A Hydrologic and Geochemical Investigation of Basin Infiltrated River Water in Alluvial, Basalt, and Combination Alluvial/Basalt Aquifers

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Wayne “Cooper” Fritz, Jr.

Major Professor: Robert W. Smith, Ph.D.
Committee Members: Jeff Langman, Ph.D.; Travis McLing, Ph.D.
Department Administrator: Alistair M.S. Smith, Ph.D.

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Abstract

Groundwater overdraft is a persistent problem in the western US including in the East Snake River Plain (ESRP) Aquifer (ESRPA), the largest in Idaho. Managed aquifer recharge (MAR) is a tool increasingly utilized for stabilizing aquifer storage volumes and is employed across the ESRP to infiltrate untreated river water through constructed recharge basins. Hydrologic and water quality data from monitoring well networks in the vicinity of three ESRP MAR basins – one each in an alluvial, basalt, and combination alluvial/basalt setting, together representative of the ESRPA – were examined. Processes investigated were hydrologic mixing between ambient groundwater and infiltrated water and whether cation exchange and calcite precipitation/dissolution reactions impacted MAR water. In addition, groundwater level increases and decreases in response to infiltration events were investigated as to whether they indicated the arrival and departure of MAR water at a pumping location. The results also provide suggestions regarding the location of hydrologic and chemical monitor well placement as MAR programs continue to evaluate new sites.

A sample analysis provided results consistent with the stratification of infiltrated and ambient groundwater at all three sites. In the alluvial and basalt settings some sampling locations were entirely infiltrated water while at the combination alluvium/basalt setting vertical stratification in the aquifer was inferred. Hydrologic responses to basin inflow events in wells chemically unimpacted by MAR water indicated that water table responses did not necessarily evidence the arrival or departure of infiltrated water but could be the result of a “mound” of infiltrated water growing under the basins that displaced ambient groundwater away from it.

At the alluvial site an analysis of samples indicated that reverse cation exchange impacted infiltrated water, but calcite precipitation (if it occurred) did not impact infiltrated water chemistry. Geochemical modeling predicted that the reverse cation exchange processes would continue with increased alluvium interaction, but that calcite precipitation would have a nondetectable impact on the chemistry of infiltrated water and in any case would not be discernable from an analysis of the samples because much of the calcium precipitated as calcite would have been derived from reverse cation exchange. All wells, located between 620 ft (190 m) downgradient and 100 ft (30 m) cross gradient, were chemically impacted by infiltrated water (primary infiltration event average of 24.8 AF [30,590 m^3] per day for 54 days) suggesting that these are appropriate distances for chemical monitor wells. However, local heterogeneities in the flow field played a larger role in the movement of infiltrated water than simple distance from the basin.

At the basalt site, fracture flow governed hydrologic and chemical impacts. Two distant (greater than 5,280 ft [1,609 m]) locations showed no chemical interactions between the aquifer matrix and infiltrated water. At a third location cation exchange processes may have impacted the samples. The three wells chemically impacted by infiltrated water were within 600 ft (183 m) of the basin while the other locations, 5,280 ft (1,609 m) or greater, were hydrologically impacted but showed no evidence of infiltrated water possibly because preferential flow paths routed the high volumes (primary infiltration event average of 730 AF [900,440 m^3] per day for 133 days) away from the wells. Together these results suggest a range in which chemical monitor wells might be located but also demonstrate the significance of flow field heterogeneity.

At the combination alluvium/basalt site, wells were located 1,250 ft (380 m) cross gradient and 6,750 ft (2,060 m) downgradient and were not chemically impacted by the basin (infiltration event average of 88.3 AF [180,900 m^3] per day for 136 days) suggesting that these locations are too distant to be appropriate for chemical monitoring. Hydrologic responses to infiltration events were observed only in the closer location.

Acknowledgements

This thesis would not have been possible without the patience and intellect of my advisor, Dr. Robert W. Smith. Without your support, I would not have finished the document. But your teachings will carry with me long after the thesis is archived. Two are prominent as I write this: 1) Tell the story that the data tells, not that which I want it to, and 2) Do not explain any more than I must to make the point. There are many other words of advice that I'll wish I had included after I submit this. Also, and just as impactful but at a scale larger than research, your teachings allow me to observe the earth and our environment through the lens of geochemistry, a lens that makes living in my surroundings all the richer. Thank you, Dr. Smith, for being a wonderful mentor.

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To my wife, Katie. I look forward to spending more unencumbered time with you, my best friend.

To my daughter, Leigh. I'm excited to be fully present with you.

To the Idaho Water Resource Board and the Idaho Department of Water Resources. Thank you for the data and the funding. My hope is that this work allows us to better interpret how our recharge operations interact with the aquifer and better understand our water level data.

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Disclaimer

The opinions and recommendations expressed in this work are those of the author and do not reflect those of the Idaho Water Resource Board, the Idaho Department of Water Resources, or the State of Idaho.

Chapter 1: Introduction

Groundwater overdraft is a persistent problem in the United States (US) with approximately 8.11 * 10^8 acre-feet (AF) (1,000 km^3) depleted between 1900 and 2008 [1] and is especially acute in the arid western portion of the country [2, 3, 4]. The East Snake River Plain (ESRP) Aquifer (ESRPA) is one of the aquifers experiencing overdraft [5, 6]. The ESRPA is in southern Idaho (Figure 1) and is one of the most productive aquifers in the US [7] as well as a sole source aquifer for more than 200,000 people [8]. The aquifer also supports the irrigation of approximately 1,237,000 acres (500,600 hectares) [6] and the largest commercial trout farming industry in the US relies on its discharges to the Snake River [9].

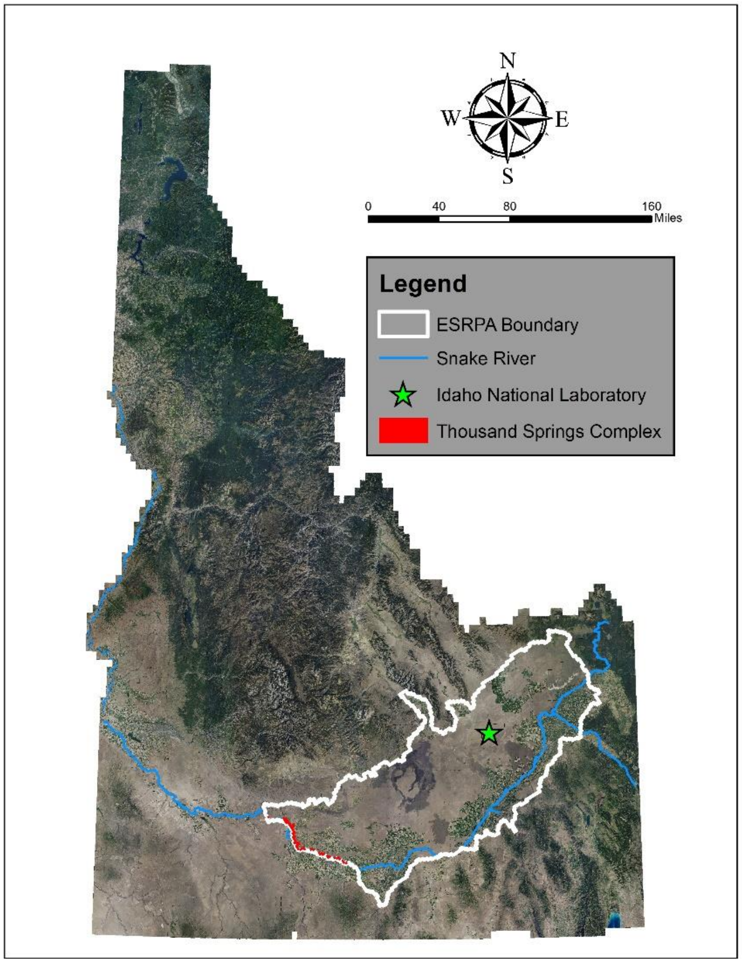

Figure 1 -- Location of the East Snake River Plain (ESRP) and its underlying aquifer (ESRPA) [10] in the State of Idaho as well as the Snake River, the approximate location of the Idaho National Laboratory (INL), and the approximate location of major springs in the Thousand Springs Complex discharging into the channel of the Snake River.

The ESRPA saw an increase in storage of approximately 17.5 million AF (21.6 km^3) from 1912 to 1976, however, the aquifer has subsequently been depleted at an average rate of 0.32 million

AF/year (0.40 km^3/year) (Figure 2). This depletion has been accompanied by substantial decreases in spring discharge to the Snake River resulting in, among other deleterious issues, potential widespread pumping curtailment across the ESRP as senior surface water right holders assert that junior groundwater users extract their water [13].

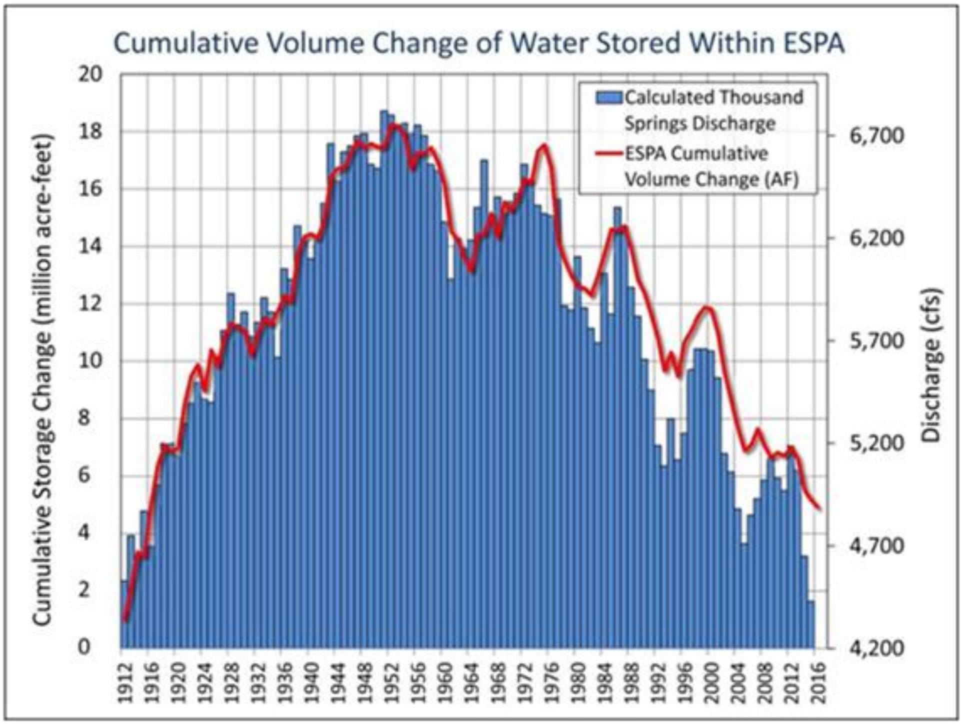

Figure 2 [11] – Increases and decreases of storage in the ESRPA and associated spring discharge rates at Thousand Springs Complex (which account for approximately 70% of the spring discharge from the ESRPA [calculated from 12]), 1912 – 2015.

Managed aquifer recharge (MAR) is a method of adding volume to the aquifer beyond that provided by seepage losses from rivers and incidental recharge from irrigation operations, thereby stabilizing and potentially increasing storage [14, 15, 16, 17] in arid watersheds. Globally, 1,200 MAR programs were in existence in 2015 [16] and increase in number by approximately five percent per year [17]. MAR strategies include the use of direct injection and recovery from the same or nearby wells (aquifer storage and recovery) of treated wastewater [15, 16] and untreated urban runoff [18, 19, 20], as well as the use of infiltration basins [15, 21, 22] utilizing water from a variety of sources (e.g., untreated river water).

Specific to the ESRPA, the State of Idaho through the Idaho Water Resource Board (IWRB) administers a MAR program (program) with a goal of recharging an average of 0.25 million acre feet (AF) (0.31 km^3) annually [23, 24] across the ESRP. The program primarily utilizes canal seepage losses during the non-irrigation season as well as infiltration basins [22]. These infiltration basins source untreated water from the Snake River and provide high volumes (e.g., up to 1,200 AF [1.5 million m^3] per day) of recharge in concentrated locations. This source of recharge is different from the distributed nature of recharge that provides most of the volume to the ESRPA and may alter the geochemical characteristics of the locally recharged groundwater because of concentrated infiltration and associated water-rock interactions. However, only a limited number of studies have addressed the hydrologic and geochemical evolution of MAR water in the vicinity of MAR infrastructure with the majority focusing on the geochemical evolution of water from various sources (e.g., pretreated wastewater [18, 25, 26] and urban stormwater runoff [19, 20, 21]) recharged via the aquifer storage and recovery method. No known studies examining hydrologic or geochemical processes resulting from water-rock interactions of untreated surface water in the vicinity of dedicated MAR infiltration basins were identified.

Here, to address the limited previous work, are the results of an investigation of hydrologic mixing, local groundwater level responses, and water-rock interactions influencing geochemical changes in groundwater chemistry during MAR operations in infiltration basins across the ESRP. Specifically, groundwater levels as well as infiltrating surface water and groundwater compositions in local monitor well networks were collected during recharge events at three MAR sites with differing geologic settings – alluvium, basalt, and combination alluvium/basalt, together characteristic of the ESRPA -- and used to infer process and their extent in influencing water composition. From this analysis, IWRB program staff and the public will be able to better interpret groundwater level data, including whether increases and decreases in groundwater levels indicate the arrival and departure of infiltrated water, and understand how MAR operations hydrologically and geochemically interact with the receiving substrate. The analysis will also be useful to the IWRB program as it continues to develop new infrastructure and associated monitor well networks in differing geologic settings across the ESRP.

East Snake River Plain Aquifer Hydrogeology

The ESRP is approximately 60 mile (100 km)-wide crescent-shaped plain which resulted from the North American continent passing west over a mantle hotspot now located under Yellowstone National Park [27] and the accompanying deposition of Pleistocene age (less than 2.6 Ma) basalt flows [28]. It is underlain by the ESRPA. Basin-and-range structures border the ESRP on its north, east, and south, the Island Park caldera to its northeast, and the Western Snake River Plain to the west [29].

More than 95% of the ESRPA host rock is basalt, with individual flows ranging in thickness from between 16.5 and 82 ft (5 and 25 m) and extending up to 30 miles (48 km) laterally [30]. Eruptions occurred intermittently, allowing for the intercalation of sedimentary layers between basalt flows [12]. The abundance of alluvial deposits increases at the outer boundaries of the aquifer [28] due to fluvial discharge from the surrounding mountains and accompanying sediment transport. Water movement through the aquifer is dominated by fracture flow within the basalt [31] and substantial (e.g., 5.8 million AF [7.15 km^3] in 1939, 1965, 1976, 1984, and 1987 [Figure 2]) but declining quantities of water from the ESRPA discharge into the Snake River through a series of large springs [12, 32] including the Thousand Spring Complex shown in Figure 1.

Lower elevations of the ESRP receive approximately 10 inches (25 cm) of precipitation annually, while some headwater mountain catchments receive over 60 inches (150 cm) [32]. Numerous rivers, including the Snake and Big Lost Rivers, discharge into or flow across the ESRP and provide some recharge to the aquifer.

Large scale irrigation projects began on the northern and eastern portions of the ESRP in the 1880s and 1890s [33], and in the southern portion of the plain after the construction of the Milner Dam in 1902 [34]. Incidental losses from these irrigation projects, including canal seepage losses and the over-application of irrigation water, increased recharge to the aquifer by approximately 70% when compared to seepage from rivers [35], as shown in Figure 2. Starting in the 1950s, changes in irrigation practices, increased groundwater withdrawals, and persistent drought combined to decrease volumetric storage in the aquifer [32, 36, 37]. Specifically, irrigators began large-scale conversion to more efficient sprinkler systems while the use of turbine water pumps increased extractions as the technology was widely adopted in the post-WWII era. Concurrently, annual precipitation began declining in headwater catchments, leading to decreased river flows and associated recharge.

