Appendix 10-1

Community Vulnerability Study

Assessing the Potential for Groundwater Pollution in Four Sierra Valley Disadvantaged Communities: An Exploratory Study of Community Well Vulnerability

Burkhard Bohm
Hydrogeologist, CCH 337

June 1, 2016

Table of Contents

Introduction

Need and Purposes for this Study

This Community Groundwater Pollution Vulnerability Study (Study) is one of two exploratory studies undertaken as part of the update of the Upper Feather River Integrated Regional Water Management (UFR IRWM) Plan. The final versions of these two studies will be included as appendices in the final UFR IRWM Plan.

This study was developed for the UFR IRWM Plan Update due to local concerns related to anticipated nitrate pollution control rules and regulations as they might relate to irrigated agriculture and septic wastewater systems in the UFR Region. The Irrigated Lands Regulatory Program (ILRP) is in the process of drafting new groundwater nitrate monitoring and abatement requirements. Additionally, new monitoring requirements are currently being issued for county environmental health departments related to the monitoring and management of individual wastewater treatment systems (i.e., septic systems). Counties will be required to comply with these new monitoring requirements by 2023, which is within the UFR IRWM Plan's 20-year planning period.

The Study demonstrates the application of an Environmental Protection Agency (EPA) approach for assessing nitrate pollution potential known as "DRASTIC" in four Sierra Valley disadvantaged communities[1] (DACs). DRASTIC[2] is a standardized system developed by the EPA for evaluating groundwater pollution potential using hydrogeologic settings. The purpose of the Study is to assess pollution potential, specifically of nitrate.

It is important to note that under current land and water use conditions in the Sierra Valley, there are currently no documented exceedances of nitrate pollution in active community public wells in the Sierra Valley.[3] Given that there are no current instances of nitrate pollution parameter exceedances in public community wells, the purposes of this Study are diagnostic and proactive rather than reactive in response to regulations and rules. The Study purposes are as follows:

1. Provide precautionary information for assessing changing conditions in land and/or water uses within or surrounding four Sierra Valley communities. The Study is focused on communities with higher than average risks for nitrate pollution based on soil, geology, and hydrology factors.

2. The Study focuses on applying the DRASTIC assessment approach to four DAC communities in Sierra Valley that rely on groundwater wells for drinking water.

[1] Disadvantaged communities (DAC) are defined by the Department of Water Resources as those communities with a median household income of 80 percent of the statewide average.
[2] DRASTIC is an acronym that stands for **D**epth to water, net **R**echarge, **A**quifer media, **S**oil media, **T**opography, **I**mpact of the vadose zone, and hydraulic **C**onductivity.
[3] Personal communication with Elizabeth Morgan, Sierra County Environmental Health Department and Jerry Sipe, Plumas County Environmental Health Department, April, 2016

The Department of Water Resources Proposition 84 and Proposition 1 Guidelines for IRWM Planning emphasize understanding the special water and wastewater needs of DACs.

A preliminary well vulnerability assessment was developed for nine disadvantaged communities (DACs) in the Mohawk Valley and Sierra Valley areas using the DRASTIC methodology. Subsequently, using professional judgment and existing information about the characteristics of community water and wastewater systems and other factors, four of the nine communities were selected for more intensive DRASTIC analysis.

COMMUNITIES RATED BY SEVERITY:

	rank		Preliminary DRASTIC index	DRASTIC scaling
Cromberg	1		186	80%
Clio	2		185	80%
Sierraville	3		173	74%
Vinton	4		164	69%
Loyalton	5		158	66%
Chilcoot, alluvium	6		155	65%
Sierra Brooks	7		153	64%
Calpine	8		144	59%
Chilcoot, bedrock	9		135	55%
Delleker	10		128	51%

Other factors considered in selecting the four DAC communities included:

- Estimated effectiveness of isolation between wastewater and drinking water systems (age and other legacy design factors).
- Data availability.
- Estimated potential for residential growth in and around the community.
- Estimated potential for highly fertilized, concentrated, and irrigated agricultural operations within or immediately adjacent to the community.
- Estimated potential overlying groundwater recharge zone for downstream or downslope valleys.
- Proximity to existing irrigated agriculture operations surrounding the community.
- Proximity to other potential point sources or non-point sources of nitrate pollution.

POINT SOURCES OF GROUNDWATER POLLUTION - examples

- underground septic tanks and leachfields
- leaking underground storage tanks (fuel and possibly non-fuel?)
- leaking above-ground storage tanks
- leaking transformers
- graveyards
- improperly constructed wells (abandoned and used)
- accidental spills

NON-POINT SOURCES OF GROUNDWATER POLLUTION - examples

- leaking wastewater disposal lines
- livestock waste
- storm water runoff
- winter road salt
- fertilizers
- drainage ditches

Communities were evaluated for these risk factors based on available data and professional judgment.

For example the community of Cromberg, although ranked highest on the preliminary DRASTIC index scale, has insufficient data to allow develop a more specific DRASTIC rating due to its extremely complex soils and geology. Although other risk factors are relatively low Clio has a high nitrate pollution potential, but the source of drinking water is a developed spring located about three miles to the southwest on the opposite side of Mohawk Valley. Delleker has other drinking water supply options including completing the five mile pipeline to the Lake Davis water treatment facility which has been approved for state funding. Sierra Brooks and Calpine have similar risk potentials; however, Calpine is located in an area that is an important groundwater recharge zone for west-central Sierra Valley. Furthermore since 2011 the Calpine community has been searching for an additional drinking water source since arsenic in one of its community wells exceeds the federal drinking water standards. Calpine has received a State order to mitigate this problem by the end of the year 2016.

Therefore, **the four DAC communities selected for intensive DRASTIC analysis are: Sierraville, Chilcoot-Vinton, Loyalton, and Calpine.**

The community selection process and the draft community selections were presented to the Plumas-Sierra Counties agricultural community on April 4, 2016, as a single presentation in an intensive, half-day agricultural water forum. Feedback was requested on the community selection criteria and process, as well as the overall Study purposes and methodology. The meeting was well-attended and the feedback received on the Study was neutral to positive.

Further community outreach to the four selected communities will include review of the draft Study with community representatives. The draft Study will also be shared with the agricultural community at a future community event. Feedback received from focused outreach and review comments on the administrative draft UFR IRWM Plan and Appendices will be used to finalize the Study.

Assessing groundwater pollution potential

Community drinking water well drilling locations are usually identified based on geologic assessment and analysis of optimal groundwater yields. Considerations of new well susceptibility from existing or future groundwater contamination will become increasingly important as new regulations are developed.

Under certain hydrogeologic conditions, land and water uses over large areas that are within the well's recharge zone can potentially affect groundwater quality and well vulnerability. Therefore, assessing the actual rather than potential drinking water risks within high pollution risk areas becomes important at the project level.

One way to assess the risk of groundwater pollution to domestic wells is by using systematic risk assessment procedures, with readily available data. Usually, groundwater data are spotty (limited to areas near wells and intermittently collected). Interpretation of pollution risks from limited data points to the larger landscape and water management systems is usually accomplished using professional judgment. Most importantly, the result of any pollution vulnerability assessments have to be undertaken by professionals using methods and analytic procedures that are acceptable and credible to regulatory entities, and that produce cost-effective results that are understandable to potentially affected landowners and water managers, existing and new community well users, land use planners, and to the public.

The "DRASTIC" well pollution vulnerability assessment approach was developed by the National Ground Water Association (NGWA) in the 1980's under a contract with the U.S. Environmental Protection Agency (EPA) (Aller et al., 1987). The "DRASTIC" acronym is the first letter of the seven most important hydrogeologic factors used for determining an area's vulnerability to ground water contamination. The DRASTIC document and procedures manual was prepared by six authors (Aller et al., 1987). They were supported by a 26 member technical advisory committee, including individuals with groundwater expertise from federal and state agencies, the Canadian government, and private consultants. The objective was to create a standardized system of consistent quantitative measures, which can be used to evaluate groundwater pollution potential. The DRASTIC system was developed to provide a numerical rating of pollution potential. The system was designed so that even users not well-versed in hydrogeology could use readily obtainable geologic, soil, and ground water data to develop a preliminary and semi-quantitative measure of groundwater pollution potential.

