Appendix A

Alternative Elements Guide

Alternative Elements Guide

California Code of Regulations - GSP Regulation Sections	*Alternative Elements*	Document which *attachment(s) contains the applicable alternative element.*	*Document which section(s), page number(s), or briefly describe why that Alternative element does not apply to the entity.*
Article 5 - Plan Contents			
SubArticle 1	**Administrative Information**		
§ 354.4.	**General Information**		
	(a) An executive summary written in plain language that provides an overview of the Plan and description of groundwater conditions in the basin.	GSP Alternative (SHN/Humboldt County, 2016)	Page i
	(b) A list of references and technical studies relied upon by the Agency in developing the Plan. Each Agency shall provide to the Department electronic copies of reports and other documents and materials cited as references that are not generally available to the public	GSP Alternative (SHN/Humboldt County, 2016)	Section 7.0
§ 354.6.	**Agency Information**		
	When submitting an adopted Plan to the Department, the Agency shall include a copy of the information provided pursuant to Water Code Section 10723.8, with any updates, if necessary, along with the following information:		
	(a) The name and mailing address of the Agency.	GSP Alternative (SHN/Humboldt County, 2016)	Section 2.5
	(b) The organization and management structure of the Agency, identifying persons with management authority for implementation of the Plan.	GSP Alternative (SHN/Humboldt County, 2016)	Section 2.5
	(c) The name and contact information, including the phone number, mailing address and electronic mail address, of the plan manager.	GSP Alternative (SHN/Humboldt County, 2016)	Section 2.5
	(d) The legal authority of the Agency, with specific reference to citations setting forth the duties, powers, and responsibilities of the Agency, demonstrating that the Agency has the legal authority to implement the Plan.	GSP Alternative (SHN/Humboldt County, 2016)	Section 2.5 and Appendix C
	(e) An estimate of the cost of implementing the Plan and a general description of how the Agency plans to meet those costs.	GSP Alternative (SHN/Humboldt County, 2016)	Section 5.0
§ 354.8.	**Description of Plan Area**		
	Each Plan shall include a description of the geographic areas covered, including the following information:		
	(a) One or more maps of the basin that depict the following, as applicable:		
	(1) The area covered by the Plan, delineating areas managed by the Agency as an exclusive Agency and any areas for which the Agency is not an exclusive Agency, and the name and location of any adjacent basins.	GSP Alternative (SHN/Humboldt County, 2016)	Figures 1-1 and 2-1
	(2) Adjudicated areas, other Agencies within the basin, and areas covered by an Alternative.	n/a	There are no adjudicated areas within the basin
	(3) Jurisdictional boundaries of federal or state land (including the identity of the agency with jurisdiction over that land), tribal land, cities, counties, agencies with water management responsibilities, and areas covered by relevant general plans.	GSP Alternative (SHN/Humboldt County, 2016)	Figure 2-1
	(4) Existing land use designations and the identification of water use sector and water source type.	GSP Alternative (SHN/Humboldt County, 2016)	Figure 2-3 and Appendix D

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	(5) The density of wells per square mile, by dasymetric or similar mapping techniques, showing the general distribution of agricultural, industrial, and domestic water supply wells in the basin, including de minimis extractors, and the location and extent of communities dependent upon groundwater, utilizing data provided by the Department, as specified in Section 353.2, or the best available information.	GSP Alternative (SHN/Humboldt County, 2016)	Figure 2-2
	(b) A written description of the Plan area, including a summary of the jurisdictional areas and other features depicted on the map.	GSP Alternative (SHN/Humboldt County, 2016)	Section 2.1
	(c) Identification of existing water resource monitoring and management programs, and description of any such programs the Agency plans to incorporate in its monitoring network or in development of its Plan. The Agency may coordinate with existing water resource monitoring and management programs to incorporate and adopt that program as part of the Plan.	GSP Alternative (SHN/Humboldt County, 2016)	Section 2.7
	(d) A description of how existing water resource monitoring or management programs may limit operational flexibility in the basin, and how the Plan has been developed to adapt to those limits.	n/a	Existing monitoring and management programs do not create operational limits.
	(e) A description of conjunctive use programs in the basin.	n/a	Conjunctive use is not practiced in the basin.
	(f) A plain language description of the land use elements or topic categories of applicable general plans that includes the following:		
	(1) A summary of general plans and other land use plans governing the basin.	GSP Alternative (SHN/Humboldt County, 2016)	Section 2.8
	(2) A general description of how implementation of existing land use plans may change water demands within the basin or affect the ability of the Agency to achieve sustainable groundwater management over the planning and implementation horizon, and how the Plan addresses those potential effects.	GSP Alternative (SHN/Humboldt County, 2016)	Section 2.8
	(3) A general description of how implementation of the Plan may affect the water supply assumptions of relevant land use plans over the planning and implementation horizon.	n/a	The GSP Alternative documents abundant water supply and sustainable groundwater management; the need to consider reduced water supplies within the next 5 to 10 years is not foreseen.
	(4) A summary of the process for permitting new or replacement wells in the basin, including adopted standards in local well ordinances, zoning codes, and policies contained in adopted land use plans.	GSP Alternative (SHN/Humboldt County, 2016)	Section 2.8
	(5) To the extent known, the Agency may include information regarding the implementation of land use plans outside the basin that could affect the ability of the Agency to achieve sustainable groundwater management.	n/a	None were identified
	(g) A description of any of the additional Plan elements included in Water Code Section 10727.4 that the Agency determines to be appropriate.	n/a	None were identified
§ 354.10.	**Notice and Communication**		
	Each Plan shall include a summary of information relating to notification and communication by the Agency with other agencies and interested parties including the following:		

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	(a) A description of the beneficial uses and users of groundwater in the basin, including the land uses and property interests potentially affected by the use of groundwater in the basin, the types of parties representing those interests, and the nature of consultation with those parties.	GSP Alternative (SHN/Humboldt County, 2016)	Section 2.1
	(b) A list of public meetings at which the Plan was discussed or considered by the Agency.	GSP Alternative (SHN/Humboldt County, 2016)	Section 2.3
	(c) Comments regarding the Plan received by the Agency and a summary of any responses by the Agency.	GSP Alternative (SHN/Humboldt County, 2016)	Appendix B; minutes from Working Group meetings are available at www.humboldtgov.org/groundwater
	(d) A communication section of the Plan that includes the following:		
	(1) An explanation of the Agency's decision-making process.	GSP Alternative (SHN/Humboldt County, 2016)	Sections 2.2 and 2.5
	(2) Identification of opportunities for public engagement and a discussion of how public input and response will be used.	GSP Alternative (SHN/Humboldt County, 2016)	Section 2.2
	(3) A description of how the Agency encourages the active involvement of diverse social, cultural, and economic elements of the population within the basin.	GSP Alternative (SHN/Humboldt County, 2016)	Section 2.2
	(4) The method the Agency shall follow to inform the public about progress implementing the Plan, including the status of projects and actions.	GSP Alternative (SHN/Humboldt County, 2016)	Section 2.2
SubArticle 2	**Basin Setting**		
§ 354.14.	**Hydrogeologic Conceptual Model**		
	(a) Each Plan shall include a descriptive hydrogeologic conceptual model of the basin based on technical studies and qualified maps that characterizes the physical components and interaction of the surface water and groundwater systems in the basin.	GSP Alternative (SHN/Humboldt County, 2016)	Section 3.1
	(b) The hydrogeologic conceptual model shall be summarized in a written description that includes the following:		
	(1) The regional geologic and structural setting of the basin including the immediate surrounding area, as necessary for geologic consistency.	GSP Alternative (SHN/Humboldt County, 2016)	Section 3.1
	(2) Lateral basin boundaries, including major geologic features that significantly affect groundwater flow.	GSP Alternative (SHN/Humboldt County, 2016)	Section 3.1
	(3) The definable bottom of the basin.	GSP Alternative (SHN/Humboldt County, 2016)	Section 3.1
	(4) Principal aquifers and aquitards, including the following information:	GSP Alternative (SHN/Humboldt County, 2016)	Section 3.1
	(A) Formation names, if defined.	GSP Alternative (SHN/Humboldt County, 2016)	Section 3.1
	(B) Physical properties of aquifers and aquitards, including the vertical and lateral extent, hydraulic conductivity, and storativity, which may be based on existing technical studies or other best available information.	GSP Alternative (SHN/Humboldt County, 2016)	Section 3.1
	(C) Structural properties of the basin that restrict groundwater flow within the principal aquifers, including information regarding stratigraphic changes, truncation of units, or other features.	GSP Alternative (SHN/Humboldt County, 2016)	Section 3.1
	(D) General water quality of the principal aquifers, which may be based on information derived from existing technical studies or regulatory programs.	GSP Alternative (SHN/Humboldt County, 2016)	Section 3.1
	(E) Identification of the primary use or uses of each aquifer, such as domestic, irrigation, or municipal water supply.	GSP Alternative (SHN/Humboldt County, 2016)	Section 3.1

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	(5) Identification of data gaps and uncertainty within the hydrogeologic conceptual model	GSP Alternative (SHN/Humboldt County, 2016)	Section 3.1
	(c) The hydrogeologic conceptual model shall be represented graphically by at least two scaled cross-sections that display the information required by this section and are sufficient to depict major stratigraphic and structural features in the basin.	GSP Alternative (SHN/Humboldt County, 2016)	Section 3.1
	(d) Physical characteristics of the basin shall be represented on one or more maps that depict the following:	GSP Alternative (SHN/Humboldt County, 2016)	Section 3.1
	(1) Topographic information derived from the U.S. Geological Survey or another reliable source.	GSP Alternative (SHN/Humboldt County, 2016)	Section 3.1
	(2) Surficial geology derived from a qualified map including the locations of cross-sections required by this Section.	GSP Alternative (SHN/Humboldt County, 2016)	Section 3.1
	(3) Soil characteristics as described by the appropriate Natural Resources Conservation Service soil survey or other applicable studies.	GSP Alternative (SHN/Humboldt County, 2016)	Section 3.1
	(4) Delineation of existing recharge areas that substantially contribute to the replenishment of the basin, potential recharge areas, and discharge areas, including significant active springs, seeps, and wetlands within or adjacent to the basin.	GSP Alternative (SHN/Humboldt County, 2016)	Section 3.1
	(5) Surface water bodies that are significant to the management of the basin.	GSP Alternative (SHN/Humboldt County, 2016)	Section 3.1
§ 354.16.	**Groundwater Conditions**		
	Each Plan shall provide a description of current and historical groundwater conditions in the basin, including data from January 1, 2015, to current conditions, based on the best available information that includes the following:	GSP Alternative (SHN/Humboldt County, 2016)	Section 3.2
	(a) Groundwater elevation data demonstrating flow directions, lateral and vertical gradients, and regional pumping patterns, including:	GSP Alternative (SHN/Humboldt County, 2016)	Section 3.2
	(1) Groundwater elevation contour maps depicting the groundwater table or potentiometric surface associated with the current seasonal high and seasonal low for each principal aquifer within the basin.	GSP Alternative (SHN/Humboldt County, 2016)	Section 3.2
	(2) Hydrographs depicting long-term groundwater elevations, historical highs and lows, and hydraulic gradients between principal aquifers.	GSP Alternative (SHN/Humboldt County, 2016)	Section 3.2
	(b) A graph depicting estimates of the change in groundwater in storage, based on data, demonstrating the annual and cumulative change in the volume of groundwater in storage between seasonal high groundwater conditions, including the annual groundwater use and water year type.	GSP Alternative (SHN/Humboldt County, 2016)	Section 3.2
	(c) Seawater intrusion conditions in the basin, including maps and cross-sections of the seawater intrusion front for each principal aquifer.	GSP Alternative (SHN/Humboldt County, 2016)	Section 3.2
	(d) Groundwater quality issues that may affect the supply and beneficial uses of groundwater, including a description and map of the location of known groundwater contamination sites and plumes.	GSP Alternative (SHN/Humboldt County, 2016)	Section 3.2

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	(e) The extent, cumulative total, and annual rate of land subsidence, including maps depicting total subsidence, utilizing data available from the Department, as specified in Section 353.2, or the best available information.	GSP Alternative (SHN/Humboldt County, 2016)	Section 3.2
	(f) Identification of interconnected surface water systems within the basin and an estimate of the quantity and timing of depletions of those systems, utilizing data available from the Department, as specified in Section 353.2, or the best available information.	GSP Alternative (SHN/Humboldt County, 2016)	Section 3.2
	(g) Identification of groundwater dependent ecosystems within the basin, utilizing data available from the Department, as specified in Section 353.2, or the best available information.	GSP Alternative (SHN/Humboldt County, 2016)	Section 3.2
§ 344.18.	**Water Budget**		
	(a) Each Plan shall include a water budget for the basin that provides an accounting and assessment of the total annual volume of groundwater and surface water entering and leaving the basin, including historical, current and projected water budget conditions, and the change in the volume of water stored. Water budget information shall be reported in tabular and graphical form.	GSP Alternative (SHN/Humboldt County, 2016)	Section 3.3 and Appendix H; see text for explanation why projected water budget conditions were not developed
	(b) The water budget shall quantify the following, either through direct measurements or estimates based on data:	GSP Alternative (SHN/Humboldt County, 2016)	Section 3.3 and Appendix H
	(1) Total surface water entering and leaving a basin by water source type.	GSP Alternative (SHN/Humboldt County, 2016)	Section 3.3 and Appendix H
	(2) Inflow to the groundwater system by water source type, including subsurface groundwater inflow and infiltration of precipitation, applied water, and surface water systems, such as lakes, streams, rivers, canals, springs and conveyance systems.	GSP Alternative (SHN/Humboldt County, 2016)	Section 3.3 and Appendix H
	(3) Outflows from the groundwater system by water use sector, including evapotranspiration, groundwater extraction, groundwater discharge to surface water sources, and subsurface groundwater outflow.	GSP Alternative (SHN/Humboldt County, 2016)	Section 3.3 and Appendix H
	(4) The change in the annual volume of groundwater in storage between seasonal high conditions.	GSP Alternative (SHN/Humboldt County, 2016)	Section 3.3 and Appendix H
	(5) If overdraft conditions occur, as defined in Bulletin 118, the water budget shall include a quantification of overdraft over a period of years during which water year and water supply conditions approximate average conditions.	n/a	Overdraft conditions do not exist
	(6) The water year type associated with the annual supply, demand, and change in groundwater stored.	GSP Alternative (SHN/Humboldt County, 2016)	Section 3.3 and Appendix H
	(7) An estimate of sustainable yield for the basin.	n/a	See explanation in Section 3.3 why an estimate of sustainable yield is not presented
	(c) Each Plan shall quantify the current, historical, and projected water budget for the basin as follows:		
	(1) Current water budget information shall quantify current inflows and outflows for the basin using the most recent hydrology, water supply, water demand, and land use information.	GSP Alternative (SHN/Humboldt County, 2016)	Section 3.3 and Appendix H

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	(2) Historical water budget information shall be used to evaluate availability or reliability of past surface water supply deliveries and aquifer response to water supply and demand trends relative to water year type. The historical water budget shall include the following:	n/a	This level of analysis is unwarranted, because the Basin has been managed sustainably without undesirable effects.
	(A) A quantitative evaluation of the availability or reliability of historical surface water supply deliveries as a function of the historical planned versus actual annual surface water deliveries, by surface water source and water year type, and based on the most recent ten years of surface water supply information.	n/a	This level of analysis is unwarranted, because the Basin has been managed sustainably without undesirable effects.
	(B) A quantitative assessment of the historical water budget, starting with the most recently available information and extending back a minimum of 10 years, or as is sufficient to calibrate and reduce the uncertainty of the tools and methods used to estimate and project future water budget information and future aquifer response to proposed sustainable groundwater management practices over the planning and implementation horizon.	n/a	This level of analysis is unwarranted, because the Basin has been managed sustainably without undesirable effects.
	(C) A description of how historical conditions concerning hydrology, water demand, and surface water supply availability or reliability have impacted the ability of the Agency to operate the basin within sustainable yield. Basin hydrology may be characterized and evaluated using water year type.	n/a	This level of analysis is unwarranted, because the Basin has been managed sustainably without undesirable effects.
	(3) Projected water budgets shall be used to estimate future baseline conditions of supply, demand, and aquifer response to Plan implementation, and to identify the uncertainties of these projected water budget components. The projected water budget shall utilize the following methodologies and assumptions to estimate future baseline conditions concerning hydrology, water demand and surface water supply availability or reliability over the planning and implementation horizon:	n/a	This level of analysis is unwarranted, because the Basin has been managed sustainably without undesirable effects.
	(A) Projected hydrology shall utilize 50 years of historical precipitation, evapotranspiration, and streamflow information as the baseline condition for estimating future hydrology. The projected hydrology information shall also be applied as the baseline condition used to evaluate future scenarios of hydrologic uncertainty associated with projections of climate change and sea level rise.	n/a	This level of analysis is unwarranted, because the Basin has been managed sustainably without undesirable effects.
	(B) Projected water demand shall utilize the most recent land use, evapotranspiration, and crop coefficient information as the baseline condition for estimating future water demand. The projected water demand information shall also be applied as the baseline condition used to evaluate future scenarios of water demand uncertainty associated with projected changes in local land use planning, population growth, and climate.	n/a	This level of analysis is unwarranted, because the Basin has been managed sustainably without undesirable effects.

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	(C) Projected surface water supply shall utilize the most recent water supply information as the baseline condition for estimating future surface water supply. The projected surface water supply shall also be applied as the baseline condition used to evaluate future scenarios of surface water supply availability and reliability as a function of the historical surface water supply identified in Section 354.18(c)(2)(A), and the projected changes in local land use planning, population growth, and climate.	n/a	This level of analysis is unwarranted, because the Basin has been managed sustainably without undesirable effects.
	(d) The Agency shall utilize the following information provided, as available, by the Department pursuant to Section 353.2, or other data of comparable quality, to develop the water budget:		
	(1) Historical water budget information for mean annual temperature, mean annual precipitation, water year type, and land use.	GSP Alternative (SHN/Humboldt County, 2016)	Section 3.3 and Appendix H
	(2) Current water budget information for temperature, water year type, evapotranspiration, and land use.	GSP Alternative (SHN/Humboldt County, 2016)	Section 3.3 and Appendix H
	(3) Projected water budget information for population, population growth, climate change, and sea level rise.	n/a	This level of analysis is unwarranted, because the Basin has been managed sustainably without undesirable effects.
	(e) Each Plan shall rely on the best available information and best available science to quantify the water budget for the basin in order to provide an understanding of historical and projected hydrology, water demand, water supply, land use, population, climate change, sea level rise, groundwater and surface water interaction, and subsurface groundwater flow. If a numerical groundwater and surface water model is not used to quantify and evaluate the projected water budget conditions and the potential impacts to beneficial uses and users of groundwater, the Plan shall identify and describe an equally effective method, tool, or analytical model to evaluate projected water budget conditions.	GSP Alternative (SHN/Humboldt County, 2016)	Section 3.3 and Appendix H
	(f) The Department shall provide the California Central Valley Groundwater-Surface Water Simulation Model (C2VSIM) and the Integrated Water Flow Model (IWFM) for use by Agencies in developing the water budget. Each Agency may choose to use a different groundwater and surface water model, pursuant to Section 352.4.	n/a	n/a
§ 344.20.	**Management Areas**		
	(a) Each Agency may define one or more management areas within a basin if the Agency has determined that creation of management areas will facilitate implementation of the Plan. Management areas may define different minimum thresholds and be operated to different measurable objectives than the basin at large, provided that undesirable results are defined consistently throughout the basin.	n/a	Establishment of management areas has been determined to be unwarranted.
	(b) A basin that includes one or more management areas shall describe the following in the Plan:	n/a	Establishment of management areas has been determined to be unwarranted.
	(1) The reason for the creation of each management area.	n/a	Establishment of management areas has been determined to be unwarranted.

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	(2) The minimum thresholds and measurable objectives established for each management area, and an explanation of the rationale for selecting those values, if different from the basin at large.	n/a	Establishment of management areas has been determined to be unwarranted.
	(3) The level of monitoring and analysis appropriate for each management area.	n/a	Establishment of management areas has been determined to be unwarranted.
	(4) An explanation of how the management area can operate under different minimum thresholds and measurable objectives without causing undesirable results outside the management area, if applicable.	n/a	Establishment of management areas has been determined to be unwarranted.
	(c) If a Plan includes one or more management areas, the Plan shall include descriptions, maps, and other information required by this Subarticle sufficient to describe conditions in those areas.	n/a	Establishment of management areas has been determined to be unwarranted.
SubArticle 3	**Administrative Information**		
§ 354.24.	**Sustainability Goal**		
	Each Agency shall establish in its Plan a sustainability goal for the basin that culminates in the absence of undesirable results within 20 years of the applicable statutory deadline. The Plan shall include a description of the sustainability goal, including information from the basin setting used to establish the sustainability goal, a discussion of the measures that will be implemented to ensure that the basin will be operated within its sustainable yield, and an explanation of how the sustainability goal is likely to be achieved within 20 years of Plan implementation and is likely to be maintained through the planning and implementation horizon.	GSP Alternative (SHN/Humboldt County, 2016)	Section 4.1
§ 354.26.	**Undesirable Results**		
	(a) Each Agency shall describe in its Plan the processes and criteria relied upon to define undesirable results applicable to the basin. Undesirable results occur when significant and unreasonable effects for any of the sustainability indicators are caused by groundwater conditions occurring throughout the basin.	GSP Alternative (SHN/Humboldt County, 2016)	Section 4.2
	(b) The description of undesirable results shall include the following:		
	(1) The cause of groundwater conditions occurring throughout the basin that would lead to or has led to undesirable results based on information described in the basin setting, and other data or models as appropriate.	n/a	This level of analysis is unwarranted, because the Basin has been managed sustainably without undesirable effects.
	(2) The criteria used to define when and where the effects of the groundwater conditions cause undesirable results for each applicable sustainability indicator. The criteria shall be based on a quantitative description of the combination of minimum threshold exceedances that cause significant and unreasonable effects in the basin.	n/a	This level of analysis is unwarranted, because the Basin has been managed sustainably without undesirable effects.
	(3) Potential effects on the beneficial uses and users of groundwater, on land uses and property interests, and other potential effects that may occur or are occurring from undesirable results.	n/a	This level of analysis is unwarranted, because the Basin has been managed sustainably without undesirable effects.

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	(c) The Agency may need to evaluate multiple minimum thresholds to determine whether an undesirable result is occurring in the basin. The determination that undesirable results are occurring may depend upon measurements from multiple monitoring sites, rather than a single monitoring site.	n/a	This level of analysis is unwarranted, because the Basin has been managed sustainably without undesirable effects.
	(d) An Agency that is able to demonstrate that undesirable results related to one or more sustainability indicators are not present and are not likely to occur in a basin shall not be required to establish criteria for undesirable results related to those sustainability indicators.	GSP Alternative (SHN/Humboldt County, 2016)	Section 4.2
§ 354.28.	**Minimum Threshold**		
	(a) Each Agency in its Plan shall establish minimum thresholds that quantify groundwater conditions for each applicable sustainability indicator at each monitoring site or representative monitoring site established pursuant to Section 354.36. The numeric value used to define minimum thresholds shall represent a point in the basin that, if exceeded, may cause undesirable results as described in Section 354.26.	n/a	See discussion in Section 4.3 why minimum thresholds are not established
	(b) The description of minimum thresholds shall include the following:		
	(1) The information and criteria relied upon to establish and justify the minimum thresholds for each sustainability indicator. The justification for the minimum threshold shall be supported by information provided in the basin setting, and other data or models as appropriate, and qualified by uncertainty in the understanding of the basin setting.	n/a	See discussion in Section 4.3 why minimum thresholds are not established
	(2) The relationship between the minimum thresholds for each sustainability indicator, including an explanation of how the Agency has determined that basin conditions at each minimum threshold will avoid undesirable results for each of the sustainability indicators.	n/a	See discussion in Section 4.3 why minimum thresholds are not established
	(3) How minimum thresholds have been selected to avoid causing undesirable results in adjacent basins or affecting the ability of adjacent basins to achieve sustainability goals.	n/a	See discussion in Section 4.3 why minimum thresholds are not established
	(4) How minimum thresholds may affect the interests of beneficial uses and users of groundwater or land uses and property interests.	n/a	See discussion in Section 4.3 why minimum thresholds are not established
	(5) How state, federal, or local standards relate to the relevant sustainability indicator. If the minimum threshold differs from other regulatory standards, the Agency shall explain the nature of and basis for the difference.	n/a	See discussion in Section 4.3 why minimum thresholds are not established
	(6) How each minimum threshold will be quantitatively measured, consistent with the monitoring network requirements described in Subarticle 4.	n/a	See discussion in Section 4.3 why minimum thresholds are not established
	(c) Minimum thresholds for each sustainability indicator shall be defined as follows:		

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	(1) Chronic Lowering of Groundwater Levels. The minimum threshold for chronic lowering of groundwater levels shall be the groundwater elevation indicating a depletion of supply at a given location that may lead to undesirable results. Minimum thresholds for chronic lowering of groundwater levels shall be supported by the following:	n/a	See discussion in Section 4.3 why minimum thresholds are not established
	(A) The rate of groundwater elevation decline based on historical trends, water year type, and projected water use in the basin.	n/a	See discussion in Section 4.3 why minimum thresholds are not established
	(B) Potential effects on other sustainability indicators.	n/a	See discussion in Section 4.3 why minimum thresholds are not established
	(2) Reduction of Groundwater Storage. The minimum threshold for reduction of groundwater storage shall be a total volume of groundwater that can be withdrawn from the basin without causing conditions that may lead to undesirable results. Minimum thresholds for reduction of groundwater storage shall be supported by the sustainable yield of the basin, calculated based on historical trends, water year type, and projected water use in the basin.	n/a	See discussion in Section 4.3 why minimum thresholds are not established
	(3) Seawater Intrusion. The minimum threshold for seawater intrusion shall be defined by a chloride concentration isocontour for each principal aquifer where seawater intrusion may lead to undesirable results. Minimum thresholds for seawater intrusion shall be supported by the following:	n/a	See discussion in Section 4.3 why minimum thresholds are not established
	(A) Maps and cross-sections of the chloride concentration isocontour that defines the minimum threshold and measurable objective for each principal aquifer.	n/a	See discussion in Section 4.3 why minimum thresholds are not established
	(B) A description of how the seawater intrusion minimum threshold considers the effects of current and projected sea levels.	n/a	See discussion in Section 4.3 why minimum thresholds are not established
	(4) Degraded Water Quality. The minimum threshold for degraded water quality shall be the degradation of water quality, including the migration of contaminant plumes that impair water supplies or other indicator of water quality as determined by the Agency that may lead to undesirable results. The minimum threshold shall be based on the number of supply wells, a volume of water, or a location of an isocontour that exceeds concentrations of constituents determined by the Agency to be of concern for the basin. In setting minimum thresholds for degraded water quality, the Agency shall consider local, state, and federal water quality standards applicable to the basin.	n/a	See discussion in Section 4.3 why minimum thresholds are not established
	(5) Land Subsidence. The minimum threshold for land subsidence shall be the rate and extent of subsidence that substantially interferes with surface land uses and may lead to undesirable results. Minimum thresholds for land subsidence shall be supported by the following:	n/a	See discussion in Section 4.3 why minimum thresholds are not established
	(A) Identification of land uses and property interests that have been affected or are likely to be affected by land subsidence in the basin, including an explanation of how the Agency has determined and considered those uses and interests, and the Agency's rationale for establishing minimum thresholds in light of those effects.	n/a	See discussion in Section 4.3 why minimum thresholds are not established

California Code of Regulations - GSP Regulation Sections	*Alternative Elements*	**Document which *attachment(s) contains the applicable alternative element.***	***Document which section(s), page number(s), or briefly describe why that Alternative element does not apply to the entity.***
	(B) Maps and graphs showing the extent and rate of land subsidence in the basin that defines the minimum threshold and measurable objectives.	n/a	See discussion in Section 4.3 why minimum thresholds are not established
	(6) Depletions of Interconnected Surface Water. The minimum threshold for depletions of interconnected surface water shall be the rate or volume of surface water depletions caused by groundwater use that has adverse impacts on beneficial uses of the surface water and may lead to undesirable results. The minimum threshold established for depletions of interconnected surface water shall be supported by the following:	n/a	See discussion in Section 4.3 why minimum thresholds are not established
	(A) The location, quantity, and timing of depletions of interconnected surface water.	n/a	See discussion in Section 4.3 why minimum thresholds are not established
	(B) A description of the groundwater and surface water model used to quantify surface water depletion. If a numerical groundwater and surface water model is not used to quantify surface water depletion, the Plan shall identify and describe an equally effective method, tool, or analytical model to accomplish the requirements of this Paragraph.	n/a	See discussion in Section 4.3 why minimum thresholds are not established
	(d) An Agency may establish a representative minimum threshold for groundwater elevation to serve as the value for multiple sustainability indicators, where the Agency can demonstrate that the representative value is a reasonable proxy for multiple individual minimum thresholds as supported by adequate evidence.	n/a	See discussion in Section 4.3 why minimum thresholds are not established
	(e) An Agency that has demonstrated that undesirable results related to one or more sustainability indicators are not present and are not likely to occur in a basin, as described in Section 354.26, shall not be required to establish minimum thresholds related to those sustainability indicators.	GSP Alternative (SHN/Humboldt County, 2016)	Section 4.3
§ 354.30.	**Measurable Objectives**		
	(a) Each Agency shall establish measurable objectives, including interim milestones in increments of five years, to achieve the sustainability goal for the basin within 20 years of Plan implementation and to continue to sustainably manage the groundwater basin over the planning and implementation horizon.	n/a	See discussion in Section 4.4 why measurable objectives are not established; a functionally-equivalent goal-setting framework is proposed.
	(b) Measurable objectives shall be established for each sustainability indicator, based on quantitative values using the same metrics and monitoring sites as are used to define the minimum thresholds.	n/a	See discussion in Section 4.4 why measurable objectives are not established; a functionally-equivalent goal-setting framework is proposed.
	(c) Measurable objectives shall provide a reasonable margin of operational flexibility under adverse conditions which shall take into consideration components such as historical water budgets, seasonal and long-term trends, and periods of drought, and be commensurate with levels of uncertainty.	n/a	See discussion in Section 4.4 why measurable objectives are not established; a functionally-equivalent goal-setting framework is proposed.
	(d) An Agency may establish a representative measurable objective for groundwater elevation to serve as the value for multiple sustainability indicators where the Agency can demonstrate that the representative value is a reasonable proxy for multiple individual measurable objectives as supported by adequate evidence.	n/a	See discussion in Section 4.4 why measurable objectives are not established; a functionally-equivalent goal-setting framework is proposed.

California Code of Regulations - GSP Regulation Sections	*Alternative Elements*	**Document which *attachment(s) contains the applicable alternative element.***	***Document which section(s), page number(s), or briefly describe why that Alternative element does not apply to the entity.***
	(e) Each Plan shall describe a reasonable path to achieve the sustainability goal for the basin within 20 years of Plan implementation, including a description of interim milestones for each relevant sustainability indicator, using the same metric as the measurable objective, in increments of five years. The description shall explain how the Plan is likely to maintain sustainable groundwater management over the planning and implementation horizon.	n/a	See discussion in Section 4.4 why measurable objectives are not established; a functionally-equivalent goal-setting framework is proposed.
	(f) Each Plan may include measurable objectives and interim milestones for additional Plan elements described in Water Code Section 10727.4 where the Agency determines such measures are appropriate for sustainable groundwater management in the basin.	n/a	See discussion in Section 4.4 why measurable objectives are not established; a functionally-equivalent goal-setting framework is proposed.
	(g) An Agency may establish measurable objectives that exceed the reasonable margin of operational flexibility for the purpose of improving overall conditions in the basin, but failure to achieve those objectives shall not be grounds for a finding of inadequacy of the Plan.	n/a	See discussion in Section 4.4 why measurable objectives are not established; a functionally-equivalent goal-setting framework is proposed.
SubArticle 4	**Monitoring Networks**		
§ 354.34.	**Monitoring Network**		
	(a) Each Agency shall develop a monitoring network capable of collecting sufficient data to demonstrate short-term, seasonal, and long-term trends in groundwater and related surface conditions, and yield representative information about groundwater conditions as necessary to evaluate Plan implementation.	GSP Alternative (SHN/Humboldt County, 2016)	Section 4.5
	(b) Each Plan shall include a description of the monitoring network objectives for the basin, including an explanation of how the network will be developed and implemented to monitor groundwater and related surface conditions, and the interconnection of surface water and groundwater, with sufficient temporal frequency and spatial density to evaluate the affects and effectiveness of Plan implementation. The monitoring network objectives shall be implemented to accomplish the following:	n/a	This level of analysis is unwarranted, because the Basin has been managed sustainably without undesirable effects.
	(1) Demonstrate progress toward achieving measurable objectives described in the Plan.	n/a	This level of analysis is unwarranted, because the Basin has been managed sustainably without undesirable effects.
	(2) Monitor impacts to the beneficial uses or users of groundwater.	n/a	This level of analysis is unwarranted, because the Basin has been managed sustainably without undesirable effects.
	(3) Monitor changes in groundwater conditions relative to measurable objectives and minimum thresholds.	n/a	This level of analysis is unwarranted, because the Basin has been managed sustainably without undesirable effects.
	(4) Quantify annual changes in water budget components.	n/a	This level of analysis is unwarranted, because the Basin has been managed sustainably without undesirable effects.
	(c) Each monitoring network shall be designed to accomplish the following for each sustainability indicator:		
	(1) Chronic Lowering of Groundwater Levels. Demonstrate groundwater occurrence, flow directions, and hydraulic gradients between principal aquifers and surface water features by the following methods:	GSP Alternative (SHN/Humboldt County, 2016)	Section 4.5

California Code of Regulations - GSP Regulation Sections	Alternative Elements	Document which attachment(s) contains the applicable alternative element.	Document which section(s), page number(s), or briefly describe why that Alternative element does not apply to the entity.
	(A) A sufficient density of monitoring wells to collect representative measurements through depth-discrete perforated intervals to characterize the groundwater table or potentiometric surface for each principal aquifer.	GSP Alternative (SHN/Humboldt County, 2016)	Section 4.5
	(B) Static groundwater elevation measurements shall be collected at least two times per year, to represent seasonal low and seasonal high groundwater conditions.	GSP Alternative (SHN/Humboldt County, 2016)	Section 4.5
	(2) Reduction of Groundwater Storage. Provide an estimate of the change in annual groundwater in storage.	GSP Alternative (SHN/Humboldt County, 2016)	Section 4.5
	(3) Seawater Intrusion. Monitor seawater intrusion using chloride concentrations, or other measurements convertible to chloride concentrations, so that the current and projected rate and extent of seawater intrusion for each applicable principal aquifer may be calculated.	GSP Alternative (SHN/Humboldt County, 2016)	Section 4.5
	(4) Degraded Water Quality. Collect sufficient spatial and temporal data from each applicable principal aquifer to determine groundwater quality trends for water quality indicators, as determined by the Agency, to address known water quality issues.	n/a	Existing drinking water and contaminant site programs are sufficient; no new SGMA-based monitoring is warranted
	(5) Land Subsidence. Identify the rate and extent of land subsidence, which may be measured by extensometers, surveying, remote sensing technology, or other appropriate method.	n/a	Monitoring for land subsidence is unwarranted due to basin conditions.
	(6) Depletions of Interconnected Surface Water. Monitor surface water and groundwater, where interconnected surface water conditions exist, to characterize the spatial and temporal exchanges between surface water and groundwater, and to calibrate and apply the tools and methods necessary to calculate depletions of surface water caused by groundwater extractions. The monitoring network shall be able to characterize the following:	GSP Alternative (SHN/Humboldt County, 2016)	Section 4.5
	(A) Flow conditions including surface water discharge, surface water head, and baseflow contribution.	GSP Alternative (SHN/Humboldt County, 2016)	Section 4.5 - water elevation monitoring only is reasonable and appropriate; potential modifications will be considered at the five-year assessment
	(B) Identifying the approximate date and location where ephemeral or intermittent flowing streams and rivers cease to flow, if applicable.	n/a	Section 4.5 - water elevation monitoring only is reasonable and appropriate; potential modifications will be considered at the five-year assessment
	(C) Temporal change in conditions due to variations in stream discharge and regional groundwater extraction.	n/a	Section 4.5 - water elevation monitoring only is reasonable and appropriate; potential modifications will be considered at the five-year assessment
	(D) Other factors that may be necessary to identify adverse impacts on beneficial uses of the surface water.	n/a	Water elevation monitoring only is reasonable and appropriate; potential modifications will be considered at the five-year assessment
	(d) The monitoring network shall be designed to ensure adequate coverage of sustainability indicators. If management areas are established, the quantity and density of monitoring sites in those areas shall be sufficient to evaluate conditions of the basin setting and sustainable management criteria specific to that area.	GSP Alternative (SHN/Humboldt County, 2016)	Section 4.5

California Code of Regulations - GSP Regulation Sections	*Alternative Elements*	**Document which *attachment(s) contains the applicable alternative element.***	***Document which section(s), page number(s), or briefly describe why that Alternative element does not apply to the entity.***
	(e) A Plan may utilize site information and monitoring data from existing sources as part of the monitoring network.	GSP Alternative (SHN/Humboldt County, 2016)	Section 4.5
	(f) The Agency shall determine the density of monitoring sites and frequency of measurements required to demonstrate short-term, seasonal, and long-term trends based upon the following factors:	GSP Alternative (SHN/Humboldt County, 2016)	Section 4.5
	(1) Amount of current and projected groundwater use.	GSP Alternative (SHN/Humboldt County, 2016)	Section 4.5
	(2) Aquifer characteristics, including confined or unconfined aquifer conditions, or other physical characteristics that affect groundwater flow.	GSP Alternative (SHN/Humboldt County, 2016)	Section 4.5
	(3) Impacts to beneficial uses and users of groundwater and land uses and property interests affected by groundwater production, and adjacent basins that could affect the ability of that basin to meet the sustainability goal.	GSP Alternative (SHN/Humboldt County, 2016)	Section 4.5
	(4) Whether the Agency has adequate long-term existing monitoring results or other technical information to demonstrate an understanding of aquifer response.	GSP Alternative (SHN/Humboldt County, 2016)	Section 4.5
	(g) Each Plan shall describe the following information about the monitoring network:		
	(1) Scientific rationale for the monitoring site selection process.	GSP Alternative (SHN/Humboldt County, 2016)	Section 4.5
	(2) Consistency with data and reporting standards described in Section 352.4. If a site is not consistent with those standards, the Plan shall explain the necessity of the site to the monitoring network, and how any variation from the standards will not affect the usefulness of the results obtained.	GSP Alternative (SHN/Humboldt County, 2016)	Section 4.5
	(3) For each sustainability indicator, the quantitative values for the minimum threshold, measurable objective, and interim milestones that will be measured at each monitoring site or representative monitoring sites established pursuant to Section 354.36.	n/a	This GSP Alternative is not establishing minimum thresholds or measurable objectives
	(h) The location and type of each monitoring site within the basin displayed on a map, and reported in tabular format, including information regarding the monitoring site type, frequency of measurement, and the purposes for which the monitoring site is being used.	GSP Alternative (SHN/Humboldt County, 2016)	Section 4.5
	(i) The monitoring protocols developed by each Agency shall include a description of technical standards, data collection methods, and other procedures or protocols pursuant to Water Code Section 10727.2(f) for monitoring sites or other data collection facilities to ensure that the monitoring network utilizes comparable data and methodologies.	GSP Alternative (SHN/Humboldt County, 2016)	Section 4.5
	(j) An Agency that has demonstrated that undesirable results related to one or more sustainability indicators are not present and are not likely to occur in a basin, as described in Section 354.26, shall not be required to establish a monitoring network related to those sustainability indicators.	GSP Alternative (SHN/Humboldt County, 2016)	provision noted
§ 354.36.	**Representative Monitoring**		
	Each Agency may designate a subset of monitoring sites as representative of conditions in the basin or an area of the basin, as follows:		

California Code of Regulations - GSP Regulation Sections	Alternative Elements	Document which attachment(s) contains the applicable alternative element.	Document which section(s), page number(s), or briefly describe why that Alternative element does not apply to the entity.
	(a) Representative monitoring sites may be designated by the Agency as the point at which sustainability indicators are monitored, and for which quantitative values for minimum thresholds, measurable objectives, and interim milestones are defined.	n/a	Representative monitoring is discussed in Section 4.5, however this GSP Alternative is not establishing minimum thresholds or measurable objectives
	(b) Groundwater elevations may be used as a proxy for monitoring other sustainability indicators if the Agency demonstrates the following:	GSP Alternative (SHN/Humboldt County, 2016)	Section 4.5
	(1) Significant correlation exists between groundwater elevations and the sustainability indicators for which groundwater elevation measurements serve as a proxy.	GSP Alternative (SHN/Humboldt County, 2016)	Section 4.5
	(2) Measurable objectives established for groundwater elevation shall include a reasonable margin of operational flexibility taking into consideration the basin setting to avoid undesirable results for the sustainability indicators for which groundwater elevation measurements serve as a proxy.	n/a	This GSP Alternative is not establishing measurable objectives
	(c) The designation of a representative monitoring site shall be supported by adequate evidence demonstrating that the site reflects general conditions in the area.	GSP Alternative (SHN/Humboldt County, 2016)	Section 4.5
§ 354.38.	**Assessment and Improvement of Monitoring Network**		
	(a) Each Agency shall review the monitoring network and include an evaluation in the Plan and each five-year assessment, including a determination of uncertainty and whether there are data gaps that could affect the ability of the Plan to achieve the sustainability goal for the basin.	n/a	This level of analysis is unwarranted for a GSP Alternative
	(b) Each Agency shall identify data gaps wherever the basin does not contain a sufficient number of monitoring sites, does not monitor sites at a sufficient frequency, or utilizes monitoring sites that are unreliable, including those that do not satisfy minimum standards of the monitoring network adopted by the Agency.	n/a	This level of analysis is unwarranted for a GSP Alternative
	(c) If the monitoring network contains data gaps, the Plan shall include a description of the following:	n/a	This level of analysis is unwarranted for a GSP Alternative
	(1) The location and reason for data gaps in the monitoring network.	n/a	This level of analysis is unwarranted for a GSP Alternative
	(2) Local issues and circumstances that limit or prevent monitoring.	n/a	This level of analysis is unwarranted for a GSP Alternative
	(d) Each Agency shall describe steps that will be taken to fill data gaps before the next five-year assessment, including the location and purpose of newly added or installed monitoring sites.	n/a	This level of analysis is unwarranted for a GSP Alternative
	(e) Each Agency shall adjust the monitoring frequency and density of monitoring sites to provide an adequate level of detail about site-specific surface water and groundwater conditions and to assess the effectiveness of management actions under circumstances that include the following:	n/a	This level of analysis is unwarranted for a GSP Alternative
	(1) Minimum threshold exceedances.	n/a	This level of analysis is unwarranted for a GSP Alternative
	(2) Highly variable spatial or temporal conditions.	n/a	This level of analysis is unwarranted for a GSP Alternative
	(3) Adverse impacts to beneficial uses and users of groundwater.	n/a	This level of analysis is unwarranted for a GSP Alternative

California Code of Regulations - GSP Regulation Sections	Alternative Elements	Document which attachment(s) contains the applicable alternative element.	Document which section(s), page number(s), or briefly describe why that Alternative element does not apply to the entity.
	(4) The potential to adversely affect the ability of an adjacent basin to implement its Plan or impede achievement of sustainability goals in an adjacent basin.	n/a	This level of analysis is unwarranted for a GSP Alternative
§ 354.40.	**Reporting Monitoring Data to the Department**		
	Monitoring data shall be stored in the data management system developed pursuant to Section 352.6. A copy of the monitoring data shall be included in the Annual Report and submitted electronically on forms provided by the Department.	GSP Alternative (SHN/Humboldt County, 2016)	Section 5.0
SubArticle 5	**Projects and Management Actions**		
§ 354.44	**Projects and Management Actions**		
	a) Each Plan shall include a description of the projects and management actions the Agency has determined will achieve the sustainability goal for the basin, including projects and management actions to respond to changing conditions in the basin.	GSP Alternative (SHN/Humboldt County, 2016)	Section 5.0
	(b) Each Plan shall include a description of the projects and management actions that include the following:	n/a	see discussion in Section 5.0
	(1) A list of projects and management actions proposed in the Plan with a description of the measurable objective that is expected to benefit from the project or management action. The list shall include projects and management actions that may be utilized to meet interim milestones, the exceedance of minimum thresholds, or where undesirable results have occurred or are imminent. The Plan shall include the following:	n/a	see discussion in Section 5.0
	(A) A description of the circumstances under which projects or management actions shall be implemented, the criteria that would trigger implementation and termination of projects or management actions, and the process by which the Agency shall determine that conditions requiring the implementation of particular projects or management actions have occurred.	n/a	see discussion in Section 5.0
	(B) The process by which the Agency shall provide notice to the public and other agencies that the implementation of projects or management actions is being considered or has been implemented, including a description of the actions to be taken.	n/a	see discussion in Section 5.0
	(2) If overdraft conditions are identified through the analysis required by Section 354.18, the Plan shall describe projects or management actions, including a quantification of demand reduction or other methods, for the mitigation of overdraft.	n/a	see discussion in Section 5.0
	(3) A summary of the permitting and regulatory process required for each project and management action.	n/a	see discussion in Section 5.0
	(4) The status of each project and management action, including a time-table for expected initiation and completion, and the accrual of expected benefits.	n/a	see discussion in Section 5.0
	(5) An explanation of the benefits that are expected to be realized from the project or management action, and how those benefits will be evaluated.	n/a	see discussion in Section 5.0

California Code of Regulations - GSP Regulation Sections	*Alternative Elements*	**Document which *attachment(s) contains the applicable alternative element.***	***Document which section(s), page number(s), or briefly describe why that Alternative element does not apply to the entity.***
	(6) An explanation of how the project or management action will be accomplished. If the projects or management actions rely on water from outside the jurisdiction of the Agency, an explanation of the source and reliability of that water shall be included.	n/a	see discussion in Section 5.0
	(7) A description of the legal authority required for each project and management action, and the basis for that authority within the Agency.	n/a	see discussion in Section 5.0
	(8) A description of the estimated cost for each project and management action and a description of how the Agency plans to meet those costs.	n/a	see discussion in Section 5.0
	(9) A description of the management of groundwater extractions and recharge to ensure that chronic lowering of groundwater levels or depletion of supply during periods of drought is offset by increases in groundwater levels or storage during other periods.	n/a	see discussion in Section 5.0
	(c) Projects and management actions shall be supported by best available information and best available science.	GSP Alternative (SHN/Humboldt County, 2016)	Section 5.0
	(d) An Agency shall take into account the level of uncertainty associated with the basin setting when developing projects or management actions.	GSP Alternative (SHN/Humboldt County, 2016)	Section 5.0
Article 7	**Annual Reports and Periodic Evaluations by the Agency**		
§ 356.2	**Annual Reports**		
	Each Agency shall submit an annual report to the Department by April 1 of each year following the adoption of the Plan. The annual report shall include the following components for the preceding water year:	GSP Alternative (SHN/Humboldt County, 2016)	Section 6.0
	(a) General information, including an executive summary and a location map depicting the basin covered by the report.	GSP Alternative (SHN/Humboldt County, 2016)	Section 6.0
	(b) A detailed description and graphical representation of the following conditions of the basin managed in the Plan:	GSP Alternative (SHN/Humboldt County, 2016)	Section 6.0
	(1) Groundwater elevation data from monitoring wells identified in the monitoring network shall be analyzed and displayed as follows:	GSP Alternative (SHN/Humboldt County, 2016)	Section 6.0
	(A) Groundwater elevation contour maps for each principal aquifer in the basin illustrating, at a minimum, the seasonal high and seasonal low groundwater conditions.	GSP Alternative (SHN/Humboldt County, 2016)	Section 6.0
	(B) Hydrographs of groundwater elevations and water year type using historical data to the greatest extent available, including from January 1, 2015, to current reporting year.	GSP Alternative (SHN/Humboldt County, 2016)	Section 6.0
	(2) Groundwater extraction for the preceding water year. Data shall be collected using the best available measurement methods and shall be presented in a table that summarizes groundwater extractions by water use sector, and identifies the method of measurement (direct or estimate) and accuracy of measurements, and a map that illustrates the general location and volume of groundwater extractions.	GSP Alternative (SHN/Humboldt County, 2016)	Section 6.0
	(3) Surface water supply used or available for use, for groundwater recharge or in-lieu use shall be reported based on quantitative data that describes the annual volume and sources for the preceding water year.	GSP Alternative (SHN/Humboldt County, 2016)	Section 6.0

California Code of Regulations - GSP Regulation Sections	*Alternative Elements*	**Document which *attachment(s) contains the applicable alternative element.***	***Document which section(s), page number(s), or briefly describe why that Alternative element does not apply to the entity.***
	(4) Total water use shall be collected using the best available measurement methods and shall be reported in a table that summarizes total water use by water use sector, water source type, and identifies the method of measurement (direct or estimate) and accuracy of measurements. Existing water use data from the most recent Urban Water Management Plans or Agricultural Water Management Plans within the basin may be used, as long as the data are reported by water year.	GSP Alternative (SHN/Humboldt County, 2016)	Section 6.0
	(5) Change in groundwater in storage shall include the following:	GSP Alternative (SHN/Humboldt County, 2016)	Section 6.0
	(A) Change in groundwater in storage maps for each principal aquifer in the basin.	GSP Alternative (SHN/Humboldt County, 2016)	Section 6.0
	(B) A graph depicting water year type, groundwater use, the annual change in groundwater in storage, and the cumulative change in groundwater in storage for the basin based on historical data to the greatest extent available, including from January 1, 2015, to the current reporting year.	GSP Alternative (SHN/Humboldt County, 2016)	Section 6.0
	(c) A description of progress towards implementing the Plan, including achieving interim milestones, and implementation of projects or management actions since the previous annual report.	GSP Alternative (SHN/Humboldt County, 2016)	Section 6.0
§ 356.4	**Periodic Evaluation by Agency**		
	Each Agency shall evaluate its Plan at least every five years and whenever the Plan is amended, and provide a written assessment to the Department. The assessment shall describe whether the Plan implementation, including implementation of projects and management actions, are meeting the sustainability goal in the basin, and shall include the following:	GSP Alternative (SHN/Humboldt County, 2016)	Section 6.0
	(a) A description of current groundwater conditions for each applicable sustainability indicator relative to measurable objectives, interim milestones and minimum thresholds.	GSP Alternative (SHN/Humboldt County, 2016)	Section 6.0
	(b) A description of the implementation of any projects or management actions, and the effect on groundwater conditions resulting from those projects or management actions.	GSP Alternative (SHN/Humboldt County, 2016)	Section 6.0
	(c) Elements of the Plan, including the basin setting, management areas, or the identification of undesirable results and the setting of minimum thresholds and measurable objectives, shall be reconsidered and revisions proposed, if necessary.	GSP Alternative (SHN/Humboldt County, 2016)	Section 6.0
	(d) An evaluation of the basin setting in light of significant new information or changes in water use, and an explanation of any significant changes. If the Agency's evaluation shows that the basin is experiencing overdraft conditions, the Agency shall include an assessment of measures to mitigate that overdraft.	GSP Alternative (SHN/Humboldt County, 2016)	Section 6.0
	(e) A description of the monitoring network within the basin, including whether data gaps exist, or any areas within the basin are represented by data that does not satisfy the requirements of Sections 352.4 and 354.34(c). The description shall include the following:	GSP Alternative (SHN/Humboldt County, 2016)	Section 6.0

California Code of Regulations - GSP Regulation Sections	*Alternative Elements*	**Document which *attachment(s) contains the applicable alternative element.***	***Document which section(s), page number(s), or briefly describe why that Alternative element does not apply to the entity.***
	(1) An assessment of monitoring network function with an analysis of data collected to date, identification of data gaps, and the actions necessary to improve the monitoring network, consistent with the requirements of Section 354.38.	GSP Alternative (SHN/Humboldt County, 2016)	Section 6.0
	(2) If the Agency identifies data gaps, the Plan shall describe a program for the acquisition of additional data sources, including an estimate of the timing of that acquisition, and for incorporation of newly obtained information into the Plan.	GSP Alternative (SHN/Humboldt County, 2016)	Section 6.0
	(3) The Plan shall prioritize the installation of new data collection facilities and analysis of new data based on the needs of the basin.	GSP Alternative (SHN/Humboldt County, 2016)	Section 6.0
	(f) A description of significant new information that has been made available since Plan adoption or amendment, or the last five-year assessment. The description shall also include whether new information warrants changes to any aspect of the Plan, including the evaluation of the basin setting, measurable objectives, minimum thresholds, or the criteria defining undesirable results.	GSP Alternative (SHN/Humboldt County, 2016)	Section 6.0
	(g) A description of relevant actions taken by the Agency, including a summary of regulations or ordinances related to the Plan.	GSP Alternative (SHN/Humboldt County, 2016)	Section 6.0
	(h) Information describing any enforcement or legal actions taken by the Agency in furtherance of the sustainability goal for the basin.	GSP Alternative (SHN/Humboldt County, 2016)	Section 6.0
	(i) A description of completed or proposed Plan amendments.	GSP Alternative (SHN/Humboldt County, 2016)	Section 6.0
	(j) Where appropriate, a summary of coordination that occurred between multiple Agencies in a single basin, Agencies in hydrologically connected basins, and land use agencies.	GSP Alternative (SHN/Humboldt County, 2016)	Section 6.0
	(k) Other information the Agency deems appropriate, along with any information required by the Department to conduct a periodic review as required by Water Code Section 10733.	GSP Alternative (SHN/Humboldt County, 2016)	Section 6.0

Appendix B

Workshop Summary (April 27, 2015)

DEPARTMENT OF PUBLIC WORKS

C O U N T Y O F H U M B O L D T

MAILING ADDRESS: 1106 SECOND STREET, EUREKA, CA 95501-0579
AREA CODE 707

ARCATA-EUREKA AIRPORT TERMINAL McKINLEYVILLE FAX 839-3596		PUBLIC WORKS BUILDING SECOND & L ST., EUREKA FAX 445-7409				CLARK COMPLEX HARRIS & H ST., EUREKA FAX 445-7388	
AVIATION	839-5401	ADMINISTRATION	445-7491	NATURAL RESOURCES	445-7741	LAND USE	445-7205
		BUSINESS	445-7652	NATURAL RESOURCES PLANNING	267-9540		
		ENGINEERING	445-7377	PARKS	445-7651		
		FACILITY MAINTENANCE	445-7493	ROADS & EQUIPMENT MAINTENANCE	445-7421		

WORKSHOP SUMMARY

Groundwater in the Eel River Valley: Responding to the New State Groundwater Legislation

Monday, April 27, 2015 10:00 am - Noon
Humboldt County Agriculture Center (5630 S. Broadway, Eureka)

Overview

The workshop was convened by Humboldt County Public Works and UC-Cooperative Extension. 36 people signed the sign-in sheet. Supervisor Rex Bohn welcomed the workshop attendees on behalf of Humboldt County. Supervisor Bohn noted that the Rural County Representatives of California (www.rcrcnet.org) has provided assistance by distributing information and convening workshops in response to the new legislation.

Hank Seemann (Humboldt County Public Works) provided an overview of the new state groundwater legislation and how it applies to the Eel River Valley. The legislation requires designation of a Groundwater Sustainability Agency for the Eel River Valley by 2017 and adoption of a Groundwater Sustainability Plan by 2022. The legislation authorizes the Groundwater Sustainability Agency to apply a variety of management tools (including requiring well meters and limiting extractions), however these tools are discretionary and not mandatory. Historical groundwater level data collected by the state Department of Water Resources (DWR) for wells located in Ferndale, Loleta, and Fortuna were presented. Historical groundwater levels in the wells monitored by DWR appear to be generally stable and do not indicate an overdraft condition. Key data and information gaps were identified: location of important recharge areas, details of groundwater and surface water interactions, groundwater levels along the Van Duzen River, aggregate pumping rates within the valley, and an overall water budget for the basin. The proposal for a stakeholder working group to help formulate a groundwater program in response to the legislation was presented.

Gary Simpson (SHN Consulting Engineers and Geologists, Inc.) provided an overview of the geologic setting for groundwater in the Eel River Valley. The valley contains three primary aquifers. The near-surface aquifer is alluvium (with thicknesses ranging from less than 100 feet to over 200 feet), underlain by units of the Carlotta or Hookton Formations. The aquifer system varies in configuration, size, and composition throughout the valley.

John Vevoda (Ferndale dairyman, California Farm Bureau) provided opening remarks from the agricultural producer perspective. Mr. Vevoda expressed a preference for local control and a concern about how the legislation addresses the concept of “beneficial use.” Mr. Vevoda stated that future management decisions should account for the fact that not all extraction is pumping from the same source (different aquifers will have different yields and recharge rates).

Merritt Perry (City of Fortuna) expressed the City’s interest in collaborating on regional groundwater issues. Fortuna depends on groundwater for its municipal water supply and is the largest municipal water user within the basin. The City has a network of five monitoring wells which have been monitored for over 15 years. Mr. Perry expressed preference for local control of groundwater management decisions.

Brad Job (Pacific Watershed Associates) discussed the role of groundwater within the hydrologic cycle and linkages between groundwater and surface water. Mr. Job emphasized the need for good data to support management decisions and encouraged proactive management to prevent irreversible impacts, which have occurred elsewhere.

David Spinosa (Humboldt County, Division of Environmental Health) provided an overview of the County's existing permitting program for the installation of groundwater wells. Construction standards are applied to prevent contamination from reaching the subsurface and impacting groundwater quality.

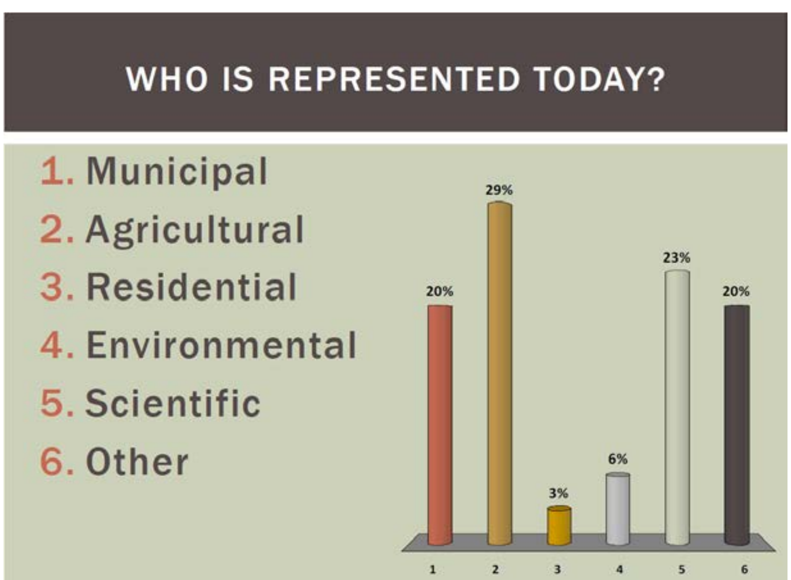
Comments

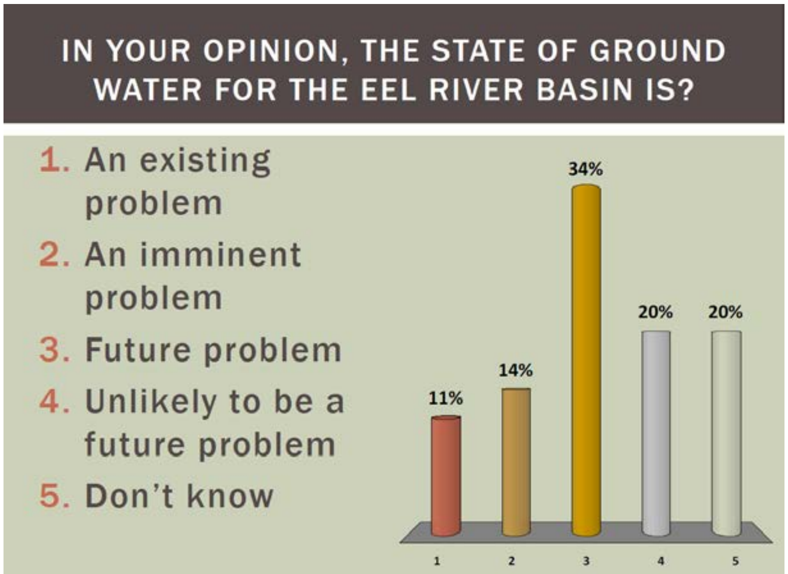
Comments raised by workshop attendees included the following:

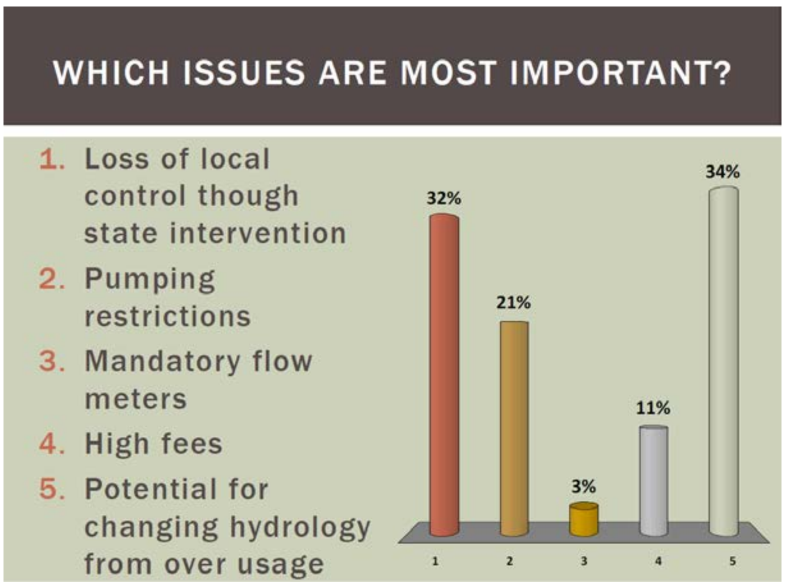
- There is a rapid increase in the number of groundwater wells and the amount of groundwater pumping throughout the County, while this process is only focusing on the Eel River Valley groundwater basin. The rest of the County should not be overlooked.
- Understanding the basic size and parameters of the aquifers within the basin is necessary for adequate management.
- The approach should aim to meet the minimum requirements while acknowledging that we are not reacting to a crisis.
- The basin boundaries are too small and should be expanded to include recharge areas and the effects of upstream users.
- The ranking criteria used by DWR to designate the Eel River Valley basin as medium priority is questionable and should be reviewed to verify that the ranking is warranted.
- More data will lead to better decisions.
- The City of Rio Dell's primary water supply source is the Eel River but the City will need to rely on groundwater resources during droughts and other emergencies.
- There is a need to quantify existing conditions and project future demands.
- More information is needed on groundwater and surface water connections.
- The approach should address the mandatory requirements with a minimum of regulation and fees.
- The approach should be based on equitable use and shared responsibility for management.
- Less governance and incentive-based approaches are desired.
- Agricultural producers have a need to continue to efficiently irrigate pastures.

