Sonoma County Well Ordinance
Public Trust Review Area Delineation

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Introduction

Sonoma County is developing a new ordinance to modify how the county's permitting agency, Permit Sonoma, will evaluate applications for proposed groundwater wells. The objective of the revised ordinance is to include a process for consideration of impacts to public trust resources (PTR), consistent with responsibilities under the Public Trust Doctrine. The Public Trust Doctrine affirms the public's right to use California's waterways for navigation, fishing, recreation, habitat protection, and other water-oriented activities. Broadly, PTR are the natural resources that the government holds 'in trust' for the benefit of current and future generations for certain public trust purposes or uses including commerce, navigation, recreation, fishing, wildlife habitat, and preservation of trust lands in their natural state.

The Public Trust Doctrine applies to navigable waters. Diversions of non-navigable surface water or groundwater that impact PTR of navigable waters are also subject to review under the Public Trust Doctrine. The doctrine applies to the extraction of groundwater that impacts a navigable waterway, and in such circumstances, the County has a responsibility to consider the impact on PTR and implement mitigation measures to the extent feasible.

Groundwater pumping has the potential to diminish such PTR by reducing streamflow, a process referred to by hydrogeologists as "streamflow depletion". For the purposes of well permitting, it is useful to identify areas where PTR may be sensitive to groundwater pumping. The "Public Trust Review Area" (PTRA) is intended to define this area. The PTRA defines portions of the County where certain requirements, standards, or conditions will apply for approval of permit applications for different categories of wells to reduce or mitigate potential impacts to PTR. Additional review and water conservation requirements are intended to avoid or mitigate adverse impacts to PTR. The PTRA has been identified based on analyses and interpretations of aquatic habitat value, hydrogeologic conditions, processes that generate streamflow, and groundwater use that could cause streamflow depletion in the County. This document summarizes these analyses and the geographic areas they delineate.

Policy and Technical Working Group members recommended that evaluation of impacts to PTR should focus on impacts to aquatic habitat of navigable and non-navigable tributary streams that support salmonids. Salmonids inhabit and depend on habitat conditions of both navigable and non-navigable waterways and migrate between the two over their various life stages. Groundwater extraction has the potential to decrease streamflow, alter flow and habitat conditions, and therefore impact salmonid habitat within non-navigable and navigable waterways. Salmonids have been found to be particularly sensitive to flow conditions in non-navigable tributary streams during periods of summer rearing.

While non-navigable waters are not subject to the public trust, in order to meaningfully address impacts to trust resources for uses including wildlife habitat where wildlife move from non-navigable to navigable waters, consideration of impacts to PTR should include an expanded scope. For this reason, working group members recommended that impacts to salmonid habitat be considered by the County when permitting wells, even when the impact may

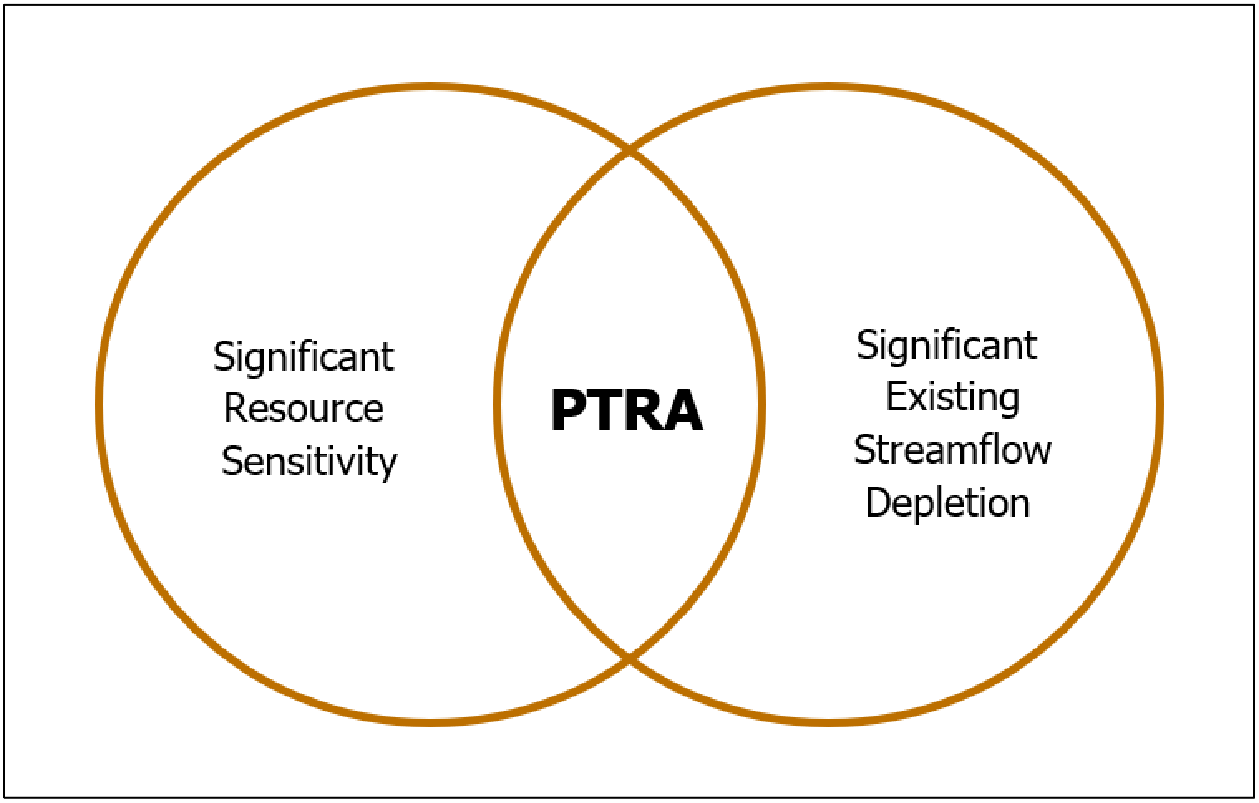

Figure 1: Diagram showing the two factors used to define the PTRA.

be to non-navigable waters that are tributary to navigable waters. Following the direction of the working groups and for the purposes of delineation of the PTRA, all navigable waters, and non-navigable waters that support salmonids are proposed for consideration in the well permit process. Non-navigable waters that do not support salmonids are not proposed for consideration in the permit process.

A risk-based approach was developed to define the PTRA. This approach considers two primary factors: the sensitivity of the PTR to streamflow depletion and the best available estimates of existing streamflow depletion. The PTRA describes the portions of the County where both sensitivity of PTR and estimated streamflow depletion are relatively high (Figure 1); in these areas, additional oversight of well construction is needed to prevent significant degradation of PTR. These areas are differentiated from areas outside the PTRA where risks are relatively low, and the County's current ministerial permitting process can continue.

Evaluation of the sensitivity of PTR focuses on aquatic habitat and uses salmonids (coho salmon and steelhead trout) as indicator species sensitive to streamflow depletion to represent overall sensitivity of PTR. This approach has received general consensus from working group members as well as from the Groundwater Dependent Ecosystem practitioner working groups that were convened as part of the Groundwater Sustainability Agency process for the Santa Rosa Plain, Sonoma Valley, and Petaluma Valley groundwater basins. Estimates of existing streamflow depletion are based on county-wide estimates of groundwater pumping in comparison to estimates of groundwater recharge from prior hydrologic modeling (Kobor & O'Connor, 2017). The relationship between estimated groundwater pumping and estimated groundwater recharge as a predictor of streamflow depletion is derived from existing distributed hydrologic models of three watersheds that are calibrated using existing data to directly simulate streamflow depletion as a function of groundwater pumping (Kobor & O'Connor, 2016, Kobor et al., 2020; Kobor et al., 2021).

Public Trust Review Area Mapping Overview

There are many potential approaches to mapping the PTRA spanning a wide range of complexity and data requirements. The adopted approach was selected as the best use of available data and numerical model predictions pertaining to streamflow depletion for implementation at the county scale within the time constraints of the ordinance development process. The approach integrates various existing data sources describing habitat and groundwater recharge and pumping conditions and uses predictions from existing numerical hydrologic models to interpret those data in relation to streamflow depletion and effects on PTR. Simpler approaches are more likely to result in less skillful predictions due to lack of representation of key factors driving streamflow depletion that are better represented in available numerical models, whereas more complex approaches would require significant input data and estimation of poorly constrained aquifer hydraulic parameter values across complex and variable hydrogeologic settings leading to larger uncertainty. Although the adopted approach is considered the preferred approach given data and implementation timeline constraints, it is subject to limitations and uncertainty associated with data availability and simplifying assumptions.

