**Colusa County On-Farm Multi-Benefit Groundwater Recharge Project**

Amanda Gateley

**Abstract**

As a result of years of persistent and severe droughts, California's groundwater resources have dwindled to concerning levels, which prompted the creation and implementation of legislation with the goal of sustainable management of the state's groundwater. Low groundwater levels pose a risk to the communities that depend on pumping for their domestic, municipal, industrial, and agricultural water usage. In California's Central Valley, sustainable use of groundwater is becoming more necessary than ever. One method of supporting farmers and working towards sustainable water resources is agricultural managed aquifer recharge (AgMAR), a process that involves purposefully flooding unused fields to promote and study groundwater recharge. In partnership with The Nature Conservancy, farmers enrolled 3 main recharge sites to be flooded for this recharge study.

The objective for this study is not only to further the research on sustainable groundwater management practices, but to determine AgMAR's effects on the quality of water in nearby disadvantaged communities, since the water being recharged at these sites are nitrate-rich applied irrigation water. The research methodology mainly involved conducting economic analyses, data collection, and interpretation of that data in the context of social impacts to disadvantaged communities. The results encompass 3 specified areas of social impacts to disadvantaged communities, including Population Vulnerability, Water Access and Quantity, and Water Quality. The discovered risks to water quality and quantity, as well as the economic state of many people living in nearby disadvantaged communities, make the populations living there more vulnerable. From the results of this study, it is evident that the social impacts of implementing AgMAR in Colusa County directly affect those living in nearby disadvantaged communities.

**Introduction**

Farmers at three main recharge sites (Figure 1) agreed to participate in The Nature Conservancy's Bird Returns Program, a multi-benefit groundwater recharge program that involves flooding farmland to induce recharge while creating a "pop-up" wetland habitat for migratory shorebird stopovers (The Nature Conservancy 2020). The enrolled fields are located in Colusa County, California, in the northern part of the Central Valley. This multi-benefit recharge program will allow for the study of direct responses of AgMAR to the groundwater system at the three recharge locations and determine whether applying AgMAR to farmland has a quantifiable effect large enough to employ throughout California to sustainable manage the state's groundwater resources. The motivation for this study is not only to further the research on sustainable groundwater management practices, but to determine AgMAR's effects on the quality of water in nearby disadvantaged communities, since the water being recharged at these sites are nitrate-rich applied irrigation water.

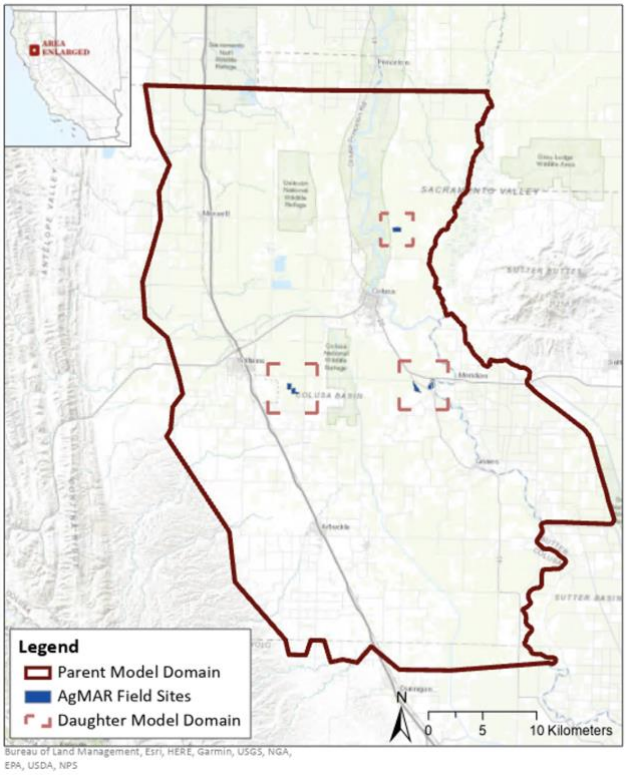


Figure 1. Map of parent model domain with three daughter model domains and recharge sites on enrolled fields in Colusa County, California.

**Objective**

There are three main aspects to this project, including hydrologic aspects, environmental or ecosystem aspects, and social aspects. The aspect to be evaluated in this project is the social aspect and the impact that this project and implementing AgMAR on farms to input recharged water into the aquifer, may have on nearby disadvantaged communities. The research objective for this project is to study the social aspect of implementing AgMAR on farms, and their effect on the water supply of disadvantaged communities.