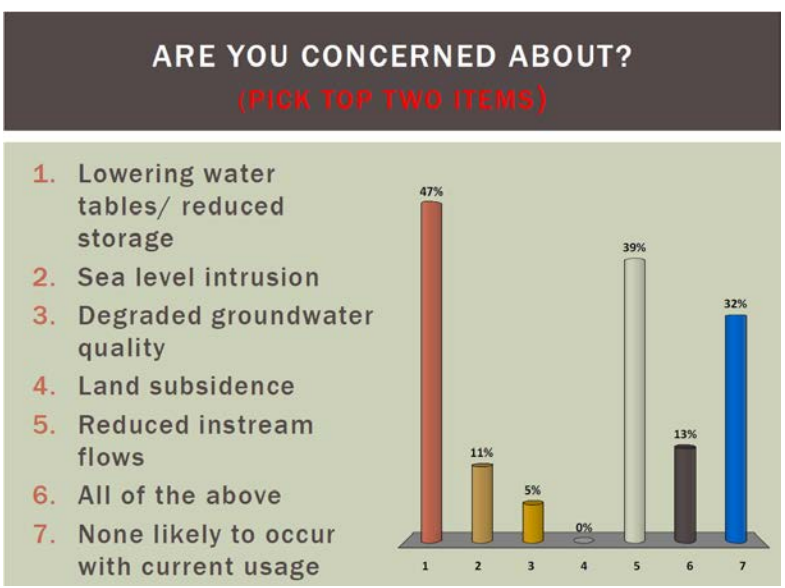
Feedback

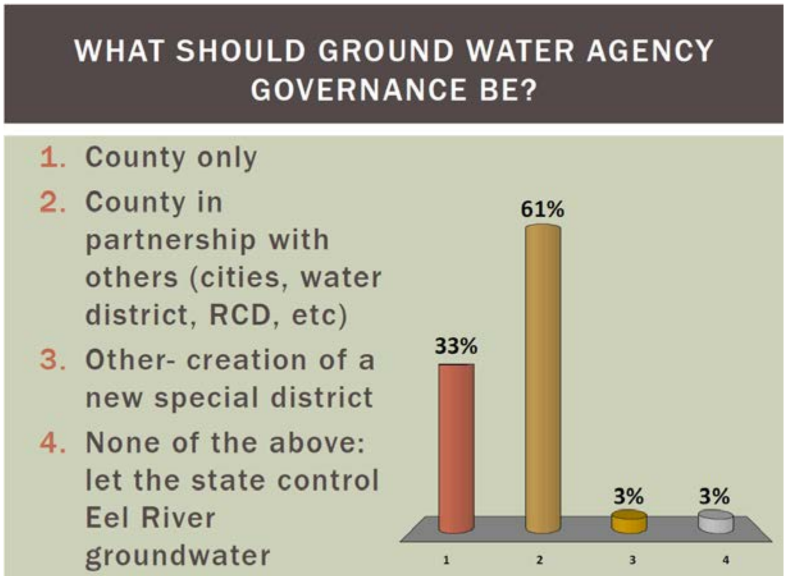
At the end of the workshop, a series of seven questions was presented to the audience for feedback. The questions and responses are summarized below:

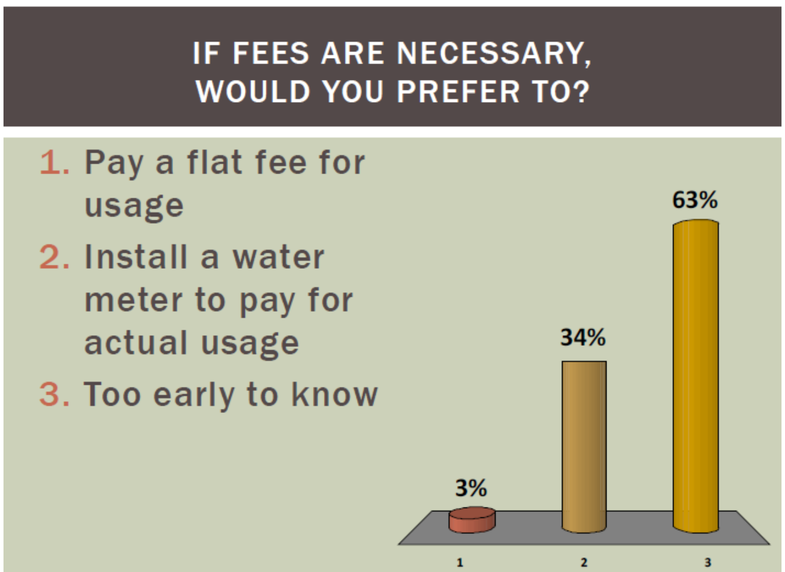


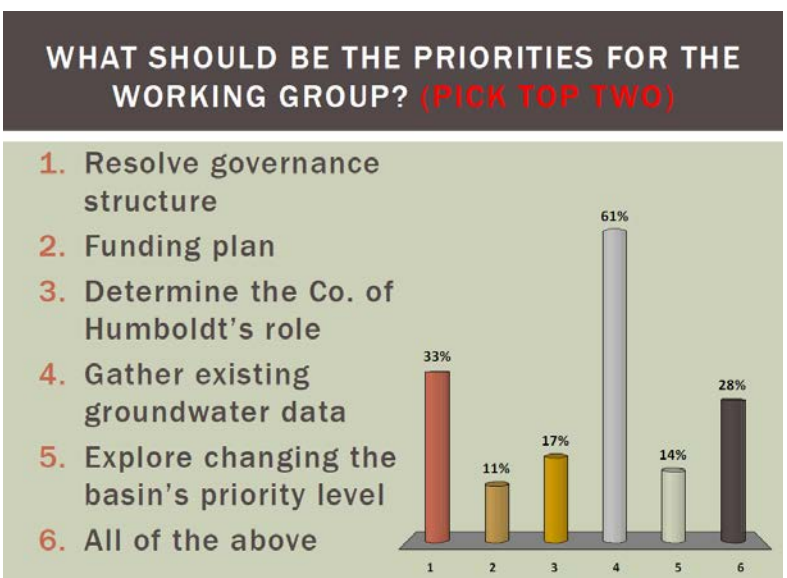

IN YOUR OPINION, THE STATE OF GROUND WATER FOR THE EEL RIVER BASIN IS?
1. An existing problem
2. An imminent problem
3. Future problem
4. Unlikely to be a future problem
5. Don't know
11%
14%
34%
20%
20%
1
2
3
4
5


WHICH ISSUES ARE MOST IMPORTANT?
1. Loss of local control though state intervention
2. Pumping restrictions
3. Mandatory flow meters
4. High fees
5. Potential for changing hydrology from over usage
32%
21%
3%
11%
34%
1
2
3
4
5


ARE YOU CONCERNED ABOUT?
(PICK TOP TWO ITEMS)
1. Lowering water tables/ reduced storage
2. Sea level intrusion
3. Degraded groundwater quality
4. Land subsidence
5. Reduced instream flows
6. All of the above
7. None likely to occur with current usage
47%
11%
5%
0%
39%
13%
32%
1
2
3
4
5
6
7


WHAT SHOULD GROUND WATER AGENCY GOVERNANCE BE?
1. County only
2. County in partnership with others (cities, water district, RCD, etc)
3. Other- creation of a new special district
4. None of the above: let the state control Eel River groundwater
33%
61%
3%
3%
1
2
3
4


IF FEES ARE NECESSARY, WOULD YOU PREFER TO?
1. Pay a flat fee for usage
2. Install a water meter to pay for actual usage
3. Too early to know
3%
34%
63%
1
2
3


WHAT SHOULD BE THE PRIORITIES FOR THE WORKING GROUP? (PICK TOP TWO)
1. Resolve governance structure
2. Funding plan
3. Determine the Co. of Humboldt's role
4. Gather existing groundwater data
5. Explore changing the basin's priority level
6. All of the above
33%
11%
17%
61%
14%
28%
1
2
3
4
5
6

List of Attendees

Name	Affiliation	Interested in Participating in Working Group
Ben Dolf	Humboldt County Division of Environmental Health	Yes
Brad Job	Pacific Watershed Associates	Yes
Carolyn Hawkins	Humboldt County Division of Environmental Health	
Cheryl Laffranchi	Northcoast Pumphouse	Maybe
Chris Howard	Alexandre EcoDairy Farms	
Clif Clendenen	Clendenen's Cider Works, Humboldt County Farm Bureau	Yes
David Manthorne	Cal. Department of Fish & Wildlife	
David Spinosa	Humboldt County Division of Environmental Health	
Denver Nelson	Humboldt County Fish and Game Advisory Committee, dairy owner	Yes
Doreen Hansen	Humboldt County Resource Conservation District	
Estelle Fennel	Humboldt County Board of Supervisors	
Frances Tjarnstrom	Humboldt County Resource Conservation District	Yes
Gary Markegard	Humboldt County Resource Conservation District	
Gary Simpson	SHN Consulting Engineers and Geologists	
Hank Seemann	Humboldt County Public Works Department	
Jay Russ	Humboldt County Farm Bureau, cattle rancher	Yes
Jeffrey Stackhouse	University of California Cooperative Extension	
Johanna Rodoni	Buckeye Conservancy, Humboldt County Farm Bureau	
John Vevoda	California Farm Bureau, Humboldt County Farm Bureau, dairyman	Yes
Jon Shultz	USDA-Natural Resources Conservation Service	Yes
Julie Houtby	American AgCredit	
Justin Ebrahemi	HSU graduate student	
Katherine Zeimer	Humboldt County Farm Bureau	
Kyle Knopp	City of Rio Dell	Yes
Lee Mora	Humboldt Grassfed Beef	Yes
Marcus Drumm	Loleta Community Services District	Yes
Mark Smelser	California Department of Fish & Wildlife	
Melissa Lema	Western United Dairymen	Yes
Merritt Perry	City of Fortuna	
Nancy Trujillo	Riverside Community Services District	Yes
Nick Angeloff	Rio Dell Planning Commission, Rio Dell-Scotia Chamber of Commerce	
Pat Higgins	Eel River Recovery Project	
Patrick Sullivan	GHD, Inc.	Yes
Randy Hooper	Del Norte County	
Rex Bohn	Humboldt County Board of Supervisors	
Robert Vogt	Humboldt County Public Works Department	
Russ Forsburg	American AgCredit	
Scott Greacon	Friends of the Eel River	Yes
Tom Gast	Fisheries consultant	Yes
Troy Hubner	Del Oro Water Company	
Vivian Helliwell	Pacific Coast Federation of Fishermen’s Associations	Yes
Yana Valachovic	University of California Cooperative Extension	

Appendix C

Humboldt County Board of Supervisors
Resolution No. 16-142

BOARD OF SUPERVISORS, COUNTY OF HUMBOLDT, STATE OF CALIFORNIA
Certified copy of portion of proceedings, Meeting of December 13, 2016

RESOLUTION NO. 16-142

RESOLUTION AUTHORIZING THE PUBLIC WORKS DEPARTMENT TO SUBMIT A GROUNDWATER SUSTAINABILITY PLAN ALTERNATIVE FOR THE EEL RIVER VALLEY GROUNDWATER BASIN TO THE CALIFORNIA DEPARTMENT OF WATER RESOURCES

WHEREAS, the Department of Water Resources ("DWR") designated the Eel River Valley groundwater basin ("Basin") as a medium-priority basin for the initial prioritization under the Sustainable Groundwater Management Act which went into effect on January 1, 2015; and

WHEREAS, the Sustainable Groundwater Management Act authorizes local agencies to submit an Alternative to a Groundwater Sustainability Plan ("Alternative") that provides analysis of basin conditions demonstrating that the basin has operated within its sustainable yield over a period of at least 10 years (California Water Code §10733.6); and

WHEREAS, the content of an Alternative must contain the functional equivalent of Articles 5 and 7 of the Groundwater Sustainability Plan regulations (California Code of Regulations, Title 23, §358.2(d)); and

WHEREAS, an Alternative must be submitted to DWR for review by January 1, 2017, and every five years thereafter; and

WHEREAS, the County of Humboldt is a local public agency with land use responsibilities within the unincorporated areas of the Basin; and

WHEREAS, the County of Humboldt serves as the monitoring entity for the California Statewide Groundwater Elevation Monitoring program within the Basin in collaboration with DWR; and

WHEREAS, on October 6, 2015, the Board of Supervisors approved the formation of an Eel River Valley Groundwater Working Group to consist of stakeholders representing agricultural, municipal, and environmental interests and provide input on organizing the local response to the Sustainable Groundwater Management Act for the Eel River Valley; and

WHEREAS, the Eel River Valley Groundwater Working Group has convened seven meetings between October 21, 2015, and December 2, 2016; and

WHEREAS, in July 2016, DWR awarded the County of Humboldt a Proposition 1 Sustainable Groundwater Planning Grant to conduct a geologic and hydrogeologic investigation to determine whether groundwater levels within the Eel River Valley groundwater basin are declining or fluctuating to the point of causing impacts such as reduced groundwater storage, seawater intrusion, threatening or degrading water quality, land subsidence, and/or surface water depletion; and

BOARD OF SUPERVISORS, COUNTY OF HUMBOLDT, STATE OF CALIFORNIA
Certified copy of portion of proceedings, Meeting of December 13, 2016

RESOLUTION NO. 16-142

WHEREAS, the results of the aforementioned technical studies indicate that there is sufficient evidence to prepare an Alternative for the Basin.

NOW, THEREFORE, BE IT RESOLVED BY THE HUMBOLDT COUNTY BOARD OF SUPERVISORS THAT:

1. In accordance with California Water Code §354.6(d) and §358.2(c)(3), the County of Humboldt has the legal authority to submit and implement an Alternative to a Groundwater Sustainability Plan for the Eel River Valley Groundwater Basin; and
2. The Public Works Department is hereby authorized to prepare and submit an Alternative to a Groundwater Sustainability Plan for the Eel River Valley Groundwater Basin by January 1, 2017.

Dated: December 13, 2016

MARK LOVELACE, Chair
Humboldt County Board of Supervisors

Adopted on motion by Supervisor Fennell, seconded by Supervisor Sundberg, and the following vote:

AYES:	Supervisors	Sundberg, Fennell, Lovelace, Bohn
NAYS:	Supervisors	--
ABSENT:	Supervisors	Bass
ABSTAIN:	Supervisors	--

STATE OF CALIFORNIA)
County of Humboldt)

I, KATHY HAYES, Clerk of the Board of Supervisors, County of Humboldt, State of California, do hereby certify the foregoing to be an original made in the above-entitled matter by said Board of Supervisors at a meeting held in Eureka, California.

IN WITNESS WHEREOF, I have hereunto set my hand and affixed the Seal of said Board of Supervisors.

By ANA HARTWELL
Deputy Clerk of the Board of Supervisors of the County of Humboldt, State of California

Appendix D

Irrigation Water Use Study (HCRCD, 2016)

Humboldt County Resource Conservation District
5630 South Broadway Eureka, CA 95503
Phone (707) 442-6058 Ext. 5
hcrcd@yahoo.com

Technical Memorandum – Irrigation Water Use Study

Date: December 8, 2016

To: Hank Seemann, Humboldt County Department of Public Works (County)

From: Jill Demers, Executive Director, Humboldt County Resource Conservation District (HCRCD)

Re: Evaluation of Irrigated Acres and Irrigation Water Use Rates in the Eel River Valley Groundwater Basin

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This memorandum provides the results of the evaluation performed by the HCRCD to assist the County in characterizing irrigated lands and irrigation water use rates within the Eel River Valley Groundwater Basin, Humboldt County, CA to support the Eel River Valley Groundwater Working Group.

The purpose of this effort is to support agricultural producers, Humboldt County, and other stakeholders in preparing a response to the Sustainable Groundwater Management Act of 2014 by developing estimates of water use rates from agricultural irrigation that can account for annual variation in precipitation, crop production, and total acres irrigated in the Eel River Valley Groundwater Basin. A primary objective is to develop supporting data and information for estimates of water applied in an irrigation season and total number of acres irrigated for Water Year 2007 through 2016. Within Humboldt County, few (if any) irrigation systems are equipped with flow meters, therefore water use rates must be estimated indirectly. It is understood that the estimates of water use will be reasonable approximations of the aggregate irrigation practices within the Eel River Valley using the best available information; however, there will be an inherent level of variability and uncertainty.

HCRCD staff, along with County representatives, initially determined steps to be taken to identify the information provided in this memo. HCRCD also consulted regularly with Cheryl and Don Laffranchi from NorthCoast Pumphouse, who have 42 years of experience working with agricultural producers on irrigation systems and management practices in the basin, and Jeff Stackhouse, Humboldt County Livestock and Natural Resource Advisor University of California Cooperative Extension (UCCE) throughout this process. Below, we describe the sources of information, methods, and assumptions in calculating irrigated acres and water use rates in the basin.

1 METHODS

1.1 Water Year Classification

Long-term rainfall records (March 1963 through the present) were obtained from Rob Roberts and Jerry Lema of Ferndale, CA. A rain gauge has been operated at the Ferndale Museum (515 Shaw Avenue) since October 1994. The current rain gauge was manufactured by Productive Alternatives and was provided by the National Weather Service in the 1990s when the museum served as an official gauging site. From October 1970 through October 1994, daily rainfall measurements were collected by George Anderson at 1345 Main Street in Ferndale. Information regarding the location of the rain gauge from March 1963 through October 1970 was not readily available.

Monthly rainfall totals are shown in Attachment 1. Rainfall amounts are grouped by water year (for example, Water Year 2016 extends from October 2015 through September 2016).

In the coastal regions of Humboldt County, the typical growing season extends from April through October. Producers begin to operate irrigation systems in the spring when the soil moisture provided by rainfall is insufficient to support optimal vegetation growth. The end-date when irrigation systems are turned off is traditionally October 1, while the start-date will vary year to year primarily based on the timing and amounts of rainfall during the winter and spring, with wind and air temperature as secondary factors. For the purpose of this study, we classified three types of water years and estimated the start-date for and duration of an irrigation season in each type of water year as follows:

a) Dry water year – April 15 through October 1 (168 days)
b) Normal water year – May 15 through October 1 (138 days)
c) Wet water year – June 1 through October 1 (121 days)

To assist with classifying water year type, we grouped the wet-season rainfall amounts into four two-month totals (October-November, December-January, February-March, April-May). We compared the annual rainfall amount and the four two-month rainfall amounts to the 50-year averages and assigned a water year classification to each year using our professional judgment and historical knowledge of irrigation practices in the Eel River Valley Groundwater Basin. The classification of water years from 2007 through 2016 are shown in Attachment 1. For this ten-year period, there were a total of five dry years, three normal years, and two wet years.

1.2 Irrigated Acres

The HCRCD began the process of identifying and characterizing irrigated lands by digitizing in ArcGIS (ESRI© 2010) pastures and/or entire parcels within the Eel River Valley Groundwater Basin using the Department of Water Resources (DWR) Groundwater Basin 1-10 boundary GIS polygon (updated October 2016), current aerial imagery, our knowledge of current irrigation practices on the ground, interviews with agricultural producers, and consultations with professional experts Cheryl and Don Laffranchi, NorthCoast Pumphouse and Jeff Stackhouse, UCCE. We interviewed seven land managers and agricultural producers in the basin using the questionnaire developed by HCRCD and UCCE and provided as Attachment 2. We selected these producers to represent the different irrigation equipment types used in the basin and designed questions about their land management practices to capture information such as acres irrigated, the type of equipment used and irrigation infrastructure currently in place, the number of water sources and water source type used for irrigation water, seasonal irrigation scheduling, crop types grown or growing, and any planned future land management or equipment changes. Interviews and consultations took place during the months of September and October 2016.

We developed criteria and classified an area as irrigated if it was irrigated during the 2016 calendar year, irrigated within the last 5 years, or had irrigation infrastructure in place (e.g., agricultural well and functional irrigation pipeline(s) and/or irrigation equipment). We further characterized irrigated areas by crop type, water source, irrigation equipment type, and geographical area.

Based on information collected from agricultural producers and land managers, Don and Cheryl Laffranchi, and Jeff Stackhouse, we identified the dominant crop types grown throughout the basin in 2016. HCRCD and Jeff Stackhouse, UCCE, performed ground-truth verifications by driving around the basin to map and quantify crop types grown in 2016 and reviewing aerial imagery. We grouped crop types into four categories: pasture (grazed pastures/hay production/alfalfa production), corn, quinoa, and tree/row crops (including tree farms, vegetable production). We did not include small backyard vegetable gardens, nurseries and greenhouses, or cannabis. The cultivation of cannabis likely occurs in the basin, but at this time the extent of this crop type is not readily quantifiable, therefore it is not included in this study. We recommend future studies to quantify water usage associated with cannabis.

We identified three sources of water used for irrigation in the basin: surface water; groundwater; and reclaimed wastewater. Several pasture sites in the Ferndale, Fernbridge, Rio Dell/Metropolitan, and Scotia areas are irrigated using reclaimed wastewater from treatment plants (e.g., City of Ferndale, City of Rio Dell, Town of Scotia wastewater treatment plants) or from a milk production facility (i.e., Humboldt Creamery). Therefore, we characterized these pastures as irrigated by reclaimed wastewater. We characterized pastures where irrigation water is sourced from springs or surface water diversions as irrigated by surface water.

We determined that there are five dominant irrigation equipment types used in the basin: handline; traveling gun; center pivot; K-line; and wheel-line. The use of other irrigation equipment, such as hoses and flood irrigation, was infrequent and uncommon and we classified this equipment as other.

We assigned geographical area based on the proximity of an area to the nearest city or town. These designations include: Alton, Carlotta, Fernbridge, Ferndale, Fortuna, Hydesville, Loleta, Metropolitan, Rohnerville, Rio Dell, and Scotia.

We classified pastures and fields located within the Eel River Valley but outside of or bisected by the DWR basin boundary as irrigated due to irrigation water being sourced from groundwater well(s), the elevation of wells, and the proximity to the basin boundary. In addition, we classified areas where quinoa is grown and irrigation infrastructure is present as irrigated despite quinoa being a dry farm crop.

We completed area calculations within ArcGIS to obtain the total number of irrigated acres in the Eel River Valley Groundwater Basin and by geographical area, crop type, and irrigation equipment type. All maps were reviewed by Cheryl and Don Laffranchi of NorthCoast Pumphouse to verify designations and acreages based on their direct knowledge working with agricultural producers. Maps presenting the results of the 2016 irrigated acreage survey are provided in Attachments 3a – 3c.

1.3 Irrigation Water Use Rate

HCRCD interviewed seven producers as described in Section 1.2 and Attachment 2 to determine the producers' average number of irrigation events (referenced herein as "irrigation sets") in dry, normal, or wet water years (as described in Section 1.1). HCRCD and Don Laffranchi also reviewed aerial imagery of the basin and, based on historical working knowledge of the area, delineated pastures and parcels by the type of irrigation equipment used by individual producers. As described in Section 1.2, irrigation equipment used in the basin consists of five main types: handline; traveling gun; center pivot; K-line; and wheel-line. We identified a few instances of irrigation by other equipment types, however, because it was less than 0.001% of the total area, we excluded it from the water use rate calculations. In addition, HCRCD and Don Laffranchi conducted field calibrations and evaluations of irrigation equipment types at multiple sites throughout the basin. Field calibrations consisted of observing irrigation equipment while in operation, measuring area where water is applied by equipment type, calculating run times, and an evaluation of well and pump capacity by Don Laffranchi to calculate gallons per minute of water applied.

Our goal is to develop a reasonable estimate of the annual amount of groundwater used for irrigation. Therefore, we developed the average water use rate accounting only for acres irrigated by groundwater as determined in Section 1.2 and did not include surface water or reclaimed wastewater. Although crop type for 2016 was distinguished in our survey, we assumed that all irrigation water was applied to grazed pasture or hay and alfalfa production. This crop type represents over 85% of irrigation water usage in the Eel River Valley. Other crops require less irrigation; for example, irrigation for corn occurs less frequently, and quinoa is a dry farm crop. However, crop types grown in the Eel River Valley Groundwater Basin can change from year to year, and the crop type changes over the last ten years were not quantified. Therefore, we developed the average water use rate assuming all irrigation is applied for pasture to estimate the greatest potential irrigation water use for typical crops grown in the Eel River Valley. Future applications of the methodology developed in this memorandum could distinguish crop type, if desired. We also excluded cannabis, small backyard vegetable gardens, and nursery and greenhouse operations from this calculation.

We used the following equations to estimate the irrigation water use rates for a) the entire basin (acre feet/basin) and b) per acre (acre-feet/acre) for each water year. One acre-foot of water is equivalent to 325,851 gallons. This approach provides a weighted average of groundwater applied for irrigation based on equipment type.

Equation A:

$$Sum\left\{\left[\left(\frac{\left(\left(equipment\ type\ \frac{gallons}{minute}\right)\left(\frac{minutes}{set}\right)\right)}{\left(\frac{gallon}{acre\ feet}\right)}\right)\Big/\left(equipment\ type\ \frac{acres}{set}\right)\right]\times\left(\frac{sets}{water\ year}\right)\times\left(\begin{matrix}equipment\ type\\ irrigated\ acres\end{matrix}\right)\right\}=\frac{acrefeet}{basin}\ water\ year$$

Equation B:

$$\frac{\left(\frac{acrefeet}{basin}\ water\ year\right)}{(total\ irrigated\ acres\ )}=\frac{acrefeet}{acre}water\ year$$

We describe the value of the parameters used in the equations below and provide Attachment 4 to show the detailed calculation steps. Calculation parameters for *Equation A* are:

Equipment type gallons/minute
Each type of equipment is capable of applying a different rate of water based on pump size, nozzle size, hose or pipe length, and pipe diameter. We averaged the results from producer interviews and field calibrations to estimate average gallons per minute (GPM) for each type of equipment.

Minutes/set
The number of minutes per set varies by equipment type used and the individual operation. We obtained estimates of hours/set from producer interviews and from this data, calculated the average minutes/set for each equipment type.

Gallons/acre foot
There are 325,851 gallons/acre-foot.

Equipment type acres/set
The area irrigated during a set will vary by operation based on size of individual fields and irrigation infrastructure. We obtained estimates of the acres/set during producer interviews and calculated the average acres/set for each equipment type.

Sets/water year
We classified each water year as dry, normal, and wet and determined the duration of the irrigation season in each water year in days as described in Section 1.1. We obtained estimates of number of sets per water year from producer interviews. On average, producers reported that they were able to irrigate an area every 26 – 30 days. We assigned the number of days between sets to each water year type: we assigned 26 days between sets to a dry year, 27 days between sets to a normal water year, and 30 days between sets to a wet water year. For each water year, we divided the number of days in an irrigation season by the number of days between sets to obtain sets/water year as follows:

a) Dry water year (April 15-October 1) – 6.5 sets per year
b) Normal water year (May 15-October 1) – 5.3 sets per year
c) Wet water year (June 1-October 1) – 4.0 sets per year

Equipment type irrigated acres
The number of acres irrigated by different equipment types using groundwater as described in Section 1.2 and Table 4.

For *Equation B*, the total irrigated acres parameter is the acres of land in the basin irrigated by groundwater sources only, as determined in Section 1.1.

2 RESULTS & DISCUSSION

2.1 Irrigated Acres

The total area of irrigated land in the Eel River Valley Groundwater Basin is estimated at 14,022 acres. Table 1 describes the amount of estimated irrigated land (acres) within the identified geographical areas. This estimate is less than what has previously been reported (DWR, 2012) as discussed in Section 3. We believe the estimate developed in our study more accurately captures on-the-ground conditions and reflects local data and professionals' knowledge of the basin. For example, we did not find extensive irrigation occurring in the western portions of the Eel River Valley Groundwater Basin (attachments 3a – 3b) and irrigation infrastructure is not in place. This is locally recognized to be due to landscape and soil features that provide "sub-irrigation", or moisture for crops from soil reserves. Similarly, there are other areas throughout the basin that we identified as not receiving irrigation and thus contributed to the lower estimate.

Table 1. Estimated area (acres) irrigated in each geographical area in the Eel River Basin Valley Groundwater, Humboldt County, CA.

Geographical Area	Acres
ALTON	887
CARLOTTA	383
FERNBRIDGE	160
FERNDALE	10,299
FORTUNA	13
HYDESVILLE	122
LOLETA	1,463
RIO DELL/METROPOLITAN	566
ROHNERVILLE	13
SCOTIA	116
Total Acres	**14,022**

Pasture accounts for 85% of the irrigated crop type in the basin (Table 2). Groundwater is the principle irrigation water source in the basin, accounting for 13,558 of the acres irrigated, or

97% of the basin (Table 3). Within the area where groundwater is the principle irrigation water source, handlines and traveling guns were the primary irrigation equipment types used (Table 4).

Table 2. Estimated area (acres) irrigated by crop type grown in 2016 in the Eel River Valley Groundwater Basin, Humboldt County, CA.

Crop Type Grown in 2016	Acres
Corn	1,750
Pasture	11,994
Quinoa	127
Tree/Row	151
Total Acres	**14,022**

Table 3. Estimated area (acres) irrigated by water source in the Eel River Valley Groundwater Basin, Humboldt County, CA.

Irrigation water source	Acres
Ground Water	13,558
Surface Water	126
Reclaimed Wastewater	339
Total Acres	**14,022**

Table 4. Total acres and percent of total acres irrigated by equipment type using groundwater in the Eel River Valley Groundwater Basin, Humboldt County, CA.

Equipment Type	Acres	% of Total Acres
Handline	7,044	52%
Traveling Gun	4,310	32%
Wheel Line	1,107	8%
K-Line	989	7%
Center Pivot	88	1%
Other	20	<0.001%
Total	**13,558**	**100%**

2.2 Irrigation Water Use Rates

We estimate that groundwater use throughout the Eel River Valley Groundwater Basin ranges from 10,265 acre-feet in a wet water year to 16,680 acre-feet in a dry water year (Table 5). Per acre, groundwater use ranges from 0.8 acre-feet/acres in a wet water year to 1.2 acre-feet/acres in a dry water year (Table 5).

Table 5. Irrigation groundwater use rate by water year in the Eel River Valley Groundwater Basin, Humboldt County, CA.

Water Year	Total Acre-Feet in Basin	Acre-Feet/Acre	Estimate of Water Use in Last 10 Years
Dry Irrigation Season (April 15th – October 1st)	16,680	1.2	2008, 2009, 2013, 2014, 2015
Normal Irrigation Season (May 15th – October 1st)	13,600	1.0	2007, 2012, 2016
Wet Irrigation Season (June 1st – October 1st)	10,265	0.8	2010, 2011

This effort attempts to estimate the annual amount of groundwater used for irrigation in the Eel River Valley Groundwater Basin. We believe that these estimates of water use are reasonable approximations of groundwater use within the Eel River Valley, however there will be an inherent level of variability and uncertainty. Variation exists between each agricultural operation, as each has its own land base, infrastructure and management approach. For example, the number of irrigation sets / water year can vary based on type of equipment, pasture configuration, equipment failures, scheduling irrigation by peak hour electrical use rates, and availability of labor. The results that are provided here represent the best information readily available from a sample of farms within the basin.

3 COMPARISON WITH OTHER PUBLISHED VALUES

USGS (1978)

The U.S. Geological Survey published "Ground-Water Conditions in the Eureka Area, Humboldt County, California, 1975" (Water-Resources Investigations 78-127) in December 1978. The estimated groundwater use in the Eel River floodplain and the Eel and Van Duzen River valleys upstream of the confluence for 1975 was 17,300 acre-feet (Table 3 in USGS, 1978). This estimate utilized the "energy-lift" method based on electricity usage records and pump information. The 1978 USGS report also presents data compiled by DWR from 1968 which indicated a total of 18,800 acre-feet over 11,700 acres within the same study area. The 1968 DWR data were based on the "land-use" method which utilized a unit applied-water factor ranging from 1.0 to 1.7 acre-feet per acre based on crop type. USGS (1978) concluded that groundwater pumpage had remained fairly stable from the late 1950s to the mid-1970s.

DWR (2003)

DWR updated "California's Groundwater" (Bulletin 118) in 2003. The description for the Eel River Valley Groundwater Basin (updated February 27, 2004) includes an estimate of 49,000 acre-feet of water use for agricultural purposes. The document does not provide an estimate of irrigated acreage or water use rate (acre-feet per acre) within the basin. The document references a survey conducted by DWR in 1996; however, additional information regarding the survey data or methodology is not provided. The results in the DWR Bulletin (2003) are significantly higher than the results presented in this memorandum.

DWR (2012)

In 2015, the DWR Red Bluff office provided Humboldt County an unpublished spreadsheet titled "Developed Water Use Balance" for the year 2010. This spreadsheet indicates an estimate of 21,900 acre-feet over 23,700 acres for the Lower Eel River detailed analysis unit (DAU) and 2,500 acre-feet over 3,100 acres for the Van Duzen DAU, for a total of 24,400 acre-feet over 26,800 acres within the groundwater basin. The implied water use rate over the entire basin is 0.91 acre-feet per acre. While the irrigated acreage values in DWR (2012) are nearly two times higher than the results presented in this memorandum, the water use rate in DWR (2012) is comparable to the water use rate we estimated for a normal water year.

USDA (2013)

U.S. Department of Agriculture published a 2013 Farm and Ranch Irrigation Survey (FRIS) [https://www.agcensus.usda.gov/Publications/2012/Online_Resources/Farm_and_Ranch_Irrigation_Survey/]. On Table 36 of USDA (2013), the average acre-feet of applied water per acre in California is 3.8 for "alfalfa and mixtures"; 2.8 for "all other hay (dry hay, greenchop, and silage)"; and 2.0 for "pastureland, all types." These results reflect state-wide averages and are not representative of the climatic characteristics of coastal Humboldt County. The close proximity to the Pacific Ocean leads to mild summer temperatures and regular occurrences of heavy fog. The relatively low air temperature and high relative humidity results in the North Coast having the lowest evapotranspiration rate in California, as shown on the state-wide Reference Evapotranspiration zone map (DWR, 1999). Therefore, water use rates within the Eel River Valley Groundwater Basin are expected to be significantly lower than warmer and more arid regions of the state.

4 OBSERVATIONS ON CHANGES OVER THE LAST 10 YEARS AND POTENTIAL CHANGES OVER THE NEXT 5 YEARS

Through producer interviews we identified changes to land management over the last 10 years and future changes planned for the next 5 years.

In the past 10 years, there has been an increase in the number of wells drilled in the Eel River Valley Groundwater Basin through cost-share assistance provided to eligible producers from the USDA-Natural Resources Conservation Service (NRCS) Environmental Quality Incentives

Program (EQIP) for Drought Assistance and the USDA-Farm Service Agency (FSA) Emergency Conservation Program (ECP). Older wells have also been deepened due to recent drought conditions. New infrastructure and/or improvements to existing irrigation systems have allowed some producers to increase the number of acres they irrigate. Producers have been and continue to replace older, inefficient irrigation equipment with newer, more efficient equipment. Currently, there are approximately 49 dairies that operate in the Eel River Valley Groundwater Basin. All except a few of these are now certified organic, which requires an increased focus on effective management of pastures, including irrigation. In the past 10 years, we have seen approximately 8 dairies switch to beef and/or crop-only production. In the last 3 years, there has been a trend towards more dry farm cropping (quinoa), although this crop type can be rotated with perennial pasture grassland crops. Overall, these changes are relatively small, and we do not believe there were any major changes in water use over the last 10 years.

In the next 5 years, land managers anticipate continued improvements of irrigation infrastructure and more efficiently applying irrigation water on crops. The types of crops grown may vary by year, and we expect crops to be influenced by factors such as climatic conditions and industry supply and demand.

5 ABOUT HCRCD

Established in 1987 as the Eel River Valley Resource Conservation District, the Humboldt County Resource Conservation District (HCRCD) has a proven track record of accomplishments with our local dairy industry, and has successfully implemented soil and water conservation projects with dairies for the past 17 years. The HCRCD recently completed the North Coast Irrigation Water and Fertigation Management Plan to provide increased knowledge to producers on practices that optimize irrigation water and fertilizer usage, increase sustainable use and conservation of groundwater resources, and improve pasture productivity.

Attachment 1: Monthly rainfall totals (inches) recorded in Ferndale, Humboldt County, CA

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Annual	Oct-Nov	Dec-Jan	Feb-Mar	Apr-May	Water Year Classification
1963						6.91	10.89	1.70	0.35	0.27	0.14	0.51						
1964	4.20	7.12	3.44	10.72	1.18	5.25	0.43	1.42	0.54	0.23	0.22	0.07	34.82					
1965	2.59	11.50	18.55	7.26	1.61	1.06	6.01	0.29	0.51	0.07	0.35	0.06	49.86					
1966	0.74	7.01	6.58	9.88	3.85	6.37	1.39	0.03	0.36	0.22	0.44	1.25	38.12					
1967	0.71	9.87	7.48	8.49	0.97	8.51	4.73	1.16	0.58	0.02	0.06	1.84	44.42	10.58	15.97	9.48	5.89	
1968	2.29	4.77	4.66	9.32	2.98	4.10	0.62	0.81	0.17	0.22	2.11	0.35	32.40	7.06	13.98	7.08	1.43	
1969	2.56	5.81	11.55	13.88	11.1	1.45	3.57	1.10	0.53	0.16	0.01	0.38	52.10	8.37	25.43	12.55	4.67	
1970	1.85	3.96	9.72	12.4	3.77	2.88	1.62	0.80	0.21	0.00	0.00	0.00	37.21	5.81	22.12	6.65	2.42	
1971	1.57	10.91	10.75	6.32	3.49	7.93	2.73	0.77	1.25	0.13	0.45	1.03	47.33	12.48	17.07	11.42	3.5	
1972	1.36	7.20	8.21	6.61	6.89	4.30	3.29	0.71	0.47	0.02	0.07	0.48	39.61	8.56	14.82	11.19	4	
1973	4.77	5.23	7.12	8.13	4.48	7.25	0.77	0.00	0.49	0.01	0.11	1.88	40.24	10.00	15.25	11.73	0.77	
1974	3.45	19.67	7.89	9.66	6.78	8.24	4.08	0.38	0.49	0.35	0.37	0.00	61.36	23.12	17.55	15.02	4.46	
1975	1.18	2.14	8.71	5.45	9.30	11.92	3.07	0.56	0.29	0.15	0.31	0.00	43.08	3.32	14.16	21.22	3.63	
1976	6.91	5.51	5.95	2.19	7.66	3.00	3.50	0.28	0.16	0.00	0.17	3.37	38.70	12.42	8.14	10.66	3.78	
1977	2.14	5.32	7.38	10.35	8.59	3.88	4.80	0.94	0.19	0.14	1.58	0.06	45.37	7.46	17.73	12.47	5.74	
1978	0.16	3.65	0.62	1.93	3.20	4.72	1.13	2.44	0.32	0.06	0.41	2.71	21.35	3.81	2.55	7.92	3.57	
1979	0.04	0.99	2.80	4.63	6.97	3.31	3.20	1.81	0.03	0.28	0.67	0.55	25.28	1.03	7.43	10.28	5.01	
1980	7.66	5.86	4.19	3.51	7.21	5.58	4.45	1.27	0.14	0.01	0.08	0.25	40.21	13.52	7.7	12.79	5.72	
1981	1.05	2.07	6.83	11.55	4.40	5.32	0.72	1.46	0.24	0.05	0.06	0.93	34.68	3.12	18.38	9.72	2.18	
1982	3.57	10.91	7.57	5.47	4.68	8.42	7.61	0.06	0.56	0.18	0.14	0.48	49.65	14.48	13.04	13.1	7.67	
1983	5.91	7.89	11.64	9.26	11.40	10.97	6.23	1.32	0.71	0.90	3.78	0.18	70.19	13.80	20.9	22.37	7.55	
1984	1.04	12.69	14.46	0.66	4.97	4.35	2.77	1.60	1.00	0.02	0.05	0.13	43.74	13.73	15.12	9.32	4.37	
1985	3.68	16.34	4.47	0.76	4.18	4.94	0.27	0.70	0.96	0.05	0.32	1.10	37.77	20.02	5.23	9.12	0.97	
1986	3.97	3.42	2.66	8.50	11.65	6.31	1.58	1.88	0.14	0.02	0.02	2.92	43.07	7.39	11.16	17.96	3.46	
1987	1.53	1.90	4.80	6.76	4.43	10.03	0.90	0.31	0.17	0.24	0.08	0.05	31.20	3.43	11.56	14.46	1.21	
1988	0.75	3.87	12.55	6.78	0.18	1.21	2.14	1.89	2.68	0.09	0.03	0.05	32.22	4.62	19.33	1.39	4.03	
1989	0.56	9.93	7.67	5.08	3.11	7.98	1.66	1.16	0.25	0.02	0.37	0.95	38.74	10.49	12.75	11.09	2.82	

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Annual	Oct-Nov	Dec-Jan	Feb-Mar	Apr-May	Water Year Classification
1990	3.25	2.01	0.71	7.46	5.77	3.18	1.45	3.65	0.23	0.43	0.51	0.12	28.77	5.26	8.17	8.95	5.1	
1991	2.07	2.89	2.63	0.91	3.36	7.84	1.43	1.88	0.31	0.43	0.93	0.08	24.76	4.96	3.54	11.2	3.31	
1992	1.24	2.33	2.10	3.18	6.70	4.41	1.87	0.22	0.72	0.19	0.15	0.17	23.28	3.57	5.28	11.11	2.09	
1993	1.98	2.57	10.44	8.20	6.20	4.36	4.60	3.70	1.71	0.49	0.64	0.27	45.16	4.55	18.64	10.56	8.3	
1994	0.47	1.77	7.61	5.54	8.59	2.86	3.12	1.49	0.57	0.13	0.04	0.20	32.39	2.24	13.15	11.45	4.61	
1995	0.50	7.21	7.69	16.22	2.17	12.52	6.72	1.38	1.11	0.26	0.19	0.46	56.43	7.71	23.91	14.69	8.1	
1996	0.58	1.32	11.97	9.70	8.53	3.33	5.02	1.90	0.03	0.07	0.11	0.75	43.31	1.90	21.67	11.86	6.92	
1997	2.43	5.19	23.13	9.71	2.50	2.65	2.76	0.44	1.13	0.07	0.63	0.85	51.49	7.62	32.84	5.15	3.2	
1998	2.68	8.36	5.95	14.76	17.08	8.79	3.51	3.48	0.76	0.53	0.14	0.17	66.21	11.04	20.71	25.87	6.99	
1999	2.26	11.80	6.05	4.95	12.13	10.43	3.00	1.40	0.30	0.17	0.65	0.15	53.29	14.06	11	22.56	4.4	
2000	1.79	7.97	4.93	10.70	9.71	3.00	3.38	2.22	0.56	0.26	0.14	0.44	45.10	9.76	15.63	12.71	5.6	
2001	3.13	3.41	2.29	5.18	5.61	2.96	3.04	0.46	0.77	0.33	0.54	0.24	27.96	6.54	7.47	8.57	3.5	
2002	0.95	7.66	11.50	6.36	5.58	4.87	2.45	0.80	0.22	0.11	0.05	0.18	40.73	8.61	17.86	10.45	3.25	
2003	0.26	3.93	26.71	4.98	3.63	6.55	12.98	1.45	0.09	0.06	0.47	0.45	61.56	4.19	31.69	10.18	14.43	
2004	0.72	6.39	11.08	7.65	11.01	2.36	1.35	1.36	0.23	0.19	0.43	0.31	43.08	7.11	18.73	13.37	2.71	
2005	6.29	2.34	8.79	7.25	3.07	6.88	4.86	3.27	3.03	0.10	0.14	0.08	46.10	8.63	16.04	9.95	8.13	
2006	1.83	6.17	14.52	9.89	6.42	13.04	4.69	0.89	0.27	0.14	0.02	0.16	58.04	8.00	24.41	19.46	5.58	
2007	0.54	7.36	7.78	1.96	12.04	3.01	2.66	1.23	0.29	0.84	0.05	0.23	37.99	7.90	9.74	15.05	3.89	Normal
2008	3.15	2.28	7.85	10.70	4.12	2.59	1.84	0.11	0.43	0.15	0.44	0.06	33.72	5.43	18.55	6.71	1.95	Dry
2009	1.25	3.87	6.37	1.43	7.91	5.44	1.11	1.99	0.24	0.21	0.16	0.56	30.54	5.12	7.8	13.35	3.1	Dry
2010	2.86	3.80	4.41	11.29	5.57	5.85	7.94	3.28	1.81	0.08	0.35	0.62	47.86	6.66	15.7	11.42	11.22	Wet
2011	4.29	5.41	11.19	1.71	5.08	12.30	4.22	1.37	1.62	0.20	0.17	0.27	47.83	9.70	12.9	17.38	5.59	Wet
2012	3.25	4.53	1.67	5.81	3.42	12.10	5.09	0.66	1.78	1.16	0.11	0.10	39.68	7.78	7.48	15.52	5.75	Normal
2013	2.41	8.90	11.11	2.88	1.73	3.64	1.87	0.85	0.46	0.06	0.23	2.07	36.21	11.31	13.99	5.37	2.72	Dry
2014	0.14	1.32	0.61	0.89	6.06	5.74	1.50	0.72	0.16	0.14	0.17	2.45	19.90	1.46	1.5	11.8	2.22	Dry
2015	5.56	4.15	10.72	1.13	7.82	2.20	4.06	0.25	0.13	0.19	0.57	0.68	37.46	9.71	11.85	10.02	4.31	Dry
2016	1.01	4.34	13.16	13.29	3.33	10.05	3.24	0.59	0.05	0.16	0.14	0.23	49.59	5.35	26.45	13.38	3.83	Normal
												50-year average	41.6	8.1	14.9	12.1	4.6	

Notes:

(1) Data provided by Rob Roberts and Jerry Lema. Gauge located at 515 Shaw Avenue since October 1994, and at 1345 Main Street from October 1970 to October 1994. Location prior to October 1970 was not determined.

(2) As an example, Water Year 2016 extends from October 2015 through September 2016

(3) Water year classification (Dry / Normal / Wet) is determined by comparing annual rainfall and four two-month rainfall totals to the 50-year average

Attachment 2: Producer Questionnaire

Irrigation Water Usage in Eel River Valley Basin

Interview questions for producers

Goal:
To determine irrigation water volumes applied to crops over growing seasons under normal, dry and wet years

1. What type of equipment do you use to irrigate?____

   Equipment specs: (e.g. make/model, pump HP, pump rating if known, sprinkler nozzle size, pipe diameter)

   ____

   ____

   If applicable:

   a. What is head spacing distance? (distance between sprinkler heads along line)______________

   b. What is line spacing distance? (distance between lines in field)__________________________

   c. How many sprinklers/heads used in a set (if applicable)________________________________
      [a set is defined as 1 irrigation event]

2. Do you have plans to change your irrigation equipment?____________________________________

   If yes, what type of irrigation system would you like to shift toward?_______________________

3. Irrigation sources – groundwater wells or surface water or both?____________________________

4. How many wells are used/available for irrigation?____

   a. What are well depths, if known____

   b. Are there wells that could be accessed for sounding, and would you be willing to allow sampling?

   ____

5. If multiple wells, average # acres covered by each well____________________________________

6. When do you **start** irrigating in spring: in a normal year? ______________________________

   in a dry year?______________________________

   in a wet year?______________________________

Notes____

Questionnaire developed by Humboldt County Resource Conservation District and UCCE September 2016

1

7. When do you **stop** irrigating in fall: in a normal year? ______________________

in a dry year?______________________

in a wet year?______________________

Notes____

8. How many hours do you irrigate per set?______________________

Do hours per set change based on normal, dry or wet year?______________________

Notes____

9. How many sets can you/do you irrigate: in a normal year? ______________________

in a dry year?______________________

in a wet year?______________________

Notes____

10. How many acres do you irrigate each season?______________________

11. Does your irrigated acreage change annually?______________________

Notes____

12. Do you expect your irrigated acres to change in the future?______________________

13. How many times a year does each area or field get irrigated?______________________

14. How long does it take to make a complete rotation of all acreage?______________________

15. What kinds of crops are irrigated and average production (DM/tons/acre)______________________

____

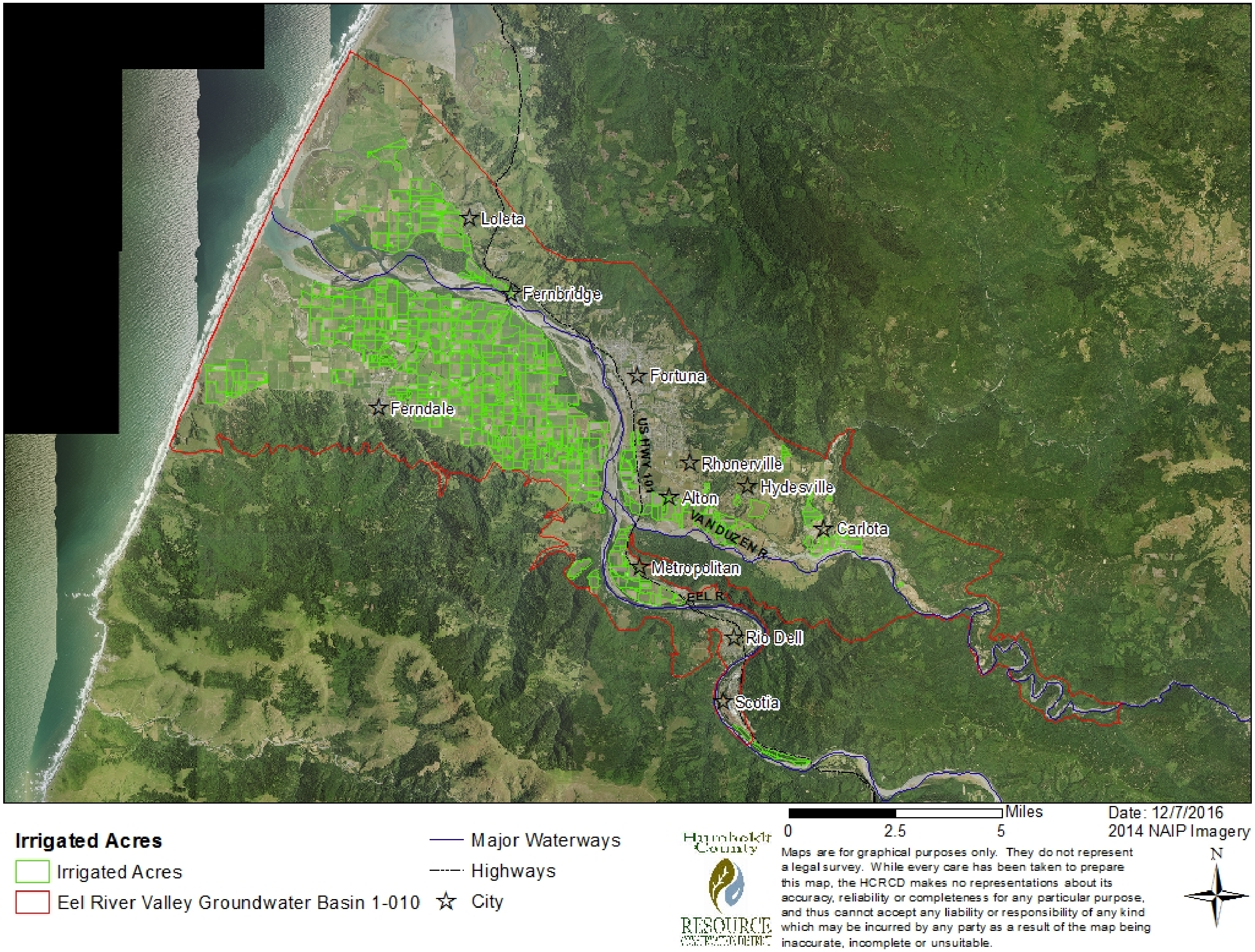
Irrigator's Equation to determine how much water applied (solve for "d"):

$$Q \times d = t \times A$$

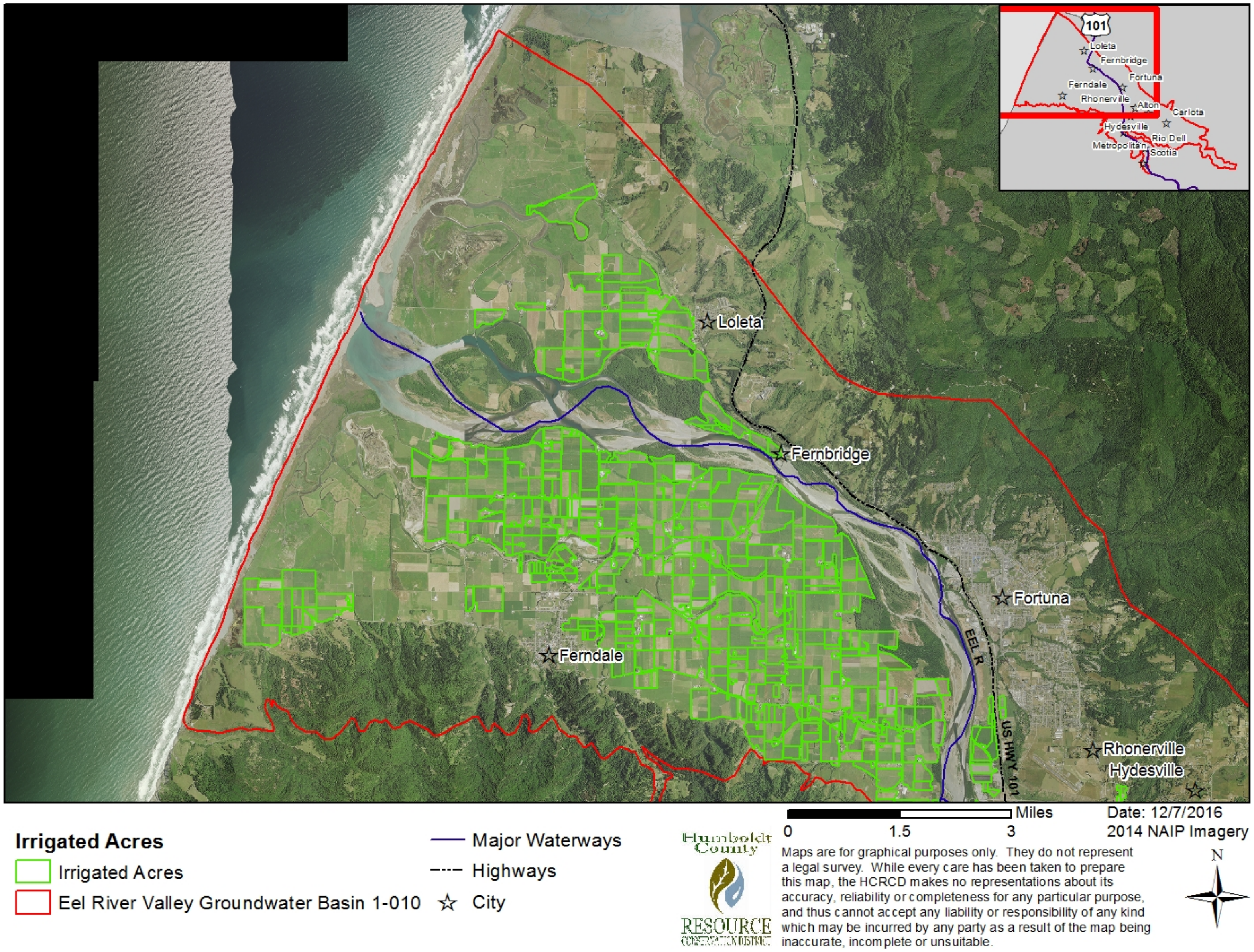
where
Q = flow rate in cubic feet per second (cfs)
t = set time or total time of irrigation (hours)
d = depth of water applied (inches)
A = area irrigated (Acres)

2

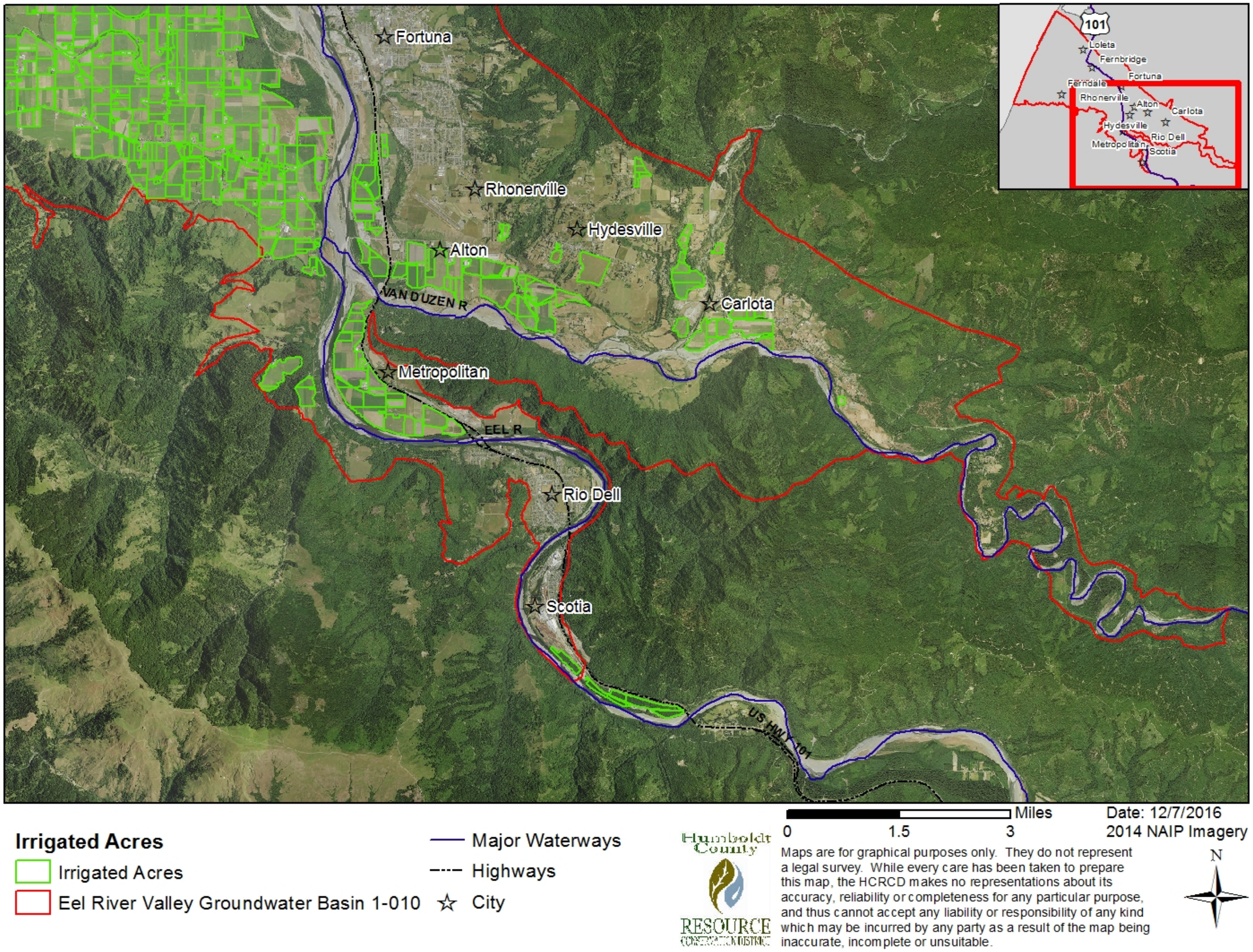
Attachment 3a: Irrigated acres in the Eel River Valley Groundwater Basin, Humboldt County, CA in 2016.



Attachment 3b: Irrigated acres in the Ferndale, Loleta, Fernbridge, and Fortuna geographical areas of the Eel River Valley Groundwater Basin, Humboldt County, CA in 2016.



Attachment 3c: Irrigated acres in the Fortuna, Rohnerville, Alton, Metropolitan, Hydesville, Carlotta, Rio Dell, and Scotia geographical areas, Eel River Valley Groundwater Basin, Humboldt County, CA in 2016.



Attachment 4: Groundwater Irrigation Use Rates Calculations. See Section 1.3 for the summary of sources of information, methods, and assumptions made in calculating water use rates and Table 5 for results.