A series of steps were performed to define the two factors (resource sensitivity & existing streamflow depletion), interpret them using a classification system, and use those interpretations to map the PTRA (Figure 2). Mapping was performed at the HUC-14 watershed scale which divides the County into a series of subwatersheds based on drainage area. This mapping scale allows for significant spatial detail but doesn't attempt to map conditions at a scale beyond what can be justified given the limits of the underlying input data and assumptions. Resource sensitivity was mapped based on a combination of critical steelhead and coho habitat. Existing streamflow depletion was mapped by estimating existing groundwater pumping and recharge, calculating the ratio of pumping to recharge, and relating those ratios to streamflow depletion based on the findings of existing numerical hydrologic models. Finally, a classification system was developed to integrate the two factors (resource sensitivity & existing streamflow depletion) and map the PTRA (Figure 2). Each of these steps is explained in greater detail below.

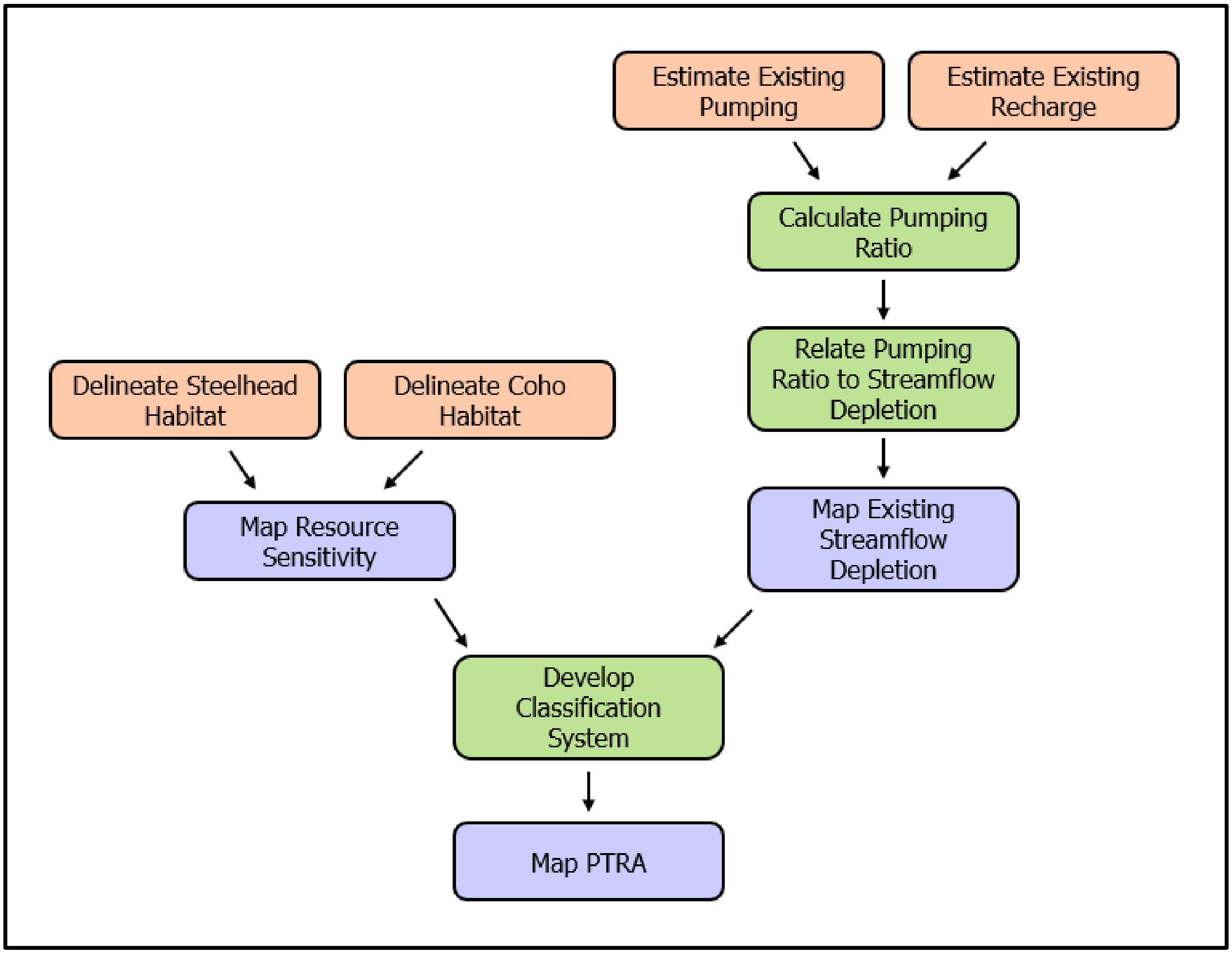

Figure 2: Diagram showing the steps used to define the PTRA.

Habitat & Resource Sensitivity Mapping

Central California Coast coho salmon (*Oncorhynchus kisutch*) are listed as endangered under the Federal Endangered Species Act (ESA) and extensive efforts are underway to restore habitat conditions in the key watersheds in Sonoma County that support the species. For purposes of defining the PTRA, these key watersheds were considered representative of the areas of the county where PTR are most sensitive. High priority coho habitat streams within the Russian River basin were identified from an ArcGIS shapefile obtained from the California Department of Fish & Wildlife (CDFW, 2023). High priority coho habitat streams outside of the Russian River basin were based on the 'Core' and 'Phase I Expansion' areas identified as priority areas for restoration in the Federal recovery plan for central coast coho (NMFS, 2012). The HUC-14 watersheds corresponding to the high priority coho streams were selected to represent waters with "High" sensitivity PTR.

Central California Coast Steelhead and Northern California Steelhead (*Oncorhynchus mykiss*) are listed as threatened under the Federal ESA. Watersheds providing steelhead habitat were selected to represent waters with “Medium” sensitivity PTR. ArcGIS shapefiles of critical steelhead habitat streams were obtained from the National Marine Fisheries Service (NMFS, 2023). The HUC-14 watersheds corresponding to the high priority steelhead streams that were not coded as “High” sensitivity as described above for coho habitat were coded as ”Medium” sensitivity PTR.

HUC-14 watersheds not considered as priority habitat of either coho or steelhead were coded as “Low” sensitivity PTR.

Within the Petaluma River basin, HUC-14 watershed boundaries were adjusted to include areas draining to streams with documented steelhead spawning activity based on available spawning survey information (Leidy et al., 2005; NMFS, 2014) and coded as ”Medium” PTR sensitivity; watersheds not identified as providing spawning habitat were coded as ”Low” for PTR sensitivity. Within the lower portions of the Sonoma Creek basin, areas draining to creeks not identified as critical habitat for steelhead or coho that flow directly into tidally influenced reaches were coded as ”Low” sensitivity PTR.

A group of fisheries experts from NMFS, CDFW, Cal Trout, Sonoma Water, and Sonoma Ecology Center with detailed local knowledge of habitat conditions in Sonoma County was convened. The group reviewed the draft aquatic habitat classification maps discussed above and suggested a set of revisions designed to improve the initial mapping by incorporating more detailed local knowledge. Due to their critical importance at the basin and state-wide level, a new “Very High” sensitivity category was added for Mill, Mark West, Green Valley, and Dutch Bill Creeks. These four watersheds were the subject of the 2015 State Water Resources Control Board’s Emergency Information Order and are widely considered to be the most important watersheds for supporting coho restoration efforts in the lower Russian River. The Wheatfield Fork of the Gualala River watershed and the Adobe Creek watershed were reclassified from medium to high given they are considered the most important steelhead streams in the Gualala River and Petaluma River watersheds respectively. The Ward Creek watersheds were also reclassified from medium high to high consistent with the rest of the Austin Creek Watershed. The Windsor Creek Watershed and portions of the southern Sonoma Valley were reclassified from medium to low owing to their low importance for supporting steelhead compared to the other identified priority watersheds (Leidy et al., 2005; Sonoma Water et al., 2022).

Watersheds with high or very high sensitivity PTR comprise ~482 square miles (30% of the County) including the Salmon, Willow, Dutch Bill, Green Valley, Austin, Porter, Mill, Pena, Dry, Mark West and Redwood Creek watersheds as well as the South Fork Gualala River watershed (Figure 1). Watersheds with medium sensitivity PTR comprise ~665 square miles (41% of the County) and include most of the Russian River watershed not classified as high or very high excluding the Santa Rosa Plain and drainages impounded behind Warm Springs Dam. Watersheds with medium sensitivity PTR also include significant portions of the Sonoma Creek and Petaluma River drainages. Low resource sensitivity watersheds comprise the remaining ~477 square miles of the County (Figure 3).