East Snake River Plain Aquifer Geochemistry

Investigations of water-rock interactions influencing ESRPA groundwater chemistry have largely focused on the data rich Idaho National Laboratory (INL) site (Figure 1). The field parameters and geochemical composition of the average (as calculated from [38]) non-contaminated groundwater sample from the upper 250 ft (76.2 m) of the ESRPA in the southeast portion of the INL (closest to the study areas) and surface waters sampled from tributary basins which supply incidental recharge to the aquifer at the INL site are provided in Table 1. The groundwaters are of a calcium-bicarbonate type, typically oversaturated with respect to carbonate minerals (aragonite, calcite, and dolomite) and undersaturated with respect to gypsum. The typical sample collection date of the surface water in Table 1 was July 2, potentially impacting the reported concentrations and parameters (e.g., temperature).

Previous investigations of water-rock interactions within the ESRPA basalt minerals have been inferred the dissolution of olivine [40, 41, 42], pyroxene [40, 41], plagioclase [40, 42, 43, 44], pyrite [40, 42], potassium feldspar [41, 42, 43], silica [43], kaolinite [43], halite [42, 43], volcanic glass [44], and the congruent dissolution of olivine, diopside, amorphous silica, and anhydrite [45]. Precipitation of secondary calcite [40, 41, 42, 43, 44, 45], silica [40], montmorillonite [43], Ca- and/or Na-smectite [42], gibbsite [42], and ferric hydroxide [42, 45] has been observed or inferred. Other processes of potential relevance include cation exchange reactions [41, 44, 46] and the mixing of waters from differing recharge sources [38, 41, 42, 43]. Cation exchange capacities of ESRPA materials have variously been reported [46, 47, 48, 49, 50, 51, 52, 53]. These previous aquifer-scale water-rock interaction investigations provide results that are relevant at scales of tens to hundreds of miles (km) distance and years of time, much different than the distance and time scales characteristic of MAR operations which are localized to the vicinity of a recharge basin and occur on time scales of week to months.

In addition to aquifer-scale investigations, investigations of localized discharges and leaks of contaminated water associated with INL facilities and infrastructure at scales similar to MAR operations found that cation exchange processes, which occurred predominantly within sedimentary interbeds, influenced the migration of cations in the vadose zone and ESRPA [54, 55, 56, 57, 58].

Table 1 -- The geochemistry of average groundwater samples from the southeast portion of the INL and surface water tributary to the ERPA at the INL as calculated from [38]. Log Q/K and *f*CO_2 calculated via [39].

	Temperature (°C)	pH	Specific Conductance (µS/cm at 25 °C)	Alkalinity (mg/l as CaCO3)	Dissolved Oxygen (mg/l)	Ca^{2+} (mg/l)	Mg^{2+} (mg/l)	Na^{+} (mg/l)	K^{+} (mg/l)	HCO_3^{-} (mg/l)	
Average Tributary Surface Water	13.05	8.22	296.91	116.83	8.64	30.83	9.28	4.78	1.37	142.17	
Average Groundwater	14.29	8.12	365.4	137.5	7.7	35.89	13.73	15.11	3.26	167.6	
	CO_3^{2-} (mg/l)	Cl^{-} (mg/l)	SO_4^{2-} (mg/l)	F^{-} (mg/l)	NO_3^{-} (mg/l)	SiO_2 (mg/l)	Aragonite (log Q/K)	Calcite (log Q/K)	Dolomite (log Q/K)	Gypsum (log Q/K)	CO_2 (log fugacity)
Average Tributary Surface Water	1.16	3.28	14.74	0.18	0.09	10.70	0.25	0.42	1.38	-2.77	-3.14
Average Groundwater	0.964	17.68	17.63	0.53	1.13	30.23	0.28	0.45	1.55	-2.67	-2.97

Chapter 2: Materials and Methods

Study Site Descriptions

Alluvial Site – The Jones Pit

Constructed in 2018, the four-acre (1.62 hectare) basin known as the Jones Pit is in the eastern portion of the ESRPA (Figure 3). Based on five recharge events between 2018 and 2021, the Jones Pit is capable of infiltrating approximately 30 AF (37,000 m^3) per day [22]. The site is in Pleistocene era glacial outwash alluvium of the Snake River [33]. The alluvium is approximately 200 ft (61 m) thick and underlain by basalt **[59]**. Depth to water varies seasonally from a high of 50 ft (15 m) below ground surface (bgs) in October to a low of 110 ft (33.5 m) bgs in April [22]. Groundwater flow directions determined from the local potentiometric surface is from east to west (Figure 3) and is consistent with the regional (ESRPA) gradient provided by East Snake River Plain Aquifer Model (ESPAM) [10].

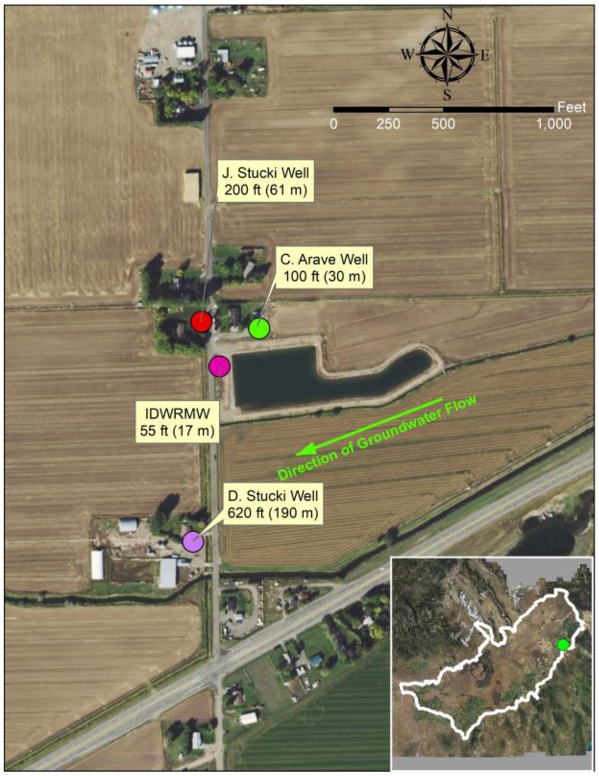

Figure 3 – The alluvial infiltration basin, known as the Jones Pit, and its monitor well network, as well as its location within ESRP. Callouts provide the sampling well names and approximate horizontal distances to the basin and direction of groundwater flow was provided by [10].

The monitoring network (Figure 3) consists of four wells located adjacent to the infiltration basin at distances of between 55 ft (17 m) and 620 ft (190 m). The IDWRMW was the only well with a pressure transducer for continuous monitoring of water levels and is located immediately downgradient of the basin. The other monitoring wells, C. Arave, J. Stucki, and D. Stucki, are located increasingly farther away from the basin, orthogonal to the regional gradient. Wells logs are provided in Appendix A.

Water diverted from the South Fork of the Snake River below the Heise gauge (USGS monitoring location #13037500, two miles [3.2 km] to the east) is delivered to the basin by the Farmers Friend Irrigation Company (Farmers Friend). The Farmers Friend system is approximately 21.9 miles (35.2 km) from diversion to terminus and infiltrated approximately 140 AF (172,000 m^3) per day during a 2018 infiltration event [22]. Assuming the canal seeps a uniform volume of water and that approximately 0.4 miles (0.64 km) of canal borders the vicinity of the site (Figure 3), 2.56 AF (3,160 m^3) per day of incidental recharge probably occurs immediately adjacent to the basin. Assuming half flows towards the monitor well network, incidental recharge supplies approximately four percent of the volume when the basin is infiltrating its maximum capacity.

Basalt Site – MP29/31

Two subbasins in the western portion of the ESRPA, Milepost 29 and Milepost 31, connect on the surface during infiltration operations and can be considered as a single basin (MP29/31). Milepost 31 (MP31), an approximately 271-acre (100 hectare) basin, was constructed in 2014 and had subsequently been utilized annually during the non-irrigation season (i.e., September through June). Milepost 29 (MP29), an approximately 335-acre (135.6 hectare) basin, was constructed in 2020, and has been subsequently utilized in tandem with MP31. The basin has an operational capacity of approximately 1,200 AF (1.4 million m^3) per day based on eight infiltration events [22]. The site is in an olivine tholeiite basalt section deposited approximately 2.4 Ma but includes some flows as old as 3 Ma [28] and extends beyond a depth of 363 ft (110.6 m) (Appendix B). A review of water table depths from 10/8/2019 through 10/8/2021 suggest that groundwater levels are controlled by events in the basin, rising during the non-irrigation season when infiltration operations occur and declining after their conclusion. Depth to water during that time ranged between 238.12 ft (72.58 m) bgs on 4/11/20 and 269.23 ft (82.06 m) bgs on 9/21/21. A 2016 fluorescein dye tracer test [60] (tracer test) found local east to west groundwater flow (Figure 4) consistent with the regional gradient provided by ESPAM, although no regionally-upgradient (upgradient) wells were sampled.

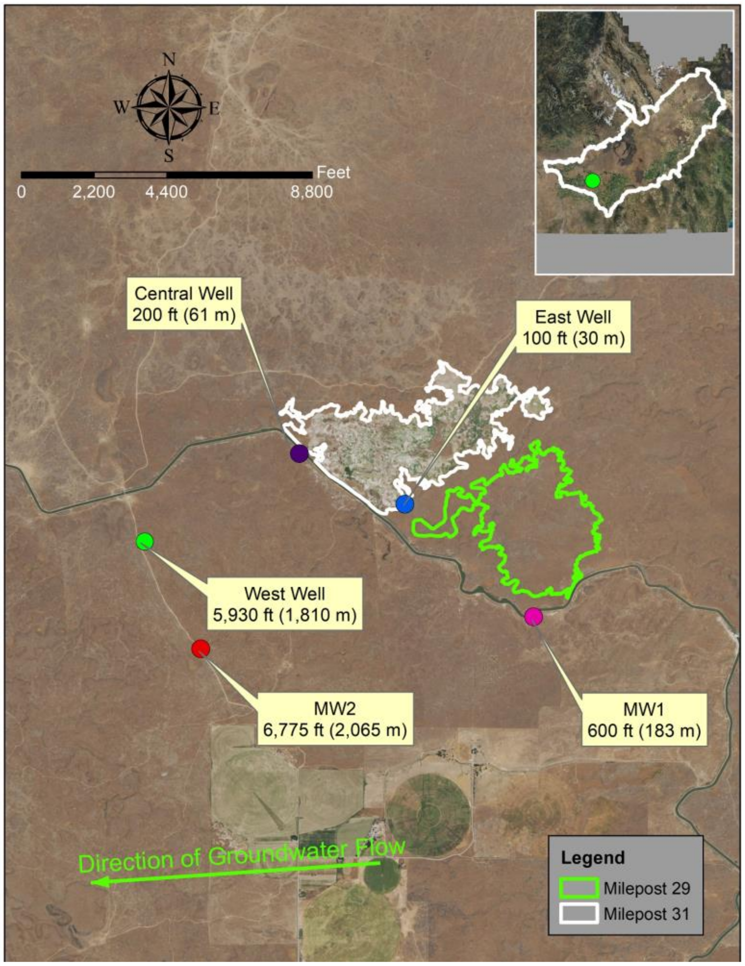

Figure 4 – The basalt infiltration basin(s), known as MP29/31, and its monitor well network, as well as its location within the ESRP. Callouts provide the sampling well names and approximate horizontal distances to the closest basin. Direction of groundwater flow provided by [10].

The monitoring network consists of five wells (Figure 4, well logs in Appendix B) each equipped with a pressure transducer allowing for continuous water level measurements. There are three close wells (East, Central, and MW1) located within 600 ft (183 m) of the basin and two outer wells (West and MW2) each located greater than a mile (1.6 km) from the basin. All wells are downgradient except for MW1, which is regionally cross-gradient (cross gradient) from both basins and 5,280 ft (1,609 m) from MP31.

Water diverted from the Snake River at Milner Dam is delivered by the American Falls Reservoir District Number 2 Irrigation District via the Milner-Gooding Canal to MP29/31. Headgates into the basin are located 29 and 31 miles (46.7 and 50 km) from the river. Between the river and the basin, the canal seeps approximately 59.5 AF (73,400 m^3) per day [22]. Assuming uniform conveyance losses and 4.5 miles (7.2 km) of canal in the vicinity of the site (Figure 4), approximately 8.9 AF

(1,100 m^3) per day of canal seepage is estimated to impact the monitor network, or less than one percent of the inflow volume of the infiltration basin at maximum capacity.

Combination Alluvial/Basalt Site – West Egin Lake

The 300-acre (121 hectare) basin known as West Egin Lake is in the northern portion of the ESRPA (Figure 5). It is the largest basin in a privately operated recharge complex that is dispersed over an area of approximately 2.4 $miles^2$ (6.2 km^2). Groundwater recharge in the complex began in 1972, after which the basin had been used consistently for MAR. West Egin Lake has a maximum measured infiltration capacity of approximately 220 AF (271,350 m^3) per day [22]. The site is in an interlayered section of basalt and fine-grained sediments (well 07N 39E 07 BDA1 located on a knoll inside of the basin, Appendix C). The olivine tholeiite basalt consists of primarily of flow less than 2.6 Ma but includes some flows as old as 3 Ma [28] with a clay interbed identified at approximately 183 – 188 ft (55.8 - 57.3 m) bgs with basalt continuing beneath the interbed to a depth of at least 320 ft bgs (Appendix C). Depth to water ranged between 82.85 ft (25.25 m) and 84.90 ft (25.88 m) during the analyzed infiltration event.

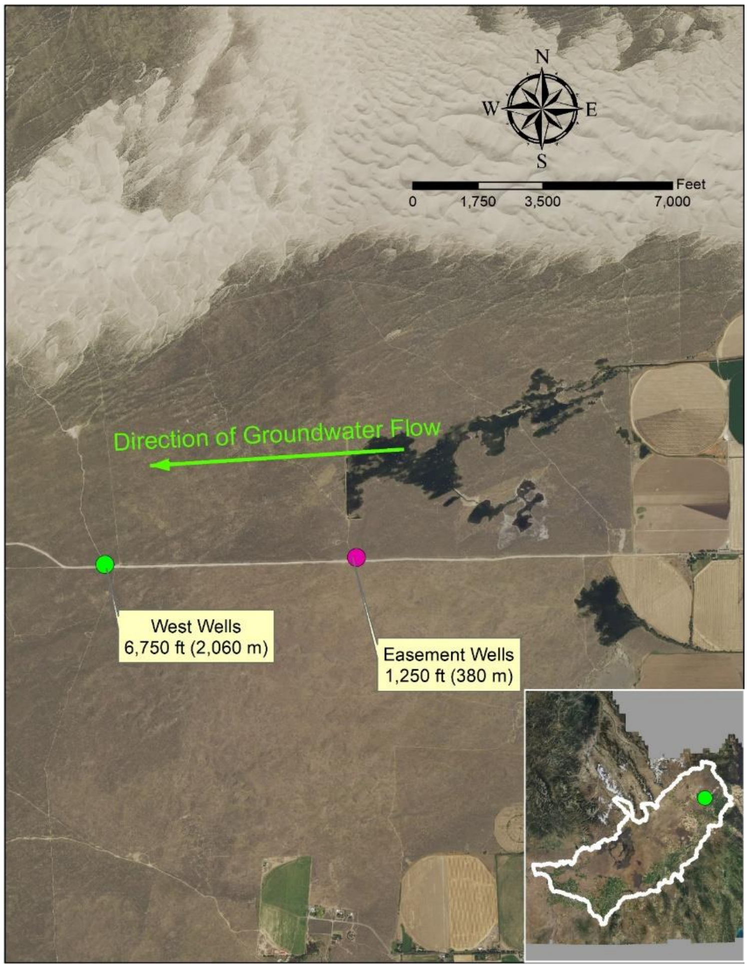

Figure 5 – The combination alluvial/basalt infiltration basin (seen north of road and full of water), known as West Egin Lake, and its monitor well network, as well as its location within the ESRP. Callouts provide the sampling well names and approximate horizontal distances to the basin. A deep and a shallow well are drilled at each called out location. Direction of groundwater flow provided by [10].

