2020 Update of Ground Water Conditions in the Blue Gulch Critical Ground Water Area

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The Idaho Department of Water Resources designates Critical Ground Water Areas (CGWAs) and Ground Water Management Areas (GWMAs) under Idaho Code §42-233a and §42-233b, respectively. A CGWA is all or part of a groundwater basin that does not have sufficient ground water to provide a reasonably-safe supply for irrigation or other uses at the current or projected rates of withdrawal. A GWMA is all or part of a groundwater basin that may be approaching the conditions of a CGMA. The Blue Gulch Critical CGWA was designated in 1970 based on a study by Chapman & Ralston (1970) showing that the region was in overdraft (discharge exceeds recharge). This report describes the status and trends of aquifer levels in the Blue Gulch CGWA in Owyhee and Twin Falls Counties.

Introduction

The Idaho Department of Water Resources (IDWR) maintains a ground water level monitoring network in the Blue Gulch Critical Ground Water Area (CGWA). IDWR staff make semi-annual measurements of the network with visits typically occurring in November and April to avoid pumping influences and to capture low and high points in the hydrograph, respectively. Most measurements are taken manually with a calibrated electric tape. A pressure transducer with a data logger recording measurements twice per day was installed in fall of 2019 in well 10S 12E 10AAD1 (fig. 12). Since the previous report, the frequency of measurements has decreased, though the network is still able to capture multi-year trends with only two measurements per year. As of 2019, the network consists of nine wells. More wells are presented here because they were measured after Bendixsen (1993), but were subsequently dropped, or are only measured during a 5-year periodic synoptic measurement of the Eastern Snake Plain. Bendixsen (1993) used seven wells in his report and at times there can be up to 12 wells measured in a given year in the CGWA. All wells locations can be seen in figure 1. Information about each well can be seen in table 1.

The Blue Gulch area (figure 1) is located in southern Idaho on the south side of the Snake River and covers approximately 300 square miles west of Twin Falls and south of Glenns Ferry. Elevations range from 2,800 to 4,500 feet (ft) with an average elevation of 3,697 ft. The 30-year average annual precipitation is 9.5 inches (in) and the region is classified as cold semi-arid (BSk, Koppen climate classification) where potential evapotranspiration exceeds precipitation and there is at least one month of average temperatures below freezing.

The primary use of ground water in the area is for agriculture in the central and southeastern portion of the CGWA, which has largely remained unchanged since rapid development in the 1960s (Bendixsen, 1993). There are 132 active ground water rights within the CGWA boundary. Of those water rights, 82 are for irrigation and the remainder are for stockwater and domestic uses. Ground water irrigation rights have an overall maximum diversion rate of 2,067 cubic feet per second (cfs) and provide water for up to 16,374 acres within the CGWA. Three owners account for 95% of ground water diversions by diversion rate. Figure A.1 maps the places of use for irrigation rights by water source (ground or surface water). There are 100 active surface water rights that irrigate 15,344 acres within the CGWA. Surface water irrigated lands are primarily in the east closer to Salmon Falls Creek and the Magic Water Canal, which forms part of the eastern boundary of the CGWA in Township 9S, Range 13E. Mixed source places of use exist in the south-eastern part of the CGWA.

Table 1: Blue Gulch area well descriptions.

Well Number	Altitude (ft amsl[1])	Total Depth (ft bgs[2])	Open Interval (ft bgs)	Monitoring Date Start	Monitoring Date End	Longitude	Latitude	Active [3]	In Bendixsen (1993)	USGS ID
07S 10E 22DDD1	3158	735	695-735	1982-4	2020-5	-115.25975	42.79697	O	-	424749115153101
08S 11E 33BCD1	3168	290	250-285	1967-2	2020-5	-115.17756	42.68907	A	Y	424121115103601
08S 12E 24CCC1	3469	500	46-500	1966-7	2020-4	-115.00589	42.71074	A	Y	424239115001801
08S 13E 23CCD1	3390	100	50-100	1967-2	2020-4	-114.90506	42.7109	A	Y	424242114541601
09S 12E 29BBA1	3605		-	1985-7	2020-5	-115.08062	42.62185	A	Y	423719115044701
09S 13E 20CCD1	3805	920	165-920	1966-4	2020-5	-114.96373	42.62253	A	Y	423722114574801
09S 13E 22DDD1	3698	575	46-575	1974-12	2018-3	-114.91172	42.62268	S	-	423723114543901
09S 13E 28DDD1	3800	800	625-800	1971-5	2020-5	-114.9294	42.60886	A	-	423632114554601
09S 13E 32CDD2	3811	700	100-700	1966-6	2020-5	-114.95906	42.59357	A	-	423537114573301
10S 12E 10AAD1	3750	1215	-	1966-2	2020-5	-115.02566	42.57472	A	-	423429115013201
10S 12E 11DBD1	3761	700	6-688	1962-8	2020-5	-115.01034	42.56824	A	Y	423406115003401
10S 13E 05CBD1	3822	575	100-575	1965-4	2013-4	-114.96228	42.58296	S	-	423458114574301
09S 12E 29ACD1	3625	530	10-530	1967-3	1982-9	-115.06978	42.61518	I	Y	423655115041001

[1] above mean sea level
[2] below ground surface
[3] A = active, I = inactive, S = USGS Eastern Snake Plain synoptic only, O = outside CGWA

In 1970, the Idaho Department of Water Resources - then the Department of Water Administration - designated Blue Gulch as a Critical Groundwater Area due to large declines in aquifer levels and outstanding, approved ground water appropriation permits estimated to quadruple groundwater pumping discharge (IDWR, 1970; Chapman & Ralston, 1970). The designation followed a ground water quantity and quality study by Chapman & Ralston (1970). To prevent further depletion of the resource, a moratorium on new ground water appropriations was issued when the CGWA was designated. Bendixsen (1993) prepared the most recent report on the status of the Blue Gulch CGWA.

Purpose and Scope

This report provides an update to the status of the Blue Gulch CGWA ground water monitoring network, which was last summarized in 1993. All known water level data is presented and used to analyze trends in aquifer levels and produce water level contours and change maps in the CGWA.

Hydrogeology and Climate Data in Blue Gulch

Geology and Hydrogeology

The Idavada Volcanics and Banbury Basalt host the primary aquifer in the region. The lower Plioecene aged Idavada Volcanics are the base of the aquifer and are comprised of brown, silicic and welded ash flows that outcrop in the southern portion of the area. Maximum thickness may exceed 1,700 ft (Chapman & Ralston, 1970). The Banbury Basalt overlays the Idavada Group. The three members of Banbury Basalt are a lower fractured rubbly basalt with alteration products in fractures and vesicles (several hundred feet), a variably thick sedimentary unit of silt, sand, and fine gravel (several feet to 600 ft), and a thick olivine basalt with columnar jointing and many flow contacts (several hundred feet).

Several sub-parallel normal faults have been mapped with roughly NW-SE striking fault traces. Blocks drop to the north east. Faulting is a result of subsidence of the Snake River Plain and uplift of mountains to the south. Fracture zones surrounding the faults exhibit higher permeability in the Idavada Volcanics and high-production irrigation wells tend to be located in these fracture zones.