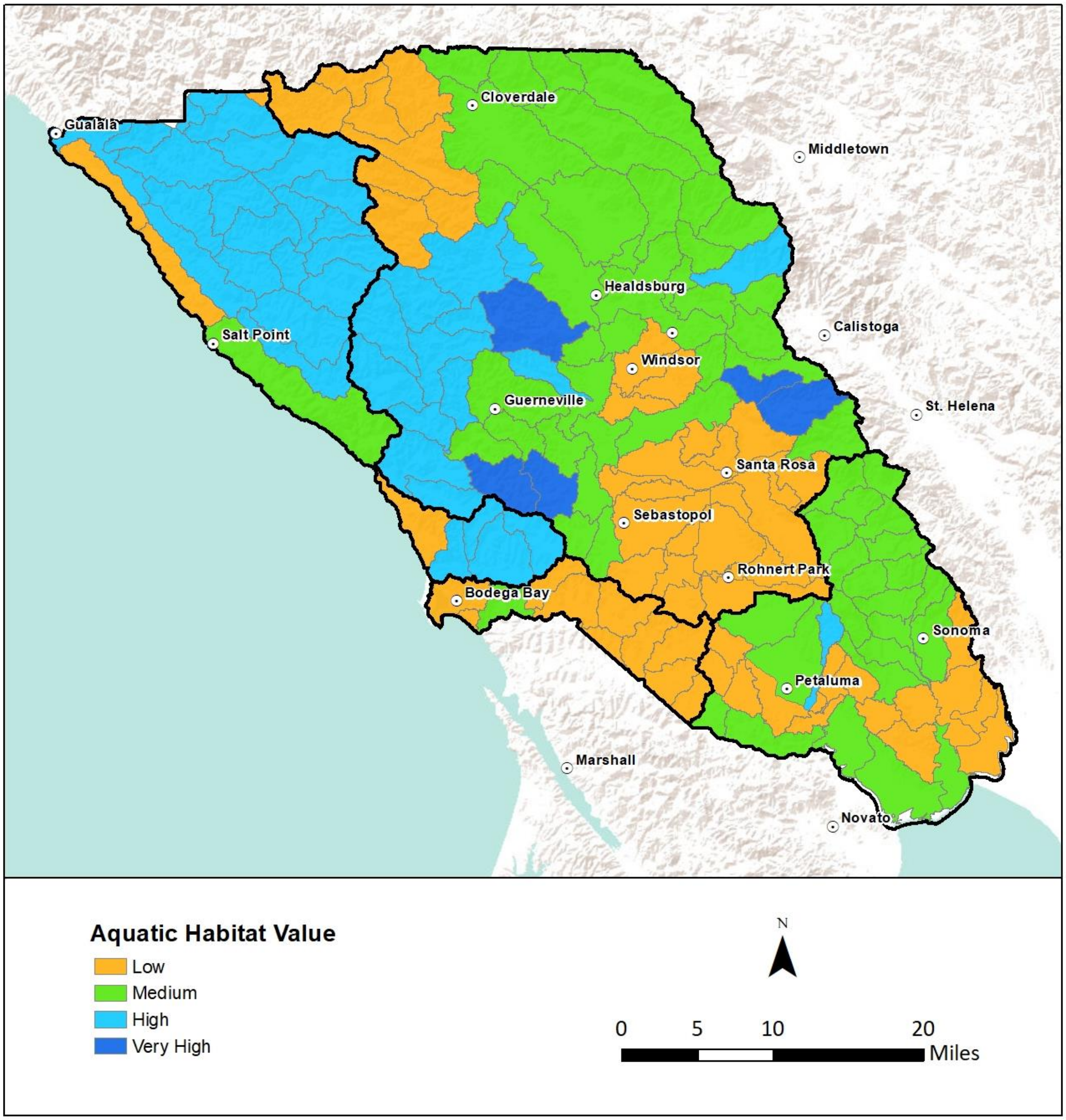

Figure 3: Subwatershed resource sensitivity classification based on aquatic habitat value.

Streamflow Depletion Estimation

Background

For the purposes of this analysis, streamflow depletion is defined as the reduction in streamflow resulting from groundwater pumping. Streamflow depletion is a consequence of the law of physics requiring the conservation of mass applied to water balance models describing the movement of water in watersheds and groundwater aquifers. In such water balance models, inflows to an aquifer must be balanced by outflows from the aquifer adjusted for changes in the volume of water in storage. In most watersheds, streamflow accounts for the majority of outflow; as groundwater pumping proceeds, the volume of water supplied to wells is largely balanced by decreases in streamflow and/or aquifer storage. In the short-term, water supplied to wells is derived primarily from decreases in aquifer storage. Over longer periods these storage changes generally stabilize and streamflow depletion becomes the primary source of water pumped from wells (Barlow & Leake, 2012).

To better understand the definition of streamflow depletion, it is helpful to differentiate between “acute” and “cumulative” streamflow depletion. Acute manifestations of streamflow depletion occur when the time response of streamflow depletion is relatively short such that pumping by an individual well causes streamflow depletion coincident or near-coincident with the timing of pumping. Wells causing acute streamflow depletion are likely to have a disproportionate effect on streamflow because, in general, the timing of pumping over the summer/early fall months corresponds to the timing of minimum streamflows. Cumulative streamflow depletion occurs when the total volume of water pumped by a population of wells becomes significant relative to the total inflows to the aquifer and can occur regardless of the time response.

There are many methods available for estimating streamflow depletion due to groundwater pumping including field techniques, statistical and analytical solutions, and numerical models (Rathfelder, 2016; Zipper et al., 2022). There are distinct advantages and disadvantages to each of these approaches and direct application of any of them at the county-wide scale with limited time and resources is infeasible. Field investigation and statistical techniques for estimating streamflow depletion are inherently problematic owing to the difficulties of differentiating between changes in measured streamflow caused by groundwater pumping and changes caused by other factors such as climate-related fluctuations or surface water diversion. Analytical solutions are mathematical representations and predictions of the effect of individual pumping wells on groundwater elevations and the consequent reductions in groundwater flow delivered to stream channels. Analytical solutions are generally most applicable for addressing acute impacts from individual wells. Analytical solutions have the advantage of being relatively easy to implement but require many necessary simplifying assumptions regarding aquifer and stream channel geometries and hydraulic characteristics used to calculate groundwater flow (Rathfelder, 2016; Zipper et al., 2022). These simplifications and associated uncertainties limit the accuracy of analytical solutions in describing specific real-world conditions (Barlow & Leake, 2012). Physically based, spatially distributed and calibrated hydrologic numerical models are generally considered the most accurate tools for estimating streamflow depletion; however, these models require large amounts of input data and effort to implement.

The proposed approach for the PTRA analysis uses a relatively simple water balance method to estimate cumulative streamflow depletion that can be implemented across the County. This simple water balance approach is significantly enhanced by simulations of streamflow depletion from existing calibrated numerical hydrologic models of high priority coho watersheds. The approach also uses analytical solutions to guide determination of buffer zones around streams within which additional oversight of well construction may be required to prevent or mitigate acute streamflow depletion.

Groundwater Recharge, Pumping, & Pumping Ratio

As alluded to above in the discussion of water balance methods, for a conceptual watershed water balance with a control volume including groundwater aquifers, the status of the hydrologic system can be expressed most simply as:

Inflow = Outflow +/- Change in Storage (1)

Inflow and outflow terms in Equation 1 can be expanded to include more details describing hydrologic processes. For a water balance describing a groundwater system, inflows to an aquifer typically include groundwater recharge and subsurface inflow. Outflow terms typically include streamflow, groundwater pumping, evapotranspiration from groundwater, and subsurface outflow (Healy, 2010). Over long periods of time (years or decades), groundwater recharge generally represents the majority of inflow to an aquifer and stream baseflow (streamflow) and groundwater pumping generally represent the majority of outflow. Consequently, an approximate aquifer water balance can be restated as:

Groundwater Recharge ≈ Streamflow + Groundwater Pumping +/- Change in Storage (2)

As is clear from Equation 2, as groundwater pumping increases, those increases must be balanced by either reductions in streamflow (streamflow depletion), reductions in storage, or increases in groundwater recharge. Over the long-term, changes in storage and recharge generally stabilize such that the majority of water supplied to wells is balanced by streamflow depletion (Barlow & Leake, 2012). Cumulative streamflow depletion increases in proportion to cumulative groundwater pumping. As the rate of groundwater pumping approaches the rate of groundwater recharge, streamflow approaches zero; this scenario is equivalent to a ratio of groundwater pumping to groundwater recharge equal to one. From these relationships, it can be seen that the ratio of groundwater pumping to groundwater recharge (i.e., groundwater pumping divided by groundwater recharge) provides an objective, hydrologically significant, indicator of the relative magnitude of streamflow depletion occurring in a given watershed.