Equation A:

$$Sum\left\{\left[\left(\frac{\left(\left(equipment\ type\ \frac{gallons}{minute}\right)\left(\frac{minutes}{set}\right)\right)}{\left(\frac{gallon}{acre\ feet}\right)}\right)\Big/\left(equipment\ type\ \frac{acres}{set}\right)\right]\times\left(\frac{sets}{water\ year}\right)\times\left(\begin{matrix}equipment\ type\\ irrigated\ acres\end{matrix}\right)\right\}=\frac{acrefeet}{basin}\ water\ year$$

Parameters included in Equation A:

Equipment Type	Gallons / Minute*	Minutes / Set*	Gallons / Acre-foot	Acres / Set*	Sets / Water Year **			Acres Irrigated by Groundwater	***SUM {Equation A} = Acre-feet/Basin by Water Year***		
					Wet Water Year	**Normal Water Year**	**Dry Water Year**		**Wet Water Year**	**Normal Water Year**	**Dry Water Year**
Handline	375	600	325,851	2.4	4.0	5.3	6.5	7,044	*8,106.78*	*10,741.49*	*13,173.53*
Traveling Gun	220	960		9.0				4,310	*1,241.55*	*1,645.06*	*2,017.53*
Pivot	200	1440		4.0				88	*77.41*	*102.57*	*125.80*
K-line	600	720		10.3				989	*509.09*	*674.55*	*827.28*
Wheel-line	300	720		8.9				1,107	*329.82*	*437.01*	*535.95*
Other	-	-		-				20	-	-	-
								13,558	**10,264.7**	**13,600.7**	**16,680.1**

* Averaged from data collected during producer interviews

** Sets/water year is the estimated number of times any given acre is irrigated in a water year as calculated in Section 1.3.

Equation B:

$$\frac{\left(\frac{acrefeet}{basin}\ water\ year\right)}{(total\ irrigated\ acres\ )} = \frac{acrefeet}{acre} water\ year$$

Equation B: Parameters and Results

Water Year	Total Acre-feet/Basin	Acre-feet/Acre
Dry	16,680	1.2
Normal	13,600	1.0
Wet	10,265	0.8

Appendix E

Eel River Valley Groundwater Basin Surface Discharge Measurement Field Report (TGAEC, 2016)

Eel River Valley Groundwater Basin Surface Discharge Measurement Field Report

2016

Prepared for SHN Engineers and Geologists and Humboldt County Public Works

Prepared By:
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December 23, 2016

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Eel River Groundwater Basin Surface Flow Measurements

Twelve sites in the Eel River Basin, on the Eel River, Van Duzen River, and Yager Creek, were selected for discharge measurements to inform the groundwater assessment and water balance model. Thomas Gast & Associates Environmental Consultants (TGAEC) measured surface flows on three occasions in 2016: August 16, August 23 and 24, and October 4.All measurements were taken during the late summer/early fall low flow period. The locations of discharge sites are depicted in Figures 1, 2, and 3 and given in UTM coordinates in Table 1.

The August 16 trip was initiated immediately after getting the start work order and revealed that additional land owner access agreements would have to be in place for certain locations. Additionally Tom Shultz, Humboldt Redwoods Company (HRC) Forest Manager, at a meeting near Yager Creek, offered to share the HRC weekly discharge measurements. We subsequently coordinated the Yager Creek flow measurements with HRC.

On August 23 and 24, the TGAEC measured all discharge sites except Yager 1 which was measured by HRC hydrologist, Rich Rossen. There was no precipitation immediately before or during the measurements.

TGAEC measured river flows on October 4, 2016, a date selected to coincide with the end of irrigation season while low flows still persisted prior to extensive rain in the watershed. The Eureka weather station recorded almost a half inch of rain on October 2, 2016 which had slightly increased the stream flows from the season lows. Some irrigation was observed to be continuing on October 4. This measurement trip included five sites, Eel 4, Eel 3, Eel 2, Scotia, and Lower Van Duzen 2. In addition to flow, conductivity and temperature, as potential indicators for groundwater interaction, were measured during the October 4 trip.

An additional flow measurement trip including all sites was planned for base flow conditions (approximately 100 cfs and 15 cfs on the Eel and Van Duzen respectively) after sufficient precipitation increased the river flows to that level. Persistent October precipitation elevated and maintained streamflow well above the base flow conditions precluding this flow measurement trip.

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Figure 1. Lower Eel River Basin downstream discharge sites.

Figure 2. Lower Eel River Basin upstream Eel River discharge sites and Van Duzen River sites.

(The Bridgeville USGS site is not shown on this figure)

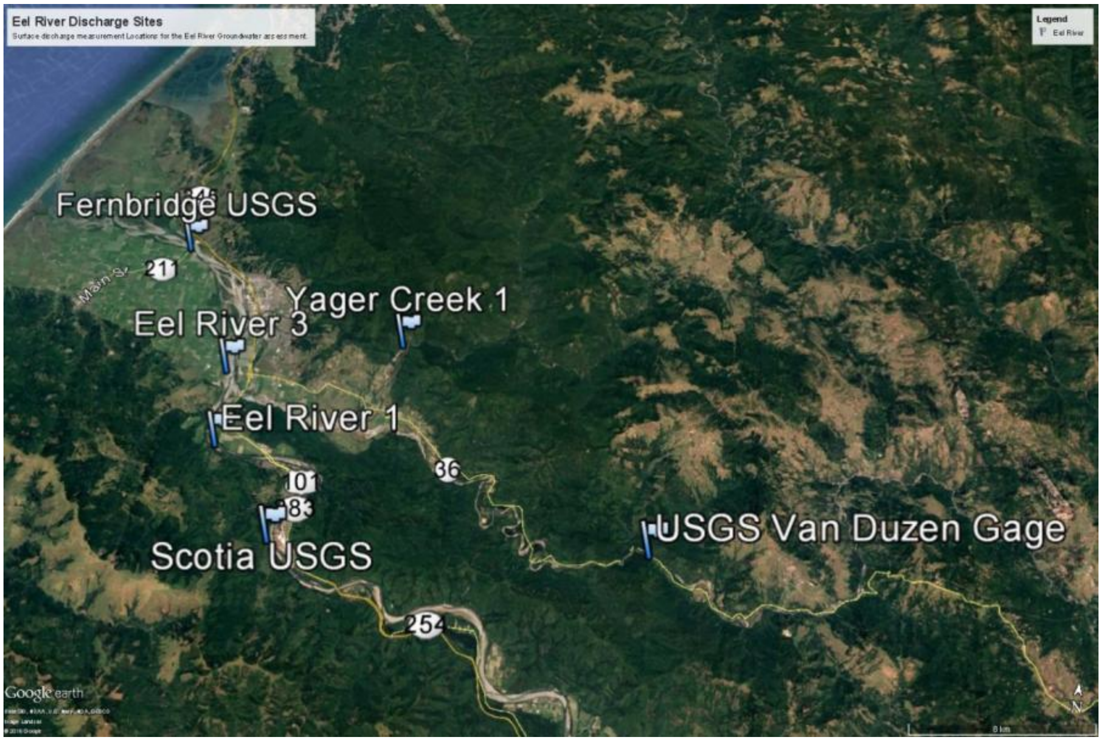

Figure 3. Overview of the Eel River Basin and extent of discharge site locations.

Table 1. Locations of the discharge sites in UTM.

	UTM coordinates		
Site Name	Zone	Easting	Northing
Fernbridge USGS	10 T	398426.00 m E	4496100.00 m N
Eel River 4	10 T	401587.00 m E	4493315.00 m N
Eel River 4_SC	10 T	401733.00 m E	4493513.00 m N
Eel River 3	10 T	402122.00 m E	4489133.00 m N
Eel River 2	10 T	401967.00 m E	4487855.00 m N
Eel River 1	10 T	402518.00 m E	4485150.00 m N
Scotia USGS	10 T	406131.00 m E	4480679.00 m N
Lower Van Duzen 1	10 T	402954.00 m E	4487943.00 m N
Lower Van Duzen 1SC	10 T	403057.00 m E	4487917.00 m N
Lower Van Duzen 2	10 T	408636.00 m E	4486735.00 m N
Lower Van Duzen 3	10 T	416612.23 m E	4483352.14 m N
USGS Van Duzen Gage	10 T	424209.56 m E	4481644.93 m N
Yager Creek 2	10 T	409978.00 m E	4487973.00 m N
Yager Creek 1	10 T	410923.73 m E	4491393.62 m N

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Methods

Discharge Measurements

Cross-sectional transects were established with rebar pins and a measuring tape at the best laminar locations within each site area. Data was collected using high quality vertical axis cup meters (USGS type Gurley Meters) and wading measurement techniques at shallow transects, and using an acoustic Doppler current profiler (ADCP) mounted on an inflatable kayak in deep water transects. The TRDI RiverPro 1200kHz ADCP sends and receives acoustic pulses in order to measure the Doppler shift and the phase change of the echoes to calculate depth and velocity patterns and can be easily deployed by two people in water deeper than 1.5 feet.

The techniques for measuring shallow water discharge generally followed the guidelines outlined by Rantz (1982). A minimum of 20 wetted stations per discharge measurement were established. The boundaries of each station along each transect was normally established at consistent increments, but significant changes in velocity, substrate, depth, or other important stream features required additional stationing. Mean column velocity at each station was the average velocity measured at six tenths of the water depth for a minimum of 40 seconds in water less than 2.5 feet. Deeper water was measured at two and eight tenths of the water depth and averaged or with the ADCP.

Conductivity and Temperature

A calibrated YSI Pro2030 handheld meter was used to measure conductivity and temperature.

Quality Assurance/Quality Control

To assure quality control in the collection of field data, the following data collection procedures and protocols were utilized:

Vertical axis cup meters (USGS Gurley AA and mini meters) in good condition on topset rods were used for manual measurements. The meters were checked in the office prior to deployment by spinning the cups in calm air. The minimum allowed spin time was three minutes for the AA meters and 60 seconds for the mini meters. Maintenance on the meters was performed until they met the minimum requirements.

Staff gauges were established and continually monitored throughout the course of collecting data. Any changes in the water surface elevation during the measurements were recorded in the field notes and reported.

Prior to deployment, the ADCP was system checked, compass calibrated, moving bed test performed, and user configured for each individual transect with appropriate commands for the existing environmental conditions. Each transect measurement length and discharge calculation was compared to repetitive measurements in order to ensure accurate bottom tracking and velocity measurements. Real time graphic depictions of depth and velocity were examined during data collection for inconsistencies and obvious errors. Each ADCP transect was measured for a minimum of 12 minutes and the repetitive measurements averaged to obtain a maximum standard deviation of 5%. As a precaution against data loss, all electronic data files were copied onto a separate USB drive at the end of each field day.

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All calculations were completed in the field, given adequate time and daylight. Discharges were calculated on-site and compared between transect discharges taken during the same day. If an excessive amount of discharge (greater than 10% of the stream flow) was noted for an individual transect cell, additional adjacent stations were established to more precisely define the velocity distribution patterns at that portion of the transect.

Photographs were taken of all transects, downstream, across, and upstream.

All data (stationing, depth profiles, and velocities) were entered into the Excel computer files. Data graphing routines were then used to identify any errors or deficiencies.

Results

Discharge measurements are described for each site. Tables 2, 3, and 4 list times, flows, and notes for August 16, August 23-24, and October 4 respectively. Flows during August and September are typically receding and this year was not an exception; however rainfall began early in October and persisted throughout the month. Table 5 lists the difference in flow between measurements show the initial decrease and subsequent increase in flow. There was 0.06 inches of precipitation recorded in Eureka for the last two weeks of July, 0.04 inches of precipitation for the month of August, and 0.1 inches in September (http://w2.weather.gov/climate/index.php?wfo=eka).The Eureka weather station recorded almost a half inch of rain on October 2, 2016 prior to the October 4 measurements which slightly increased the stream flows from the season lows. Persistent record rainfall occurred during the month of October resulting in 10.92 inches in Eureka compared to the average October rainfall of 2.24 inches. Photos of each discharge site are included in Appendix A.

Scotia USGS

The USGS maintains a gaging station at the Scotia Bridge. Real time flow data is available at http://waterdata.usgs.gov/ca/nwis/inventory/?site_no=11477000. The USGS calibrates the gage at about six week intervals by measuring discharge downstream of the gage so that the water level measured by the gage corresponds to discharge. The correlation between discharge and water level degrades with time after calibration primarily due to changes at the hydraulic control. Aspiring young engineers who build fun dams and algal growth are primary culprits this time of year; however, fallen trees, clippings, motor vehicles in the river, and various other debris can also cause the changes to the gage rating curve. At the Scotia gage during low flow, a 0.01 foot change in water level will result in a change of a couple cfs. The USGS had last calibrated the gage on August 11 at a flow of 83.3 cfs prior to the TGAEC measurements. The TGAEC measured discharge was within 5% of the USGS gage reported discharge on August 24 and 20% higher than the reported discharge on October 4.

TGAEC chose to measure the discharge at the best accessible location upstream of the Scotia Park, upstream of the USGS gage. The site is in a confined low flow channel through gravel. Some seepage through the gravel could be seen (Appendix A, photos) into the backwater downstream of the site; however, sediment stirred up in the backwater did not flow downstream and the seepage into that backwater can be considered minimal.

Eel 1

TGAEC accessed Eel 1 by boat. The kayak was launched off the Rio Dell public access river bar (4 WD required) at the end of Edwards Road. Eel 1 is in a constricted low flow channel downstream of a hydraulic control for a long pool. Eel 1 was measured on August 23.

Eel 2

Eel 2 is upstream of the Van Duzen River confluence and alluvial fan in a constricted low flow channel. A 4WD can utilize the same access as for Eel 3 to get close to the Eel 2 location. TGAEC measured Eel 2 on August 23 and October 4. Extensive gravel mining was occurring downstream of the site on the east bank on October 4.

Eel 3

Eel 3 is downstream from the Van Duzen River confluence. The site is downstream from a hydraulic control in a constricted low flow channel. The river bar is accessible for a 4WD vehicle from a small spur off Grizzly Bluff Road or East Ferry Road. The Van Duzen River was dry at the confluence (Appendix A photos) during the discharge measurements on August 16, August 23, and October 4. Extensive gravel mining was in process on the east bank of the Eel River and the Van Duzen alluvial fan on October 4.

Eel 4

Eel 4 is at the downstream end of the long, deep pool adjacent to the River Lodge in Fortuna. The tail of the pool is too wide and shallow for accurate velocity measurement at low flow. The discharge site is downstream of the pool hydraulic control and the channel is split with the main channel to the west. The river bar is wide and accessible with a 4WD vehicle via E. Ferry Road. TGAEC measured the discharge on August 16, August 23, and October 4.

Fernbridge

The Fernbridge location is influenced by the flood tide; however, the river flows freely during ebb tides. Care must be taken to complete the discharge measurement at or after ebb tide when the river is flowing freely and not backwatered by the flood tide. Even during the ebb tide river, flow could still include some residual bank discharge from the inundation at high tide. A USGS water level gage records water level at Fernbridge, but only registers at the higher high tides during the low flow period (http://waterdata.usgs.gov/nwis/inventory/?site_no=11479560).

Fernbridge was measured with the ADCP after a minus 0.52 tide on August 16 and manually during a 1.24 ebb tide on August 23 with no tidal influence. Higher high tide occurred at the gauge site 11.5 hours prior to measurement on August 16 and 17.5 hours prior to the measurement on August 23.

USGS Van Duzen Gage

The USGS Van Duzen Gage site is located off Highway 36 upstream of Grizzly Creek State Park. TGAEC measured the discharge on August 24 at the first good measurement site downstream of the gage. The USGS measures the low flow calibration flows upstream of the highway bridge. The USGS calibrated the gage on August 3 at a flow of 8.93 cfs and on September 16 at a flow of 4.34 cfs. On August 24, the TGAEC measured discharge was 86% of the USGS gage reported discharge.

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Lower Van Duzen 3

Lower Van Duzen 3 is accessible by parking at Pamplin Grove County Park off Highway 36. The site is in the pool tail from the popular swimming area. TGAEC measured Lower Van Duzen 3 on August 24.

Lower Van Duzen 2

Lower Van Duzen 2 is downstream of the confluence with Yager Creek and accessible by parking at the end of Fisher Road. Permission to access this site was granted by Jack Noble. The site is in a constricted low flow channel downstream of a hydraulic control. Algae was a problem at this site and the location had to be cleared prior to measurement. TGAEC measured Lower Van Duzen 2 on August 24 and October 2.

Lower Van Duzen 1

The Lower Van Duzen seeped into the gravel bar downstream of the Highway 101 Bridge, before reaching the confluence on August 16 and August 24. The discharge was taken upstream of the 101 bridge and downstream of the gravel mining operations. The channel is split and the smaller eastern channel seeped into the gravel bar downstream of the measurement site on August 24. Access to this site is gained by parking at the end of Sandy Prairie Road.

Yager 1

Humboldt Redwoods Company (HRC) hydrologist Rich Rossen measured discharge at Yager 1 on August 24 and October 4. HRC has been conducting flow measurements in the Van Duzen and Yager Creek watersheds for several years and Lead Hydrologist Nick Harrison summarized that information. The historical Yager Creek measurements are included in Appendix B.

Yager 2

The Yager 2 discharge site is just upstream of the Highway 36 Bridge in Carlotta. TGAEC measured the discharge on August 24. Some seepage into the cobble bar upstream of the site was evident. There is substantial loss between Yager 1 and Yager 2.

Conductivity and Water Temperature

The conductivity and water temperature was measured at each site on October 4 (Table 6). The water temperature ranged from 16.1^{o}C to 20.6^{o}C. The conductivity of the water could indicate connections to groundwater or residual salt from tidal influence. The conductivity of the water raged from 248µs/cm to 346µs/cm, with the highest values at the most upstream sites indicating that the surface water neither showed evidence of residual salt nor increases in conductivity potentially from groundwater interaction.

References

Rantz, S.E. 1982. Measurement and computation of streamflow: Volume 1. Measurements of stage and discharge. United States Geological Survey Water Supply Paper 2175. 284pp.

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Table 2. Flows measured on August 16, 2016

Station	Date	Time	Flow m3/s	Flow cfs	Note	
Fernbridge	8/16/2016	10:00	2.304	81.36	After minus tide, no tide influence. ADCP measurement	
Lower Van Duzen 1	8/16/2016	17:00	0.041	1.43	Dries before confluence	
Yager 1	8/16/2016				NE	Humboldt Redwood Property. Access needs permission
Yager 2	8/16/2016				NE	Humboldt Redwood Property. Access needs permission
Scotia	8/16/2016	12:00	2.251	79.5	USGS gage reading	
Eel 1	8/16/2016				NE	No bank access. Need to float or gain access through private property.
Eel 2	8/16/2016				NE (not evaluated)	
Eel 3	8/16/2016	14:36	2.157	75.81	Van Duzen at Confluence was dry	
Eel 4	8/16/2016	13:10	2.11	74.16		
Van Duzen Gage	8/16/2016	12:00	0.195	6.9	USGS gage reading	
Lower Van Duzen 3	8/16/2016				NE	Pamplin Grove access closed (Sign said Grove Reserved)
Lower Van Duzen 2	8/16/2016				NE	Contact Jack Noble for access

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Table 3. Second discharge trip August 23 and 24.

Station	Date	Time	Flow m3/s	Flow cfs	Note
Scotia	8/24/2016	10:00	1.592	55.96	Gravel bar upstream weir at park. USGS gage 61 cfs
Eel 1	8/23/2016	15:50	1.793	63.03	
Eel 2	8/23/2016	17:48	1.509	53.03	
Eel 3	8/23/2016	16:15	1.627	57.19	
Eel 4	8/23/2016	11:30	1.441	50.65	Split channel, wide bar
Fernbridge	8/23/2016	9:30	1.745	61.31	Low tide, but potential bank discharge. No stage change during measurement
Van Duzen Gage	8/24/2016	16:09	0.139	4.89	USGS gage 5.7 cfs
Lower Van Duzen 3	8/24/2016	15:00	0.195	6.84	Pamplin Grove
Lower Van Duzen 2	8/24/2016	15:31	0.178	6.25	End of Fisher Road
Lower Van Duzen 101	8/24/2016	12:41	0.017	0.60	Split channel, wide bar, gravel mining
Yager 1	8/24/2016	11:25	0.086	3.02	HRC measurement
Yager 2	8/24/2016	17:24	0.017	0.59	Seepage through cobble bar

Table 4. October 4 discharge measurements.

Station	Date	Time	Flow m3/s	Flow cfs	Note
Scotia	10/4/2016	15:00	1.872	65.80	USGS gage at 55 cfs
Eel 1					NE
Eel 2	10/4/2016	13:20	1.733	60.92	
Eel 3	10/4/2016	10:50	2.026	71.21	
Eel 4	10/4/2016	9:30	1.808	63.55	
Fernbridge					NE
Van Duzen Gage					USGS gage at 6.5 cfs
Lower Van Duzen 3					NE
Lower Van Duzen 2	10/4/2016	16:50	0.196	6.90	
Lower Van Duzen 101					NE
Yager 1	10/4/2016	13:15	0.123	4.31	HRC discharge measurement
Yager 2					NE

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Table 5. Change in flow from August 16 to August 23/24 and from August 23/24 to October 4.

Station	Δ Flow m3/s	Δ Flow cfs	Δ Flow m3/s	Δ Flow cfs
	August 16 to August 23/24		Aug. 23/24 to Oct. 4	
Scotia (Gage)	-0.516	-18.500	0.280	9.838
Eel 1				
Eel 2			0.224	7.888
Eel 3	-0.530	-18.616	0.399	14.017
Eel 4	-0.669	-23.510	0.367	12.905
Fernbridge	-0.559	-20.050		
Van Duzen Gage (Gage)	-0.033	-1.200		
Lower Van Duzen 3				
Lower Van Duzen 2			0.018	0.650
Lower Van Duzen 101	-0.024	-0.834		
Yager 1			0.037	1.290
Yager 2				

Table 6. Conductivity and temperature measured at each discharge site on October 4, 2016.

Site	Time	Conductivity µs/cm	Temperature ^{o}C
Scotia	15:00	295.2	
Eel 2	13:20	272.1	20.6
Eel 3	12:00	282	17.8
Eel 4	9:30	248.2	16.1
Lower Van Duzen 2	16:50	346.5	19.9

Appendix A. Photos of Discharge Measurement Locations

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Scotia Discharge Site

August 24

Seepage through the gravel.

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Scotia Discharge Site (cont.)

October 4

Eel 1 Discharge Site

August 23

Eel 2 Discharge Site

August 23

October 4

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Van Duzen and Eel Confluence Discharge Site

August 16



Eel 3 Discharge Site

August 23


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Eel 3 Discharge Site (cont.)

October 4


Eel 4 Discharge Site

August 16



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Eel 4 Discharge Site (cont.)

October 4

Side Channel

Side Channel

Side Channel

Fernbridge Discharge Site

August 16




Van Duzen Gage Discharge Site

August 24



Lower Van Duzen 3 Discharge Site

August 24

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Lower Van Duzen 2 Discharge Site

August 24

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Lower Van Duzen 2 Discharge Site (cont.)

October 4

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Lower Van Duzen 101 Discharge Site

August 24

Yager 2 Discharge Site

August 24

Appendix B

Humboldt Redwood Company Discharge Measurements

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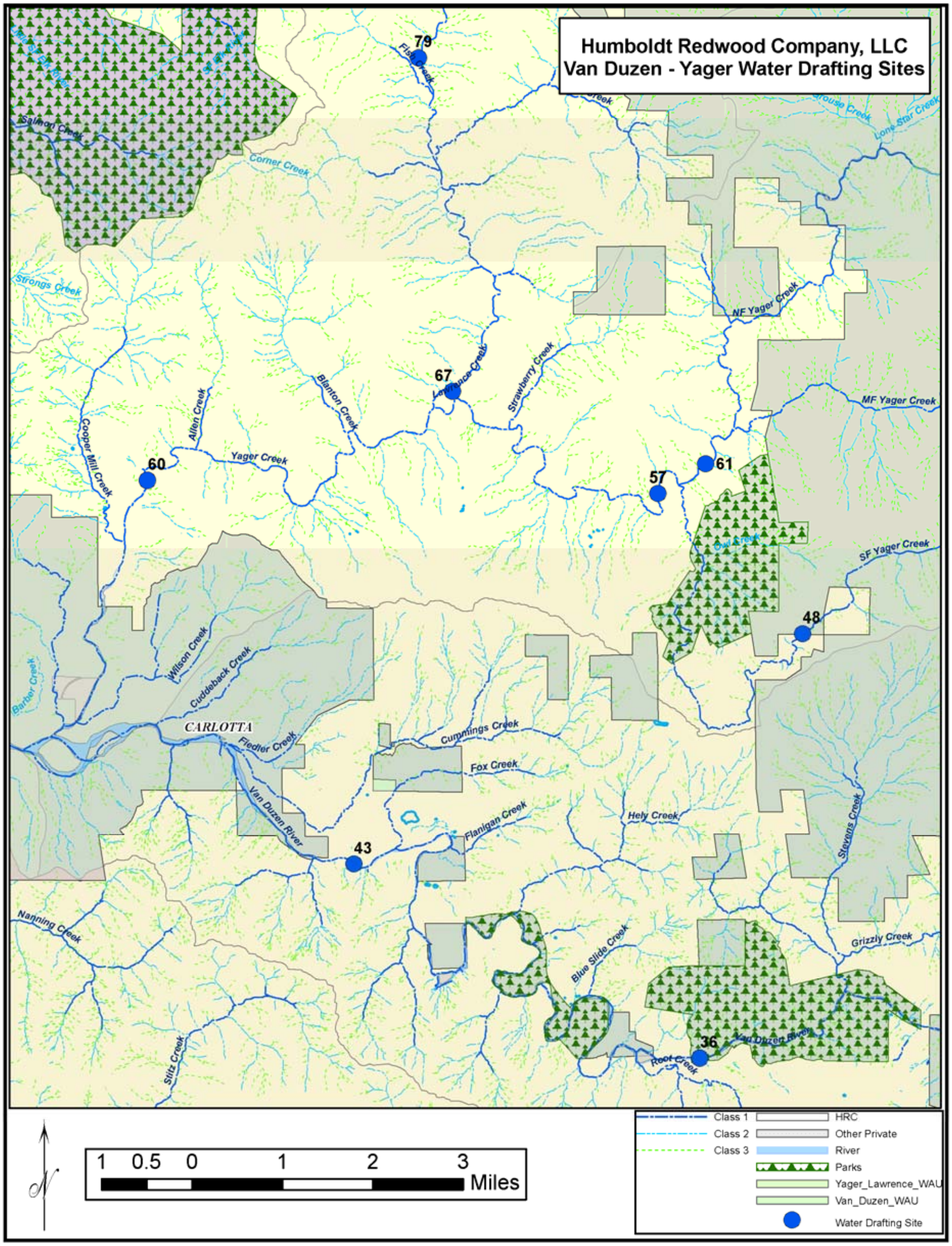

Figure B-1. Map of Humboldt Redwoods Discharge Sites. Courtesy of HRC.

Stream Name	Site Number	Date (mm/dd/yy)	Stage (m)	Stage (ft)	Discharge (cms)	Discharge (cfs)
SF Yager Creek	48	07/01/05	0.40	1.31	0.15	5
SF Yager Creek	48	07/06/05	0.20	0.66	0.08	3
Van Duzen River	36	08/14/15	NO DATA	NO DATA	0.09	3
Van Duzen River	43	08/14/15	NO DATA	NO DATA	0.14	5
Van Duzen River	43	08/28/15	NO DATA	NO DATA	0.12	4
Van Duzen River	36	08/29/15	NO DATA	NO DATA	0.07	2
Van Duzen River	36	09/11/15	NO DATA	NO DATA	0.10	3
Van Duzen River	43	09/11/15	NO DATA	NO DATA	0.14	5
Van Duzen River	36	09/25/15	NO DATA	NO DATA	0.14	5
Van Duzen River	43	09/25/15	NO DATA	NO DATA	0.28	10
Van Duzen River	43	10/09/15	NO DATA	NO DATA	0.17	6
Van Duzen River	43	10/23/15	NO DATA	NO DATA	0.19	7
Yager Creek	57	07/01/05	0.33	1.08	1.35	48
Yager Creek	61	07/01/05	0.42	1.38	1.01	36
Yager Creek	57	07/06/05	0.29	0.95	1.16	41
Yager Creek	61	07/06/05	0.36	1.18	0.66	23
Yager Creek	61	07/12/05	0.35	1.15	0.51	18
Yager Creek	57	06/23/06	0.50	1.64	0.33	12
Yager Creek	57	07/13/06	0.45	1.48	0.17	6
Yager Creek	57	08/01/06	0.41	1.33	0.06	2
Yager Creek	57	08/22/06	0.35	1.15	0.03	1
Yager Creek	57	08/16/07	0.65	2.13	0.06	2
Yager Creek	60	06/16/11	0.32	1.05	2.14	75
Yager Creek	60	08/05/11	0.13	0.43	0.50	18
Yager Creek	60	09/02/11	0.11	0.36	0.21	7
Yager Creek	60	06/27/12	0.56	1.84	0.56	20
Yager Creek	60	07/25/12	0.47	1.54	0.48	17
Yager Creek	60	06/13/13	0.44	1.43	1.24	44
Yager Creek	60	07/08/13	0.38	1.25	0.19	7
Yager Creek	60	07/19/13	0.32	1.05	0.18	6
Yager Creek	60	08/02/13	31.00	101.71	0.08	3
Yager Creek	60	08/16/13	0.30	0.98	0.04	1
Yager Creek	60	08/16/13	0.31	1.02	0.07	3
Yager Creek	60	09/13/13	0.28	0.92	0.04	2
Yager Creek	60	09/27/13	0.39	1.26	0.19	7
Yager Creek	60	10/11/13	0.38	1.25	0.10	4
Yager Creek	60	10/25/13	0.36	1.16	0.12	4
Yager Creek	60	11/07/13	0.36	1.18	0.07	3
Yager Creek	60	04/18/14	0.67	2.20	1.57	56
Yager Creek	60	05/02/14	0.59	1.92	0.96	34

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Yager Creek	60	05/16/14	0.55	1.80	0.71	25
Yager Creek	60	04/21/15	0.71	2.33	2.66	94
Yager Creek	60	06/08/15	0.45	1.48	0.41	14
Yager Creek	60	06/19/15	0.42	1.38	0.21	8
Yager Creek	60	07/02/15	0.36	1.18	0.17	6
Yager Creek	60	07/17/15	0.36	1.16	0.13	5
Yager Creek	60	07/31/15	0.31	1.02	0.09	3
Yager Creek	60	08/14/15	0.30	0.98	0.05	2
Yager Creek	60	08/21/15	0.28	0.92	0.04	2
Yager Creek	60	09/18/15	0.35	1.15	0.07	3
Yager Creek	60	09/25/15	0.31	1.00	0.06	2
Yager Creek	60	10/01/15	0.30	0.98	0.05	2
Yager Creek	60	10/09/15	0.29	0.95	0.05	2
Yager Creek	60	10/16/15	0.29	0.95	0.03	1
Yager Creek	60	10/23/15	0.31	1.02	0.05	2
Yager Creek	60	05/02/16	0.91	2.97	4.42	156
Yager Creek	60	05/20/16	0.68	2.23	1.22	43
Yager Creek	60	06/03/16	0.61	2.00	1.10	39
Yager Creek	60	06/17/16	0.57	1.85	0.45	16
Yager Creek	60	06/30/16	0.52	1.71	0.35	12
Yager Creek	60	07/18/16	0.48	1.56	0.20	7
Yager Creek	60	08/01/16	0.45	1.48	0.12	4
Yager Creek	60	08/11/16	0.40	1.31	0.18	6
Yager Creek	60	10/01/15	0.35	1.15	0.07	3

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Appendix F

Monitoring Well Installation, Aquifer Testing, and Water Level Data Collection (SHN, 2016)

Appendix F. Monitoring Well Installation, Aquifer Testing and Water Level Data Collection

As part of the Proposition 1 Sustainable Groundwater Planning (SGWP) Grant, SHN Engineers and Geologists worked in cooperation with Humboldt County (County) and Fisch Drilling to design and install a network of monitoring wells within the Eel River Valley Groundwater Basin (Basin). Following the installation of the monitoring wells, a network of 20 pressure transducers were installed in the rivers and wells to collect water elevation data through the 2017 water year. The purpose of this discussion is to provide details about the well installation, results of aquifer testing, and preliminary analysis of continuous water level monitoring.

Well Installation

Monitoring wells were installed at nine locations within the Basin. Six of the locations have been developed into paired monitoring wells. The distribution and depths of the wells were designed to meet the following objectives:

1) evaluate the surface water-groundwater (SW-GW) interaction of the Eel River, Van Duzen River, and Yager Creek, and their adjacent aquifers,

2) evaluate vertical and horizontal groundwater gradients in the basin,

3) evaluate stratigraphy and the distribution of aquifers,

4) perform aquifer testing, and

5) provide the opportunity to collect depth-discrete samples for chloride testing near the seawater-freshwater transition zone.

Monitoring wells were installed by Fisch Drilling of Hydesville, California, between October 24 and November 4, 2016. All well locations were installed within County right-of-way areas adjacent to roads for easy access and maintenance. Well locations were determined based on their intended purpose and accessibility for the drilling equipment. Six of the well locations were cored with a direct push dual-tube coring system. Cores were opened onsite and used to determine well screen intervals. Wells were then installed using hollow stem augers. Total depths of wells installed using the coring/hollow stem auger methods were generally limited to depths of 60 feet. Three of the well locations were explored to depths ranging from 160 to 300 feet using mud rotary methods. Stratigraphy was logged from cuttings and screen intervals were designed based on the results of electric logging. Fisch Drilling developed all of the wells following installation and performed pneumatic slug testing.

Monitoring well construction details, including well identification, date of installation, location, borehole total depth, well diameter, well screen interval, ground surface elevation, and drilling method, are presented in Table F-1. The locations of the monitoring wells are shown on Figure F-1. Monitoring well logs are included at the back of this Appendix.

Table F-1 Eel River Valley Monitoring Well Details Eel River Valley Groundwater Basin, Groundwater Sustainability Plan Alternative							
Monitoring Well ID	**Installation Date**	**Primary Well Purpose**	**Borehole Depth (feet)**	**Well Diameter (inches)**	**Screened Interval (feet BGS[1])**	**Ground Surface Elevation (feet NAVD88[2])**	**Drilling Method**
MW-1S	10/26/16	SW/GW[3]	60	1	30-35	23.26	DP[4]/HSRA[5]
MW-1D					55-60		
MW-2S	10/24/16	SW/GW	60	1	30-35	43.89	DP/HSRA
MW-2D					55-60		
MW-3S	10/26/16	SW/GW	56	1	30-35	58.00	DP/HSRA
MW-3D					55-60		
MW-5S	11/4/16	chloride testing	220	2	100-110	13.16	MUD ROTARY
MW-5D					200-210		
MW-7S	11/2/16	chloride testing	300	2	30-40	18.92	MUD ROTARY
MW-7D					240-250		
MW-8	10/31/16	Monitoring[6]	160	2	120-130	44.16	MUD ROTARY
MW-9S	10/27/16	SW/GW	48	1	20-25	73.59	DP/HSRA
MW-9D					43-48		
MW-10	10/28/16	monitoring	29	1	24-29	145.96	DP/SFA[7]
MW-11	10/28/16	monitoring	46	1	41-46	148.76	DP/HSRA

1. BGS: below ground surface
2. NAVD88: North American Vertical Datum of 1988
3. SW/GW: surface water-groundwater monitoring
4. DP: direct push continuous core
5. HSRA: hollow stem rotary auger
6. Monitoring: groundwater elevation monitoring
7. SFA: solid flight auger

Aquifer Testing

Hydraulic conductivity within the screened aquifers of thirteen of the wells was determined by analyzing data from pneumatic slug tests. These tests were performed by Fisch Drilling between November 1, 2016, and November 15, 2016. The wells tested were: MW-1s/d, MW-2s/d, MW-3d, MW-7s/d, MW-9s/d, MW-10, and MW-11 (locations shown on Figure F-1). The depth of the wells range from 20 to 230 feet below the ground surface (BGS).

The method for pneumatic slug testing includes: attaching a valve cluster and regulator to the well head, installing a pressure transducer in the well, determining the pre-test equilibrium water level, pressurizing to between 30 and 40 pounds per square inch (psi), and releasing the pressure and recording data until the water level returns to the pre-test level. At least three tests were performed to ensure stable results.

The raw slug test data was analyzed using either the Bouwer and Rice (1976) or the van der Kamp (1976) method. The Bouwer and Rice method was used for water levels that smoothly and gradually returned to the pre-test level, and the van der Kamp method was used when the water level oscillated back to the pre-test level. Results of the analysis are included in Table F-2.

Table F-2
Aquifer Hydraulic Conductivity Results from Slug Tests
Eel River Valley Groundwater Basin, Groundwater Sustainability Plan Alternative

Monitoring Well	Screened Interval[1] (feet)	Aquifer Material	Hydraulic Conductivity (ft/day)[2]
MW-1d[3]	55-60	Sand and Gravel	240
MW-1s[4]	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	200-210	Sand and Gravel	11
MW-7d	240-250	Sand and Gravel	110-140
MW-7s	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

1. depth referenced off of the top of the well box
2. ft/day: feet per day
3. d: deep
4. s: shallow

Aquifers tested at monitoring well locations MW-1, MW-2, MW-3 and MW-8 (Figure F-1) had the highest hydraulic conductivity, ranging from 190 to 420 feet per day (ft/day). The values at monitoring wells MW-1, MW-2, and MW-3 correspond to the alluvial aquifer adjacent to the Eel River which is composed of older channel deposits of relatively unconsolidated sand and gravel. Monitoring well MW-8 is screened in the gravelly alluvium below a 120-foot thick deposit of silt. Aquifers screened at monitoring wells MW-9, MW-10 and MW-11 have low- to mid-range hydraulic conductivity values from 4.1 to 56 ft/day which correspond to the older (deeper) alluvium and/or Carlotta deposits within the Van Duzen watershed. Monitoring wells MW-5d and MW-7s had relatively low values ranging from 3 to 11 ft/day, whereas monitoring well MW-7d had moderate to high values ranging from 110 to 140 ft/day. Additional well development at monitoring wells MW-5 and MW-7 was performed following the performance of the pneumatic slug testing, so the actual hydraulic conductivity may be higher than shown in Table F-2.

Surface and Groundwater Monitoring using Pressure Transducers

To monitor the surface water and groundwater levels over the course of the 2017 water year, pressure transducers were installed at four locations within the rivers (three in the Eel River and one in the Van Duzen River), three private wells, and all but one of the newly installed monitoring wells (20 total locations). On December 10, 2016, data was downloaded and processed for analysis. The area had received a significant amount of precipitation, including two significant storm events. A discussion of the locations monitored and an analysis of the data collected is provided below.

On October 12, 2016, prior to the start of the rainy season, three transducers were installed in private irrigation wells (20, 22, and C-23) to capture the seasonal low groundwater conditions and to monitor the rebound of the aquifers at the outset of the wet season. The hydrographs for these wells are included as Figures F-2, F-3, and F-4. From comparisons to nearby river hydrographs, it is clear that Well 20 is hydrologically connected to the Eel River with characteristic spikes and falling curves associated with river fluctuations. Wells 22 and C-23 show a more subdued response, but steps in the rise in the groundwater surface are coincident with precipitation events.

Monitoring wells MW-1, MW-2, MW-3, and MW-9 were specifically located to provide water level information near the Eel River and Van Duzen River. Each of these well locations has paired 1-inch wells for monitoring vertical gradients within the shallow aquifer. Transducers were also installed in four locations directly in the river's surface flows to allow analysis of the SW-GW interaction. A comparison of the hydrographs for each of these four well locations along with their corresponding river levels is provided in Figures F-5, F-6, F-7, and F-8. All screened aquifers show good hydrologic communication with the rivers. Analysis of the gradients show that the SW-GW conditions near monitoring wells MW-1, MW-2 and MW-3 alternate from gaining to losing as river levels fluctuate. The deep screened aquifer at monitoring well MW-3 shows only losing stream conditions. Vertical gradients in the wells along the Eel River are flat, whereas the vertical gradient at MW-9 shows a transition from a downward gradient to an upward gradient.

Monitoring wells MW-5, MW-7 and MW-8 were installed within the interior of the Eel River Valley and were installed to depths ranging from 160 to 250 feet. Monitoring well MW-8 was installed in the southeastern portion of the valley to evaluate thickness of fine-grained alluvial deposits and to monitor groundwater elevations underlying these deposits. Monitoring wells MW-5 and MW-7 were installed within the zone of transition from seawater to freshwater and are each outfitted with paired 2-inch wells screened at variable depths. Transducers installed in these wells provide an opportunity to monitor changes in vertical gradient. Hydrographs for these wells are provided in Figures F-9, F-10 and F-11. Both deep screened wells in Monitoring wells MW-5 and MW-7, as well as the well within monitoring well MW-8, show tidal fluctuation, indicating that they have tapped into regional (Carlotta) aquifers that are hydrologically connected to the ocean. The vertical gradient within monitoring well MW-7 is downward whereas the gradient is upward in monitoring well MW-5. The erratic hydrograph of monitoring well MW-5s appears to be affected by an adjacent well or some other unknown disturbance.

Monitoring well MW-10 is located within the upper portions of the basin and is monitoring the aquifer conditions in the Carlotta formation within the Yager Creek drainage. The hydrograph for this well is shown on Figure F-12 and indicates there is good SW-GW connection between the aquifer and Yager Creek flows.

Fall 2016 Groundwater Elevation Measurement and Chloride Testing

Depth-to-water measurements wells throughout the Basin was performed by a team of staff from SHN; the Humboldt County Resource Conservation District (HCRCD); Humboldt County Public Works; and volunteer citizens, Don and Cheryl Laffranchi. Depth-to-water sampling was also conducted by the Department of Water Resources (DWR) in six of the California Statewide Groundwater Elevation Monitoring (CASGEM) wells. A discussion of the results is included in Section 3.2.1 of the preceding report, and a groundwater contour map is provided in Figure 3-13 (Appendix I).

Chloride sampling and testing in 27 wells within the seawater-freshwater transition zone were conducted during the last week of October and first week of November 2016. A discussion of the sampling effort and analysis of results is included in Section 3.2.3 of the preceding report, and a map with results plotted is provided in Figure 3-20 (Appendix I).

Details of the elevation monitoring and chloride testing are included in Table F-3.

Table F-3
Elevation Monitoring and Chloride Testing
Eel River Valley Groundwater Basin, Groundwater Sustainability Plan Alternative

Well Location	Field ID	Depth to Water Measurement Date	Chloride Sampling Date	GW Elevation (ft, NAVD88)[1]	CC (mg/L)[2]	Well Depth	Analyzed by
PRIVATE WELLS							
02N02W 03E001H	1		10/24/2016	--	39		SHN[3]/ HCRCD[4]
03N02W 34K002H	2	10/24/2016	10/24/2016	7.18	2,600	260	SHN/ HCRCD
03N02W 34K001H	3	10/24/2016	10/24/2016	2.91	41	26	SHN/ HCRCD
03N02W 34H001H	4	10/25/2016	10/25/2016	4.86	62	80	SHN/ HCRCD
03N02W 34R001H	5	10/25/2016	10/25/2016	7.09	130	120	SHN/ HCRCD
03N02W 35B001H	6	10/24/2016	10/24/2016	2.95	32	40	SHN/ HCRCD
03N02W 26Q001H	7	10/25/2016	10/25/2016	5.03	25	40	SHN/ HCRCD
03N02W 26G001H	8	10/25/2016	10/25/2016	4.72	33		SHN/ HCRCD
03N02W 13M001H	9		10/25/2016	--	28		SHN/ HCRCD
03N02W 13G001H	10	10/25/2016	10/25/2016	-0.03	38		SHN/ HCRCD
03N02W 36C001H	11	10/25/2016	10/25/2016	7.63	67		SHN/ HCRCD
03N02W 36P001H	12	10/24/2016		6.33		60	SHN/ HCRCD
02N01W 06J001H	13	10/24/2016		0.15		45	SHN/ HCRCD
02N01W 05B001H	14	10/25/2016		9.93			SHN/ HCRCD
03N01W 33P001H	15	10/24/2016		7.17		55	SHN/ HCRCD

Table F-3 Elevation Monitoring and Chloride Testing Eel River Valley Groundwater Basin, Groundwater Sustainability Plan Alternative							
Well Location	**Field ID**	**Depth to Water Measurement Date**	**Chloride Sampling Date**	**GW Elevation (ft, NAVD88)[1]**	**CC (mg/L)[2]**	**Well Depth**	**Analyzed by**
PRIVATE WELLS (cont.)							
02N01W 08Q001H	16	10/24/2016		13.55		55	SHN/ HCRCD
02N01W 09F001H	17	10/24/2016		14.61			SHN/ HCRCD
02N01W 08D001H	18	10/25/2016		11.09			SHN/ HCRCD
02N01W 16J001H	19	10/24/2016		12.56		100	SHN/ HCRCD
02N01W 22H002H	20	10/24/2016		26.92		110	SHN/ HCRCD
02N01W 35C001H	21	10/24/2016		33.76		60	SHN/ HCRCD
02N01W 24E001H	22	10/24/2016		40.55		60	SHN/ HCRCD
02N01E 19L001H	C-23	10/24/2016		64.09		80	SHN/ HCRCD
03N01W 19D001H	24	10/25/2016	10/25/2016	2.45	22		SHN/ HCRCD
03N01W 18P001H	25	10/25/2016	10/25/2016	0.79	320		SHN/ HCRCD
03N02W 02R001H	26	10/25/2016	10/25/2016	10.83	450	40	SHN/ HCRCD
02N01W 16C001H	28	10/31/2016		8.96		200	SHN/ HCRCD
03N02W 22J001H	29	11/1/2016	11/3/2016	-0.12	680	30	SHN/ HCRCD
02N01E 27C001H	A	11/1/2016		106.79		50	SHN/ HCRCD
02N01E 30B001H	B	11/1/2016		64.36		45	SHN/ HCRCD
02N01W 22C001H	D	11/1/2016		24.22		120	SHN/ HCRCD
02N01W 09N001H	E	11/1/2016		17.24		45	SHN/ HCRCD
02N01W 08N001H	F	11/1/2016		7.22		50	SHN/ HCRCD
02N02W 03F001H	G	11/1/2016	11/3/2016	9.44	47	160	SHN/ HCRCD
03N02W 34M001H	H		11/3/2016	7.49	89	120	SHN/ HCRCD
02N02W 05E001H	I	11/1/2016	11/3/2016	13.55	87	200	SHN/ HCRCD
03N01W 31A001H	J	11/1/2016		8.41		50	SHN/ HCRCD
03N02W 26M001H	L	11/1/2016	11/3/2016	6.96	180	40	SHN/ HCRCD
03N02W 13R001H	M	11/1/2016		6.39		50	SHN/ HCRCD
03N02W 12R001H	N	11/1/2016		8.74			SHN/ HCRCD

Table F-3
Elevation Monitoring and Chloride Testing
Eel River Valley Groundwater Basin, Groundwater Sustainability Plan Alternative

Well Location	Field ID	Depth to Water Measurement Date	Chloride Sampling Date	GW Elevation (ft, NAVD88)[1]	CC (mg/L)[2]	Well Depth	Analyzed by
PRIVATE WELLS (cont.)							
03N02W 27G001H	Q	11/1/2016	11/3/2016	5.91	250	60	SHN/ HCRCD
03N02W 13N001H	R	11/1/2016		8.11			SHN/ HCRCD
03N02W 13N002H	R_ Shop		11/3/2016		1,500	50	SHN/ HCRCD
COUNTY WELLS							
03N01W 29Q001H	MW-1s	10/28/2016	11/22/2016	2.98	23	35	SHN
03N01W 29Q002H	MW-1d	10/28/2016	11/22/2016	3.04	20	60	SHN
02N01W 10R002H	MW-2d	10/28/2016		18.02		60	SHN
02N01W 22H001H	MW-3d	10/30/2016		16.99		60	SHN
03N02W 34A002H	MW-5d		11/22/2016	--	63	210	SHN
02N02W 03C001H	MW-7s		11/23/2016	--	36	40	SHN
02N02W 03C002H	MW-7d		11/23/2016	--	170	240	SHN
02N01W 07J001H	MW-8	10/30/2016		3.51		160	SHN
02N01E 19Q001H	MW-9s	10/28/2016		64.77		25	SHN
02N01E 16R001H	MW-10	10/30/2016		130.01		29	SHN
02N01E 23N001H	MW-11	10/30/2016		119.12		46	SHN
CASGEM WELLS [5]							
02N01W 08B001H	23178	10/19/2016		10.33		40	DWR[6]
02N01W 09K001H	36942	10/19/2016		15.59		30	DWR
03N01W 34J001H	36944	10/19/2016		20.80		496	DWR
02N02W 02G001H	36943	10/19/2016		9.02		210	DWR
03N02W 35M001H	23183	10/19/2016		6.21		42	DWR
03N01W 30N001H	23181	10/19/2016		1.02		50	DWR
MUNICIPAL WELLS							
02N02W 01D001H	Del Oro	10/25/2016	10/25/2016	16.16	49		MUNICIP.
02N02W 03Q001H	Riverside	10/25/2016	10/25/2016	16.50	49		MUNICIP.
02N01W 11G001H	Fortuna #1	10/25/2016		31.54			MUNICIP.

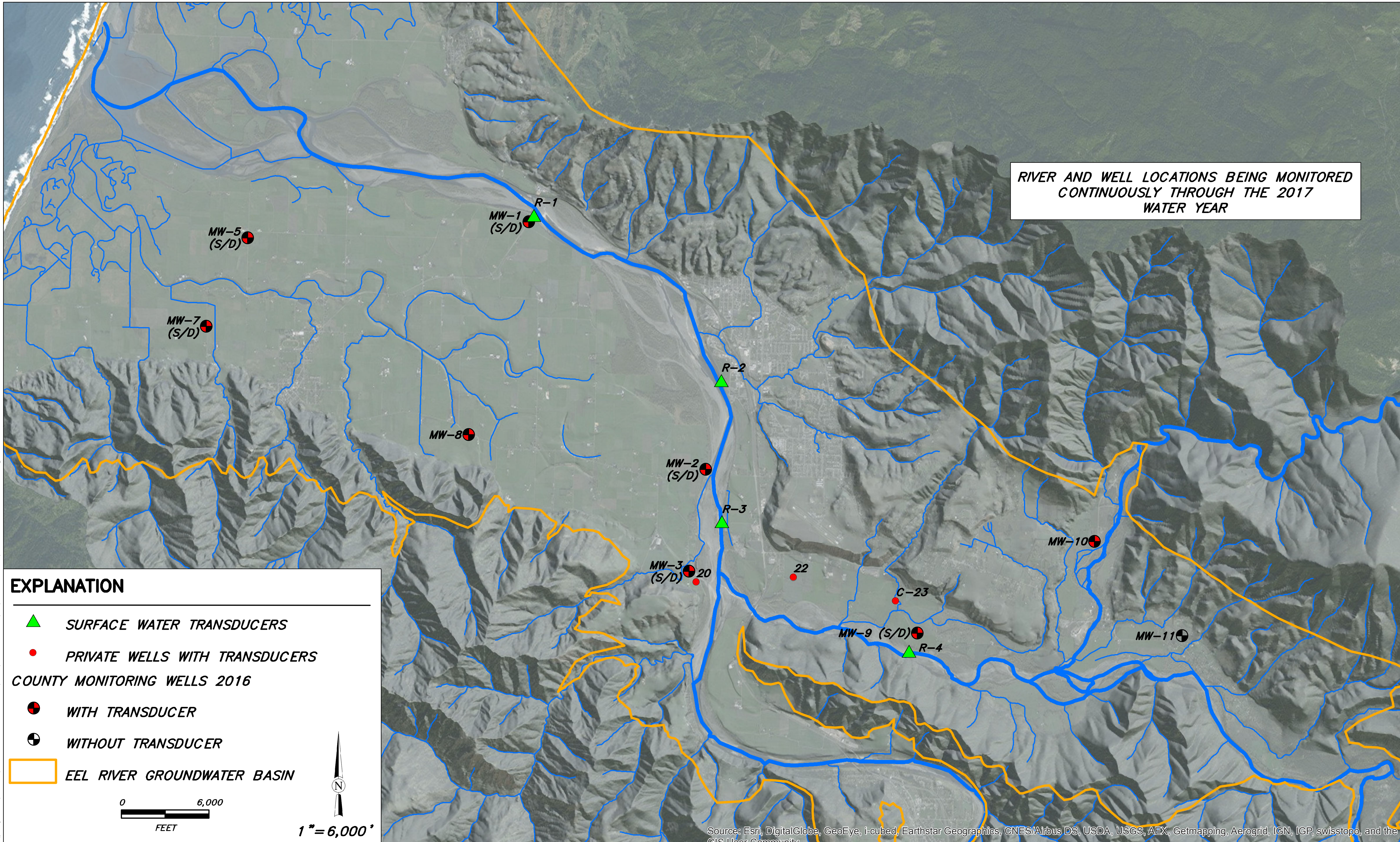
Table F-3 Elevation Monitoring and Chloride Testing Eel River Valley Groundwater Basin, Groundwater Sustainability Plan Alternative							
Well Location	**Field ID**	**Depth to Water Measurement Date**	**Chloride Sampling Date**	**GW Elevation (ft, NAVD88)[1]**	**CC (mg/L)[2]**	**Well Depth**	**Analyzed by**
MUNICIPAL WELLS (cont.)							
02N01W 11G002H	Fortuna #4	10/25/2016		23.41			MUNICIP.
03N01W 33A001H	Palmer Creek #1	10/25/2016		8.12			MUNICIP.
03N01W 33A002H	Palmer Creek #2	10/25/2016		7.00			MUNICIP.
HUMBOLDT CREAMERY WELLS							
03N01W 29H001H	GWR-1	11/8/2016		21.85		34.10	SHN
03N01W 29C001H	GWR-2	11/9/2016		7.51		29.60	SHN
03N01W 29D002H	GWR-3	11/9/2016		7.38		29.45	SHN
03N01W 19R002H	GWR-4	11/8/2016		7.91		29.45	SHN
03N01W 29G001H	GWR-5	11/8/2016		29.09		28.70	SHN
03N01W 29G002H	GWR-6	11/8/2016		19.69		31.56	SHN
03N01W 30A001H	GWR-7	11/9/2016		7.37		31.30	SHN
03N01W 19Q001H	GWR-8	11/8/2016		7.71		31.44	SHN
03N01W 19R001H	GWR-9	11/9/2016		7.64		31.15	SHN
03N01W 29D001H	GWR-10	11/9/2016		23.92		28.69	SHN

1. Groundwater elevation (measured by the foot; North American Vertical Datum of 1988)
2. Chloride concentration measured in milligrams per liter (mg/L)
3. SHN: SHN Engineers & Geologists
4. HCRCD: Humboldt County Resource Conservation District
5. CASGEM: California Statewide Groundwater Elevation Monitoring (CASGEM) wells
6. DWR: California Department of Water Resources

References

Bouwer, H., and R. C. Rice (1976). "A slug test for determining hydraulic conductivity of unconfined aquifers with completely or partially penetration wells," Water Resour., 12(3), 423-428. NR:WRR.

van der Kamp, G. (1976). "Determining aquifer transmissivity by means of well response tests: The underdamped case," Water Resour., 12(1), 71–77. NR:WRR.



SHN Consulting Engineers & Geologists, Inc.

Humboldt County Public Works
Eel River Groundwater Assessment
Humboldt County, California

Groundwater and Surface Water Monitoring Locations
SHN 016219

December 2016 | F-1_GWSW_Monitoring_Locations | Figure F-1

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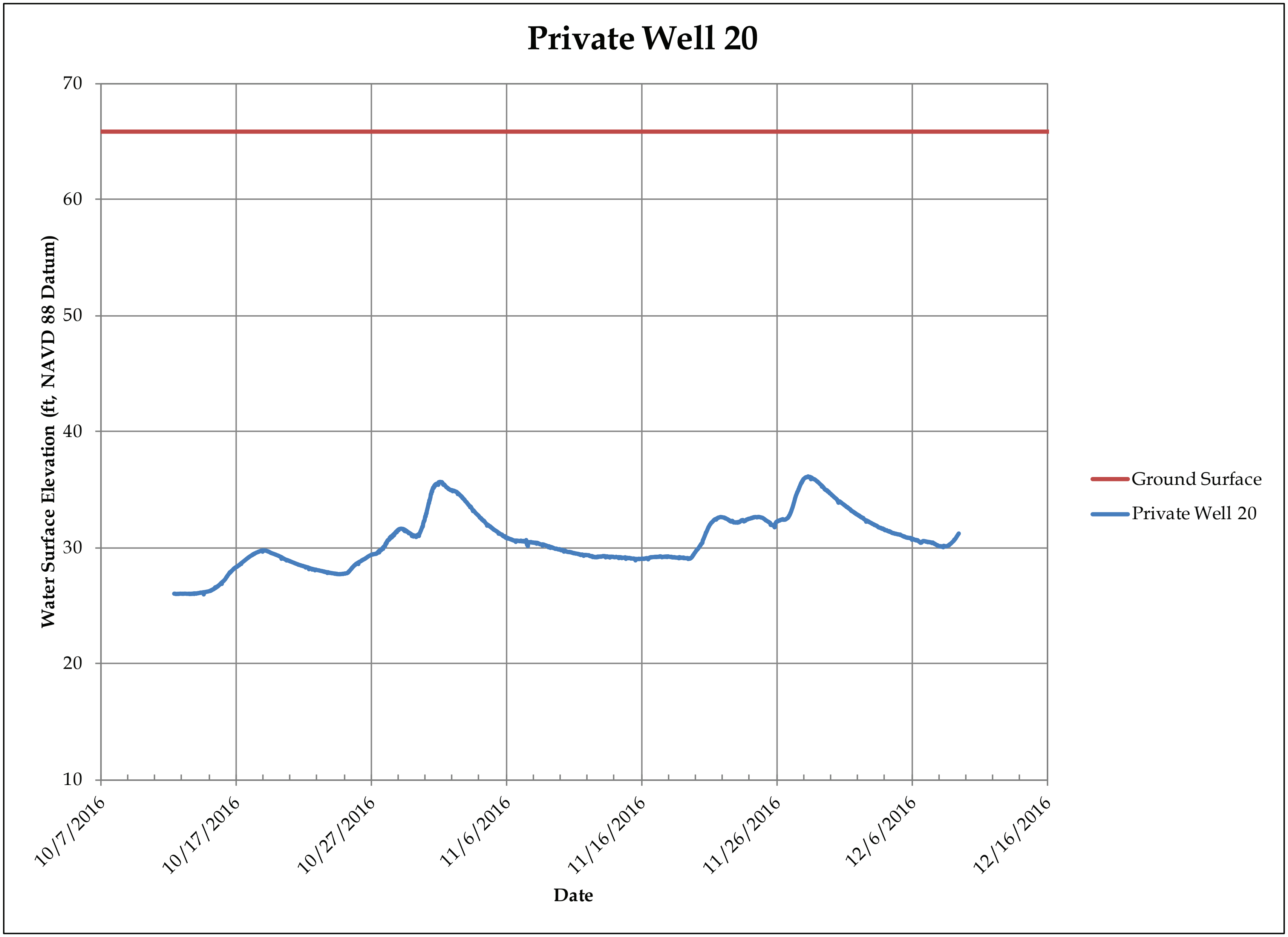

Consulting Engineers & Geologists, Inc.

