APPENDIX 3-C. Scott Valley Dry Well Risk Analysis

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Contents

Introduction

This analysis seeks to determine the number of wells that may be dewatered due to declining groundwater levels. In the Scott Valley, groundwater elevations are highly seasonal, so the highest risk of dewatering occurs in the late summer and early fall.

A thorough assessment would involve a comparison of historic and current water levels against well construction details across all or a representative subset of wells in Scott Valley. However, two key data limitations inhibit a comparison of well construction details with water levels where they have been measured in wells:

- Well depth and perforated intervals, on one hand, and water level observations on the other have been collected by multiple organizations/agencies. They are listed here along with their abbreviations used in Table 1.
  - California Department of Water Resources (DWR)
  - UC Davis researchers, in a 2013 review of Well Completion Reports (UCD Review 2013)
  - Quartz Valley Indian Reservation (QVIR)
  - Transducer data collected by Larry Walker and Associates for the County of Siskiyou, referred to collectively as the Groundwater Observatory (LWA GWO)
- For most wells associated with water level measurements, no well construction information is readily available, making a direct comparison of water levels and well depth or perforated interval impossible without significant further reconnaisance.
  - In some cases, well construction details may be available for some wells with observations, but matching them is currently not possible because different organizations/agencies refer to wells with different identifiers.

Consequently, rather than comparing groundwater elevations with screened intervals, this analysis focuses on interpolated groundwater elevation data to assess the aggregated risk of wells not being able to pump water due to low water levels (“well outages”). The risk analysis necessarily utilizes basic information that is readily available and is therefore limited in its specificity. Future analysis may provide a more refined risk assessment.

Methods

Information available for conducting this well outage risk analysis is shown below in Table 1. All wells are associated with location (latitude and longitude). Well locations are accurate to the section level (1 square mile). Well completion reports (e.g., https://water.ca.gov/Programs/Groundwater-Management/Wells/Well-Completion-Reports) may have more detailed information, but these are generally not digitized and field-validated for their exact location and elevation datum.

Estimating the elevation datum for each well is based on the USGS reported elevation at the location of the well reported by the respective program agency (mostly DWR). The accuracy of the elevation is estimated to be within 3% of one-half mile, i.e., 80 feet, where 3% represents a general maximum landscape slope within the Scott Valley groundwater basin and one-half mile represents the maximum distance of the actual well location from the reported well location. Clearly, for comparison of water levels with well depth, an inaccuracy of potentially several tens of feet in the well location elevation is highly problematic.

Hence, a first step in this analysis was to identify wells where observed water levels could be directly compared against screened intervals, or, failing that, against the total depth of the well within which the measurement was taken. Wells located in the UC Davis 2013 Well Review, during development of the Scott Valley Integrated Hydrologic Model, were associated only with a well completion report. DWR's CASGEM program collected observations and some well construction information for a limited number of wells. The Quartz Valley Indian Reservation's private monitoring program has collected observations in domestic wells, but well construction information for these wells was not available. Similarly, well depth is available for only 6 wells participating in the LWA GWO transducer program (i.e. continuous water elevation monitoring).

A direct comparison of water levels to screened interval or well depth is not currently possible for the overwhelming majority of Scott Valley wells. A future matching effort would help connect some of the UCD Review wells (from Well Completion Reports) with anonymized well identifiers used for recent water level observations, for an aggregated analysis of well outage risk within the network of wells with known water levels.

Instead, the analysis focuses a) on overall well depth distribution in Scott Valley and b) a preliminary, highly approximative estimate of the depth of the bottom of a well below the water table ("wet water column depth of wells") that is used to determine the cumulative distribution of well depth, especially at depths that are approximately equal to the water level.

Table 1: Available information for Scott Valley wells, collected by 4 different monitoring programs/agencies.

Depth, Obs., Perf. Available?	Well Info Source	No. of Wells
None (location only)	LWA GWO	7
None (location only)	QVIR	3
Total Depth Only	LWA GWO	3
Total Depth Only	UCD Review 2013	136
Observations Only	DWR	5
Observations Only	LWA GWO	1
Observations Only	QVIR	16
Observations Only	UCD Review 2013	50
Perforation Only	–	0
Observations and Depth	DWR	6
Observations and Depth	LWA GWO	6
Perforation and Observations	DWR	1
Perforations and Depth	UCD Review 2013	61
Depth, Obs. and Perf.	–	0

The second step in the risk analysis, after considering well depth distribution, is a comparison of an interpolated water level, obtained by mapping measured water levels in Scott Valley, against the estimated elevation of the bottom of each well for which depth information is available, at the reported location. The difference between these two values is herein referred to as the "wet water column depth", or:

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[interpolated groundwater surface] - [estimated elevation of bottom of
well] = [wet water column depth]
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Three water level maps were constructed from water levels measured in the fall of 2014 (dry year), in the fall of 2015 (dry year), and in the fall of 2017 (wet year). Most wells in Scott Valley reached their lowest recorded water levels in the fall of 2014 or in the fall of 2015, but recovered by the fall of 2017. Water level maps were constructed using spline interpolation on water level measurements in over thirty wells. The water level maps were used to digitally determine the interpolated water level elevation at the reported location of each well considered.