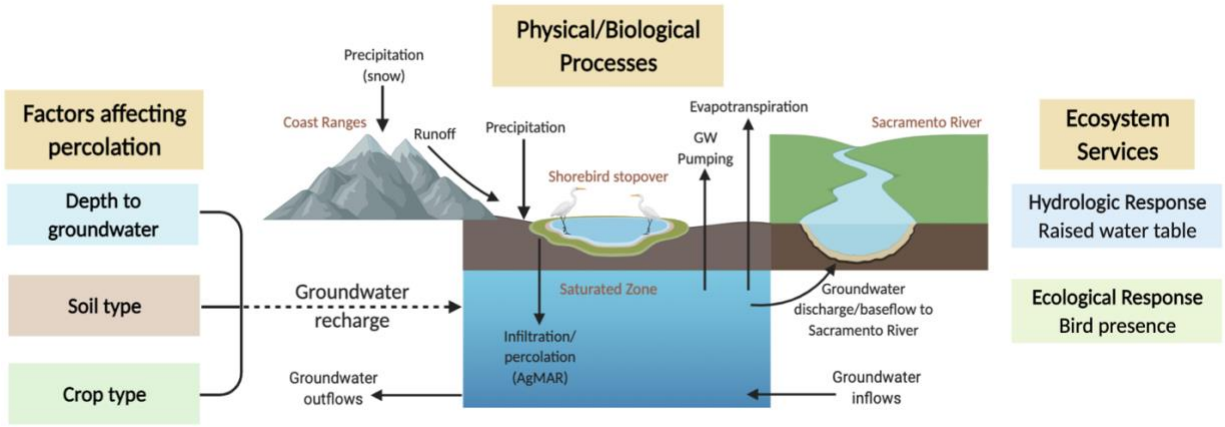


Figure 2. Conceptual model showing major physical/biological processes and ecosystem services relating to AgMAR in the project area, including fluxes into and out of the system.

**Data Sources**

Sources used to extract/extrapolate data from are listed here (all citations are in the references section):

- DAC Mapping Tool, California Department of Water Resources, 2021 (DAC Mapping Tool 2021) https://www.arcgis.com/apps/webappviewer/index.html?id=daa4b54daf0a425ab040c857b55e596a
- DWR GW Level Percentile Statistics, 2021 (DWR GW Level Percentile Statistics 2021) https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer#gwlevels
- Combined Water Quality Hazard and Exposure Risk (Dissolved Nitrate), 2021 (Water Quality Hazard and Exposure Risk 2021) https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer#waterqual
- SGMA Data Viewer, 2021 (SGMA Data Viewer 2021) https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer#gwlevels
- Well Completion Report Map Application, California Department of Water Resources, 2021 (Well Completion Report Map Application 2021)

https://dwr.maps.arcgis.com/apps/webappviewer/index.html?id=181078580a214c0986e2da28f8623b37

**Methods**

The research methodology designed to meet the research objective stated above mainly involved researching, data collection, and interpretation of that data in the context of social impacts to disadvantaged communities. I refined my search to 3 specific areas of social impacts to disadvantaged communities, including Population Vulnerability, Water Access and Quantity, and Water Quality. When assessing population vulnerability, I used the California Department of Water Resource's disadvantaged communities mapping tool (DAC Mapping Tool 2021) to locate disadvantaged communities within my area of interest. I then investigated the economic status and economic activities of the people that are living in disadvantaged communities in the areas near the recharge sites.

In order to determine water access and water quantity within the disadvantaged communities, I extracted information from DWR's Well Completion Report Map Application (Well Completion Report Map Application 2021) to obtain data relating to depths of domestic wells in the communities. From domestic well depth information I was able to assess whether the water table will be above or below the community wells' water intake while assuming that inducing recharge raises the water table in the surrounding areas. When assessing water quantity, I took into consideration depth to groundwater levels and the current state of overdraft in the basin.

When determining the impact on disadvantaged communities' water quality, my main concern was nitrate leaching into the groundwater aquifer, since flooding farmland to induce recharge will cause nitrates in the soil and the water to infiltrate and percolate through the subsurface and into the aquifer. I assessed the risks relating to nitrate infiltration and water quality of the disadvantaged communities through tools from DWR's SGMA Data Viewer (SGMA Data Viewer 2021).