Humboldt County Public Works
Eel River Groundwater Assessment
Humboldt County, California

Private Well 20
Hydrograph
SHN 016219

December 2016 | F-2_PrivateWell20_Hydrograph.ai | Figure F-2

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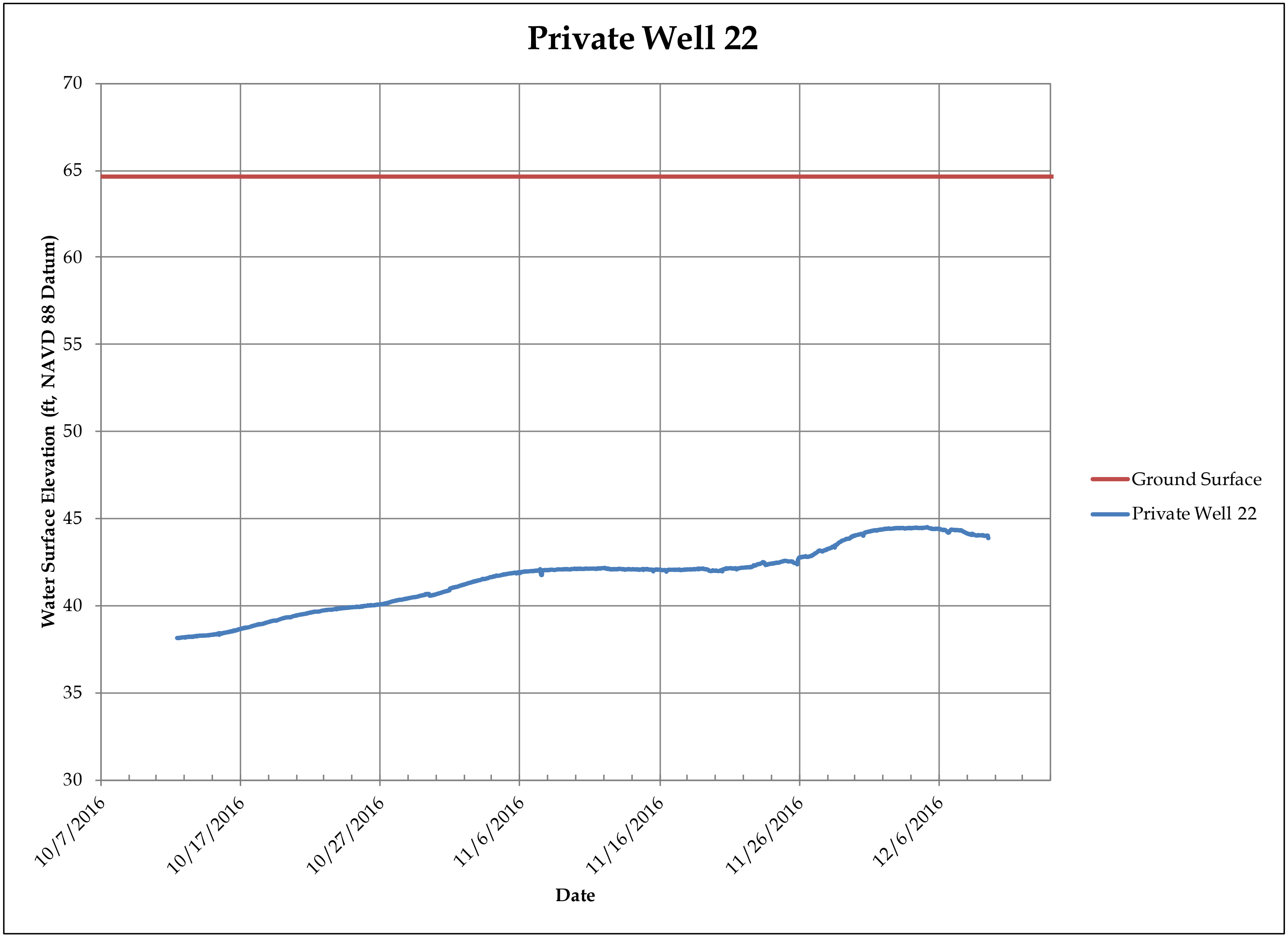
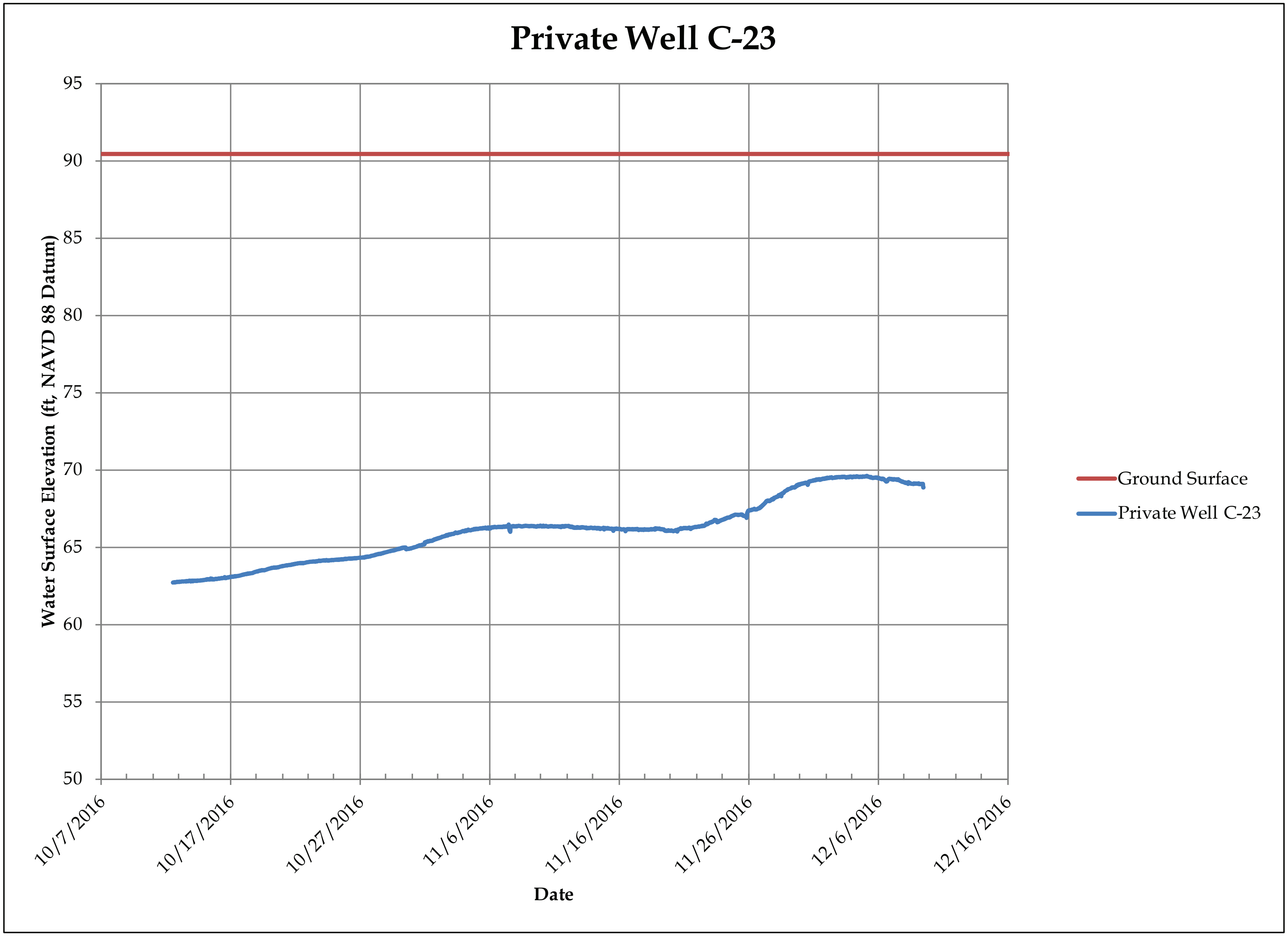


Consulting Engineers & Geologists, Inc.

Humboldt County Public Works
Eel River Groundwater Assessment
Humboldt County, California

Private Well 22
Hydrograph
SHN 016219

December 2016 | F-3_PrivateWell22_Hydrograph.ai | Figure F-3



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Humboldt County Public Works
Eel River Groundwater Assessment
Humboldt County, California

Private Well C-23
Hydrograph
SHN 016219

December 2016

F-4_PrivateWellC23_Hydrograph.ai

Figure F-4

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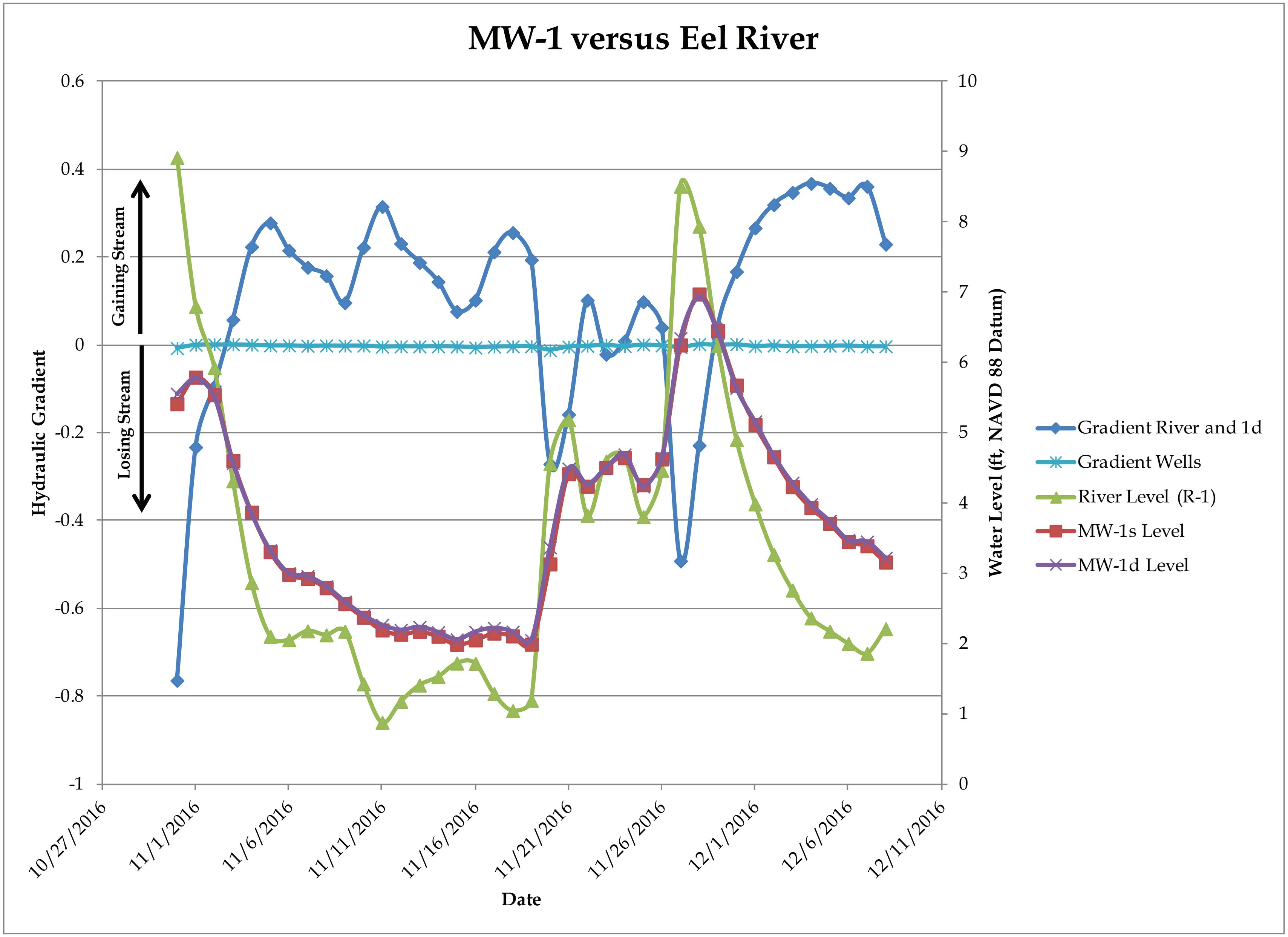

Consulting Engineers & Geologists, Inc.	Humboldt County Public Works Eel River Groundwater Assessment Humboldt County, California		MW-1 vs. Eel River Hydrograph SHN 016219
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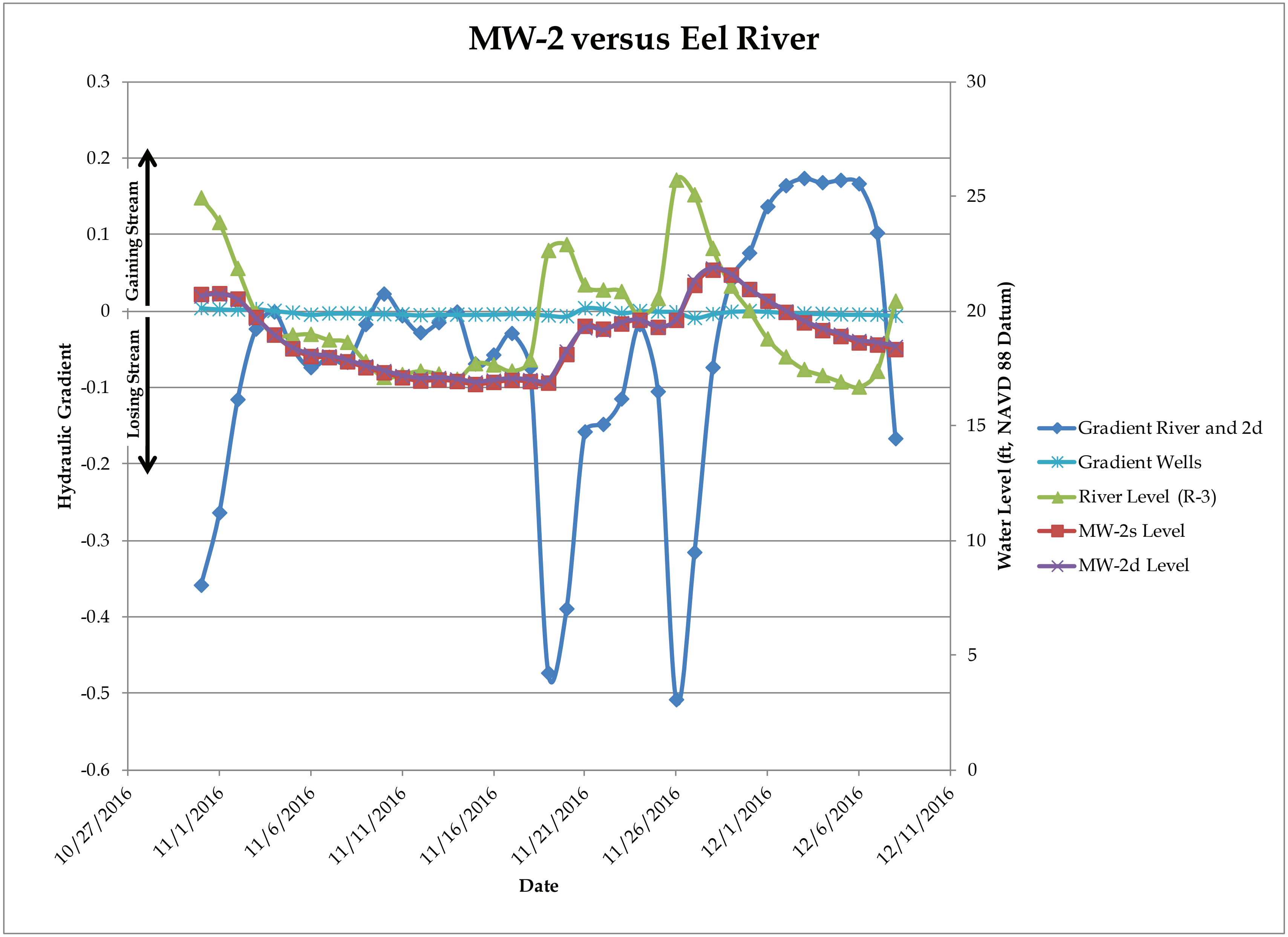

SHN Consulting Engineers & Geologists, Inc.	Humboldt County Public Works Eel River Groundwater Assessment Humboldt County, California		MW-2 vs. Eel River Hydrograph SHN 016219
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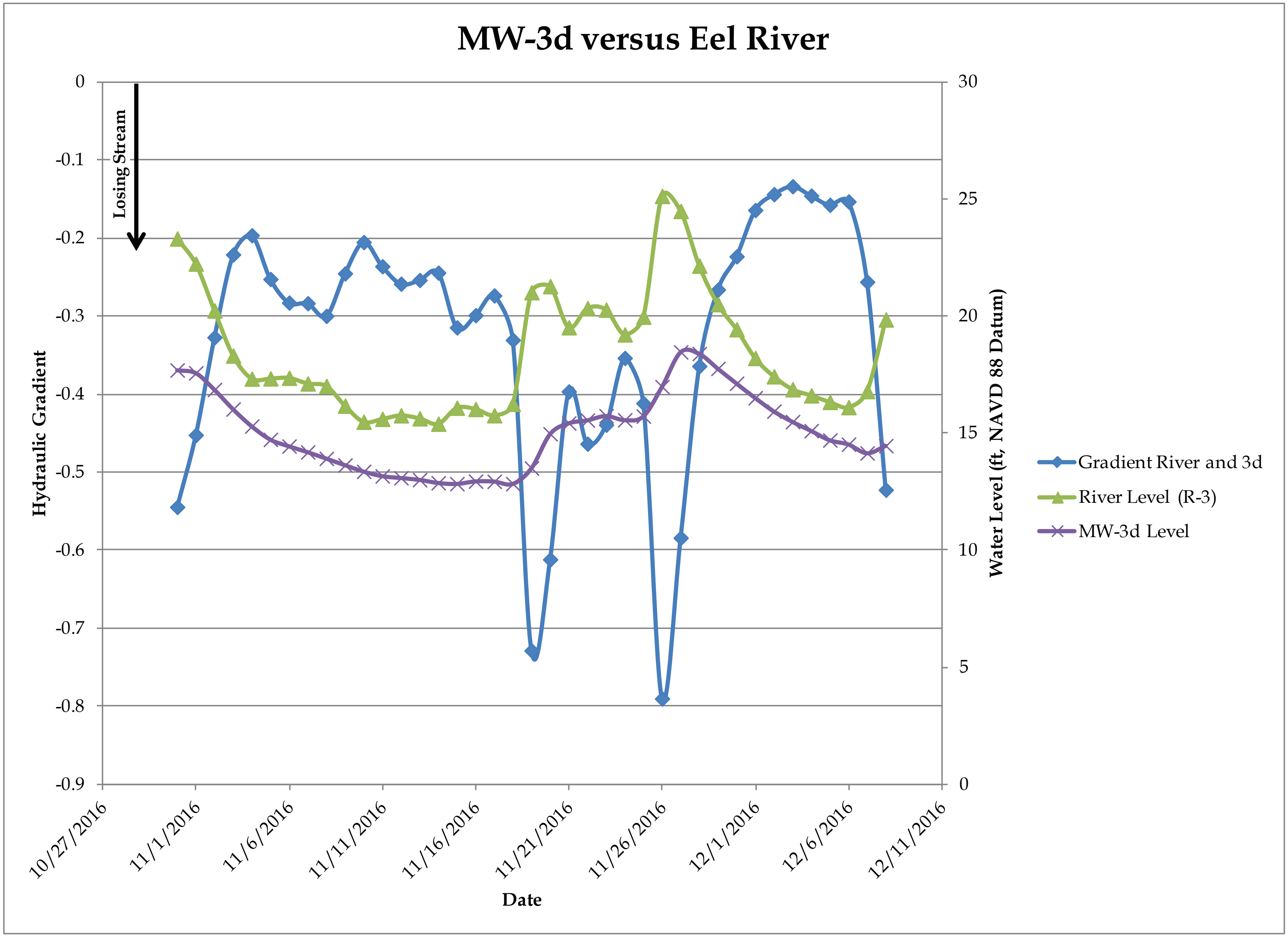

SHN Consulting Engineers & Geologists, Inc.

Humboldt County Public Works
Eel River Groundwater Assessment
Humboldt County, California

MW-3d vs. Eel River
Hydrograph
SHN 016219

December 2016 | F-7_MW3d_ER_Hydrograph.ai | Figure F-7

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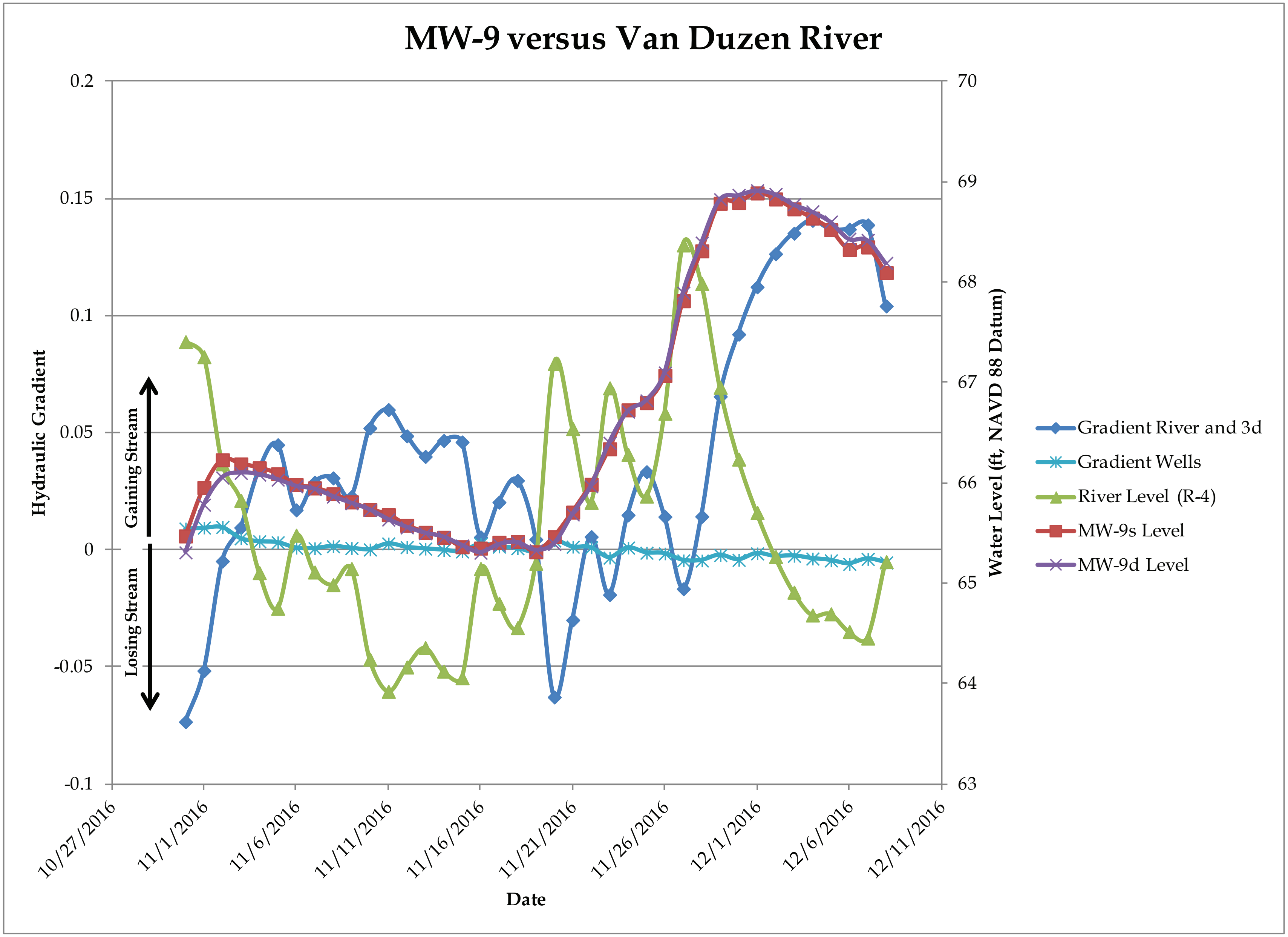

SHN Consulting Engineers & Geologists, Inc.	Humboldt County Public Works Eel River Groundwater Assessment Humboldt County, California	MW-9 vs. Van Duzen River Hydrograph SHN 016219	
December 2016	F-8_MW9_VD_Hydrograph.ai		Figure F-8

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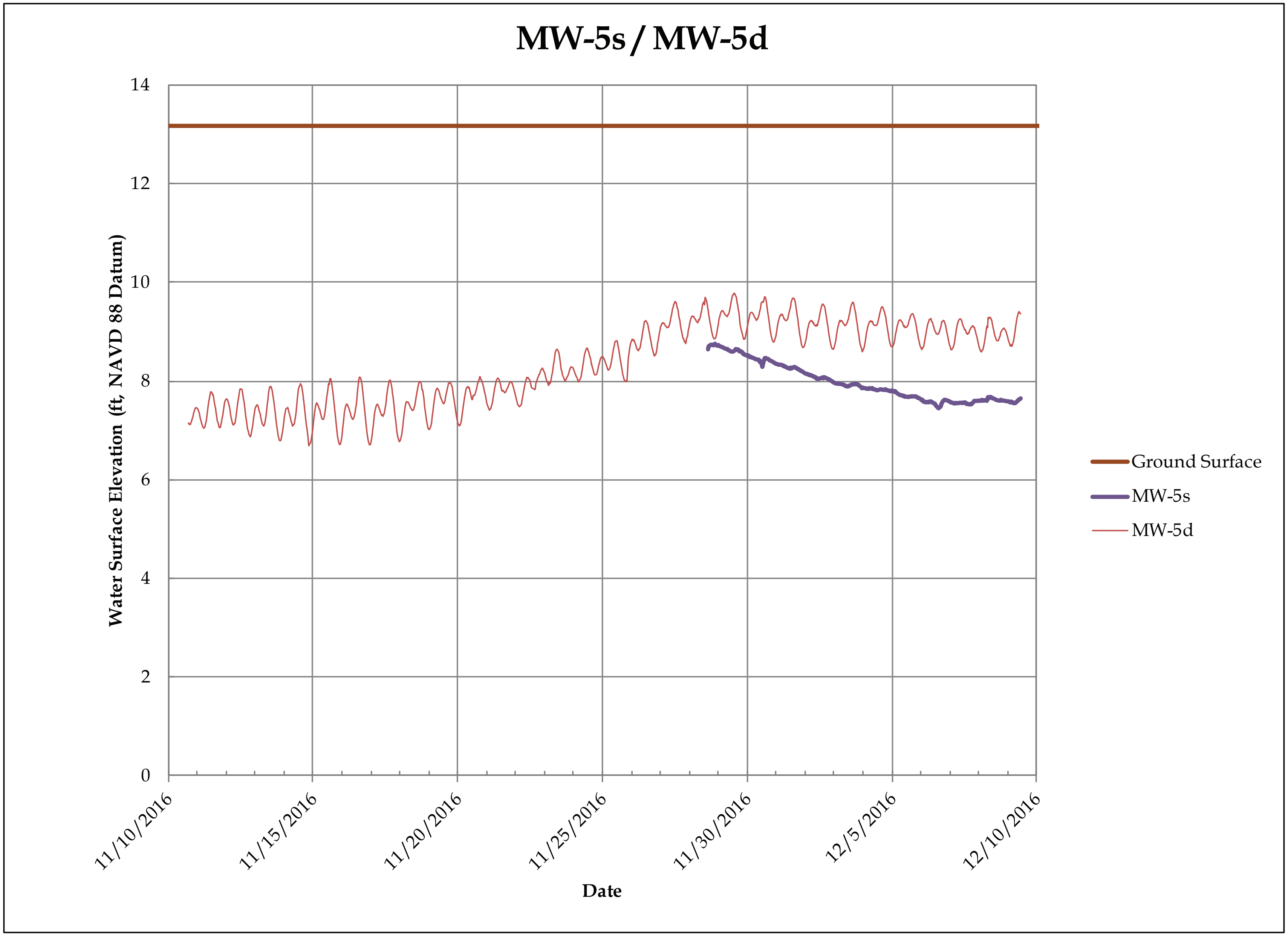

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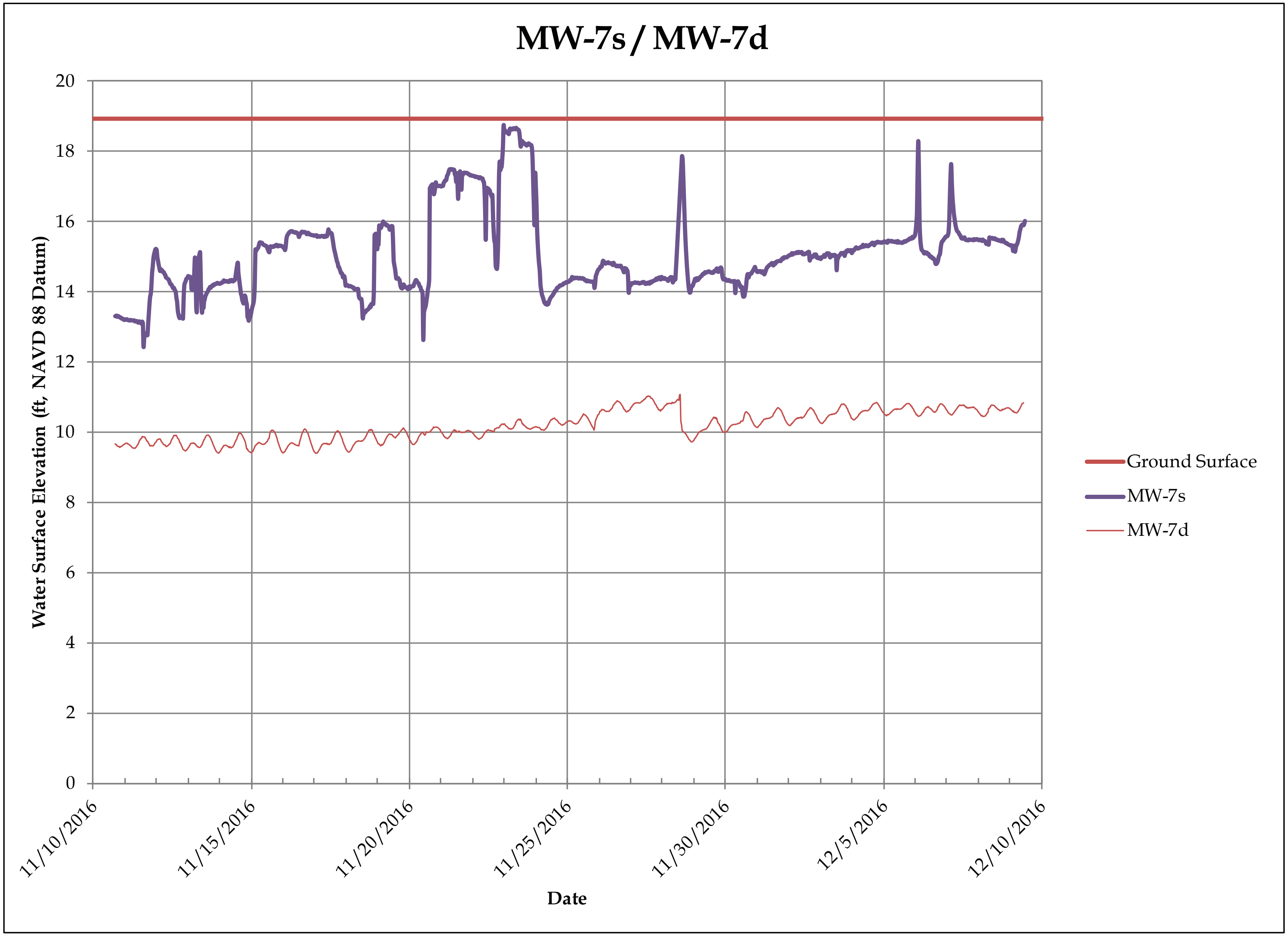

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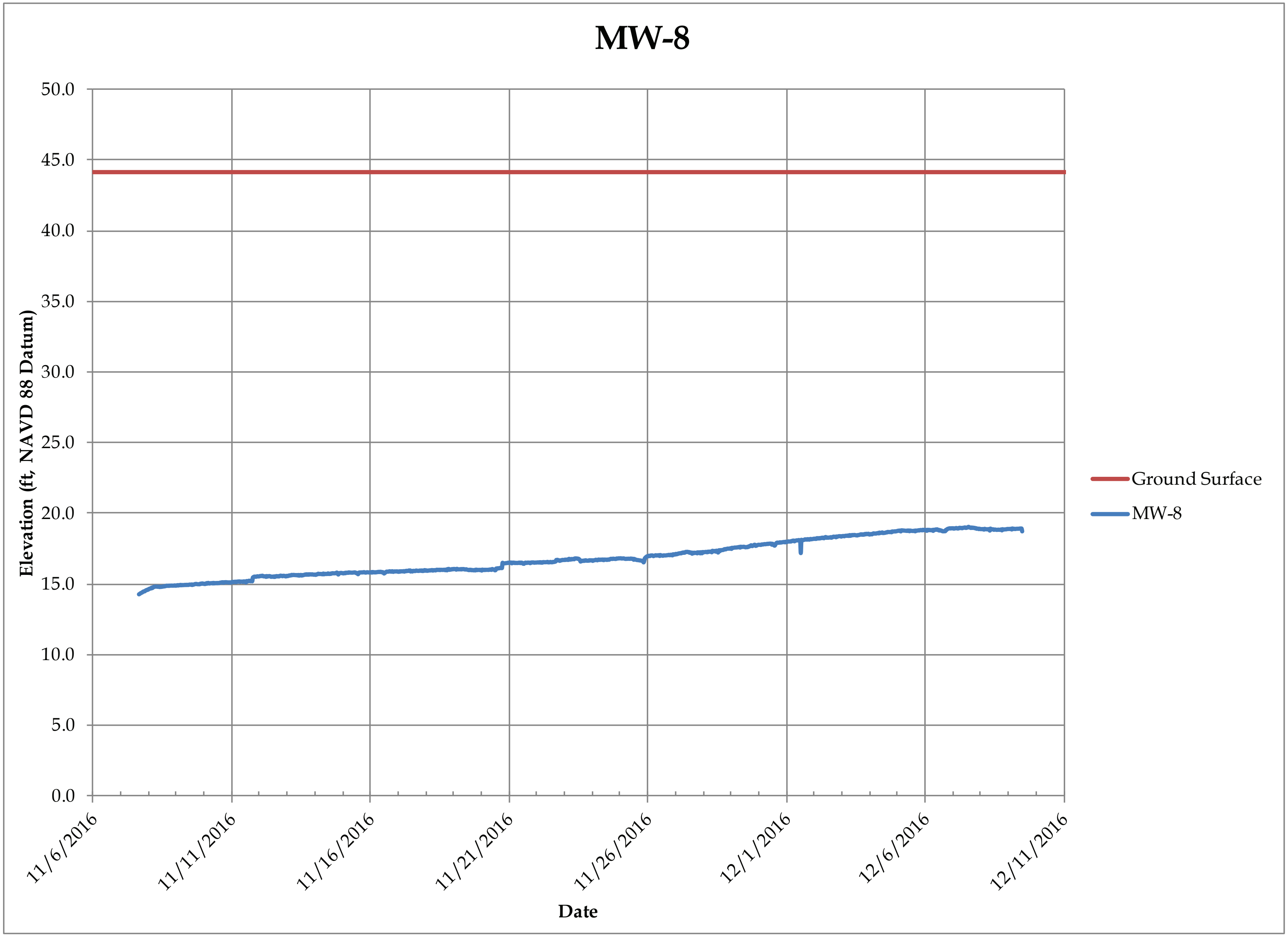

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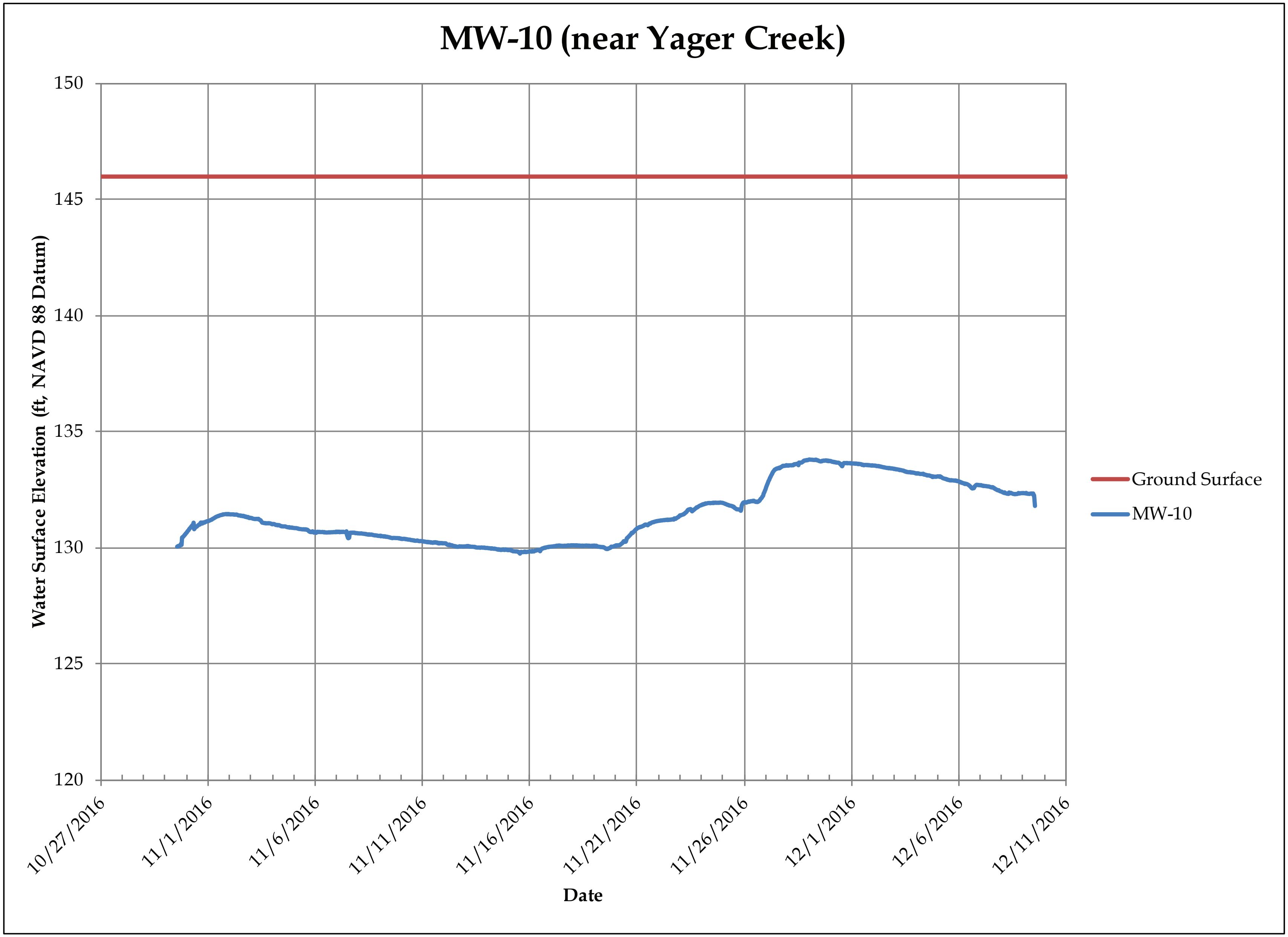

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Humboldt County Public Works
Eel River Groundwater Assessment
Humboldt County, California

MW-10
Hydrograph
SHN 016219

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Appendix G

GAMA Program Database Review (SHN, 2016)

Appendix G. GAMA Program Database Review for the Eel River Valley Groundwater Basin (1-10)

The GeoTracker/Groundwater Ambient Monitoring and Assessment (GAMA) program database was used to review the baseline groundwater quality in the Eel River Valley Groundwater Basin (Basin). The dataset was queried for the following constituents:

Aluminum (Al)	**Chloride (Cl)**	Selenium (Se)
Arsenic (As)	Chromium (Cr)	Silver (Ag)
Barium (Ba)	Lead (Pb)	**Sodium (Na)**
Boron (B)	Mercury (Hg)	**Specific Conductance (SC)**
Cadmium (Ca)	**Nitrate-N (NO3-N)**	**Total Dissolved Solids (TDS)**

For each constituent, water quality objectives including primary and secondary maximum contaminant levels (MCL) and agricultural use limits, as applicable, were identified using the State Water Resources Control Board (SWRCB) Water Quality Goals Database (Marshack, 2015). Table G-1 summarizes the applicable water quality objectives used for the analysis.

Table G-1
Applicable Water Quality Objectives for Eel River Valley Groundwater Uses[1]
(mg/L[2], unless otherwise noted)

Chemical/Parameter	MCL[3]	Secondary MCL[4]	Agricultural Limits
Aluminum	1.0	0.2	5.0
Arsenic	**0.01**	**---[5]**	**1.0**
Barium	1.0	---	---
Boron	---	---	0.7
Cadmium	0.005	---	0.01
Chloride	**---**	**250**	**106**
Chromium	0.05	---	---
Lead	0.015	---	5.0
Mercury	0.002	---	---
Nitrate-N (as N)	**10**	**---**	**---**
Selenium	0.05	---	0.02
Silver	---	0.1	---
Sodium	**---**	**---**	**69**
Specific Conductance (umhos/cm)[6]	**---**	**900**	**700**
Total Dissolved Solids	**---**	**500**	**450**

1. Source: Water Quality Goals Database (Marshack, 2015)
2. mg/L: milligrams per liter
3. MCL: State of California Primary Maximum Contaminant Level
4. SMCL: State of California Secondary Maximum Contaminant Level
5. ---: not applicable
6. umhos/cm: microSiemens per centimeter

Of the 15 constituents queried, nine constituents had concentrations levels that were primarily non-detect for the dataset record and/or extremely low compared to the water quality objectives. Six of the constituents had concentration levels that were detected primarily above method detection levels including Arsenic, Chloride, Nitrate-N, Sodium, Specific Conductance and Total Dissolved Solids; and these constituent were selected for further analysis (as indicated in bold on the previous page).

For the six 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. The averages were then compared to applicable water quality objectives for each constituent. Figure G-1 shows the GAMA groundwater well locations in the Eel River Valley and Figures G-2 through G-7 summarize the results of the ground water quality assessment in the Eel River Valley.

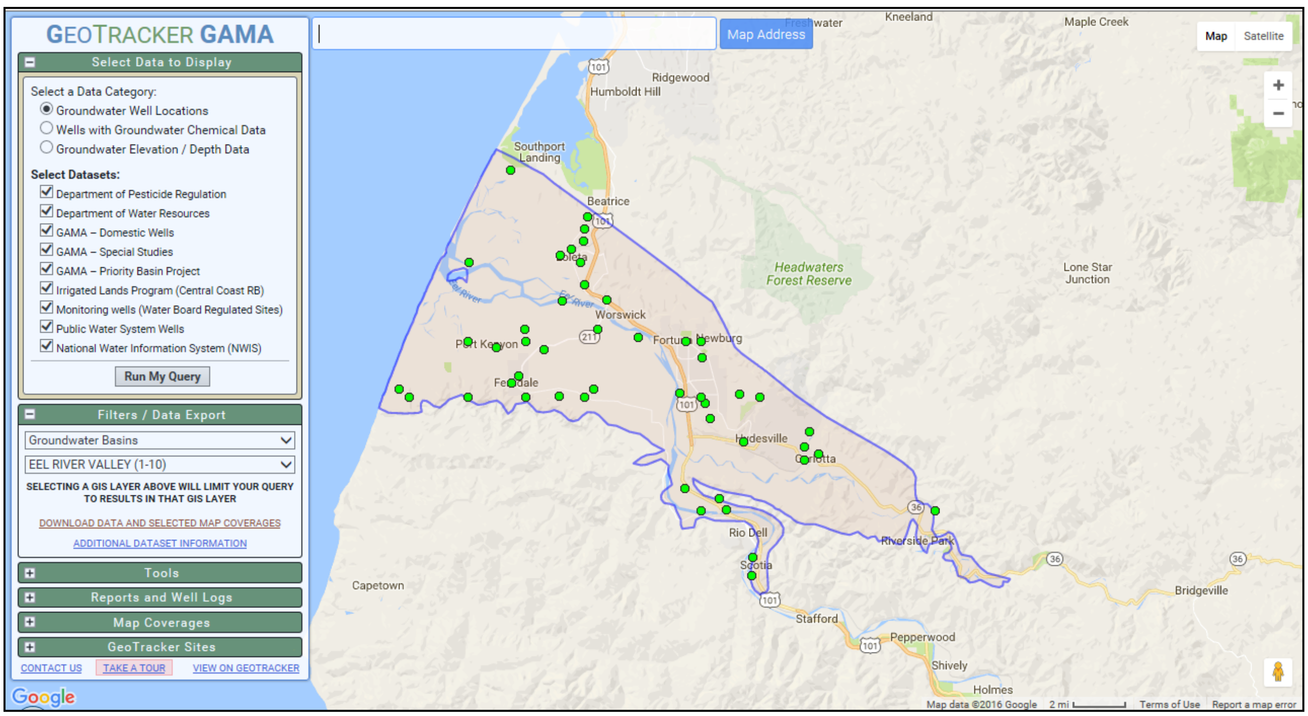

Figure G-1. GAMA Groundwater Well Locations

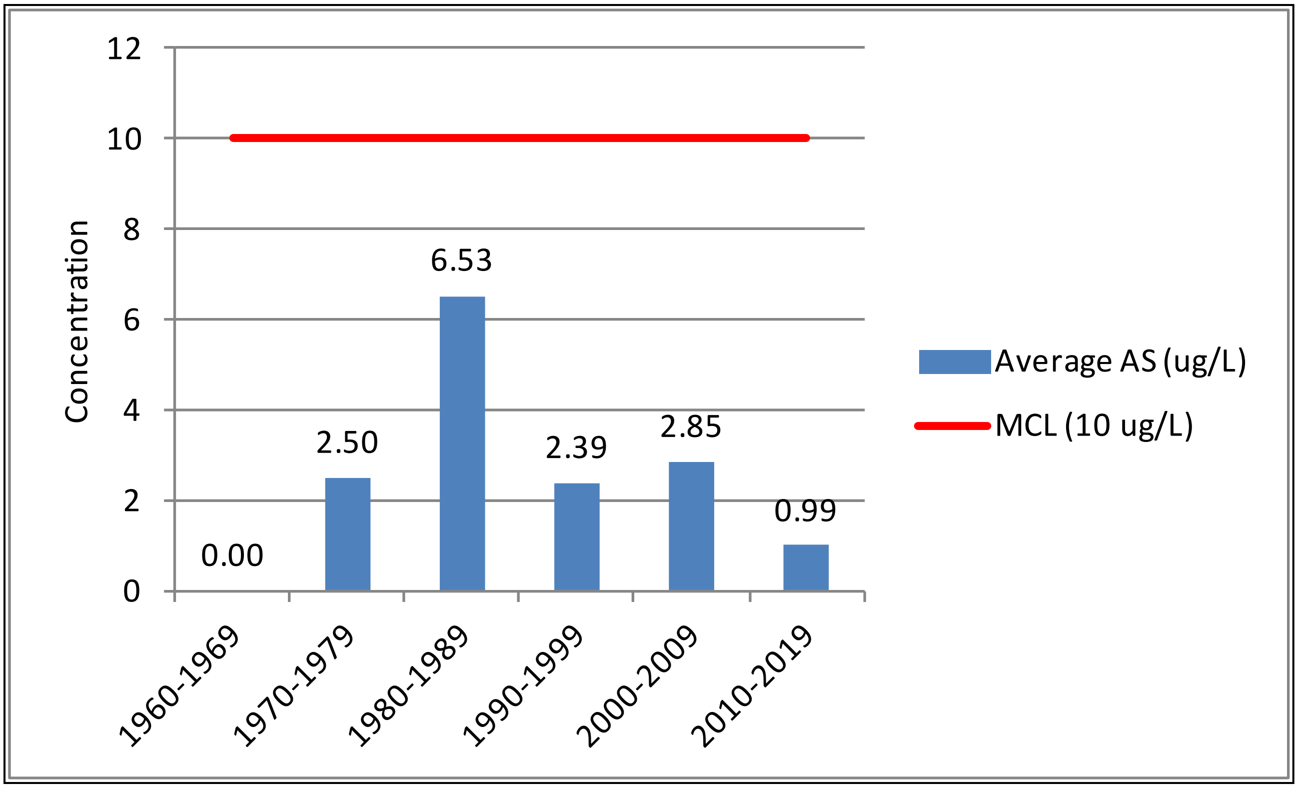

Figure G-2. GAMA Dataset – Arsenic (As) 10-Year Averages

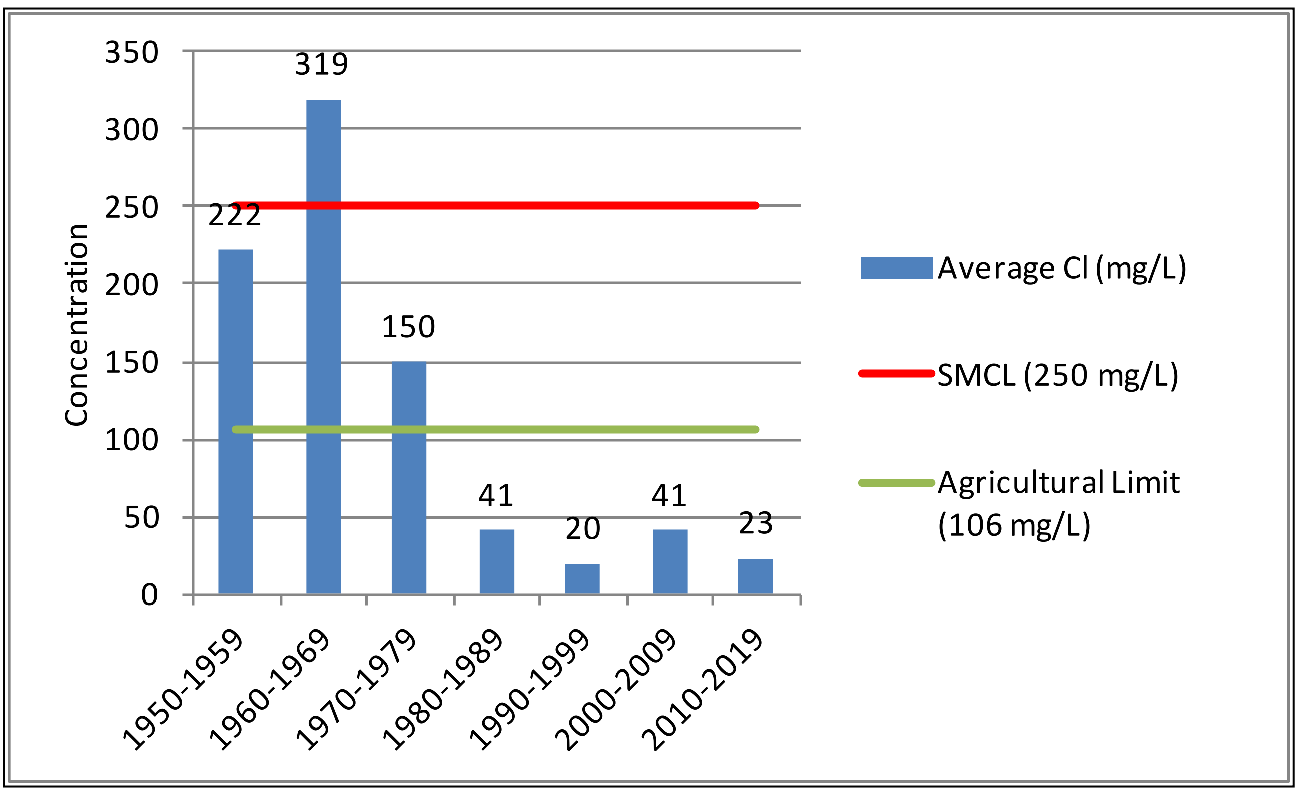

Figure G-3. GAMA Dataset – Chloride (Cl) 10-Year Averages

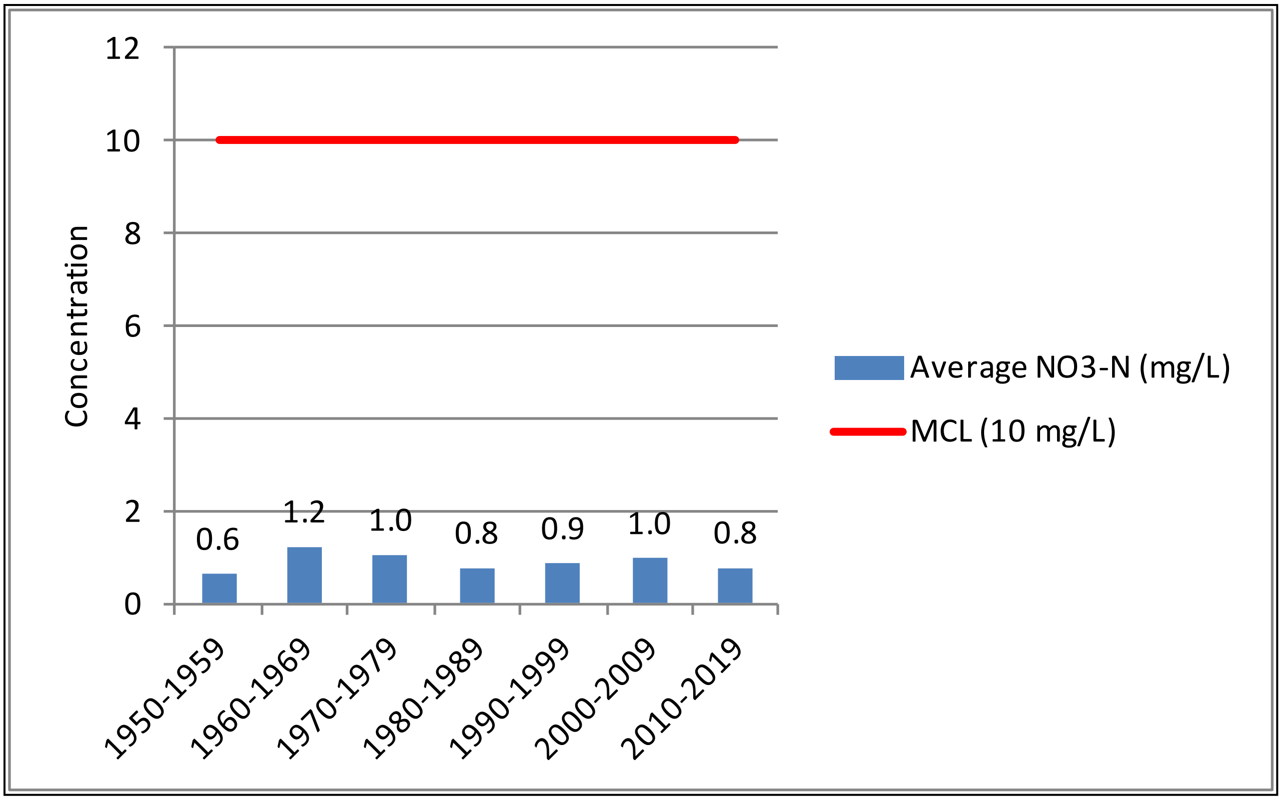

Figure G-4. GAMA Dataset – Nitrate as Nitrogen (N03-N) 10-Year Averages

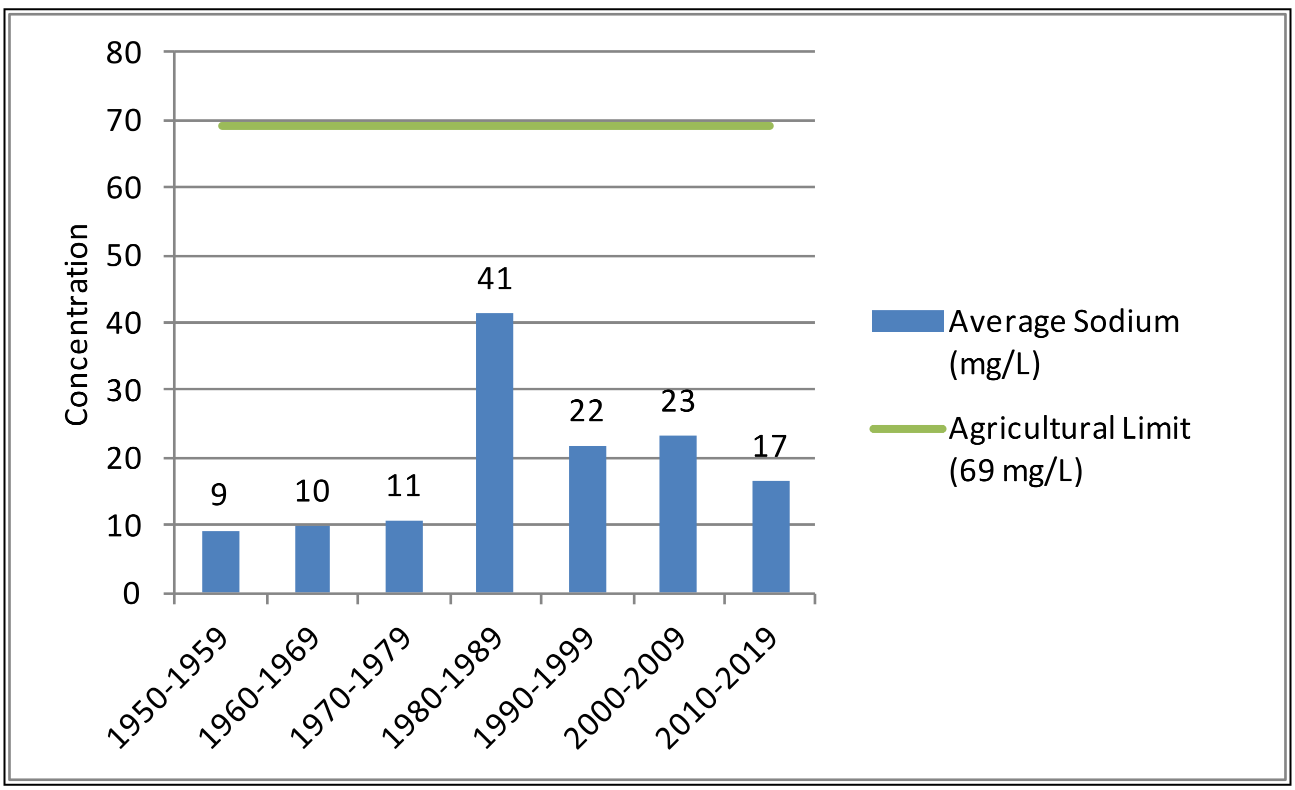

Figure G-5. GAMA Dataset – Sodium (Na) 10-Year Averages

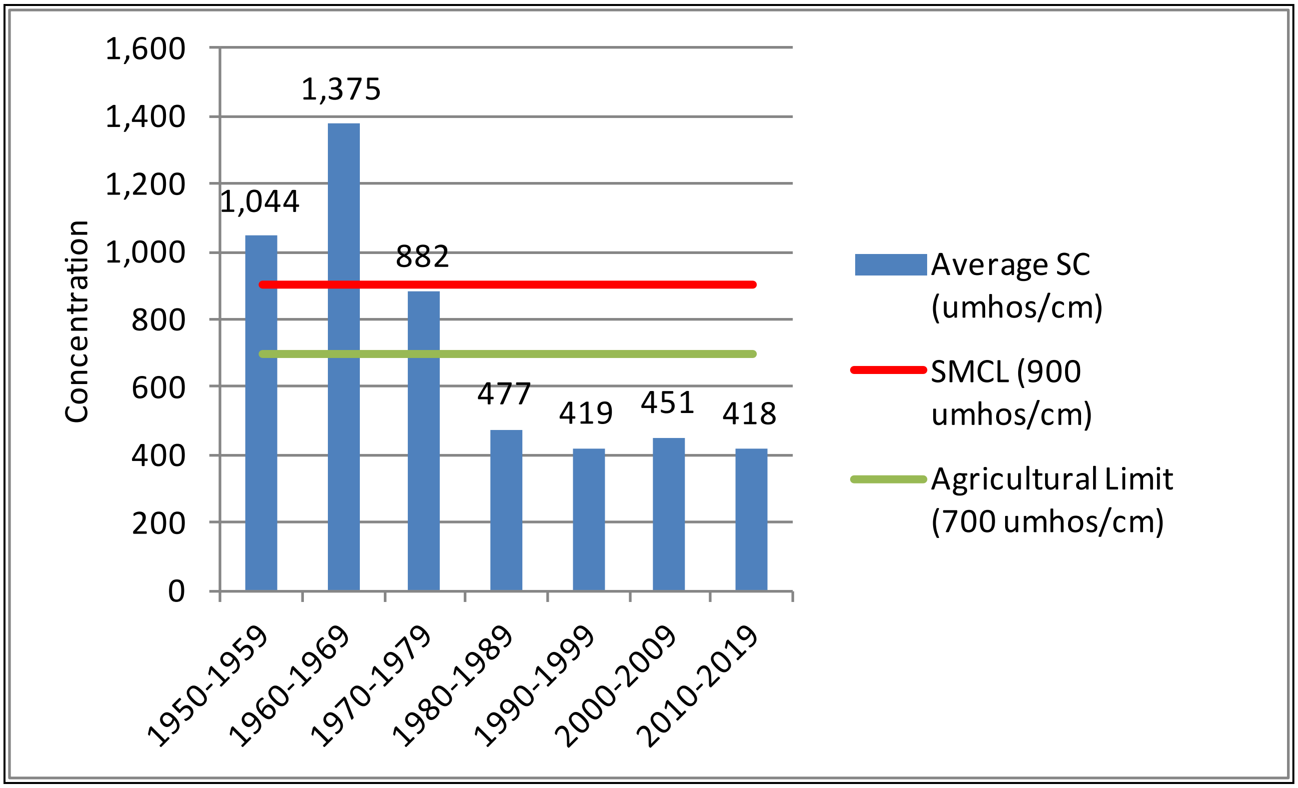

Figure G-6. GAMA Dataset – Specific Conductance (SC) 10-Year Averages

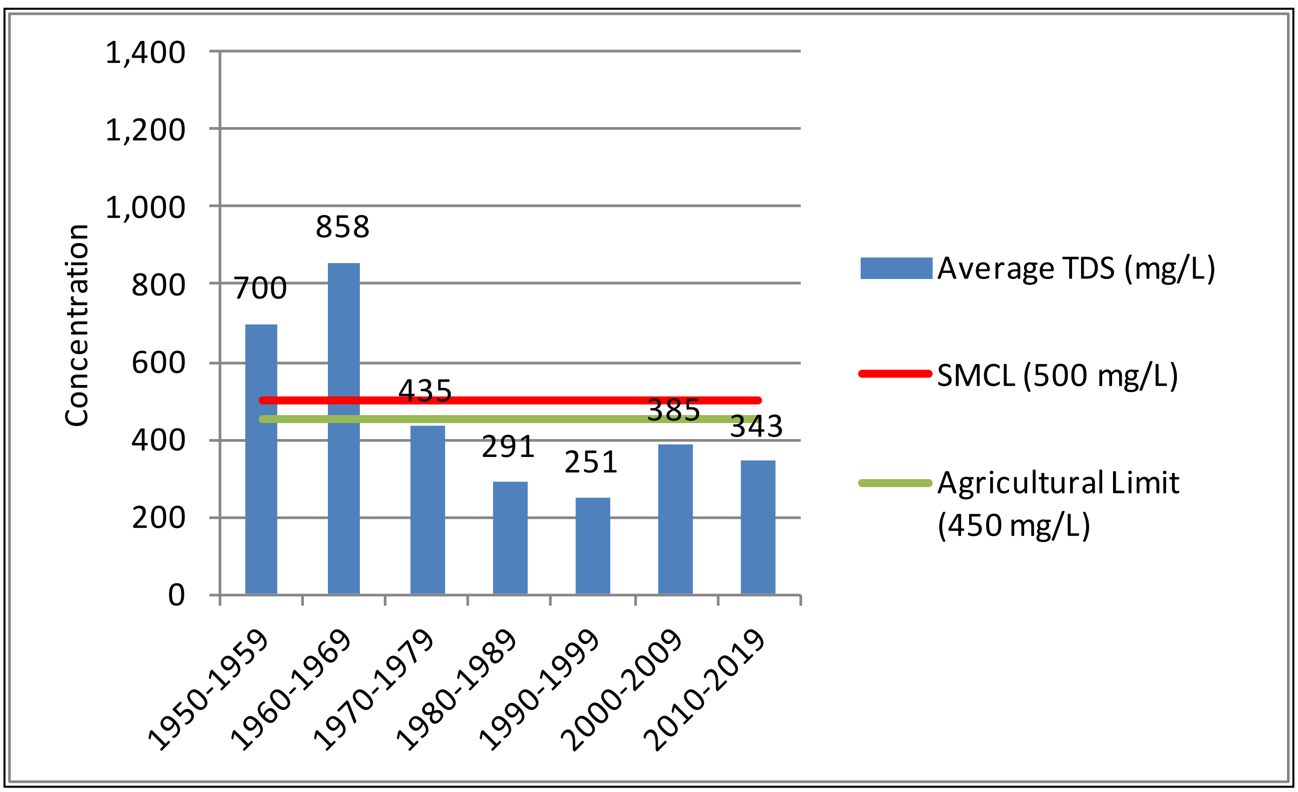

Figure G-7. GAMA Dataset – Total Dissolved Solids (TDS) 10-Year Averages

As demonstrated in Figures G-2 through G-7 above, the groundwater in the Eel River Valley appears to be of high quality and suitable for the intended municipal and agricultural uses. The average concentrations of Arsenic, Chloride, Nitrate-N, Sodium, Specific Conductance and Total Dissolved Solids have all been below their respective water quality objectives for the last 40 years. Furthermore, the water quality trends in the dataset have not shown any significant increase in concentrations in the last ten-year period of record as compared to the entire data set.