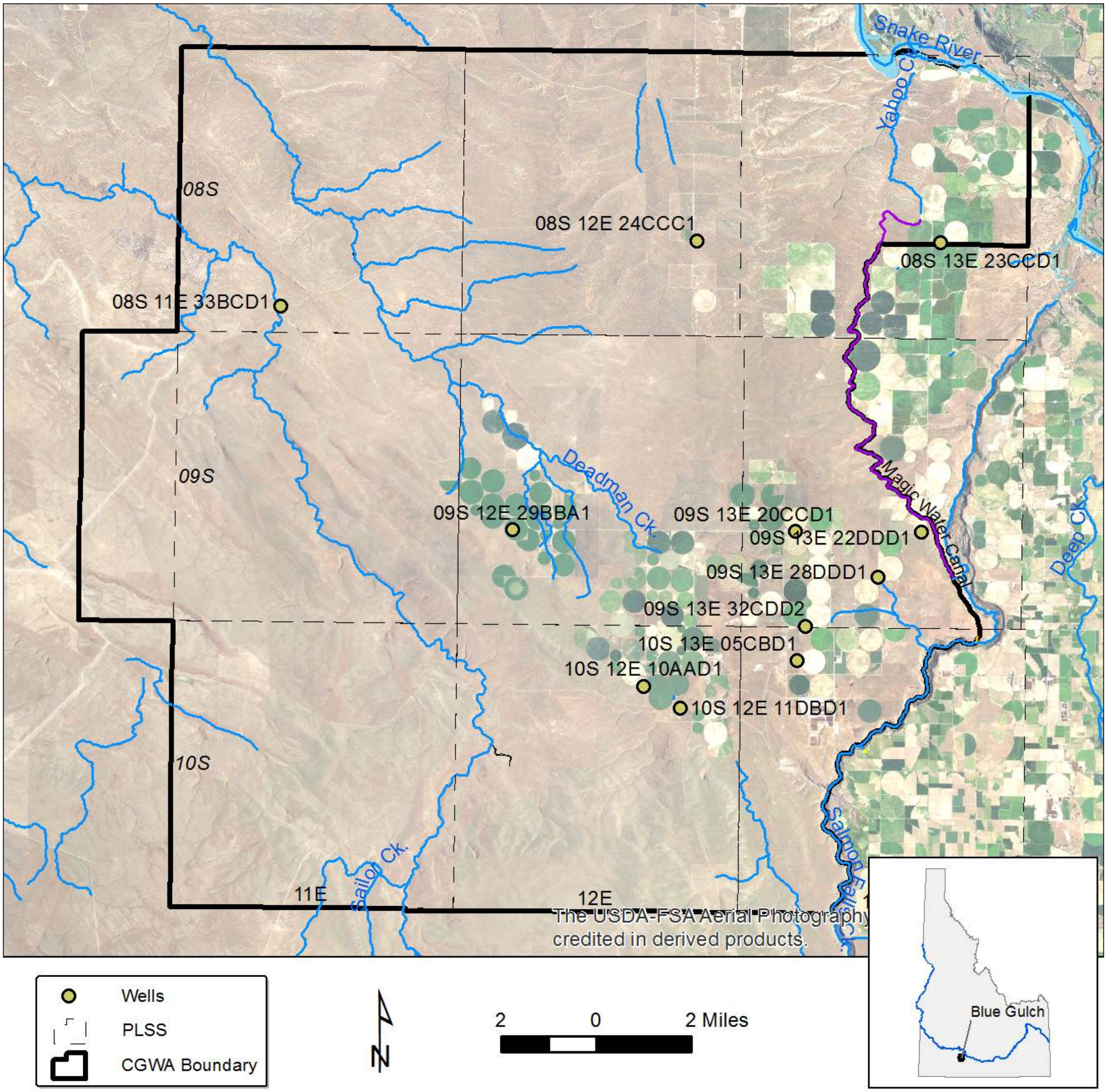


Figure 1: Blue Gulch CGWA map showing the monitoring network, ephemeral streams, Public Land Survey grid, Magic Water Canal, and USDA Aerial Imagery.

Chapman & Ralston (1970) and Bendixsen (1993) provide summaries of the Blue Gulch area geology. Consult these sources for further details on the geologic framework. Original detailed mapping was completed by Malde et al. (1963) and was compiled into a state-wide geological map by Lewis et al. (2012). The latter map is provided as a GIS database and is shown for the Blue Gulch CGWA in figure A.2.

Recharge occurs in the southern uplands and Jarbridge Mountains and potentially in ephemeral streambeds and fracture zone outcrops throughout the Blue Gulch. There is likely recharge from canal seepage and surface water irrigation where it exists, and Bendixsen (1993) speculated this recharge explains some seasonal patterns in well hydrographs that are located near surface water irrigated lands (08S 13E 23CCD1). Discharge occurs as ground water discharge to Salmon Falls Creek to the east and to the Snake River to the north as well as through ground water pumping. Chapman & Ralston (1970) estimated ground water pumping to be 26,500 acre-ft based on water rights and a consumptive use requirement of 3.5 acre-feet per acre over 7,500 acres. Bendixsen (1993) argued that 2.5 acre-ft/acre was more appropriate for a total discharge of 18,500 acre-ft.

An updated estimate for pumping discharge was made using a water balance approach where pumping discharge equals April through October evapotranspiration (ET) less precipitation. Pumping discharge here is equivalent to the crop irrigation requirement where effective precipitation is assumed to be equal to total precipitation. ET estimates were derived from the spatially distributed METRIC raster dataset (Allen et al., 2007). To obtain an approximate, first-order delineation of irrigated areas from the ET, a cutoff of 20 in per year was used. The cutoff was chosen by visual inspection and comparison of satellite imagery along with the METRIC rasters. Areas having 20 in or more of growing season ET were considered irrigated and included in the calculation while areas with less than 20 in of ET were considered non-irrigated and excluded. Water rights place of use boundaries further restricted the calculation to ground water irrigated lands. Precipitation was calculated from the PRISM dataset (PRISM Climate Group, OSU, 2020). Pumping discharge on average between 1986 and 2018 is 20,400 acre-ft over an average of 8,900 acres with an average crop irrigation requirement (CIR) of 2.3 acre-ft/acre. The mean consumptive use requirement as estimated by the ratio of ET to irrigated acres is 2.6 acre-ft/acre, which lies between previous estimates of 2.5 and 3.5 acre-ft/acre. Table 1 presents CIR results for all METRIC years.

Precipitation

Annual rainfall rates over the Blue Gulch area were calculated from the gridded Oregon State University PRISM dataset. Average annual rainfall in the area was 9.5 in from the 30-year period between 1990 and 2019, which is similar to the rainfall estimated by Bendixsen (1993). Figure 2 shows annual rainfall and the 5-year moving average. A Mann-Kendall test run on the 5-year moving average of precipitation shows a statistically significant decline in precipitation at a rate of 0.25 inches per year; however, there was no significant trend on the annual rainfall rates.

Palmer Drought Severity Index

The Palmer Drought Severity Index (PDSI) is a standardized and commonly used measure of long term regional drought that accounts for current and prior precipitation and potential evapotranspiration in a physical water-balance model (Alley, 1984). Because PDSI has been shown to be significantly correlated with soil moisture content, it is used here to quantify drought over land and is seen in figure 2 (Dai, 2019). Values of PDSI usually range between -4 to 4, with -4 and below being extreme drought and 4 and above interpreted as extremely wet. More details on drought categories are listed in table 2. The NOAA National Climatic Data Center (NCDC) calculates a monthly PDSI value for all US climate divisions. The Idaho Southwestern

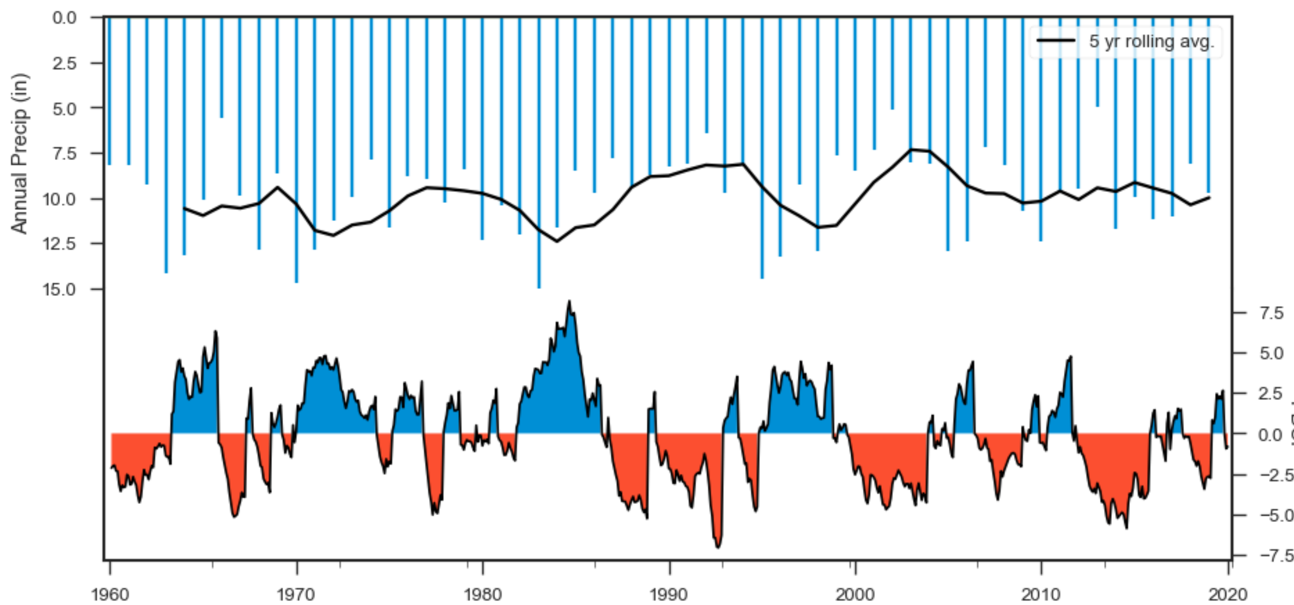


Figure 2: Precipitation and PDSI over the region. The five-year moving average is decreasing at a rate of a quarter-inch per year (Mann-Kendall Test, p=0.007)

Highlands region was used here, though the Blue Gulch falls within three separate climate divisions (NOAA NCDC, 2020).

PDSI shows that for the period from 1960 to 2019, the Blue Gulch area is in drought conditions 31.8% of the time, near normal 42.1% of the time, and relatively wet the remaining 26.1%. Dividing the PDSI dataset into periods prior to and after 1990 suggests that the post-1990 period is drier than the pre-1990 period. See table 2 for details.

Table 2: PDSI conditions since 1960.

PDSI condition	PDSI value	1960-2019	pre-1990	post-1990
Extreme Drought	$x \leq -4$	10.6%	8.1%	13.0%
Severe Drought	$-4 > x \leq -3$	10.4%	8.3%	12.5%
Moderate Drought	$-3 > x \leq -2$	10.8%	9.1%	12.5%
Near Normal	$-2 > x < 2$	42.1%	40.6%	44.5%
Unusually Moist	$2 \geq x < 3$	10.1%	12.1%	7.9%
Very Moist	$3 \geq x < 4$	7.1%	7.3%	6.8%
Extremely Moist	$x \geq 4$	8.9%	14.5%	2.8%

Water Level Analysis

Hydrographs

Figures 3 through 14 show water levels in monitoring wells in the CGWA. When last summarized, aquifer levels in the CGWA were generally increasing (Bendixsen, 1993). Since then, the overall trend has reversed with water levels in some wells now at or near the lowest elevation for the period of record (09S 12E 29BBA1, 10S 12E 11DBD1, 10S 12E 10AAD1; see figures 6,13,11). Water levels in other CGWA wells have continued to rise (08S 11E 33BCD1, figure 3) or declined at a slower rate (08S 12E 24CCC1, figure 4).