Groundwater pumping was estimated for each HUC-14 watershed in the County using the methodology adopted for the rate and fee studies that have been prepared for the three Groundwater Sustainability Agencies (GSA) in the county (SCI & LWA, 2022a; 2022b, 2022c). The method estimates residential and commercial uses at the parcel scale based on County Tax

Assessor use codes and descriptions and estimates irrigation uses at the parcel scale based on crop acreages as represented in data available from the California Department of Water Resources (DWR, 2018). Standard use rates were assigned for each use category as described in the rate and fee studies. Residential and commercial uses in areas served by public water systems (PWS) were excluded from the initial parcel-based estimates which were then aggregated to the HUC-14 watersheds. Groundwater use for PWS are reported to the state and these uses were added to the corresponding subwatershed use estimates. Five-year average annual uses were calculated within the GSAs, and outside of the GSAs the estimates were based on data from 2020.

A simplified approach was used to adjust the initial subwatershed estimates of groundwater pumping for the portion of use that is sourced from surface water. The DWR's Electronic Water Rights Information Management System (eWRIMS) data was used to associate all active points of diversion with a corresponding parcel. For small domestic water rights, surface water was assumed to meet the corresponding residential uses on a given parcel, and for all other active water rights, surface water was assumed to meet the corresponding irrigation uses on a given parcel. This approach does not consider riparian surface water rights or pre-1914 water rights not included in the eWRIMS. The final estimates of mean annual groundwater use are the sum of the initial parcel-based estimates and the PWS reported uses minus the surface water uses (Figure 4).

Annual groundwater use normalized by watershed area ranges from <0.25 to ~5 inches. The lowest cumulative groundwater use areas occurs in rural portions of the county including most of the South Fork Gualala River watershed, the Austin Creek watershed, Big Sulphur Creek watershed, and most watersheds draining to Dry Creek. The highest cumulative groundwater use areas occur in the Santa Rosa Plain, portions of the Sonoma Creek watershed, and the lower Atascadero Creek watershed (Figure 4).

Estimates of mean annual groundwater recharge were taken from an existing Soil Water Balance (SWB) model analysis of the County (Kobor & O'Connor, 2017). This model code was developed by the United States Geological Survey (USGS) to provide recharge estimates for numerical groundwater flow models. The model utilizes rainfall, temperature, land cover, and soils data and uses a curve number approach for runoff and a modified Thornthwaite-Mather soil water balance approach for simulating Actual Evapotranspiration and groundwater recharge (Westenbroek et al., 2010). The model was calibrated to available data from unimpaired watersheds at a monthly timescale (Kobor & O'Connor, 2017). This approach focuses on infiltration recharge only and does not consider streambed recharge which may be significant in some subwatersheds. Although the model does not account for spatial variations in bedrock conditions, it does represent the proportion of recharge that is unable to enter the aquifer due to aquifer hydraulic conductivity limitations (rejected recharge) through use of a calibrated maximum daily recharge value. Distributed results from the SWB analysis were aggregated to the HUC-14 watersheds (Figure 5) and the groundwater pumping ratio was calculated for each watershed as the ratio of mean annual groundwater recharge to mean annual groundwater pumping (Figure 4).

Estimated mean annual recharge ranges from ~3 to 18 inches and is largely controlled by the variations in precipitation and soil types across the county (Figure 5). The lowest recharge occurs in the drier southern portions of the County including the Sonoma and Petaluma Creek watersheds and portions of the Santa Rosa Plain particularly in areas dominated by clay-rich soils. Intermediate rates of annual recharge on the order of 9-12 inches occur over large portions of the northeastern and central parts of the County including the Alexander Valley, lower Dry Creek Valley, and the Green Valley and Atascadero Creek watersheds. The highest rates of annual recharge occur in the wetter northwestern portions of the County including the South Fork Gualala River and lower Russian River watersheds such as Austin Creek, particularly in areas dominated by silty and sandy soils (Figure 3).

The groundwater pumping ratio (groundwater pumping expressed as a percentage of estimated recharge) ranges from <2.5% to ~80% (Figure 6). The lowest ratios occur in the rural portions of the county which in general are also areas with moderate to high potential recharge rates. These areas include most of the South Fork Gualala River watershed, Big Sulphur Creek watershed, the south-flowing drainages in the lower Russian River watershed, and the upper and east-flowing watersheds draining to Dry Creek. Intermediate ratios (~5-20%) occur in the Alexander Valley, upper Green Valley and Atascadero Creek watersheds, and portions of the Santa Rosa Plain, the upper Petaluma River and upper Sonoma Creek watersheds. The largest ratios occur in the more densely developed portions of the county, particularly those areas with relatively low estimated potential recharge. These areas include most of the Santa Rosa Plain and portions of the Sonoma Creek and Petaluma River watersheds (Figure 6).

Streamflow Depletion

Existing distributed hydrologic models have been developed and calibrated to available streamflow and groundwater elevation data through several multi-year modeling efforts funded by CDFW and the California Wildlife Conservation Board (Kobor & O'Connor, 2016, Kobor et al., 2020; Kobor et al., 2021). These models cover most of the high priority coho watersheds in the county including the Mill, upper Mark West, Green Valley, Atascadero, and Dutch Bill Creek watersheds. Estimates of cumulative streamflow depletion following 50 years of pumping are available for upper Mill, Mark West, and Green Valley creeks. Each of these models was used to develop a second estimate of streamflow depletion using a hypothetical scenario with significantly higher pumping rates ranging from 3-8 times existing estimated pumping rates. A groundwater pumping ratio was calculated from the numerical models based on mean annual results over a representative 10-yr simulation period for each of the six pumping scenarios.

Despite substantial variations in geology across the watersheds, a reasonably well-defined relationship was established between the groundwater pumping ratio and the mean July through September percent streamflow depletion (Figure 7). This finding indicates that over timescales of several decades the relationship between the groundwater pumping ratio and streamflow depletion is relatively consistent across the range of bedrock geologies in Sonoma County. There

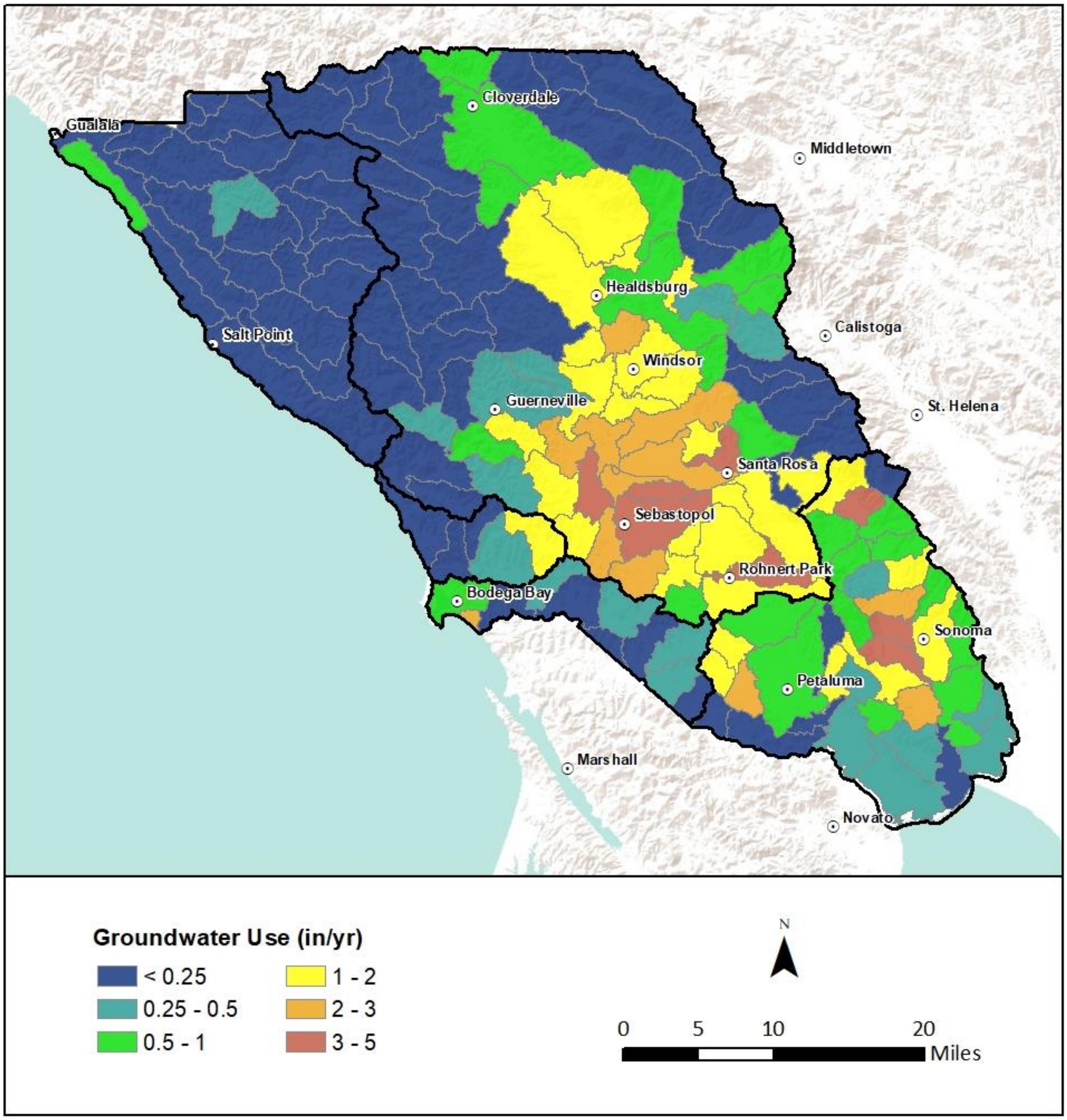

Figure 4: Estimated area-normalized mean annual groundwater use per subwatershed.