Understanding the DRASTIC methodology

The DRASTIC system is based on rating seven hydrogeologic parameters and weighing them appropriately. The sum total of these ratings provides the DRASTIC pollution potential rating. High DRASTIC scores indicate an area that is very sensitive to ground water pollution, and vice versa, a low DRASTIC score indicates less sensitivity.

The seven factors used to estimate relative ground water pollution potential are:

1. **D** – depth to ground water table
2. **R** – net recharge rate
3. **A** – nature of the aquifer
4. **S** – soil types
5. **T** – topography (slope)
6. **I** – impact of the unsaturated zone material
7. **C** – Hydraulic conductivity (permeability) of the aquifer

Table 1: The DRASTIC system for rating ground water pollution potential.

The DRASTIC system for rating ground water pollution potential.

	Parameter:	Ratings: minimum	Ratings: maximum	Weight factor
D	**depth to water**	1	10	5
R	**recharge, net**	1	9	4
A	**aquifer media**	2	10	3
S	**soil media**	1	10	2
T	**topography**	1	10	1
I	**impact of vadose zone**	1	10	5
C	**conductivity, hydraulic**	1	10	3

Ratings range from 1 to 10. Weights range from 1 to 5.

GW Pollution potential = sum of (ratings x weights)

Each parameter is rated between one and ten, except for “recharge” (1 – 9) and “aquifer media” (2 – 10). Each rating is then multiplied by a weight factor between one and five. The DRASTIC index is the sum of the products of the ratings and their respective weight factors. The parameters, their ratings, and their weight factors are summarized in Table 1.

The DRASTIC parameter ratings are tabulated in Attachment B. The minimum and maximum possible DRASTIC ratings are 26 and 226.

Applications and limitations with using DRASTIC

According to the original DRASTIC document (Aller et al., 1987), "the primary charge of DRASTIC is to provide assistance in resource allocation and prioritization of many types of groundwater related activities as well as to provide a practical educational tool." The DRASTIC index is a relative measure of groundwater pollution potential. It does not indicate suitability of a site for waste or liquid waste disposal, or other land use activities. While not the primary criteria for selecting well-drilling sites, as discussed above, it could be at least one criterion in assessing compliance with new groundwater quality regulations.

Public “groundwater awareness” is probably equally effective at preventing aquifer contamination as new regulations, especially for non-point source pollution. DRASTIC seems to be particularly useful for that purpose since it shows which hydrogeologic features are essential in creating an effective barrier between common land use activities and the groundwater resource. Conversely, in the absence of effective barriers, DRASTIC is helpful in identifying preventative measures to maintain drinking water quality in areas vulnerable to groundwater pollution.

Applications

DRASTIC is useful for identifying areas that should be monitored if changing conditions indicate higher nitrate pollution potential. Given that there are currently no known contaminated community drinking water wells in the study area, a potential beneficial application of DRASTIC in Sierra Valley is mapping areas of groundwater pollution risk/concern to address possible future changes in land use or water use conditions in this “medium priority” basin. High DRASTIC ratings indicate areas where locating new drinking water wells in areas that are relatively safe from accidental spills or potential contamination could be assisted by qualified professional advice. In areas with high DRASTIC ratings and without geologic or soils barriers, significant changes in surrounding land and water uses may suggest that further professional analysis is a prudent consideration.

Limitations

DRASTIC cannot be used to pinpoint the exact areas where contamination has occurred or will occur. It is important to understand that DRASTIC cannot be used to replace detailed site-specific hydrogeologic investigations, such as assessing the extent of on-site contamination, such as a spill. DRASTIC cannot be used to determine the potential impact of a specific contamination event. DRASTIC also cannot be used to determine the specific impacts on quantity and quality of existing or new groundwater drinking sources resulting from new projects such as urban developments or new intensive fertilizer applications or conditions. DRASTIC indicates where pollution risks may be highest but cannot quantify those impacts.

In summary, DRASTIC suggests potential risks associated with significant changes in land uses or water uses over a large geographic area, rather than determining actual risks from a specific project or action.

Practical aspects when preparing DRASTIC rating index maps

The DRASTIC guidance document contains many examples of mapping groundwater pollution potential over large areas, like entire groundwater basins and counties.

Developing a DRASTIC index map requires preparation of seven hand drawn contour maps. The final product is created by superposing all seven contour maps to prepare a final DRASTIC rating contour map. Since the contour maps are drawn by hand, this is a very time consuming approach.

An alternative and more practical and cost-effective approach is to divide a map into an equal spaced grid with equal sized squares (or “cells”), and determine DRASTIC ratings for each grid cell. Each grid cell can then be assigned a “severity index” of groundwater pollution vulnerability. The severity can be displayed either as a percentage on a scale of possible DRASTIC ratings, or by using a color code. This gridded approach is much more flexible and cost-effective at larger groundwater basin scales or for important groundwater recharge areas. The DRASTIC maps can be updated as new data becomes available.

It is important to keep in mind that most hydrogeologic data used for DRASTIC are localized. In other words they are represented only by spot measurements from which an aerial continuum has to be interpolated. The spotty data occurrence that provides the factual foundation for a DRASTIC map is not evident when looking at the final product. For example, using too small grid cell sizes creates an illusion of high resolution and a high degree of accuracy. Because usually, the amount of groundwater data is limited, requiring so much interpolation based on professional judgment, the authors of the DRASTIC manual recommend that the parcel size should not be smaller than 100 acres.

Data locations shown on maps of the California groundwater basins (including Sierra Valley) are based on the grid of the “township-range-section” (TRS) system, which divides the State into a grid with approximately one square-mile spacing. For example well locations are identified by “well number”, which identifies an approximate location in an area down to 1/16th of a square mile (an area about 1320-by-1320 ft). For the purpose of this project a grid cell size of 160 acres is chosen, i.e. the size of a quarter section. Professional judgment associated with interpolation has to be utilized to derive a balanced picture of drinking water well vulnerability in the four selected communities.

Groundwater conditions in four Sierra Valley disadvantaged communities

Groundwater conditions in the Chilcoot-Vinton area

Background

Since the mid-1980's, the Chilcoot-Vinton area has experienced significant suburban growth. Beginning around 1985 a number of suburban land development proposals were submitted to Plumas County. Under the rules of the newly established Sierra Groundwater Management District (SVGMD), each one of these subdivisions were required to conduct formal groundwater resource evaluations, subject to the following requirements:

- Determination if the available groundwater resources were sufficient to meet the demand of the proposed number of parcels.
- Determination of the impact of the proposed project, most importantly impacts of groundwater pumping in the proposed project area and adjacent areas, and impacts of wastewater disposal on groundwater quality.

As a result, the developers had to drill several test wells that were subjected to pumping tests in order to investigate groundwater conditions in the fractured bedrock and alluvial aquifers. Typically, the bedrock formations required more wells than the alluvial formations. By 1995, about five (5) large subdivision proposals were approved and a number of individual lots were developed. Eventually, in 1995, at least four of the proposed subdivisions were consolidated into one project, motivating one developer to collect data that would later become the basis of a more comprehensive groundwater management plan for a larger part of the Chilcoot sub-basin. Due to the late 1990's real estate market decline, this combined project went bankrupt, and the parcels were sold off to individual land owners. Consequently, the prospect of a comprehensive groundwater management plan in the Chilcoot sub-basin came to an end.

Nevertheless, a fair amount of aquifer data was collected; data that is still helpful to further our understanding of the northeastern Sierra Valley hydrology and groundwater quality dynamics.

Chilcoot sub-basin groundwater conditions

The bedrock underlying the Chilcoot sub-basin is fractured granite and contact metamorphic rocks, which are blanketed by silty sand in the low elevation areas north of Chilcoot and south of Beckwourth Pass (Walters, 1986; Juncal and Bohm, 1986 & 1992; Bohm, 2002). The bedrock outcrops north of Chilcoot and the surrounding mountains indicate that the bedrock formations are well jointed and fractured and are of sufficient strength to hold open fractures. The silty sand is apparently deposited by wind (evident in the wind-carved bedrock outcrops north of the town of Chilcoot) and is probably derived from shoreline deposits (beach sand) formed in the lake that once occupied Sierra Valley (Durrell, 1986).

The Chilcoot sub-basin is deemed a groundwater recharge area (DWR, 1983; Bohm, 1996). The sand contains only poorly developed soils with a high percolation rate for groundwater recharge and wastewater leachate. The percolation rates quite frequently exceed the permissible limits adopted by Plumas County.