Both long-term and annual signals are captured by the measurements in many of the hydrographs. The annual signals are captured by the fall and spring measurements while the long-term record captures a multi-decadal signal of 30 to 40 years. Amplitudes of both signals vary from well to well. A datalogger installed in 10S 12E 10AAD1 during the fall of 2019 records water levels two times per day and produces a hydrograph showing smoothly varying levels peaking around April (figure 12).

The water level dataset includes occasional outliers from the local mean. Outliers often are attributable to pumping when the well is equipped with a pump and the water level is significantly lower than during previous and subsequent measurements. On the other hand, possible explanations for anomalously high water level measurements, such as made in well 9S 13E 20CCD1 during spring 2011 (figure 7), include incidental recharge, rapid percolation from land surface along the well casing, and cascading water from an overlying perched aquifer. These outliers do not appear to obscure the overall trends.

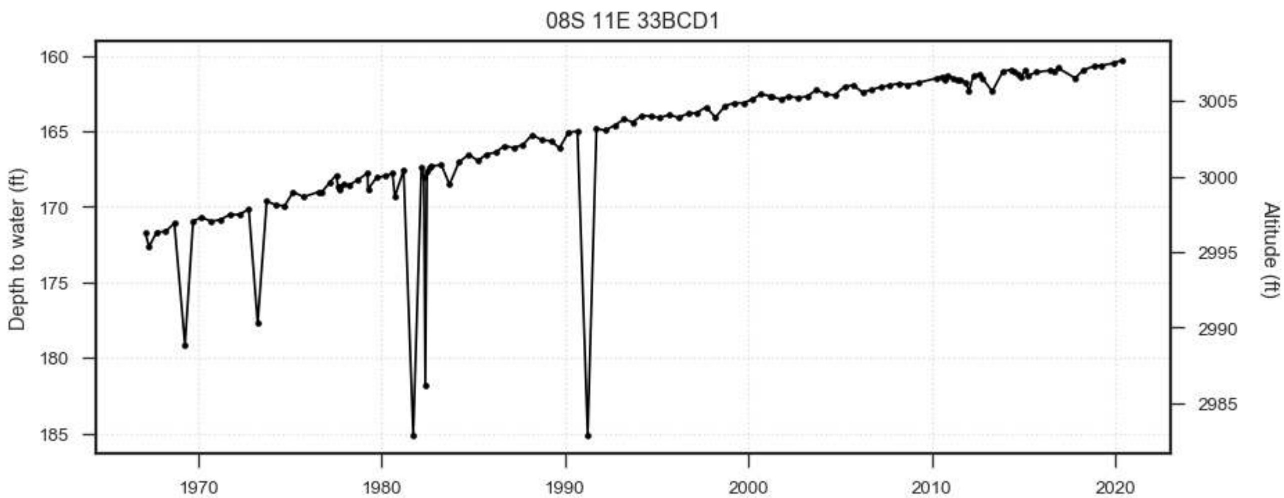
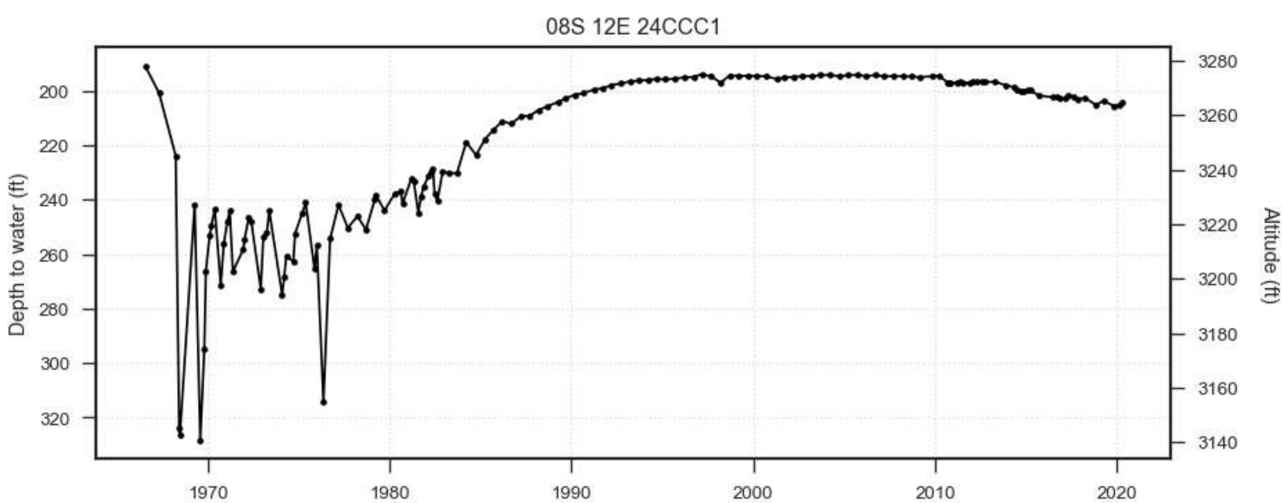


Figure 3



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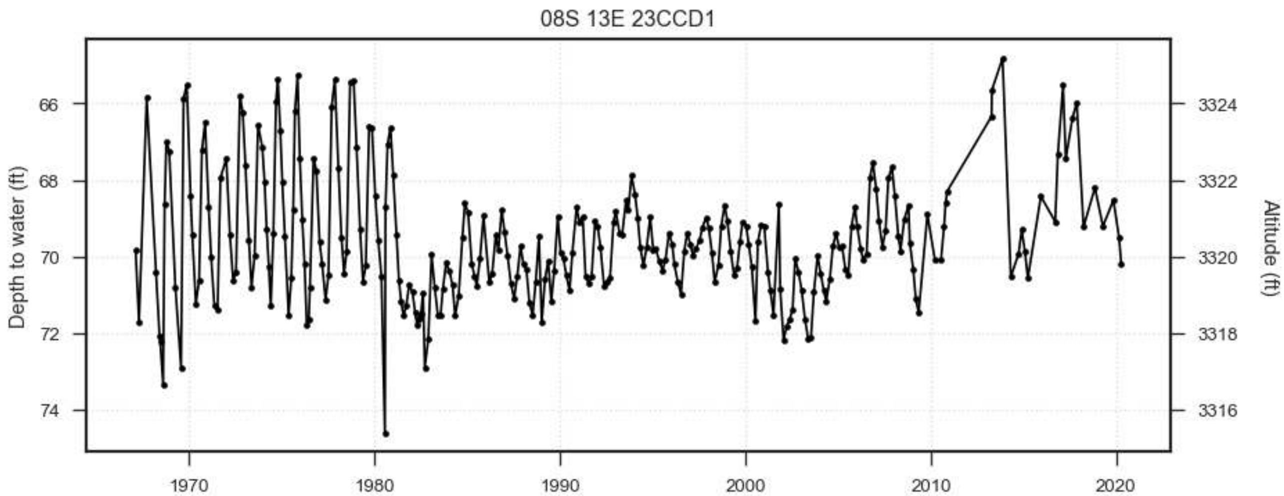

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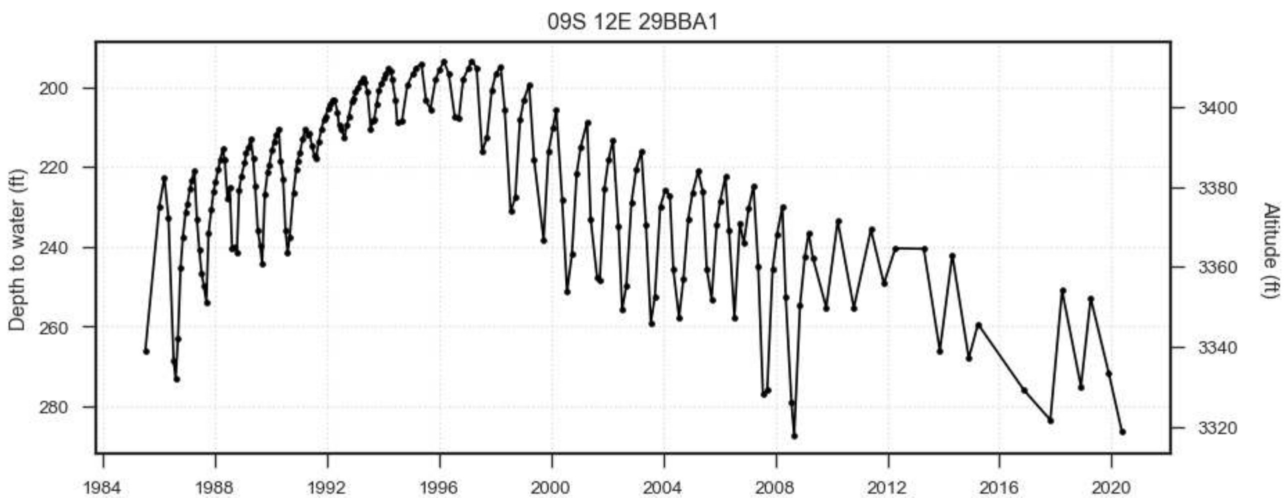

