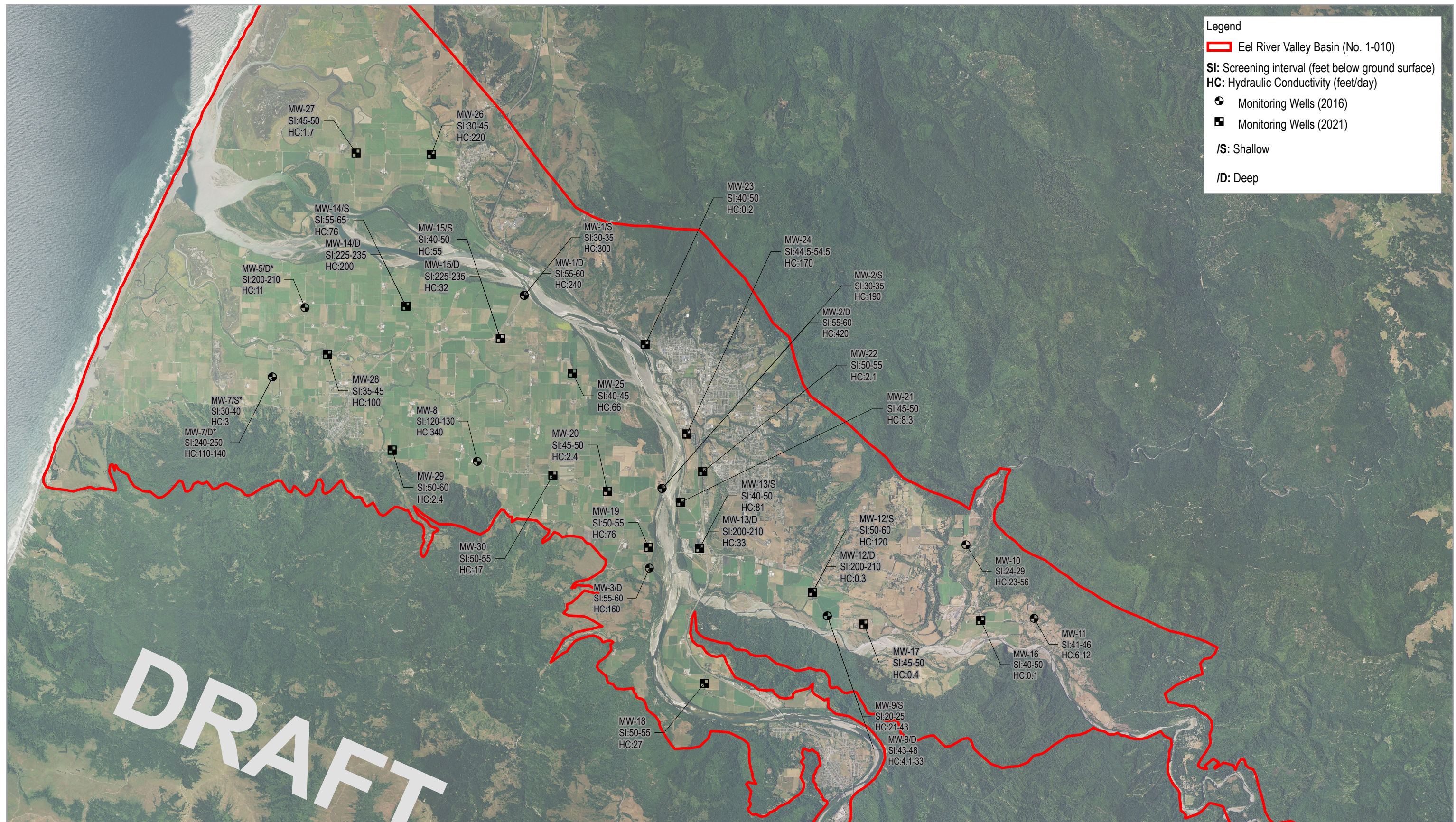
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Appendix A Figures and Tables



Legend

- ▬ Eel River Valley Basin (No. 1-010)
- SI:** Screening interval (feet below ground surface)
- HC:** Hydraulic Conductivity (feet/day)
- Monitoring Wells (2016)
- Monitoring Wells (2021)
- /S:** Shallow
- /D:** Deep



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

Humboldt County Department of Public Works
Eel River Groundwater
Sustainability Plan

Project No. 11217388
Revision No. -
Date Sept 2021

**Conductivity Values for
County Monitoring Wells**

FIGURE 1

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Data source: NAIP_orhio_Caf023_2020. Created by: jlopez4

Table 1
Aquifer Slug Test Results

Monitoring Well ID	Screened Interval ¹ (feet)	Aquifer Material	Hydraulic Conductivity (feet per day)
MW-1d ²	55-60	Sand and Gravel	240
MW-1s ³	30-35	Sand and Gravel	300
MW-2d	55-60	Gravel	420
MW-2s	30-35	Sand and Gravel	190
MW-3d	55-60	Sand and Gravel	160
MW-5d ⁴	200-210	Sand and Gravel	11
MW-7d ⁴	240-250	Sand and Gravel	110-140
MW-7s ⁴	30-40	Silt	3
MW-8	120-130	Gravel	340
MW-9d	43-48	Sand	4.1-33
MW-9s	20-25	Sand and Gravel	21-43
MW-10	24-29	Sand and Gravel	23-56
MW-11	41-46	Sand and Gravel	6-12
MW-12s	50-60	Sand and Gravel	120
MW-12d	200-210	Sand, Silt, Clay, and Gravel	0.3
MW-13s	40-50	Sand and Gravel	81
MW-13d	200-210	Sand	33
MW-14s	55-65	Sand and Gravel	76
MW-14d	225-235	Sand and Gravel	200
MW-15s	40-50	Sand and Gravel	55
MW-15d	225-235	Sand and Gravel	32
MW-16	40-50	Silt	0.1
MW-17	45-50	Sand, Silt, and Gravel	0.4
MW-18	50-55	Silt and Gravel	27
MW-19	50-55	Sand and Gravel	76
MW-20	45-50	Sand	2.4
MW-21	45-50	Sand and Gravel	8.3
MW-22	50-55	Sand and Gravel	2.1
MW-23	40-50	Sand and Silt	0.2
MW-24	44.5-54.5	Sand and Gravel	170
MW-25	40-45	Sand and Gravel	66
MW-26	30-45	Sand and Gravel	220
MW-27	45-50	Sand and Silt	1.7
MW-28	35-45	Sand, Silt, and Gravel	100
MW-29	50-60	Silt and Gravel	2.4
MW-30	50-55	Sand and Gravel	17

1. depth reference off of the top of the well box
2. d: deep
3. s: shallow
4. Additional well development at monitoring wells was performed following the performance of the pneumatic slug testing, so the actual hydraulic conductivity may be higher than shown.