Observation well water level data collected in February 1986 and from January till May 1996 indicated that the timing of bedrock water level response to major recharge events depends on the depth of water level below land surface (Bohm, 1996). The alluvial aquifers in the low elevation areas are apparently recharged by the underlying bedrock formations, as is indicated by the artesian flow conditions increasing with depth (Juncal and Bohm, 1986; Bohm 1996b).

Wastewater disposal

Before 1986, the entire Chilcoot sub-basin north and northeast of Chilcoot and the area between Chilcoot and Vinton were zoned mostly “agricultural,” with the only residential lots occurring in the communities of Chilcoot and Vinton. Currently, the entire Chilcoot sub-basin contains more than 250 individual parcels and more than 150 existing homes, based on a review of Plumas County and Sierra County Assessors maps. Assuming an average disposal of 200 gallons per day (gpd) per parcel, at full build-out approximately 50,000 gpd or 55 acre-feet (AF) per year of wastewater could be disposed into the subsurface in the Chilcoot sub-basin. Each of these lots is served by individual wells, often on small lots where it can be difficult to meet the Plumas County and Sierra County setback requirements for wells and leach fields.

No known anomalous nitrate values have been reported from the Chilcoot-Vinton area. Nor have comparisons of before-and-after development of groundwater quality have been developed from data collected from test wells drilled in the 1980’s. No professional assessment of the impact of cumulative individual parcel development on groundwater quality is available. High density unsewered suburban growth in an important groundwater recharge area of Sierra Valley raises the question if someday, whether the water quality in some of the shallow valley floor wells in northeastern Sierra Valley will be affected by ongoing residential development in the Chilcoot-Vinton area.

Groundwater conditions in Calpine

Hydrogeologic setting

Calpine is located in southwestern Sierra Valley, on a gentle east-facing slope. The community is underlain by less than 200 ft of lacustrine sediments, overlying fractured granite. Groundwater recharges in the highlands to the west. The layout of the community is elongated east-west, bracing a northeast-trending draw with an ephemeral stream. In the east, the gentle draw is essentially a meadow with shallow groundwater, suggesting this may be a zone of significant underground water flows.

Quasi-linear northeast (NE) trending streams are a conspicuous feature in this part of Sierra Valley, suggesting NE striking faults in the bedrock underlying the lacustrine sediments. Detailed hydrogeologic analysis may find that the zone around the ephemeral stream in Calpine may be a fault related feature suitable as a deep bedrock drilling area. The production capacity of the two existing production wells is encouraging for this type of aquifer, suggesting that further exploration in the deep granite has a chance of success.

Calpine water supply

The Sierra County Waterworks District No. 1 (SCWD1) is an entity of Sierra County specially formed to serve the water needs of the community of Calpine; currently serving 136 hookups. Originally Calpine relied on surface water from Fletcher Creek. This was abandoned due to stringent surface water treatment requirements adopted in the early 1980's in favor of two more than 600 ft deep community wells, which were drilled west of the community and produce good quality water from fractured granite.

Though initially adequate, increasing demand due to community growth eventually exceeded the well water supply. Based on several engineering studies, the two wells are sufficient to meet current levels of summer peak day water demand. However, the current moratorium on new connections will stay in place until additional supplies can be obtained. Additionally, implementation of water conservation measures such as water efficient appliances and water efficient outdoor landscaping and distribution leak audits will be necessary. Thirty vacant lots are affected by the building moratorium. High arsenic levels in one community well may eventually require treatment.

Well water supplies

Information obtained from well drillers logs (Bohm, 2000) indicates that domestic wells in the Calpine area are between 110 and 160 ft deep, apparently producing from a shallow sandy formation between 60 and 140 ft and under confined (artesian) conditions. A clay aquitard between 140 and 190 ft is underlain by granitic sand to 240 ft, which is then underlain by fractured granite. The lower confined aquifer is comprised of the fractured granite and the overlying granitic sand (Bohm, 2010).

With average pumping capacities of 20 to 40 gpm, the shallow domestic wells reportedly commonly have problems with high iron, manganese, and hydrogen sulfide, which is supported by information gleaned from the community well drilling reports. In 1983/84 the community of Calpine drilled four exploration wells west of the community (George Ball 2007, personal communication). Two of these exploration wells were completed as production wells, which are still in service. The wells were reportedly flowing artesian before they were put into service.

Wastewater disposal: existing underground septic leachfields

The Calpine community constitutes more than 60 small parcels spread across less than 80 acres. Without a wastewater treatment plant, the community has to rely on on-site wastewater disposal (individual homeowner septic leachfields). Many parcels are affected by seasonally high groundwater tables and percolation tests can fail due to poorly drained, fine-grained soils. The small lots, which are underlain by lacustrine sediments (medium to fine-grained silty sands), are seasonally impacted by high groundwater table conditions, and have difficulties finding locations with adequate percolation rates. In situations with inadequate separation between leachfields and seasonally high groundwater, interference between leachfields and ambient groundwater can become a potential leachfield performance problem that can be aggravated by imported community well water.

Future developments: water and wastewater considerations.

A groundwater resource evaluation was prepared in 2007 for the proposed Meadow Ranch Project, a proposal to develop 30 unit single-family residential parcels immediately south of Calpine (Smith, 2007). With its community wells, the Meadow Ranch Project could eventually further stress Calpine's existing water supplies. On the other hand if new community wells in the Meadow Ranch project are productive enough, they may eventually be able to help alleviate the Calpine community's water supply difficulties, including the town's search for a low arsenic water source. (Calpine is currently under a State order to mitigate arsenic exceedance in their water supply). Wastewater management will be an important consideration for further suburbanization of the Calpine area and for assessing potential nitrate pollution for land and water uses downstream and downslope of the developments.

As part of the UFR IRWM Plan update, Calpine will be asked to participate in a region-wide DAC water and wastewater needs assessment survey to support DAC funding proposal development for Proposition 1 IRWM DAC funding.

Groundwater conditions in Sierraville

Southern Sierra Valley groundwater conditions

The community of Sierraville is located on the far southern periphery of Sierra Valley, at the junction of State highways 89 and 49. The town is located on a gently north sloping alluvial fan formed by Cold Creek and other streams which enter Sierra Valley through a narrow north-northwest (NNW) trending ravine. Groundwater is recharged in the elevated areas to the south and either discharged into the perennial streams or migration through the fractured bedrock formations into the deeper portions of the Sierra Valley Basin.

Although more than 30 wells have been drilled in the vicinity of Sierraville, not much information is available about the subsurface soil and geology characteristics under the community, although studies are being proposed at this time. Please see the UFR IRWM Plan website @ featherriverwater.org for more information on Sierraville Public Utilities

District's (SPUD) priority projects, such as MS-35 SPUD Alternative Water Source Analysis and Development project; MS-38 SPUD Leak Detection and Repair project, and MS-40; and MS-41 SPUD Pump house and Storage Tank Upgrade projects. As part of the UFR IRWM Plan update, Sierraville will be asked to participate in a region-wide DAC water and wastewater needs assessment survey to support DAC funding proposal development for Proposition 1 IRWM DAC funding.

Drilling data collected near the community and along West Willow Road (west of Randolph Hill) indicate alluvial fan deposits (presumably a mix of colluvium, lake deposits, and glacial outwash (Grose, et al., 2000)), and cobbles and boulders derived from the volcanic rock outcrops to the south. Drilling data collected for a land development project south of Willow Road indicate that these deposits are underlain by a shallow volcanic bedrock ledge no more than 75 ft deep (Bohm, 2006). Therefore, the wells in the southern area pump mostly from fractured volcanic bedrock and less from the overlying alluvial deposits. Apparently the alluvium here is too thin to yield substantial amounts of water. Well yields range between 5 and 30 gpm.

Some drilling logs indicate less than 5 ft to the static groundwater table; while others indicate more than 25 ft. Seasonally high water tables may be augmented by flood irrigation water imported from the Little Truckee River in the spring and early summer, as well as other seasonal surface water diversions.