The risk of residential wells is obviously more of a threat to human health and safety than other well types. However, because the number of residential wells within the existing database represents only a small subset of the residential wells located through out Scott Valley, threats to residential wells specifically have not been evaluated here. The uses of wells in this dataset, broken out by data source, is listed in Table 2.

Table 2: Available well use information for Scott Valley wells, collected by 4 different monitoring programs/agencies.

Well Use	Well Info Source	No. of Wells
Irrigation	DWR	1
Other	DWR	1
Residential	DWR	7
Unknown	DWR	3
Irrigation	LWA GWO	3
Observation	LWA GWO	3
Residential	LWA GWO	5
Residential	QVIR	19
Irrigation	UCD Review 2013	197

Results and Discussion

The distribution of available data on well depth and perforation intervals is shown in Figure 1. Well depth reported for irrigation wells in Scott Valley range from as little as 10 feet to as deep as 400 feet. One quarter of wells is less than 70 feet deep, one quarter of wells is more than 150 feet deep, and the average well depth is about 100 feet (all depths are below ground surface, bgs). Most irrigation wells appear to be screened from about 30 feet depth to the bottom of the well. Few irrigation wells (based on the limited number of wells for which screen information is available), have their top of screen deeper than 50 feet.

The cumulative distribution (CD) of well depth and the cumulative distribution of depth to groundwater (measurements collected 2010-2021) are compared in Figure 2. We note that the two curves represent two separate groups of wells: The dots on the blue curve do not represent the water level depth corresponding to the well depth (black dot) at the same x-axis position (directly below the blue dot). The water level depth data represent actually measured water levels from the last ten years, across the available datasets. Most wells in Scott Valley have a relatively shallow depth to groundwater: Two-thirds of measurement data show depth to the water table of less than 30 feet below ground surface. There are few wells with relatively deep water levels: About 5% of measurements indicate water level depths exceeding 75 feet. This finding corresponds to the distribution of water level depths in the representative monitoring network for groundwater levels (Chapter 3 in the Scott Valley Grounwater Sustainability Plan). Overall well depth exceeds depth to water table by more than 70 feet. However, some deep wells may have very shallow water table and some shallow wells may have intermediate depth to water table with relatively shallow water column.

The interpolated, contoured groundwater elevation in September of 2015 is shown in Figure 3, together with the location of the wells with water level measurements that are used for the water level interpolation. Estimates of water levels are most accurate near the locations of the measured wells. Estimates deteriorate in accuracy with larger distance from a measured well (also see Chapter 2 in the Scott Valley Groundwater Sustainability Plan).

The estimated wet water column depth is shown in the following map. If the interpolated elevation of the water table was above the bottom of the well, the wet water column depth is positive (color-coded blue in Figure 4 and Figure 5). If the interpolated water level elevation was below the bottom the well, the difference is shown as a negative number, and these wells are color coded orange or red in Figure 4 and Figure 5. About 10% of wells have an estimated wet water column depths that is negative. About 20% of wells are estimated to have non-negative wet water column depths that is relatively shallow - less than 50 feet. Over two-thirds of wells are estimated to have a wet water column depth of more than 50 feet, consistent with the illustrated difference between the water table depth CD and the well depth CD in Figure 2. The wells most vulnerable to well outage are those with the least (or negative) wet water column depth.

A negative wet water column depth may be the result of a real event, e.g., the well is old and has been dry for some time. A negative wet water column depth may also be the result of estimation errors:

1) the interpolated water level elevation used to estimate wet water column depth can be associated with significant error, from few feet to few tens of feet, due to limitations of the interpolation algorithm
2) the elevation at the reported well location is significantly different from the land elevation at the actual well location (up to 80 feet, see above), or
3) well depth is inaccurately reported.

The absolute value of the wet water column depth is therefore thought to be of poor accuracy. However, their cumulative distribution is indicative of the relative distribution of wet water column depths. The cumulative distribution of the wet water column depth is shown in Figure 6 for all three times for which the esimate was computed. A zoomed-in version of this Figure, focused on wet water column depths from 0 feet to 200 feet is shown in Figure 7. Fall water wet water column depths are shown for dry years 2014 and 2015 as well as the fall of 2017, following a wet winter, for comparison purposes. The cumulative distribution of wet water column depth indicates that fall 2015 water level conditions resulted in the shallow-most conditions across nearly all wells in the Scott Valley (in other words, the green curve is above - shallower than - the blue and yellow curve). As expected, wet water column depth is largest (in the figure: lowest) in 2017, a wet year. The difference between years is least where (estimated) wet water column depth is either very shallow or even negative and also where it is over 100 feet. In the intermediate range, from 30 feet to 120 feet wet water column depth, the difference between fall of 2015 and fall of 2017 is about 10 feet (about 50% of wells).

The absolute value of the wet water column depth is, as indicated, highly uncertain. However, the slope of the cumulative distribution shown is relatively uniform at either end of the distribution and is therefore much less sensitive to the above listed uncertainties. Figure 6 indicates that the slope of the CD is approximately 0.1 (in x-axis direction) per 50 feet (in y-axis direction), for the range of wet water column depths of -30 feet to 30 feet. This slope is equal to 0.02 per 10 feet or 0.01 per 5 feet. Hence, this slope is representative for the approximately one-fifth of Scott Valley wells that have the least estimated wet water column depth and would be most susceptible to well outages. Given the range over which the slope applies, the slope value is much less sensitive to the specific estimated wet water column depth at a well, but rather applies to all shallow (or negative) values. If we further assume that the minimum wet water column depth needed is similar for most domestic wells, then the slope can be interpreted as the risk for well outage with additional water level decline below the historically low values of 2014 and 2015: The slope of 0.01 per 5 feet indicates that 1% of Scott Valley wells are likely to experience well outage for every 5 feet of water level decline below water levels of 2014 and 2015.