Although the ESPAM predicted regional ground water flow from east to west (Figure 5) an observed correlation of increased streamflow in the Henry's Fork of the Snake River (located to the east and southeast of West Egin Lake) with MAR activities [61], suggested that the clay layer may serve as an aquitard, creating a local shallow aquifer that routed water back to the river rather than recharging the ESRPA thus minimizing the effectiveness of the MAR activities. In response, the Idaho Department of Water Resources (IDWR) drilled four monitor wells in 2020, one shallow and one deep in each of two locations (Figure 5, Appendix D includes the two deep well logs). The purpose of these wells were to determine the extent of the clay layer, whether the basin infiltrated into a local shallow aquifer that was distinct from the ESRPA, and to serve as dedicated water quality monitor wells for the site. A clay layer was observed at the West location, but not at the Easement location (Appendix D), suggesting that the ESRPA rather than a shallow local aquifer receives the infiltrated water. The West Deep and Shallow wells produce water from below and above the clay layer, respectively. The West wells and the Easement Well Deep host pressure transducers. The Easement wells are slightly cross gradient from the infiltration basin and the West Wells are over a mile (1.6 km) down gradient from the basin.

Water diverted from the Henry’s Fork of the Snake River near the municipality of St. Anthony is delivered to West Egin Lake via the St. Anthony Union Canal operated by Egin Bench Canal Company, Inc. The headgate into the basin is located approximately 14 miles (22.5 km) from the river. The St. Anthony Union Canal is approximately 20.5 miles (33 km) from diversion to terminus and infiltrated approximately 162.7 AF (200,700 m^3) per day during a 2019 infiltration event [22]. A smaller basin, capable of infiltrating approximately 138.8 AF (171,200 m^3) per day [22], is approximately two-miles (3.2 km) cross- and upgradient from West Egin Lake. Within that same two-mile (3.2 km) radius, approximately one mile (1.6 km) of canal is upgradient. Assuming uniform canal losses, half of which flow towards the basin and its monitor network, and that half of the volume infiltrated in the smaller basin flows towards West Egin Lake, approximately 73.5 AF (91,900 m^3) per day of water infiltrated upgradient could hypothetically reach the monitor well network, or approximately one-third of the volume infiltrated through West Egin Lake at its maximum capacity.

Water Quality Data

Water samples and field parameters (pH, dissolved oxygen [DO], specific conductivity [SC], temperature) were collected from the infiltration basins and monitoring wells by IWRB program contractors. At the alluvium and basalt sites the samples were collected in compliance with site-specific water quality monitoring regimes required by the Idaho Department of Environmental Quality (DEQ). At the combination alluvium and basalt site, which is not subject to DEQ monitoring, the samples in Table 7 were the only ones to have been collected from the monitor wells.

Samples were collected in accordance with Standard Operating Procedures for the Statewide Groundwater Quality Monitoring Program [22]. Specifically, surface water grab samples were collected from just below the headgate or near it in the canal. For groundwater samples, wells were pumped until field parameters stabilized over three successive readings, each taken five minutes apart, or until three casing volumes of water had been removed. Field parameters were measured with probes calibrated daily. Water samples for major ions chemistry were collected, unfiltered, in 250 mL high density polyethylene bottles (triple rinsed with native water), leaving a small head space in the bottle for mixing (e.g., shaking) in the laboratory. Samples for cation and anion analysis were collected together and were not acid preserved. Samples were stored in an ice-filled cooler

immediately after collection and shipped overnight for analysis to an Environmental Protection Agency certified laboratory in Boise, operated by the Idaho Bureau of Laboratories.
Specific conductivity was measured using probes that were calibrated via a one-point method using a 500 µS/cm solution. pH was measured with a glass electrode calibrated with buffer solutions with pH of 4.0, 7.0, and 10.0. DO meters were calibrated with the barometric pressure reported at the closest National Oceanic and Atmospheric Association reporting point (the Idaho Falls Regional Airport). Calcium, sodium, potassium, and magnesium concentrations were determined via inductively coupled plasma-atomic emission spectrometry [62]. Chloride and sulfate concentrations were determined via ion chromatography [63]. Alkalinity was determined via titration to an electrometrically determined end point of pH 4.5 [64]. Although measured as calcium carbonite alkalinity sampling results were returned as bicarbonate alkalinity, likely resulting from the assumption of neutral pH and dominance of bicarbonate, requiring that the results in the samples be multiplied by 1.219 ($CaCO_3$ mg/l to HCO_3^- mg/l) for reporting and analysis. Nitrate plus nitrite reported as N was determined via automated colorimetry [65].

Hydrologic Data

Inflows into the sites were measured in different ways. At the Jones Pit, a meter on an inlet pipe measured the pressure of water in the column, converted it to a rate in miner's inches averaged over 15-minute periods which allowed for volumes to be totalized into acre feet per day. The inflow rate was calibrated monthly via manual measurements of the canal flow rate above and below the inlet, performed by IWRB program staff using a SonTek Flowtracker 2 handheld Acoustic Doppler Velocimeter. Differences in reported inflow rates were interpolated between manual measurements. At MP29/31, inflows were measured using a weir and calibrated once by IWRB program staff during the analyzed recharge event with an Acoustic Doppler Current Profiler meter positioned on a moving boat. Measurements were within 1% of each other. At West Egin Lake, inflows were based on stage heights measured using a pressure transducer and a rating curve. Groundwater levels in monitor well networks were measured hourly using pressure transducers which were calibrated semiannually with a handheld electrical measurement tape. All transducers were gauged (vented to the surface) rendering barometric pressure correction unnecessary. Depth to water measurements were converted to water table elevation above the North American Vertical Datum of 1988 (NAVD 88). NAVD88 was calculated using either high accuracy GPS data collection or an automated process that digitally overlayed the latitude and longitude of the MP on a rectified topographic map and had an accuracy of ± 10 ft (3.05 m).

Geochemical Modeling

Geochemical modeling was conducted using The Geochemist's Workbench® Release 16 software package (GWB) [39] and the associated *thermo* thermodynamic data base (based on the Lawrence Livermore National Laboratory (LLNL) dataset, EQ3/6 data file *data0.3245r46*) and ESRPA specific cation exchange selectivity coefficients [46].

Charge balance and saturation state of surface and groundwater samples with respect to aquifer minerals were calculated using the GWB SpecE8 module. Saturation indices (SI) are defined as:

$$SI = \log\frac{Q_{i,T}}{K_{i,T}} \tag{1}$$

where $Q_{i,T}$ is the ion activity product (or quotient) and $K_{i,T}$ is the equilibrium constant for *ith* mineral dissolution reaction at temperature *T*. The quotient is the numerical product of activities of the individual species appearing in the *ith* reaction raised to the power (positive for product and negative for reactants) of the stochiometric coefficient of that species in the reaction. The sign of *SI* indicates the saturation state of the water with respect to the mineral; supersaturated (positive), equilibrium (zero), or undersaturated (negative).

Mass transfer calculations [66] that involve geochemical reactions that transfer ions between aqueous and solid phases (e.g., cation exchange, precipitation/dissolution, etc.) were carried out using the React module of GWB. The modeling domain was configured as a continuously stirred tank reactor (CSTR) in which water-rock interactions are simulated in a system where infiltrated water mixes with and ultimately displaces groundwater. The water:rock ratio is calculated using a fully saturated infiltration-site specific porosity [67]. ESRPA relevant cation ion exchange capacities [46] were used to define rock reactive properties.

Chapter 3: Results and Discussion

Study-Wide Water Composition

Water samples were analyzed for approximately 120 analytes including field parameters, nutrients (nitrate plus nitrite as N and total phosphorus), bacteria (total coliform, E. coli), major ions (alkalinity reported as bicarbonate, calcium, chloride, magnesium, potassium, sodium, sulfate), and anthropogenic contaminants such as hydrocarbons (e.g., gasoline), pesticides (e.g., atrazine), and herbicides (e.g., chlorophenoxy acids). The results for the full suite of analytes are available [24]. No anthropogenic contaminant concentrations of regulatory concern were observed.

The fifty-eight groundwater and nine surface water samples were analyzed in this investigation and their field parameters and major ion concentrations are reported in Tables 2, 5, 7. Charge imbalance errors ranged from +4.9% to -3.5% and were both positive and negative for all sites with no correlations noted. All waters were calcium-bicarbonate type except for the surface water at the combination alluvial/basalt site which was a sodium-bicarbonate type (Figure 6). The chemistry of water from the three sites were distinct from each other, reflecting the spatial variability of the ESRPA. The chemical variation between samples from individual sites was dominated by variations in anion concentrations (chiefly chloride and sulfate). All samples were oversaturated with respect to calcite, except one groundwater sample collected from the alluvial site (which had an anomalously low pH), and one groundwater sample and one surface water sample at the combination alluvial/basalt site.

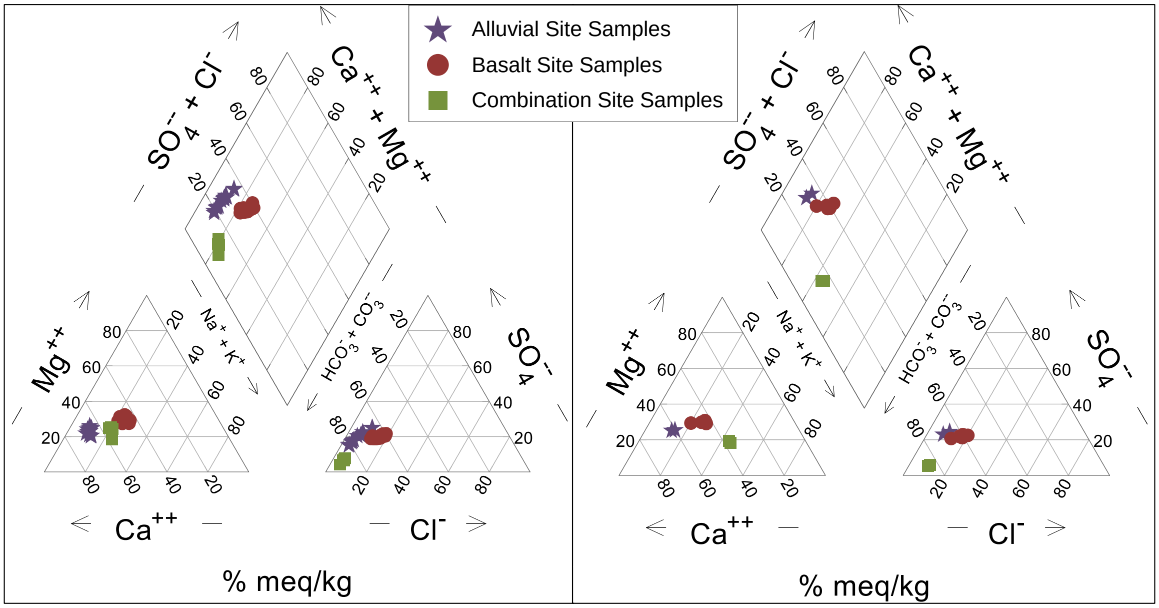

Figure 6 -- Piper diagrams of all samples analyzed. 6a) Includes all groundwater samples. 6b) Includes all surface water samples.

Hydrochemical Conceptual Model of Basin Infiltrated Water

At each site, surface water is delivered to the infiltration basin from a canal through a headgate. Surface water in the basin vertically infiltrates through the vadose zone to the saturated zone where it mounds under the basin on top of ambient groundwater, as illustrated in Figure 7. Because rates [68] of evaporation are small compared to infiltrations rate, the effects of evaporation were ignored. Ambient groundwater is defined as aquifer water that is was not chemically impacted by the infiltration event. Mixing between ambient groundwater and infiltrated surface water, if it occurs, is at the infiltrated mound-ambient groundwater interface and is referred to as aquifer mixing. In addition, the pumping of hydrologically and impacted wells in which infiltrated water and groundwater are stratified during sampling will result in the mixing of the of the two waters. This type of mixing is referred to in-well mixing. The location of the mound remains centered under the basin, but because of its presence water infiltrated later in time can displace earlier infiltrated water in all directions away from the mound at a local scale (i.e, the scale of monitor well networks), including against the regional (i.e., ESRPA) gradient. The mounding in the absence of significant mixing results in a rise in the water table with water levels increasing in surrounding wells indicating the arrival of infiltrated water. The height of the infiltration mound under the basin increases and decreases as a function of infiltration rate.

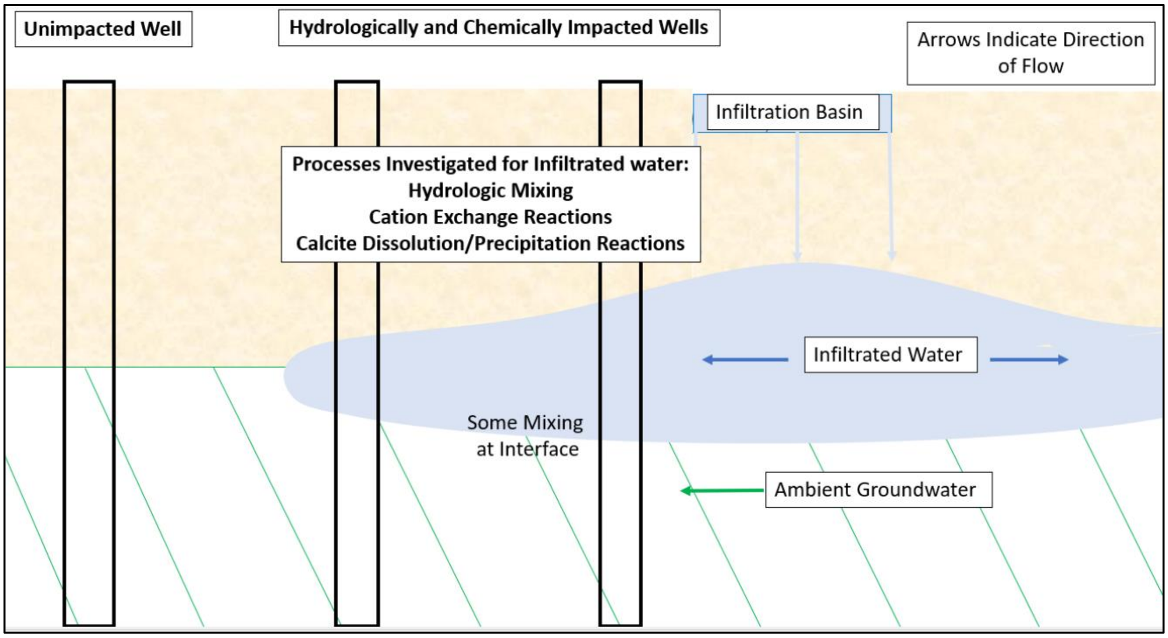

Figure 7 -- Hypothesized hydrochemical conceptual model of basin-infiltrated water and its interaction with the receiving rock matrix.

As infiltrated water moves through the aquifer matrix it may be subject to water-rock interactions including cation exchange and dissolution/precipitate reactions. Because silicate mineral reaction rates in the ESRPA are slow [45] and the reaction rates for carbonate minerals are up to 1,000 times faster [69] only carbonate mineral (i.e., calcite) dissolution/precipitation reactions are considered important in the timeframe and scale of MAR operations.

Alluvial Site – The Jones Pit

Water Quality Sample Data

Water quality results for the 18 samples collected during the fall 2019 Jones Pit MAR operation are shown in Table 2. This operation was chosen for analysis because it represents the largest infiltration event. In addition, the water quality results (Figure 6) are similar to the four other MAR operations at the site. The fall 2019 infiltration event began on 8/23/2019. Groundwater samples collected before this date (8/21/2019) represent ambient conditions. Samples from each well and from the Headgate were collected on 9/27/2019 and 10/31/2019. A fourth sample was collected from all wells on 11/7/2019, seven days after the infiltration event ended.