References

Marshack. (2015). State Water Resources Control Board Water Quality Goals Database, Last Updated December 15, 2015.

Appendix H

Water Budget (PECG, 2016)

PALMER ENVIRONMENTAL CONSULTING GROUP INC.
791 Eighth Street, Suite H, Arcata, CA 95521 t:707.218.4747

Eel River Valley Groundwater Basin GIS-Based Water Budget

V2

PECG Project #
160431

Prepared For
SHN Consulting Engineers

December 30, 2016

PALMER
ENVIRONMENTAL
CONSULTING
GROUP INC.

791 Eighth Street, Suite H, Arcata, CA 95521 t:707.218.4747

December 30, 2016

Jason Buck, CEG
Engineering Geologist
SHN Engineers & Geologists
812 W. Wabash Ave.,
Eureka, CA
95501-2138

Dear Jason:

Re: **Eel River Valley Groundwater Basin GIS-Based Water Budget**
Project #: **160431**

Palmer Environmental Consulting Group Inc. (PECG) is pleased to provide our GIS-Based Water Budget Report for the Eel River Valley Groundwater Basin to support the sustainability assessment as part of an Alternative Submittal to the California Department of Water Resources.

Yours truly,
Palmer Environmental Consulting Group Inc.

Rob Frizzell, M.Sc., P.Geo.
Senior Hydrogeologist

Jason Cole, M.Sc., P.Geo.
Partner, Hydrogeologist

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1. Introduction

1.1 Background

In 2014, the State of California passed the Sustainable Groundwater Management Act (SGMA) legislation that established a statewide framework for sustainable groundwater management. All high and medium priority groundwater basins are required to develop a Groundwater Sustainability Plan (GSP) or GSP Alternative.

The Eel River Valley Groundwater Basin was identified as a medium priority basin, primarily due to the relatively high reliance on groundwater and large amount of agricultural land-use within the basin. The Eel River Valley Groundwater Basin is located south of the city of Eureka in Humboldt County, California and has an area of 73,700 acres, comprised of the lower 8 miles of the Van Duzen River, and the lower Eel River Valley downstream of Scotia (**Figure 1**).

Water Code Section 10733.6 under SGMA provides the option of submitting a GSP Alternative if it satisfies one of the following conditions:

1. An existing groundwater management plan or other law authorizing groundwater management is already in place;
2. Management pursuant to an adjudication action; or
3. An analysis of basin conditions that demonstrates that the basin has operated within its sustainable yield over a period of at least ten years.

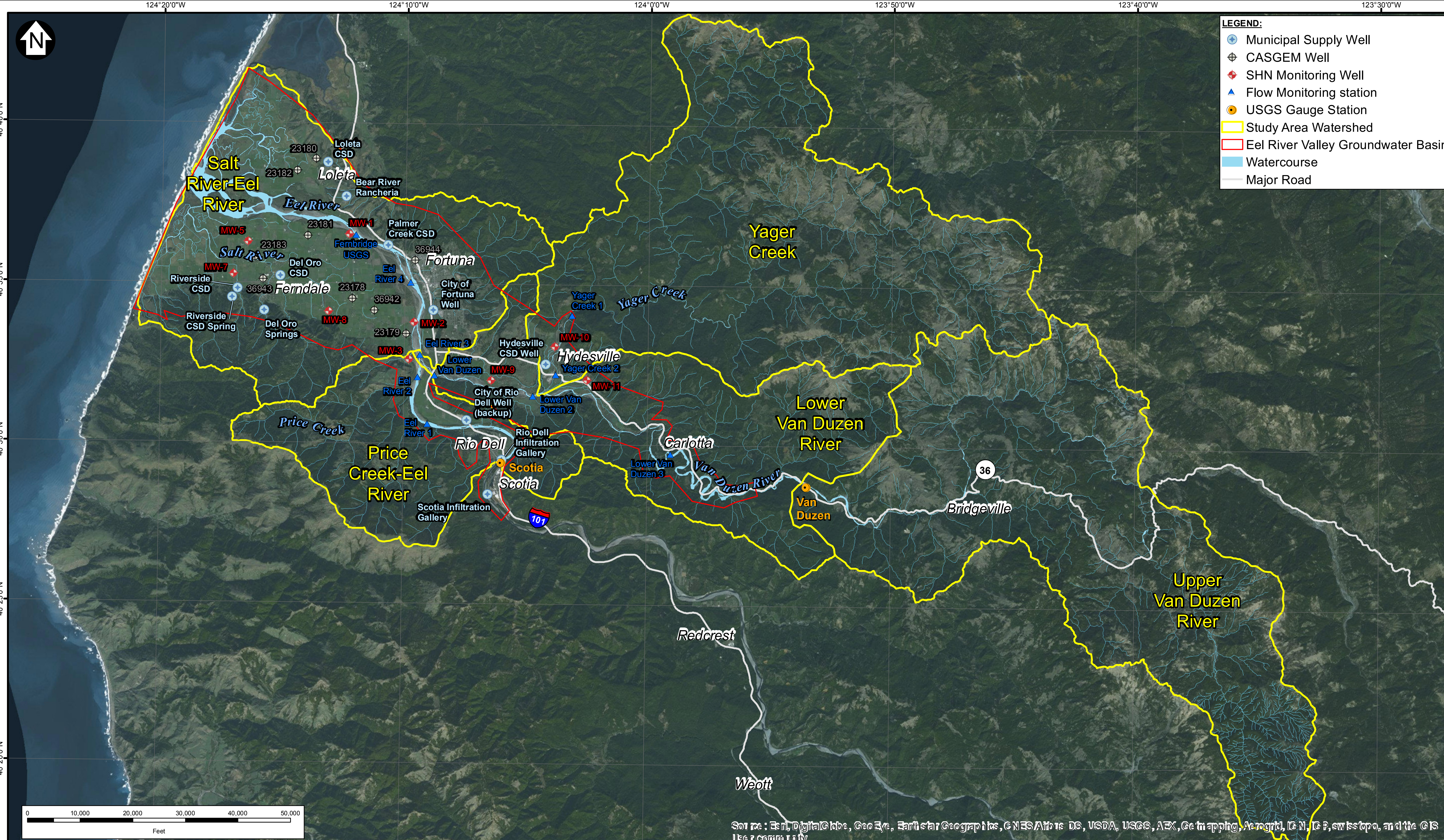
A preliminary assessment of the existing groundwater and surface water level data from within the basin suggests that the basin has operated within its sustainable yield over the past 10-years. This report forms part of the GSP Alternative being developed by Humboldt County in order to demonstrate the sustainability of the basin.

1.2 Project Scope and Objectives

SHN Engineers & Geologists (SHN) was retained by the Humboldt County Public Works Department (HCPWD) to assist with completing a GSP Alternative for the Eel River Groundwater Basin. Palmer Environmental Consulting Group Inc. (PECG) was retained by SHN to support these efforts by completing a water budget for the basin.

The objective of the PECG Water Budget Study is to quantify the volume of water entering and leaving the basin, and to assist Humboldt County in evaluating the sustainability of the water takings within the Eel River Valley Groundwater Basin.

The water budget will provide an accounting and assessment of the total annual volume of groundwater and surface water entering and leaving the basin, including historical, current and projected water budget



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NOTES:
1. Hydrographic data from USGS NHD (https://nhd.usgs.gov/data.html)
2. Scale: 1:210 000 at original page size of 11" by 17"
3. PROJECTION: NAD 1983 UTM Zone 10N
4. COORDINATE GRID: Degrees

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Figure 1
Eel River Valley
Groundwater Basin Study Area

conditions, and the change in the volume of water stored. Specifically, the following items have been addressed in this report, which are consistent with the SGMA requirements:

- Total surface water entering and leaving a basin by water source type.
- Inflow to the groundwater system by water source type, including subsurface groundwater inflow and infiltration of precipitation, applied water, and surface water systems, such as lakes, streams, rivers, canals, springs and conveyance systems.
- Outflows from the groundwater system by water use sector, including evapotranspiration, groundwater extraction, groundwater discharge to surface water sources, and subsurface groundwater outflow.
- The change in the annual volume of groundwater in storage between seasonal high conditions.
- If overdraft conditions occur, as defined in Bulletin 118, the water budget shall include a quantification of overdraft over a period of years during which water year and water supply conditions approximate average conditions.
- The water year type associated with the annual supply, demand, and change in groundwater stored.
- An estimate of sustainable yield for the basin.

To complete this assessment, PECG has developed a Geographic Information System (GIS) water budget model based on the best available information to provide, long-term (i.e., 30-year) and yearly estimates of water budget parameters over the past 10-years (precipitation (P), evapotranspiration (ET), groundwater recharge (R), and surface water runoff (RO)). This information has been summarized for the groundwater basin, as well as for the full watershed area of the contributing watercourses. This simplified approach is designed to reduce uncertainty and provide an estimated water budget that is commensurate with the quantity and quality of available data.

While the Eel River Groundwater basin represents the area in which majority of groundwater resources in the lower Eel River valley are utilized for agricultural, municipal and domestic use, it is important to recognize that the groundwater and surface water that supports this basin is derived from a much larger watershed area, as shown on **Figure 1**. To ensure that all contributing water to the basin was captured in this assessment, and to reduce the overall uncertainty in estimating the volume of water entering the basin, the complete watershed area for the following watercourses were included in the water budget analysis:

- Lower Eel River downstream of the Scotia USGS hydrometric station;
- Van Duzen River;
- Yager Creek;
- Salt River;
- Price Creek; and
- Other small tributaries that flow directly to the Eel River downstream of the Scotia USGS hydrometric station.

The area encompassing the Eel River Groundwater basin and the contributing watersheds is referred to as the "study area". Additional methodology for the water budget is described in Section 4.

2. Study Area

2.1 Eel River Valley Groundwater Basin

2.1.1 Geology

The Eel River Valley Groundwater Basin is within a structurally controlled valley located just north of the Mendocino Triple Junction, the intersection point of the Gorda, North American, and Pacific plates (McLean, 1988). Regional crustal convergence of these plates has resulted in a synclinal fold known as the Eel River syncline, which generally coincides with the lower reaches of the Eel River. Geology of the area is predominantly sedimentary, and consists of a series of Plio-Pleistocene aged units collectively referred to as the Wildcat Group underlain by Franciscan/ Yager bedrock complexes. The Wildcat units include, from oldest to youngest, the Pullen, Eel River, Rio Dell, Scotia Bluffs, and Carlotta formations. The Hookton formation overlies the Wildcat Group, and thick deposits of alluvium overlie the consolidated sedimentary basin. Geology of the study area is presented on **Figure 2**, and a cross-section (from SHN, 2016) is provided on **Figure 3**.

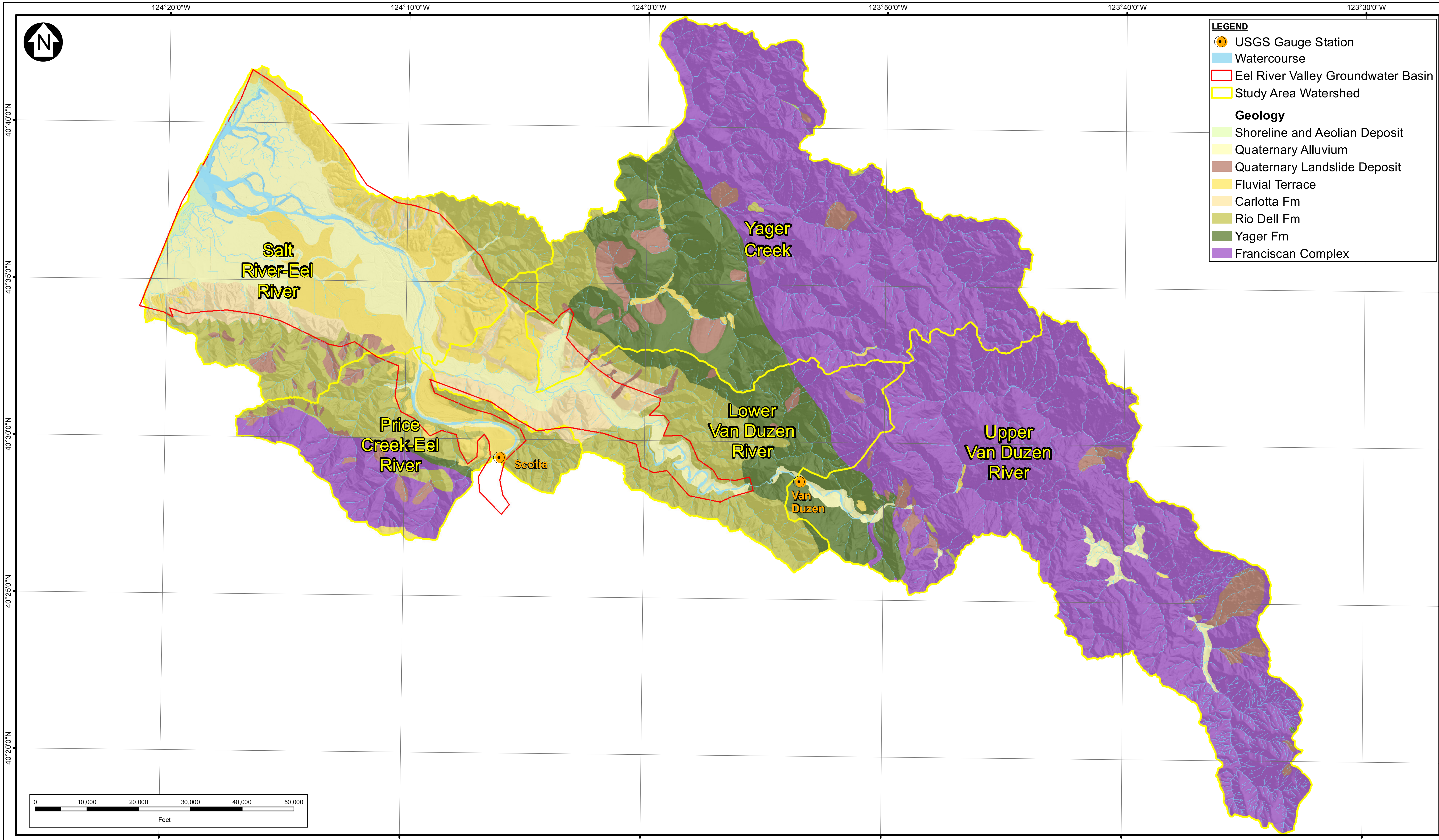
The stratigraphic units are described below:

Basement Rocks - Franciscan and Yager Formation basement complexes (Jurassic to Cretaceous aged) comprise the eastern portion of the study area within the Yager Creek and Upper and Lower Van Duzen watersheds, and a small portion of the southern Price Creek-Eel River watershed (**Figure 2**). The older Franciscan rocks are in fault contact with the Yager Formation units (Ogle, 1953, McLean, H., 1988). The Eel River area the Franciscan consists principally of massive graywacke, and a minor amount of platy, dark-gray shale, thin-bedded chert, dark-green greenstone-basalt, and glaucophane schist. The Yager Formation is described as a dark-gray indurated mudstone, shale, graywacke, and conglomerate (Ogle, 1953).

Pullen formation: This formation forms an unconformable contact with the highly folded beds of the Yager formation. Strata consists of diatomaceous siltstone and mudstone, however fragments of the underlying Yager and Franciscean formations are common due to the unconformable contact (Ogle, 1953). This formation is exposed along Eel River near Scotia.

Eel River formation: This formation overlies the Pullen formation, and consists of a series of dark gray-black mudstone, siltstone, and sandstone. Deposition of this unit likely occurred under shallow marine conditions, as indicated by the lower conglomerate and sandstone (Ogle, 1953). This formation is exposed along the west bank of Eel River near Scotia.

Rio Dell formation: This formation is the thickest of the Wildcat group, and overlies the Eel River formation. It is divided into Upper, Middle, and Lower units, where the upper unit consists of massive gray mudstone, the middle unit is primarily thin alternating layers of light gray sandstone and gray mudstone, and the lower unit is mainly light gray siltstone with some sandstone (Ogle, 1953).



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NOTES:
1. Source: Bedrock simplified from McLaughlin et al., 2000 (MF-2336)and modified with Dibblee, 2008. Hydrographic data from USGS NHD (https://nhd.usgs.gov/data.html)
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3. PROJECTION: NAD 1983 UTM Zone 10N
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Figure 2
Eel River Water Budget
Geology

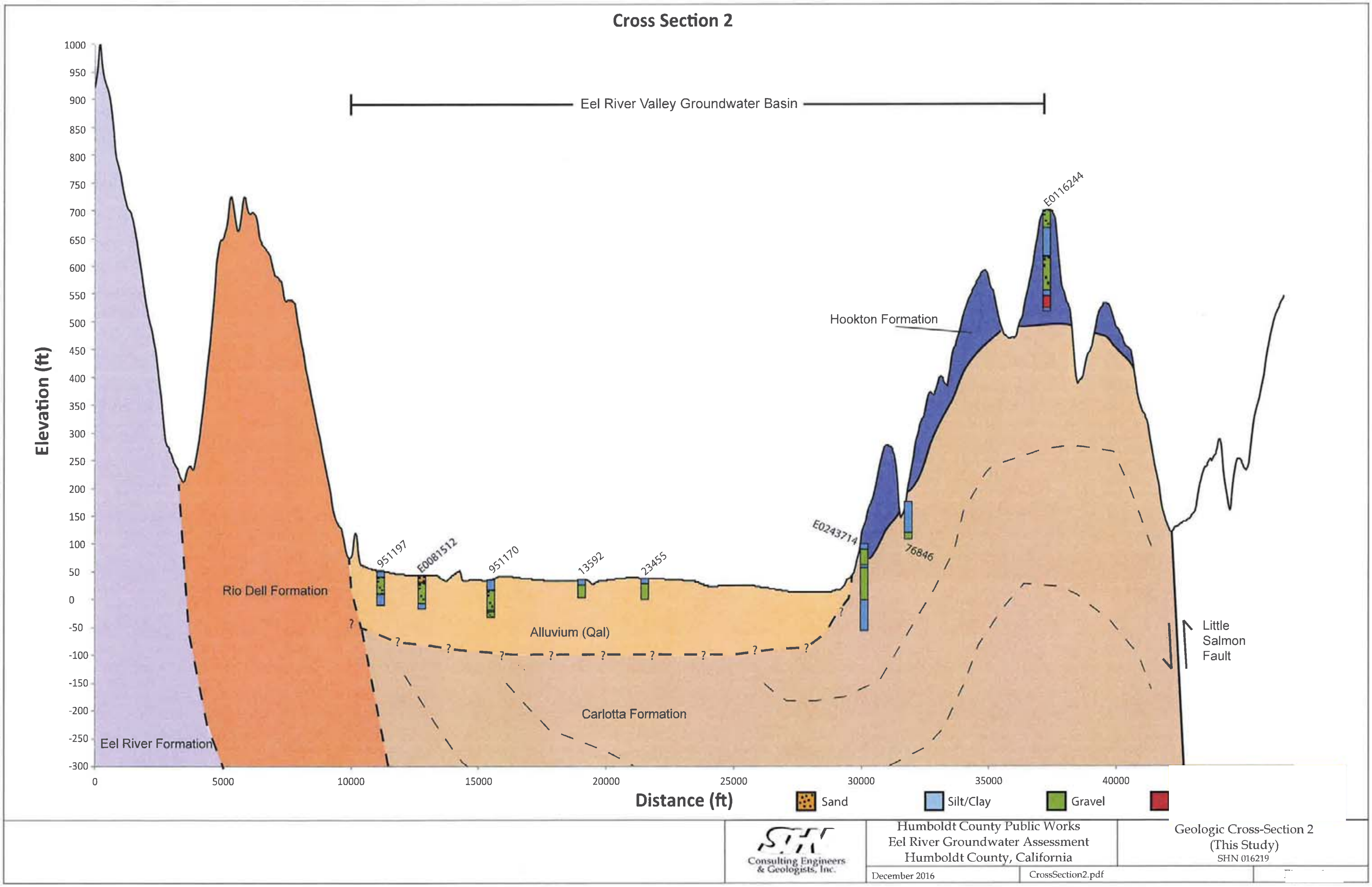


Figure 3. Eel River Valley Cross Section (from SHN, 2016)

Scotia Bluffs formation: This formation, along with the Carlotta formation, makes up the upper portion of the Wildcat group. The Scotia Bluffs is predominantly massive fine-grained sandstone deposited under shallow marine conditions (Ogle, 1953). This unit is exposed in the Eel River-Van Duzen River area.

Carlotta formation: This formation is the uppermost unit of the Wildcat group, and consists of non-marine conglomerate, sandstone, and claystone. Generally, the sequence fines upwards from poorly sorted conglomerate to fine gray silt and claystone (Ogle, 1953).

Hookton formation: This formation is characterized by yellow-orange gravel, sand, silt, and clay deposits that can range in thickness up to 100 feet. This formation was deposited following a folding of the Wildcat group, which resulted in an unconformable contact. These sediments are commonly exposed throughout the Eel River Valley area, more generally on the south and north sides of the Eel River syncline (Ogle, 1953).

Alluvium: This unit is characterized by thick unconsolidated deposits of silt, sand, and gravel that underlies the Eel River floodplain, located within the Eel River syncline. Deposits can reach up to 200 feet in thickness, and range from coarser grained sand and gravel sediments near the active river channel to finer silt and clay sediments within the floodplain (Ogle, 1953). This unit forms a highly productive aquifer and has the capacity to yield high volumes of ground water for supply.

2.1.2 Hydrostratigraphy

Hydrostratigraphic units can be subdivided into two distinct groups based on their capacity to allow groundwater movement. An aquifer is classically defined as a layer of soil that is permeable enough to permit a usable supply of water to be extracted. Conversely, an aquitard is a layer of soil that inhibits groundwater movement due to its low permeability. Within the Eel River Valley area, groundwater flow is primarily influenced by two key hydrostratigraphic units: the alluvium, and the Carlotta formation. The Hookton formation also conducts groundwater flow, though to a lesser extent.

Alluvial Aquifer: This aquifer is composed of unconsolidated deposits of gravel, sand, silt, and clay, and is the primary source of groundwater in this area. Specific capacities from this unit vary; however can reach up to 600 gpm per foot of drawdown (DWR, 1965).

Hookton Formation Aquifer: The least productive aquifer unit is the Hookton Formation Aquifer, which underlies the alluvium, and is characterized by loosely consolidated clay, silt, sand, and gravel. Specific capacities from this aquifer are generally low, and are commonly less than 30 gpm (Ogle, 1953).

Carlotta Formation Aquifer: The Carlotta formation is characterized by poorly sorted conglomerate and sandstone. Although not as productive as the Alluvium Aquifer, the Carlotta Formation Aquifer has the capacity to yield up to 1,200 gpm in wells west of Ferndale and up to 500 gpm in wells east of Ferndale (DWR, 1965).

The remaining units include the Jurassic and Cretaceous aged consolidated bedrock, and the Pullen, Eel River, Rio Dell, and Scotia Bluffs formations. Though these may contain certain water bearing units (i.e. fracture zones, or sand and gravel beds), they are considered aquitards on the whole (Ogle, 1953). No wells are installed within them.

2.2 Contributing Watersheds

The Eel River Groundwater basin is 73,7000 acres in size and is support by surface water and groundwater flow from 5 major watersheds: Eel River, Van Duzen River, Yager Creek, Salt Creek and Price Creek (**Figure 1**). With the exception of the Eel River upstream of the USGS hydrometric station at Scotia, which was excluded due the large size, the other watersheds are contained within the water budget model. The area of all contributing watersheds used on the model is 308,934 acres.

3. Data Summary and Interpretation

Long-term and recent monthly estimates of hydrologic, hydrogeological, and water budget data were prepared for the Eel River Groundwater basin and contributing watersheds. Compilation of these data provides an understanding of surface flow, groundwater flow, climate, evapotranspiration, and the relationship between groundwater and surface water, particularly in the lower basin.

3.1 Hydrology

Long-term hydrological analysis and streamflow discharge data was obtain from US Geological Survey Water-Supply report issued by the California Department of Water Resources for three waterways within the Lower Eel River Watershed. Stream-gauging station discharge data for Eel River at Scotia, Van Duzen River near Dinsmore, and Yager Creek near Carlotta were used to better understand the flow duration and river discharge within the Eel River watershed. The locations of the Scotia and van Duzen hydrometric stations are shown on **Figure 1**. The drainage area of Lower Eel River basin is approximated 3,113 sq mi, while the tributary basins range from 127 sq mi (Yager Creek) and 214 sq mi (Van Duzen River).

Recent discharge data collected by the USGS between 2007 and 2016 show an average discharge of 5,664 cfs for the Eel River at Scotia (**Table 1**), while the Van Duzen River has an average discharge of 702 cfs (**Table 2**). These recent data will be utilized for the GSP Alternative.

Table 1. Scotia Station Flow Summary

Water Year	Average (cfs)	10th Percentile (cfs)	50th Percentile (cfs)
2007	5,029	62	1,300
2008	3,778	64	1,040
2009	7,140	166	2,830
2010	9,525	133	4,010
2011	4,732	83	626
2012	4,774	61	833
2013	2,223	37	210
2014	4,228	47	725
2015	9,147	49	1,200

Table 2. Van Duzen Station Flow Summary

Water Year	Average (cfs)	10th Percentile (cfs)	50th Percentile (cfs)
2007	600	6	149
2008	570	5.6	125
2009	804	15	444
2010	1,011	10	505
2011	641	8.5	92
2012	576	5.5	85
2013	302	3.1	26
2014	531	3.7	82
2015	1,066	4.6	90

Figures 4 and **5** present the discharge hydrographs for the Eel River at Scotia and the Van Duzen River for the period between 2007 and 2015. The discharge at the Lower Eel River near Scotia and the Van Duzen River vary dramatically throughout the year, with highest discharge values typically seen during December and February and the lowest flows recorded during the summer and fall months.

3.1.1 Baseflow Separation

Baseflow was estimated for the Eel River at Scotia and for the Van Duzen River using the USGS BFLOW model (Neff et al. 2006). The BFLOW model examines changes in surface water level and provides three estimates of baseflow to the river, a low, medium and high estimate. The selection of the final baseflow estimate is left up to the discretion of the model user.

Figures 4 and **5** show the baseflow separation curves plotted on the hydrographs for the time period between 2007 and 2015. The BFLOW model predicted a baseflow of 2106 cfs for the Eel River at Scotia and 247 cfs for the Van Duzen River. These values were further refined by removing peak flow values, particularly during the 2011 water year. Based on this refinement, the baseflow for the Eel River at Scotia between 2007 and 2015 was estimated at approximately 2000 cfs and the baseflow for the Van Duzen River downstream of Bridgeville between 2007 and 2015 was estimated at approximately 200 cfs.

Estimating baseflow is an important step in a water budget analysis, as on a watershed scale, baseflows are analogous to groundwater recharge and are used to calibrate the GIS Model. Assuming limited loss of groundwater to deep aquifer systems, the total volume of groundwater recharge should be equal to the average annual baseflow for a subcatchment. In addition, long-term changes in groundwater level or recharge would have a direct effect on the long-term, relatively steady, addition of baseflow to the river.

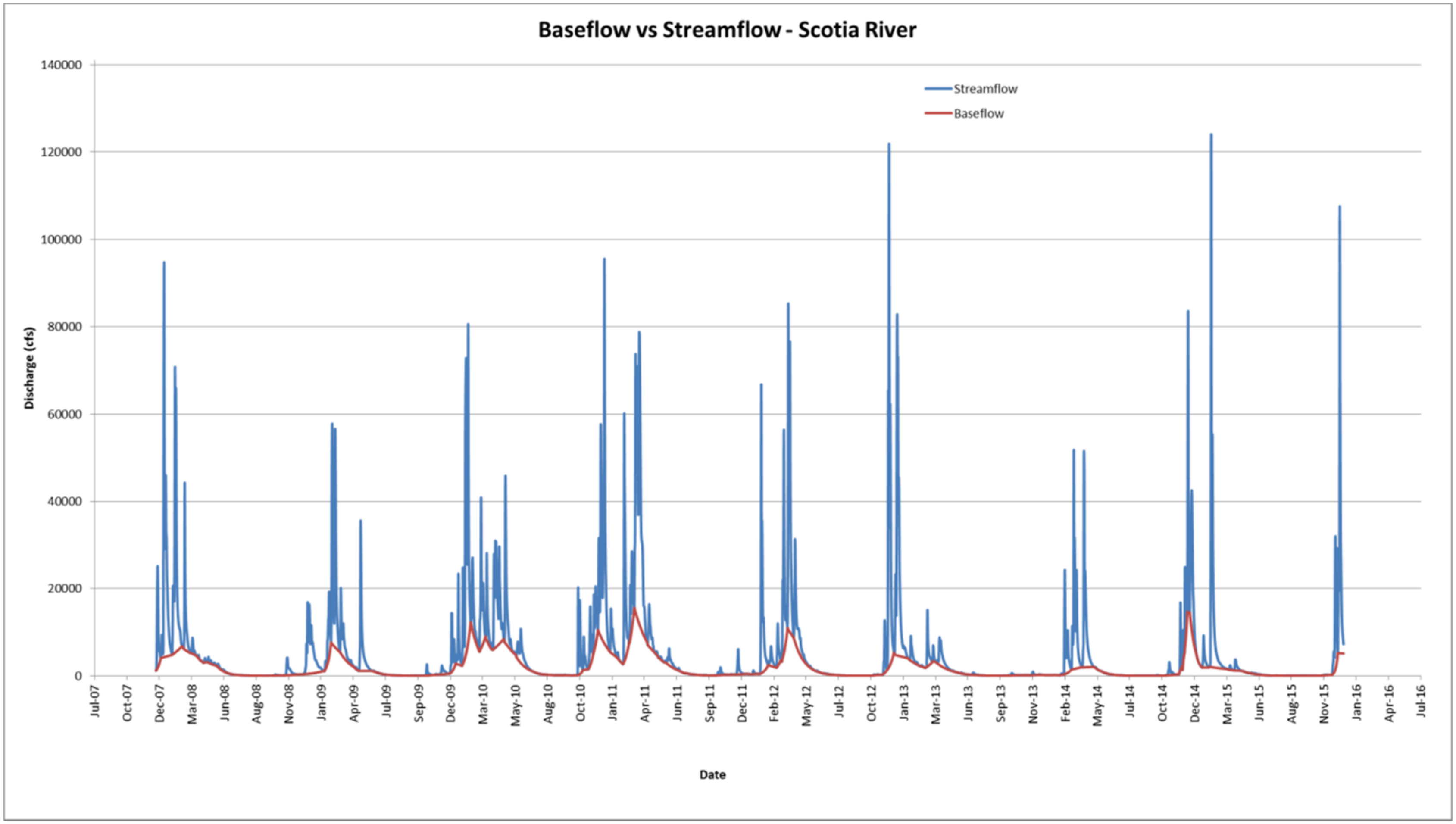


Figure 4. Hydrograph - Eel River at Scotia 2007 - 2015

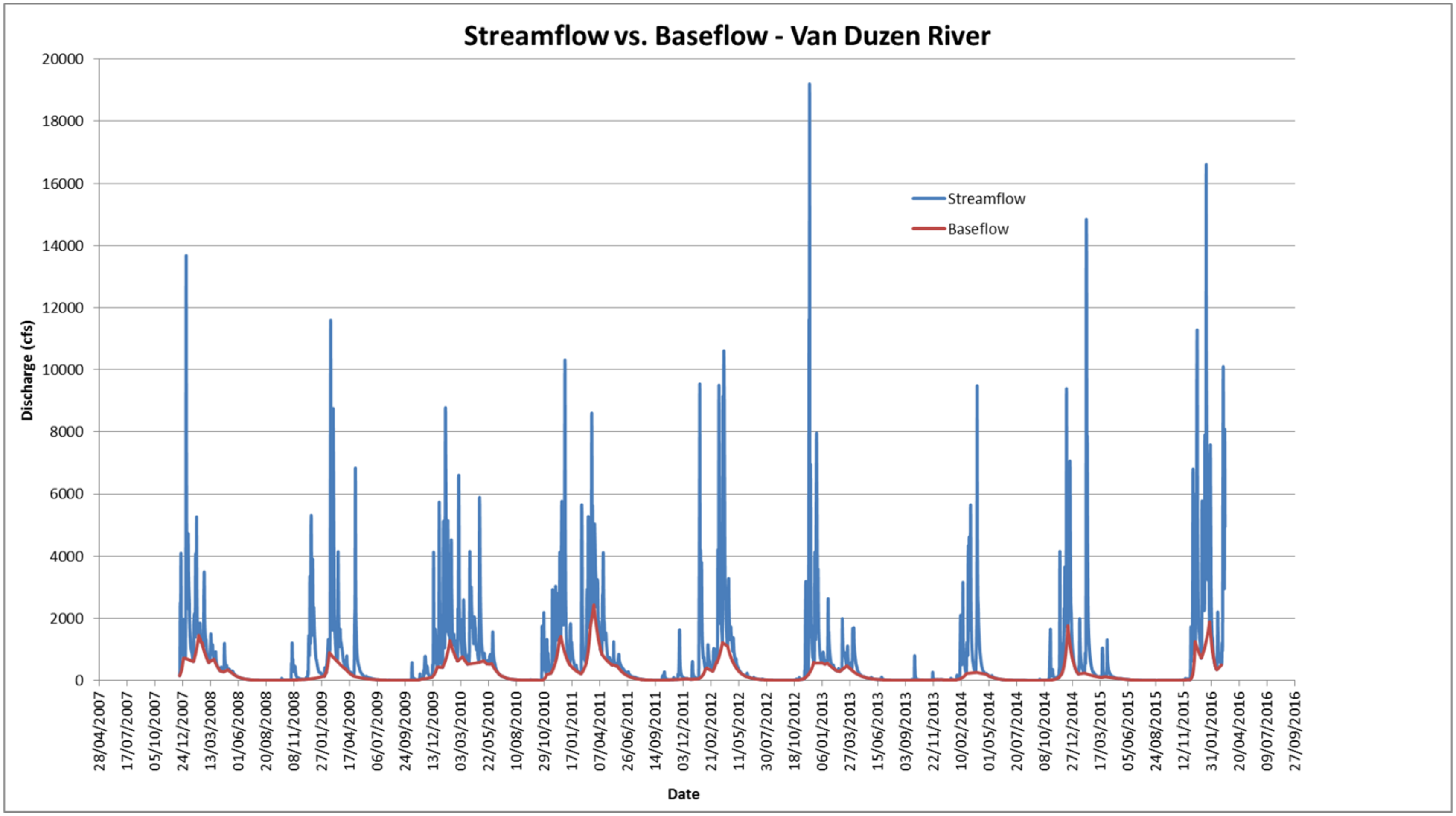


Figure 5. Hydrograph - Van Duzen River at Bridgeville 2007 - 2015

3.2 Climate

The variability in stream discharge rates in the lower Eel River and Van Duzen River are due to the high variability of precipitation throughout the year in Northern California. Monthly precipitation rates are driven by the onset of large storms off the Pacific Coast during the winter months, while summer months are dominated by long periods of little to no precipitation. The precipitation amounts throughout the Eel River Valley Groundwater Basin also vary, with total precipitation increasing further inland and coinciding with an increase in elevation. Four climate stations within the study area are used to better understand how elevation and proximity to the coast affect the total amount of precipitation a region will receive.

The Ferndale Station 043030 represents the lowest elevation (approximately 56 ft) and the closest proximity to the coast. It has a limited dataset from between 1963 and 1973. Scotia station 048045 represents the second lowest elevation (136 ft) and the next closest station to the coast. The Scotia Station has a complete period of record between 1926 and 2016, and will be primarily utilized for water balance calculations for the basin. The Grizzly Creek State (043647) station has an elevation of 413 ft and is further inland with a period of record between 1979 and 2011. The final station, Bridgeville 4 NNW (041080) is at an elevation of 2100 ft and situated on a high ridge north of the Town of Bridgeville with a period of record between 1954 and 2001. A summary the historical precipitation and temperature data are provided in **Tables 3** and **4**. These data are presented graphically on **Figures 6** and **7**.

The months with the lowest precipitation typically occur between June and September for all sites, with the lowest recorded monthly total precipitation recorded at the Scotia station during July (0.08 inches). The highest average monthly total precipitation is recorded at the Bridgeville 4 NNW station in January (11.75 inches). The average total annual precipitation ranges from 47.98 inches at the Scotia station to 67.53 inches at the Bridgeville 4 NNW station.

Table 3. Long-Term Precipitation Summary

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Period of Record
Ferndale	9.5	4.2	4.9	3.3	0.8	0.5	0.1	0.4	0.9	2.1	7.3	7.7	41.7	1963 - 1973
Scotia	7.6	7.2	6.9	3.4	1.9	0.7	0.1	0.1	0.6	2.3	5.1	9.6	45.6	1985 - 2016
Grizzly	8.7	8.5	7.8	4.6	2.4	0.8	0.1	0.4	0.7	3.0	7.1	10.0	54.0	1979 - 2011
Bridgeville	11.8	10.2	9.1	5.1	2.8	0.7	0.1	0.8	1.3	4.3	9.9	11.5	67.5	1954 - 2001

Table 4. Long-Term Temperature Summary

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Period of Record
Ferndale	46.6	48.5	48.7	49.3	52.5	55.8	57.1	58.2	57.3	54.6	51.7	46.7	52.3	1963 - 1973
Scotia	49.1	50.0	51.3	53.2	56.4	59.4	61.9	62.7	61.7	58.4	52.3	48.1	55.4	1985 - 2016
Grizzly	43.4	45.4	47.7	51.0	55.8	59.4	62.7	62.8	59.7	54.2	46.8	42.7	52.6	1979 - 2011
Bridgeville	48	49	49	50	53	56	57	58	57	55	52	49	52.75	N/A

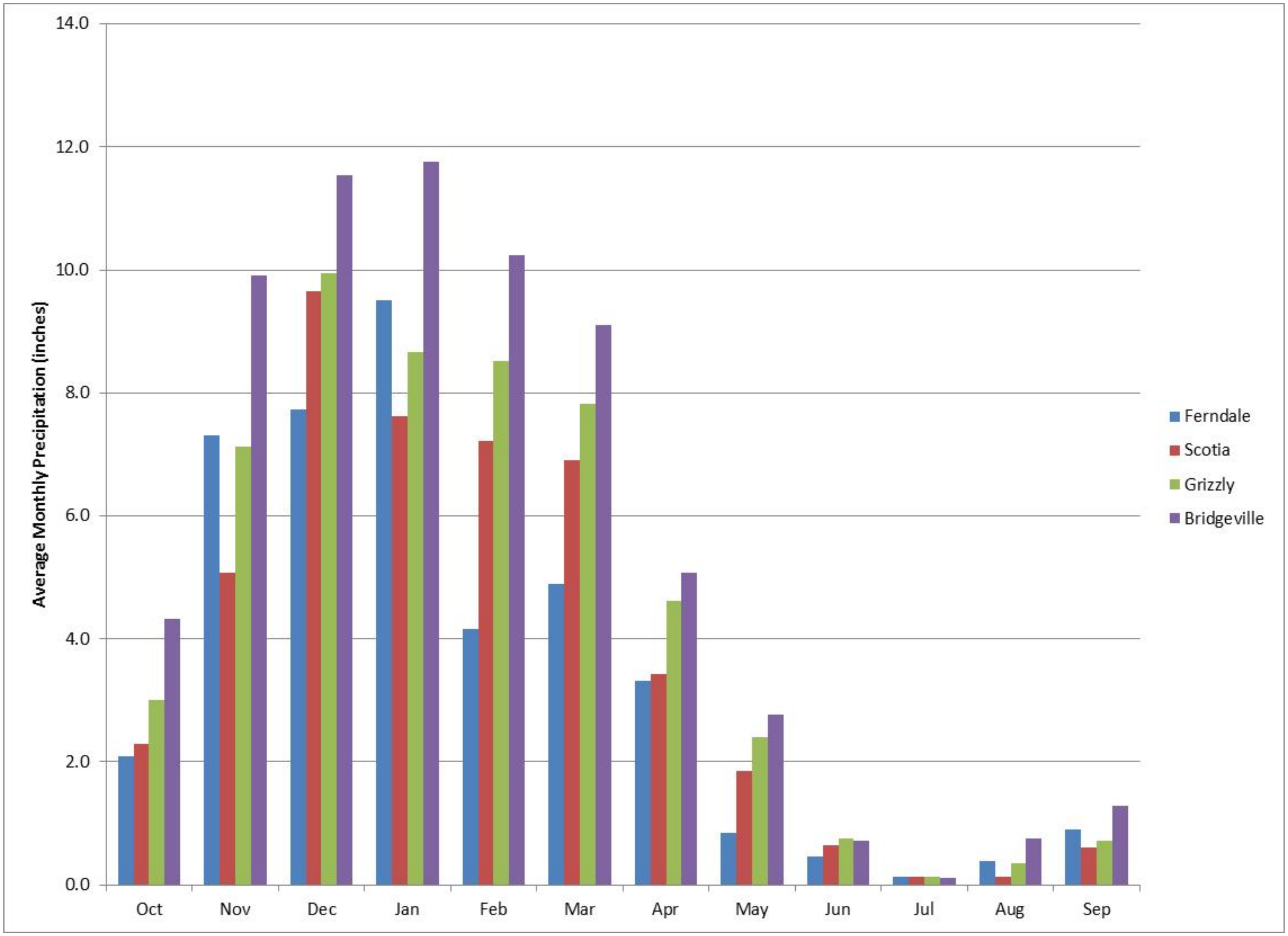


Figure 6. Monthly Precipitation Comparison

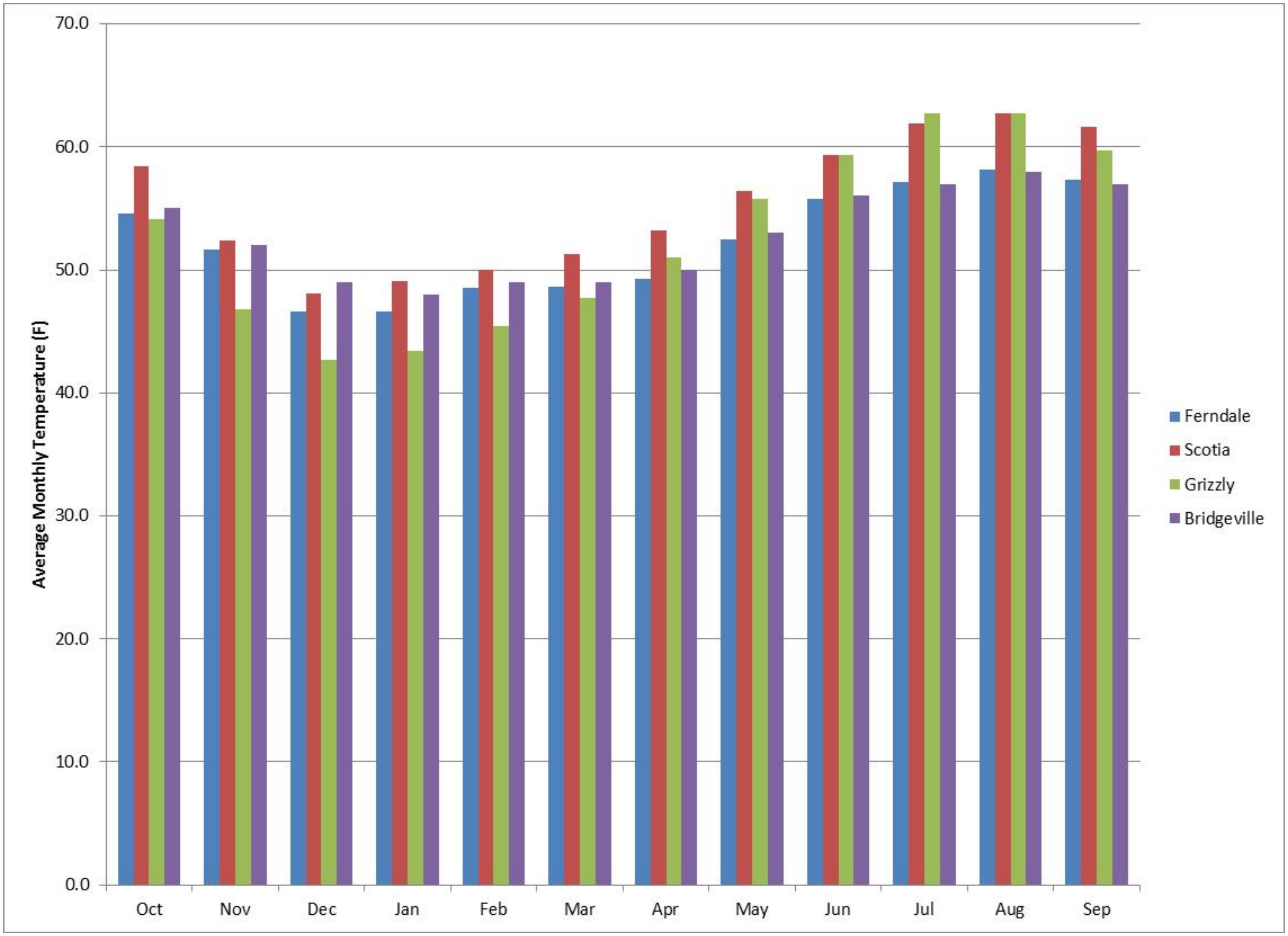


Figure 7. Monthly Temperature Comparison

Monthly precipitation and temperature totals between 1985 and 2015 from the Scotia Station were used to complete the water balance and calculate ET (described in Section 3.4) to meet the GSP Alternative requirements. It is however, important to recognize that the climate varies significantly throughout the study area based largely on elevation and distance from the ocean. The precipitation totals at the Bridgeville Station are approximately 28% higher than at the Scotia Station, while the temperature is only 3% lower.

Figure 8 was obtained from the USGS online archives and shows the large variability in precipitation between the lower and upper portions of the study area. Near the coast, average annual precipitation is approximately 40 inches, but higher in the watershed, particularly in the upper Van Duzen watershed, rainfall amounts can exceed 80 inches.

Unfortunately, the Bridgeville station does not have the required long-term dataset for temperature and precipitation to meet the requirements of the SGMA reporting. In addition, from a water balance and ET perspective, this additional source of water needs to be captured to accurately model recharge and runoff. To account for this, the water budget and model calibration used a correction factor to increase the precipitation within the study as represented by the Scotia Station proportional to the additional volume from the Bridgeville Station.

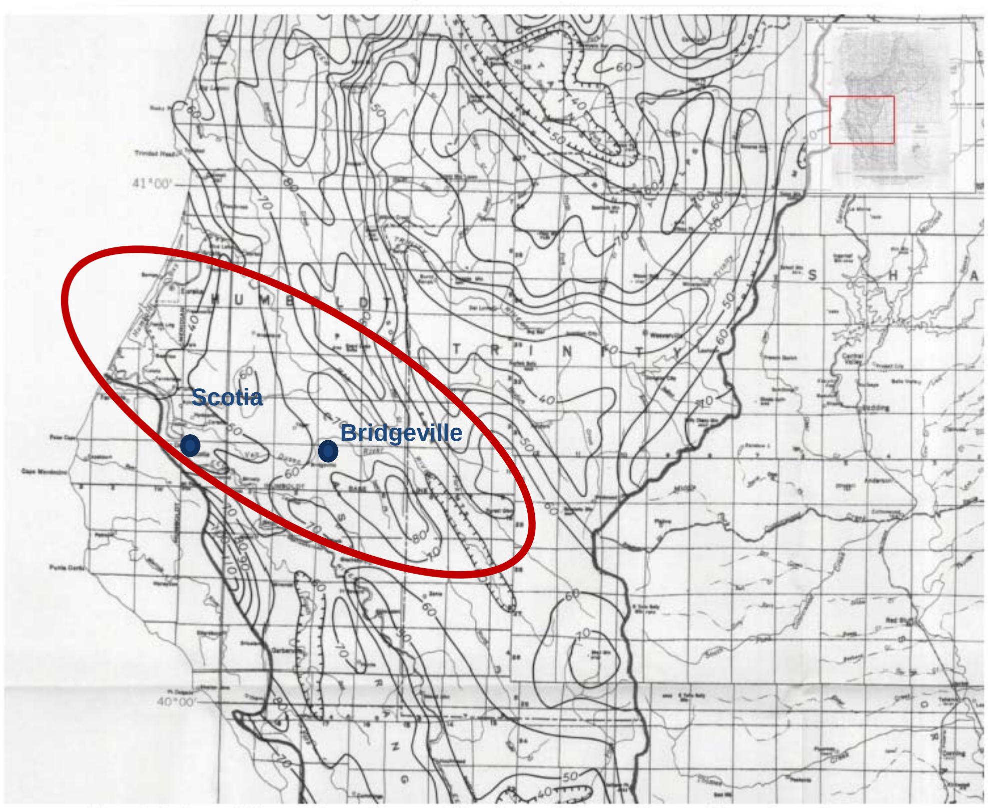


Plate 2: Isohyetal Map of Coastal Basins of Northern California Showing Mean Annual Precipitation for 60-Year Period, 1900-1959
Image provided by U.S. Geological Survey Publications Warehouse

Figure 8. Mean Annual Precipitation (1900-1959)

from USGS National Geologic Map Database (accessed online Dec 2016)

3.3 Evapotranspiration and Surplus

Potential evapotranspiration (PET), or lake evaporation, was calculated using the Thornwaite and Mather (1957) method using the P and T data from between 1985 and 2015 from the Scotia Station as described above. PET was converted to actual evapotranspiration (AET) using soil and land cover, and an estimate for average soil moisture storage within the entire basin. The simplified land cover is presented in **Figure 13**, and was obtained from the USDA Forest Service. Consideration was given to root depth for different types of vegetation/ forest cover and soils types to estimate soil water holding capacity based on Table 10 in Thornthwaite and Mather (1957).

AET is a difficult parameter to measure, even at the site scale. Rosenberry et al. (2007) quantified the uncertainties associated with multiple techniques to calculate PET in New Hampshire, US. Additionally, a comment by Szilagyi (2007) on the Rosenberry et al. (2007) article describes potentially significant differences in the calculated PET when using data from the middle of a small lake compared to using data from the shoreline of a lake only 200 m away. This example highlights the uncertainty associated with extrapolating AET from point measurements to regional estimates, which is the case for calculating AET in the Eel River Valley Groundwater Basin and contributing watersheds. Despite these uncertainties, the Thornthwaite and Mather (1957) techniques produce a reasonable estimate of AET for the study area with the limited available data.

The Surplus (S) is calculated from P – AET. This is the water available, after taking into account evaporation, transpiration, and changes in soil moisture storage, to recharge the groundwater table or support stream flow. This is the key component to the GIS-Based Water Budget completed for this project.

P, AET and S values for the study area were calculated for the following water year scenarios (**Tables 5, 6** and **7**):

- 30-Year Average between 1985 and 2015
- 2010 Wet Water Year
- 2014 Dry Water Year

On average the lower basin receives 45.6 inches of rainfall and has 27.4 inches of PET. This value is consistent with Rantz (1964), which estimated a range of between 20 and 31 inches within the study area. Taking into account changes in soil moisture, an AET was estimated to 14.6 inches leaving 31.0 inches of water as Surplus to support groundwater levels, baseflow and stream flow (**Table 5**). During a wet year in 2010, precipitation was approximately 23% higher resulting in a surplus of water of 38.2 inches (**Table 6**). During a dry year, such as 2014, precipitation was only 18.3 inches (60% less than average), and the resulting surplus was only 8.7 inches (T**able 7**).

Table 5. Monthly Water Balance Scotia Station (Long-Term Average Conditions)

Water Balance (inches)	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Year
Precipitation	2.3	5.1	9.6	7.6	7.2	6.9	3.4	1.9	0.7	0.1	0.1	0.6	45.6
Temperature	58.4	52.3	48.1	49.1	50.0	51.3	53.2	56.4	59.4	61.9	62.7	61.7	55.4
Potential Evapotranspiration (PET)	2.4	1.5	1.0	1.2	1.2	1.7	2.1	2.8	3.3	3.7	3.6	3.0	27.4
P - PET	-0.1	3.6	8.6	6.4	6.0	5.2	1.4	-0.9	-2.6	-3.6	-3.4	-2.4	18.1
Change in Soil Moisture Storage	0.4	0.6	0.4	-0.1	0.0	-0.4	-0.3	-0.5	-0.3	-0.2	0.1	0.3	-1.4
Soil Moisture Storage	3.9	4.6	4.9	4.8	4.8	4.4	4.1	3.6	3.3	3.1	3.2	3.5	-
Actual Evapotranspiration (AET)	1.9	1.5	1.0	1.2	1.2	1.7	2.1	2.4	0.9	0.4	0.1	0.3	14.6
Soil Moisture Deficit (mm)	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.4	2.3	3.4	3.5	2.7	12.9
Surplus (P - AET)	0.4	3.6	8.6	6.4	6.0	5.2	1.4	-0.5	-0.3	-0.2	0.1	0.3	31.0

Table 6. Monthly Water Balance Scotia Station (2010 - Wet Year)

Water Balance (inches)	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Year
Precipitation	4.3	4.6	4.6	16.2	6.2	5.5	8.0	3.2	1.6	0.0	0.2	0.5	54.9
Temperature	58.3	52.2	47.7	52.9	52.9	52.3	52.0	54.0	59.4	60.6	61.7	64.0	55.7
Potential Evapotranspiration (PET)	2.3	1.4	1.0	1.5	1.5	1.8	1.9	2.4	3.2	3.5	3.4	3.3	27.3
P - PET	2.0	3.2	3.6	14.7	4.7	3.7	6.1	0.8	-1.7	-3.5	-3.2	-2.8	27.6
Change in Soil Moisture Storage	0.6	0.7	0.4	-0.5	0.0	-0.2	-0.1	-0.4	-0.5	-0.2	0.0	0.0	0.0
Soil Moisture Storage	3.9	4.6	5.0	4.5	4.5	4.3	4.3	3.9	3.4	3.2	3.3	3.3	-
Actual Evapotranspiration (AET)	2.3	1.4	1.0	1.5	1.5	1.8	1.9	2.4	2.1	0.2	0.1	0.5	16.7
Soil Moisture Deficit (mm)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	3.3	3.3	2.8	10.6
Surplus (P - AET)	2.0	3.2	3.6	14.7	4.7	3.7	6.1	0.8	-0.5	-0.2	0.0	0.0	38.2

Table 7. Monthly Water Balance Scotia Station (2014 - Dry Year)

Water Balance (inches)	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Year
Precipitation	0.0	0.9	0.6	0.9	4.2	7.2	0.9	0.8	0.2	0.1	0.0	2.5	18.3
Temperature	56.1	52.9	45.5	51.1	51.8	54.3	55.2	60.6	60.6	64.0	64.2	64.8	56.8
Potential Evapotranspiration (PET)	2.0	1.4	0.8	1.3	1.3	1.9	2.2	3.3	3.3	3.9	3.7	3.3	28.5
P - PET	-2.0	-0.5	-0.1	-0.4	2.9	5.3	-1.3	-2.5	-3.1	-3.9	-3.7	-0.9	-10.2
Change in Soil Moisture Storage	0.9	0.4	0.6	-0.4	-0.1	-0.5	-0.2	-0.7	0.0	-0.3	0.1	0.2	0.0
Soil Moisture Storage	4.2	4.6	5.2	4.8	4.7	4.2	4.1	3.3	3.3	3.0	3.1	3.3	-
Actual Evapotranspiration (AET)	-0.8	0.4	0.1	1.3	1.3	1.9	1.1	1.6	0.2	0.4	-0.1	2.3	9.6
Soil Moisture Deficit (mm)	2.8	1.0	0.7	0.0	0.0	0.0	1.1	1.7	3.1	3.6	3.8	1.1	18.9
Surplus (P - AET)	0.9	0.4	0.6	-0.4	2.9	5.3	-0.2	-0.7	0.0	-0.3	0.1	0.2	8.7

Precipitation, AET and S are expected to differ between the lower basin and the upper watershed areas of Yager Creek and the Van Duzen River. This is primarily a result of increased precipitation in the upland areas, which was a strong effect on water surplus. Yearly average precipitation and temperature data from Tables 3 and 4 were used to calculate PET, AET and S for the Scotia, Grizzly, and Bridgeville Stations (**Table 8**).

Based on the watershed areas shown on **Figure 1**, it is assumed that the values at Scotia represent the Salt River-Eel River watershed and the Price Creek-Eel River Watershed; the Grizzly Stations represents the Yager Creek and Lower Van Duzen River Watersheds, and Bridgeville represents the Upper Van Duzen Watershed. A weighted average and the percentage (%) greater than Scotia were calculated to demonstrate this difference (**Table 8**) and to apply a correction factor to future climatic datasets.

Table 8. Precipitation, ET and Surplus Comparison

Station	Area (acres)	Precip (in)	ET (in)	Surplus (in)	Weighted Average (in)			% Greater than Scotia		
					Precip	ET	Surplus	Precip	ET	Surplus
Ferndale	-	-	-	-	1,406	381	1,025	122%	103%	130%
Scotia	89,770	45.6	14.6	31.0						
Grizzly	132,613	54.1	14.2	39.9						
Bridgeville	86,551	67.5	16.7	50.8						

3.4 Groundwater Flow

The Eel River Valley Groundwater Basin contains a series of aquifer systems. The lower basin is primarily comprised of an alluvial aquifer containing coarse gravel and sand with minor amounts of silt and clay along the Eel River to its confluence with the Van Duzen River that can be up to 200 ft in thickness (**Figure 2**) (DWR, 2008). The specific capacity of wells screen in the alluvium can be up to 600 gpm/ ft (DWR, 1965). The alluvial deposits are underlain by the permeable Hookton and Carlotta Formations (**Figure 2** and **3**). The Carlotta Formation is described as a poorly sorted cobble conglomerate, with well yields generally bewtween 15 – 20 gpm/ft (DWR, 2008). The Eel River Groundwater basin generally follows the surface extent of the contact between the Carlotta Formation and the Rio Dell Formation.

While the lower basin predominantly contains unconsolidated aquifer materials, the area outside the basin within the watersheds of Yager Creek and the upper Van Duzen River, contains Jurassic and Cretaceous aged consolidated rock of the Yager Formation and the Franciscan Complex (**Figure 2**). These rocks are considered to be aquitards that greatly limit groundwater flow and promote runoff of surface water.

Long-term groundwater level monitoring data from the CASGEM wells (shown on **Figure 1**), show that horizontal groundwater flow within the alluvial aquifer follows topography and flows from east to west under a horizontal hydraulic gradient that ranges from approximately 0.003 ft/ft in the upper basin along the Van Duzen River to 0.0002 ft/ft in the lower basin (**Figure 3**). Downwards groundwater flow into the

Carlotta Formation from the alluvium is expected along the margins of the basin, changing to upwards groundwater flow between the Carlotta and alluvium in the lower portions of the basin. CASGEM wells and well records generally show a neutral or upwards hydraulic gradient between the Carlotta Formation and the alluvium in the lower valley.

No groundwater monitoring wells are installed within the consolidated rock of the Yager or upper Van Duzen watersheds. The transmissivity of these rocks are estimated to be more than 3-orders of magnitude less than the permeable alluvium or Carlotta Formations. Both horizontal and vertical groundwater flow in these rocks formations is considered to be negligible, and groundwater flow will be concentrated in the upper fractured zone and discharge locally to streams and rivers.

Municipal groundwater supply wells are shown on **Figure 1** and generally obtain groundwater supplies from the alluvial aquifer or the Carlotta Formation in the lower basin.

3.4.1 Groundwater Entering and Leaving the Basin

An advantage of considering the entire supporting watershed area of the Eel River Groundwater basin (excluding the Eel River beyond Scotia) is that estimates of groundwater entering the study area can be simplified. If it is assumed that surface water catchment (i.e., watershed) and groundwater catchments are the same, the volume of groundwater entering the study area would be negligible, and assumed to be zero. The exception to this is at the Scotia hydrometric station where groundwater flow from the Eel River enters the basin.

Based on local well logs, it is estimated that the saturated thickness of the alluvial aquifer at Scotia is approximately 45 ft thick, and the valley is approximately 300 ft wide. SHN (2016) estimates a hydraulic conductivity of 160 ft/day for the alluvial aquifer and a local horizontal gradient of 0.02 ft/ft. Based upon these values, it is estimated that about 43,200 ft^3/day or 362 acre-ft/yr of groundwater enter the Eel River Groundwater basin.

Groundwater exits the basin through discharge to watercourses, through deep percolation and through flow into the ocean. The volume of groundwater discharge to watercourses is captured through the stream flow and baseflow analysis, and deep groundwater percolation is expected to be negligible due to the low permeability consolidated rocks underlying the basin below the Plio-Pleistocene formations. Groundwater discharge to the ocean was estimated based on the complete thickness of unconsolidated sediment (i.e., alluvium and Carlotta Formation) of 3000 ft, a width of 6 miles along the salt water/ freshwater interface (SHN, 2016), and a gradient of 0.003 ft/ft. Assuming a hydraulic conductivity of 160 ft/day, the total volume of groundwater leaving the basin through the ocean would be approximately 40,700 acre-ft/yr.