Importantly, this approach to estimating well outage risk does not require knowledge of specific well information about pumping bowl elevation relative to the screen location, or about a minimum wet water level depth needed to pump properly. It only assumes that the historically low water level depths of 2014 and 2015 brought some wells close to well outage (or did cause unreported outage) and, hence, the selected slope is representative of the 20% wells at most risk to well outage.

This allows for an estimate of the undesirable result that would occur if water levels declined to the minimum threshold. The depth to water level at the minimum threshold is defined as 110% of the deepest depth to water level observed. In most areas of the groundwater basin, the deepest depth to the water level observed over time is less than 30 feet (see above), hence the minimum threshold in most areas would allow at most 3 feet of additional lowering of water levels. Only one well in the Representative Monitoring Network has a water level depth of 100 feet, and would be allowed an additional 10 feet of water level lowering. Given that a 5 foot decline puts about 1% of Scott Valley wells at risk of well outage, the selection of the minimum threshold does not pose a significant risk of widespread well outage: about 10 wells out of approximately 1,000 domestic wells would be at risk of well outage if water levels lowered to the minimum threshold everywhere in Scott Valley.

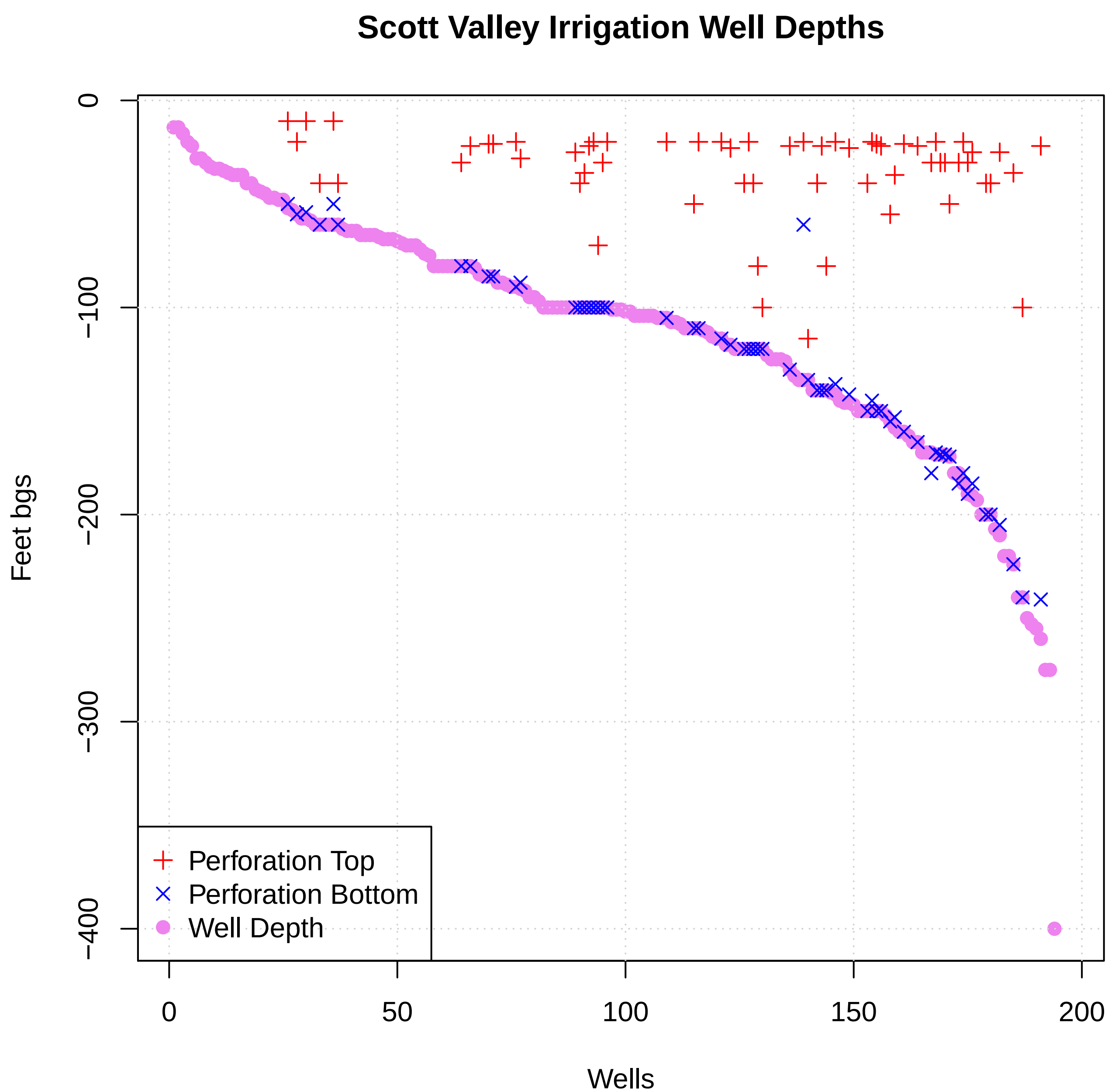

Figure 1: Distribution of well depths and associated screened intervals available for Scott Valley wells.