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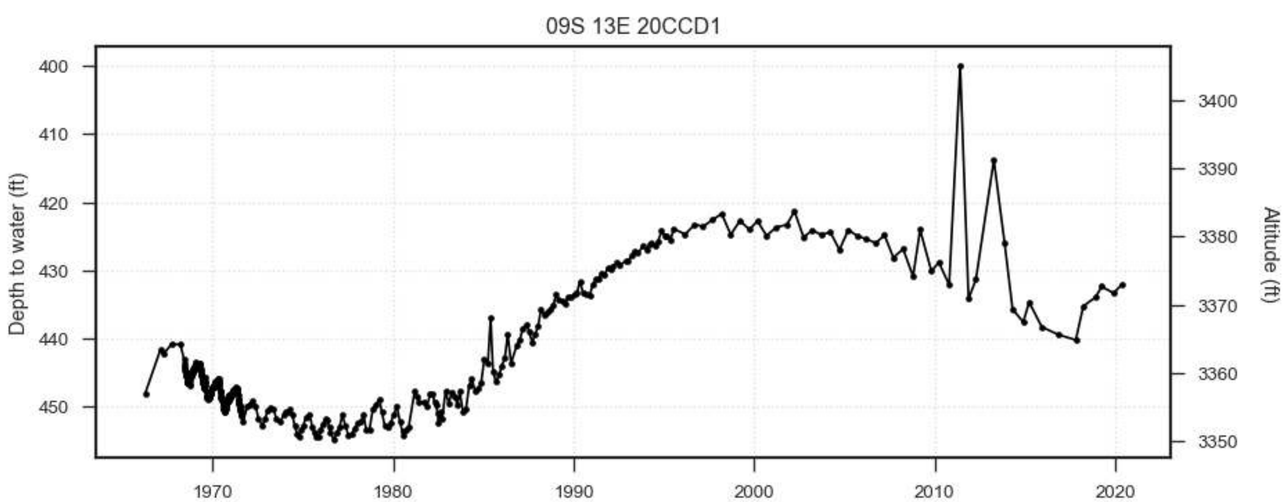

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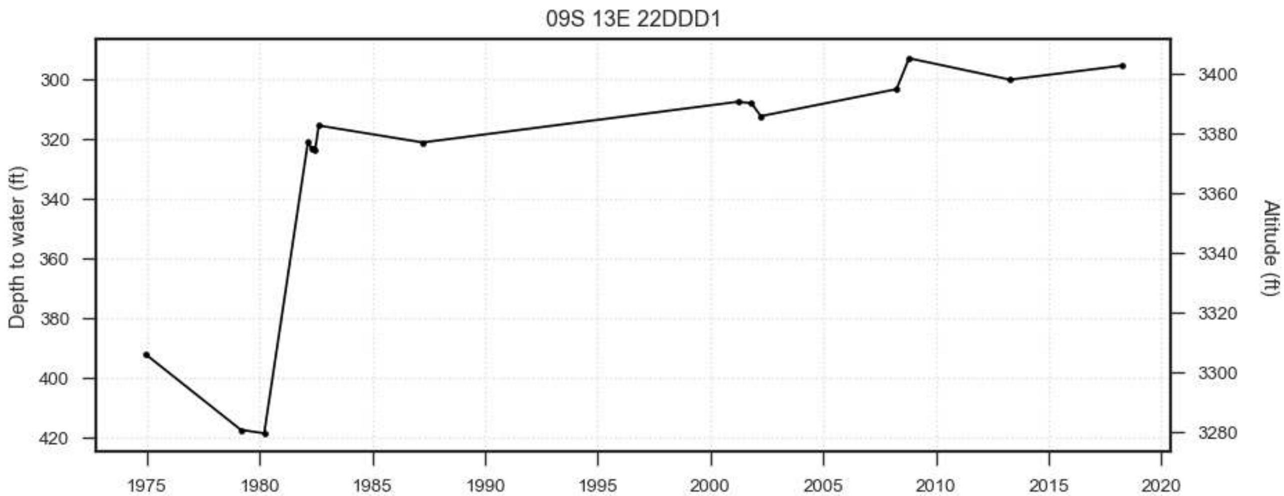

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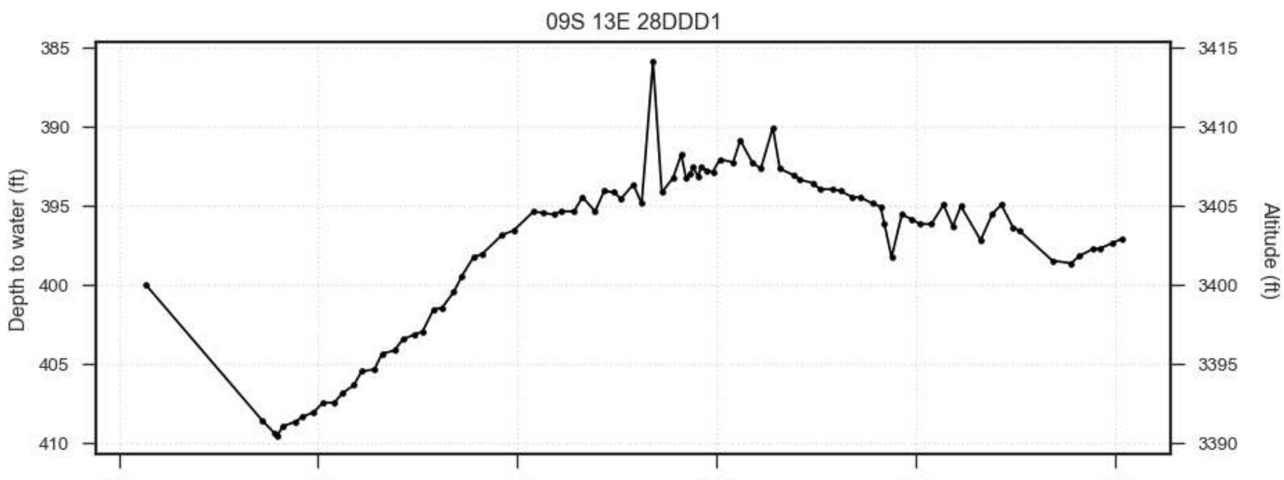