No other significant sources of water entering or leaving the basin were considered for this assessment.

3.5 Groundwater/ Surface Water Interactions

There is a complex relationship between the shallow groundwater system and surface water within the Van Duzen and Lower Eel River. Baseflow monitoring events taken during August and October 2016 (**Table 9**) at locations shown in **Figure 1** confirm that during low-flow conditions, there are both gaining (groundwater discharge) and losing (groundwater recharge) sections within the rivers. Whether reaches of the Eel or Van Duzen are gaining or losing water is going to be dependent on the seasonal changes in the groundwater table, and river stage. As river levels increase, the head pressure can cause hydraulic gradients to weaken or reverse, pushing water into the groundwater systems. During dry periods when surface water levels are low, groundwater under upward pressure within the alluvial deposits and Carlotta formation can result in groundwater discharge to the river systems. Observations from monitoring wells taken during the low flow period within the Eel River during Fall 2016, confirm that the groundwater table was supporting the river levels within the lower basin, and changes in river stage, caused reversals in vertical hydraulic gradients.

Although the data presented in **Figures 9 to 12** below are considered preliminary, with only a limited duration of results, the data generally supports the overall conceptual hydrogeological understanding of the watersheds.

Table 9. Stream Flow Measurement Summary

Station	Flow cfs (August 16, 2016)	Flow cfs (August 23/24, 2016)	Flow cfs (October 4, 2016)
Scotia		56.0	65.8
Scotia Gauge	79.5	61.0	55.0
Eel 1	-	63.0	-
Eel 2	-	53.03	60.9
Eel 3	75.8	57.2	71.2
Eel 4	74.2	50.7	63.6
Fernbridge	81.4	81.4	- *
Van Duzen Gauge	6.9	5.7	6.5
Van Duzen 3	-	6.8	-
Van Duzen 2	-	6.3	6.9
Van Duzen 1	^1.4	^0.6	^

*From gauge data; ^ Van Duzen dry at confluence with the Eel

3.5.1 Van Duzen River

Table 9 shows that up to approximately 6.9 cfs of flow was lost from the Van Duzen River to the shallow groundwater system as recharge, and sub-flow, between the Van Duzen 2 station and the confluence with the Eel River. Sub-flow is a commonly used term in the Eel River basin area and simply refers to lateral groundwater migration within the course grained alluvial deposits (the result of aggradation) at the lower Eel River and the VanDuzen near the Eel River confluence. Results of the monitoring well and river stage monitoring being conducted within the Van Duzen watershed (**Figure 1**) is presented on

Figure 9. The data confirms that hydraulic gradients between the Van Duzen River, and MW9d are upwards when the river level is low (or dry) and returns to a downward hydraulic gradient as water levels rise. The hydraulic gradient between the monitoring wells, both installed within alluvial sediments, is trending to weakly downward as would be expected for this portion of the river. Generally, the hydraulic gradients between the shallow and deep monitoring wells (MW1, MW2, and MW9) is very weak, as a result of the short screen spacing (approximately 15'), and the fact that the alluvial aquifer is vertically hydraulically connected and conductive, with average hydraulic conductivity values measured to be approximately 170 feet/day.

The upstream portions of the VanDuzen (beyond Van Duzen 3) are more likely to be gaining sections from a groundwater perspective throughout the year. Monitoring data now be collected will be used to confirm seasonal groundwater and surface water interactions.

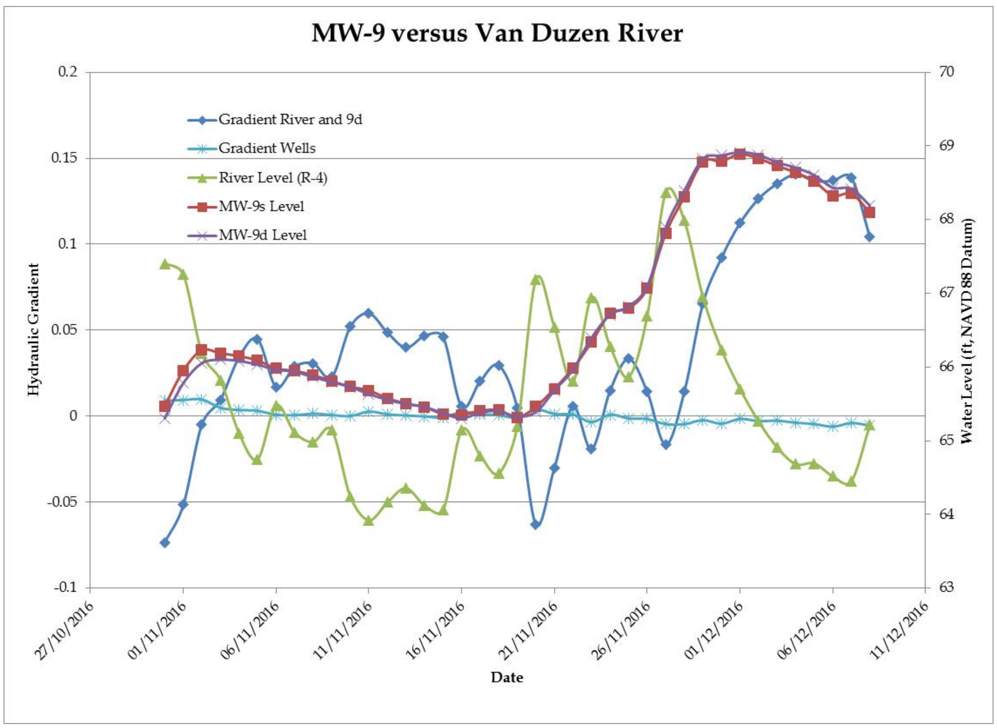


Figure 9. Preliminary Level and hydraulic gradient at MW9 – Van Duzen River

3.5.2 Eel River

The Eel River showed both gaining and losing sections as presented in **Table 9.** Preliminary data shows losing sections between Eel River 1 and 3 and Eel River 3 and 4. The total volumes of water lost or gained within the basin, however, was relatively minor. This is likely due to the fact that the groundwater table is essentially at the river level within the lower basin, resulting is very weak vertical hydraulic gradients either upwards or downwards during the low flow period. **Figures 10 and 11** (MW1 and MW2) show that hydraulic gradients between the river and deep monitoring wells fluctuate largely based on river stage. MW3 (**Figure 12**), showed a downward hydraulic gradient between the river and alluvial aquifer throughout the brief reporting period. It is anticipated that throughout most of the year (wet and average rainfall periods), groundwater will primarily be recharging from the river to the groundwater system between the Scotia Gauge Station and Eel River 4. Monitoring data now being collected will be used to confirm seasonal groundwater and surface water interactions.

3.5.3 Surface Water and Groundwater Flux Estimate

The water balance required a preliminary estimate of the amount of recharge from the Van Duzen and Eel River to the groundwater system. In order to provide a reasonable value with the limited data, the measured groundwater flux taken during August, 2016 (**Table 9**) was replicated using a darcy flux calculation which used i) estimated vertical hydraulic gradients from MW1, MW2, and MW9, ii) measured hydraulic conductivity values of the alluvial aquifer from the monitoring well slug tests (with a correction factor for the potential presence of river bed silts, and fine sands), and iii) the area of the river bed available during the low flow period for recharge. Once the calculated flux values matched observed, the hydraulic gradients and total area available for recharge was approximately doubled to replicate average annual conditions with the rivers. It should be noted that vertical hydraulic gradients were assumed to be higher in upstream portions of the Eel and Van Duzen river based simply on topography and estimated deeper water table.

The resulting value was an approximate groundwater recharge value of approximately 69,000 acre-feet/year of water. While preliminary, this value is generally consistent with what is expected based on the water balance results and fits the limited observed data. This value should be revisited after the surface water and groundwater monitoring program is completed in Late 2017.

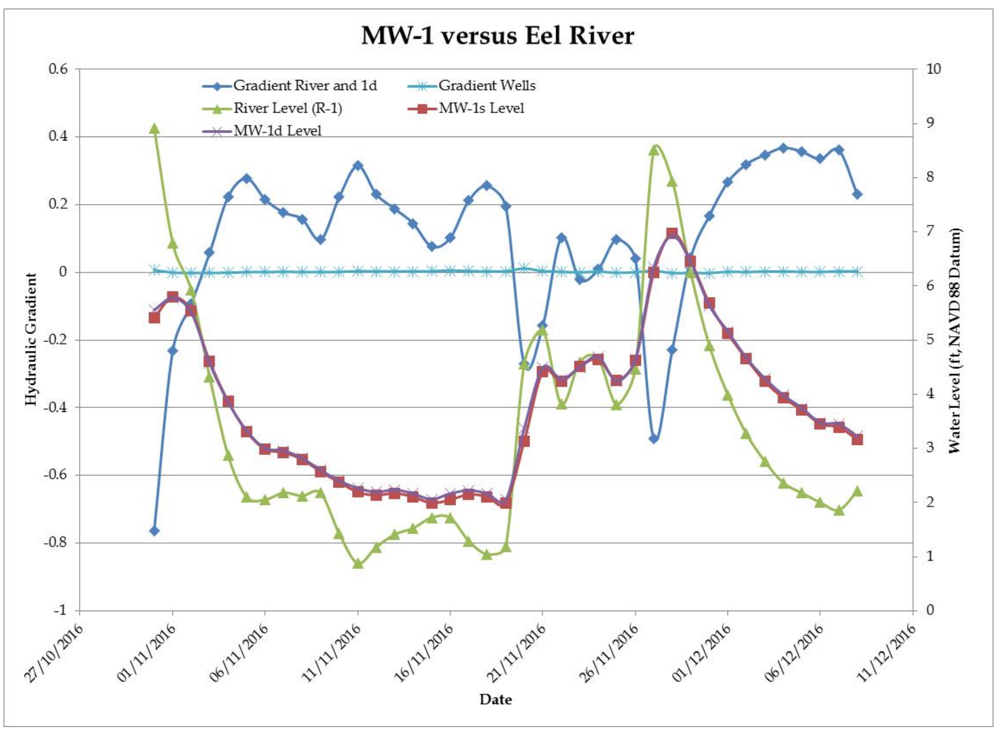


Figure 10. Preliminary Level and hydraulic gradient at MW1 – Eel River

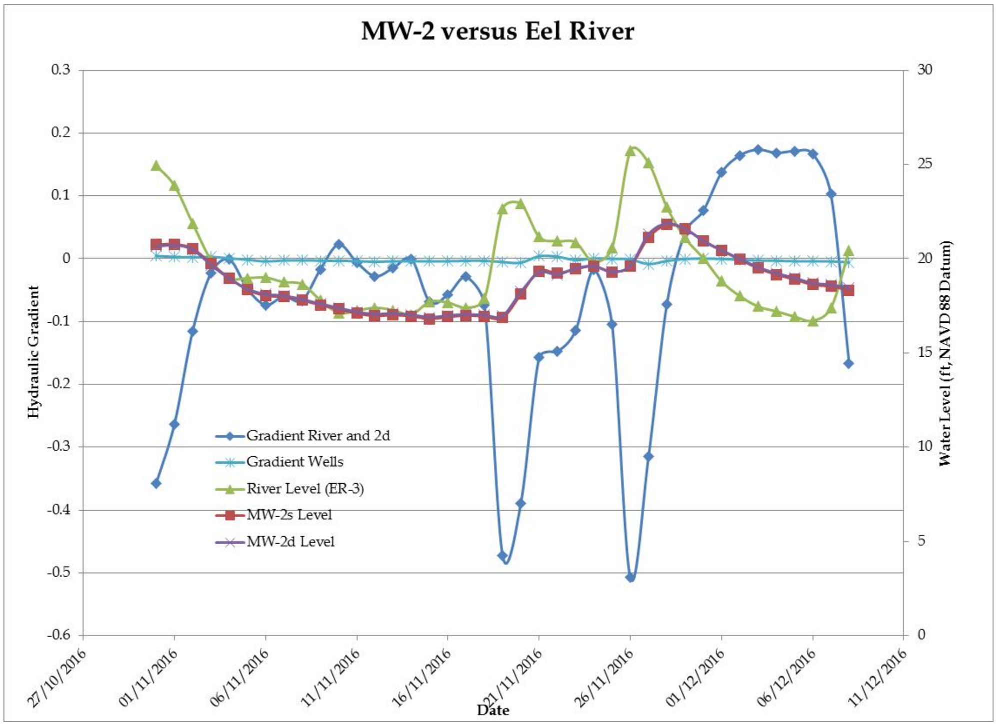


Figure 11. Preliminary Level and hydraulic gradient at MW2 – Eel River

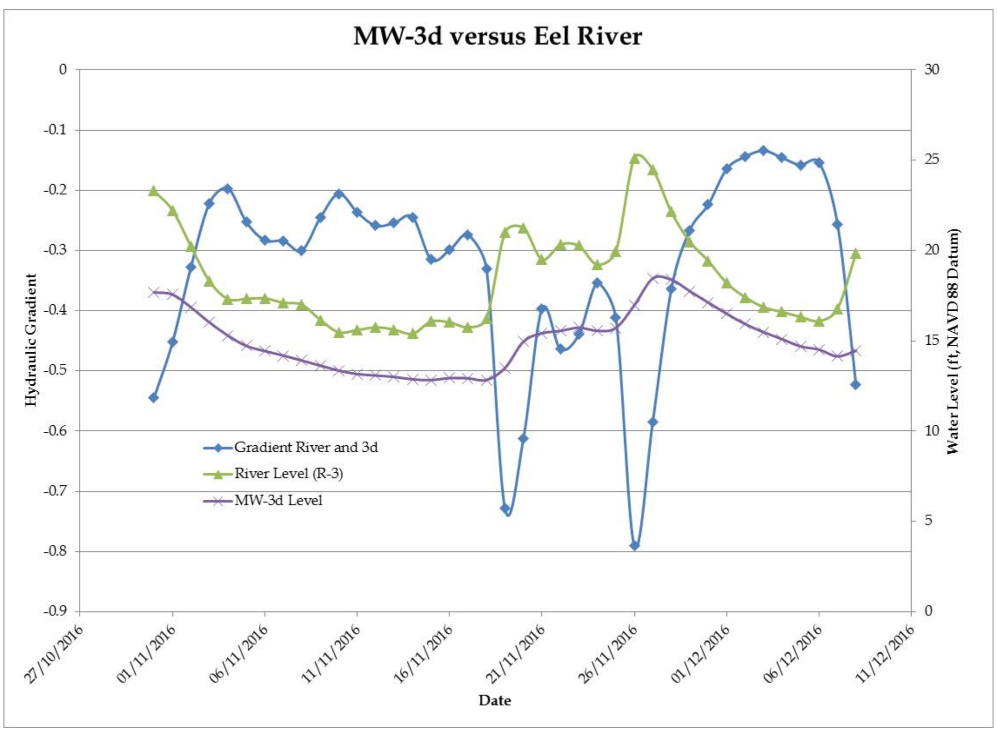


Figure 12. Preliminary Level and hydraulic gradient at MW3 – Eel River

4. Water Budget

4.1 Water Budget Methodology

The intent of the following water budget method is to outline a method to quickly and simply estimate groundwater recharge over a large area with limited available data. There are many other methods for estimating groundwater recharge at a regional scale, however, these methods have complex data requirements, and the data required for these methods is not often available at a regional scale. For example the Water Table Fluctuation Method used by Healy and Cook (2002) requires knowledge of the specific yield and temporal changes in water table level. This data is limited in the Eel River Groundwater basin and supporting watersheds due to the few number of wells that are completed through the unconfined aquifer, and the absence of long-term water table level monitoring data.

Water balance calculations for the study area used a modified version of the Thornthwaite and Mather monthly soil-moisture balance approach (Thornthwaite, 1948, Thornthwaite and Mather, 1955, and Thornthwaite and Mather, 1957) and a GIS-Based analytical platform. This approach relies upon an understanding of the hydrogeological and hydrological setting, and utilizes commonly available tabular datasets for (1) precipitation and temperature, (2) land-use classification, (3) surficial geology, (4) topography/ slope, and (5) soil-water holding capacity.

There are many examples of groundwater recharge estimates utilizing a GIS-based, soil water balance methodology. The US Environmental Protection Agency (US EPA) developed the HELP model based on a soil-moisture balance code and can be imported into GIS software. Batelaan and de Smedt (2001) developed WetSpass, which is a simple, GIS-based model for estimating recharge on a regional scale. Westenbroek and others (2010) developed a GIS-Based soil water balance code for the USGS, based on a modified version of Thornthwaite and Mather (1957), similar to the methodology utilized for this study.

The water budget model provides long-term (average) estimates of water balance parameters (precipitation (P), potential evapotranspiration (PET), actual evapotranspiration (AET), groundwater recharge (R) and surface water runoff (RO)) summarized on an annual basis for the Eel River Valley Groundwater Basin and the major contributing watersheds (Yager River, Salt River, and Van Duzen River). As well, it provides a general understanding of climate, surface water, and groundwater interactions and how water moves throughout the basin. The water balance estimates from the Conceptual Water Balance only apply on an average-annual regional scale. Average annual regional values do not apply to individual years or to individual subwatersheds. Actual values will vary temporally and spatially across the Region.

The water budget is designed to identify any groundwater basins with that may have water quantity stresses, and quickly and efficiently screen out unstressed basins using existing information and a targeted field program.

The Water Balance can be divided into four steps.

1. Define the watershed boundary for all contributing surface water and groundwater inputs to the study area;
2. Estimate the water balance components for the study area (i.e., P, PET, AET, R and RO);
3. Determine the percent (%) water demand for the study area taking into account irrigation, municipal and domestic water supply and water diversions; and,
4. Define a basin stress level based on percent % water demand relative to a sustainable volume of available groundwater and surface water.

The first task is to characterize the conceptual hydrogeological and hydrological model for the study area. This is described in detail in SHN (2016).

The second task is to estimate the water budget components for the study area based on water year type. This includes all sources of water entering the basin and watershed area, and all water exiting. Because the water budget model takes into account the entire watershed area for Yager Creek, the Van Duzen River, Salt Creek, Price Creek and associated tributaries, it can be assumed that no surface water or groundwater is entering the study area, except at the Scotia USGS hydrometric station along the Eel River. Characterizing the study area based on watershed greatly reduced uncertainty in the water budget analysis. Changes in groundwater storage were estimated between seasonal high and seasonal low conditions, based on wells with sufficient long-term datasets.

The third task is the estimate the total groundwater and surface water demand in the study area for water year type. These data include water used for irrigation, municipal, industrial and domestic supplies, as well as any water transferred out of the basin. These data were provided to PECG by Humboldt County Public Works Department (2016). Estimates on population growth and future agricultural demand were made to assess future water taking requirements, and future sustainability.

The fourth task is to compare water demand against the available water from the water budget analysis and groundwater storage calculations to determine a sustainable yield. Criteria determining sustainability will be based on the available groundwater level data from the CASGAM wells, stream baseflow analysis, long-term average groundwater recharge, and an assessment of current and future water use demand.

Following the principal of conservation of mass, inputs must balance with changes in storage and outputs over a period of time. The water budget for a controlled area (i.e., a watershed) can be expressed as the following mathematical expression:

$$P + SW_{in} + GW_{in} + \ + ANTH_{in} + DIV_{in} = \ AET + SW_{out} + GW_{out} + \ \Delta S_{SW} + \ \Delta S_{GW} + ANTH_{out} + DIV_{out}$$

Where

P = precipitation
SW_{in} = surface water flow into the basin
GW_{in} = groundwater flow into the basin
$ANTH_{in}$ = anthropogenic flow into the basin (e.g., cross watershed wastewater discharges)
DIV_{in} = diversions of water into the basin (e.g., trans-watershed boundary wastewater discharges)

AET = actual evatotranspiration (evaporation + transpiration) within the basin
SW_{out} = surface water flow out of the basin
GW_{out} = groundwater flow out of the basin
ΔS_{sw} = Change in surface water storage within the basin
ΔS_{gw} = Change in groundwater storage within the basin

$ANTH_{out}$ = anthropogenic flow out of the basin (e.g., cross watershed wastewater discharges)
DIV_{out} = diversions of water out of the basin (e.g., trans-watershed boundary wastewater discharges)

Based on the conditions of the Eel River Valley Groundwater Basin, the water balance equation can be reduced to:

$$P + SW_{in} + GW_{in} = AET + SW_{out} + GW_{out} + \Delta S_{SW} + \Delta S_{GW}$$

following these simplifications:

- All watersheds considered in the water budget are treated as headwater watersheds (e.g. extend to the headwaters) resulting in no stream flow coming into the watershed at the boundary therefore SW_{in} is reduced to zero.
- The groundwater flux into and out of the control volume is considered to be negligible. The volume of groundwater flowing into the control volume at the up-gradient boundary is assumed to equal the volume of groundwater flowing out of the control volume at the down-gradient boundary. Therefore, with the exception of the area near Scotia Station, the net groundwater flux or GW_{net} (GW_{out} minus GW_{in}) for the purpose of this water budget is reduced to zero. Detailed groundwater models would be needed to more accurately define groundwater movement.
- The water budget addresses movement of water into and out of the watershed. Therefore, other fluxes of water that occur in each subwatershed (e.g. storage, canopy interception, overland flow) are considered negligible.
- Most anthropogenic fluxes are internal fluxes and are not reported in this section.
- There are no known major diversions in the Eel River Valley Groundwater Basin or contributing watersheds so this term can be ignored.

Using a GIS Based model based on long-term climate averages, SW_{out} minus SW_{in} components can be represented by the total surface water runoff (RO) within the basin, and GW_{out} minus GW_{in} components can be represented by the total recharge (R) within the basin. Based upon this simplification, the water balance equation can be re-written as follows:

$$P = AET + RO + R$$

4.1.1 Limitations

The water budget for the basin and contributing watersheds is limited by the available data, particularly in the upper basin, and in areas of the Yager Creek and upper Van Duzen watersheds. Limited recent and long-term data sets for groundwater levels, surface water flow, precipitation, temperature, and water use were available for these areas. In addition, the lower Eel River valley is a highly complex system that is influenced by shallow and deep groundwater flow systems, gaining and losing watercourses, large differences in precipitation and temperature between upland and lowland areas, and ocean tides. Long-term flow data for water leaving the Eel River Basin would help support the water budget assessment. Additional groundwater levels and surface water levels would help quantify the relationship between surface water and groundwater in the lower basin, and calculate the recharge volumes.

4.2 Partitioning Between Groundwater Recharge and Surface Water Runoff

The average annual water Surplus was partitioned into recharge (R) and Runoff (RO) using infiltration factors developed by MOEE (1995) for use in land development applications. This method utilizes an infiltration factor, which takes into consideration three factors (topography/slope, soil type, and land cover) that influence the ability of precipitation to infiltrate in to the ground. This methodology is similar to the use of the runoff coefficient (e.g., USDA NRCS curves using calculate runoff volumes), as the infiltration factor is multiplied by the available water Surplus to estimate the amount of groundwater recharge (R) and runoff (RO) available for a given study area. This method is best suited to the total annual available depth of water rather than storm based events, and needs to be calibrated with long-term hydrometric data (i.e., the Van Duzen Station at Bridgeville).

4.2.1 Infiltration Factors

The partitioning of the water surplus between runoff and infiltration depends on soil type, topography and vegetation cover. Water will infiltrate more easily through sands compared to clays, on flat slopes compared to steep slopes, and through naturally vegetated soils compared to agricultural crops or urban areas. The method developed by Bernard (1935), Gray (1970), and described by the MOEE (1995) was used to determine the infiltration factors within the Eel River Valley Groundwater Basin and contributing watersheds. The infiltration factors where tailored based on an interpretation of the relative ability of each geological unit and vegetation community in the study area to store water and accept recharge. The original infiltration factors from MOECC (1995) are provided in **Table 10** for reference.

The infiltration factor is calculated by summing the individual sub-factors at the site. The water surplus is then multiplied by the infiltration factor to determine the partitioning between the amount of runoff and the amount of infiltration that occurs annually. By way of example, an infiltration factor of 0.4 means that 40% of the water surplus will infiltrate the ground while the remaining 60% will become runoff (i.e., 1 – R = RO).

Table 10. Infiltration Factors from MOEE (1995)

Description of Area/Development Site	Value of Infiltration Factor
TOPOGRAPHY	
• Flat and average slope not exceeding 0.01%	0.30
• Rolling land, average slope of 0.4%	0.20

• Hilly land, average slope of 5%	0.10
SOIL/ ROCK	
• Tight impervious clay	0.10
• Medium combinations of clay and loam	0.20
• Open sandy loam	0.40
COVER	
• Cultivated lands and pasture lands	0.10
• Woodlands	0.20

Note: Modified from MOEE (1995), Technical Guidelines for the Preparation of Hydrogeological Studies for Land Development Applications

Infiltration factors were developed for the Eel River Valley Groundwater Basin and the full extent of the contributing watersheds as shown on **Figure 1**. The soil/ geology sub-factors are based on the geological map of the study area (**Figure 2**), hydrogeological data collected by SHN (2016), by field visits conducted by the study authors and professional experience. The following soil/ geology factors were used for the Eel River Water Balance:

- Franciscan Complex 0.05
- Rio Dell Formation 0.15
- Quaternary Landslide Deposit 0.3
- Shoreline and Aeolian Deposit 0.4
- Fluvial Terrace 0.3
- Carlotta Formation 0.35
- Quaternary Alluvium 0.4
- Yager Formation 0.1

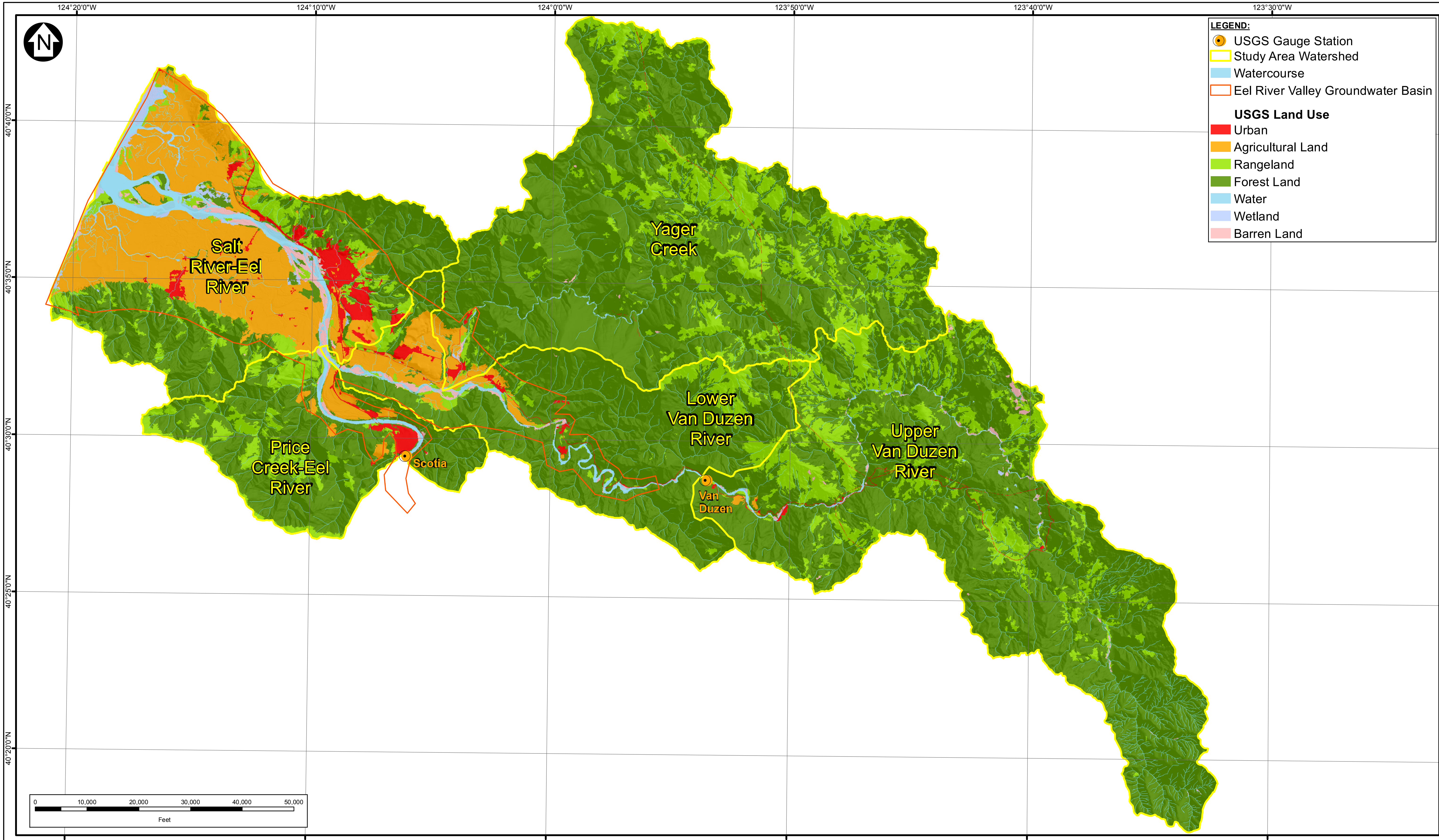
Infiltration factors for the land-use cover in the study area (**Figure 13**) were estimated to be:

- Urban 0.025
- Agricultural Land 0.1
- Range Land 0.15
- Forest Land 0.2
- Water 0
- Wetland 0.25

Slope/ topography factors were determine from a 15 x 15 ft DEM for the study area (**Figure 14**) and the values are based on the MOEE (1995) table, which are related based on the following equation:

$$y = -0.0479\text{Ln}(x) + 0.1585$$

Within the lower Eel River basin the surficial soils consist mainly of permeable alluvial sands and gravels, which has been assigned a geology sub-factor of 0.4. Therefore, for an area with a flat slope (0.2 sub-factor) and agricultural land use (0.1 sub-factor), it would be expected that 70% of the precipitation would



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NOTES:

1. Source: Simplified from CALVEG, [ESRI personal geodatabase]. (2004). McClellan, CA: USDA-Forest Service, Pacific Southwest Region. EvegTile03B_99_04_v2. [2009]. Hydrographic data from USGS NHD (https://nhd.usgs.gov/data.html)
2. Scale: 1:210 000 at original page size of 11" by 17"
3. PROJECTION: NAD 1983 UTM Zone 10N
4. COORDINATE GRID: Degrees

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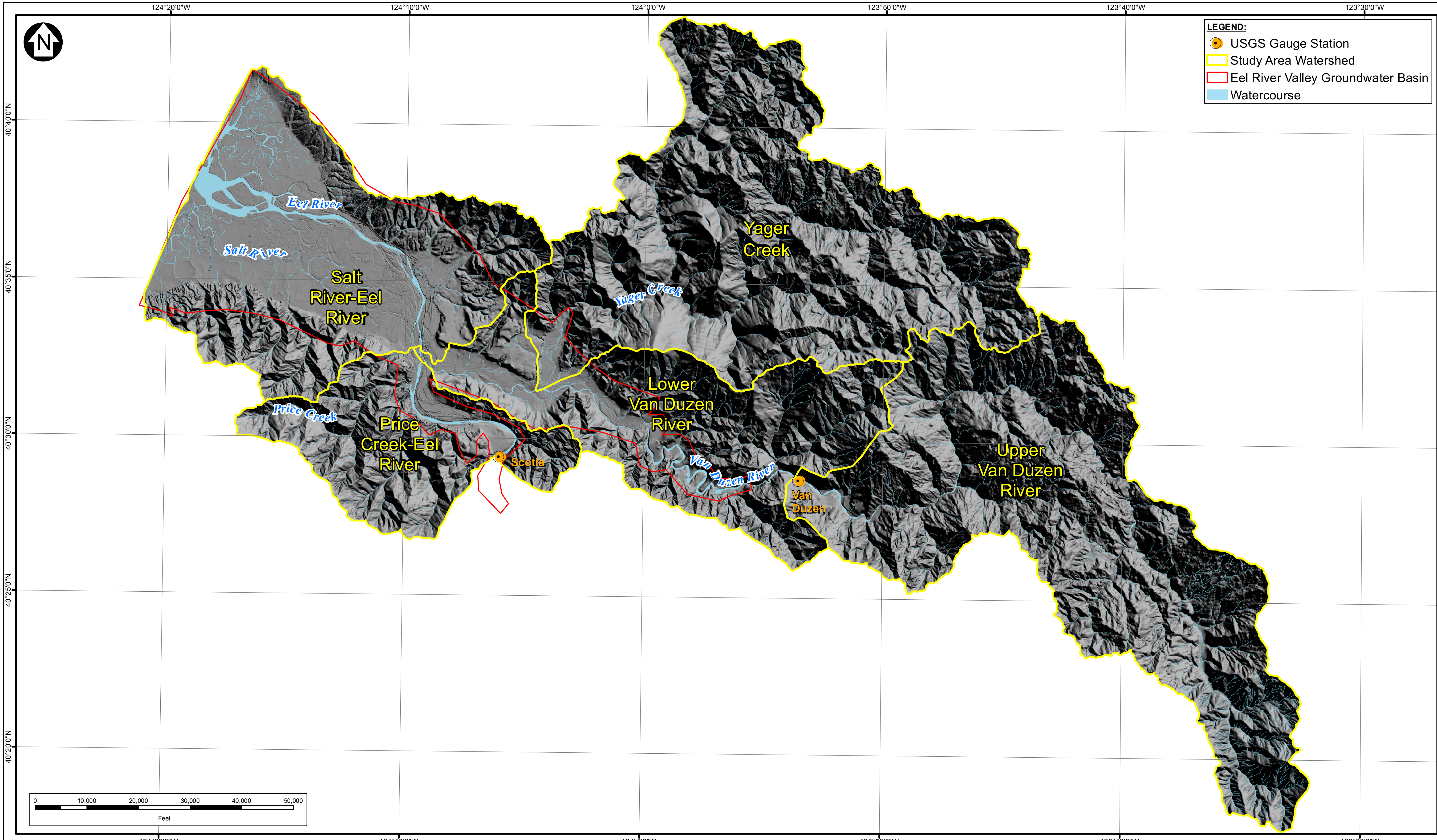
Figure 13
Eel River Water Budget
USGS Landuse



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NOTES:
1. Source: Elevation data from National elevation dataset (10 m: catalog.data.gov/dataset/national-elevation-data), and NOAA (1 m - Eel River Valley: https://coast.noaa.gov/dataviewer/#/lidar)
2. Scale: 1:210 000 at original page size of 11" by 17"
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Figure 14
Eel River Water Budget
Topography

infiltrate and 30% would become runoff. Conversely, the areas of consolidated bedrock of the in the upper Van Duzen Watershed has geology sub-factor of 0.05, steep slopes exceeding 5% (0.05) and vegetation cover of forest lands (0.2 sub-factor), which gives an infiltration factor of 0.3. Therefore, we would expect that 30% of the water would infiltrate and 70% would runoff.

4.3 Water Budget Model Results

Using a GIS-Based model with 15 ft x 15 ft cells across the entire study area, the infiltration factors for soils/ geology, vegetation/ land cover and slope/ topography were overlain to determine the combined infiltration coefficient by summing each factor as follows:

$$Infiltration\ Coefficient = \sum Infiltration\ factors\ (slope, land\ cover, soils)$$

To determine the groundwater recharge volume, the Infiltration Coefficient was multiplied by the water Surplus from the Scotia Station (from **Table 5**) as follows:

$$(P - AET)\ x \sum Infiltration\ factors\ (slope, land\ cover, soils) = Groundwater\ Recharge\ Volume$$

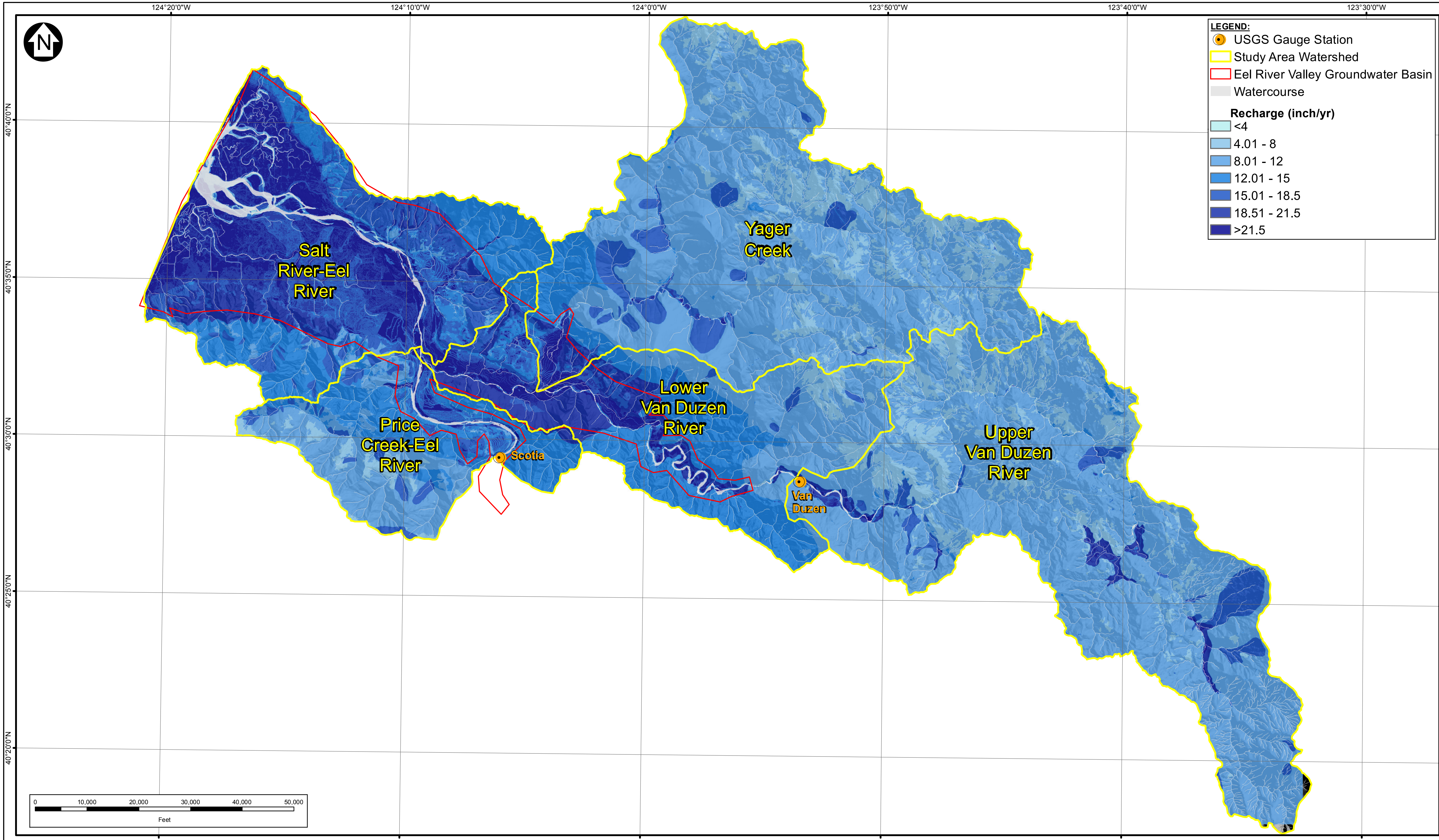
Based on an average Surplus, the results of the water budget calculations and modelling are presented on **Figures 15** and **16,** and represent the potential groundwater recharge and potential surface runoff for the entire study area. The purpose of these maps is to highlight areas where there is a greater potential for groundwater recharge, which should correspond to more productive hydrostratigraphic units. The opposite is true for surface runoff. Areas where there is a greater potential for surface runoff should correspond to poorly developed groundwater resource areas and higher peak flows in streams.

The total estimated potential annual recharge and runoff for the Eel River Valley Groundwater Basin is 316,602 acre-ft/yr and 482,087 acre-ft/yr, respectively. This means that on average, recharge accounts for approximately 40% of the total water balance for the study area, with surface runoff accounting for the remaining 60%. It is important to highlight that the spatial distribution of recharge and runoff vary greatly between the lower Eel River valley area and the upper contributing watershed areas.

The following section provides a brief discussion on the results of the potential recharge and runoff modelling.

4.3.1 Groundwater Recharge

The permeability (i.e., the ability of soils to convey groundwater flow) of surficial geological formations is the most important factor influencing groundwater recharge rates. Although groundwater recharge will occur everywhere within a basin, from a practical point of view, only higher permeability soils can transmit enough recharge to support a significant water taking such as a municipal or agricultural supply. The potential recharge in the study area generally falls between 4 21.5 inches/yr and <21.5 inches/yr (**Figure 15**). The area covered by the Eel River Valley Groundwater Basin have the highest recharge values, typically



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NOTES:
1. Hydrographic data from USGS NHD (https://nhd.usgs.gov/data.html)
2. Scale: 1:210 000 at original page size of 11" by 17"
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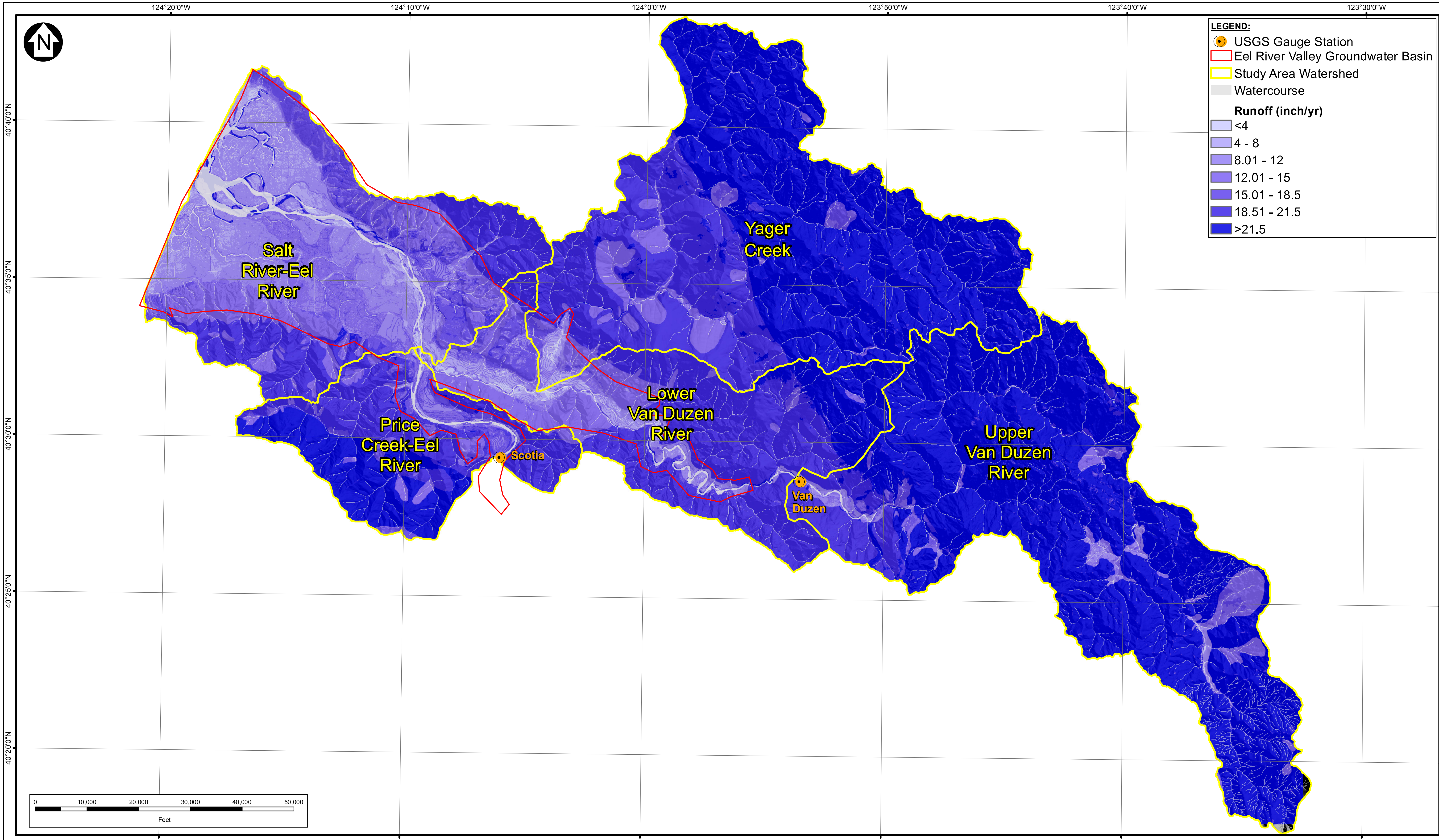
Total Eel River Estimated Recharge: 316 602 acre-ft/yr

Figure 15
Eel River Water Budget
Estimated Recharge



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Total Eel River Estimated Runoff: 482 087 acre-ft/yr

Figure 16
Eel River Water Budget
Estimated Runoff

greater than 18.5 inches/yr, while the upper Yager Creek and Van Duzen River watersheds have the lowest, typically between 4 inches/yr and 8 inches/yr. These values are reflective of areas covered by thick sequences of alluvium and the permeable Carlotta Formation, compared to the consolidated rocks of the Yager Formation and Franciscan Complex (**Figure 2**).

Table 11 presents the estimated recharge and mean infiltration coefficient for each watershed area that contributes to the Eel River Valley Groundwater Basin. The area covered by the Salt River-Eel River watershed has the highest infiltration coefficient and estimated recharge at 90,458 acre-ft/yr. This is the primary area utilized for agricultural and municipal takings. While it is estimated that only 32 to 33 % of the Surplus infiltrates in the upper Van Duzen and Yager Creek watersheds, the overall volume of water is similar to the lower Eel River valley. This highlights the importance of the capturing this source of water in the water budget study, particularly as it was shown in Section 3.5 that the Van Duzen River and the lower Eel River lose an estimated 68,864 acre-ft/yr to the groundwater table.

Table 11. Estimated Recharge by Watershed

Watershed	Area (acres)	Mean Infiltration Coefficient	Standard Deviation	Surplus (in/yr)	Recharge (acre-ft/yr)
Salt River-Eel River	61,988	0.56	0.14	31.0	90,458
Upper Van Duzen River	86,551	0.32	0.08	31.0	70,900
Yager Creek	87,675	0.33	0.09	31.0	75,720
Lower Van Duzen River	44,938	0.44	0.14	31.0	51,691
Price Creek-Eel River	27,783	0.39	0.10	31.0	27,833
Total	308,934	-	-	-	316,602

4.3.2 Surface Runoff

When rainfall encounters a saturated or low permeability surficial soil, rather than infiltrating into the ground, the majority of the precipitation runs off via overland flow into the surface water system. Part of this runoff water is responsible for causing peak flows and flood conditions in surface water bodies. In the study area, peak flows are especially pronounced during the late fall and winter months.

Like with groundwater recharge, some soil types are more conducive to surface runoff than others. Consolidated bedrock surfaces were shown to allow less than 8 inches/yr of infiltration, resulting in high runoff rates that can exceed 21.5 inches/yr (**Figure 16**). Upland areas where alluvium is absent and steep slopes exist have the highest rates of runoff in the study area. This area includes the upper Van Duzen River and Yager Creek, but also includes the headwater areas of Salt Creek, Price Creek, and areas of the lower Van Duzen River.

Table 12 presents the estimated runoff and mean runoff coefficient (1 – infiltration coefficient) for each watershed area that contributes to the Eel River Valley Groundwater Basin. The area covered by the Salt River-Eel River watershed has the lowest runoff coefficient and estimated runoff at 69,799 acre-ft/yr. Given the limited drainage channels in the lower basin, this result would seem appropriate. A significant volume of water runs off and becomes stream flow in the upper Van Duzen and Yager Creek watersheds. Given the relatively small drainage area of the upper Van Duzen, the hydrograph shown in **Figure 5** would support this conclusion, and suggests that more water may be available (i.e., precipitation has been underestimated by the Scotia Station as discussed in Section 3.2).

Table 12. Estimated Runoff by Watershed

Watershed	Area (acres)	Mean Runoff Coefficient	Standard Deviation	Surplus (in/yr)	Runoff (acre-ft/yr)
Salt River-Eel River	61,988	0.44	0.14	31.0	69,799
Upper Van Duzen River	86,551	0.68	0.08	31.0	152,860
Yager Creek	87,675	0.67	0.09	31.0	150,946
Lower Van Duzen River	44,938	0.56	0.14	31.0	64,488
Price Creek-Eel River	27,783	0.61	0.10	31.0	43,993
Total	308,934				482,087

4.3.2.1 Calibration to Baseflow and Average Flow – Upper Van Duzen Watershed

Since the water budget assessment was completed within a closed system (i.e., watershed), and using the conservation of mass, the recharge and runoff estimates can be compared to long-term stream flow and baseflow data to verify and calibrate the model results. Assuming no deep loss of groundwater, at the outlet of a watershed, average annual baseflow should be equal to the average annual recharge, and the average annual stream flow should be equal to the average annual runoff + recharge.

Table 13 shows a comparison between the estimated BFLOW baseflow results and average surface water flow at the Van Duzen Hydrometric Station at Bridgeville, against the estimated recharge and runoff from the water budget model. This table has calculated the total recharge based on a Surplus of 50.8 inches/yr at the Bridgeville Climate Station, which is considered more representative of the upper Van Duzen than the Scotia Station (**Table 8**). Westenbroek and others (2010) completed a similar comparison to verify their GIS-Based model results for the Black Earth Creek Watershed in Wisconsin.

Table 13. Water Budget Comparison to Baseflow

Station	Average Baseflow (cfs)	Average Annual Stream Flow (cfs)	Water Budget Recharge Total (cfs)	Water Budget Runoff Total (cfs)	Baseflow % Difference	Stream Flow % Difference
Van Duzen at Bridgeville	200	702	164	516	-18%	-26%

Based upon this comparison, the water budget recharge values were 18% lower than predicted by the BFLOW results, and the runoff values were 26% lower than predicted. Since both values were lower than the measured values by a similar percentage, it is concluded that the estimated infiltration factors are reasonable, but the total precipitation, and hence Surplus is low. This result is consistent with the discussion on Section 3.2 and **Figure 8**, which shows up to 80 inches of rainfall occurring in this watershed.

Overall, the similarity between the watershed scale recharge estimates and the stream and baseflow measurements, suggests for the purpose of this study the methodology produced adequate estimates of groundwater recharge and runoff at a regional scale. Furthermore, if additional precipitation data was available from the upper Van Duzen watershed to add to the estimate, the result would have matched closely. Without additional field data it is difficult to address the level of uncertainty, however, this assessment provides confidence in the results to support the overall conclusions within the GSP Alternative reporting.

4.4 Water Demand

Irrigation in the lower Eel River Valley is the largest user of groundwater resources in the basin. A recent study by HCRCD (2016) estimates that agricultural extractions total 16,680 acre-ft/yr during a dry year; 13,600 acre-ft/yr during a normal year; and 10,265 acre-ft/yr during a wet year. These values are significantly less than was estimated by the California Department of Water Resources in 1996 and described in the Eel River Valley Groundwater Basin Bulletin 118, which estimated that agricultural groundwater extraction totals 49,000 acre-feet/yr. However, it is thought that this value may represent total available well yield rather than actual use data, or may have been based on state-wide average agricultural water use rates rather than local rates.

Data on Municipal water takings for drinking water and industrial usage were provided by the County of Humboldt (2016) and are summarized in **Table 14**. The largest water user in the basin is the City of Fortuna that uses between 1,333 and 1,654 acre-ft/yr. On average, municipal groundwater withdrawals account for 2,903 acre-ft/yr of groundwater usage in the basin. In addition, it is estimated that private domestic wells withdraw 1,000 acre-ft/yr.

In total, it is estimated that total water demand in the Eel River Valley Groundwater Basin ranged from 14,054 acre-ft/yr during a wet water year to 20,721 acre-ft/yr during a dry water year. This also fits with the estimates of Johnson (1975) for the basin.

4.4.1 Future Demand

HCRCD (2016) indicated that significant changes in agricultural water use are not expected within the next five years. Municipal and domestic water use is also not expected to change significantly for a rural area with less than 2% annual population growth. Due to a very limited future demand, no future population or water demand scenarios were considered for the Eel River Valley Groundwater Basin.

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Table 14. Municipal Water Demand 2005 - 2015

Location	Water Source	No. of Wells	System Capacity		Connections	Water Use (acre-ft/yr)										
			MGD	acre-ft/yr		2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005
City of Fortuna[1]	Upland wells	5	8.25	9,241	4,403	1,445	1,595	1,654	1,540	1,333	1,399	1,423	1,439	1,479	1,479	1,479
City of Rio Dell	Infiltration gallery	n/a	0.432	484	1,220	254	294	351	315	304	305	327	330	365	280	264
	Upland wells (back-up)	2	n/a	n/a	n/a	-	-	-	-	-	-	-	-	-	-	-
Town of Scotia[2]	Infiltration gallery	n/a	n/a	n/a	317	346	363	325	362	422	432	421	430	471	397	397
Del Oro	Upland well	1	0.324	363	775	46	41	33	29	12	11	19	26	44	58	51
Loleta	Upland well	1	0.232	260	258	23	23	21	20	20	20	20	19	21	25	31
Riverside	Upland well	1	0.200	224	95	24	31	35	32	32	33	32	31	26	26	38
Palmer Creek*	Upland well	2	0.210	235	114	3.0	3.1	3.2	3.4	2.9	2.8	4.0	3.2	3.2	3.2	3.2
Hydesville[3]	Upland well	2	0.600	672	420	97	107	118	124	161	153	126	138	148	162	133
Bear River*	Upland well (village)	1	0.2	224	50	224	224	224	224	224	224	224	224	224	224	224
	Upland well (casino)	1	0.041	46	1,883	46	46	46	46	46	46	46	46	46	46	46
Waddington Water Works	Springs	n/a	n/a	n/a	n/a	-	-	-	-	-	-	-	-	-	-	-
TOTAL	-	**16**	**10.489**	**11,749**	**9,535**	2,508	2,727	2,809	2,695	2,556	2,626	2,642	2,687	2,826	2,700	2,666
AVERAGE						**2,677**										

Notes:
* Water Use conservatively assumed to equal system capacity
1 - 2005, 2006, and 2007 estimated as the average of 2008-2015
2 - 2005 and 2006 estimated as the average of 2007-2015
3 - 2005 estimated as the average of 2006-2015
4 - 2005 - 2008 estimated as the average of 2009-2015
5 - 2004 and 2008 estimated as the average of other years

4.5 GSP Alternative Water Budget

Table 15 presents the estimated water budget for the Eel River Valley Groundwater Basin for all water years between 1985 and 2015, taking into account all contributing watershed areas. All data are presented in acre-ft/yr to describe all water entering and exiting the basin. An interpretation has been made to identify average, wet and dry water years. Data from the Scotia Climate Station were used to quantify long-term precipitation, ET, and Surplus (Recharge and Runoff) for the basin. As previously discussed in Section 3.2 and **Table 8**, a correction factor was added to the Scotia Climate data to better represent the high volumes of precipitation in the upper watershed areas. Due to tidal effects at the Ferndale USGS Hydrometric station, no discharge data out of the basin could be reliably measured. The SW_{out} term of the water budget equation was calculated based on known stream flow data and modelled water budget results.

The water budget *inflow* components are:

- Precipitation (from Scotia Climate Station);
- Surface water inflow at the USGS Scotia Hydrometric Station;
- Groundwater inflow through the alluvial aquifer at the USGS Scotia Hydrometric Station;
- Direct groundwater recharge from within the Salt Creek-Lower Eel River basin watershed as calculated by the GIS-Based water balance; and
- Groundwater recharge from loss of surface water flow from the Eel River and Van Duzen River.

Stream flow data from the Eel River at Scotia and Van Duzen River at Bridgeville for the period between 2007 and 2015 were quantified, and an average discharge value was applied to the period between 1985 and 2006. Recharge from loss of flow in the Eel and Van Duzen Rivers was estimated based upon data collected in 2016 and applied to all water years.

The water budget *outflow* components are:

- Evapotranspiration (ET);
- Surface water outflow as estimated by:

$$= \sum Eel\ River\ Flow\ at\ Scotia + Van\ Duzen\ River\ Flow\ at\ Bridgeville$$
$$+ (water\ balance\ model\ recharge\ and\ runoff total\ from\ Yager\ Creek, Price\ Creek, Salt\ Creek\ and\ Lower\ Van\ Duzen\ R$$
$$- recharge\ in\ the\ Salt\ Creek/lower\ Eel\ Basin)$$

- Groundwater discharge to the Pacific Ocean; and
- Consumptive water takings from irrigation, municipal and domestic use.

For the period between 2005 and 2015, water demand values irrigation and municipal usage were obtained from HCRCD (2016). Outside of this range, an average value was used based on water year classification.

Table 15. Long-Term Water Budget and Groundwater Storage

Water Year Type	DRY 1985	NORMAL 1986	DRY 1987	DRY 1988	NORMAL 1989	DRY 1990	DRY 1991	DRY 1992	WET 1993	DRY 1994	WET 1995	WET 1996	WET 1997	WET 1998	NORMAL 1999	NORMAL 2000
Inputs																
Precipitation @ Scotia (inches)	38.6	52.7	34.1	39.9	44.7	31.7	33.1	35.0	52.6	35.6	69.8	50.2	54.6	71.5	52.3	45.7
Precipitation @ Scotia (acre-ft)	994,813	1,355,743	876,631	1,028,362	1,149,888	816,121	853,218	900,247	1,354,526	915,653	1,797,454	1,291,584	1,405,610	1,840,834	1,345,303	1,177,153
1.22 correction factor[1]	1,213,671	1,654,006	1,069,490	1,254,601	1,402,863	995,668	1,040,926	1,098,302	1,652,522	1,117,097	2,192,893	1,575,733	1,714,844	2,245,818	1,641,270	1,436,126
Surface Water Inflow																
Eel River at Scotia (acre-ft)[2]	4,070,861	4,070,861	4,070,861	4,070,861	4,070,861	4,070,861	4,070,861	4,070,861	4,070,861	4,070,861	4,070,861	4,070,861	4,070,861	4,070,861	4,070,861	4,070,861
Groundwater Inflow																
Eel River at Scotia (acre-ft)	362	362	362	362	362	362	362	362	362	362	362	362	362	362	362	362
Recharge From Eel and Van Duzen Rivers (acre-ft)	68,684	68,684	68,684	68,684	68,684	68,684	68,684	68,684	68,684	68,684	68,684	68,684	68,684	68,684	68,684	68,684
Recharge in Salt Creek-Lower Eel River Watershed (acre-ft)	48,650	125,504	150,725	88,196	65,513	74,318	69,990	115,804	121,027	105,955	220,715	188,033	102,075	230,713	136,697	95,210
TOTAL Input (acre-ft)	5,402,228	5,919,417	5,360,122	5,482,704	5,608,283	5,209,893	5,250,823	5,354,013	5,913,457	5,362,959	6,553,515	5,903,672	5,956,826	6,616,438	5,917,873	5,671,244
Outputs																
Temperature (oF)	53.4	54.6	54.9	54.0	53.7	54.2	53.0	56.3	54.3	54.2	54.1	55.1	55.6	54.3	53.2	56.5
Evapotranspiration (ET) (acre-ft)	295,960	418,602	272,648	337,516	355,761	345,625	380,086	370,964	370,964	284,811	318,259	393,262	365,896	337,516	316,232	369,950
1.03 correction factor[1]	304,839	431,160	280,828	347,642	366,433	355,994	391,489	382,093	382,093	293,356	327,807	405,060	376,873	347,642	325,719	381,049
Surface Water Outflow																
Eel River at Scotia + Van Duzen River + (runoff + recharge from water budget - recharge in lower basin) (acre-ft)	4,820,418	5,232,034	5,367,109	5,032,221	4,910,734	4,957,890	4,934,712	5,180,083	5,208,057	5,127,332	5,741,959	5,566,922	5,106,551	5,795,509	5,291,979	5,069,786
Groundwater Outflow																
Groundwater Flow to Ocean (acre-ft)	40,669	40,669	40,669	40,669	40,669	40,669	40,669	40,669	40,669	40,669	40,669	40,669	40,669	40,669	40,669	40,669
Groundwater Withdrawal																
Irrigation (acre-ft)	16,880	13,600	16,880	16,880	13,600	16,880	16,880	16,880	10,265	16,880	10,265	10,265	10,265	10,265	13,600	13,600
Municipal (acre-ft)	2,667	2,667	2,667	2,667	2,667	2,667	2,667	2,667	2,667	2,667	2,667	2,667	2,667	2,667	2,667	2,667
Domestic (acre-ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Total Withdrawal (acre-ft)	20,547	17,267	20,547	20,547	17,267	20,547	20,547	20,547	13,932	20,547	13,932	13,932	13,932	13,932	17,267	17,267
TOTAL Output (acre-ft)	5,186,473	5,721,130	5,709,153	5,441,079	5,335,104	5,375,100	5,387,416	5,623,392	5,644,751	5,481,904	6,124,367	6,026,584	5,538,026	6,197,752	5,675,633	5,508,771
Change in Groundwater Storage (acre-ft)	215,755	198,287	-349,031	41,626	273,180	-165,207	-136,594	-269,379	268,706	-118,945	429,148	-122,911	418,800	418,685	242,240	162,473

Table 15 Continued. Long-Term Water Budget and Groundwater Storage

Water Year Type	*DRY*	*DRY*	*WET*	*NORMAL*	*WET*	*WET*	*NORMAL*	*DRY*	*DRY*	*WET*	*WET*	*NORMAL*	*DRY*	*DRY*	*DRY*	
	2001	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**AVERAGE**
Inputs																
Precipitation @ Scotia (inches)	32.9	42.1	65.0	46.5	51.6	70.8	40.5	41.0	34.3	54.9	52.8	32.3	40.4	18.3	41.7	45.4
Precipitation @ Scotia (acre-ft)	847,643	1,083,297	1,672,887	1,197,880	1,328,072	1,822,793	1,041,943	1,056,640	882,104	1,413,110	1,359,290	832,338	1,040,322	471,510	1,072,756	1,168,572
1.22 correction factor[1]	1,034,125	1,321,622	2,040,922	1,461,414	1,620,248	2,223,807	1,271,171	1,289,101	1,076,167	1,723,995	1,658,334	1,015,453	1,269,192	575,242	1,308,762	1,413,972
Surface Water Inflow																
Eel River at Scotia (acre-ft)[2]	4,070,861	4,070,861	4,070,861	4,070,861	4,070,861	4,070,861	4,070,861	3,643,280	2,737,279	5,172,292	6,900,433	3,428,005	3,457,504	1,609,785	3,063,005	3,988,432
Groundwater Inflow																
Eel River at Scotia (acre-ft)	362	362	362	362	362	362	362	362	362	362	362	362	362	362	362	362
Recharge From Eel and Van Duzen Rivers (acre-ft)	68,684	68,684	68,684	68,684	68,684	68,684	68,684	68,684	68,684	68,684	68,684	68,684	68,684	68,684	68,684	68,684
Recharge in Salt Creek-Lower Eel River Watershed (acre-ft)	130,578	155,500	147,591	126,698	179,676	177,885	96,106	107,149	81,779	110,358	83,570	137,294	80,861	25,283	109,238	118,990
TOTAL Input (acre-ft)	5,304,610	5,617,029	6,328,419	5,728,019	5,939,831	6,541,599	5,507,183	5,108,576	3,964,272	7,075,690	8,711,383	4,649,798	4,876,603	2,279,356	4,550,051	5,602,125
Outputs																
Temperature (oF)	55.6	56.3	57.4	57.8	57.2	56.2	56.2	53.8	55.7	55.7	55.3	55.2	55.9	56.8	58.6	55.3
Evapotranspiration (ET) (acre-ft)	308,123	263,526	300,015	341,571	416,574	290,893	352,720	214,875	370,964	430,764	406,439	341,571	385,154	225,011	307,110	338,367
1.03 correction factor[1]	317,367	271,432	309,015	351,818	429,072	299,619	363,302	221,322	382,093	443,687	418,632	351,818	396,709	231,761	316,323	348,518
Surface Water Outflow																
Eel River at Scotia + Van Duzen River + (runoff + recharge from water budget - recharge in lower basin) (acre-ft)[3]	5,259,209	5,392,685	5,350,324	5,238,429	5,522,164	5,512,573	5,074,581	4,651,589	3,588,428	6,351,214	8,080,047	4,627,723	4,311,645	2,065,019	4,032,726	5,109,731
Groundwater Outflow																
Groundwater Flow to Ocean (acre-ft)	40,669	40,669	40,669	40,669	40,669	40,669	40,669	40,669	40,669	40,669	40,669	40,669	40,669	40,669	40,669	40,669
Groundwater Withdrawal																
Irrigation (acre-ft)	16,880	16,880	10,265	13,600	10,265	10,265	13,600	16,680	16,680	10,265	10,265	13,600	16,680	16,680	16,680	13,973
Municipal (acre-ft)	2,667	2,667	2,667	2,667	2,666	2,700	2,826	2,687	2,642	2,626	2,556	2,695	2,809	2,727	2,508	2,670
Domestic (acre-ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Total Withdrawal (acre-ft)	20,547	20,547	13,932	17,267	13,931	13,965	17,426	20,367	20,322	13,891	13,821	17,295	20,489	20,407	20,188	17,644
TOTAL Output (acre-ft)	5,637,792	5,725,333	5,713,940	5,648,182	6,005,836	5,866,826	5,495,978	4,933,946	4,031,512	6,849,461	8,553,169	5,037,505	4,769,512	2,357,857	4,409,906	5,516,561
Change in Groundwater Storage (acre-ft)	-333,182	-108,304	614,479	79,836	-66,005	674,773	11,206	174,629	-67,240	226,229	158,214	-387,708	107,092	-78,501	140,145	***85,564***

Notes

Water year classification (Dry / Normal / Wet) between 2007 and 2015 was determined by comparing annual rainfall and four two-month rainfall totals to the 50-year average from HCRCD (2016). Between 1985 and 2006, water year classification was interpreted from the 2007 – 2015 results.