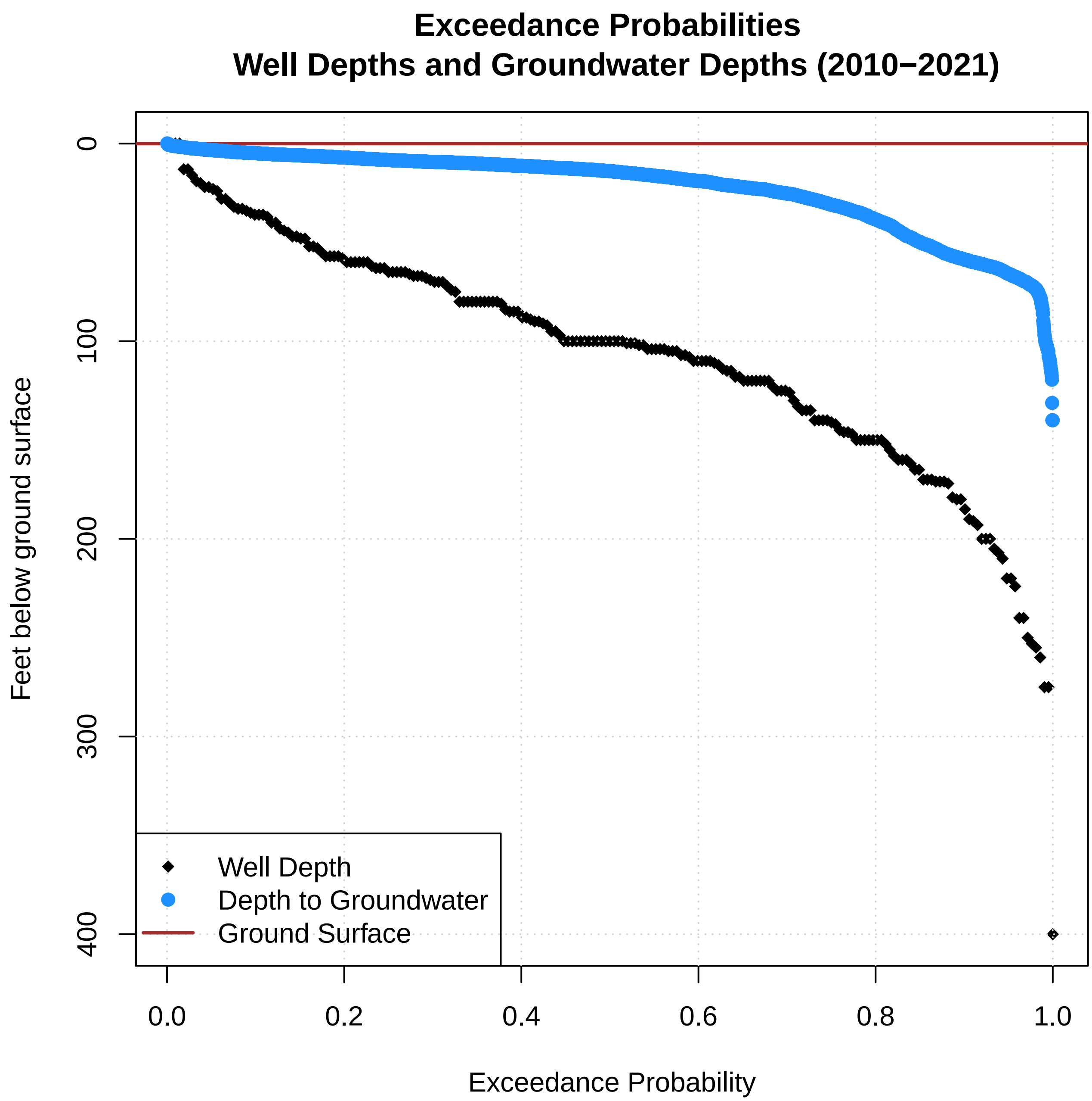

Figure 2: Distribution of all well depths and, separately, distribution of the last 10 years of water level data available for Scott Valley wells.