**Calculation/Results**

*Population Vulnerability*

Four disadvantaged communities were found communities in the project area near recharge sites: Princeton, Colusa, Meridian, and Grimes (Figure 3). Princeton and Meridian are both classified as disadvantaged communities, meaning the median household income for the population is between $42,737 and $56,982. Colusa and Grimes are classified as severely disadvantaged communities, meaning the median household income for the population living there is less than $42,737. The total population

among these four disadvantaged communities is 6,962. Meridian and Grimes have a similar population, with 405 residents living in Meridian and 358 residents living in Grimes. Colusa is much more densely populated than the other three with a population of 5,902, while Princeton has the smallest population with just 297 residents.

As for the economic status for these disadvantaged communities, the demographics of those living in poverty are mainly white and Hispanic (Data USA 2021). One of the most common – if not the most common – occupations for people living in these communities is the farming, fishing & forestry occupation, so many of the people in this area are working in fields related to agriculture (Data USA 2021). The most common crops produced in Colusa County are rice, almonds, tomatoes, vegetables, and vine crops.

29.6% of people living in Princeton live below the poverty line, and 64% of children in Princeton are living in poverty (Census Reporter 2021). This high level of poverty is double the percentage of Colusa County as a whole. Colusa and Meridian have low poverty rates, with 11.6% of Colusa's population and 6.3% of Meridian's population living in poverty (Census Reporter 2021). Grimes has an alarming poverty rate that is more than double that of Princeton's, with 70.8% of its population living under the poverty line (Census Reporter 2021).

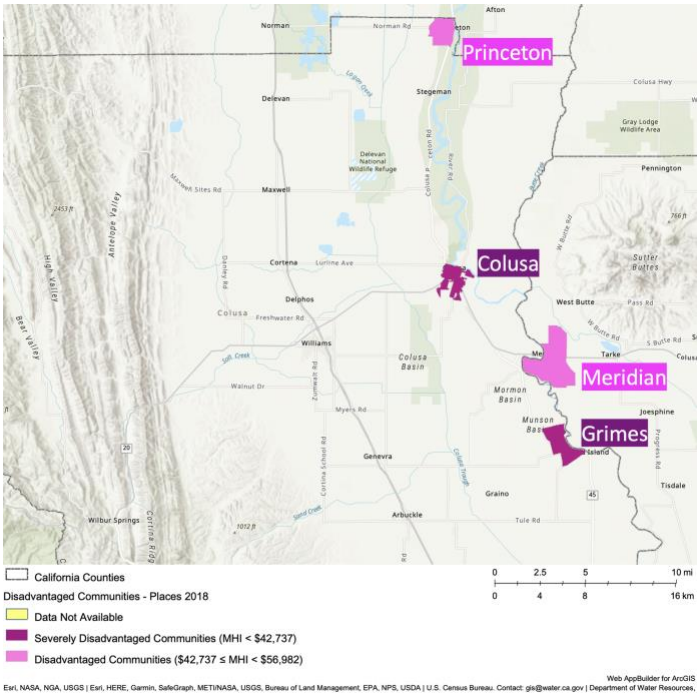


Figure 3. Map of four disadvantaged communities in the project area, located in Colusa County, California.

*Water Access and Quantity*

The average depths of the domestic wells in the disadvantaged communities were calculated to be 90 ft in Princeton, 143 ft in Colusa, 122 ft in Meridian, and 153 ft in Grimes (Well Completion Report Map Application 2021). Since current contours (SGMA Data Viewer 2021) show that the areas along the Sacramento River, including the four disadvantaged communities, has a depth to groundwater of approximately 10 ft, there doesn't seem to be a great risk of the water table being below domestic well intake in most of these areas along the river (Figure 4).