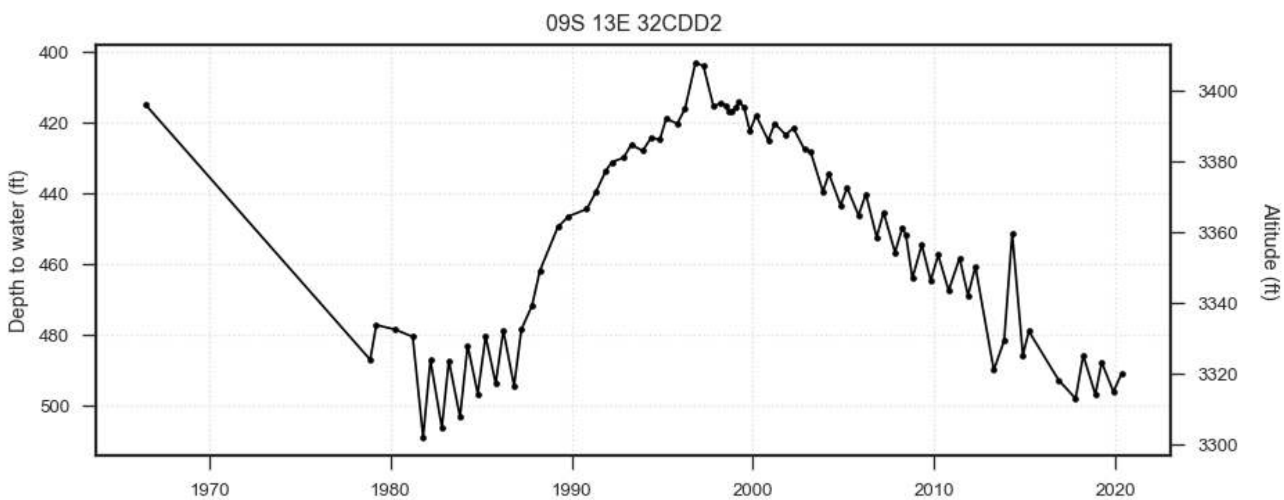


Figure 10

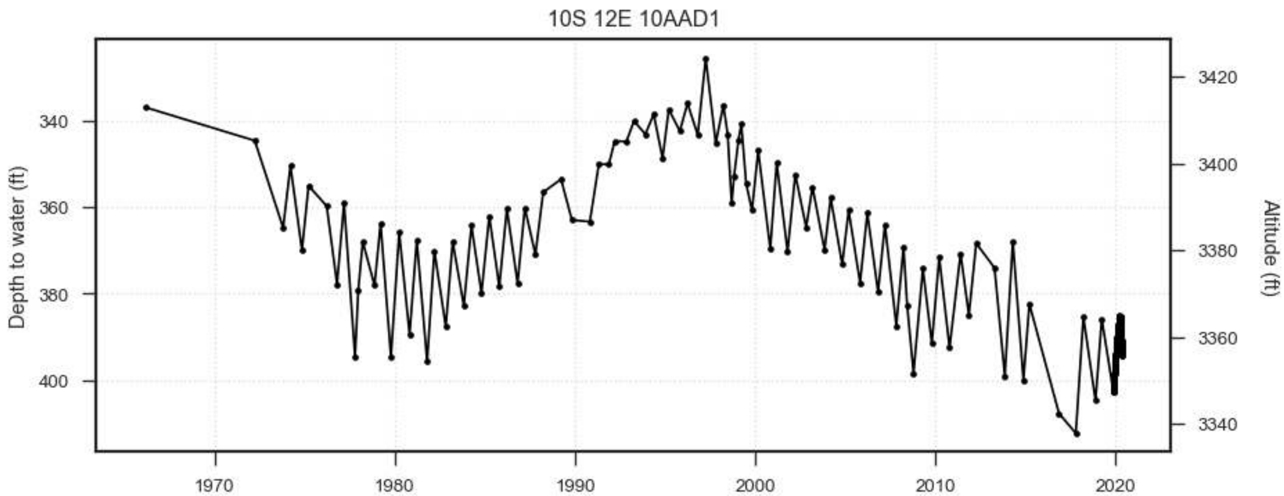


Figure 11

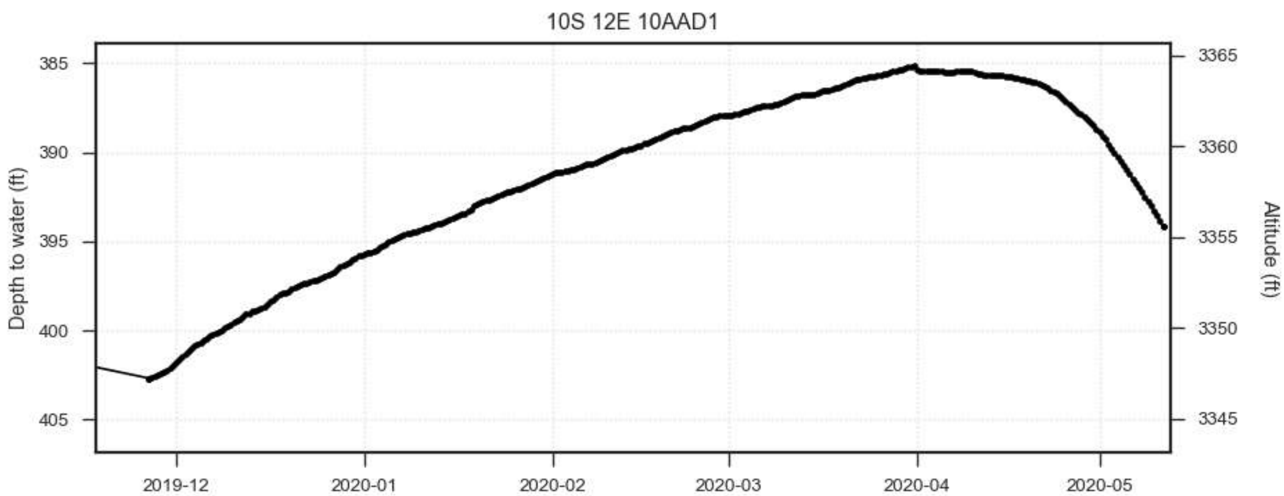


Figure 12: Detail of pressure transducer installed in 10S 12E 11DBD1.

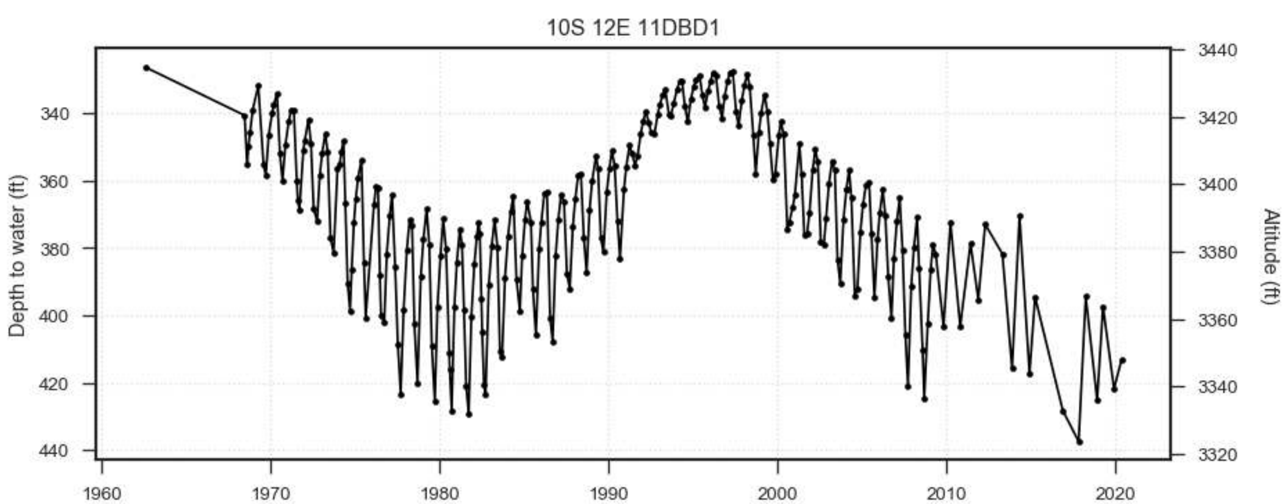


Figure 13

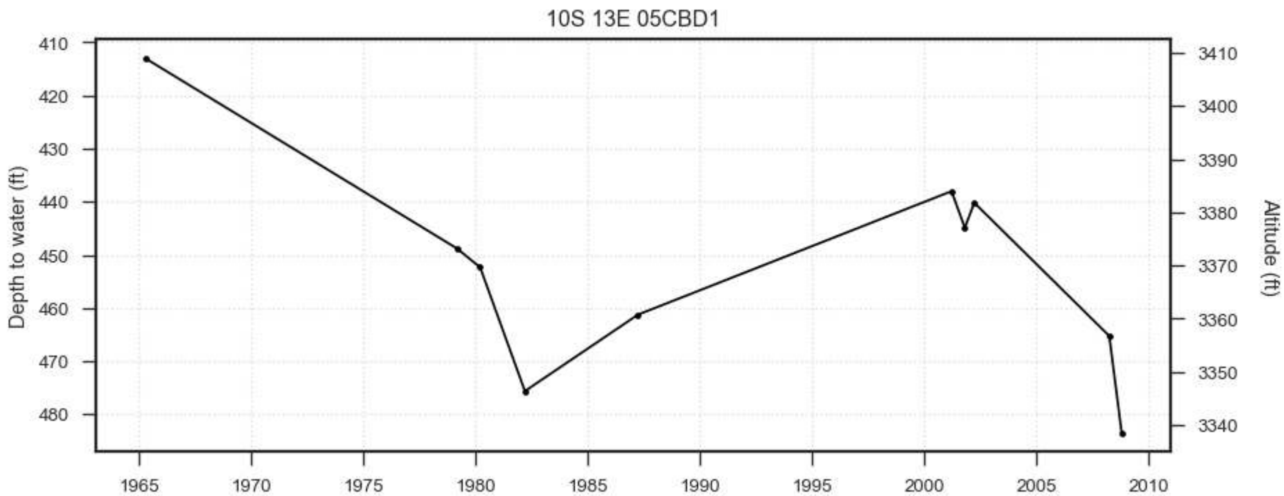


Figure 14

Trend Analysis

The traditional Mann-Kendall non-parametric test for trend and a family of tests based on the Mann-Kendall are used here on water level, precipitation, and climatological datasets. The Mann-Kendall tests calculate a correlation coefficient, Kendall's τ, a test statistic, S, the standard normal deviate, Z, a p-value for trend significance and a slope. For this analysis, positive values for slope, S, and z indicate a declining water level as the dataset analyzed for trend is depth to water through time. A τ of 1 (or -1) is perfectly correlated.

A Seasonal Kendall extension allows for testing of user-defined seasons that in part removes serial auto-correlation in the dataset. The Regional Kendall test analyzes for a consistent trend with time over multiple sites. Tests were calculated with a DOS command-line program published by the USGS (Helsel et al., 2006).

The tests show several statistically significant trends for ground water levels, both pre- and post-1990. A regional test of fall water levels prior to 1990 showed a significant rise of 0.336 feet per year (ft/yr), while after 1990 the trend switches to a significant decline of 1.4 ft/yr. Figure 15 displays plots of individual wells and several different test configurations that corroborate the regional trends. Statistically significant declines were computed for a majority of the wells during the post-1990 time frame.