Potential causes of groundwater contamination

While homes outside the community of Sierraville rely on individual wells for their water supply, the homes and businesses in Sierraville are tied into a community water supply system, which is fed by two developed springs. The springs are located in the eastern portion of section 23, immediately southwest of Randolph Hill. Sierraville is not sewered, and the residences depend on on-site wastewater disposal by means of septic leachfields. Many parcels in the downtown area are underlain by a clay-rich layer causing low percolation rates. As a result the newer leachfields are required to be designed by an engineer as "mounded" leachfields or in installations where the leachfields excavations are dug deep enough to allow leaching into the underlying gravel layers.[4] Given the high groundwater table and the potential of individual domestic wells to become affected by leachfields, the community was able to develop a community water supply outside the community area. However, existing shallow groundwater conditions are aggravated by on-site effluent discharge, which acts as a source of "artificial groundwater recharge" that is imported from community wells located outside the community area. In summary, the Sierraville community, the SPUD, and Sierra County are actively engaged in developing studies and projects to address identified and future water supply and quality concerns that may potentially be eligible for additional support from Proposition 1 DAC funding.

[4] Elizabeth Morgan, personal communication, April, 2016.

Groundwater conditions in the Loyalton area

Aquifer conditions

The city of Loyalton is located in the southeast corner of Sierra Valley, at the northwestern periphery of the alluvial fan formed by Smithneck Creek. The deeper aquifer is likely recharged from fractured bedrock at depth, whereas the shallow aquifer is likely recharged by infiltration of Smithneck Creek water into the alluvial fan deposits. As a result, the static water level in the city area is probably about 5 to 10 ft below land surface. The pumping levels in the city wells and the industrial wells (Sierra Pacific Industries/SPI) are about 50 to 100 ft below land surface (Bohm, 1997).

A transmissivity of 13,000 gpd/ft was calculated from pumping test data from the SPI well #3 (Bohm, 1997). Assuming the 100 ft screened interval is representative of the aquifer thickness, the estimated unconsolidated aquifer hydraulic conductivity is approximately 1,300 gpd/ft^2 (to be used for DRASTIC rating).

Wells in the Loyalton area

More than 100 wells are located in the vicinity of Loyalton, within the perimeter four miles west, two miles north, and approximately two miles east and southeast of Loyalton. The deeper wells are used for agricultural irrigation, municipal (City of Loyalton), and industrial (SPI cogeneration plant) purposes. More than 90 percent of the Loyalton area wells are less than 400 ft deep. Very few wells pump from bedrock. Well yield is largely dependent on depth. Wells less than 200 ft deep yield not more than 50 gpm, whereas yields range between 300 and 2,000 gpm from wells deeper than 200 ft.

Loyalton relies on three wells (with depths of 200, 260, and 410 ft) and one spring for its water supply. One of these wells is located at the north end of town, and two are located approximately one mile south of the city. Lewis Spring is located about 1.5 miles to the south of the City at an elevation of 5200 ft. Three deep industrial wells are located approximately ½ mile south of Loyalton on the same property on which the cogeneration plant (SPI) is located.

Most of the wells in the Loyalton area serve single residences outside the municipal service area. These wells are mostly producing from alluvial fan deposits and lacustrine sediments (sand and gravel). Only very few wells are drilled into bedrock. The residential wells, presumably serving single residences, are typically less than 200 ft deep. The highest concentration of domestic wells is in section 14, with at least 25 wells (approximately ½ mile west of Loyalton).

Potential sources of groundwater contamination

The City of Loyalton is sewered and serviced by the wastewater treatment plant located approximately one mile northwest of Loyalton, on the flat valley floor. The treated effluent is discharged into a lined evaporation pond. Since this facility is operated and maintained by the City, groundwater contamination from this facility is deemed unlikely, unless the liner in the pond becomes compromised.

A more likely source of potential groundwater contamination would be leaking sewer lines. Like many other small rural communities, leakage from aging sewer collection systems is a potential problem. Increasing sewer flows during heavy rainstorms have been observed, indicating that the Loyalton sewer system is impacted by inflow/infiltration within the collection system (Ray Kruth, Stantec Engineering, Reno, personal communication). Loyalton is interested in further development of the City's ongoing leak detection and repair program for water use efficiency and continued water quality protection. As part of the UFR IRWM Plan update, Loyalton will be asked to participate in a DAC needs assessment survey to support DAC funding proposal development for Proposition 1 IRWM DAC funding.

Onsite wastewater treatment and disposal (septic systems) on residential lots outside the City's service area are another potential source of bacterial and nitrate pollution to groundwater. To our knowledge, no data are available that could indicate groundwater contamination from septic leachfields in the Loyalton area.

Comparison of selected communities' groundwater issues

Although located in the same groundwater basin, each of the four communities selected for this study are unique in their distinct combination of groundwater and wastewater disposal issues. The table below summarizes the unique challenges faced by each community.

Table comparing selected communities' and their surroundings' water supply and wastewater issues

community	sewer ed?	bedrock outcrops?	perc rates often too low	perc rates often too high	high GW table	individual wells	commu nity wells
Chilcoot-Vinton		yes		yes		yes	
Calpine			yes		yes	yes	yes
Sierraville	yes		yes		yes	yes	yes
Loyalton	yes					yes	yes

Parts of the Chilcoot-Vinton community are characterized by small parcel sizes located on poorly developed sandy soils overlying shallow fractured bedrock. With residences dependent on individual wells, this combination is generally considered problematic from a groundwater protection standpoint.

Soils in Calpine are characterized by low percolation rates and discoloration by iron hydroxide deposits (an indication of poor drainage and sometimes high groundwater tables). Combined with high-density parcel sizes and water being imported from distant wells of a community water distribution system, the conditions for on-site wastewater disposal are expected to worsen.

The fine-grained Sierraville soils are often only marginally suited for leachfields. Further complicating the conditions, high groundwater may in part be an artifact of nearby flood irrigation augmented by stream water importation from the Little Truckee River. The high water table situation may be worsened by leachfields importing and artificially recharging water imported by the community water distribution system, creating the need for engineered leachfields (mound systems).

In the City of Loyalton, the water distribution system and the wastewater collection system do not interfere with each other. An exception may be leaks in the aging wastewater system. Whether leaks in the aging system are significant enough to become a threat to the city wells remains unanswered. However, adverse effects from septic leachfields in the outskirts of Loyalton on nearby wells remain a possibility.

General observations

While focusing on the disadvantaged communities (DAC's) of Chilcoot-Vinton, Calpine, Sierraville, and Loyalton, groundwater pollution from non-urban sources elsewhere in Sierra Valley cannot be ignored. Furthermore, single residences are common in many other areas; in particular the peripheral areas of Sierra Valley such as the Beckwourth area, the areas south and southwest of Calpine, Sattley, areas west of Loyalton, and many others. Another potential pollution source is varying natural groundwater quality parameters due to changing pumping patterns (for example boron occurrence).

Managing groundwater quality of an aquifer underlying an agricultural area with interspersed growing suburban development faces a multitude of challenges. Individual leachfields are essentially systems that recycle minimally treated wastewater into the underlying aquifer. Functioning leachfields are meant to remove solids, bacteria, and viruses. They are, however, not designed to remove solutes, like nitrate, phosphorus, TDS, chloride and common household chemicals. These solutes, when diluted, pose no concern in a well-flushed aquifer (adequate groundwater flow). But when dispersion is inadequate, alarming "spikes" will show in the monitoring data.

Given enough time on a valley floor with the right kind of underlying sediments, any human activities will eventually impact groundwater quality (as the groundwater quality data collected in American Valley show). With time, impacts on groundwater quality due to a multi-facetted range of activities are becoming an increasing probability.

Lessons learned: applying DRASTIC to American Valley

A "wellhead protection demonstration program", funded by US-EPA was conducted in American Valley in the mid 1990's (Bohm, 1998). The study entailed a review of all available groundwater data to develop a comprehensive assessment of the groundwater conditions in American Valley. Preparation of a DRASTIC map was one part of the project, focusing on groundwater pollution potential. The final map was created with GIS software. Students from Feather River Junior College assisted with the project, making the project a significant public education benefit as well. Through the DRASTIC method, an impressive mapping product was created to draw the community's attention to the importance of groundwater protection.

Although the wellhead protection study stimulated the public interest in groundwater protection, public education to continue to inspire the community's groundwater awareness soon became superseded by more pressing immediate concerns. The drought and new legislation (SGMA) triggered needs such as drilling new wells and developing a regional groundwater authority in order to comprehensively develop and manage the groundwater resource of the entire American Valley.

What were the lessons learned for developing community groundwater resources? Although there appears to be plenty of groundwater available, perceived favorable potential drilling sites can quickly become compromised by lack of access (changing land ownership), water quality (natural and contamination), limited well yield, and pipeline cost.