Table 2 – Water quality results from the alluvial site – The Jones Pit, calcite SI calculated by [39].

Sample Location	Date	Electrical conductivity	pH	Temperature	O_2 (aq)	Ca^{2+}	Na^+	Mg^{2+}	K^+	Cl^-	SO_4^{2-}	HCO_3^-	NO_3^- + NO_2^- as N	Charge imbalance error	Sodium Adsorption Ratio	Calcite
		uS/cm		C	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l			SI
C. Arave	8/21/2019	358	7.72	15.7	8.00	60	9.1	14.0	2.4	9.07	45.2	210.9	1.100	0.77%	0.27	0.35
C. Arave	9/27/2019	349	7.78	11.7	7.85	62	9.2	14.0	2.4	7.87	40.2	230.4	1.700	-0.23%	0.27	0.41
C. Arave	10/31/2019	325	7.37	8.4	9.16	52	8.8	12.0	2.2	10.20	40.7	181.6	0.410	2.81%	0.29	-0.24
C. Arave	11/7/2019	323	7.76	11.1	8.77	52	8.5	12.0	2.2	10.20	40.3	181.6	0.360	0.20%	0.28	0.21
J. Stucki	8/21/2019	378	7.62	15.9		66	9.4	16.0	2.6	8.20	40.8	245.0	2.000	1.67%	0.27	0.35
J. Stucki	9/27/2019	403	7.74	13.9	7.44	69	9.5	15.0	2.5	7.33	37.6	252.3	2.600	1.48%	0.27	0.47
J. Stucki	10/31/2019	327	7.84	7.7	9.10	53	8.6	12.0	2.2	10.50	40.6	179.2	0.320	1.00%	0.28	0.25
J. Stucki	11/7/2019	325	7.73	11.2	12.55	52	8.3	11.0	2.1	11.40	41.8	175.5	0.190	-0.47%	0.27	0.17
D Stucki	8/21/2019	360	7.70	18.2		60	9.6	13.0	2.0	7.88	39.1	213.3	0.450	1.54%	0.29	0.37
D Stucki	9/27/2019	367	7.82	12.5	5.31	64	9.7	13.0	1.9	6.91	35.0	242.6	0.480	-0.56%	0.29	0.49
D Stucki	10/31/2019	318	7.84	7.1	7.05	53	8.9	11.0	1.8	11.10	41.2	175.5	0.084	0.43%	0.29	0.23
D Stucki	11/7/2019	325	7.86	10.6	10.79	52	8.8	11.0	1.8	11.70	42.0	175.5	0.076	-0.91%	0.29	0.29
IDWRMW	8/21/2019	362	7.80	18.0		68	10.0	13.0	1.8	7.91	40.1	229.2	2.100	2.22%	0.29	0.55
IDWRMW	9/27/2019	289	8.00	11.5	6.16	50	9.0	9.3	1.6	9.08	38.9	156.0	0.120	1.62%	0.31	0.39
IDWRMW	10/31/2019	334	7.85	10.6	8.87	55	11.0	10.0	1.8	15.50	49.5	163.3	0.010	0.37%	0.36	0.27
IDWRMW	11/7/2019	334	7.93	11.9	9.05	54	11.0	10.0	1.7	15.40	49.2	164.6	0.010	-0.74%	0.36	0.37
Headgate	9/27/2019	299	8.50	12.0	6.67	45	10.0	11.0	1.7	10.70	40.5	156.0	0.009	-1.67%	0.35	0.84
Headgate	10/31/2019	367	8.57	4.0	9.90	55	14.0	14.0	2.2	17.10	53.7	182.8	0.009	-0.98%	0.44	0.93

Hydrogeologic Investigation

Figure 8 shows the aquifer water table elevation measured in the IDWRMW, inflow volumes of infiltrating water into the basin, and an overview of the Anderson Canal operations. The MAR operation occurred as two events, the first and smaller (approximately 10 AF [12,335 m^3] per day) from 8/24/2019 to 8/27/2019 and the second larger (approximately 25 AF (38,000 m^3] per day) from 9/8/2019 to 10/31/2019 which together infiltrated 1,380 AF (1.7 million m^3) of surface water. The Anderson Canal is located approximately 1,100 ft (335 m) south of the Jones Pit and diverted for irrigation operations 500 AF (616,740 m^3) per day or more from the Snake River during the month of August [70] (High Canal Flows). On 9/1/2019 the canal began a near linear reduction in its diversion rate that lasted until 9/24/2019 (Declining Canal Flows), when it stabilized at approximately 100 AF (123,350 m^3) per day (Low Canal Flows) until concluding irrigation operations on 10/9/2019 (Figure 8).

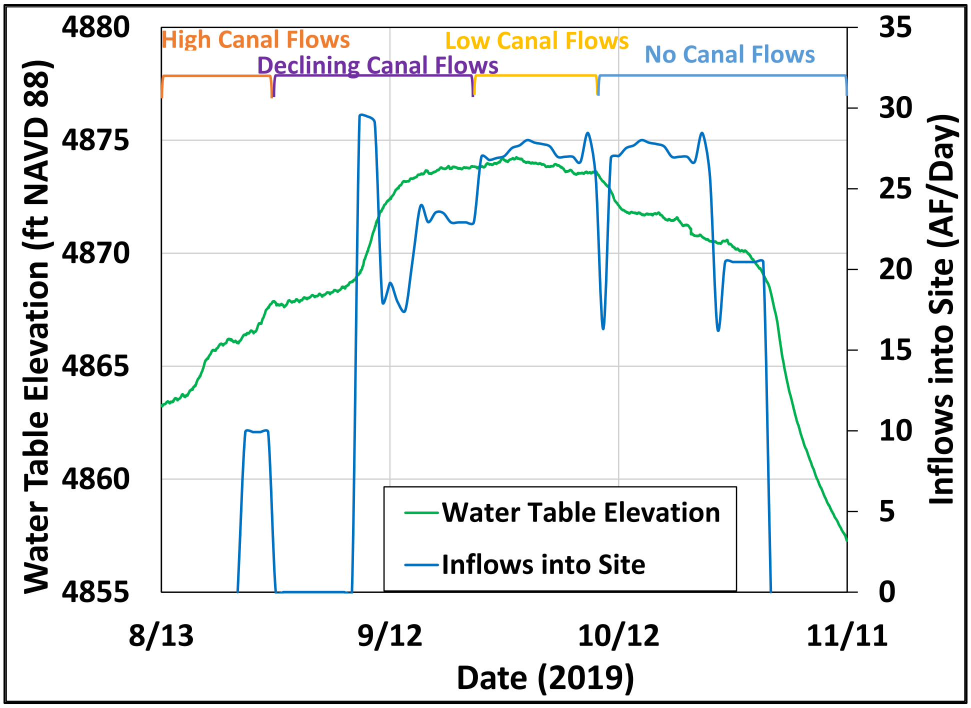

Figure 8 -- Inflows into the alluvial site -- Jones Pit, water levels at the IDWRMW, and a general description of nearby canal operations vs time.

Groundwater levels (Figure 8) reflect the combined effect of MAR operations and variable incidental recharge from the Anderson Canal. The rise in water table elevation prior to the larger MAR event corresponds to high canal flows. The primary infiltration operation began on 9/8/2019 near the start of declining canal flows and resulted in a six day rise in groundwater elevation that began on the same day as the larger infiltration operation and therefore was probably not the arrival of infiltrated water at the location. Following this rise, the groundwater level remained relatively constant until the flow in the Anderson Canal was stopped, at which time the groundwater level declined even though the infiltration rate remained constant. When MAR operations were completed on 10/31/2019 the groundwater levels rapidly decreased.

Sample Source Determination and Hydrologic Mixing Analysis

The chloride, sulfate, and nitrate plus nitrite concentrations for groundwater samples collected on 8/21/2019 were distinct from the headgate samples collected on 9/27/2019 and 10/31/2019 (Table 2) suggesting that these anions could be used as tracers to assess mixing of infiltrated surface water(s) and ambient groundwater. Chloride and sulfate are naturally present in water due to the dissolution of ocean evaporates at the start of the hydrologic cycle (e.g., NaCl [halite] and $CaSO_4$ [anhydrite]) and can also be from anthropogenic sources (i.e., KCl and $CaSO_4 \cdot 2H_2O$ [agricultural fertilizers]) [47]. Because of its low affinity for anion exchange [71] chloride is commonly used as a conservative (i.e., non-reactive) aqueous tracer in groundwater studies [72, 73 74] on the temporal scale of weeks relevant to MAR events. In addition, under oxidizing conditions and low concentrations characteristic of the ESRPA, sulfate can also serve as a conservative aqueous tracer as demonstrated by its strong correlation (not shown) with chloride concentration. Because chloride and sulfate are correlated, the sulfate-to-chloride ratio (ratio) was utilized to estimate the extent of mixing between ambient groundwater and infiltrated surface water. Nitrate across the ESRP is primarily sourced from inorganic fertilizer applied to agricultural fields [47] and is also conservative on the timescales of MAR events.

Examining the sulfate-to-chloride ratios and nitrate concentrations of all groundwater and headgate water samples (Figure 9) shows that the groundwater samples fall into two groups, those interpreted as ambient groundwater (all samples from 8/21/2019 and samples from the C. Arave, D. Stucki, and D. Stucki wells [more distant wells] from 9/27/2019) with relatively high ratios and nitrate concentrations, and those interpreted as a mixture of infiltrated water and ambient groundwater (IDWRMW [closest well] from 9/27 and all samples from 10/31 and 11/7/2019) with ratios and nitrate concentrations intermediate between ambient groundwater and headgate water. The groundwater level was declining when chemically impacted samples were collected from the IDWRMW (Figure 8) indicating that water table decreases do not necessarily demonstrate the departure of infiltrated water.

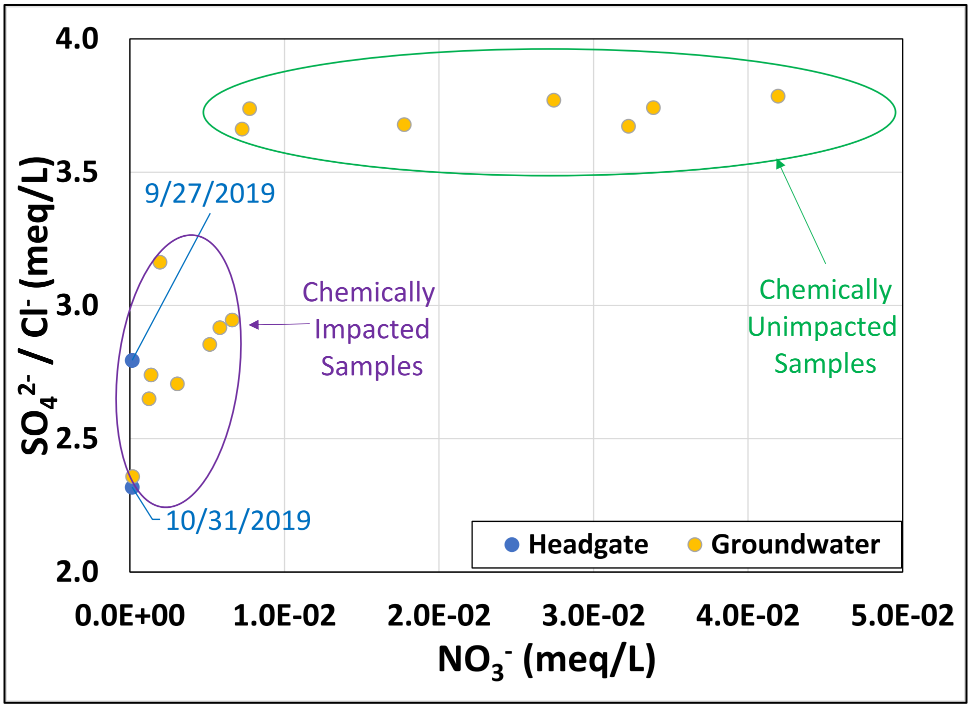

Figure 9 -- Sulfate-to-chloride ratios vs nitrate concentrations in all samples at the alluvial site -- Jones Pit.

Although there are two sources of water, the composition of the headgate varied as function of time (Figure 9). In addition to the 9/27/2019 and 10/31/2019 headgate water quality data, weekly SC measurements between 9/12/2019 and 11/7/2019 (Figure 10, Appendix E) suggest that the surface water composition varied systematically and continuously. This trend may reflect a decreasing fraction of water released from Palisades Reservoir during the MAR event and an increasing fraction of relatively stable base flows resulting in total decreased flows at the Heise gauge [70] (Figure 10). Regardless of the reason for the trend, surface water composition at time between sampling event can be treated as a mixture of the 9/27/2019 and 10/31/2019 headgate water.

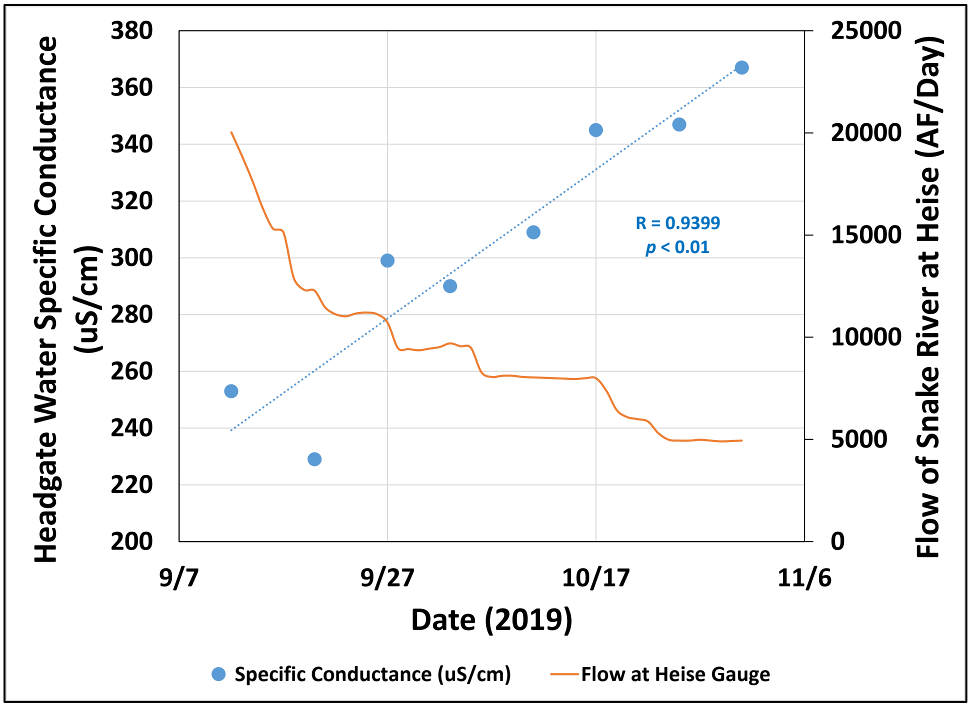

Figure 10 -- Specific conductance at the Headgate and flow of the Snake River at the Heise gauge vs date at the alluvial site – Jones Pit.

To estimate the fractions of ambient groundwater and infiltrated headgate water in the mixed groundwater sample, a three-end member mixing model (the ambient groundwater composition of each well [outer well samples from 9/27/2019 and IDWRMW sample from 8/21/2019], and the 9/27/2019 and 10/31/2019 headgate compositions) was used. The three-endmember mixing equation is

$$[X_i]_{mixed} = f_1[X_i]_1 + f_2[X_i]_2 + f_3[X_i]_3 \quad (2)$$

Where

$$f_3 = 1 - f_1 - f_2 \quad (3)$$

and $[X_i]_{mixed}$ is the concentration of the *ith* conserved ion in the mixed groundwater, f_1, f_2, and f_3 are the mixing fraction of the indexed end members, and $[X_i]_1$, $[X_i]_2$, and $[X_i]_3$ are the concentrations of *ith* conserved ion in the indexed end member resulting in three mixing equations, one each for sulfate, chloride, and nitrate. The Solver function of Microsoft Excel [75] was used to estimate f_1 and f_2 by minimizing the sum of squares of the relative difference between the measure and calculated sample concentrations.

$$\sum \left(\frac{[X_i]_{measured} - [X_i]_{calculated}}{[X_i]_{measured}}\right)^2 \quad (4)$$

The estimated mixing fractions are given in Table 3. As expected, a decrease in the fraction of ambient groundwater with increased duration of the infiltration event was observed for all wells. Complete displacement of ambient groundwater by infiltrated water is inferred in the 55 ft (17 m) regionally downgradient (downgradient) IDWRMW on 10/31/2019 and 11/7/2019 and indicates that the increased water table elevation beginning on the day of the infiltration operation might evidence the growth of a mound of infiltrated water under the basin which transmitted ambient groundwater away from it. The limited mixing of infiltrated water with ambient groundwater observed in the location on 9/27/2019 is consistent with a stratified aquifer with infiltrated water "sitting" atop the ambient groundwater and mixing of the two waters occurring in the well during pumping.