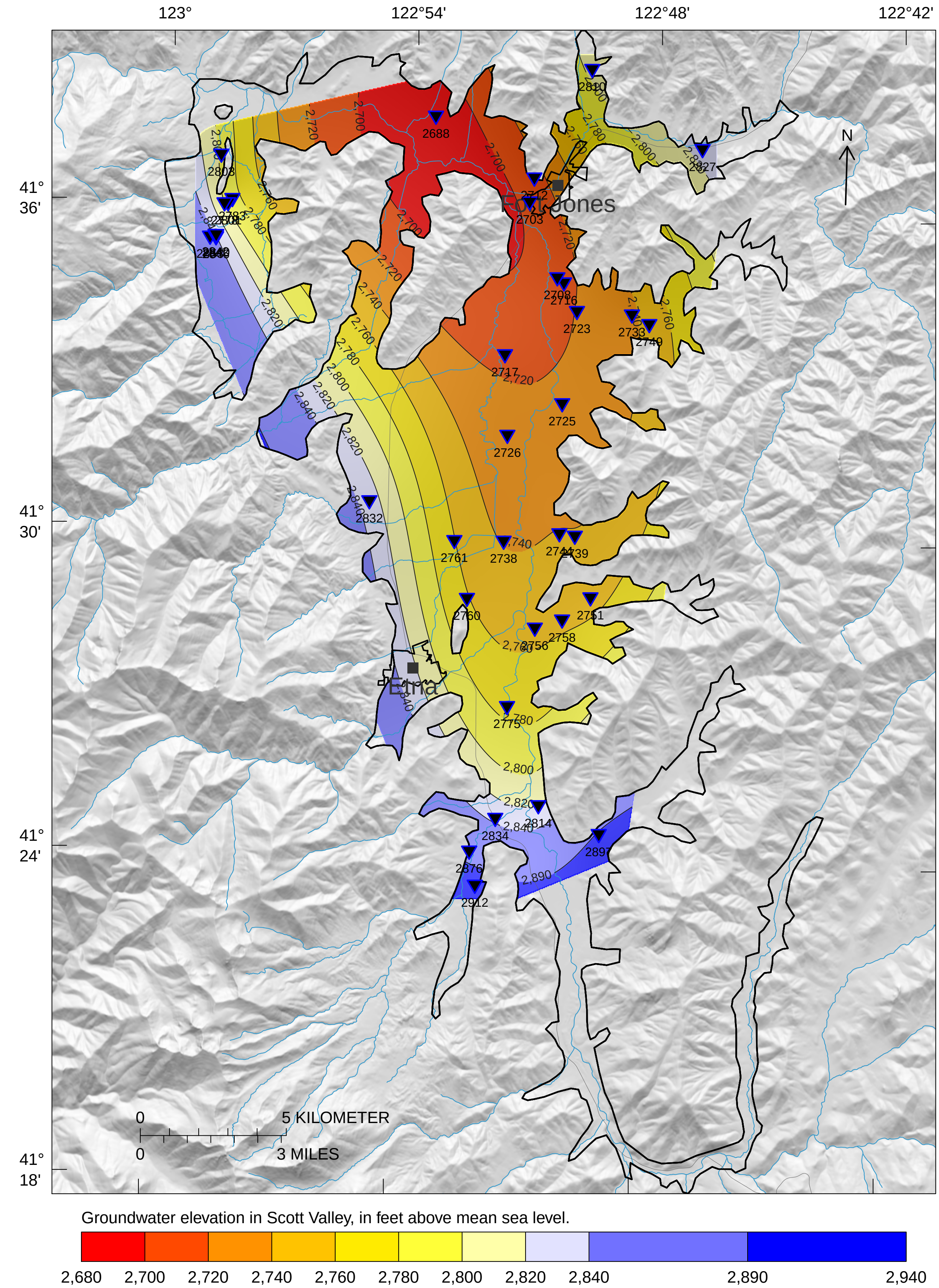

Figure 3: Interpolated (splined) Scott Valley groundwater table elevation, September 2015. Blue triangles indicate points of measurement.