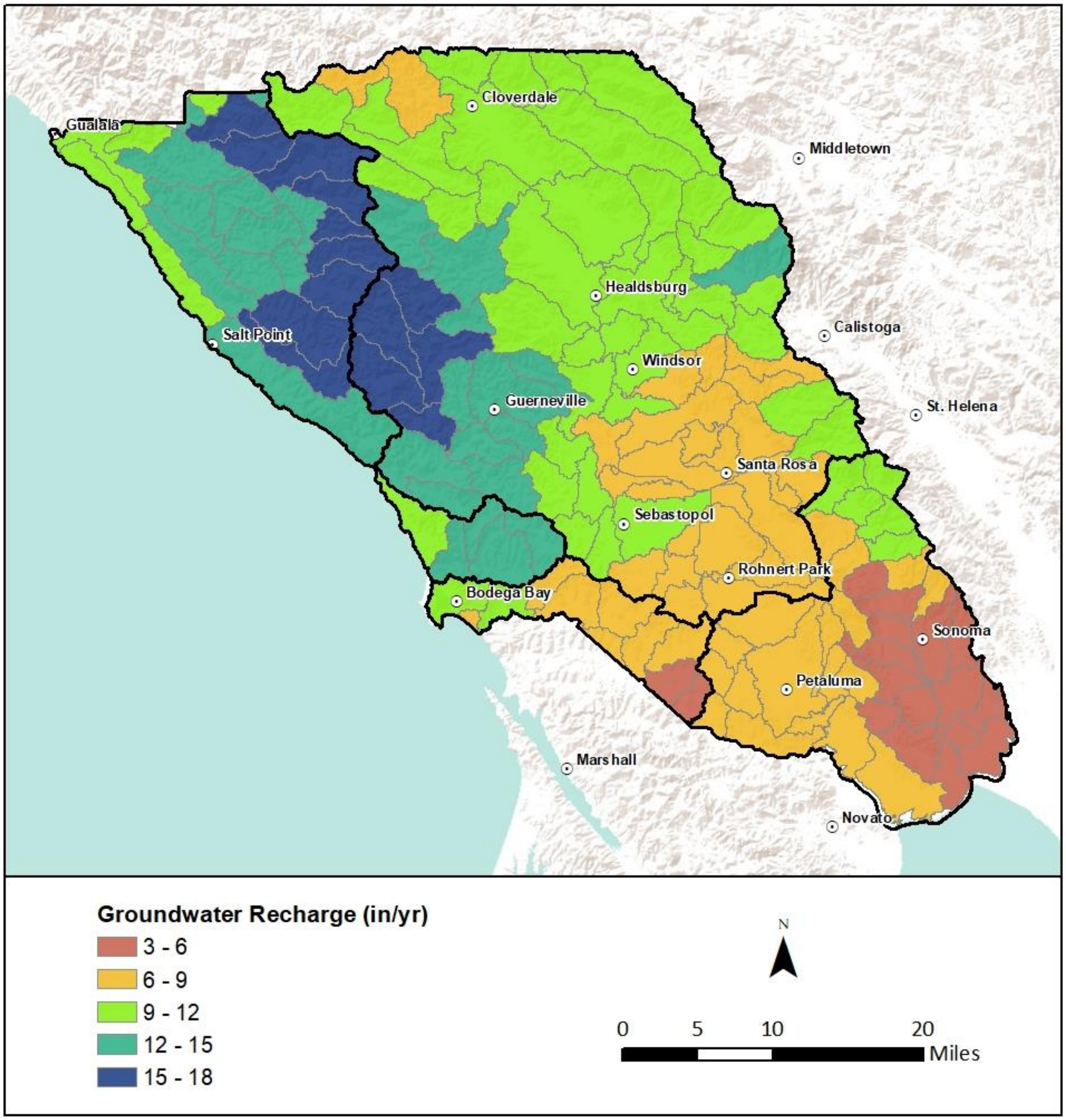

Figure 5: Estimated mean annual groundwater recharge per subwatershed.

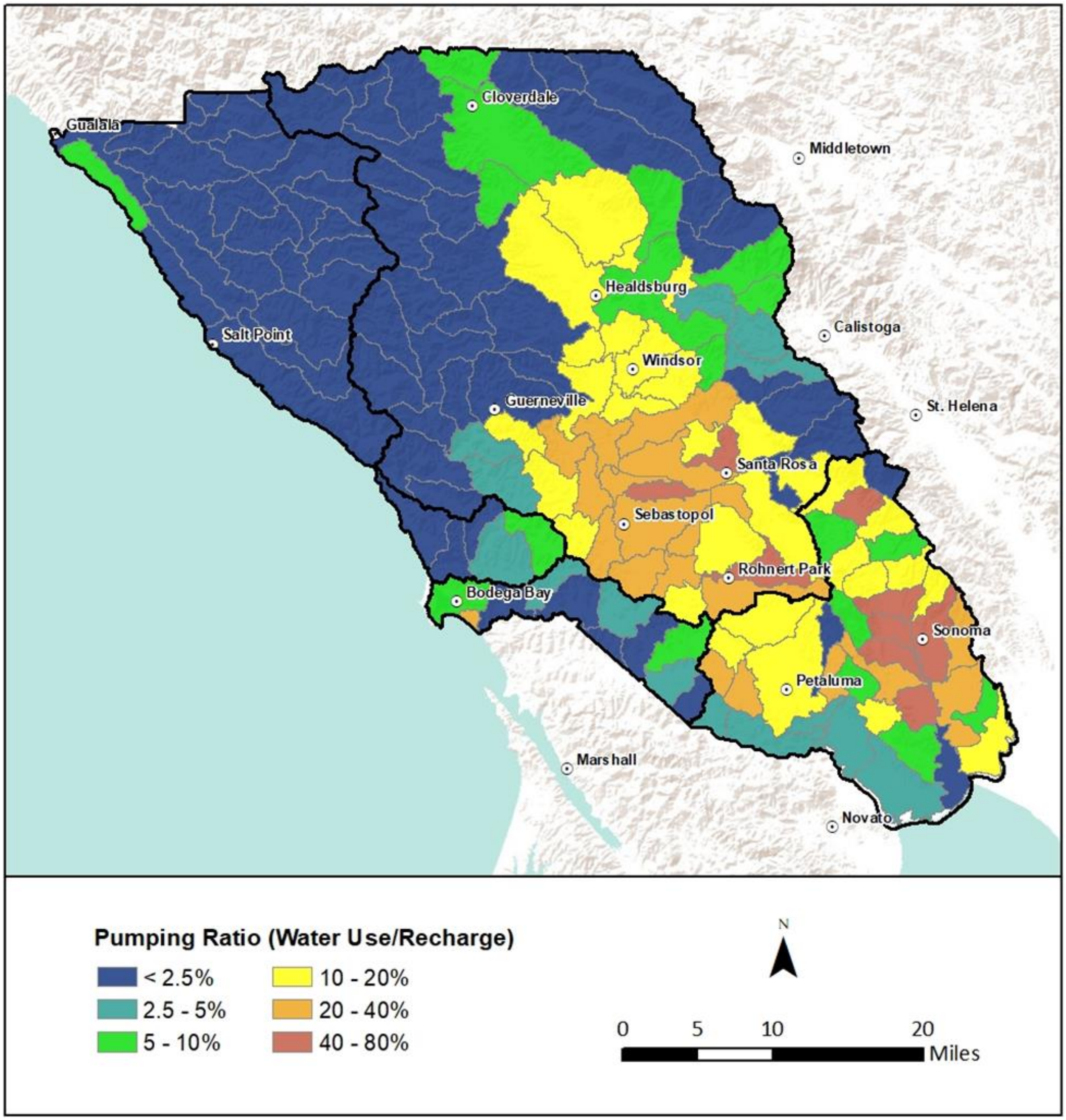

Figure 6: Groundwater pumping ratio per subwatershed.