Table 3 – The estimated percentage of water from ambient groundwater (sample collected from each location on 9/27/2019 [8/21/2019 IDWRMW]), water entering the basin on 9/27/2019 (H 9/27), and water entering the basin on 10/31/2019 (H 10/31) for each groundwater sample collected on 9/27/2019, 10/31/2019, and 11/7/2019 at the alluvial site – Jones Pit.

	IDWRMW			D. Stucki		
	H 9/27	H 10/31	Ambient	H 9/27	H 10/31	Ambient
9/27/2019	94.7%	0.0%	5.3%	0.0%	0.0%	100.0%
10/31/2019	24.9%	75.0%	0.0%	68.4%	15.7%	15.9%
11/7/2019	26.5%	73.5%	0.0%	61.7%	24.1%	14.2%
	J. Stucki			C. Arave		
	H 9/27	H 10/31	Ambient	H 9/27	H 10/31	Ambient
9/27/2019	0.0%	0.0%	100.0%	0.0%	0.0%	100.0%
10/31/2019	84.8%	3.2%	12.0%	73.6%	2.7%	23.7%
11/7/2019	78.3%	14.7%	7.0%	77.9%	1.4%	20.8%

No evidence of infiltrated water was observed in the more distant wells on 9/27/2019 (Table 3). On 10/31/2019, the D. Stucki well, which is downgradient and farthest (620 ft [190m]) from the basin, was 16% ambient groundwater compared to 12% for the closer (200 ft [61 m]) and the slightly orthogonal J. Stucki well. The cross-gradient C. Arave well is located 100 ft (30 m) from the basin and had the largest percentage of ambient water remaining in its sample on 10/31/2019. The chemical presence of infiltrated water at cross-gradient wells further suggests the presence of a mound under the basin that allows infiltrated water to move across the regional gradient. The results also indicate that local heterogeneities in the flow field play a larger role in the movement of water during the infiltration event than simple distance from the basin. By 11/7/2019, the percentage of ambient groundwater in all of the more distant wells had decreased compared to 10/31/2019, consistent with the infiltrated water moving through the monitoring wells between sampling events and seven days after the infiltration event concluded. In addition, and as expected, the relative abundance of 10/31/2019 compared to 9/27/2019 headgate water in the D. Stucki and J. Stucki wells increased as newer headgate water displaced older headgate water. At the C. Arave the opposite was observed, although for both the 10/31/2019 and 11/7/2019 samples the fraction of 10/31/2019 headgate water is estimated to be less than 3%. These results from wells that are cased to approximately the same depth near the bottom of the alluvium (Appendix A) indicate that the infiltrated water packet may have been elongated and moved faster in the direction of the regional gradient than orthogonal to it, and that ambient water is displaced from the top-down.

Travel times to the monitoring wells can be bounded by the mixing fractions estimates. The larger infiltration event began on 9/8/2019 and by 9/27/2019 95% of the water at IDWRMW was estimated to be headgate water suggesting a travel time of significantly less than 19 days. No infiltrated water was observed in the more distant wells on 9/27/2019 but was on 10/31/2019 suggesting travel times of between 20 and 53 days, with relative travel times being J Stucki ≤ D Stucki < C Arave.

Geochemical Investigation

In addition to mixing, infiltrated waters may undergo water-rock interactions with the aquifer matrix through cation exchange reactions (Equation 5) and/or dissolution-precipitation of carbonate minerals (i.e., calcite, Equation 6).

$$>X{:}Na^{+} + 0.5Ca^{2+} \leftrightarrow Na^{+} + >X{:}Ca^{2+}{}_{0.5} \quad (5)$$

$$CaCO_3 + CO_2 + H_2O \leftrightarrow Ca^{2+} + 2HCO_3^{-} \quad (6)$$

These potential reactions were assessed by using the mixing fractions from Table 3 and the end member water compositions from Table 2 to calculate the devised compositions of mixed waters in the absence of any other processes. The devised compositions were compared to the measured compositions of the corresponding groundwater sample. The difference between the devised and measured compositions are referred to as $[\text{Species}]_{\text{excess}}$ and are shown in Table 4. Positive and negative values of $[\text{Species}]_{\text{excess}}$ indicate the addition or removal of a species from the groundwater by water-rock interactions, respectively. The estimated uncertainties (standard deviation) in these calculations are 0.09, 0.09, 0.04, 0.01, and 0.13 meq/L for calcium, magnesium, sodium, potassium, and bicarbonate, respectively, as described in Appendix F.

Table 4 – $[Species]_{Excess}$ ion concentrations in chemically impacted samples at the alluvial site -- Jones Pit.

		$[Species]_{Excess}$ Ion Concentrations					
		IDWRMW			C Arave		
		9/27/2019	10/31/2019	11/7/2019	9/27/2019	10/31/2019	11/7/2019
Ca^{2+}	meq/L	0.19	0.12	0.08		0.14	0.17
Mg^{2+}	meq/L	-0.15	-0.27	-0.26		0.02	0.03
Na^{+}	meq/L	-0.04	-0.09	-0.08		-0.05	-0.06
K^{+}	meq/L	0.00	-0.01	-0.01		0.01	0.01
$\sum Cation_{excess}$	meq/L	-0.01	-0.24	-0.28		0.11	0.14
HCO_3^-	meq/L	0.00	-0.09	-0.10		0.44	0.27
		J Stucki			D Stucki		
Ca^{2+}	meq/L		0.24	0.19		0.17	0.09
Mg^{2+}	meq/L		0.03	-0.06		-0.06	-0.08
Na^{+}	meq/L		-0.06	-0.10		-0.07	-0.09
K^{+}	meq/L		0.01	0.01		0.00	0.00
$\sum Cation_{excess}$	meq/L		0.22	0.04		0.03	-0.08
HCO_3^-	meq/L		0.27	0.28		0.12	0.10

As may be seen in Table 4 many of the $[Species]_{excess}$ values are of similar or smaller magnitude than their respective uncertainties (especially at the two-standard deviations level) that make it difficult to draw definitive conclusions *for individual sampling locations and dates*. This uncertainty is highlighted by the differences between $\sum \mathit{Cation}_{excess}$ and HCO_3^- $[Species]_{Excess}$ values which because of charge balance requirements should be the same ($[Species]_{Excess}$ values for Cl^- and SO_4^{2-} are essentially zero as they were used to calculate the mixing fractions). However, by averaging across all locations and dates, $[Species]_{Excess}$ values of 0.15, -0.09, -0.07, 0.00 and 0.14 meq/L for calcium, magnesium, sodium, potassium, and bicarbonate, respectively are calculated and can be used to infer specific geochemical processes. The almost equal milliequivalent increase in calcium and decrease in combined magnesium and sodium is consistent with cation exchange reactions in which magnesium and sodium in the infiltrated water displace calcium from aquifer sediments. Alternatively, the equal milliequivalent increase in calcium and bicarbonate is consistent with the dissolution of calcite. However, because all groundwater samples are oversaturated with respect to calcite (Table 2, C Arave 10/31/2019 being an outlier) dissolution of calcite is highly unlikely. Cation exchange with exchange site preference of $Na^+ \approx Mg^{2+} > Ca^{2+}$ was the only geochemical process that can be confirmed during the MAR operation.

To further assess the geochemical interactions a mass transfer model using the GWB React module was developed that accounted for coupled cation exchange and calcite precipitation. Conceptually ambient groundwater, represented by the average composition of all 8/24/2019 and 9/27/2019 (except IDWRMW) groundwater samples, in a fixed volume of pore space was displaced by four pore volumes of infiltrating 10/31/2019 Headgate water resulting in less than 1% of ambient water remaining at the end of the simulation. The volume (and mass) of aquifer sediments were estimated using a porosity of 0.413 (the average of ESRPA sedimentary interbeds [67]) and a sediment grain density of 2.65 g/cm^3 resulting in a water:rock ratio of 1:3.8. A cation exchange capacity (CEC) of 0.21 meq/g$_{rock}$ and Gapon exchange coefficients measured for ESRP sediments [46] were used to describe equilibrium cation exchange. Calcite precipitation was modeled using a mixed kinetic-equilibrium approach. On average ESRPA groundwaters are oversaturated with respect to calcite (Table 1, SI of approximately 0.4), however, widespread rapid calcite precipitation is not observed suggesting that at this level of oversaturation precipitation is very slow in comparison to the duration of MAR operations. To account for this in the model calcite was only allowed to precipitate if its SI value was greater than 0.4. Six different reaction scenarios were considered:

1. Mixing (no cation exchange or calcite precipitation),
2. Mixing and precipitation (no cation exchange),
3. Mixing and cation exchange (no calcite precipitation),
4. Mixing, cation exchange, and calcite precipitation,
5. Mixing and cation exchange (no calcite precipitation) with a 10x increase in the CEC (equivalent to a volume of water seeing more aquifer sediments),
6. Mixing, cation exchange, and calcite precipitation with a 10x increase in the CEC.

Simulation results (Appendix G) are presented in Figure 11 in terms of the sodium adsorption ratio (SAR) [76] and the sulfate-to-chloride ratio. Also shown in Figure 11 are values for Jones Pit waters. SAR is a derived parameter to assess irrigation water quality and is defined as:

$$SAR = \frac{[Na^{+}]}{\sqrt{\frac{[Ca^{2+}]+[Mg^{2+}]}{2}}} \tag{7}$$

where concentrations are in meq/L. Because SAR includes contributions from the major cations, it is a simplified proxy for assessing water-rock interaction.

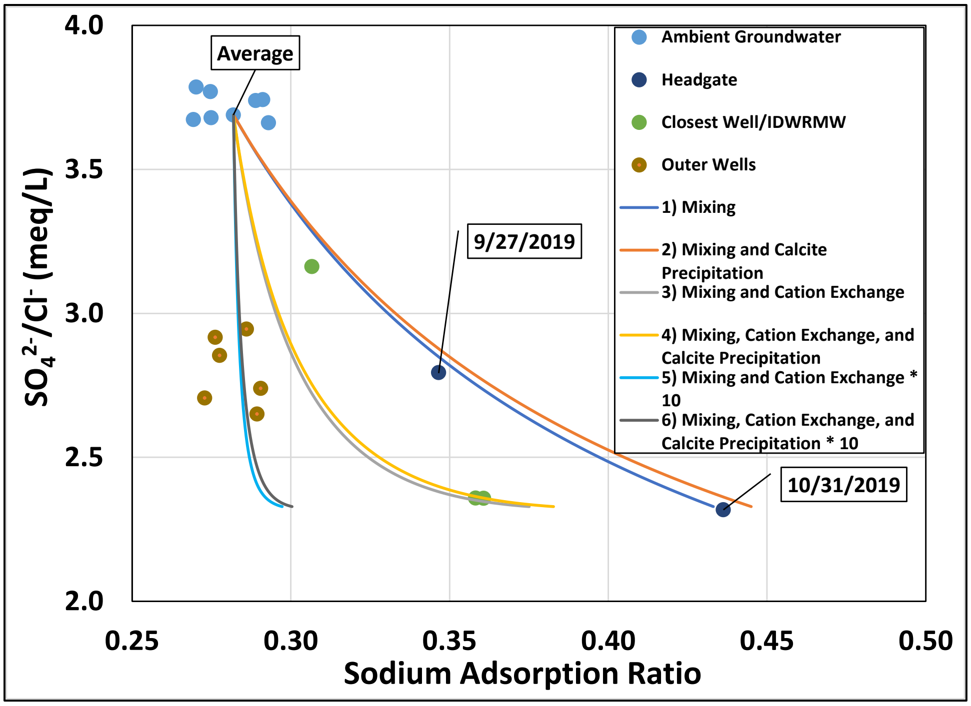

Figure 11 – A graphical depiction of modeling results for various scenarios with mixing functions (sulfate-to-chloride ratios) vs sodium adsorption ratio (SAR) functions at the alluvial site -- Jones Pit.

The sulfate-to-chloride ratios in Figure 11 demonstrate that mixing (Scenario 1) is predicted to play a primary role in the evolution of the infiltrated water along with cation exchange (Scenarios 3 and 5), which dominates the changes in SAR values. The precipitation of calcite (Scenarios 2, 4, and 6) is predicted to have minimal effect on SAR values. Two samples from the IDWRMW plot close to the Scenario 3 curve indicating that cation exchange might have impacted samples collected at this well and they also plot in the vicinity of the Scenario 4 curve suggesting that calcite precipitation might also have occurred but its impact on SAR was nondetectable. The SAR of samples from the outer wells plot near the Scenarios 5 and 6 curves with less scatter than ambient groundwater indicating that cation exchange reactions might have continued to impact the infiltrated water as it interacted with additional sediments in the longer flow path to the outer wells. Again, the precipitation of calcite is predicted to have minimal to no impact on the SAR values for these wells.

Simulated changes in aquifer sediments for Scenario 6 (mixing, cation exchange, and calcite precipitation) are presented in Figure 12 and given in Appendix H. The figure shows that as infiltrated water displaces ambient groundwater it promotes cation exchange in which of sodium and magnesium in the mixed groundwater displace calcium from cation exchange sites in equal equivalent concentrations, a result that is consistent with the direct observations based on $[\text{Species}]_{\text{excess}}$ calculations presented earlier. In addition, a majority (70 to 80%) of the desorbed calcium is precipitated as calcite rather than remaining in solution. This explains why calcite precipitation, if it is occurring, cannot be concluded solely from groundwater measurements. Overall, the coupled cation exchange – calcite precipitation reaction is given by

$$Na^{+} + 0.5Mg^{2+} + 2{>}X{:}Ca^{2+}_{0.5} + 2HCO_3^{-} \rightarrow CaCO_3 + H_2O + CO_2 + {>}X{:}Na^{+} + {>}X{:}Mg^{+}_{0.5} \quad (8)$$

and supports the exchange site preference of $Na^{+} \approx Mg^{2+} > Ca^{2+}$ inferred from Table 4.