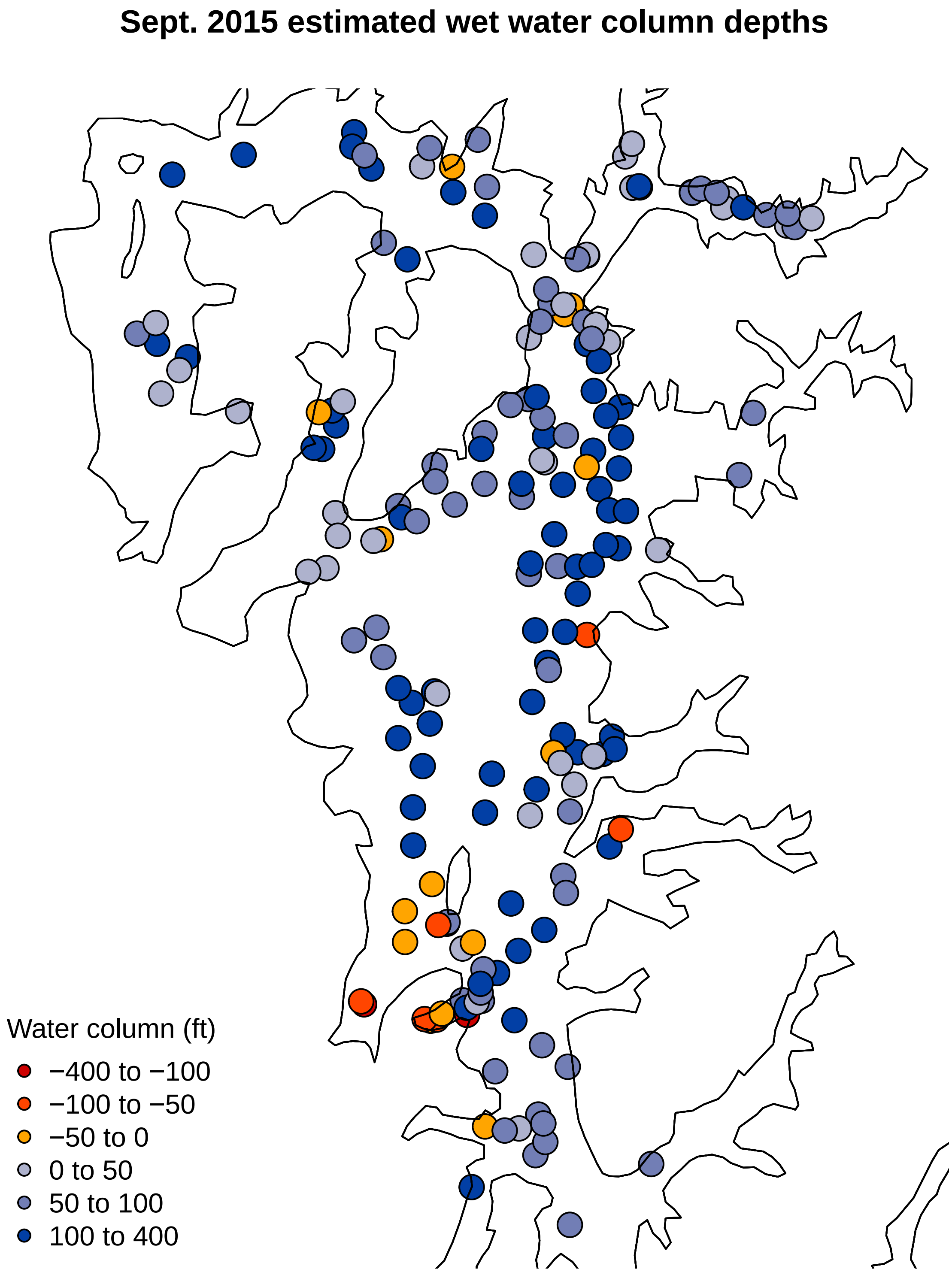

Figure 4: Wet water column depths based on interpolated, contoured groundwater level elevations, September 2015. Negative values indicate that the interpolated groundwater level is below the estimated depth of the well (see Discussion for further information).

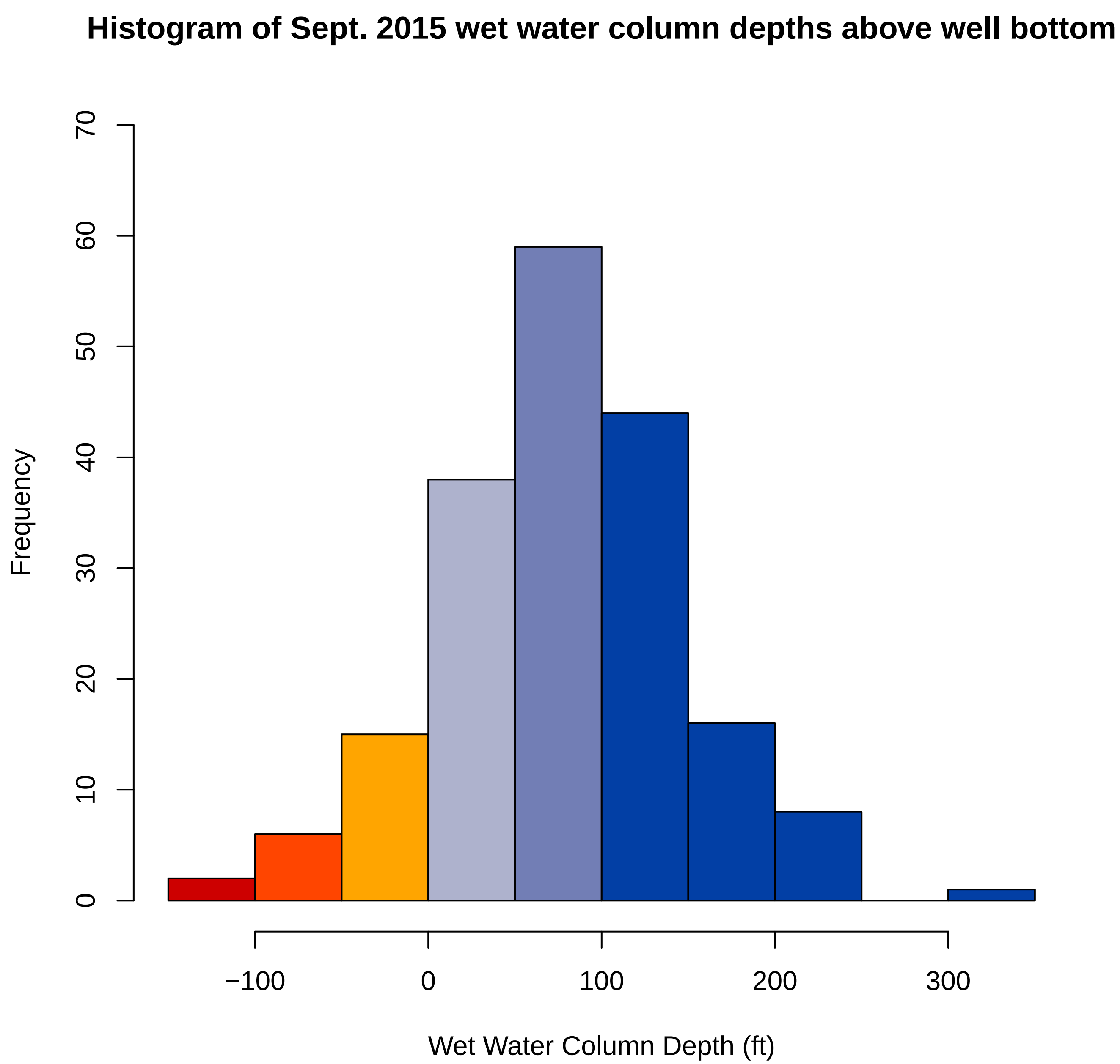

Figure 5: Histogram of wet water column depths based on interpolated, contoured groundwater level elevations, September 2015.