1 – correction factor added to account for additional precipitation in the upper watershed areas not captured by the Scotia Station (see Table 8).

2 – flow data between 1985 and 2007 calculated as an average of 2008 to 2015 flow data

3 – flow data for the Van Duzen River between 1985 and 2007 calculated as an average of 2008 to 2015 flow data

On average, flow from the Eel River entering the basin at Scotia accounts for 71% of the total water entering the basin. Of this water, it was calculated that 68,684 acre/ft-yr from the Eel River recharges the water table or about 2% of the flow. Recharge from precipitation in the Salt-Creek/ lower Eel basin contributes 118,990 acre-ft/yr of recharge. Groundwater inflow from outside of the study area is interpreted/assumed to represent a very small portion of the water budget.

Similarly to the water entering the basin, the Eel River is estimated to account for 93% of the water leaving the basin. The remaining water is lost through ET, discharge to the ocean and through groundwater extraction. Groundwater discharge to the ocean takes into account the full saturated thickness of the alluvium and the Carlotta Formation (approx. 3,000 ft), accounting for deep groundwater flow.

4.5.1 Groundwater Storage

In a closed system, the sum of inputs and outputs of a water budget should equal zero. The difference between these terms is the change in groundwater storage (ΔS_{GW}). **Figure 17** presents the yearly change in groundwater storage in the Eel River Valley Groundwater Basin. The average groundwater storage within the basin was estimated to be 85,564 acre-ft/yr (**Table 15**). The change in groundwater storage over time is directly correlated with changes in precipitation (**Figure 17**). Precipitation is the largest source of water that supported recharge and runoff within, and outside of the basin. Following multiple years of above average or below average precipitation, the change in groundwater storage has a delayed response.

Over the past 10-years, groundwater storage has ranged from 674,773 acre-ft/yr in 2006 to -387,708 acre-ft/yr in 2012. Over this 10-year period, there have been 5 dry water years (2008, 2009, 2013, 2014 and 2015), and the overall changes in groundwater storage has remained positive at an average of 81,167 acre-ft/ yr. This result is consistent with the long-term stable groundwater levels and change in groundwater storage as determined from in the CASGEM wells (SHN, 2016), and strongly suggests that groundwater storage in the basin is not being overdrawn. This was also concluded by Johnson (1975) that the lack of a downwards water level trend indicates that the basin is not being overdrawn.

The groundwater storage volumes already take into account current volumes of water used for irrigation, municipal and domestic supply, so the estimated available groundwater in the basin is 85,564 acre-ft/yr. As summarized in **Table 16**, groundwater withdrawals account for only a small percentage of the overall water budget in the Eel River Valley.

Table 16. Groundwater Withdrawal Comparison to Water Budget Results

Groundwater Extraction Relative to Water Budget	Total Water Input	Total Recharge in Study Area	Total Recharge in Lower Eel River Valley Area	Average Yearly Change in Groundwater Storage + Current Groundwater Withdrawals
% of Groundwater Extraction	0.3%	4%	9%	17%

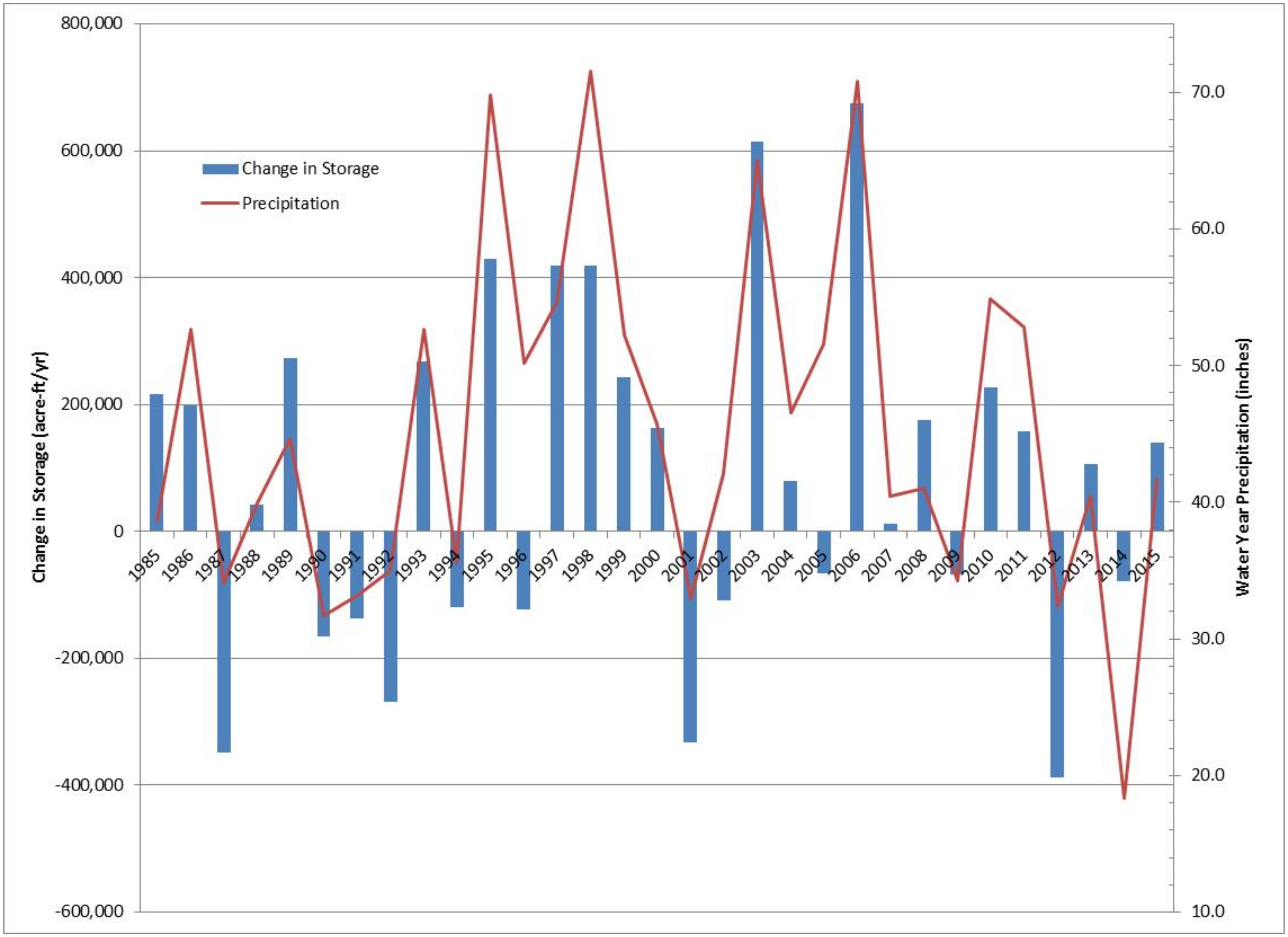

Figure 17. Change in Groundwater Storage and Water Year Precipitation

5. Sustainable Yield

Sustainable Yield under the Sustainable Groundwater Management Act of 2014 is defined as "the maximum quantity of water, calculated over a base period representative of long-term conditions in the basin and including any temporary surplus, that can be withdrawn annually from a groundwater supply without causing an undesirable result." Undesirable result means one or more of the following effects caused by groundwater conditions occurring throughout the basin: chronic lowering of groundwater levels, depletion of interconnected surface water, significant and unreasonable loss of storage, subsidence, saltwater intrusion, and degradation of water quality. The SHN GSP Alternative Report (2016) concludes that there have been no undesirable effects present in the basin.

The data presented in this report supports this overall conclusion for the following reasons:

- The total water taking within the basin represents a small percentage of the available recharge (approximately 4%),
- The total water taking within the highest demand area of the lower Eel River Valley is only 9% of total recharge in the lower basin,
- There has been no net loss in groundwater storage through time, a conclusion supported by stable water levels in the CASGEM wells,
- The current water taking is well below the estimated available groundwater storage, and
- Baseflows have remained stable over time, suggesting that there has not been a significant change in groundwater recharge from the river due to groundwater pumping.

As also noted in the GSP Alternative Report (2016), there is currently insufficient information to establish minimum thresholds for undesirable results, and there is insufficient information on the dynamics of the system to accurately predict how sustainability indicators would respond to significant increases in water extraction or other changes in water budget conditions. A theoretical maximum sustainable yield for the Lower Eel River Basin would likely be based on preventing an undesirable depletion of interconnected surface water. Predicting these effects would require significantly more data combined with numerical groundwater modelling of surface-water and groundwater interactions to determine reach specific triggers for reductions in groundwater supported baseflows, This complex assessment is based on factors such as aquatic habitat characteristics, species present, and an understanding of natural variability in groundwater discharge, recharge and baseflows. This level of analysis was confirmed by Humboldt County and the working group to be beyond the scope of the ongoing Basin Assessment study.

6. Conclusions and Recommendations

The following Conclusions and Recommendations are provided:

- A water budget was prepared for the Eel River Groundwater Basin using a Geographic Information System (GIS) water budget model. This model was based on the best available information to provide long-term (i.e., 30-year), and yearly estimates of water budget parameters over the past 10-years. Water budget parameters include precipitation (P), evapotranspiration (ET), groundwater recharge (R), and surface water runoff (RO). This information has been summarized for the groundwater basin, as well as for the larger watershed area of the contributing watercourses.
- The Eel River Groundwater basin is 73,700 acres in size and is support by surface water and groundwater flow from 5 major watersheds: the lower Eel River, Van Duzen River, Yager Creek, Salt Creek and Price Creek. The area of all contributing watersheds used on the model is 308,934 acres.
- Within the Eel River Groundwater Basin, groundwater flow is primarily influenced by two key hydrostratigraphic units: the alluvium, and the Carlotta formation. The Hookton formation also conducts groundwater flow, though to a lesser extent.
- There is a complex relationship between the shallow groundwater system and surface water within the Van Duzen and Eel rivers. The Van Duzen and Eel rivers provide an important groundwater recharge function throughout the year, particularly in the reaches immediately updstream of the lower Eel River Basin, where the alluvial deposits are relatively thin, and directly overly the permeable Carlotta formation. Vertical hydraulic gradients within the lower Eel River Basin are relatively weak, and affected by Eel river stage and seasonal changes in groundwater levels. During low flow periods, upwards groundwater pressure from the Carlotta Formation into the alluvial aquifer supports shallow groundwater pressure and groundwater levels beneath the River.
- Monthly precipitation and temperature totals between 1985 and 2015 from the Scotia Climate Station were used to complete the water balance and calculate evapotranspiration (ET). The precipitation amounts throughout the Eel River Valley Groundwater basin vary substantially, with total precipitation increasing further inland, coinciding with an increase in elevation. Final precipitation values were estimated using data from four climate stations within the study area.
- Potential evapotranspiration (PET) was calculated using the Thornthwaite and Mather (1957) method. The Surplus (S) is calculated from P – AET and represents the water available, after taking into account evaporation, transpiration, and changes in soil moisture storage, to recharge the groundwater table, or runoff as streamflow. Values were estimated for normal, wet and dry water years.
- On average the lower basin receives 45.6 inches of rainfall, of which 14.6 inches is lost to AET, and 31.0 inches remains to support groundwater levels, baseflow and total stream flow.
- The Surplus (S) water was partitioned between runoff and infiltration/recharge based on soil type, topography, land use/vegetation cover. Results of the partitioning were calibrated to average stream

flow (runoff) and baseflow values (recharge) from USGS gauge stations on the Van Duzen River and Eel River.

- The total estimated potential annual recharge and runoff for the Eel River Valley Groundwater Basin is 316,602 acre-ft/yr and 482,087 acre-ft/yr, respectively.
- Irrigation in the lower Eel River Valley is the largest user of groundwater and reported to be 16,680 acre-ft/yr during a dry year; 13,600 acre-ft/yr during a normal year; and 10,265 acre-ft/yr during a wet year. On average, municipal groundwater withdrawals account for 2,677 acre-ft/yr of groundwater usage in the basin, and private domestic wells withdraw is estimated at 1,000 acre-ft/yr. Total water demand in the Eel River Valley Groundwater Basin ranged from 13,891 acre-ft/yr during a wet water year to 20,489 acre-ft/yr during a dry water year.
- No significant increases in agricultural water use or municipal water taking (2% population growth estimate) are expected within the next five years according to HCRCD. Overall, groundwater withdrawals account for only a small percentage of the groundwater recharge available within the basin.
- Over the past 10-years, groundwater storage has ranged from 674,773 acre-ft/yr in 2006 to -387,708 acre-ft/yr in 2012. There have been 5 dry years (2008, 2009, 2013, 2014 and 2015), and the overall change in groundwater storage within the basin has remained positive. This is consistent with the stable groundwater levels and available storage as measured in the CASGEM wells (SHN, 2016) and strongly suggests that groundwater storage in the basin is not being overdrawn.
- The estimated available groundwater in the basin is 85,564 acre-ft/yr.
- The GSP Alternative Report (SHN, 2016) concludes that there are currently no undesirable results effects within the Eel River Groundwater Basin as a result of the groundwater withdrawals. The results of this water budget assessment support this conclusion.
- There is not currently sufficient data to determine a maximum theoretical sustainable yield for the basin, although the water budget data strongly suggests that the current volume of yearly groundwater use is sustainable.

7. Closure

Thank you for the opportunity to work with your team on this interesting and challenging project. Please contact the undersigned if you have any questions regarding this submission.

Yours truly,

Palmer Environmental Consulting Group Inc.

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Appendix I

Report Figures

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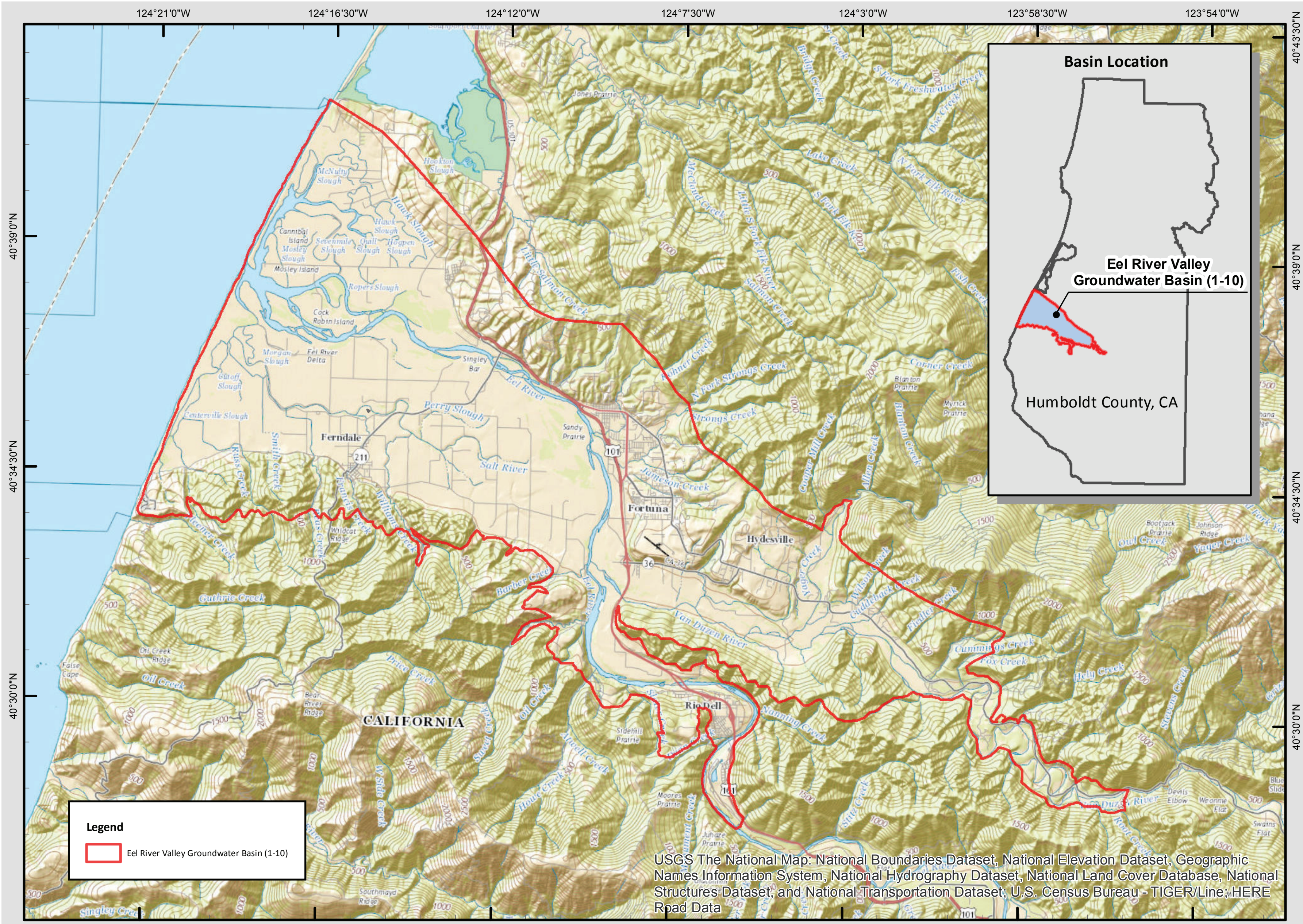

BASEMAP FROM HUMBOLDT COUNTY PUBLIC WORKS (DECEMBER, 2016)

SHN Consulting Engineers & Geologists, Inc.

Humboldt County Public Works
Eel River Groundwater Assessment
Humboldt County, California

Site Location Map
SHN 016219

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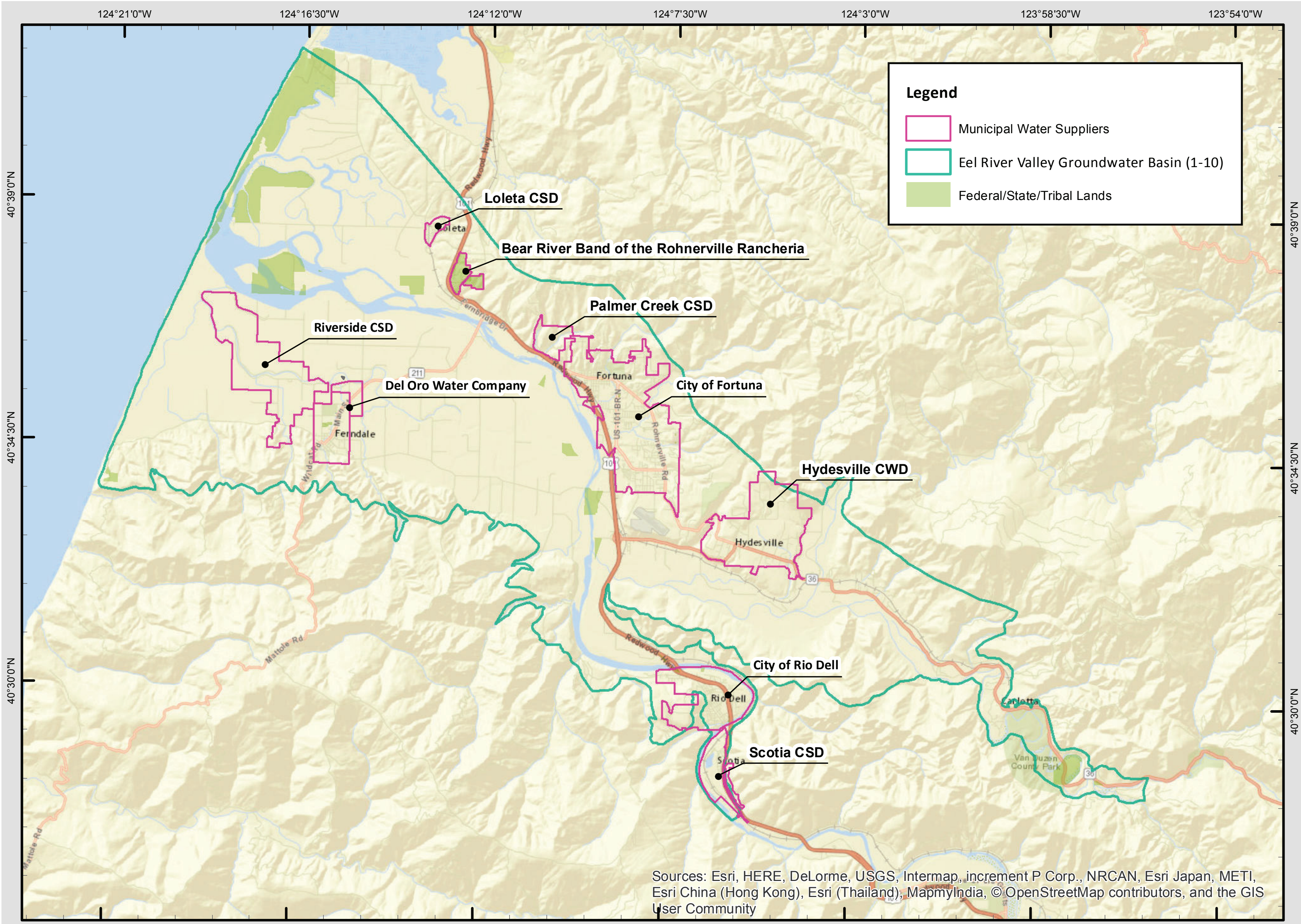

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Municipal Water Suppliers

SHN 016219

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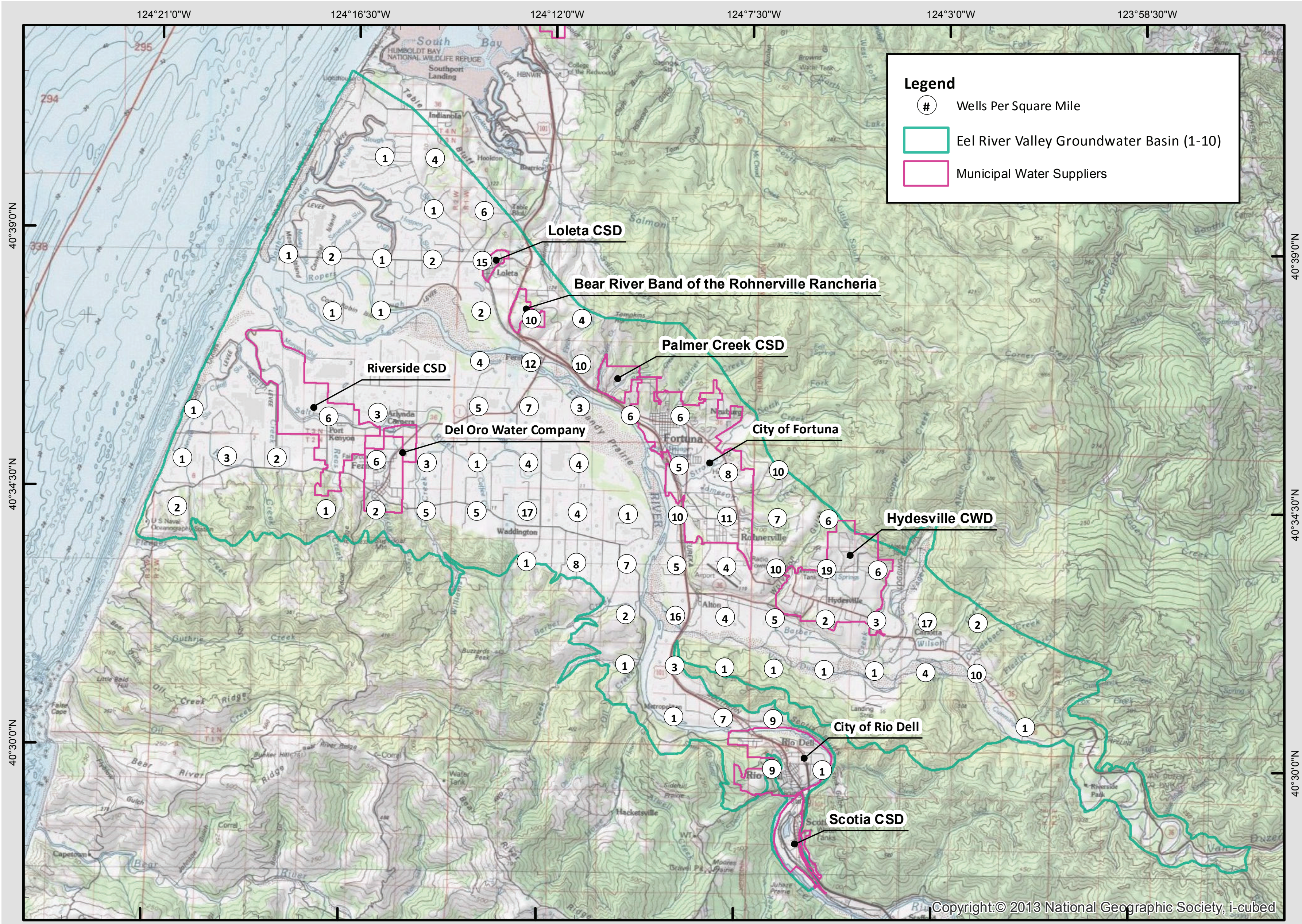

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Humboldt County, California

Well Densities

SHN 016219

December 2016

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Figure 2-2

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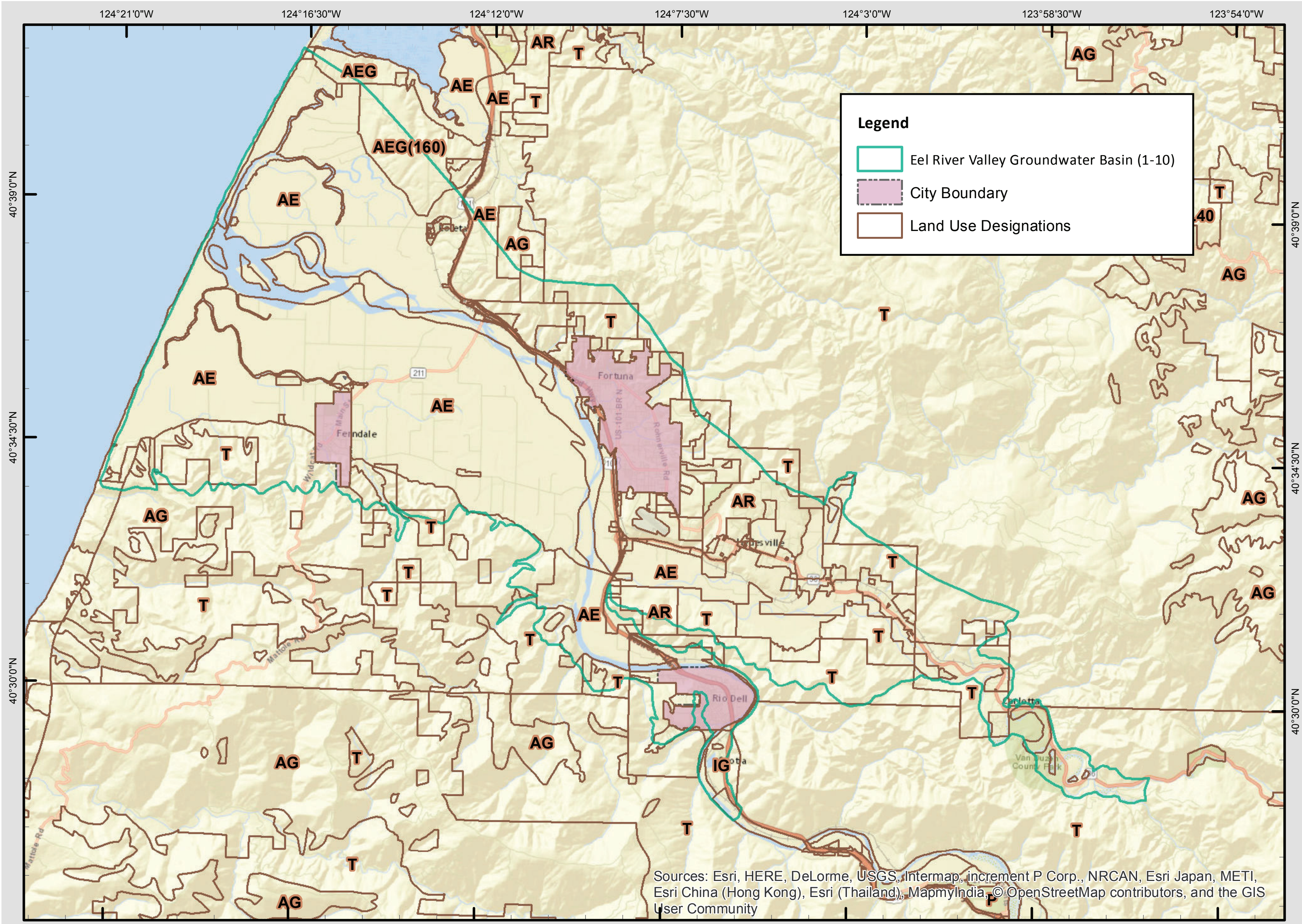

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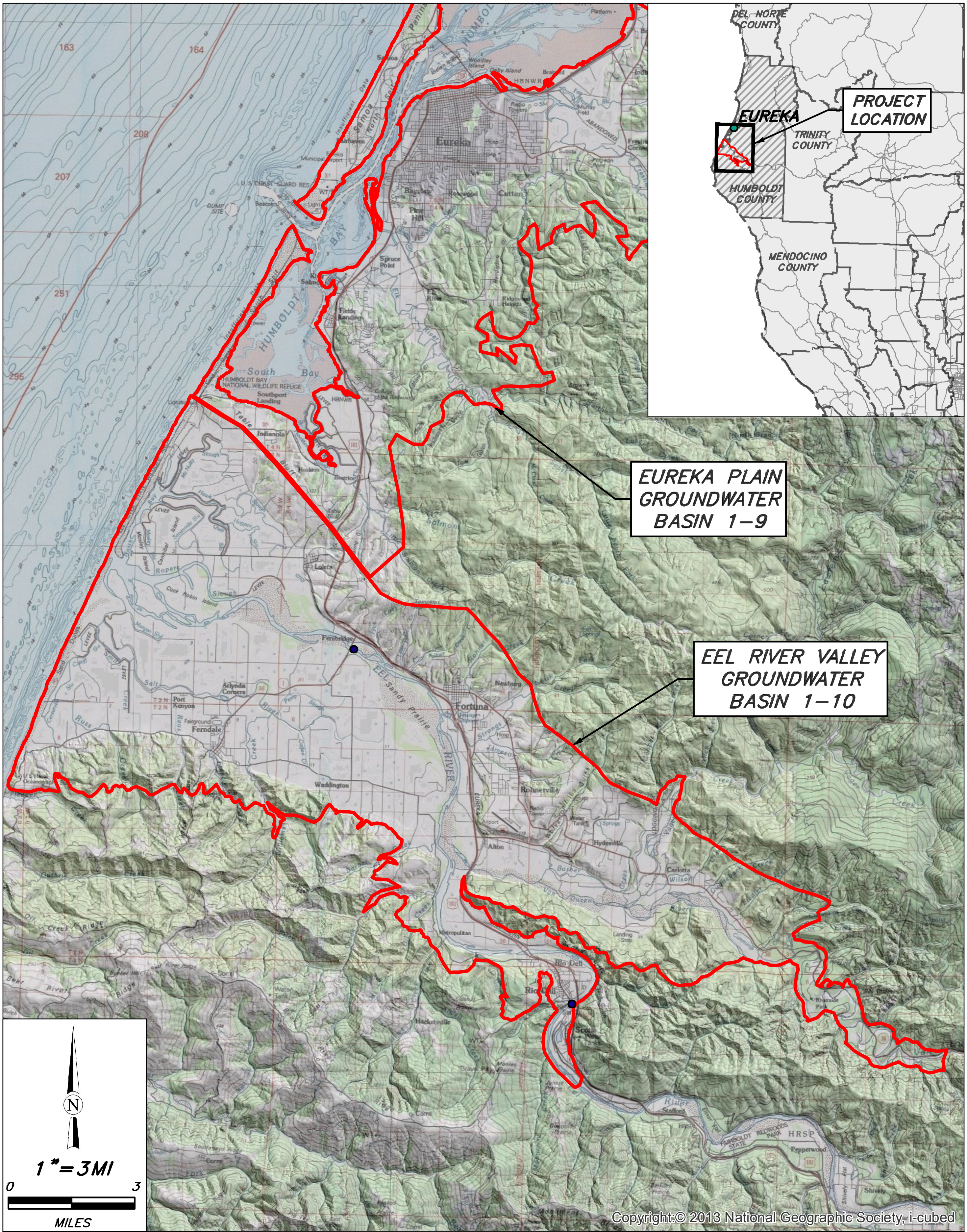
Humboldt County Public Works
Eel River Groundwater Assessment
Humboldt County, California

Existing Land Use Designations

SHN 016219

December 2016 | 2-3_ExistingLandUseDesignations.ai | Figure 2-3



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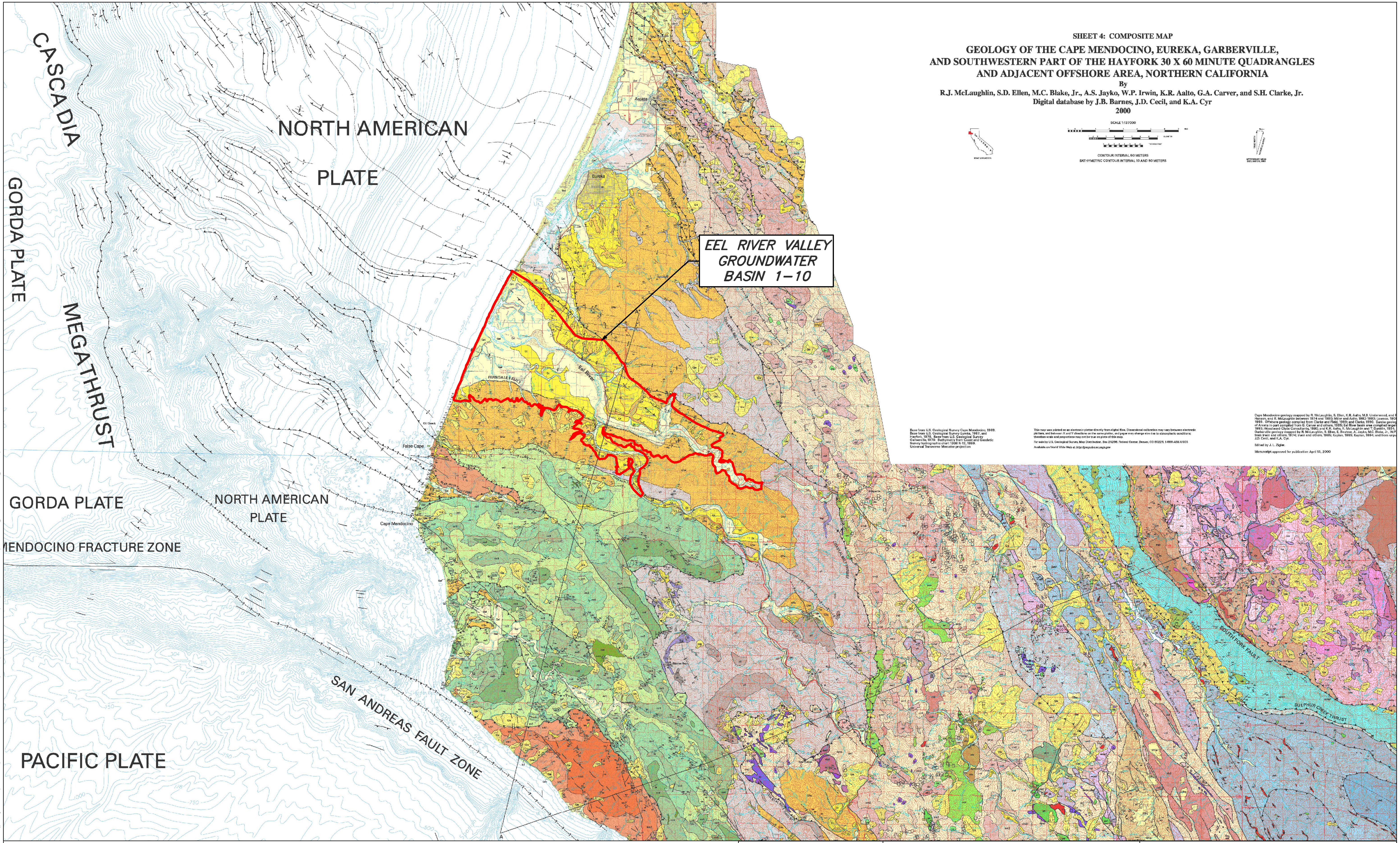
SHN Consulting Engineers & Geologists, Inc.	Humboldt County Public Works Eel River Valley Groundwater Assessment Humboldt County, California	Project Location SHN 016219
	December 2016 / 3_1_ProjectLocationMap	Figure 3-1



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Consulting Engineers & Geologists, Inc.

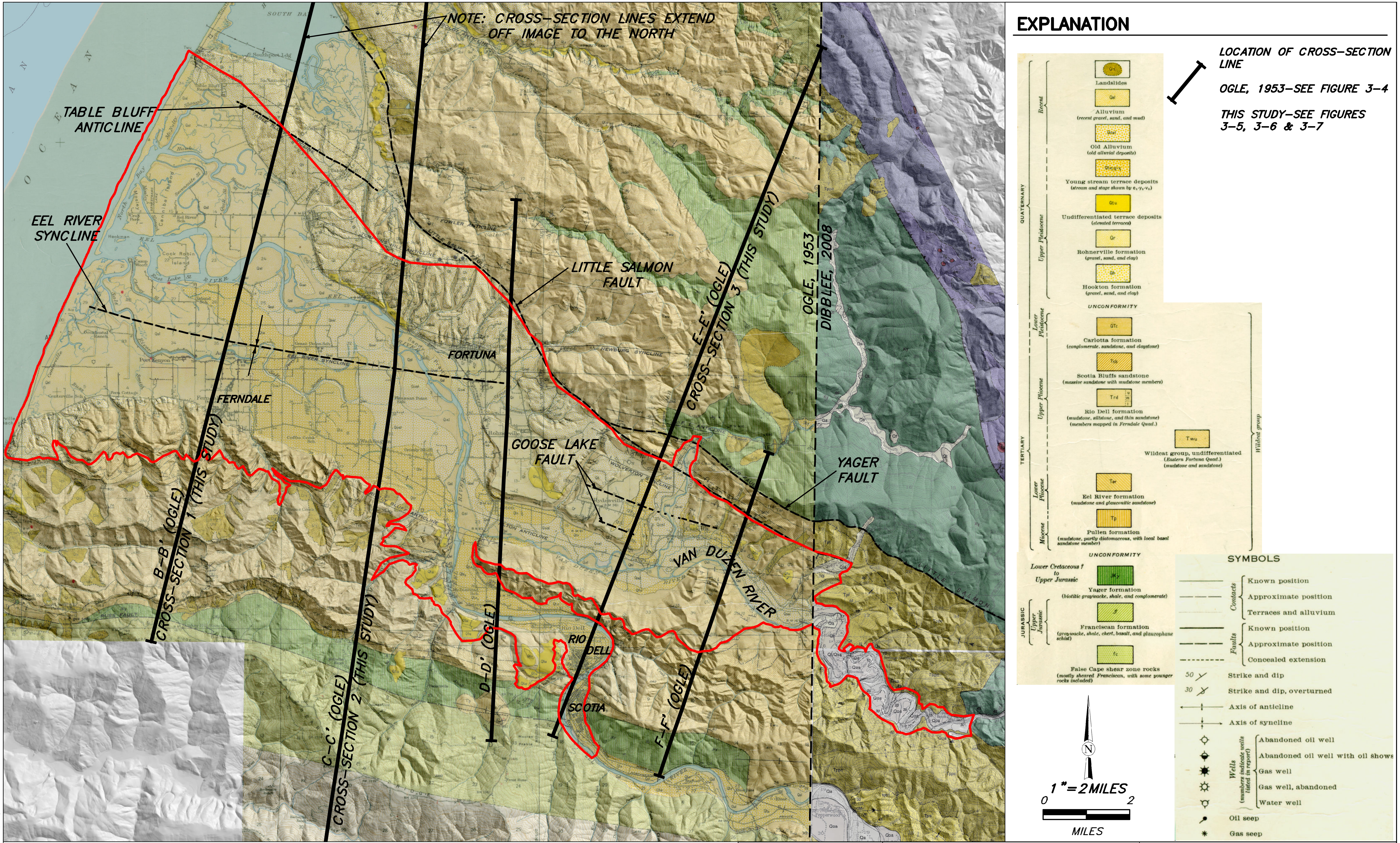
Humboldt County Public Works
Eel River Groundwater Assessment
Humboldt County, California

Geologic Map
(McLaughlin, 2002)
SHN 016219

December 2016

McLaughlin_GeologicMap

Figure 3-2



SHN Consulting Engineers & Geologists, Inc.

Humboldt County Public Works
Eel River Groundwater Assessment
Humboldt County, California

Geologic Map
(Ogle, 1953; Dibblee, 2008)
SHN 001283

December 2016 | GeologicMap_OgleDibblee | Figure 3-3

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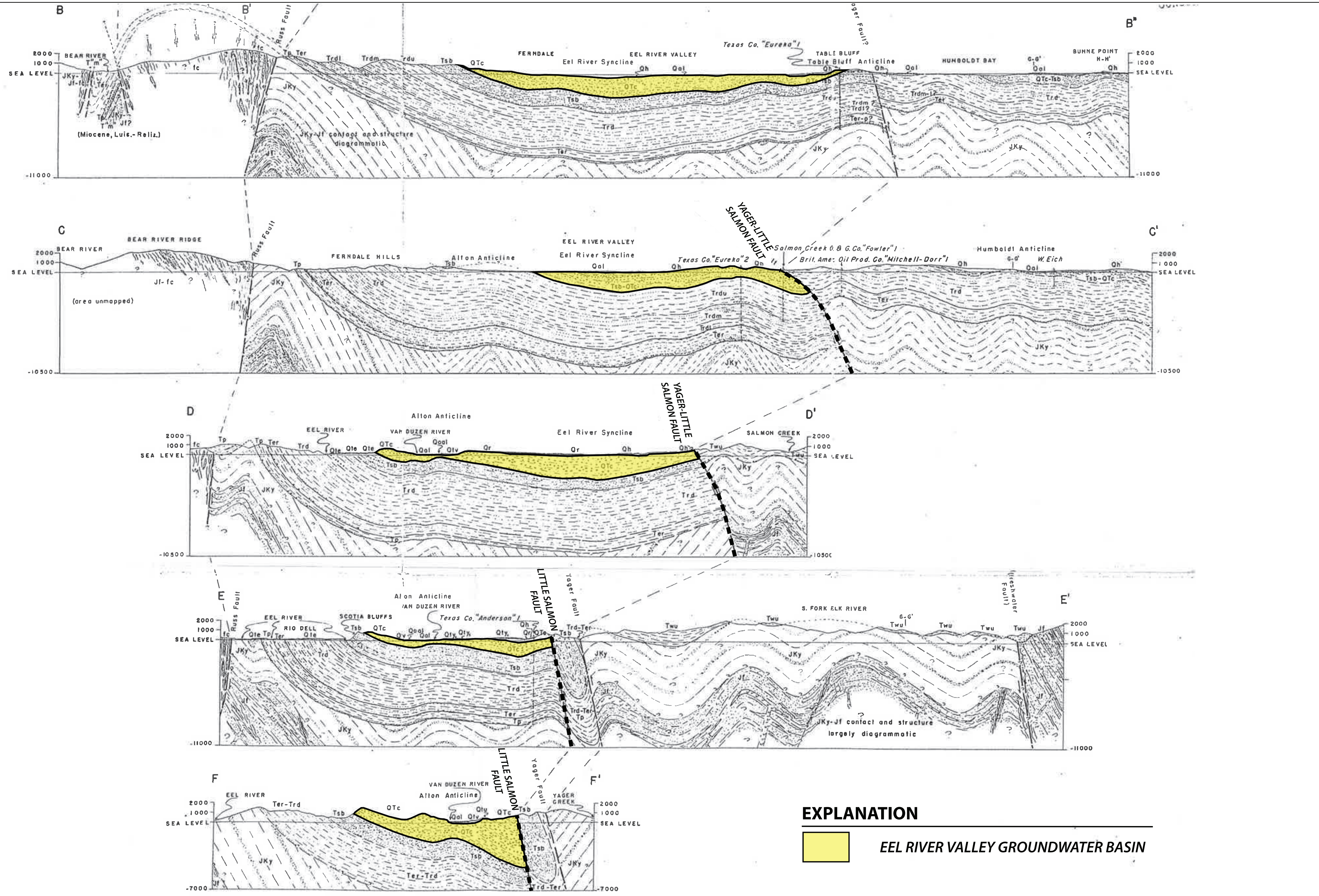

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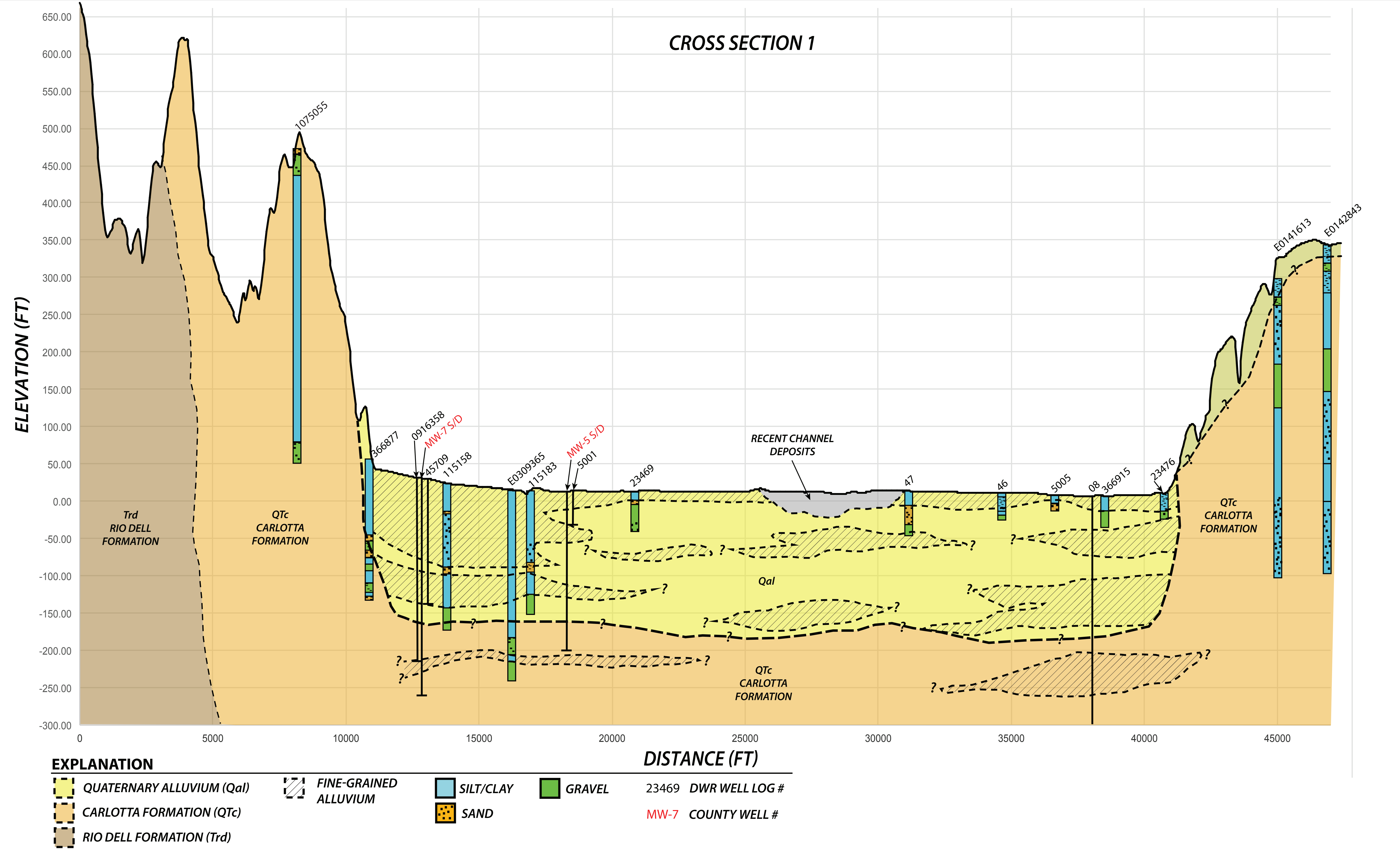
Humboldt County Public Works
Eel River Groundwater Assessment
Humboldt County, California

Geologic Cross-Sections
(Ogle, 1953)
SHN 016219

December 2016 | OgleCrossSections.ai | Figure 3-4



SCHEMATIC SECTION SHOWS SHALLOW STRATIGRAPHY ALONG CROSS-SECTION LINE B-B' AS SHOWN ON FIGURE 3-3.

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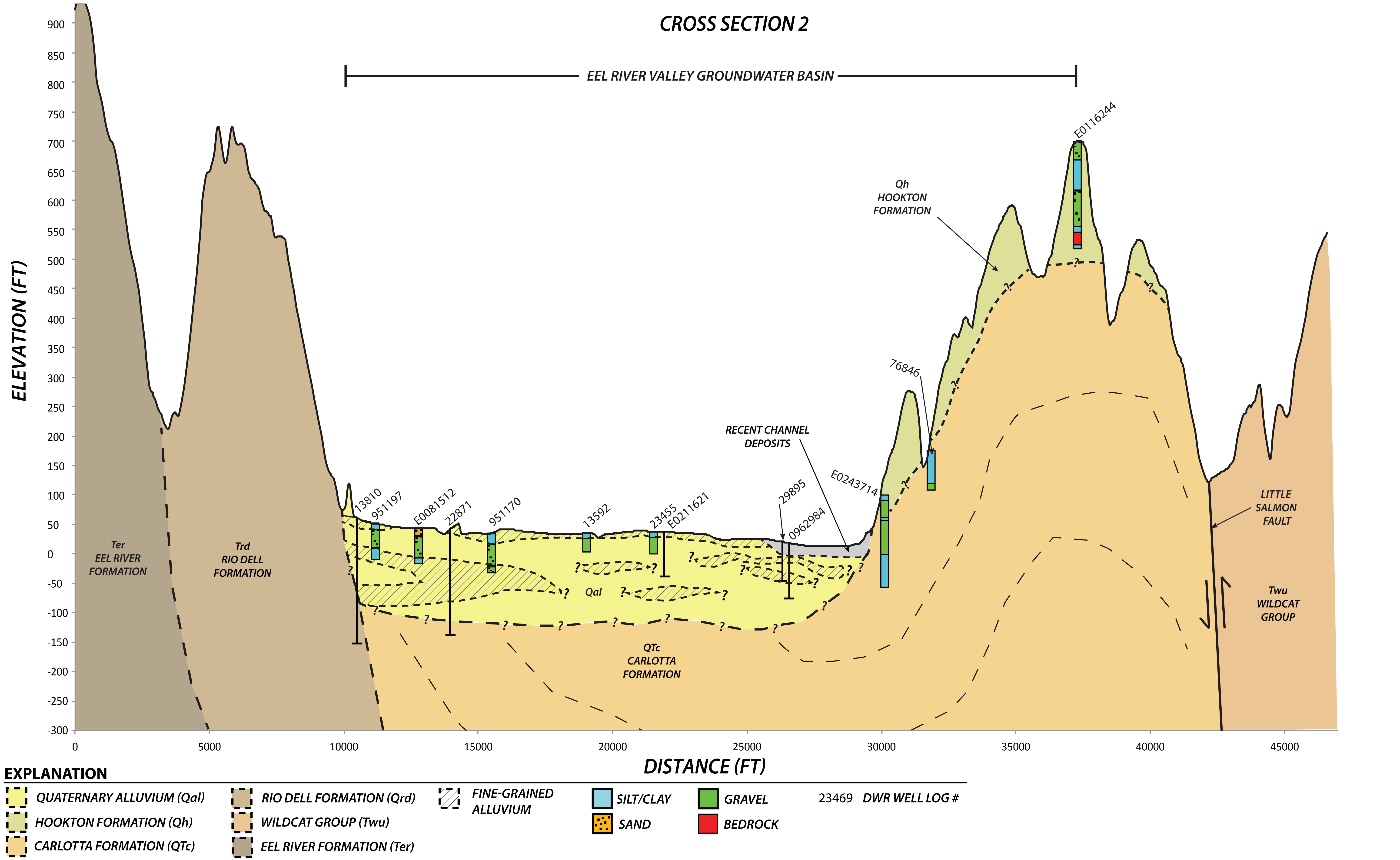
Humboldt County Public Works
Eel River Groundwater Assessment
Humboldt County, California

Geologic Cross-Section 1
(This Study)
SHN 016219

December 2016 | CrossSection1.ai | Figure 3-5



SCHEMATIC SECTION SHOWS SHALLOW STRATIGRAPHY ALONG CROSS-SECTION LINE C-C' AS SHOWN ON FIGURE 3-3.

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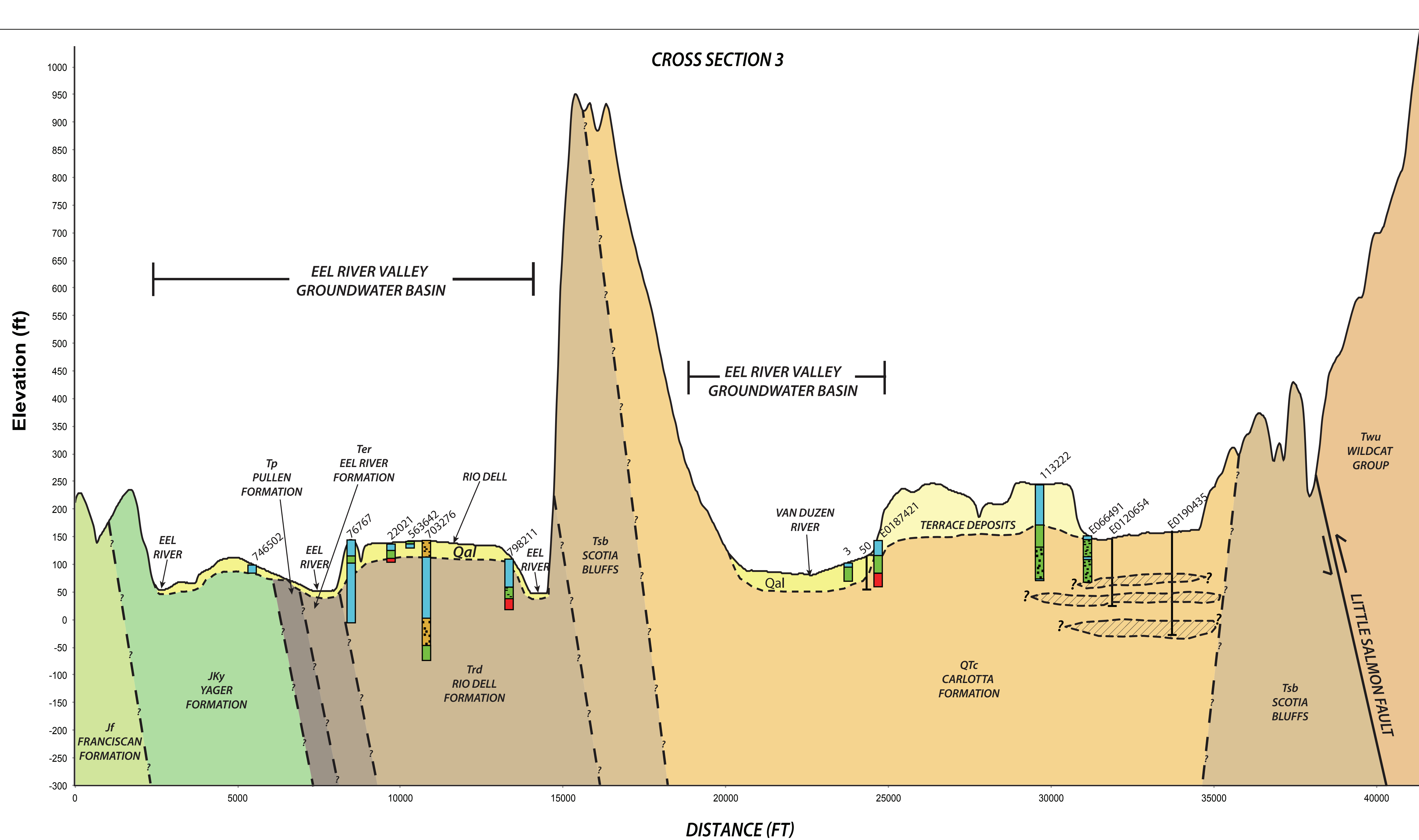
Humboldt County Public Works
Eel River Groundwater Assessment
Humboldt County, California

Geologic Cross-Section 2
(This Study)
SHN 016219

December 2016

CrossSection2.ai

Figure 3-6



EXPLANATION

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

SCHEMATIC SECTION SHOWS SHALLOW STRATIGRAPHY ALONG CROSS-SECTION LINE E-E' AS SHOWN ON FIGURE 3-3.