Perhaps the biggest lesson was that concurrent developments that threaten (or potentially threaten) aquifer integrity can be controlled only to a limited extent. Once such complicating factors are in place, groundwater development must adjust accordingly. Under these conditions, if a well becomes contaminated there are two alternatives: continue pumping at the same location and treat the water, or drill another well at a location away from potential pollution (and protect the new resource).

Most commonly, a number of more pressing daily issues and shortage of funds tend to override long-term groundwater planning. Sometimes out of pure necessity a wellfield continues to be developed in an area that is known to be gradually deteriorating. Well site location decisions include other factors than only hydrogeologic and aquifer protection factors. In emergencies, such as accidental spills and aging well failures long-term contingency plans will be circumvented. However, managing a wellfield through long-term planning is more economically feasible rather than by a series of emergency solutions; limited time makes it difficult to acquire adequate financial resources. It becomes a vicious cycle: without long term financial and technical planning and management will be repeatedly forced into a series of short-term (more expensive) solutions.

Bibliography

Aller L, T Bennett, JH Lehr, RJ Petty, and G Hackett, 1987. DRASTIC: A standardized system for evaluating ground water pollution potential using hydrogeologic settings. Robert S. Kerr Environmental Research Laboratory, US-EPA, Ada, OK, EPA-600/2-87-035. April 1987.

Ball G, 2001. Calpine water supply wells 1 and 2. Data summary. Engineering and planning by Wateresources Engineers, Reno, NV (George Ball)

Bohm B, 1997. Drilling and testing Cogeneration Plant Well No. 3, Sierra Pacific Industries, Loyalton, and Sierra County, California. Report prepared for SPI, May 1997.

Bohm B, 1998. American Valley wellhead protection demonstration program, Plumas County, California. Prepared by Plumas Geo-Hydrology for Quincy Community Services District, (530) 836-2208. February 28, 1998.

Bohm B, 2000. Recommendations: Well drilling at the Calpine Fire hall. Prepared for Mike Freschi, Calpine VFD. December 8, 2000.

Bohm B, 2006. Ground Water Resource Evaluation of the Amodei Ranch Subdivision Southern Sierra Valley, Sierra County, California. Technical Summary Report. Prepared for Tim Beals, Director Sierra County Department of Planning and Building Inspection. June 2006.

Bohm B, 2010. Drilling and Testing the Well at the Fire Hall in Calpine, Sierra County, California. Technical Summary Report prepared for Sierra County Waterworks District No.1. June 2010.

Bohm B and RW Juncal, 1986. Ground water resource evaluation for the Frenchman Lake Road Estates and Chilcoot Springs Ranches Subdivisions, Chilcoot, Plumas County, California. Technical summary report, Waterwork Corp. July 1986.

Bohm B and RW Juncal, 1989. Ground water resource evaluation: Rendezvous Highlands near Beckwourth Pass. Prepared for Lambdin and Lambdin, Inc., Reno, Nevada. Technical summary report, Waterwork Corp., April 1989.

Bohm B, 1995. Isotope and hydrochemical hydrology, Chilcoot Sub-basin, Eastern Sierra Valley, California. (Including a Review of Current Ground Water Resource Estimates). Current Status of Investigations, prepared for Lambdin Development Group, Chilcoot, CA, September 1995.

Durrell C, 1987. Geologic History of the Feather River Country, California. Univ. California Press, Berkeley. 337 pages.

DWR, 1983. Sierra Valley Ground Water Study. Memorandum Report. California Dept. of Water Resources. June 1983.

Ford, et al., 1963. Northeastern Counties Ground Water Investigation. California Department of Water Resources.

Heath RC, 1989. Basic ground-water hydrology. USGS Water Supply Paper 2220.

Pruitt WO, E Fereres, RL Snyder, 1987. Reference Evapotranspiration (Et_o) for California. Agricultural Experiment Station, University of California. Bulletin 1922.

Sketchly HR, 1975. Soil survey of Sierra Valley Area, California, Parts of Sierra, Plumas and Lassen Counties. United States Department of Agriculture Soil Conservation Service and Forest Service in cooperation with University of California Agricultural Experiment Station. 131 pages, 23 maps.

Smith DL, 2007. Hydrogeologic review of the proposed Meadow Ranch Project, near the community of Calpine, Sierra County, California. Prepared for North Fork Associates, Auburn, CA, by Interflow Hydrology, Inc., Truckee, California. April 2007.

Walters Engineering, 1986. Ground water supply evaluation and completion report on Well no. 1 and Well no. 2. Prepared for Robert F. Carmody, Sierra View Subdivision, Chilcoot, Plumas County, CA. January 1986.

Attachment A: Sierra Valley DAC "DRASTIC" ratings maps

Steps in creating the DRASTIC maps

The first step in the study was to gather data sources and the possible range of each variable was surveyed, including: water level data, precipitation, evapotranspiration data, aquifer data (geologic formations), soil data, topography, and hydraulic conductivity.

Creating a DRASTIC ratings map for each community began by developing an Excel workbook. For each community, a rectangular, equal-spaced grid with 2640-by-2640 ft grid-cells (160 acres) was defined on the topographic map to cover the community and surrounding area. The ratings for each grid cell were entered into one of seven separate worksheets in the workbook. The final ratings were calculated in the 8th sheet by summation of the individual ratings multiplied by their weighting factors. Each cell in the final rating grid was then converted into a percentage scale between the minimum and maximum possible DRASTIC ratings, i.e. between 26 and 226. The grid was then printed onto a topographic map to become the final DRASTIC ratings map.

Since the topographic map already contains a lot of information, for clarity a "well vulnerability index" between 1 and 5 and a corresponding color code (green, yellow and red) were assigned to each cell in a separate map (without the topographic background).

In the end, for each community two kinds of maps were created:

A. A topographic map with a blue grid, including the percentage ratings in each grid-cell printed onto a topographic map to become the final DRASTIC ratings map.

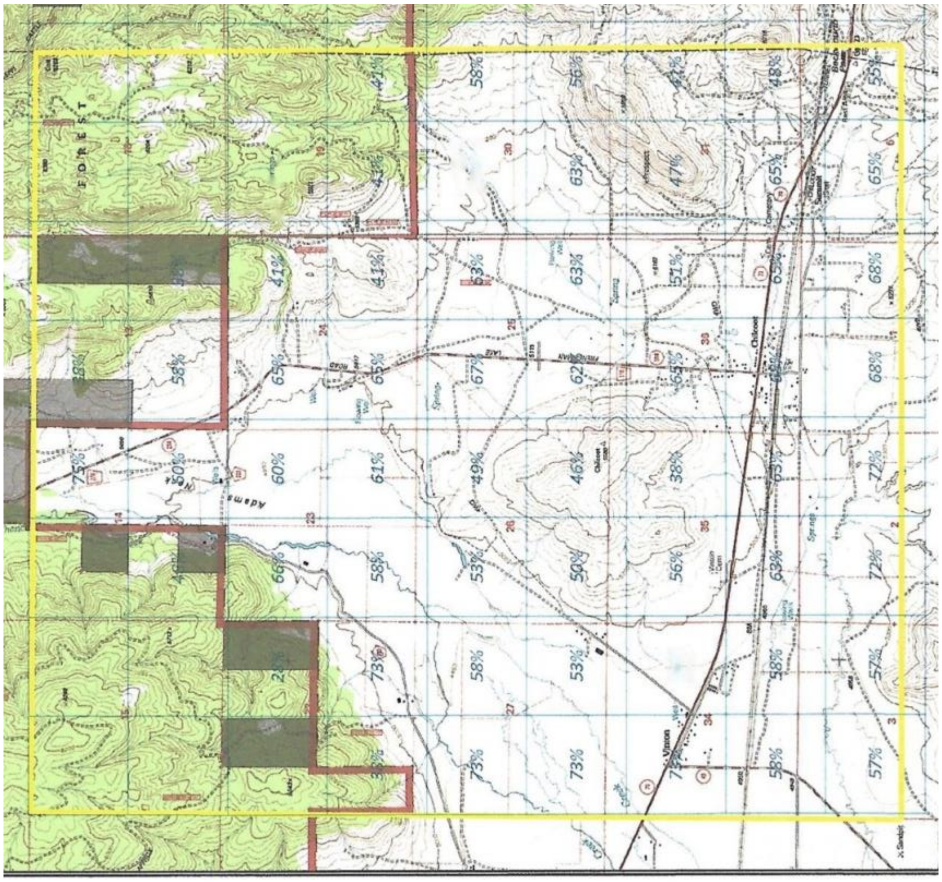
B. Since the topographic map already contains a lot of information, for clarity a "well vulnerability index" between 1 and 5 and a corresponding color code (green, yellow and red) were assigned to each cell in a separate grid-map (without topography).