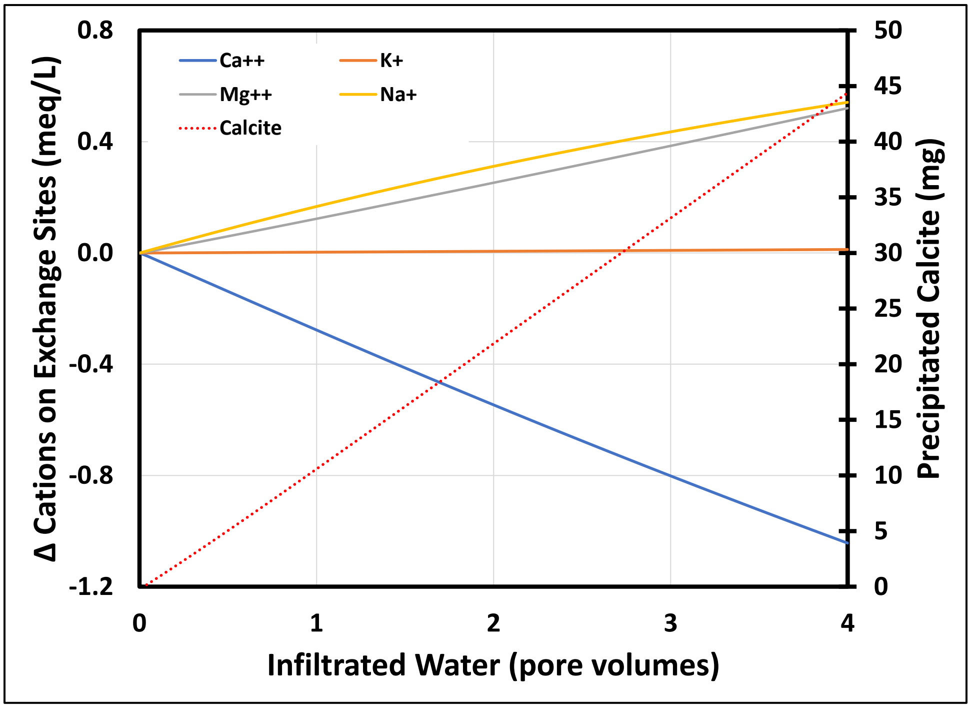

Figure 12 – Modeling predictions for the change in cation concentrations on exchange sites and calcite precipitated vs infiltrated water in the system at the alluvial site -- Jones Pit.

ESRP sediments have cation selectivity of $Ca^{2+} > Mg^{2+} > K^{+} > Na^{+}$ [44, 45] probably because bonds formed with divalent cations are stronger than those formed with monovalent cations. However, reverse cation exchange [77] occurs when monovalent sodium is removed from water by a stochiometric exchange of divalent calcium and/or magnesium from the aquifer matrix despite the generally higher affinities of exchange sites for the latter. Reverse cation change can occur because, in addition to exchange site affinity, cation exchange processes are influenced by the distribution of cations available for exchange and therefore are related to the activity of cations in solution. As the activity of sodium, potassium, and/or magnesium increases relative to calcium in water, the affinity of exchange sites for the monovalent cation or magnesium can exceed the affinity for calcium [44] promoting reverse cation exchange.

Synthesis and Conceptual Model

Water levels in the vicinity of the Jones Pit basin were controlled by the nearby Anderson Canal and the MAR event in the basin. Two of the three samples from the closest well were 100% infiltrated water and all hydrologic mixing observed was inferred to have occurred in-well. All wells, located between 100 ft (30 m) cross gradient and 620 ft (190 m) downgradient, were impacted by infiltrated water suggesting that these are appropriate distances for chemical monitor wells in alluvium. However, local heterogeneities in the flow field played a larger role in the movement of infiltrated water during the MAR event than simple distance from the basin. Water level rises did not necessarily indicate the arrival of infiltrated water but might have evidenced the growth of a mound of infiltrated water under the basin that transmitted ambient groundwater away from it. In addition, water table declines did not indicate the departure of infiltrated water. Reverse cation exchange was observed and was modeled to be the primary process impacting infiltrated water and predicted to continue with increased interactions with sediments. The precipitation of calcite was not found to be an important process influencing water composition. The findings are synthesized in a reinterpretation of Figure 7 and presented in Figure 13. Figure 13 is not to scale but is best suited for the 10/31/2019 sampling date when MAR was still occurring and a mound of infiltrated water was present under the basin.

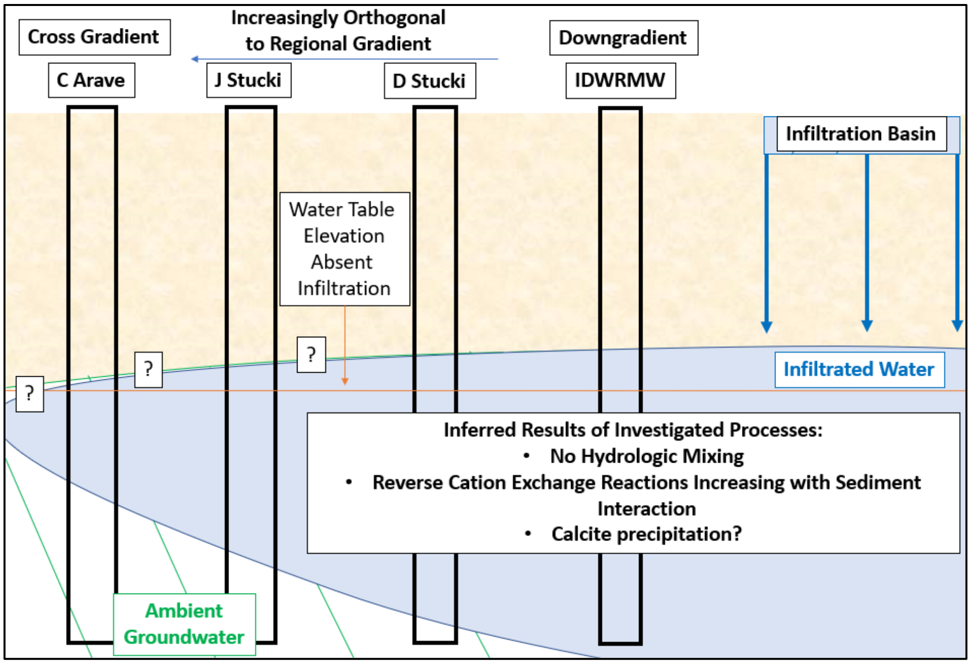

Figure 13 – A conceptual model of the alluvial site -- Jones Pit that is not to scale but is most applicable to the 10/31/2019 sampling date.

Basalt Site – MP29/31

Water Quality Sample Data

Water quality results for 41 samples-collected at the MP29/31 site between 8/24/2020 and 4/8/2021 (sampling season) in association with the two events are shown in Table 6. Field parameters for the six surface water samples were not measured as part of sampling and instead temporally relevant measurements at USGS gauge number 13093383, Snake River at Pigeon Cove near Twin Falls, Idaho located 22.5 miles (36.25 km) southwest of the site are provided. The fall of 2020 through spring of 2021 operation was chosen for analysis because it was the most recent operation at the commencement of this investigation. In addition, water quality data from the seven other MP29/31 MAR operations were similar to those shown Figure 6. There were two primary recharge events, one at MP31 occurring from 9/8/2020 through 9/28/2020 and a second in both basins from 11/6/2020 through 3/18/2021.

Table 5 -- Water quality results from the basalt site – MP29/31, calcite SI calculated by [39].

Sample Location	Date	Electrical Conductivity	pH	Temper-ature	O_2(aq)	Ca^{2+}	Na^+	Mg^{2+}	K^+	Cl^-	SO_4^{2-}	HCO_3^-	NO_3^- + NO_2^- as N	Charge Imbalance Error	Sodium Adsorption Ratio	Cal-cite
		uS/cm		C	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l			SI
East Well	8/24/2020	435.4	7.96	9.3	8.1	40	24	15	4.1	27.3	40.1	171.9	1.05	0.03%	0.82	0.25
East Well	9/17/2020	410.9	7.88	10.4	5.9	40	18	14	3.8	18.5	38.7	164.6	0.432	0.94%	0.62	0.17
East Well	10/7/2020	428.9	7.85	13	5.9	41	20	15	4.2	19.8	38.8	170.7	0.519	2.08%	0.68	0.20
East Well	1/6/2021	541	8.3	8.5	9.8	47	27	18	6.0	32.8	53.4	209.7	2.01	-3.52%	0.85	0.71
East Well	2/9/2021	540	8.24	5.6	9.1	47	29	19	6.6	33.9	52.8	208.4	1.56	-1.38%	0.90	0.61
East Well	3/11/2021	447.9	8.14	5.3	7.7	48	29	19	6.5	34.6	51.3	199.9	1.72	0.73%	0.90	0.50
East Well	4/8/2021	444.8	7.82	6.2	8.3	47	32	18		35.0	53.3	196.3	1.6	-0.04%	1.01	0.17
Central Well	8/24/2020					41	24	15	4.2	26.4	40.6	176.8	0.963	-0.83%	0.82	
Central Well	9/17/2020	437.2	7.81	9.7	7	43	20	17	4.2	20.1	40.3	175.5	0.895	3.90%	0.65	0.14
Central Well	10/7/2020	438	7.88	10.5	6.1	42	20	15	4.3	19.8	38.6	180.4	9.48	-0.94%	0.67	0.23
Central Well	1/6/2021	540	7.84	10.9	7.9	47	27	18	5.3	32.6	53.8	208.4	2.08	-2.46%	0.85	0.28
Central Well	2/9/2021	546	8.01	8.7	8.9	48	28	19	5.5	33.8	53.2	210.9	1.63	-1.60%	0.87	0.44
Central Well	3/11/2021	445.2	7.94	7.6	8.8	49	29	19	5.7	34.0	50.7	202.4	1.54	1.36%	0.89	0.34
Central Well	4/8/2021	433.6	7.86	7.9	6.2	46	29	18	5.4	33.9	51.7	188.9	1.55	1.22%	0.92	0.21
West Well	8/24/2020	435.6	7.96	14.5	7.7	40	21	17	4.2	22.9	40.7	185.3	0.883	-0.84%	0.70	0.35
West Well	9/17/2020	434.8	7.92	14.6	8.8	40	20	16	4.1	22.3	39.2	173.1	0.839	0.66%	0.68	0.29
West Well	10/7/2020	432.8	8	14.5	8.9	39	21	16	4.2	21.5	37.8	173.1	0.829	1.04%	0.72	0.36
West Well	1/6/2021	432.8	7.97	14.1	8.2	38	20	16	4.2	23.2	40.7	178	0.916	-2.31%	0.69	0.32
West Well	2/9/2021	434.4	7.99	14.2	8.4	37	21	16	4.3	23.0	39.6	178	0.87	-2.06%	0.73	0.33

Table 5 -- Water quality results from the basalt site – MP29/31 continued.

Sample Location	Date	Electrical Conductivity	pH	Temperature	O_2(aq)	Ca^{2+}	Na^{+}	Mg^{2+}	K^{+}	Cl^{-}	SO_4^{2-}	HCO_3^{-}	NO_3^{-} + NO_2^{-} as N	Charge Imbalance Error	Sodium Adsorption Ratio	Calcite
		uS/cm		C	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l			SI
West Well	3/11/2021	362.8	7.89	14.1	7.9	39	21	17	4.3	22.4	38.8	178	0.839	0.84%	0.71	0.25
West Well	4/8/2021	358.6	7.85	14.4	8.7	39	21	16	4.2	22.9	39.8	174.3	0.836	0.23%	0.72	0.21
MW1	10/7/2020	432.2	8.03	14.3	8.6	41	22	14	3.6	23.4	37.6	169.4	0.826	0.65%	0.76	0.40
MW1	11/16/2020	470.7	8.3	13.7	8.9	45	27	17	4.0	34.3	52.2	185.3	1.43	-2.18%	0.87	0.72
MW1	12/8/2020	531	8.15	11.2	9	46	30	18	4.8	32.8	53.7	197.5	1.51	-0.79%	0.95	0.57
MW1	1/6/2021	555	7.99	7.3	7.8	47	31	19	5.4	35.9	56	209.7	1.93	-1.73%	0.96	0.38
MW1	2/9/2021	560	8	8	8.6	48	31	19	5.0	35.7	54.2	212.1	1.88	-1.34%	0.96	0.42
MW1	3/11/2021	446.8	8.08	7.4	9	49	31	18	5.2	36.6	51.7	198.7	1.58	0.60%	0.96	0.47
MW1	4/8/2021	431	7.91	7.8	7.4	46	30	17	5.0	34.7	51.5	191.4	1.5	-0.01%	0.96	0.27
MW2	10/7/2020	382.4	8.1	13.9	9.1	36	18	13	3.4	19.3	33.6	149.9	0.58	0.69%	0.65	0.37
MW2	11/16/2020	381.5	8.27	13.8	8.7	34	18	13	3.4	19.6	34	152.4	0.617	-1.90%	0.67	0.52
MW2	12/8/2020	377.8	8.08	13.7	9.1	35	18	14	3.4	20.0	34.9	154.8	0.644	-0.57%	0.65	0.34
MW2	1/6/2021	378.1	8.12	13.6	9.2	34	17	13	3.3	20.4	35.6	152.4	0.664	-3.00%	0.63	0.36
MW2	2/9/2021	378.8	8.13	13.7	8.9	34	18	13	3.4	20.4	34.5	154.8	0.642	-2.58%	0.67	0.38
MW2	3/11/2021	314.8	8.02	13.7	8.7	35	18	14	3.4	20.0	35	154.8	0.62	-0.45%	0.65	0.28
MW2	4/8/2021	315	8	13.8	9	36	18	14	3.4	20.0	34.8	153.6	0.61	0.61%	0.64	0.27
Headgate	9/17/2020	614	8.3	13.5	10.4	43	18	15	3.4	18.1	38	157.3	0.611	4.49%	0.60	0.65
Headgate	11/16/2020	656	8.3	10.1	11.5	42	26	18	6.3	27.8	49.1	178	0.96	1.35%	0.85	0.63
Headgate	12/8/2020	692	8.3	7	12.1	45	28	19	7.0	31.4	54	181.6	1.32	2.03%	0.88	0.62
Headgate	1/6/2021	673	8.5	8	11.8	48	27	19	6.6	33.0	53.8	197.5	1.78	-0.62%	0.83	0.88
Headgate	2/9/2021	670	8.6	8.1	12.4	46	29	19	7.8	33.8	52.1	192.6	1.48	0.31%	0.91	0.95
Headgate	3/11/2021	658	8.7	11.3	12.9	47	30	19	8.4	34.9	51.4	169.4	1.43	4.89%	0.93	1.05

Sample Source Determination

The sulfate-to-chloride ratios for all samples over the duration of the sampling season (Figure 14) show that groundwater samples from the West Well and MW2 (outer wells) are similar, groundwater samples from the Central Well and East Wells (inner wells) are similar but different from the outer wells, and groundwater samples from cross gradient MW1 are different from both. These three groups will be discussed individually.

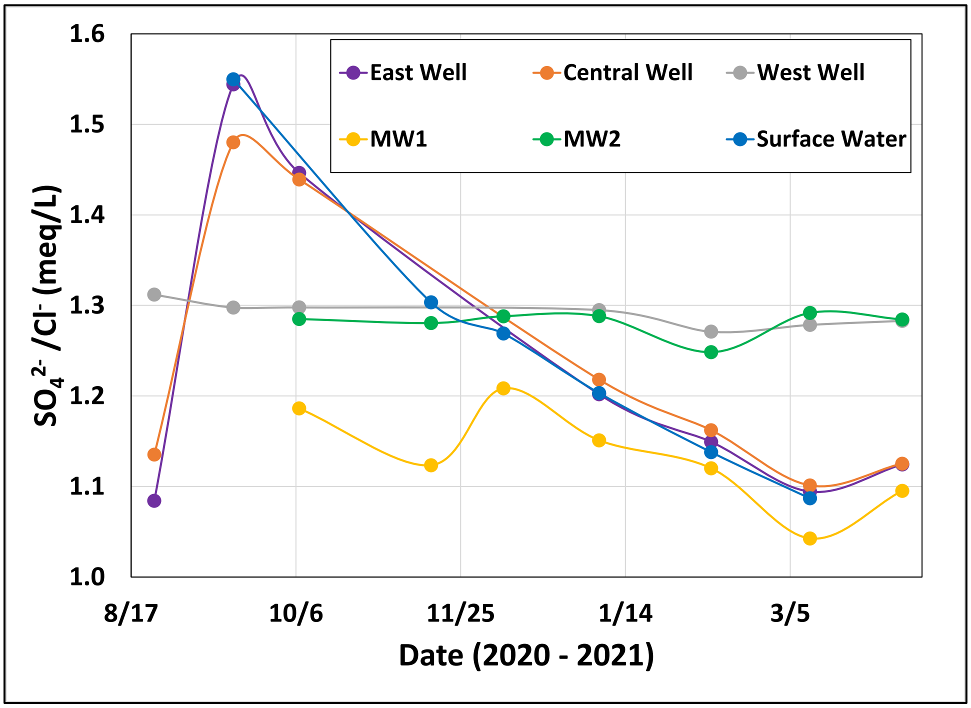

Figure 14 -- Sulfate-to-chloride in all samples vs time over the sampling season at the basalt site – MP29/31.