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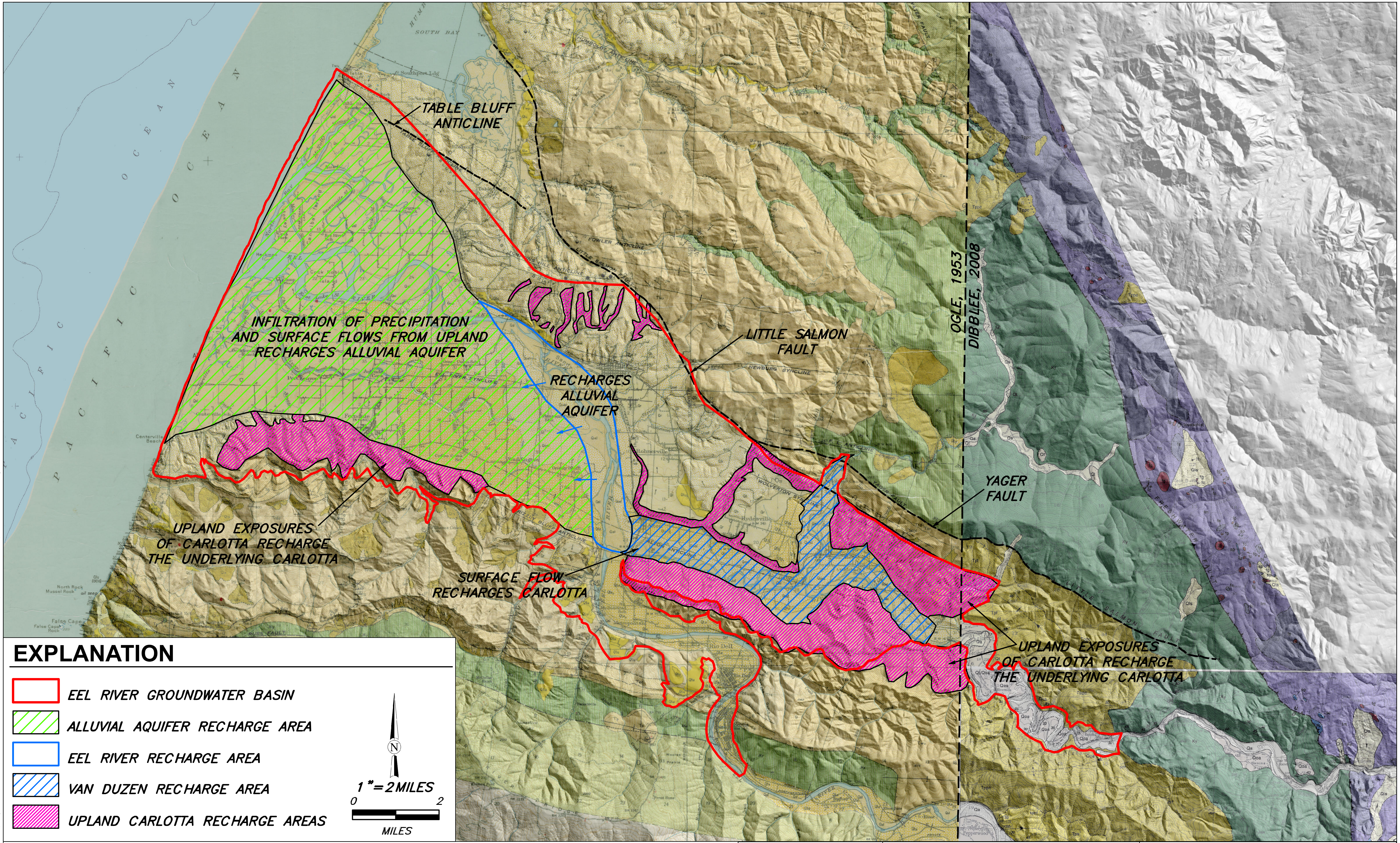
Eel River Groundwater Assessment
Humboldt County, California

Geologic Cross-Section 3
(This Study)
SHN 016219

December 2016 | CrossSection3.ai | Figure 3-7

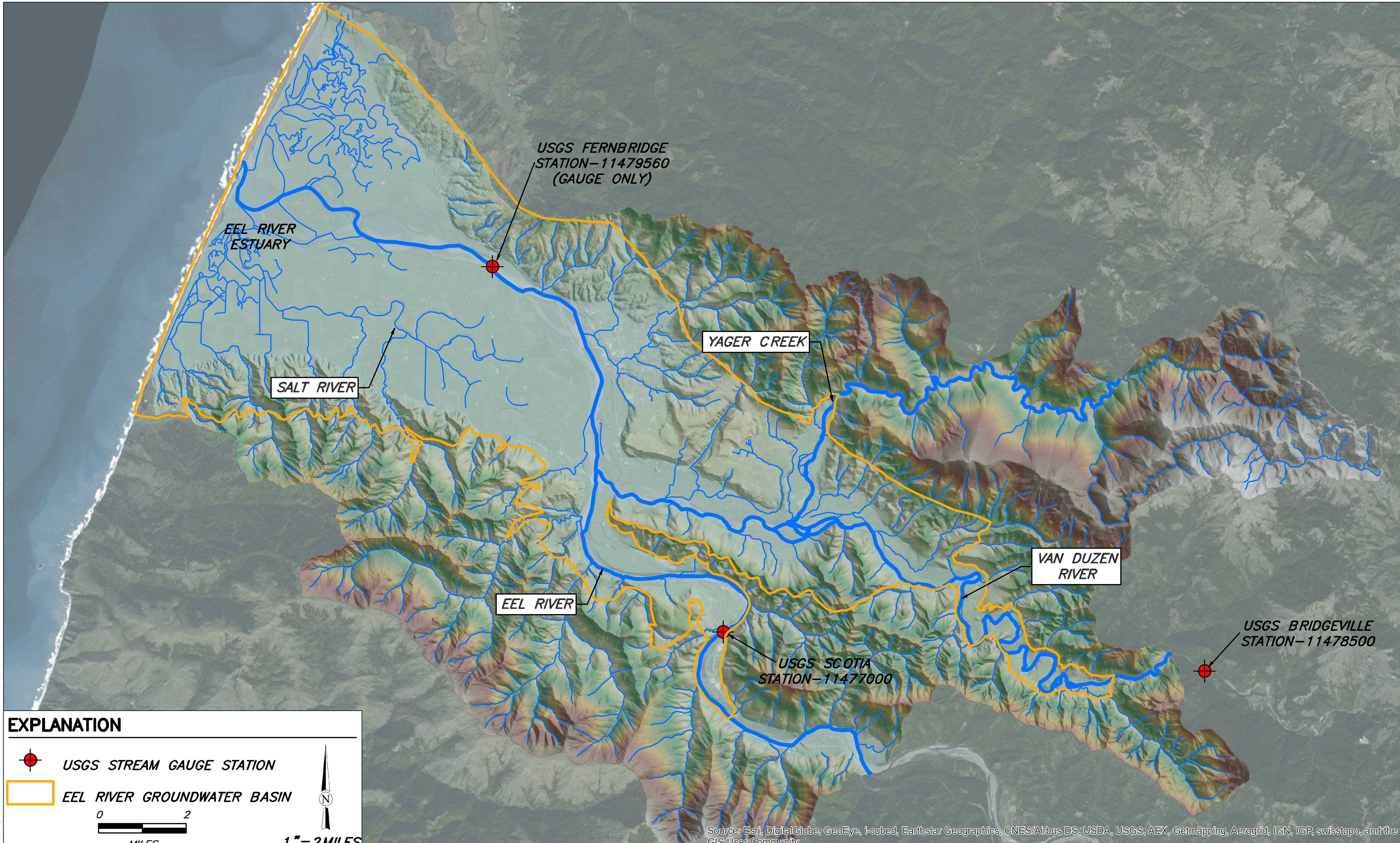


Consulting Engineers & Geologists, Inc.

Humboldt County Public Works
Eel River Groundwater Assessment
Humboldt County, California

Important Recharge Areas
SHN 001283

December 2016 | Important_Recharge_Areas | Figure 3-8



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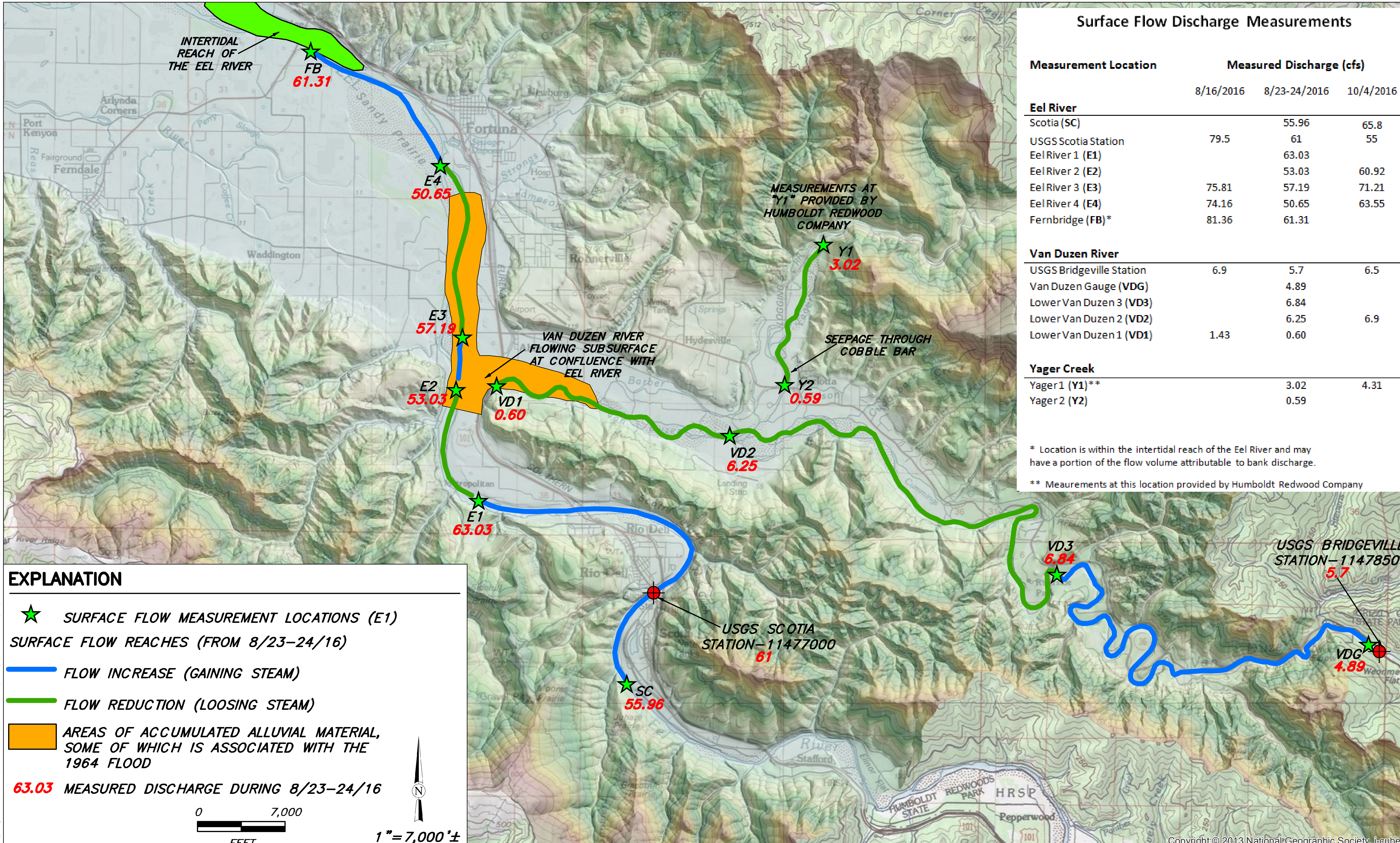
Humboldt County Public Works
Eel River Groundwater Assessment
Humboldt County, California

Surface Waters Map
SHN 016219

December 2016 | SurfaceWatersMap | Figure 3-9



Surface Flow Discharge Measurements

Measurement Location	Measured Discharge (cfs) 8/16/2016	8/23-24/2016	10/4/2016
Eel River			
Scotia (**SC**)		55.96	65.8
USGS Scotia Station	79.5	61	55
Eel River 1 (**E1**)		63.03	
Eel River 2 (**E2**)		53.03	60.92
Eel River 3 (**E3**)	75.81	57.19	71.21
Eel River 4 (**E4**)	74.16	50.65	63.55
Fernbridge (**FB**)*	81.36	61.31	
Van Duzen River			
USGS Bridgeville Station	6.9	5.7	6.5
Van Duzen Gauge (**VDG**)		4.89	
Lower Van Duzen 3 (**VD3**)		6.84	
Lower Van Duzen 2 (**VD2**)		6.25	6.9
Lower Van Duzen 1 (**VD1**)	1.43	0.60	
Yager Creek			
Yager 1 (**Y1**)**		3.02	4.31
Yager 2 (**Y2**)		0.59	

* Location is within the intertidal reach of the Eel River and may have a portion of the flow volume attributable to bank discharge.

** Meaurements at this location provided by Humboldt Redwood Company

FLOW STUDY PERFORMED BY THOMAS GAST & ASSOCIATES ENVIRONMENTAL CONSULTANTS

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Humboldt County Public Works
Eel River Groundwater Assessment
Humboldt County, California

2016 Surface Flow Discharge Measurements Locations and Results
SHN 016219

December 2016 | SurfaceFlowMap | Figure 3-10

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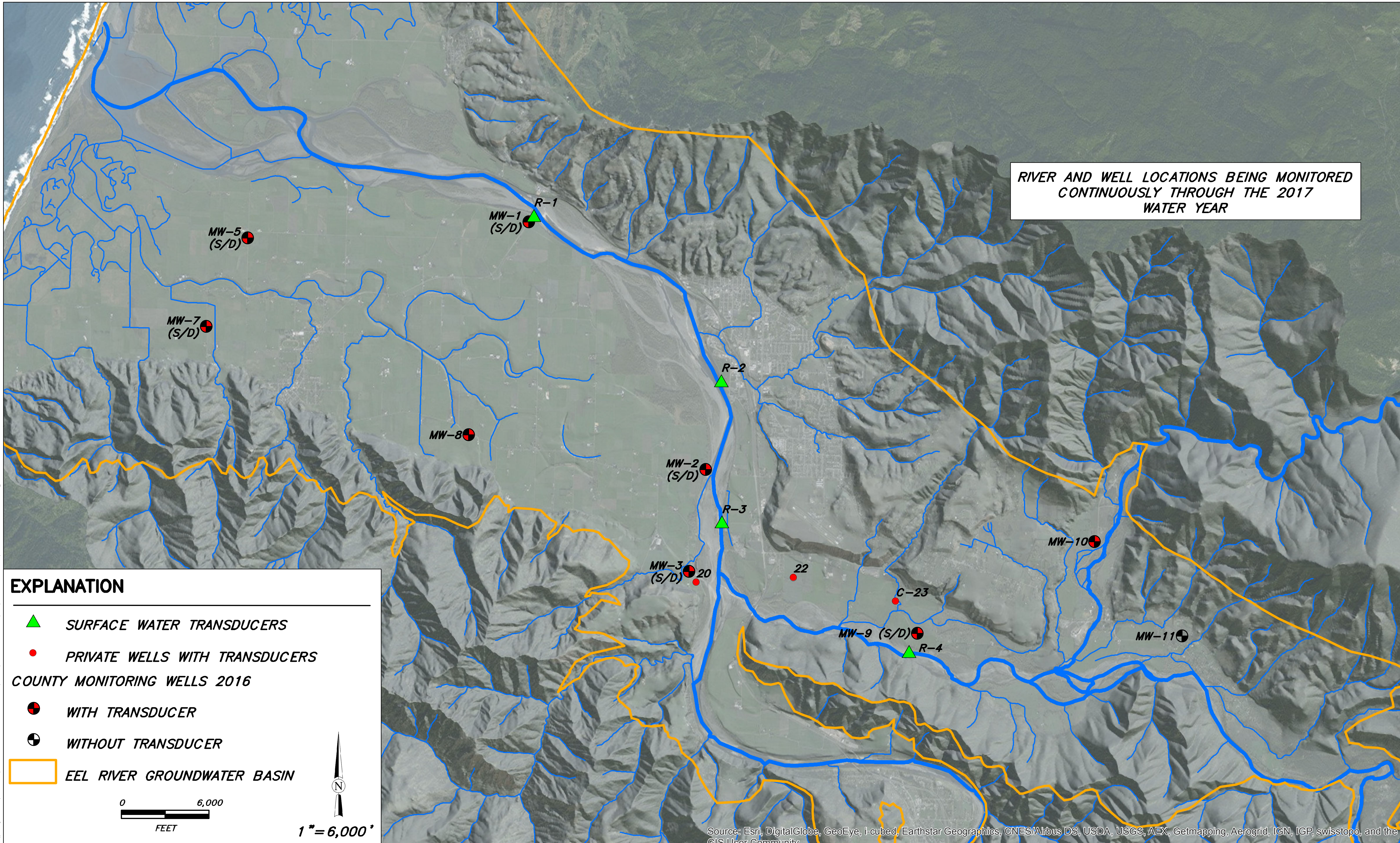

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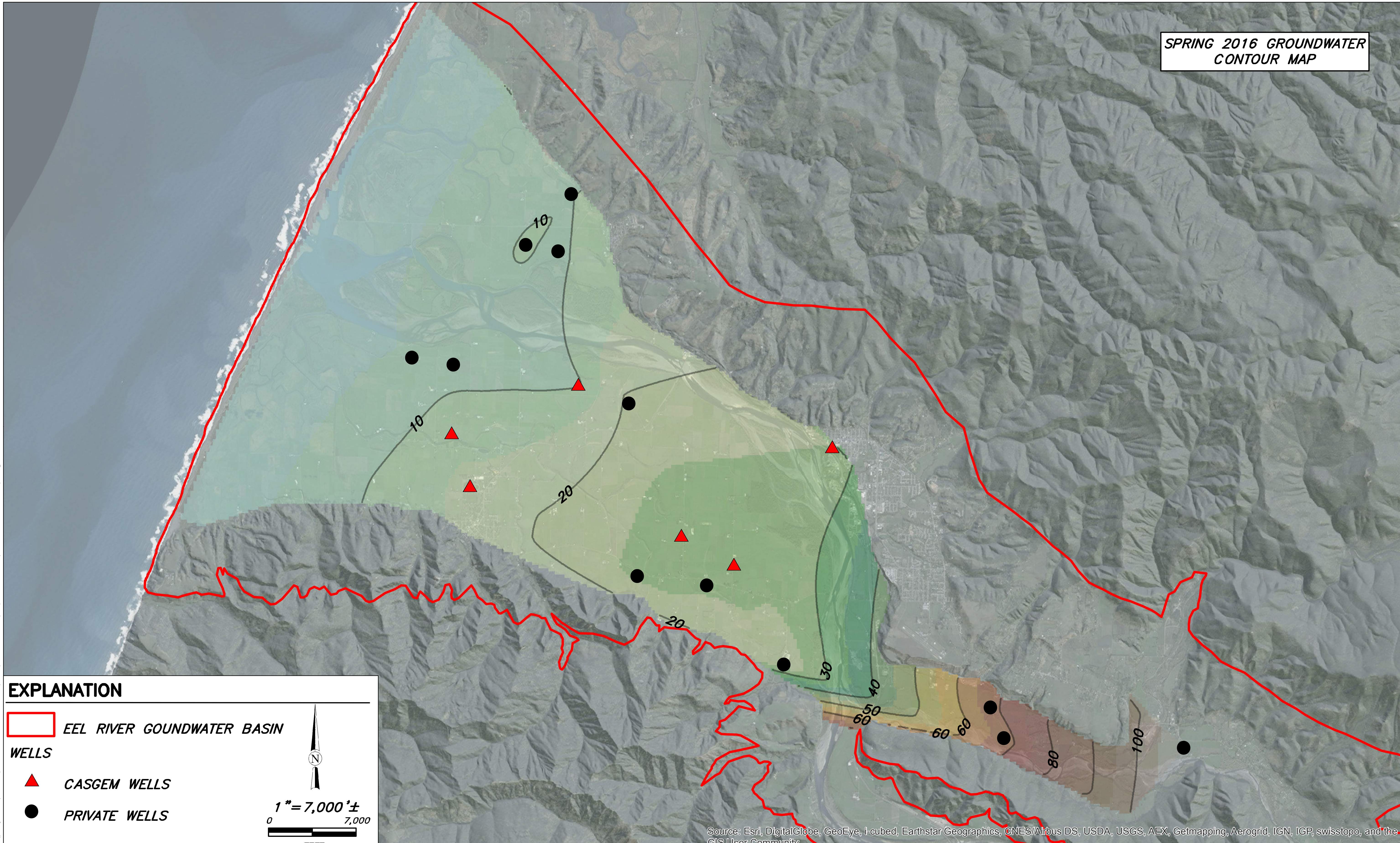
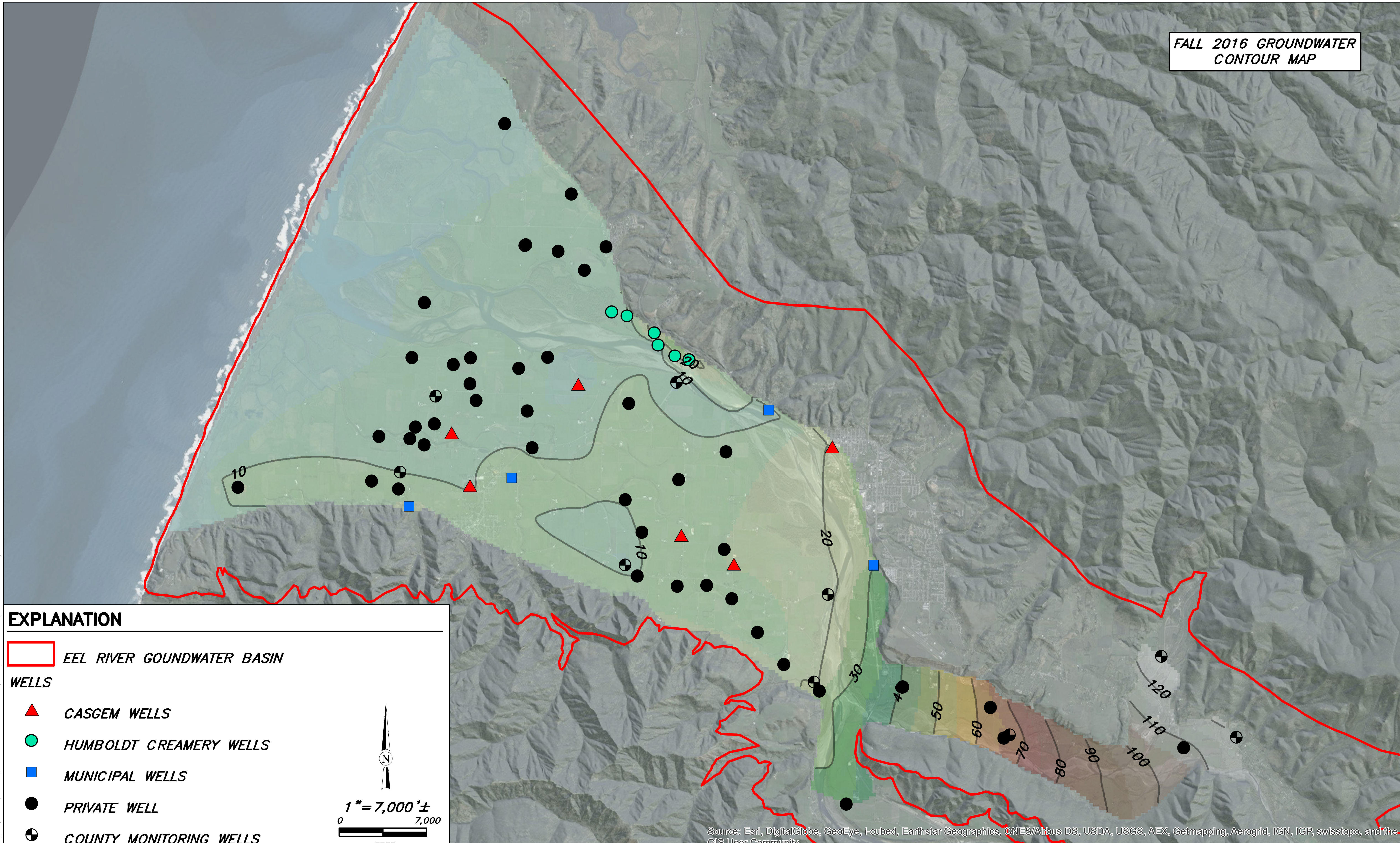
SHN Consulting Engineers & Geologists, Inc.	Humboldt County Public Works Eel River Groundwater Assessment Humboldt County, California	Groundwater and Surface Water Monitoring Locations SHN 016219	
	December 2016	GWSW_Monitoring_Locations	Figure 3-11



CASGEM WELLS MEASURED BY DWR ON 3/29/2016;
PRIVATE WELLS MEASURED BY DON AND CHERYL LAFFRANCHI ON 3/1/2016

SHN Consulting Engineers & Geologists, Inc.	Humboldt County Public Works Eel River GW Assessment Humboldt County, California	Groundwater Elevation Map - Spring 2016 SHN 016219
	December 2016 / GW_Elevations_Spring2016	Figure 3-12



SEE APPENDIX F FOR DETAILS ON SAMPLING DATES

SHN Consulting Engineers & Geologists, Inc.

Humboldt County Public Works
Eel River GW Assessment
Humboldt County, California

Groundwater Elevation Map - Fall 2016
SHN 016219

December 2016 | GW_Elevations_Fall2016 | Figure 3-13

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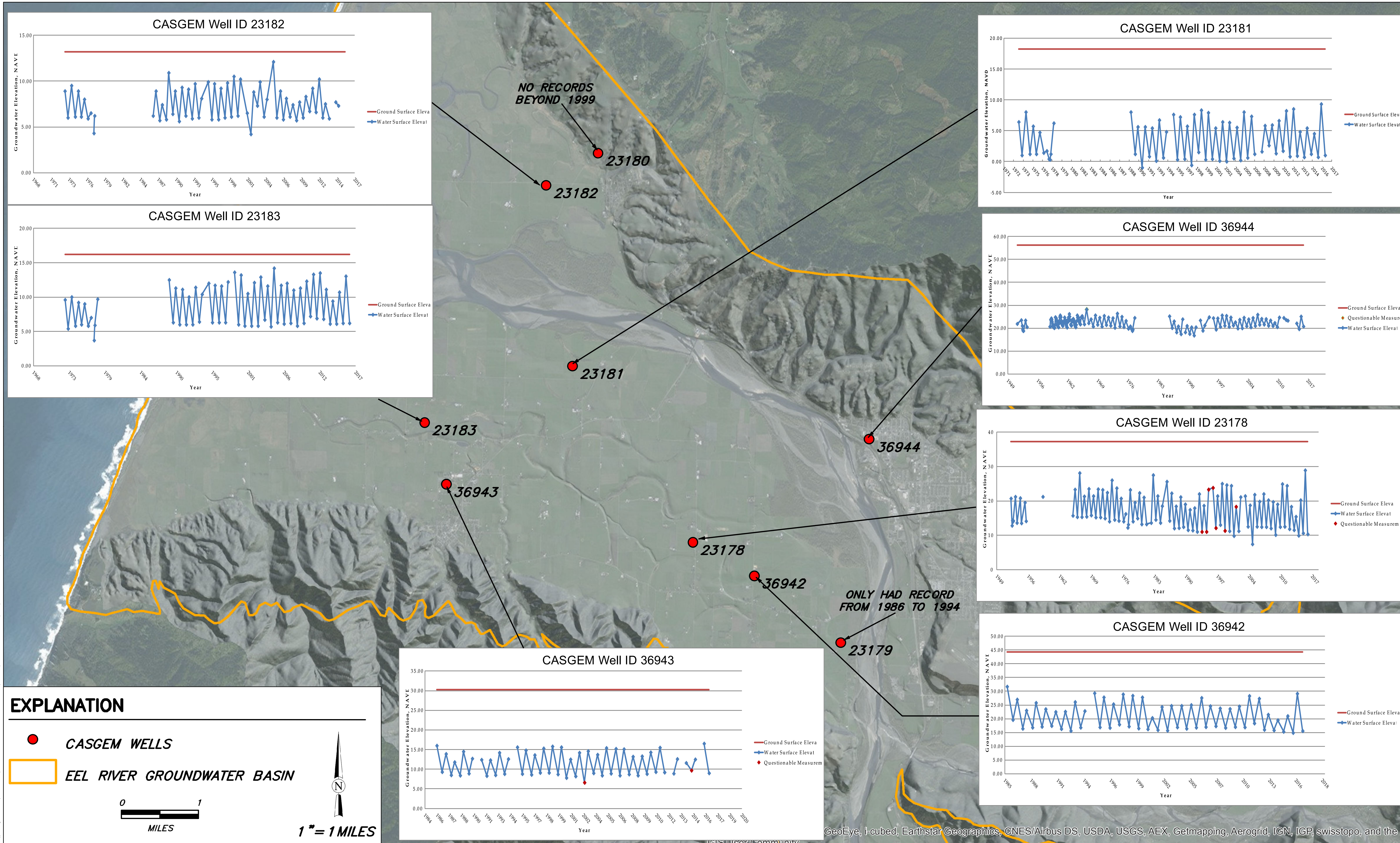

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Humboldt County Public Works
Eel River GW Assessment
Humboldt County, California

CASGEM Well
Locations and Hydrographs
SHN 016219

December 2016 | CASGEMWell_Locations | Figure 3-14

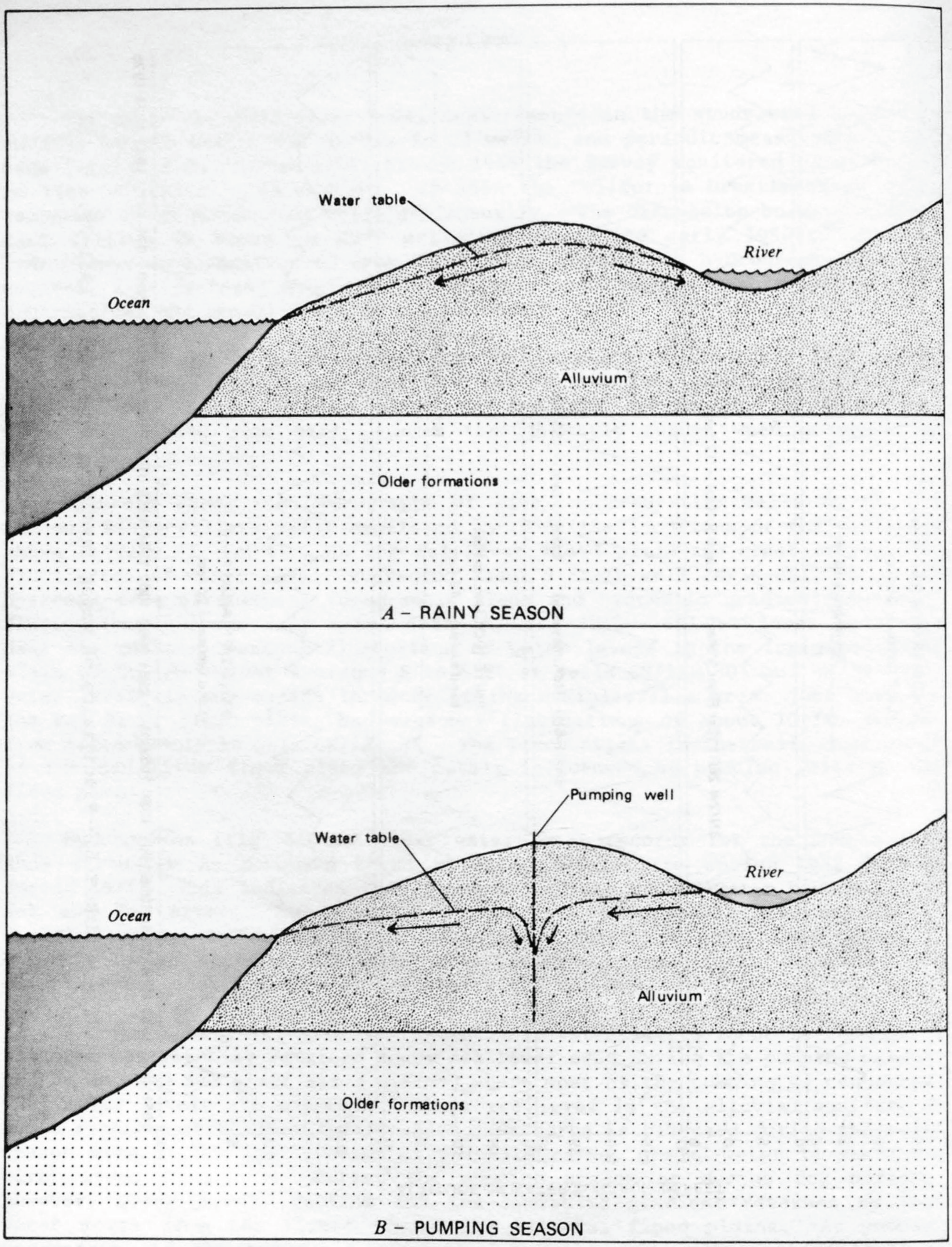
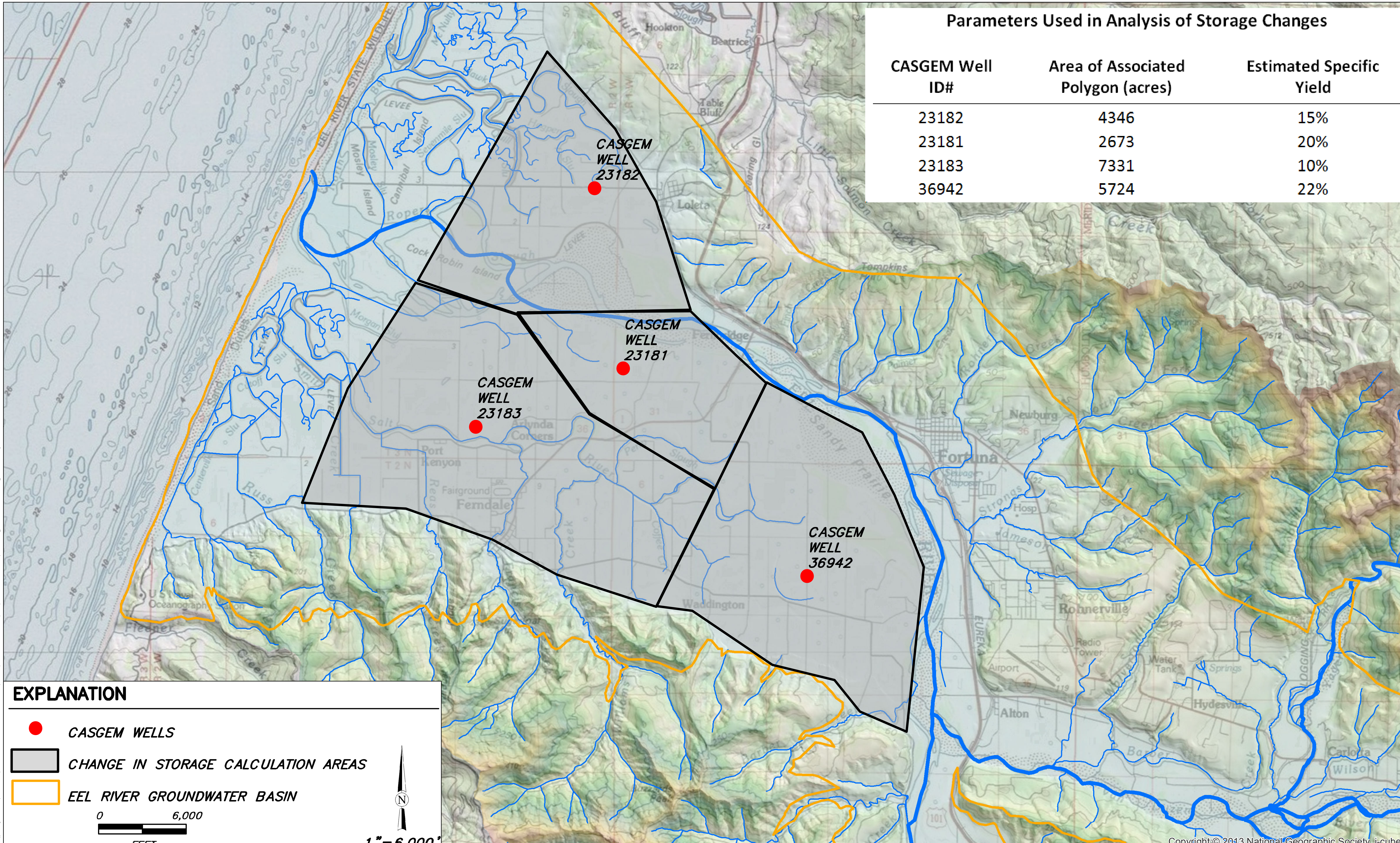


FIGURE 6.--Relation of water table to river and direction of ground-water flow during the rainy season and pumping season.

Parameters Used in Analysis of Storage Changes

CASGEM Well ID#	Area of Associated Polygon (acres)	Estimated Specific Yield
23182	4346	15%
23181	2673	20%
23183	7331	10%
36942	5724	22%



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Humboldt County Public Works
Eel River Groundwater Assessment
Humboldt County, California

CASGEM Wells and Associated Areas Used in Change in Storage Analysis
SHN 016219

December 2016 | Change_in_Storage_Analysis | Figure 3-16

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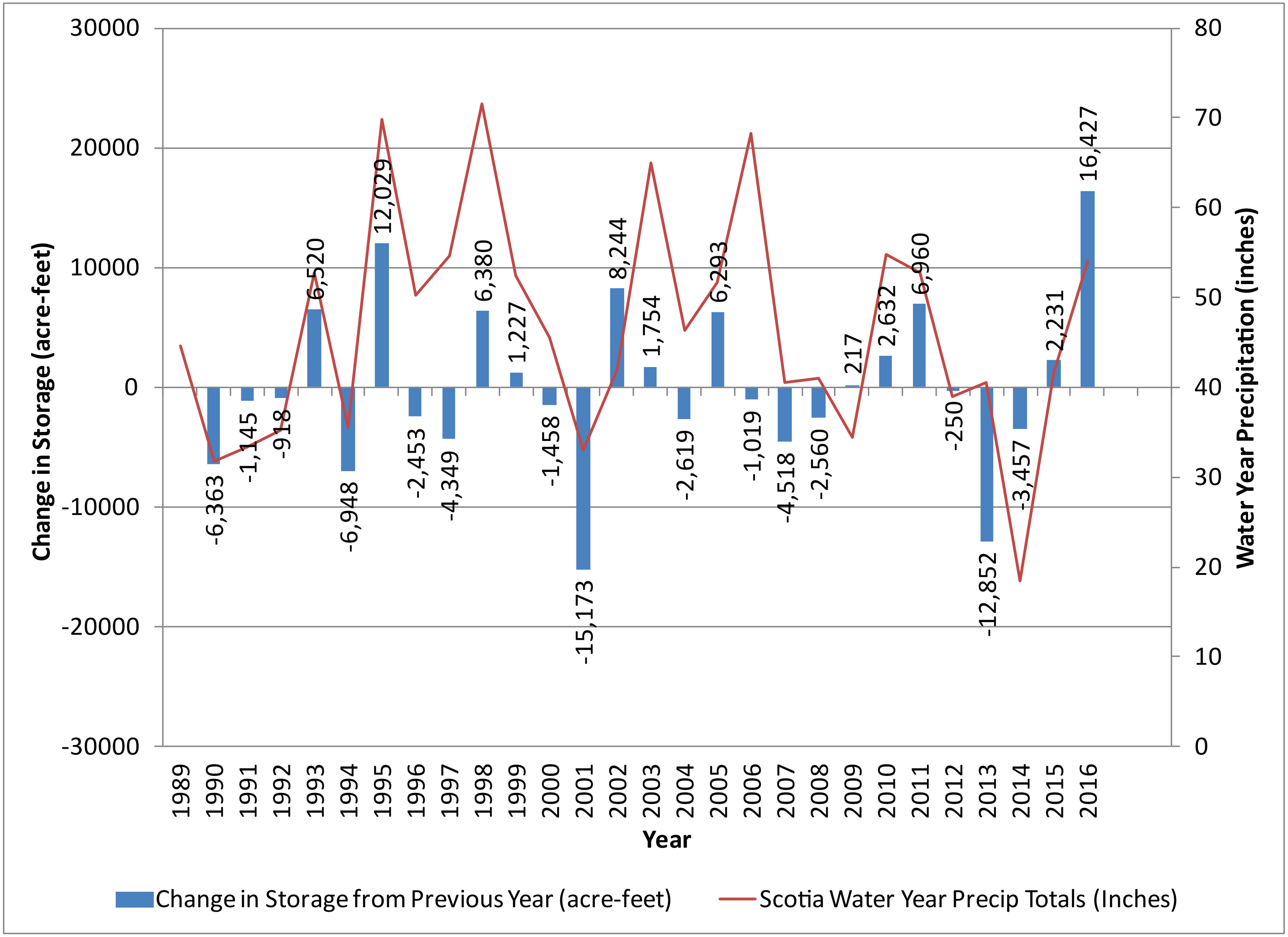

NOTE: CHANGES IN GROUNDWATER STORAGE WERE CALCULATED USING THE LONG-TERM BI-ANNUAL WATER LEVELS RECORDED BY DWR IN REPRESENTATIVE WELLS (SEE FIGURE 3-16).

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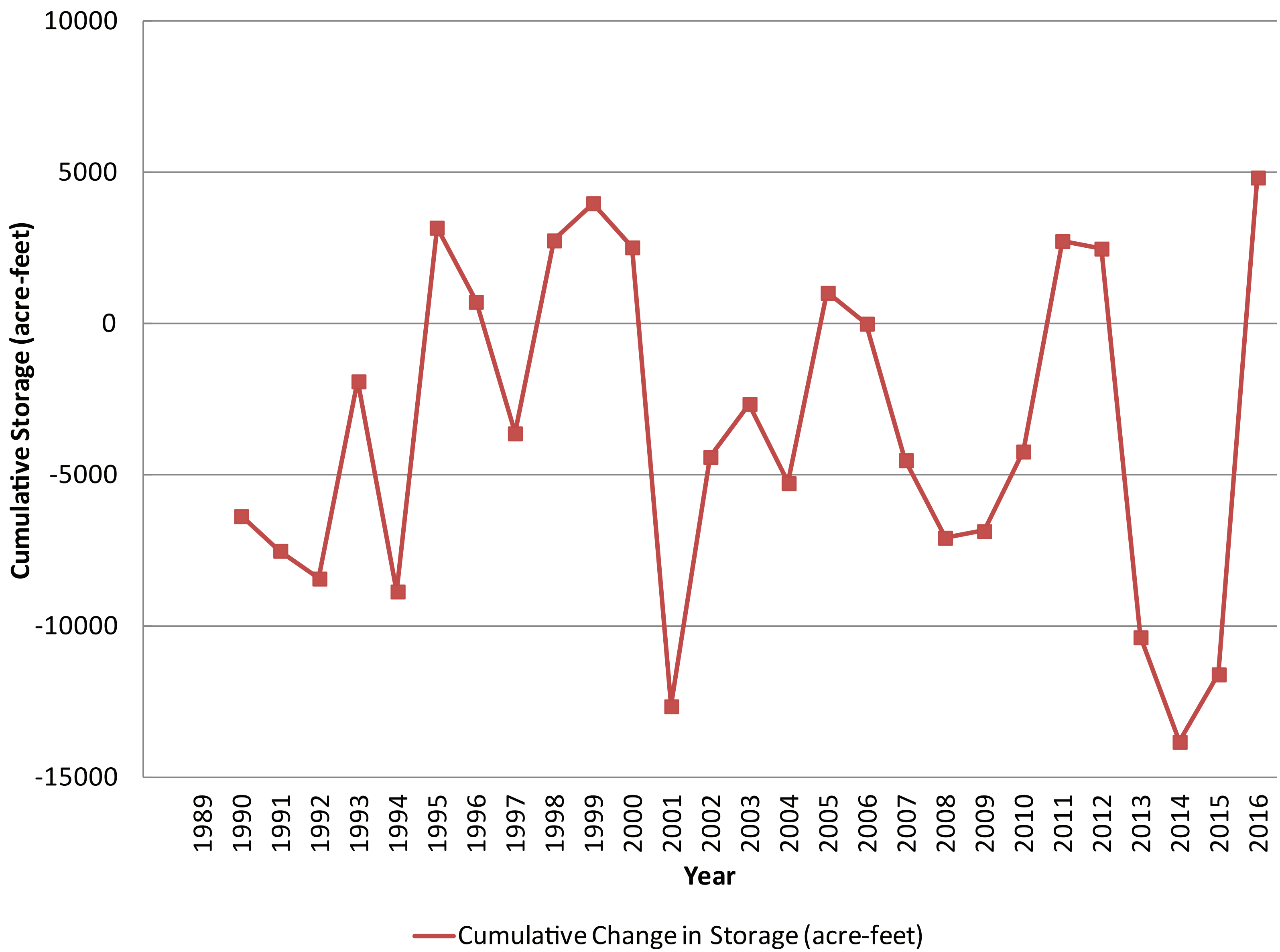
Humboldt County Public Works
Eel River Groundwater Assessment
Humboldt County, California

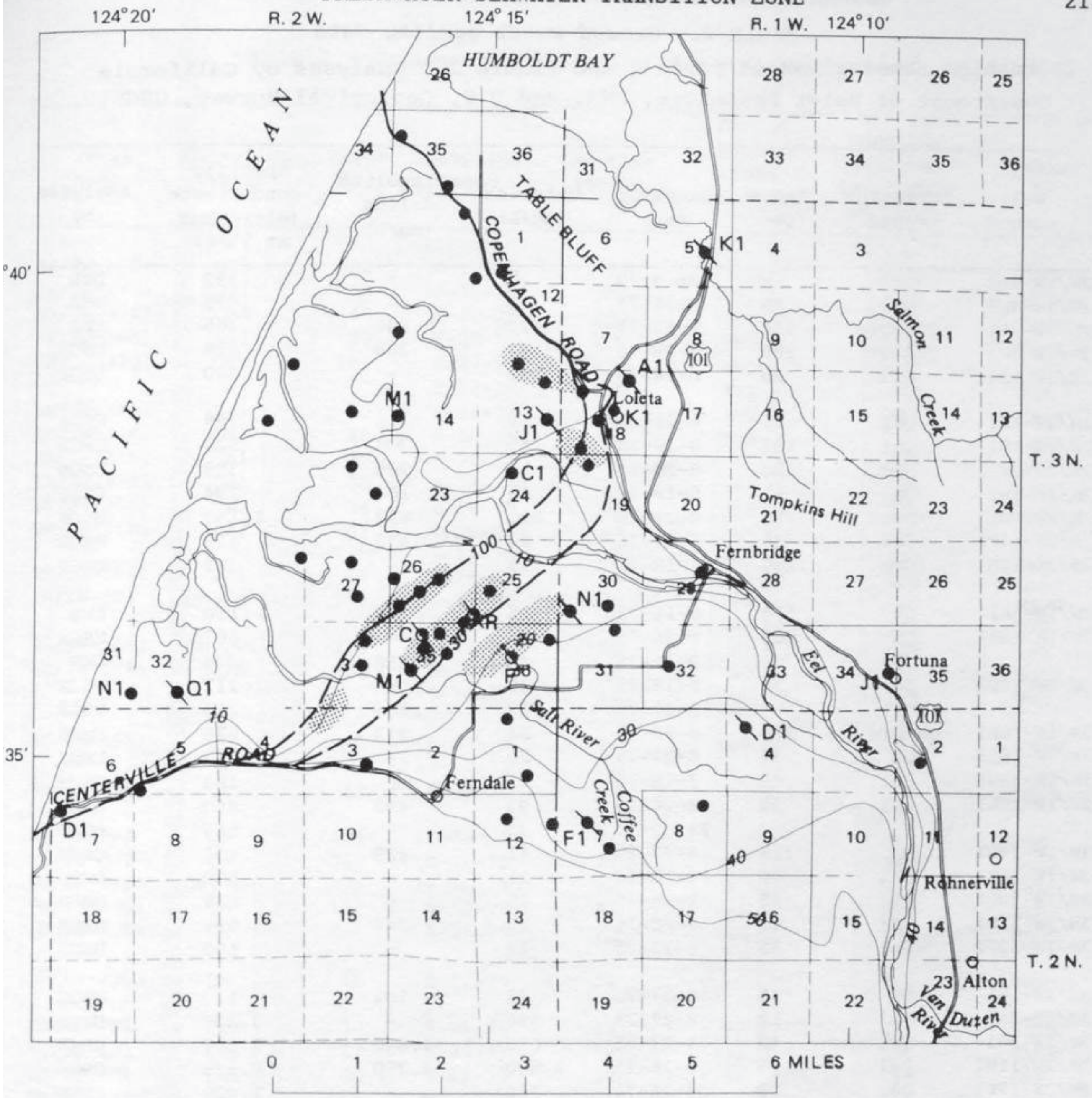
Changes in Groundwater Storage in the Lower Eel River Valley
SHN 016219

December 2016 | StorageWY.ai | Figure 3-17

Path: \\eureka\projects\2016\016219-EelRiverGW\GIS\FIGURES\Report_Figures\CumulativeStorage.pdf



SHN Consulting Engineers & Geologists, Inc.	Humboldt County Public Works Eel River Groundwater Assessment Humboldt County, California	Cumulative Changes in Storage in the Lower Eel River Valley SHN 016219
	December 2016 / CumulativeStorage.pdf	Figure 3-18



CONTOUR INTERVAL 10 FEET
DATUM IS MEAN SEA LEVEL

EXPLANATION

Area suggested for additional water-quality monitoring

—30— — LINE OF EQUAL CHLORIDE CONCENTRATION, 1975 – Dashed where approximately located. Concentration in milligrams per liter. The 100-milligrams-per-liter line indicates the landward edge of the freshwater-seawater transition zone. Area generally east of the 30-milligrams-per-liter line contains shallow ground water with chloride concentrations less than 30 milligrams per liter

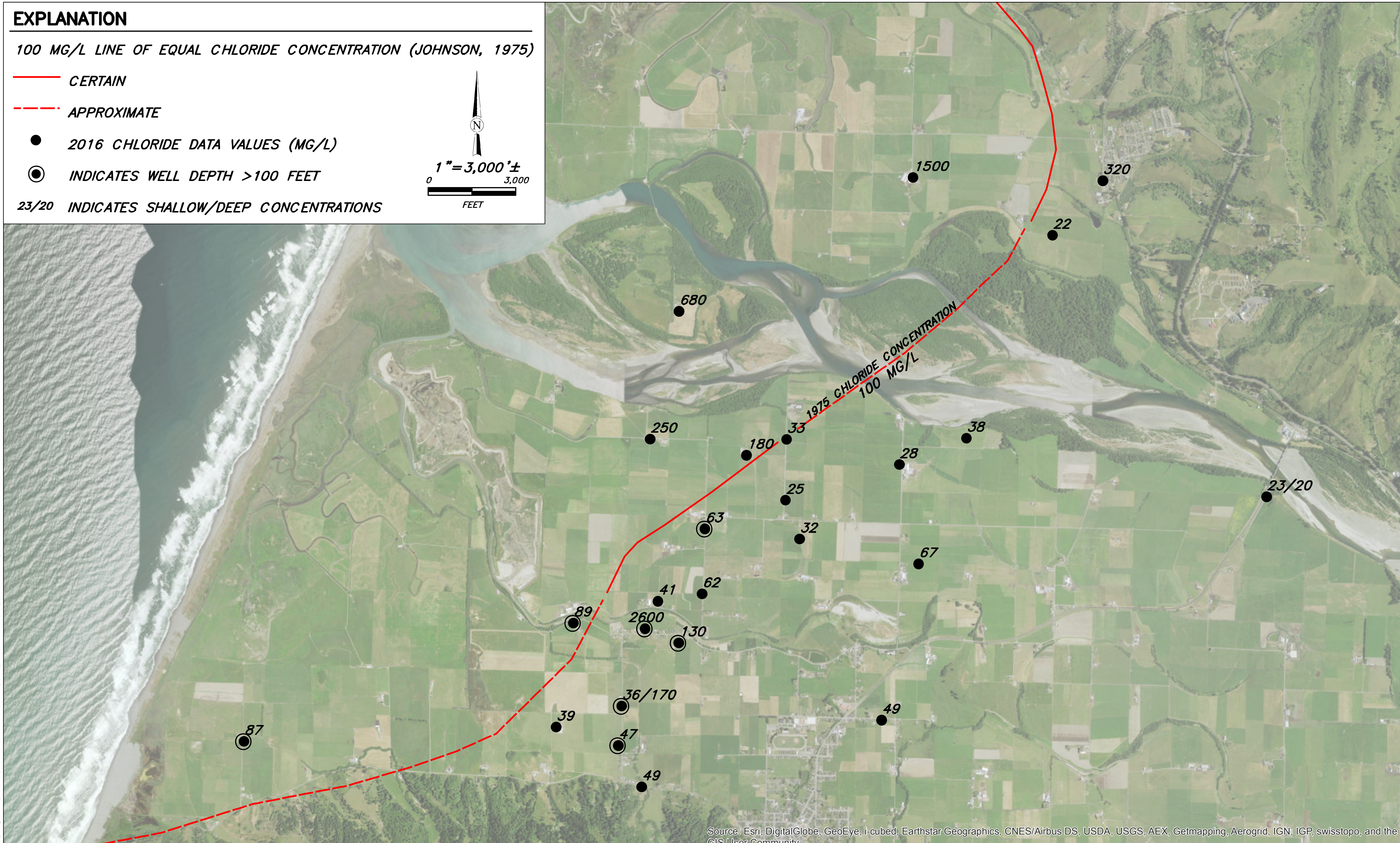
D1 ● Control well and identification for well referred to in text

M1 Well monitored by California Department of Water Resources and identification for well referred to in text

C Recommended additional monitoring well and identification for well referred to in text

NOTE: FROM USGS, 1975

SHN Consulting Engineers & Geologists, Inc.	Humboldt County Public Works Eel River Groundwater Assessment Humboldt County, California	Freshwater/Seawater Transition Zone In Alluvial Aquifer, Eel River Valley-1975 SHN 016219
December 2016	SaltwaterFreshwater_Interface_1975.pdf	Figure 3-19



NOTE: SEE APPENDIX F FOR DETAILS ON SAMPLING DATES

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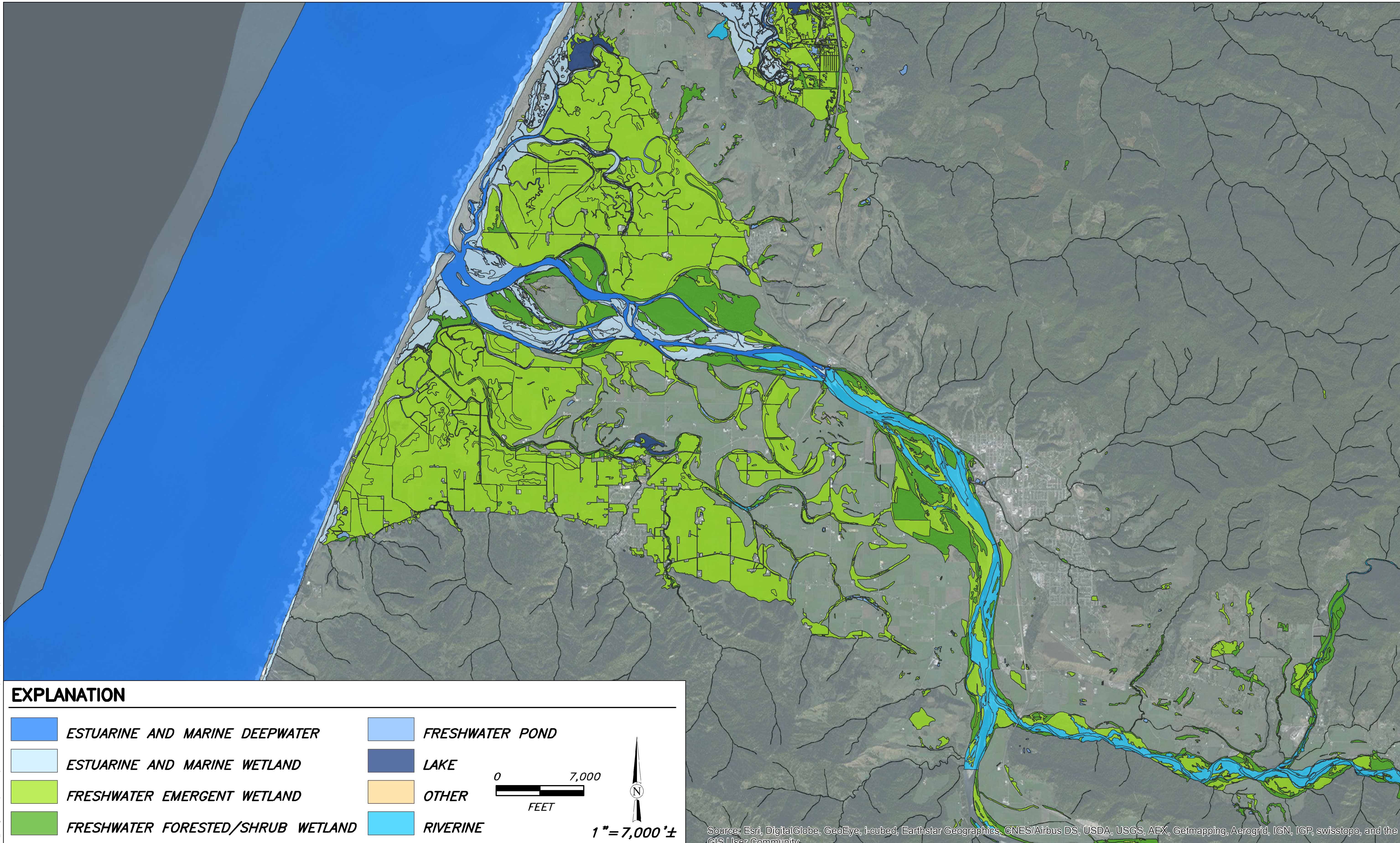
Humboldt County Public Works
Eel River Groundwater Assessment
Humboldt County, California

2016 Chloride Concentrations Map
SHN 016219

December 2016 | Chloride_Concentrations | Figure 3-20



NOTE: NATIONAL WETLANDS INVENTORY FROM U.S. FISH AND WILDLIFE SERVICE—ACCESSED 2016

SHN Consulting Engineers & Geologists, Inc.

Humboldt County Public Works
Eel River GW Assessment
Humboldt County, California

National Wetlands Inventory
SHN 016219

December 2016 | NWI | Figure 3-21

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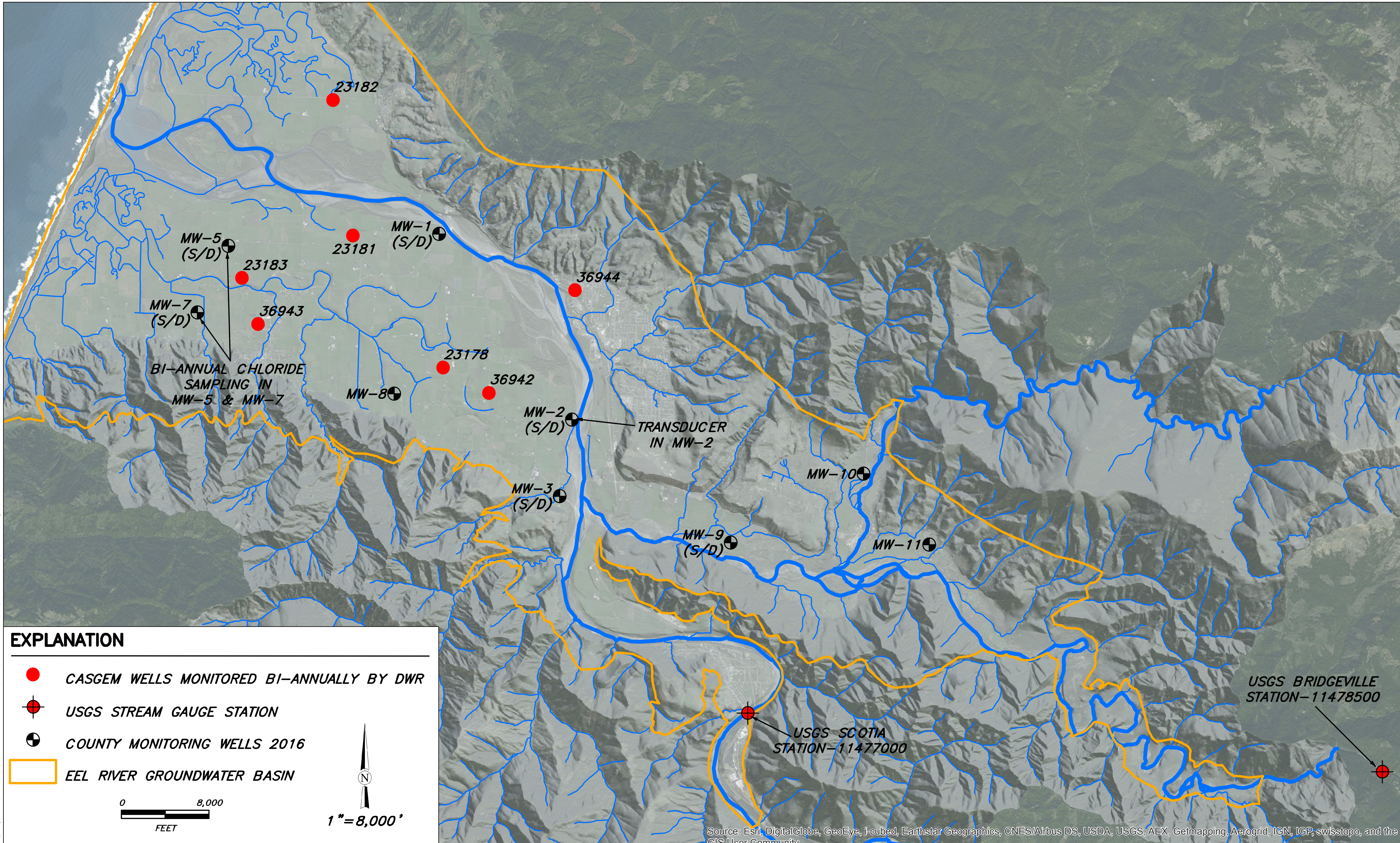

SHN Consulting Engineers & Geologists, Inc.

Humboldt County Public Works
Eel River Groundwater Assessment
Humboldt County, California

Monitoring Network Locations
SHN 016219

December 2016 | Monitoring_Network_Locations | Figure 4-1

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