The advantage of the colored grid with its "well vulnerability indices" is that it allows an immediate overview of the areas of concern.

A third map is also included:

The current (2015) County Assessors parcels maps are included to indicate the potential growth in residential water demands and wastewater outputs in an around the four selected communities. It is important to note that potential growth is not actual growth until the required development permits are issued and the developments are built and operational.

Chilcoot-Vinton well vulnerability index map

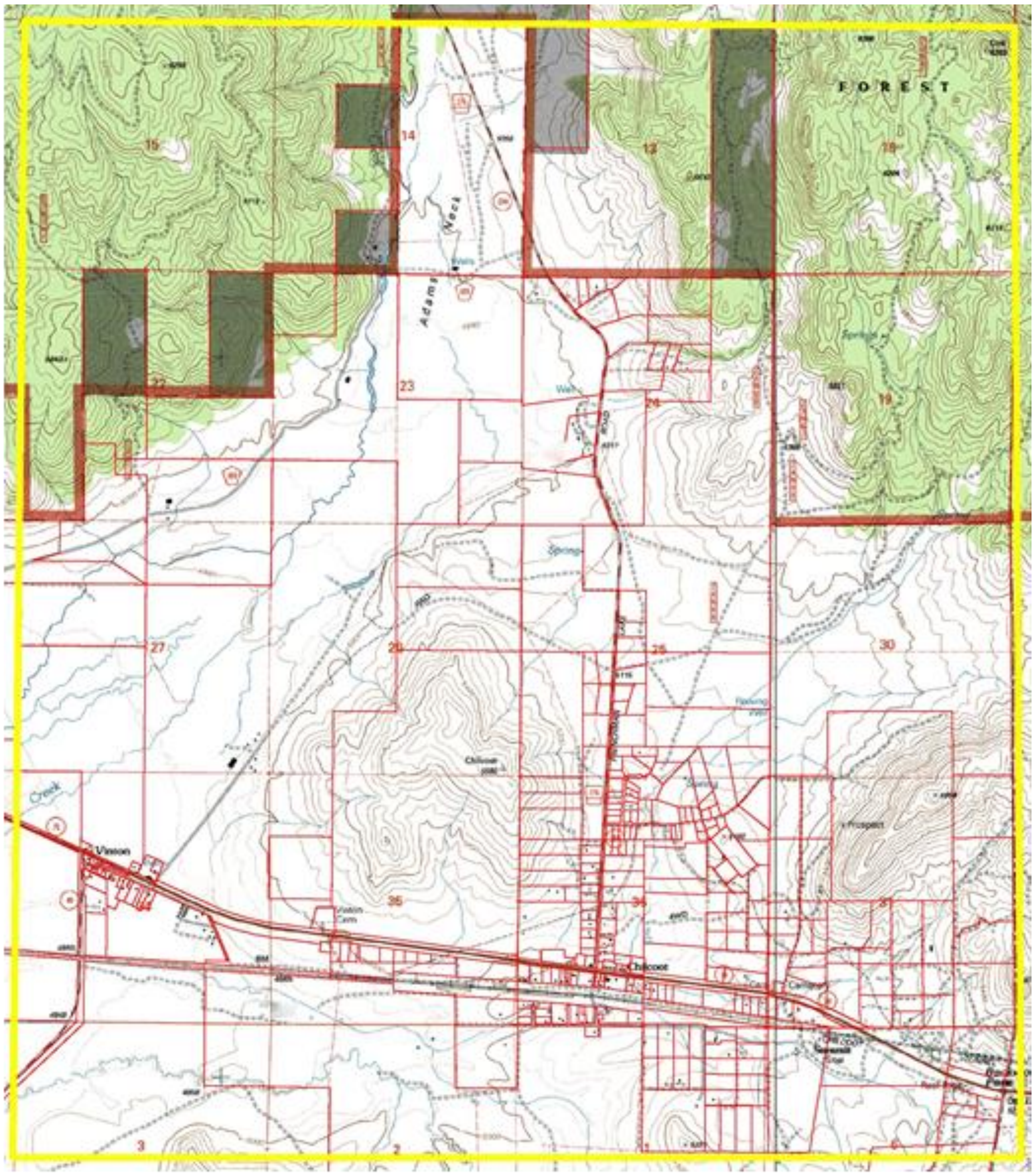


2	2	3	4	2	2	2	2
2	2	3	3	3	2	3	3
2	2	4	3	4	3	3	3
2	4	3	4	4	3	3	3
4	3	3	3	4	4	3	3
4	3	3	3	4	4	4	3
4	2	3	2	4	3	3	3
3	3	4	4	4	4	4	3
3	3	4	4	4	4	4	3