The sulfate-to-chloride ratios measured in surface water decreased almost linearly during MAR operations. After an initial increase from ambient pre-infiltration values, sulfate-to-chloride ratios for the inner wells were nearly identical to and show similar decreases with time as the infiltrating surface water. This observation is consistent with the rapid and complete displacement of ambient water with infiltrated surface water. In contrast sulfate-to-chloride ratios in the outer wells remained constant during the entire infiltration event suggesting that infiltrated water did not reach the locations. In addition, the ratios for outer wells differ from the pre-infiltration values for the inner wells showing the spatial heterogeneity in water composition.

A fluorescence dye tracer test conducted at MP31 in 2016 during an infiltration event found an average groundwater velocity of 445 ft (135.6 m) per day [60]. Based on this velocity infiltrated water would be expected to reach the inner wells (200 ft [61 m] or less down gradient) within a day and the outer wells (5,930 ft [1,810 m] to 6,775 ft [2,065 m] down gradient) within two weeks. For the inner wells, this estimated travel time is consistent with the changes in sulfate-to-chloride ratios. However, for the outer wells the presence of infiltrated water was not chemically observed indicating that these wells are not within the flow field of the MAR operation. This discrepancy may be the result of preferential fracture flow characteristic of the ESRPA basalts.

The sulfate-to-chloride ratio at MW1 did not respond to the September MP31 infiltration event as the 10/7/2020 value was like the pre-infiltration inner wells but distinctly lower than that in the surface water and the outer wells (Figure 14). Because MW1 is located 5,280 ft (1,609 m) and cross gradient from MP31, this is not unexpected. However, when infiltration began in the much closer MP29 (600 ft [183 m] cross gradient) the sulfate-to-chloride ratio for MW1 paralleled those of the surface water and the inner wells albeit at a lower value indicating chemical impact at the location from MP29 only.

Collectively these results show that the inner wells chemically respond to infiltration at MP31 and probably MP29, MW1 only chemically responds to infiltration at MP29, and the outer wells do not chemically respond to infiltration in either basin highlighting the flow heterogeneity of the site.

Hydrogeologic Investigation

The water levels in all wells and inflows into both MP29 and MP31 are shown in Figure 15. To facilitate comparison among wells groundwater levels are relative to the sampling season minimums at each location. The MAR event in September infiltrated approximately 6,634 AF (8.2 million m^3) of surface water at MP31 and the larger event from November through March infiltrated approximately 64,775 AF (80 million m^3) at MP29 and 32,750 AF (40 million m^3) at MP31.

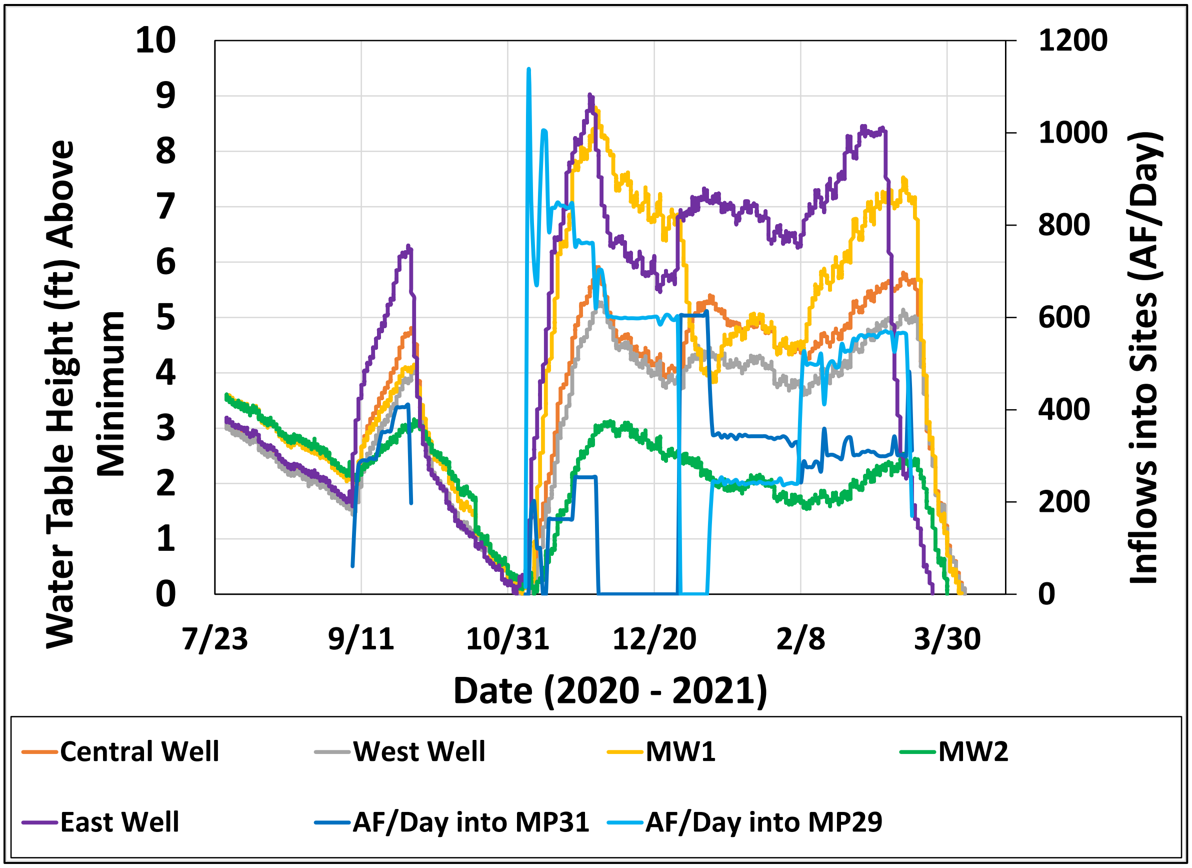

Figure 15 -- Inflows into the basalt site – MP29/31 and water levels in all wells in the monitor well network vs time.

Prior to the September infiltration event, groundwater levels had been declining (Figure 15) at the location since the completion of a 78,355 AF [96.7 million m^3] infiltration event in the spring of 2020 [24]. With the initiation of infiltration at MP31 the water table at the inner wells show up to a four ft (1.2 m) rise as a result of the arrival of infiltrated surface water (Figures 14 and 15). In addition, the water table rises to lesser extents at MW1 and the outer wells, locations that had not seen chemical evidence of infiltrated surface water (Figure 14), indicating that water level increases and decreases do not necessarily correspond to the arrival and departure of infiltrated water at a location. Instead, these hydrologic responses, when coupled with the complete displacement of ambient groundwater inferred in the inner wells above, might evidence the growth of a mound of infiltrated water directly under the basin which transmitted ambient groundwater away from it.

Figure 15 shows that the water table elevation of MW1 is heavily influenced by events in MP29. The September infiltration event utilized only MP31, and the hydrologic response at MW1 was similar to the West Well, 5,930 ft (1,808 m) downgradient from MP31. By contrast, in response to the early November inflow peak into MP29 MW1 responded similarly to the East Well, located a similar distance (535 ft [163 m] cross gradient) from MP29. This observation coupled with the parallel variations in the sulfate-to-chloride ratio of infiltrated and MW1 water (Figure 14) suggest that although not wholly displacing ambient groundwater (as was the case for the inner wells) some amount of infiltrated water is likely present at the MW1 location when MP29 is operating. Comparison of the water levels in MW1 with the East well during the late December basin switch demonstrates that the East Well is more hydrologically influenced by events in MP31 than the more distant MP29.

Geochemical Investigation

Table 6 provides the average and standard deviation of the concentration difference between the groundwater and Headgate water samples collected on the same.

Table 6 – Average concentration difference between groundwater samples at two locations, the East and Central wells (inner wells) and MW1, and the Headgate water as well as the standard deviations among the samples at the basalt site – MP29/31.

	Inner Wells		MW1	
	Average	St. Dev	Average	St. Dev
	meq/L		meq/L	
Ca^{2+}	0.01	0.09	0.07	0.08
Na^{+}	-0.01	0.04	0.09	0.05
Mg^{2+}	-0.01	0.08	-0.05	0.04
K^{+}	-0.03	0.03	-0.06	0.02
Cl^{-}	0.00	0.02	0.08	0.06
SO_4^{2-}	0.01	0.02	0.03	0.05

For the inner wells all ion concentrations differences are indistinct from zero (Table 6) and indicate that the water in these wells was surface water chemically unaltered by cation exchange or precipitation reactions despite being oversaturated with respect to calcite (Table 5). The apparent lack of water-rock reaction may be the result of low cation exchange capacity of basalt, the short residence time, or both.

Groundwater sampled at MW1 during the November to March infiltration event had chloride and sulfate concentrations higher than the infiltrating surface water and the pre-infiltration MW1 groundwater (Table 6) suggesting that there may be additional source of the ions such as road salt (NaCl) and soil amendments (e.g., $CaSO_4 \cdot 2H_2O$). The observed (Table 6) positive equal milliequivalent sodium, chloride, calcium, and sulfate differences are consistent with these possible ion sources. Negative differences of potassium and magnesium suggest that cation exchange may be occurring.

Figure 16 shows sulfate-to-chloride and sodium adsorption ratios for MW1 groundwater and infiltrated surface water. Not shown on the figure are the ratios for East and Central wells which are similar to the surface water. The SAR value for MW1 shifts from its pre-MP29 infiltration values of 0.76 to 0.87 10 days after the start of infiltration to a near constant more sodium rich value of 0.96 one month after the start of infiltration. The shift in SAR during infiltration contrasts to the near constant values observed for the Jones Pit wells J. Stucki, D. Stucki, and C. Arave and indicate that unlike the alluvium at the Jones Pit the basalt does not buffer the cation composition of the water. However, the constant SAR values and decreasing sulfate-to-chloride ratios after 12/8/2020 are consistent with some amount of buffering by cation exchange (maybe due to interactions with some sediments) occurring only when MP29 is in use. The hydrological and geochemical contrast between MW1 and the inner wells highlight the importance of local heterogeneity in controlling the hydrochemistry of fractured basalt.

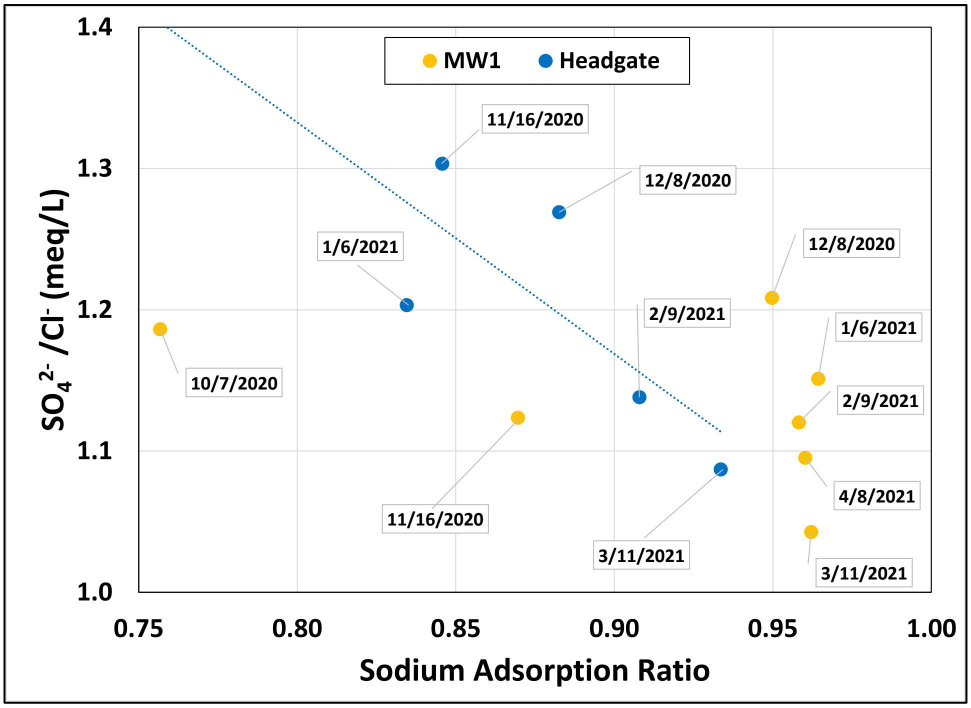

Figure 16 -- Sulfate-to-chloride ratios vs SAR in MW1 and the Headgate at the basalt site -- MP29/31.

Because the outer wells had near constant chemical composition and were chemically uninfluenced by the infiltration event, they were used to assess the combined uncertainties associated with repeated sampling and chemically characterizing groundwater wells over time, the result of which are given in Appendix F.

Synthesis and Conceptual Model

Distance from the basins influenced the water level responses in wells while flow heterogeneities (i.e., preferential fracture flow) controlled mixing and chemical impacts. The inner wells respond hydrologically and chemically to relatively close MP31. The water table at the East well specifically responds more to infiltration at MP31 than to MP29 but the chemical impact of MP29 in isolation on the inner wells could not be determined. Samples from the inner wells were completely infiltrated water demonstrating that displacement occurs without observable mixing and no chemical reactions were inferred. By contrast the water levels at MW1 were heavily influenced by the closer MP29 and only chemically impacted by events in that basin. Samples collected from MW1 showed some evidence of cation exchange only when MP29 was operating, demonstrating the importance of heterogeneous fracture flow. The chemically impacted wells were all within 600 ft (183 m) of the basin(s) which contrasts to the outer wells and MW1 when only MP29 was in operation, which were all greater than 5,280 ft (1,609 m) from the basin(s) and demonstrated no chemical evidence of infiltrated water despite the large infiltration event. This was probably because flow heterogeneities routed the infiltrated water away from the locations. Nevertheless, relatively muted water table changes in response to infiltration events were observed in the farther away locations and demonstrate that water table rises and falls in response to infiltration events do not necessarily indicate the arrival and departure of infiltrated water. Because of the dominance of fracture flow Figure 7 was not appropriate and instead Figure 4 was reinterpreted as a conceptual model of the site when both MP29 and MP31 are being utilized and presented in Figure 17.

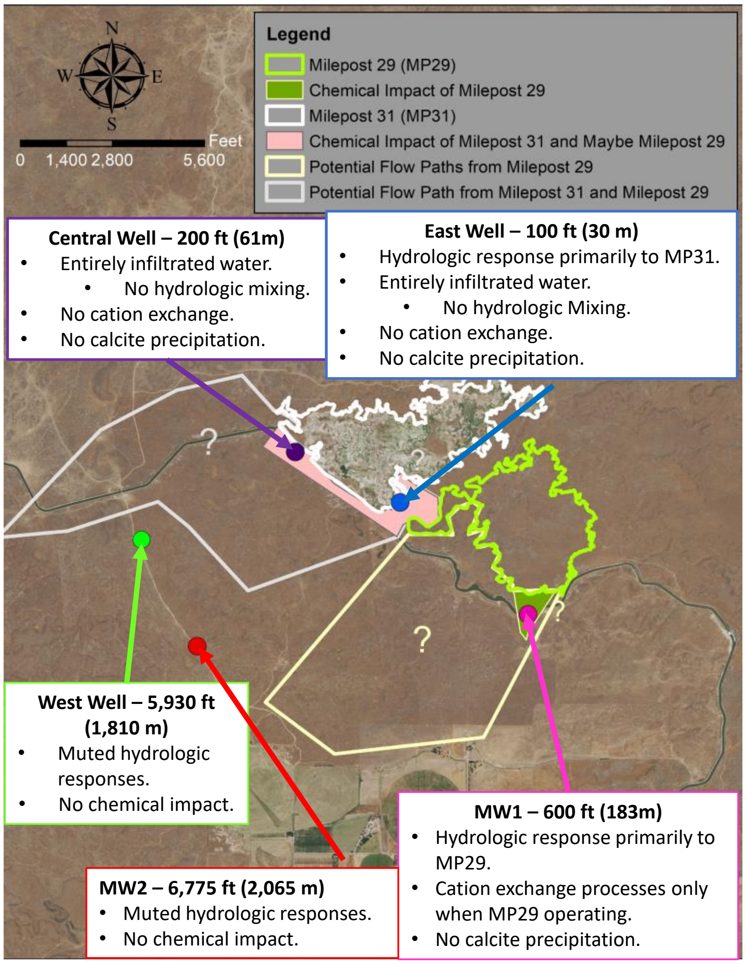

Figure 17 -- A conceptual model of MP29/31 when both basins are operating.