Ground Water Flow Direction and Level Change

Spring water level elevations were contoured for three different years; 1973, 1993, and 2019. Water level change maps were produced for change between contoured years. Spring measurements typically occur in April, though some March measurements were used if an April measurement was missing. Contouring was accomplished with the Splines tool in ArcGIS 10.6 for both elevations and change maps. In order to only interpolate within the spatial extent of the wells, a convex hull around the well points delineates an uncertainty boundary and determines where contours are dashed. Results of the water level contouring are presented in figure 16 and the changes between selected years are shown in figure 17. All three contour maps show a general flow direction towards the northwest with some easterly flow towards Salmon Falls Creek (see the contour going through 09S 13E 28DD1 in 1993 and 2019), which makes up the southeastern border of the CGWA before it turns northeast. The overall trends of first rising and then declining water levels is revealed by the change

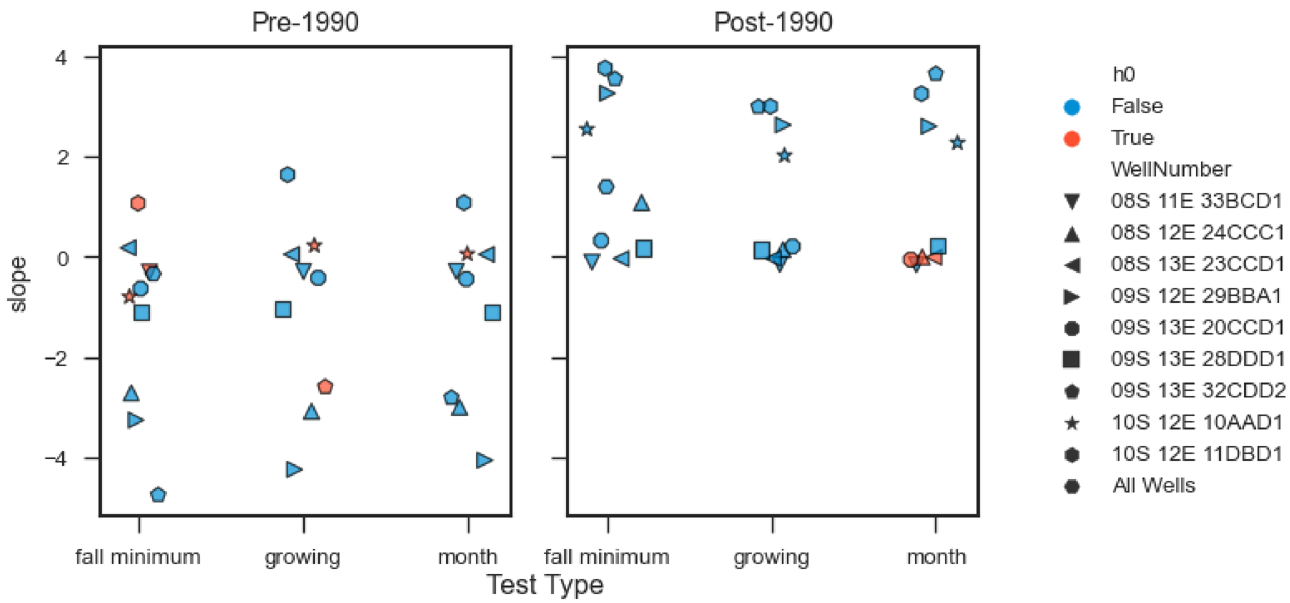
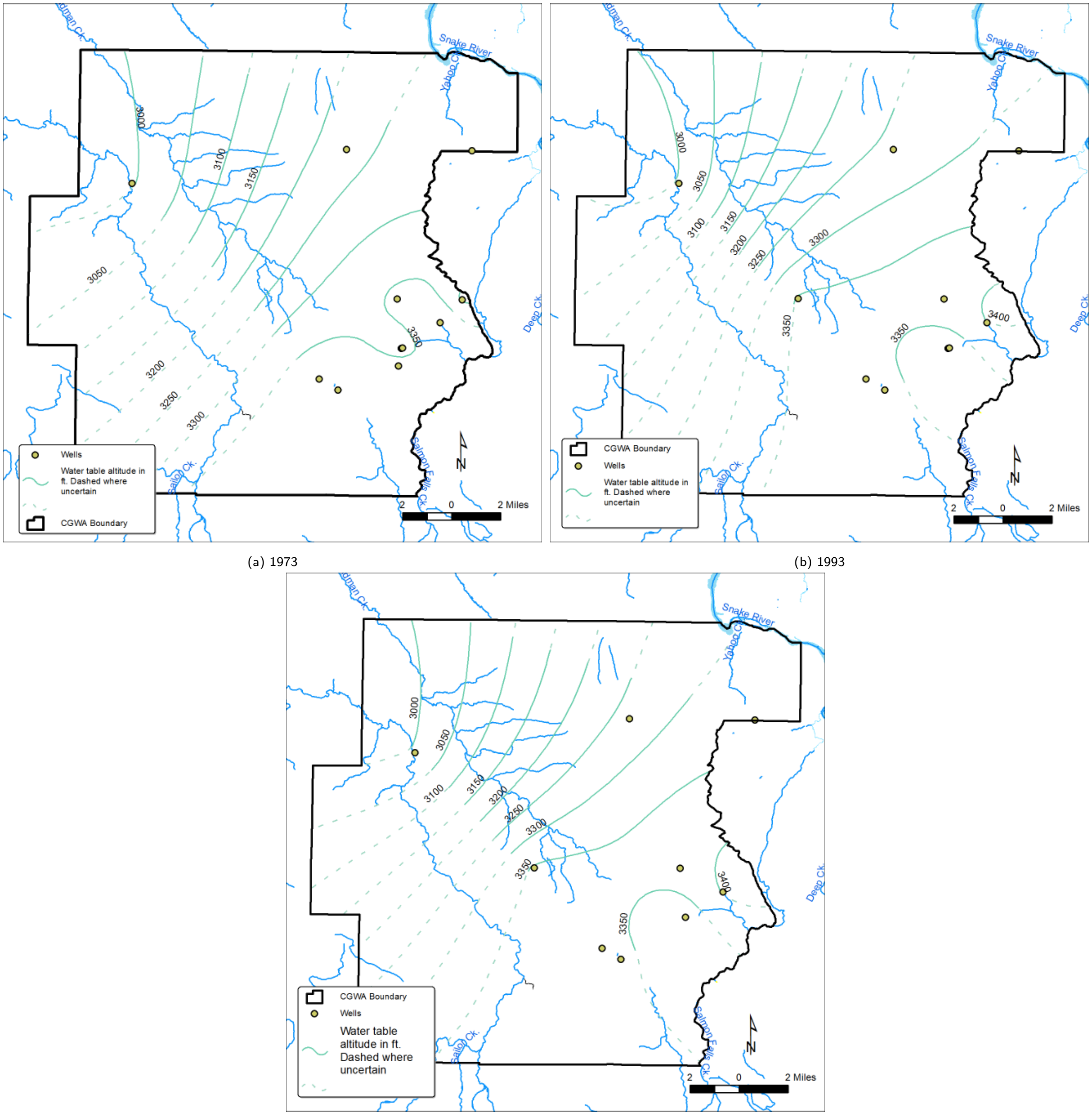


Figure 15: Depth to water trends from Mann-Kendall tests for records before and after 1990. Red markers indicate that the trend is not differentiable from a slope of zero (null hypothesis accepted). Blue markers indicate that the trend is different from zero (null hypothesis rejected). Marker shape indicates the well. Slopes are for depth to water below ground surface over time. A positive slope is interpreted as declining water levels.

maps. Although water level elevations have changed through time, the spacing between adjacent contours is relatively unchanged and suggests that the hydraulic gradient has remained effectively constant across the CGWA.

There is a high degree of uncertainty associated with contouring in the southwest corner of the CGWA due to a lack of monitoring wells located in that area. There are stockwater developments in that area, some of which appear to have wells according to the IDWR Water Rights database. These wells, should they be accessible and suitable for measurement, would add valuable data that portion of the CGWA.

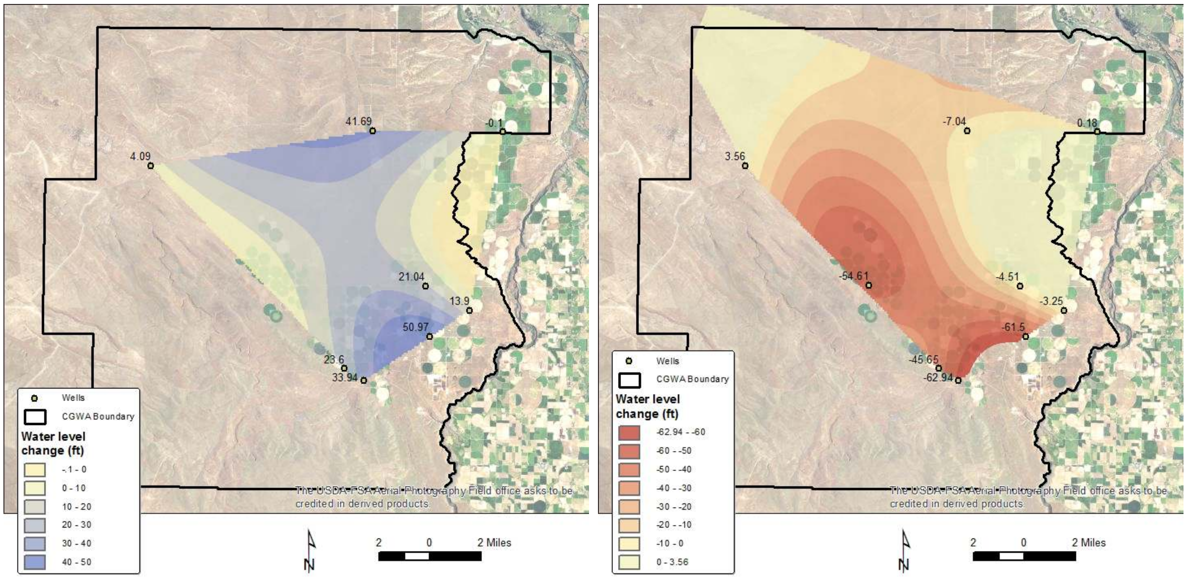


(a) 1973

(b) 1993

(c) 2019

Figure 16: Spring water table contours.



(a) Water level change between 1973 and 1993.

(b) Water level change between 1993 and 2019.

Figure 17: Ground water level change maps. Negative values indicate lower levels in the more recent year.