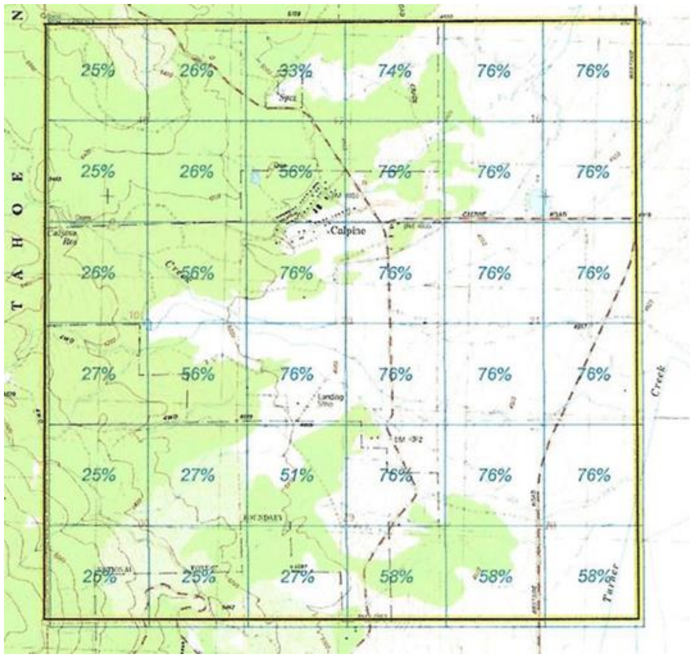
Chilcoot-Vinton

Well Vulnerability Index:	1	2	3	4	5
	low		medium		high

Chilcoot-Vinton parcel map

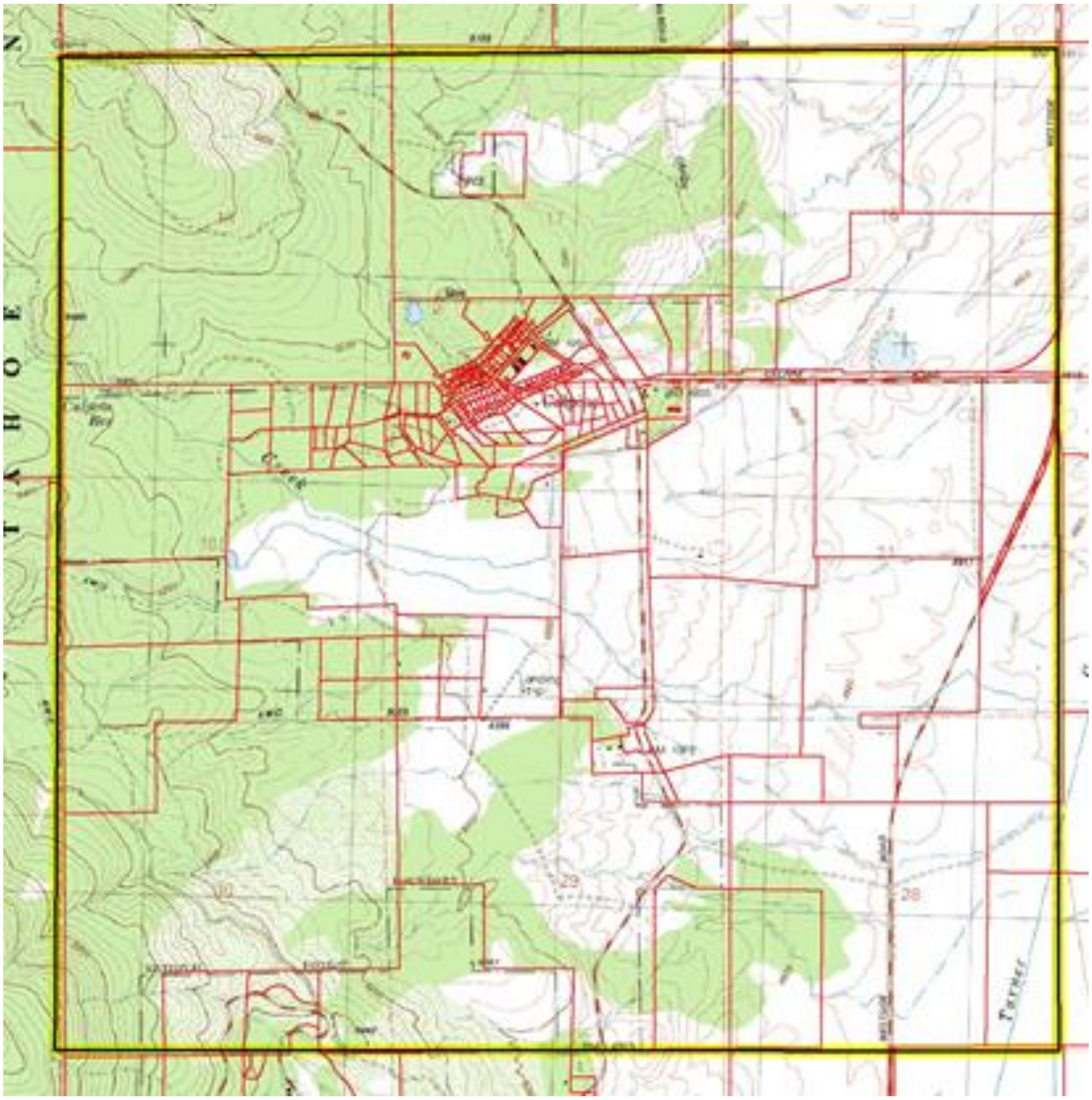


Calpine well vulnerability index maps

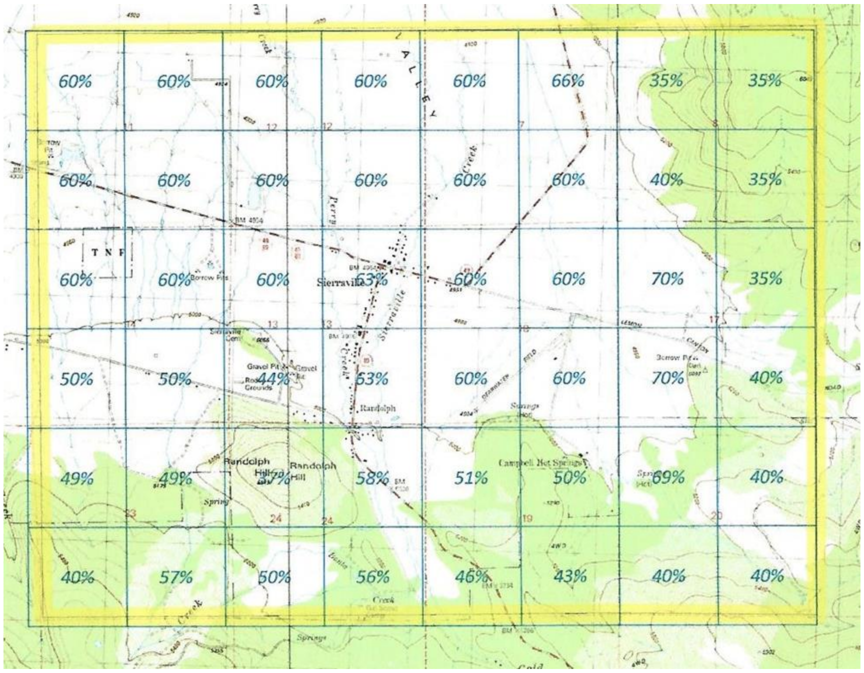


1	1	1	3	3	3
1	1	2	3	3	3
1	2	3	3	3	3
1	2	3	3	3	3
1	1	2	3	3	3
1	1	1	2	2	2
Calpine, well vulnerability index					
	1	2	3	4	5
	low		medium		high