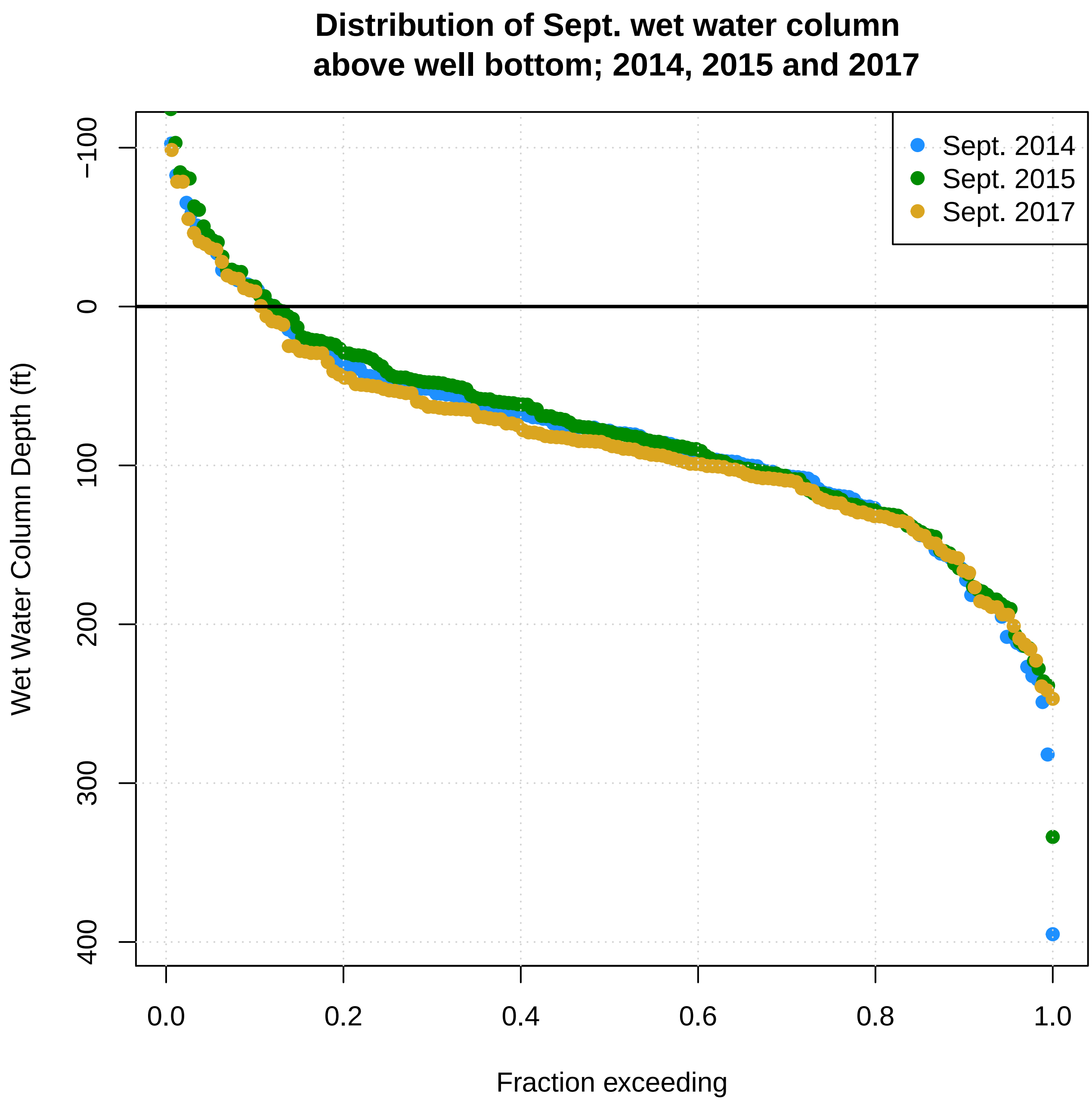

Figure 6: Cumulative distribution function of wet water column depths based on interpolated, contoured groundwater level elevations, Septembers of 2014, 2015 and 2017.