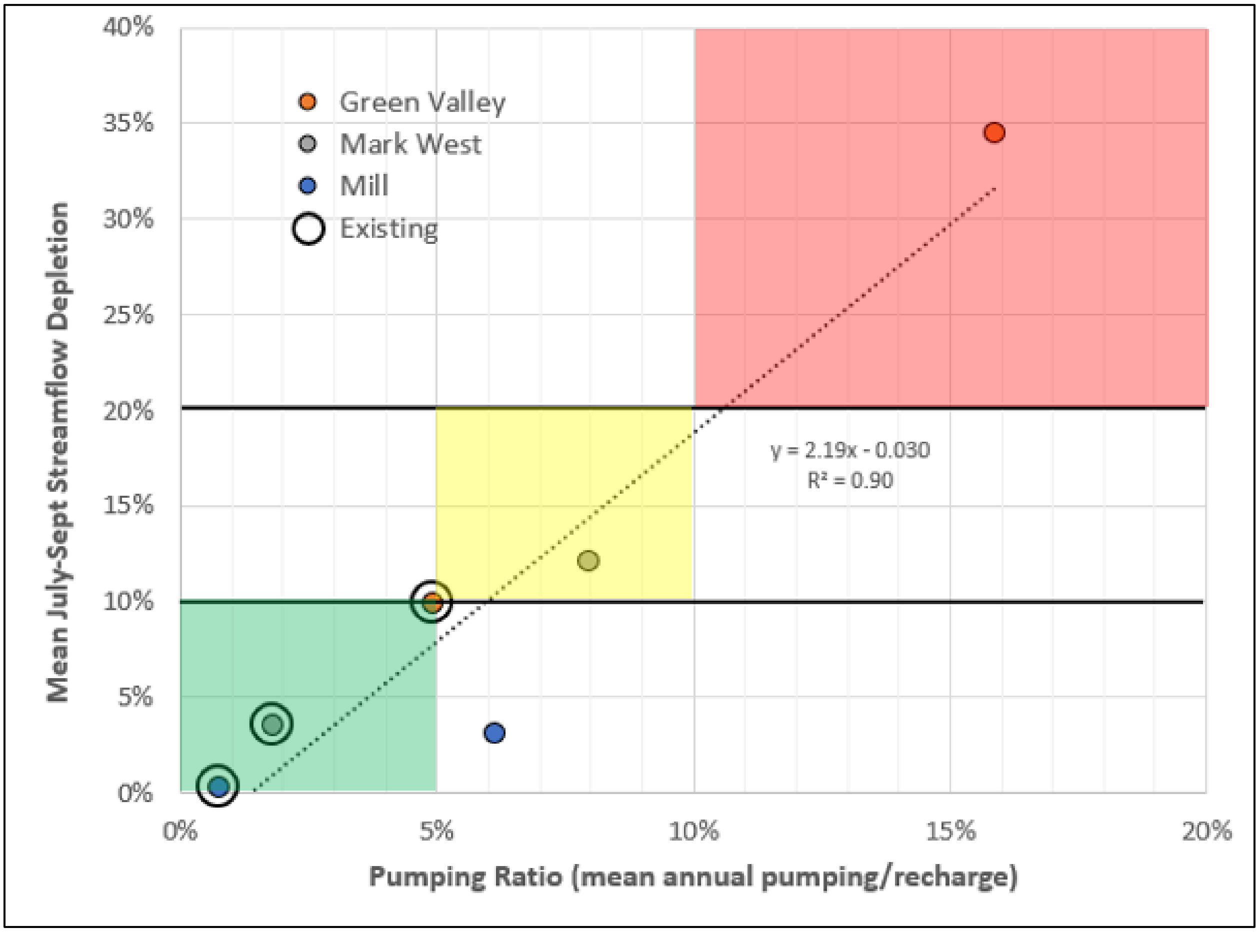

Figure 7: Relationship between the groundwater pumping ratio and summer streamflow depletion calculated from distributed hydrologic models of the upper Mill, Mark West, and Green Valley Creek watersheds. The green, yellow, and red colors indicate the zones where streamflow depletion was defined as low, medium, or high respectively based on Richter et al. (2012).

is some indication of lower depletion rates in watersheds dominated by relatively low-permeability rocks of the Franciscan Formation such as upper Mill Creek relative to those with higher permeability rocks of the Wilson Grove Formation and the Sonoma Volcanics such as upper Green Valley and Mark West Creeks.

The mean July through September streamflow was used because this time period corresponds to the typical period of lowest streamflows in Sonoma County where streamflow depletion effects on juvenile salmonid rearing habitat are expected to be greatest. Salmonids can be affected by streamflow depletion occurring during other time periods, most notably the spring smolt outmigration and adult in migration periods; however, basing the analysis on the low flow summer rearing period when impacts are expected to be greatest should also be protective of streamflows during periods corresponding to these other life stages.

To classify each subwatershed as having a Low, Medium, or High level of streamflow depletion we utilized the findings of Richter et al. (2012) who proposed presumptive standards for environmental flow protection in the absence of detailed studies evaluating site-specific environmental flow needs. A high level of ecological protection is presumed to be provided when flow alterations are no greater than 10% and a moderate level of protection is provided when flow alterations are in the 11-20% range (Richter et al., 2012). The distributed model scenarios indicate that streamflow depletion of 10% or less occurs when the groundwater pumping ratio remains below ~5% and streamflow depletion of 11-20% occurs when the groundwater pumping ratio remains below ~10%. Based on these findings, subwatersheds with a groundwater pumping ratio of less than 5% were coded as Low for streamflow depletion, subwatersheds with a groundwater pumping ratio of between 5 and 10% were coded as Medium, and subwatersheds with a pumping ration in excess of 10% were coded as High for streamflow depletion.

The distributed modeling results for Mill Creek suggest that somewhat higher thresholds could be used in areas dominated by low permeability materials such as the Franciscan Complex, however the lower thresholds are appropriate because they provide a margin of error and because it is likely that streamflow depletion in these areas would be higher (and more consistent with the other bedrock geologies) after extended time frames longer than 50-yrs. The models do not contain thick alluvial deposits such as those found in the Santa Rosa Plain, and thus their predictions are likely less applicable for these areas. Additionally, significant streambed recharge can occur in alluvial basins, complicating the relationships between the pumping ratio and streamflow depletion. Nevertheless, the pumping ratio remains a valid indicator of relative of streamflow depletion in alluvial basins and is thus broadly applicable despite the additional uncertainties.

Validation

Given the inherent difficulty of directly measuring streamflow depletion in the field, well parameterized and calibrated numerical models are generally considered the most accurate tools for evaluating streamflow depletion (Barlow & Leake, 2012; Zipper et al., 2022). To evaluate the validity of the streamflow depletion estimates obtained using the groundwater pumping ratio approach used to map the PTRA, the estimates were compared to estimates obtained from available numerical models in the County (Figure 8). These models included the Sonoma Valley and Santa Rosa Plain GSFLOW models developed for the Groundwater Sustainability Agencies (Farrar et al., 2006; Woolfenden & Nishikawa, 2014) and the MIKE SHE models of the Mill, Mark West, and Green Valley Creek subwatersheds discussed in the previous section (Kobor & O'Connor, 2016, Kobor et al., 2020; Kobor et al., 2021). Mean July-September streamflow depletion estimates were extracted from the models and expressed as a percentage of the total flow in the absence of any groundwater pumping. Calculations were performed over the most recent 10-yr period covered by the simulations which corresponded to 2009-2018 in the Sonoma Valley and Santa Rosa Plain models and 2010-2019 in the coho watershed models.

There is general agreement between the two estimates with both approaches showing Mill and Mark West Creeks having relatively low streamflow depletion and the Sonoma Valley and Santa

Rosa Plain having relatively high depletion, with Green Valley Creek in between (Figure 8). The pumping ratio approach over-predicts streamflow depletion in Green Valley Creek and underpredicts in the Sonoma Valley and Santa Rosa Plain. There are many factors potentially influencing the observed differences including differing groundwater use and recharge estimates and variability in the streamflow depletion response between basins due to the influence of local hydrogeologic and well construction details. Nevertheless, the results indicate that the relative magnitude of streamflow depletion between basins can be well-predicted using the simple pumping ratio approach and are appropriate for their intended purpose of delineating areas with low, medium, or high streamflow depletion as part of the PTRA mapping methodology.