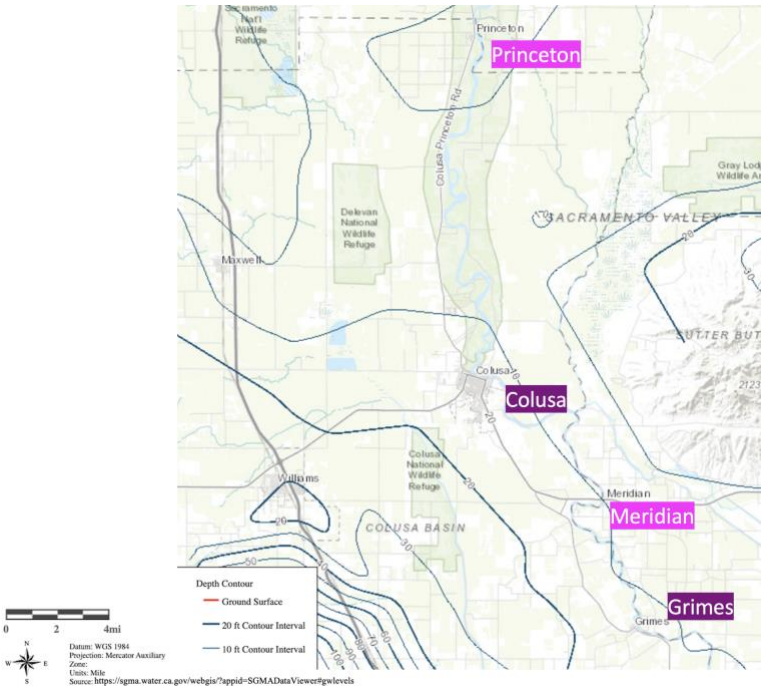


Figure 4. Groundwater level contour map in area of interest, showing locations of the four disadvantaged communities.

However, looking at groundwater levels from a well-by-well basis rather than a regional basis gives conflicting information. DWR has kept track of wells that have lower groundwater levels than usual (Figure 5), classifying lower percentiles as below normal (DWR GW Level Percentile Statistics 2021). Within and near Princeton, there seem to be quite a few below-normal groundwater levels. Colusa has some below-normal groundwater levels as well, while Meridian seems to have normal levels. Grimes doesn't have any low groundwater levels within the community, but just a few miles south the groundwater levels are at a concerning level of much-below-normal.

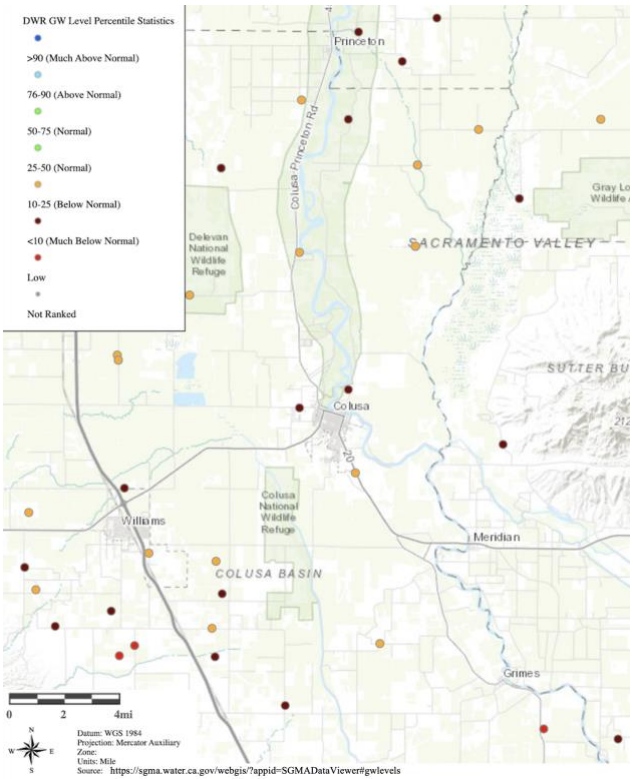


Figure 5. Map of groundwater level percentile statistics, showing all wells with recorded levels that are normal or below in the area of interest.

*Water Quality*

The results of the Combined Water Quality Hazard and Exposure Risk (Water Quality Hazard and Exposure Risk 2021) is considering the exposure risk to dissolved nitrates into groundwater. Lower percentiles mean there is lower risk, while higher percentiles indicate higher risk of exposure to dissolved nitrates and water quality hazard. If the depth to groundwater is shallow, then there's a higher risk of nitrate leaching and if it's deeper then there is a lower risk of leaching into the aquifer. Most of the areas in and around the disadvantaged communities seem to be at a lower exposure risk, but Colusa is at a higher risk, being in the 50$^{th}$ to 70$^{th}$ percentiles in some areas (Figure 6).