Calpine area parcel map

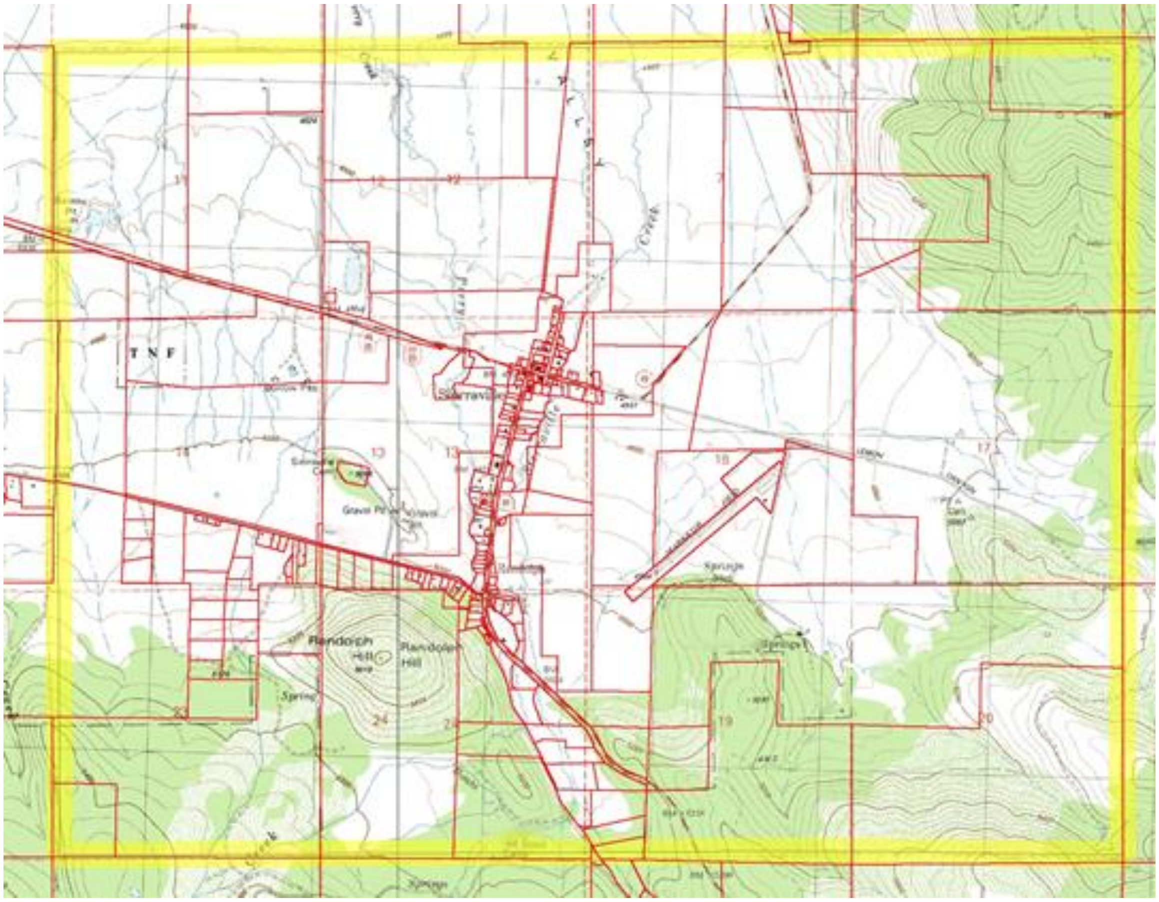


Sierraville well vulnerability index map

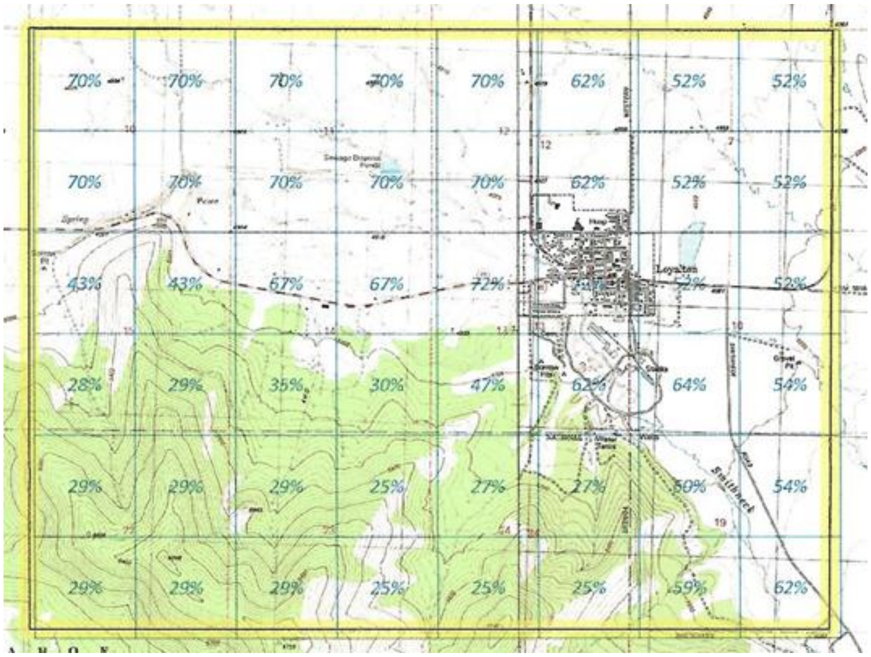


3	3	3	3	3	3	1	1
3	3	3	3	3	3	1	1
3	3	3	3	3	3	3	1
2	2	2	3	3	3	3	1
2	2	1	2	2	2	3	1
1	2	2	2	2	2	1	1
Sierraville							
Well Vulnerability Index:			1	2	3	4	5
			low		medium		high

Sierraville area parcel map

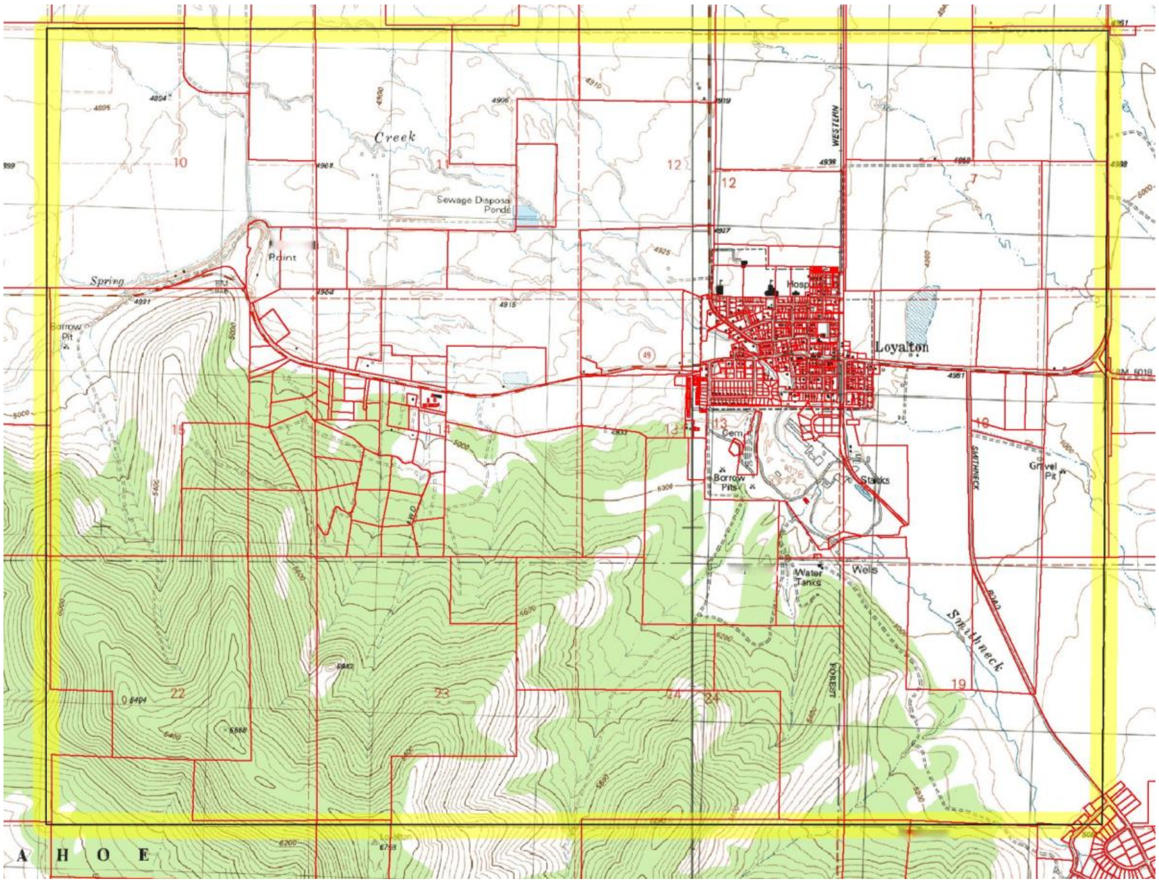


Loyalton well vulnerability index maps



3	3	3	3	3	3	2	2
3	3	3	3	3	3	2	2
2	2	3	3	3	3	2	2
1	1	1	1	2	3	3	2
1	1	1	1	1	1	2	2
1	1	1	1	1	1	2	3
Loyalton							
Well Vulnerability Index:			1	2	3	4	5
			low		medium		high

Loyalton area parcel map



Attachment B: “DRASTIC” ranges and ratings

From Aller et al., 1985

TABLE - "DRASTIC" RANGES AND RATINGS		
<u>DEPTH TO WATER</u>	<u>(FEET)</u>	
Range	**Rating**	
0-5	10	
5-15	9	
15-30	7	
30-50	5	
50-75	3	
75-100	2	
100+	1	
Weight: 5	**Pesticide Weight: 5**	
<u>NET RECHARGE</u>	<u>(INCHES)</u>	
Range	**Rating**	
0-2	1	
2-4	3	
4-7	6	
7-10	8	
10+	9	
Weight: 4	**Pesticide Weight: 4**	
<u>AQUIFER MEDIA</u>	<u>(ROCK TYPE)</u>	
Range	**Rating**	**Typical Rating**
Massive Shale	1-3	2
Metamorphic/igneous	2-5	3
Weathered Metamorphic/igneous	3-5	4
Glacial Till	4-6	5
Bedded Sandstone, Limestone and Shale Sequences	5-9	6
Massive Sandstone	4-9	6
Massive Limestone	4-9	6
Sand and Gravel	4-9	8
Basalt	2-10	9
Karst Limestone	9-10	10
Weight: 3	**Pesticide Weight: 3**	

SOIL MEDIA	(ROCK MATERIAL)	
Range	**Rating**	
Soils are thin or Absent	10	
Gravel	10	
Sand	9	
Peat	8	
Shrinking and/or Aggregated Clay	7	
Sandy Loam	e	
Loam	5	
Silty Loam	4	
Clay Loam	3	
Muck	2	
Nonshrinking and Nonaggregated Clay	1	
Weight: 2	**Pesticide Weight: 5**	

TOPOGRAPHY	(PERCENT SLOPE)	
Range, %	**Rating**	
0-2	10	
2-6	9	
6-12	5	
12-18	3	
18+	1	
Weight: 1	**Pesticide Weight: 3**	

IMPACT OF VADOSE ZONE MEDIA	(ROCK MATERIAL)	
Range	**Rating**	**Typical Rating**
Confining Layer	1	1
Silt/Clay	2-6	3
Shale	2-5	3
Limestone	2-7	6
Sandstone	4-8	6
Bedded Limestone, Sandstone, Shale	4-8	6
Sand and Gravel with significant Silt and Clay	4-8	6
Metamorphic/Igneous	2-8	4
Sand and Gravel	6-9	8
Basalt	2-10	9
Karst Limestone	8-10	10
Weight: 5	**Pesticide Weight: 4**	

HYDRAULIC CONDUCTIVITY	**(GPD/FT^2)**	
Range	**Rating**	
1-100	1	
100-300	2	
300-700	4	
700-1000	6	
1000-2000	8	
2000+	10	
Weight: 3	**Pesticide Weight: 2**	