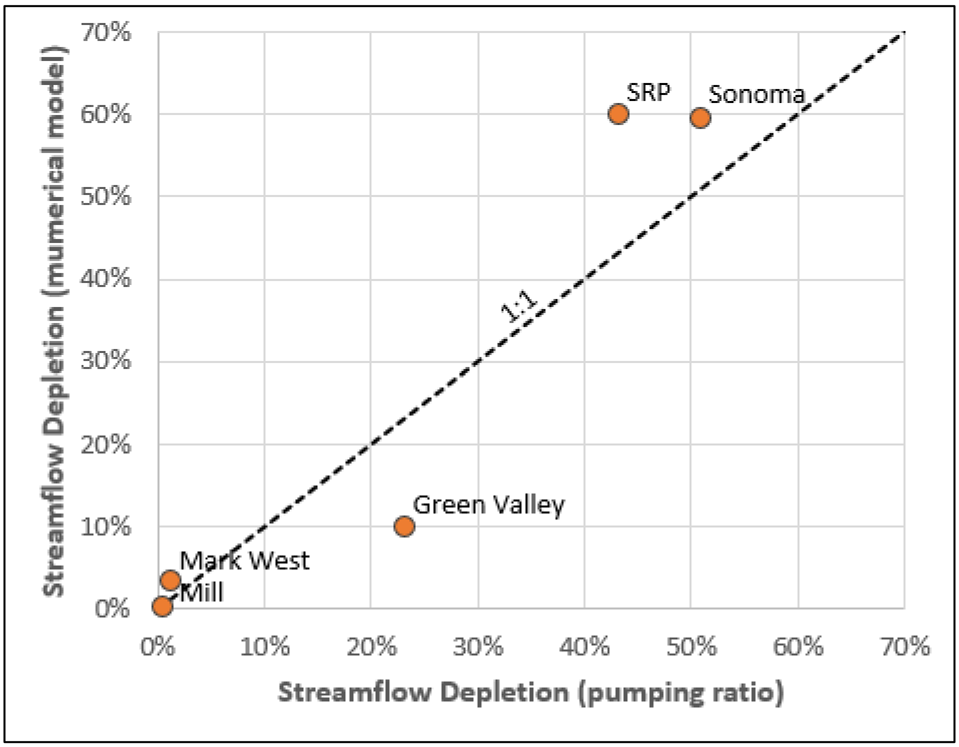

Figure 8: Comparison between summer (July-September) streamflow depletion estimated with the pumping ratio approach used to inform the PTRA mapping and estimates obtained from available numerical models.

Public Trust Review Area Mapping

Overview

A PTRA matrix was developed to define the PTRA based on the results of the resource sensitivity and streamflow depletion mapping described below (Table 1). Low risk areas not included in the PTRA consist of those areas classified as Low resource sensitivity (aquatic habitat value) as well as those areas classified as Medium resource sensitivity and Low existing streamflow depletion.

Moderate risk areas include areas classified as Medium resource sensitivity and Medium existing streamflow depletion as well as areas classified as High resource sensitivity and Low existing streamflow depletion (Table 1). The PTRA in these areas consists of stream buffers (as described in the Stream Buffers section below) designed to be protective of acute streamflow depletion impacts. High risk areas where the entire subwatersheds are included in the PTRA to be protective of both acute and cumulative streamflow depletion impacts include areas classified as Medium resource sensitivity with High existing streamflow depletion and areas classified as High resource sensitivity with Medium or High existing streamflow depletion. High risk areas also include the areas classified as Very High resource sensitivity where the entire subwatersheds are included in the PTRA regardless of the level of existing streamflow depletion (Table 1).

Table 1: PTRA matrix indicating how areas were treated based on the results of the resource sensitivity and existing streamflow depletion classes.

	Low SFD (0 – 10%)	Medium SFD (10 – 20%)	High SFD (>20%)
Low Habitat Value	Low Risk Area Not included in PTRA	Low Risk Area Not included in PTRA	Low Risk Area Not included in PTRA
Moderate Habitat Value	Low Risk Area Not included in PTRA	Moderate Risk Area Stream buffers	High Risk Area Sub-watershed
High Habitat Value	Moderate Risk Area Stream buffers	High Risk Area Sub-watershed	High Risk Area Sub-watershed
Very High Habitat Value	High Risk Area Sub-watershed	High Risk Area Sub-watershed	High Risk Area Sub-watershed

Stream Buffers Distances

Within the portions of the PTRA where stream buffers are used, existing cumulative streamflow depletion is Low or Medium and acute streamflow depletion is expected to be the primary risk to streamflow. The concept of the Stream Depletion Factor (SDF) was used to assist in defining stream buffer distances that are protective of acute streamflow depletion impacts. SDF is a relative measure of how rapidly streamflow depletion occurs in response to new pumping (Barlow & Leake, 2012). SDF is commonly used to assess the timescale and potential for near stream wells to cause streamflow depletion and it is defined as the time in days of pumping when streamflow depletion equals 50% of the pumping rate.

SDF is dependent on the transmissivity and storativity of the aquifer and the distance of the well from the stream. Wells in aquifers with high transmissivity and low storativity are associated with smaller values of SDF for a given distance from the stream. Pumping of wells with low values of SDF will quickly translate into reduced streamflow. The timing and short-term pumping regime of a near stream well may be important for determining if the well will have adverse impacts on streamflow. Pumping of wells at locations with large SDF values will translate into reduced streamflow over longer periods of time, and the short-term pumping regime is unlikely to be a relevant factor in evaluating impacts.

To assist in defining an appropriate SDF threshold that identifies stream buffer distances where acute impacts of groundwater wells may occur, streamflow depletion was evaluated for hypothetical pumping wells using the analytical depletion function from Jenkins (1968). In this exercise, the pumping well extracts groundwater on the 1st of each month at a rate of 28 to 31 gallons per minute (gpm) for a 24-hour period, equivalent to a mean monthly pumping rate of about 1 gpm (Figure 9). This hypothetical pumping regime could be representative of wells that are used for short intervals to meet high demands. Results of this analysis (Figure 8) show that when the SDF is equal to 30 days, streamflow depletion peaks at about 1.35 gpm (35% greater than the average pumping rate). When the SDF is equal to 10 days, streamflow depletion peaks at about 3 gpm (300% greater than the average pumping rate). When the SDF is equal to 180 days, streamflow depletion gradually increases with subdued oscillation to about 0.6 gpm, and would eventually deplete streamflow by about 1 gpm if simulated for a longer period of time.

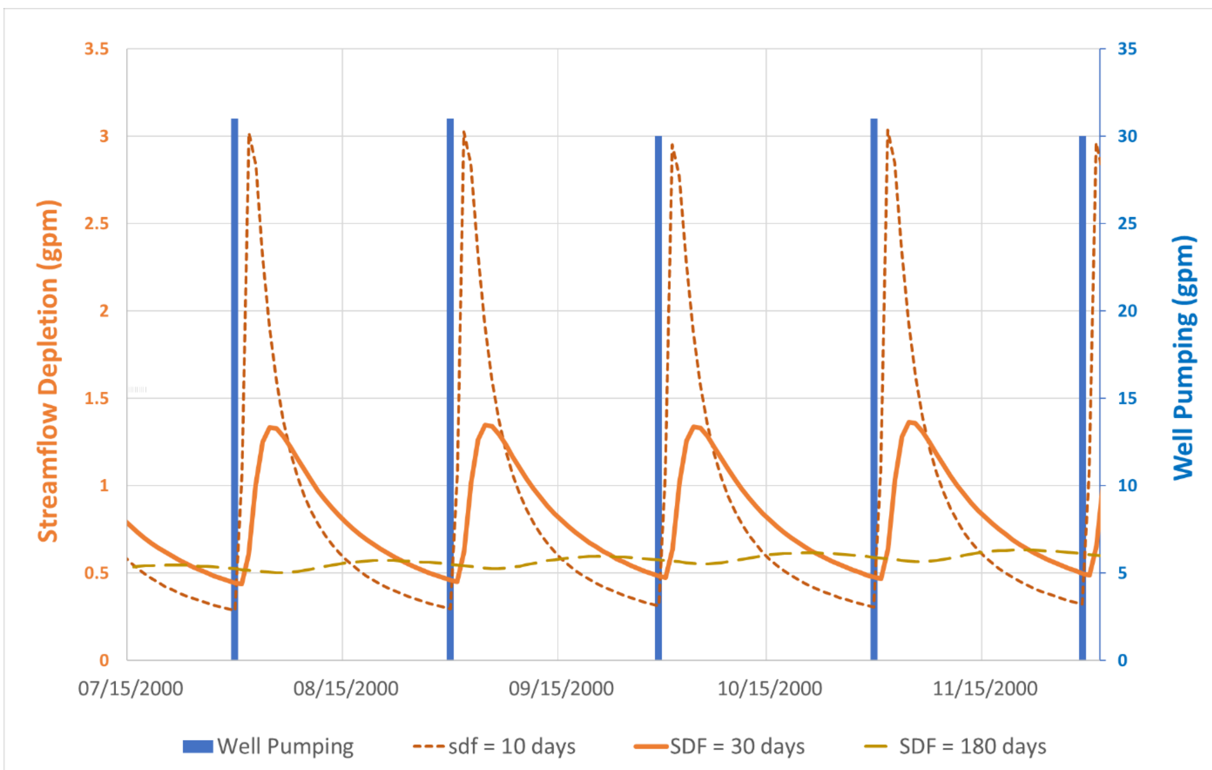

Figure 9. Streamflow depletion from hypothetical wells located at a distance corresponding to Stream Depletion Factor (SDF) of 10, 30 and 180 days based on application of an analytical depletion function (Jenkins, 1968).