Discussion

Water levels in the south-eastern part of the Blue Gulch CGWA have generally decreased since 1990. Regionally, this decline is approximately 1.4 ft/yr. The average water level change ranges from a rise of 0.11 ft/yr in well 08S 11E 33BCD1 to a decline of 3.77 ft/yr in well 10S 12E 11DBD1. There are more trends significant at the 95% confidence interval after 1990, and most are declining. Prior to 1990, the significant trends were rising as mentioned by Bendixsen (1993) and supported here with quantitative trend tests.

Variable demand for ground water over the period of record correlates well with the hydrograph trends. At the time of the previous report, there was an estimated 12,000 acres of agricultural land removed from production through the Conservation Reserve Program (CRP) administered by the Agriculture Stabilization and Conservation Service (ASCS), now jointly managed by the US. Department of Agriculture Natural Resources Conservation Service (USDA NRCS) and Farm Service Agency (FSA). Since then, enrollment in the CRP declined to 55 acres in 2016 and 37 acres in 2017 through 2020 (Periosol, personal communication). CIR estimates in this report reflect the large change in irrigated acres. Between 1986 and 1992, estimated acreage dropped from 14,799 to 3,676 acres (table 1). The expiration of CRP contracts and the re-introduction of thousands of acres of land into production is likely a factor in the post-1990 decline of groundwater levels. More frequent drought conditions and lower than average precipitation could also lead to lower aquifer levels due to an increase in crop irrigation requirements and less recharge in the highlands.

The single well showing rising levels (08S 11E 33BCD1, fig. 3) has several factors that could cause rising water levels; geology, climate, and water use. The well is located in an area of high fault density in the Glenns Ferry Formation (see Bendixsen, 1993, figure 2). Such fault density and high fault zone permeability may allow for more direct recharge to the aquifer in this area. This well is the shallowest well in the monitoring network (total depth = 290 ft), furthest away from irrigated areas, and the only well located in the Upper Sailor Creek drainage (Hydrologic Unit Code (HUC) 1705010101, see figure A.1). Upper Sailor Creek has higher average precipitation, 10.01 in, than the CGWA as a whole (9.49 in) and basins where much of the ground water irrigated lands are located; Deadman Creek (HUC 1705010104, 9.69 in), Yahoo Creek (HUC 1704021211,

Table 3: PRISM precipitation statistics for the CGWA and HUC 10s basins within the CGWA boundary in inches before and after 1990. See figure A.1 for HUC 10 boundaries.

HUC 10 or Region	Basin Name	Pre-1990			Post-1990		
		mean	max	min	mean	max	min
1704021211	Yahoo-Snake	10.20	10.83	9.60	9.62	10.53	8.79
1704021213	Tuana Gulch-Snake	10.41	10.92	9.56	9.66	10.29	8.82
1704021309	Devil-Salmon Falls	11.53	22.37	9.50	10.97	21.72	8.80
1705010101	Upper Sailor	10.90	11.79	10.14	10.04	11.06	9.25
1705010102	Pot Hole	11.05	11.56	10.36	10.13	10.73	9.25
1705010103	Roosevelt	13.68	27.39	9.88	12.60	25.03	9.01
1705010104	Deadman	10.53	11.55	9.81	9.69	10.84	8.93
1705010105	Lower Sailor	10.77	11.26	10.10	9.78	10.40	9.06
CGWA	-	10.29	11.06	9.62	9.49	10.24	8.81

9.62 in), and Tuana Creek (HUC 1704021213, 9.66 in). Of the basins within the CGWA with water rights, the exception is Devil-Salmon Falls Creek (HUC 1704021309, 10.97 in), where average precipitation is greater than Upper Sailor Creek; however, most wells there are showing downward trends in water levels. Devil-Salmon Falls Creek contains more irrigated lands than Sailor Creek, which has only stockwater places of use, and precipitation is more variable. The network wells in Devil-Salmon Falls creek are also located near the edge of the basin boundary and away from the uplands to the south where recharge is more likely to occur, possibly explaining the downward trends despite higher rainfall rates.

Conclusion and Recommendations

The Blue Gulch CGWA is monitored by the IDWR on a semi-annual basis. The monitoring network is able to provide long-term resolution of aquifer level trends. Dis-enrollment from the CRP program along with increased frequency and duration of hydrological drought have caused an overall decreasing water level trend since 1990. Current water level elevations are approximately the same as when the CGWA was first designated in 1970. Because aquifer water levels proceed to decline with current ground water use, the Blue Gulch area continues to meet the definition of a CGWA (Idaho Code §42-233a). Further appropriation would likely increase the rate of drawdown and threaten the safe supply of ground water for irrigation and other existing uses.

The monitoring network should continue as currently configured with the possibility of adding an additional monitoring well, should it exist and be measurable, in the southwest. The feasibility of instrumenting another well with a datalogger should be assessed and targeted at a well not showing the characteristic trends of a majority of the wells, such as 08S 13E 23CCD1 or 08S 12E 24CCC1. Other wells could be instrumented if resources are available.

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Appendices

Appendix A Supplemental Maps

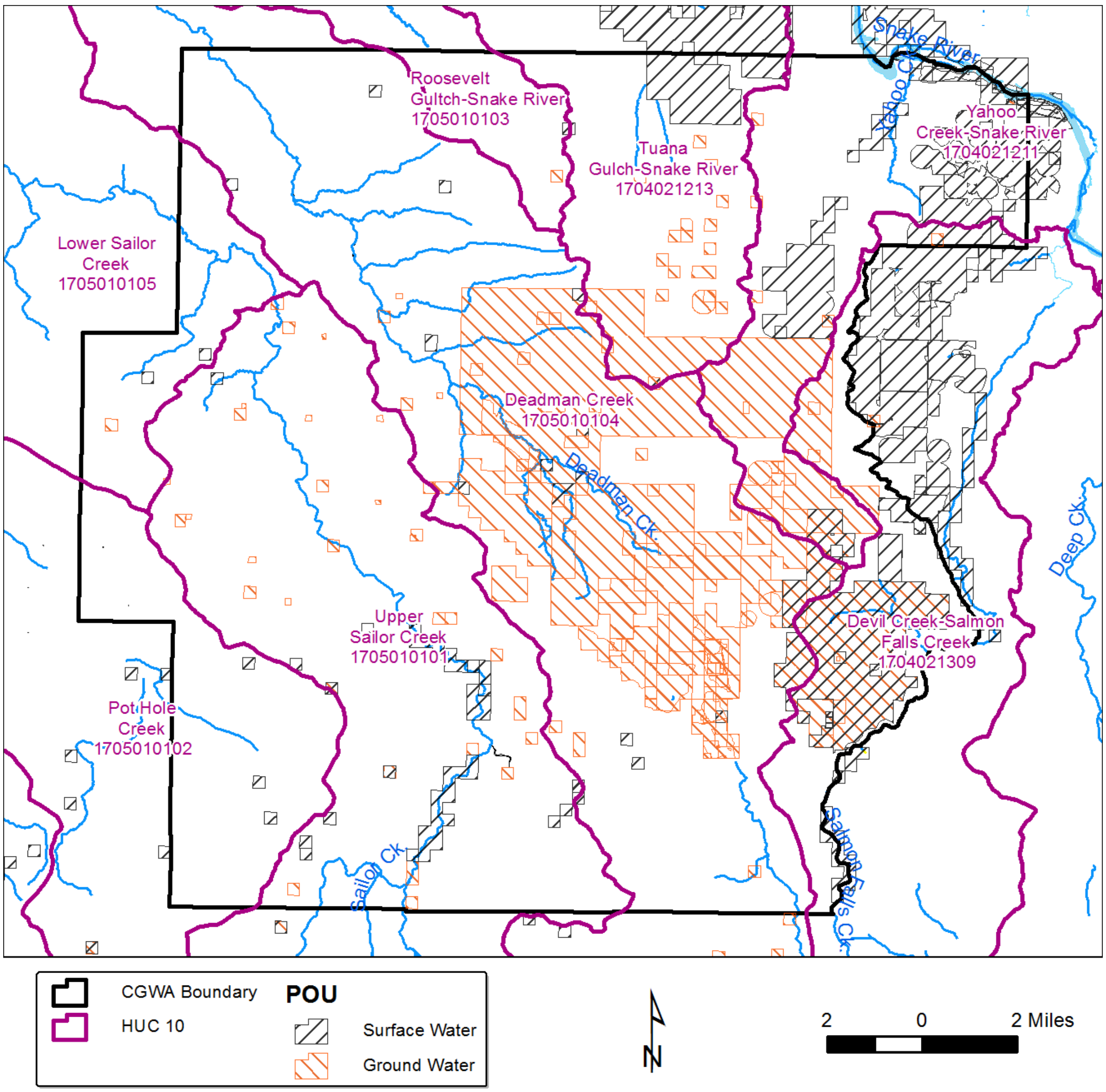

Figure A.1: Irrigation and stockwater right place of use locations by water source and USGS Hydrologic Units at the HUC 10 level. All water rights in Upper Sailor Creek (1705010101) are for stockwater use.