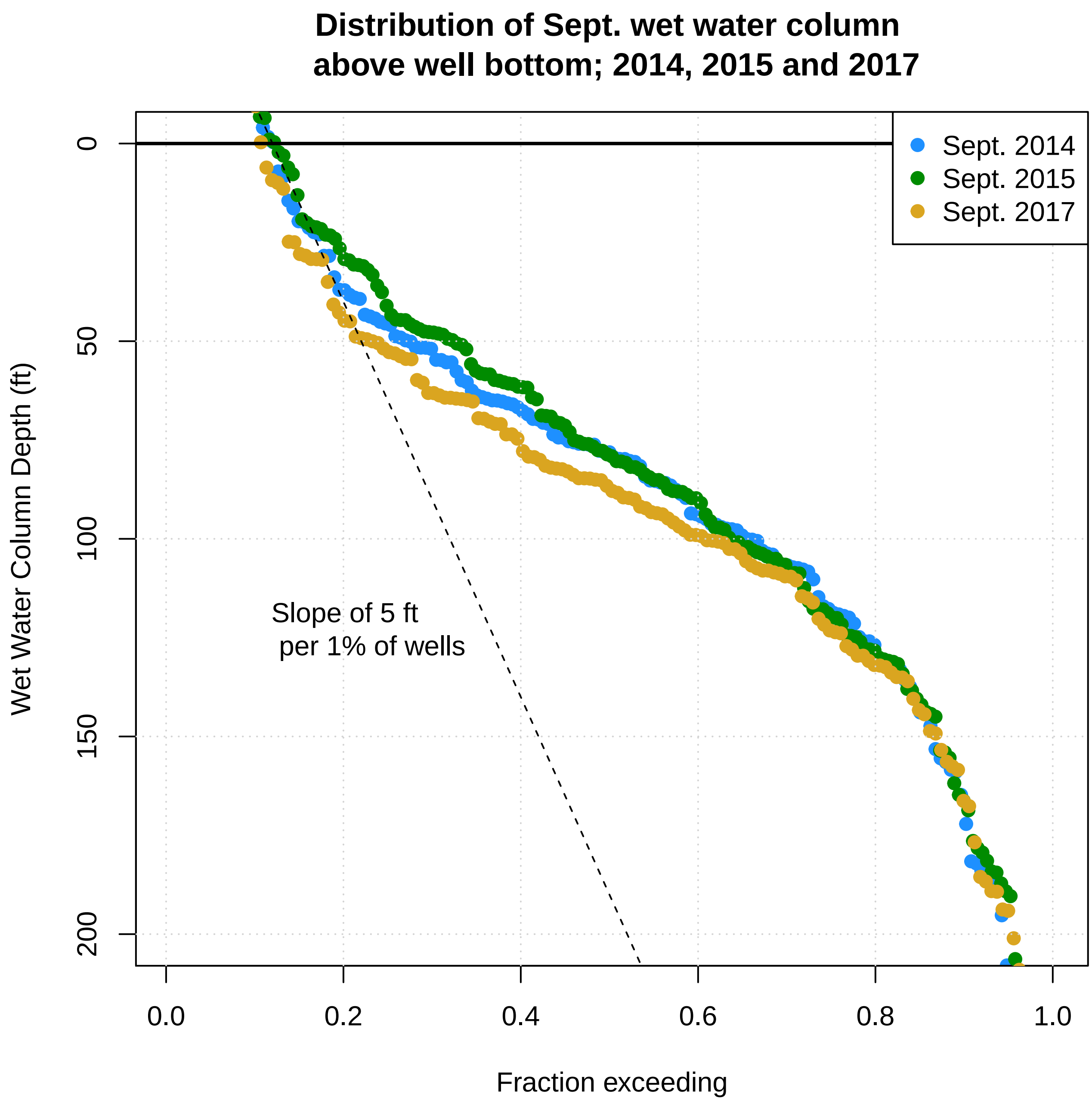

Figure 7: Cumulative distribution function of wet water column depths based on interpolated, contoured groundwater level elevations, Septembers of 2014, 2015 and 2017, here showing only the portion of the cumulative distribution function for depths 0 feet to 200 feet.

Conclusion

We identified three key findings with respect to well outages:

Majority of wells unlikely to be affected by dewatering. Most wells in Scott Valley have well depths of 50 feet or more below the interpolated groundwater elevations depths of 2014 and 2015 (at least 65%).

Uncertainty affects analysis quality. The analysis is relatively uncertain due to the lack of wells with both water level measurements and known well construction. The analysis needed to rely on interpolated water level data, which may be several feet or even tens of feet incorrect in some areas. This may be the case especially regarding the ~13% of wells which bottom out above the interpolated water level depth and wells with very shallow (< 30 feet) wet water column depth (Figure 7) in 2014, 2015 (two dry years) and 2017 (a wet year).

Negative and exceedingly shallow positive wet water column depths are the result of any of the following:

1) the well goes dry in the fall, regardless of water year type, or, if it does not,
2) the water level interpolation is erroneous, or
3) the well is located at a lower elevation than estimated for the reported location, or
4) well depth is inaccurately reported.

We relied instead on the slope of the cumulative distribution of estimated wet water column depth, which is a more stable indicator of how many additional wells fall dry per 5 foot decline in water levels below historically low water levels of 2014 and 2015. We find that:

The number of wells affected by groundwater elevations at the Minimum Threshold is probably very small. The minimum threshold is 10% lower than the minimum measured depth to the water table (see Chapter 3). In most Scott Valley areas, where water depth of groundwater is less than 30 feet, water levels at the minimum threshold would be less than 3 feet lower than in 2014. A very small number of wells would be affected by that, as shown in Figures 5 and 6. Considering Table 5 of Chapter 3 (page 35), the minimum threshold is at most 10 ft below the historically deepest measured water level. This much lowering to the MT would occur only in wells that already have a depth to water of 100 feet. For most wells, the MT is less than five feet below historically low levels. Based on slope of the CD of the wet water column depth, a five foot lowering of the water level would affect approximately 1% of domestic wells (about 10) and 1% of agricultural wells (about 2).