As evidenced by the examples above, wells located at distances that correspond with SDFs greater than 30 days are much less likely to pose acute risks to streamflow from intermittent pumping. Distances where the SDF equals 30 days were estimated for various major rock types in Sonoma County using the analytical depletion function from Jenkins (1968) and existing estimates of hydrogeologic properties for these materials (Kobor & O'Connor, 2016; Kobor et al., 2020; Kobor et al., 2021; Woolfenden & Nishikawa, 2014). Based on this analysis, this distance is ~100 ft for the Franciscan Complex, ~250 ft for the Sonoma Volcanics, and ~750 ft for the Wilson Grove Formation and alluvial sediments. Significant spatial variations in hydrogeologic properties occur within these general rock types which translates to significant variability in the distance where SDF equals 30 days, and the above distances were selected based on professional judgement of appropriate representative values for a given formation.

The major rock types were delineated based on the County's existing groundwater classification system. Class I areas represent alluvial sediments, Class II areas represent Wilson Grove Formation, Class III areas represent Sonoma Volcanics, and Class IV areas represent the Franciscan Complex. Mapping of alluvial materials by Stetson Engineering (2008) was used to refine the representation of small alluvial aquifers not captured in the groundwater classification mapping. In basins where stream buffers are used to define the PTRA, streams delineated as critical steelhead habitat by the National Marine Fisheries Service (NMFS, 2023) as well as all contributing perennial streams as identified in the National Hydrography Dataset (NHD) were used to delineate buffer widths corresponding to the defined distances for a given rock type. In reaches where the 750-ft buffer width extended beyond the extent of alluvial or sedimentary materials mapped by Stetson Engineering (2008), the uniform buffers were clipped to the extent of the mapped materials they are intended to represent.

Flow Regulated Reaches

Flows within the main-stem of the Russian River and Dry Creek are controlled by releases from Lake Mendocino and Lake Sonoma and are subject to minimum flow requirements established by the State Water Resources Control Board. Application of the methodology used in other areas of the County to define the relationship between groundwater pumping and streamflow depletion are not valid in these streams due to the controlling influence of the flow releases from the reservoirs (Steiner, 1996; Sonoma County Water Agency, 2016). Therefore, the DWR Bulletin 118 groundwater basins corresponding to the Russian River and Dry Creek were excluded from the PTRA. The groundwater basin boundaries were adjusted to exclude areas where the basins included significant drainage areas associated with tributary streams rather than their flow-regulated main-stems (Figure 10).

Summary

The final PTRA covers ~313 square miles (19% of the county) with stream buffer areas accounting for ~25 square miles and subwatersheds accounting for ~288 square miles (Figure 10). Areas within the PTRA with stream buffers include the South Fork Gualala River watershed, the Adobe, Austin, Bidwell, Crocker, Freezeout, Gill, Jenner Gulch, Pena, Sausal, and Willow Creek watersheds, and portions of the Maacama and Salmon Creek watersheds. Areas where the entire subwatershed was included within the PTRA include the Atascadero, Crane, Dutch Bill, Gird, Green Valley, Mark West, Mill, Miller, and Wine Creek watersheds, watersheds in the northern portion of the Santa Rosa Plain, upper Salmon Creek watershed, large portions of the upper and middle Sonoma Creek watershed, and the northeastern portion of the Petaluma River watershed (Figure 9).

As with any approach to delineating the PTRA, there are uncertainties and limitations associated with the adopted approach. As new data and model predictions become available it is recommended that the methodology and analysis be improved and updated over time. In particular, water use metering requirements associated with the new well ordinance would provide valuable data with which to refine estimates of existing groundwater pumping. New USGS numerical modeling of the Russian River basin is also underway which will provide refined estimates of groundwater recharge and additional estimates of existing streamflow depletion. By periodically refining the approach and analysis used to delineate the PTRA, it is expected that more accurate predictions and mapping can be developed and uncertainty can be reduced over time.

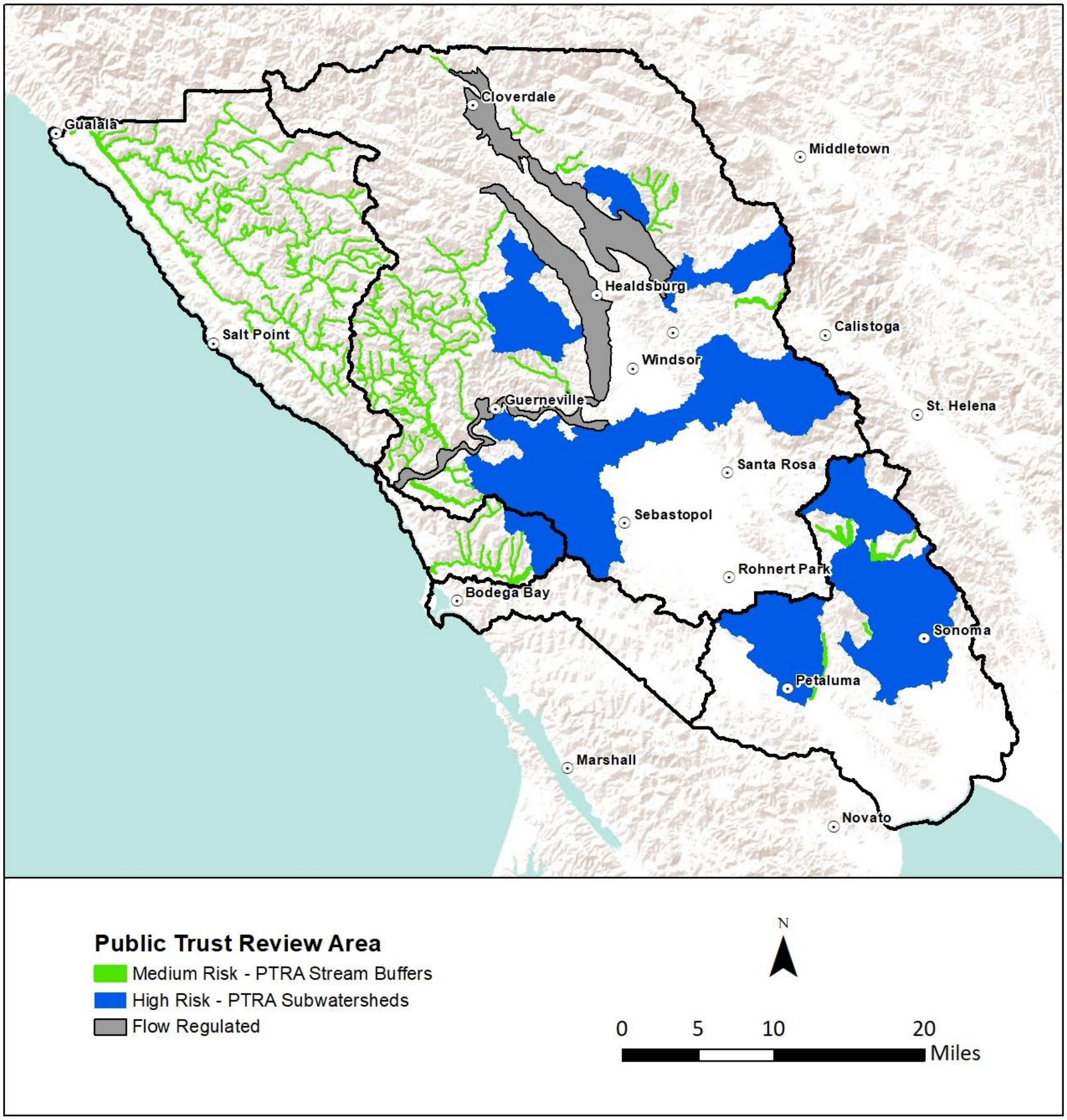

Figure 10. Public Trust Review Area for Sonoma County.

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