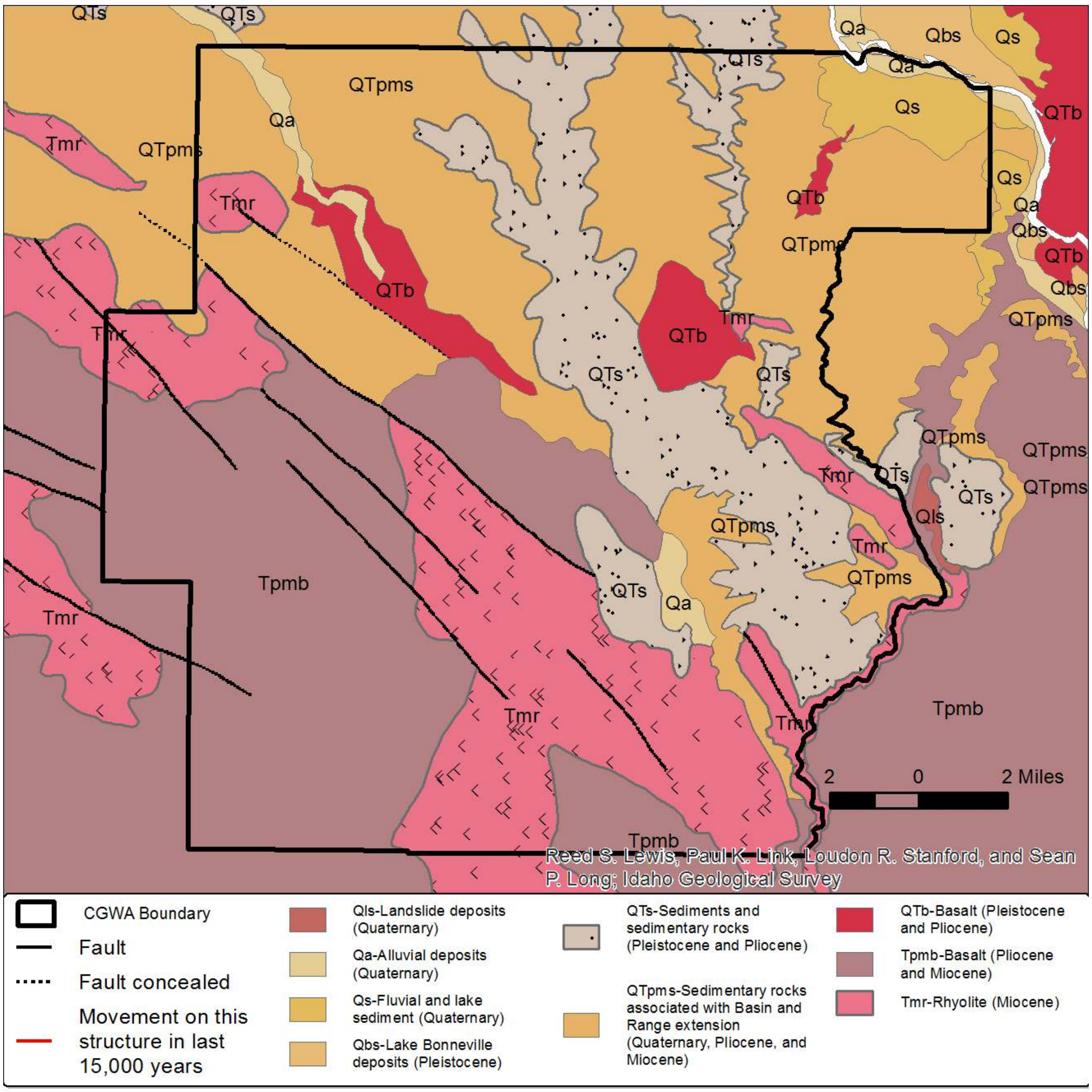

Figure A.2: Geology of the Blue Gulch, subset from Lewis et al. (2012).

Appendix B Crop Irrigation Requirement

Table 1: Crop irrigation requirements from METRIC years

Growing Season	ET (af)	Precip (af)	Irrigated Acres	CIR (af)	CIR (acre-ft/acre)	ET (acre-ft/acre)
1986	35,666	4,319	13,937	31,347	2.2	2.6
1992	8,430	758	3,461	7,671	2.2	2.4
1996	11,598	1,426	4,340	10,172	2.3	2.7
2000	22,231	2,439	8,522	19,792	2.3	2.6
2002	18,014	1,046	7,658	16,969	2.2	2.4
2006	26,344	4,677	10,028	21,667	2.2	2.6
2008	25,849	1,966	9,530	23,883	2.5	2.7
2009	28,613	5,524	9,937	23,088	2.3	2.9
2010	23,452	4,074	9,003	19,378	2.2	2.6
2011	31,420	5,275	11,582	26,145	2.3	2.7
2013	23,491	2,189	9,200	21,302	2.3	2.6
2015	29,593	3,455	10,651	26,139	2.4	2.8
2016	28,606	5,004	10,217	23,603	2.3	2.8
2017	20,305	2,308	7,882	17,997	2.3	2.6
2018	19,156	2,340	7,844	16,816	2.1	2.4
Average	23,518	3,120	8,919	20,398	2.3	2.6

Appendix C Mann-Kendall Tests

Table C.2: Regional Kendall tests of fall depth to water measurements.

	slope ($\frac{ft}{yr}$)	tau	z	S	p
Pre-1990	-0.34	-0.15	-2.20	-158	0.03
Post-1990	1.40	0.52	10.89	1449	0.00

Table C.3: Kendall Tests for fall depth to water measurements.

Well Number	Pre-1990					Post-1990				
	slope ($\frac{ft}{yr}$)	tau	z	S	p	slope ($\frac{ft}{yr}$)	tau	z	S	p
07S 10E 22DDD1	-3.04	-0.60	-1.23	-6	0.22	0.13	0.56	3.09	76	0.00
08S 11E 33BCD1	-0.30	-1.00	-1.04	-3	0.30	-0.11	-0.61	-2.19	-22	0.03
08S 12E 24CCC1	-2.71	-0.67	-2.40	-24	0.02	1.08	0.97	3.56	35	0.00
08S 13E 23CCD1	0.18	0.43	2.76	99	0.01	-0.03	-0.32	-2.35	-120	0.02
09S 12E 29BBA1	-3.25	-1.00	-2.21	-10	0.03	3.27	0.82	6.14	312	0.00
09S 13E 20CCD1	-0.63	-0.41	-2.69	-103	0.01	0.33	0.43	2.35	58	0.02
09S 13E 28DDD1	-1.10	-1.00	-4.70	-78	0.00	0.18	0.42	3.10	158	0.00
09S 13E 32CDD2	-4.75	-0.69	-2.68	-31	0.01	3.55	0.70	5.20	264	0.00
10S 12E 10AAD1	-0.79	-0.17	-0.85	-20	0.39	2.55	0.79	5.91	300	0.00
10S 12E 11DBD1	1.07	0.21	1.35	49	0.18	3.77	0.81	6.03	306	0.00

Table C.4: Seasonal Kendall tests for depth to water trends over time. "Growing" season designation splits the year into a growing season (April - October) and dormant season. "Monthly" uses 12 seasons per year.

Well Number	Season	Pre-1990					Post-1990				
		slope ($\frac{ft}{yr}$)	tau	z	S	p	slope ($\frac{ft}{yr}$)	tau	z	S	p
07S 10E 22DDD1	growing	-0.54	-0.42	-1.54	-13	0.12	0.13	0.62	6.37	434	0.00
	month	-1.01	-0.51	-3.61	-41	0.00	0.22	0.65	7.67	367	0.00
08S 11E 33BCD1	growing	-0.29	-0.86	-7.77	-385	0.00	-0.15	-0.91	-9.73	-73	0.009
	month	-0.29	-0.84	-7.70	-346	0.00	-0.16	-0.91	-9.21	-47	0.005
08S 12E 24CCC1	growing	-3.08	-0.60	-5.37	-271	0.00	0.15	0.26	2.84	221	0.00
	month	-3.00	-0.67	-6.31	-209	0.00	-0.00	-0.01	-0.06	-4	0.96
08S 13E 23CCD1	growing	0.05	0.23	2.16	124	0.03	-0.03	-0.23	-2.37	-17	0.021
	month	0.05	0.22	3.39	256	0.00	-0.01	-0.05	-0.75	-65	0.45
09S 12E 29BBA1	growing	-4.24	-1.00	-3.58	-25	0.00	2.64	0.66	6.94	498	0.00
	month	-4.06	-0.81	-6.57	-91	0.00	2.61	0.59	9.59	764	0.00
09S 13E 20CCD1	growing	-0.42	-0.27	-2.60	-154	0.01	0.21	0.23	2.35	165	0.02
	month	-0.44	-0.27	-4.45	-353	0.00	-0.05	-0.05	-0.53	-24	0.60
09S 13E 28DDD1	growing	-1.04	-0.86	-4.99	-86	0.00	0.15	0.42	3.81	189	0.00
	month	-1.10	-0.98	-5.82	-96	0.00	0.22	0.51	4.67	179	0.00
09S 13E 32CDD2	growing	-2.59	-0.33	-1.61	-22	0.11	3.00	0.63	5.77	294	0.00
	month	-2.81	-0.45	-2.19	-26	0.03	3.65	0.77	7.19	266	0.00
10S 12E 10AAD1	growing	0.23	0.06	0.35	10	0.73	2.02	0.68	6.31	334	0.00
	month	0.06	0.03	0.17	5	0.87	2.28	0.85	8.23	318	0.00
10S 12E 11DBD1	growing	1.64	0.36	3.44	191	0.00	3.00	0.65	6.86	492	0.00
	month	1.08	0.21	3.20	232	0.00	3.26	0.65	10.17	830	0.00