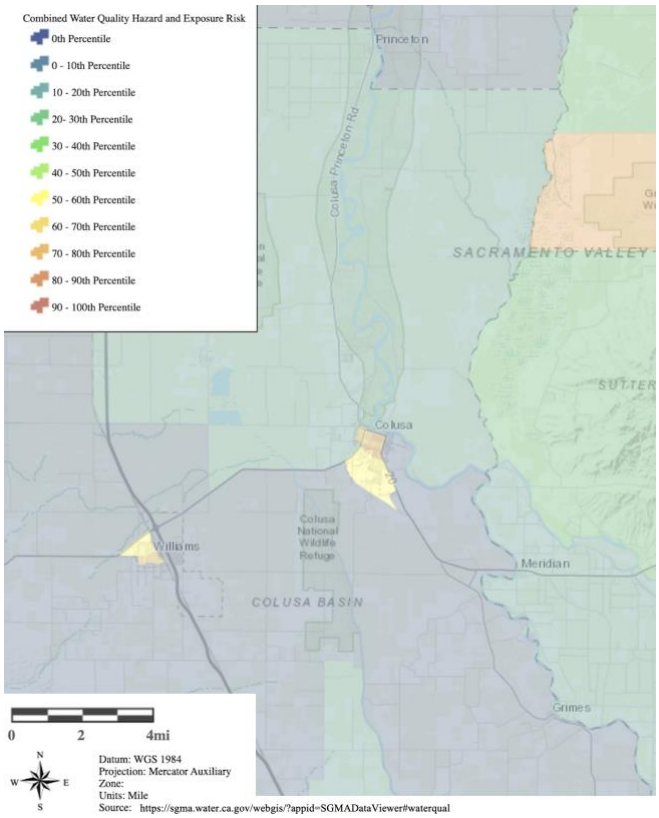


Figure 6. Map of the Combined Water Quality Hazard and Exposure Risk (Dissolved Nitrate) in the area of interest.

**Conclusions**

The Sacramento Valley groundwater basin is currently in overdraft, which means that the amount of annual groundwater extraction exceeds the long-term average annual supply of water into the basin. Although the Colusa subbasin and the Sacramento Valley groundwater basin are not considered critically overdrafted at this time, it is still classified as a high priority basin, according to SGMA, and overdraft is still a major concern for this region of California.

The social impacts of implementing AgMAR in Colusa County directly affect those living in nearby disadvantaged communities. Although most of the area is at a lower risk of dissolved nitrate leaching into the aquifer, Colusa is at a higher risk, and Colusa is also the disadvantaged community with the largest population. There seem to be no big issues with water access in disadvantaged communities, but if the current state of groundwater overdraft continues, this may pose a threat to the quantity of water available to people living in these disadvantaged communities.

As for the vulnerability of the population, the high level of poverty in some areas is very concerning. Considering the risks to water quality and quantity, as well as the economic state of many people living in these communities, all of these factors combined make the population more vulnerable.

**Recommendations**

The results of this project were enlightening and frightening, due to the fact that these disadvantaged communities are primarily working in agriculture, which keeps much of their population below the poverty line, when agriculture is also what is putting them most at risk with their water quality and quantity. The scientific community has a responsibility to expand our perspectives, and it would be beneficial to consider the social effects and humanize the people that projects like AgMAR have a direct impact on.

**References**

Census Reporter, 2021. https://censusreporter.org/profiles/16000US0631288-grimes-ca/.

DAC Mapping Tool, California Department of Water Resources, 2021. https://www.arcgis.com/apps/webappviewer/index.html?id=daa4b54daf0a425ab040c857b55e596a.

Data USA, Census Place, 2021. https://datausa.io/profile/geo/grimes-ca.

DWR GW Level Percentile Statistics, 2021. https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer#gwlevels.

Combined Water Quality Hazard and Exposure Risk (Dissolved Nitrate), 2021. https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer#waterqual.

Killpack, Scott C., Buchholz, Daryl. "Nitrogen in the Environment: Leaching." University of Missouri, Oct. 1993, https://extension.missouri.edu/publications/wq262.

SGMA Data Viewer, 2021. https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer#gwlevels.

SGMA Groundwater Basins Prioritization, 2021. https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer#boundaries.

The Nature Conservancy. 2020. Colusa County On-Farm, Multi-Benefit Groundwater Recharge Program. https://birdreturns.org/multi-benefit-groundwater-recharge/.

Well Completion Report Map Application, California Department of Water Resources, 2021. https://dwr.maps.arcgis.com/apps/webappviewer/index.html?id=181078580a214c0986e2da28f8623b37.