Combination Alluvial/Basalt Site -- West Egin Lake

Water Quality Sample Data

West Egin Lake water quality results for the seven samples collected from four dedicated monitoring wells and two samples of surface water associated with the 7/1 – 11/13/2021 MAR operations are given in Table 8 and shown in Figure 6. Samples were collected in the spring of 2021 (prior to infiltration) from both the deep and shallow West wells, the Easement Well Deep, and (because an infiltration operation was not occurring) from a canal sourced from the Henry’s Fork of the Snake River approximately seven miles (11.3 km) away from the basin. Samples were collected again during the summer from all four wells and at the basin 34 days after the infiltration event began.

Table 7 – Water quality results from the combination alluvial/basalt site – West Egin Lake, calcite SI calculated by [39].

Sample ID	Date	pH	Temperature	O_2(aq)	Ca^{2+}	Na^{+}	Mg^{2+}	K^{+}	Cl^{-}	SO_4^{2-}	HCO_3^{-}	NO_3^{-} + NO_2^{-} as N	Charge imbalance error	Sodium Adsorption Ratio	Calcite
			C	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l			SI
Surface -- Spring	3/2/21	8.61	3.2	31	12.94	16.69	3.785	2.402	6.032	4.5	84.96	0.25	-1.92%	0.55	0.10
West Deep Well -- Spring	3/2/21	7.94	10.8	16.3	28.02	11.26	7.465	2.468	5.163	7.227	131.7	1.44	1.63%	0.49	0.04
West Shallow Well -- Spring	4/13/21	7.76	11.8	14.32	29.99	11.38	7.974	2.493	5.196	7.603	139	1.56	2.71%	0.48	-0.09
Easement Well Deep -- Spring	3/2/21	8.07	9.8	15.56	31	11	8.3	2.4	5.47	9.63	140.2	2.20	1.13%	0.45	0.22
West Shallow Well -- Summer	8/4/21	8.06	17.5	14.86	29.43	11.52	7.954	2.526	5.203	7.948	141.4	1.62	0.09%	0.49	0.30
West Deep Well -- Summer	8/4/21	8.01	19.3	13.58	28.95	11.5	7.753	2.526	5.215	8.171	141.4	1.69	-0.74%	0.49	0.27
Easement Well Deep -- Summer	8/4/21	7.94	15.7	14.23	30.04	11.22	8.341	2.44	5.406	9.432	142.6	2.08	0.31%	0.47	0.16
Easement Well Shallow -- Summer	8/4/21	7.48	16	15.74	28.81	12.35	5.467	2.505	4.584	4.467	139	0.98	1.56%	0.55	-0.33
Surface -- Summer	8/4/21	8.18	23.9	17.71	12.07	15.01	3.748	2.422	5.516	3.828	82.89	0.17	-2.68%	0.51	-0.07

Sample Source Determination

Chloride and sulfate concentrations for West Egin Lake waters are shown in Figure 18. Samples collected before and during the infiltration from the deep and shallow West location have similar chloride and sulfate concentrations as does the deep well at the Easement location (the shallow well was not sampled prior to the start of the infiltration event). Collectively, these groundwater samples define a linear trend between chloride and sulfate suggesting similar processes influence water composition. These samples are considered ambient groundwater. However, the surface water samples are not part of the trend defined by the groundwater samples. Samples from the Deep and Shallow wells at the West location have similar sulfate and chloride concentration suggesting the presence of a sedimentary interbed at this location does not alter the groundwater chemistry. However, at the Easement location the sample from the Shallow and Deep wells represent the extremes of the groundwater trend shown in Figure 18 demonstrating that vertical stratification of groundwater composition can occur in the absence of a sedimentary interbed. Because the shallow well was only sampled during the infiltration event, whether the stratification pre-dated the start of infiltration is not known.

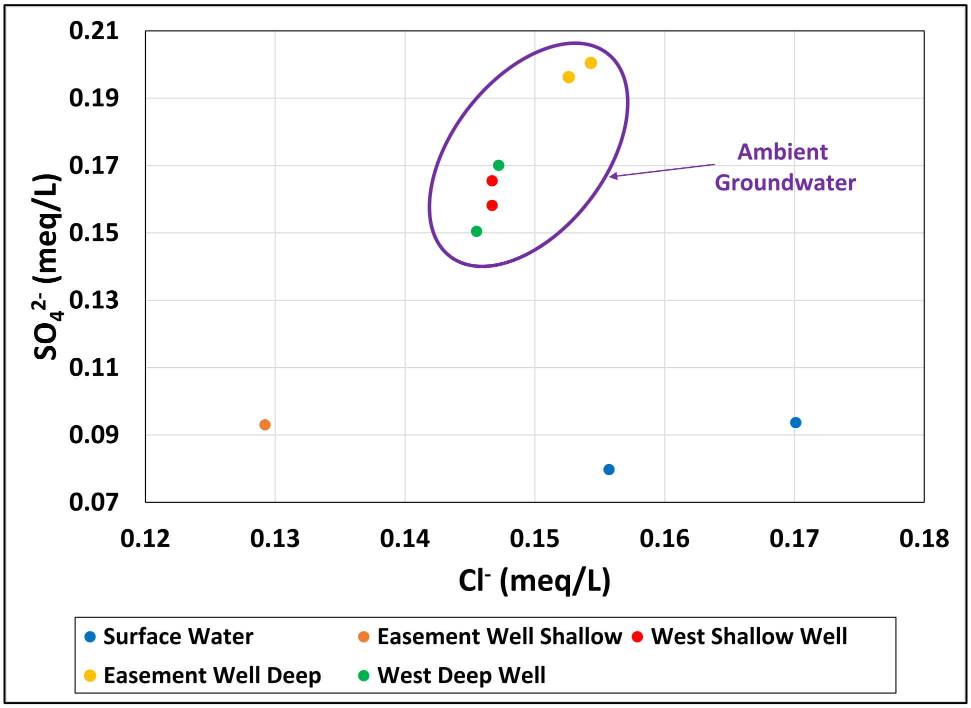

Figure 18 -- Sulfate vs. chloride concentrations in all samples at the combination alluvial/basalt site -- West Egin Lake.

Hydrogeologic Investigation

The water levels in all wells and inflows into the West Egin Lake infiltration basin are shown in Figure 19. To facilitate comparison among wells groundwater levels are relative to the sampling season minimums at each location. The infiltration event occurred from 7/1 through 11/13/2021 and recharged 12,012.5 AF (14.8 million m^3).

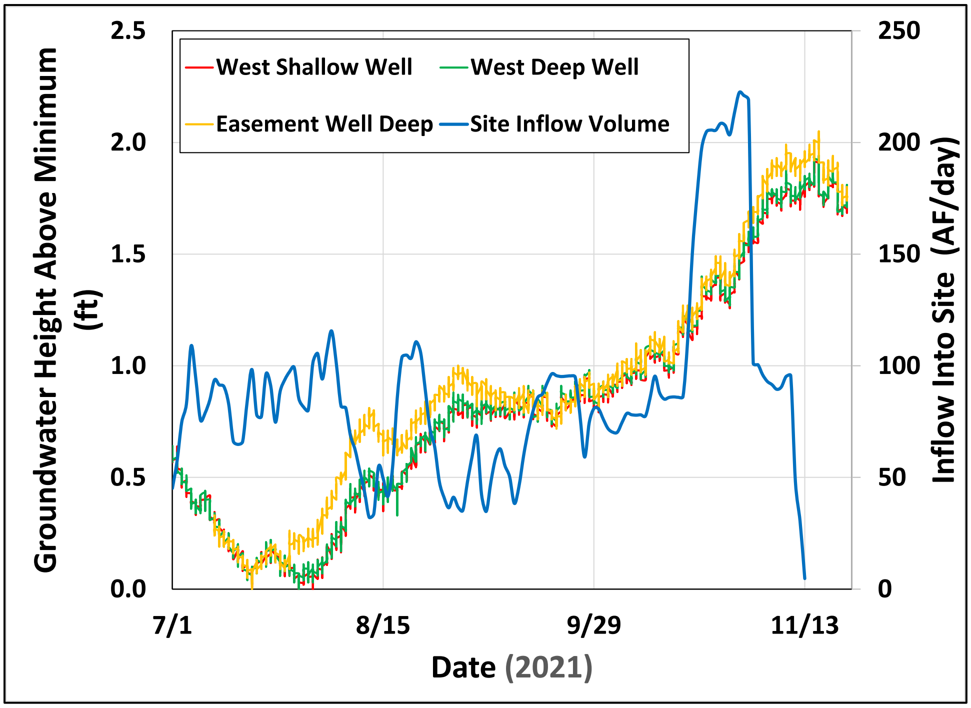

Figure 19 -- Inflows into the combination alluvial/basalt site – West Egin Lake and water levels in the monitor well network vs time.

Prior to the infiltration event, groundwater levels had been declining (Figure 19) at the location since the completion of a 18,275 AF [22.54 million m^3] infiltration event in the Fall of 2020 [22]. Because the volume of the examined infiltration event was small, and the West location is over 6,750 ft (2,060 m) from the basin it is likely that the major upward trend beginning in late July was an increase in the regional water table elevation. Because the hydrologic impact of the infiltration event was not clearly observed in the West location it was likely on the order of the difference between the West location and the Easement Well Deep which began diverging on 7/23/2021, with a maximum difference of 0.28 ft (0.09 m) on 8/12/2021 and then converged on 9/11/2021 until diverging again in response to the peak inflow event in October. A sample that was not a mixture of ambient groundwater and sampled surface water was collected from the Easement Well Deep on 8/3/2021 indicating that water table rises do not necessarily indicate the arrival of infiltrated water at a location.

Geochemical Investigation

Table 8 provides the change in ion concentrations for the same well between the spring and summer sampling events (Temporal Changes by Season) and the difference in concentrations between the deep and shallow wells at the same location from the same sampling event (Vertical Change by Location).

Table 8 – Temporal and vertical differences among select ion concentrations in all samples at the combination alluvial/basalt site – West Egin Lake.

	Temporal Changes by Season (meq/L)				Vertical Change by Location (meq/L)		
	West		Easement Deep	Surface	West		Easement Summer
Ion	Deep	Shallow			Spring	Summer	
Ca^{2+}	-0.05	0.03	0.05	0.04	-0.10	-0.02	0.06
Na^{+}	-0.01	-0.01	-0.01	0.07	-0.01	0.00	-0.05
Mg^{2+}	-0.02	0.00	0.00	0.00	-0.04	-0.02	0.24
K^{+}	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cl^{-}	0.00	0.00	0.00	0.01	0.00	0.00	0.02
SO_4^{2-}	-0.02	-0.01	0.00	0.01	-0.01	0.00	0.10

Table 8 shows little temporal differences in ion concentrations for the three wells suggesting that groundwater chemistry was unchanged by MAR operations. Vertically, there is also little difference in the composition of shallow and deep groundwater for the West location indicating chemical homogeneity of the aquifer despite the presence of a local sedimentary interbed.

By contrast, at the Easement location groundwater was vertically stratified during the summer sampling event, with shallow water being depleted with respect to magnesium, calcium, sulfate, and chloride, and enriched in sodium compared to the deep well. To further explore the variations in water chemistry, a simple mixing model was constructed with the two most extreme water samples (Easement Well Deep – spring and Easement Well Shallow – summer). The mixing model results are given in Figure 20 and show that all the groundwater samples can be described as a mixture of the two endmembers. In addition, the summer surface water sample also falls on the mixing curve (the spring surface water sample location was seven miles [11.3 km] from the infiltration basin). The surface water sample falls between the summer Easement Well Shallow and any other groundwater compositions indicating that the shallow Easement groundwater cannot be a mixture of the infiltrated surface water and ambient groundwater. However, because the surface and groundwater fall along the same mixing line, they are likely both subject to the same, unidentified hydrochemical process(es).

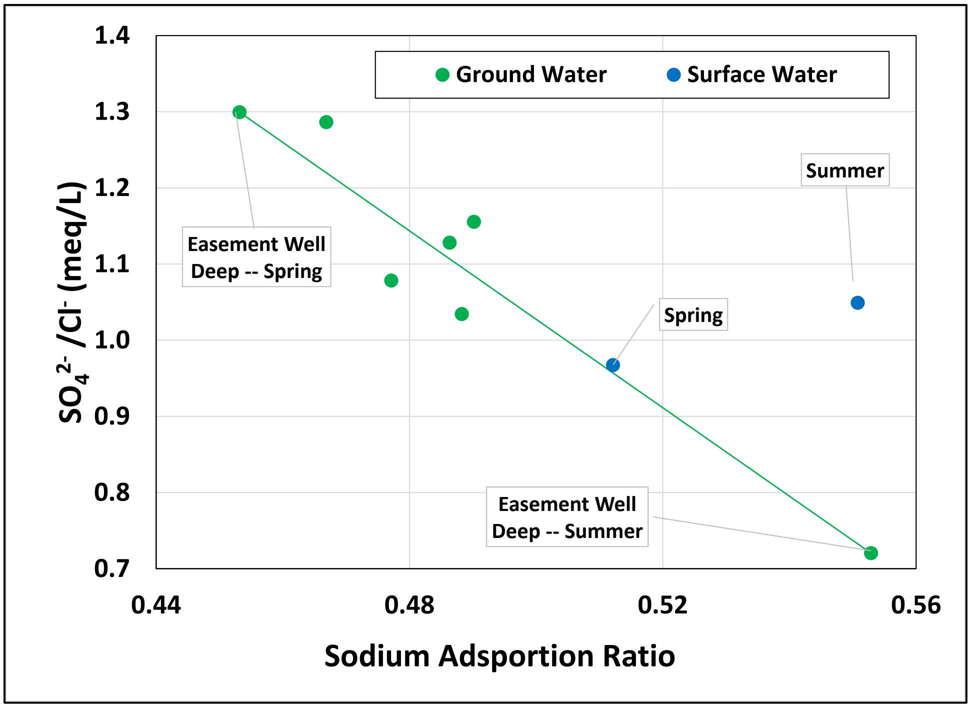

Figure 20 – Sulfate-to-chloride ratio vs SAR in all samples at West Egin Lake -- combination alluvial/basalt site with a mixing line between the Easement Well Deep – Spring and Summer samples.

Synthesis

The region of the aquifer chemically impacted by the infiltration event did not include any of the wells and hydrologic responses were not evident in the West location 6,750 ft (2,060 m) downgradient probably because of the relatively low infiltration rate and distance to the monitoring wells. The West location has a sedimentary interbed between the deep and shallow wells while the Easement location does not, but groundwater stratification was only observed in the latter indicating that a cohesive aquifer underlies the basin in which vertical stratification occurs. A sample from the Easement location was taken when the water table was elevated in response to the infiltration event but was not a mixture of the surface water and the other groundwaters demonstrating that rising water tables in response to infiltration events do not necessarily indicate the arrival of infiltrated water.

Chapter 4: Conclusions

This study was conducted to investigate hydrologic mixing, local groundwater level responses, and water-rock interactions influencing geochemical changes in groundwater chemistry during MAR operations in infiltrations across the ESRP. In pursuit of these goals, groundwater level and water quality sample data from three MAR basins, one each in alluvium, basalt, and combination alluvium/basalt, were evaluated. Together these locations are representative of the geology of the ESRPA. The major findings of this study are:

Hydrologic mixing and groundwater level data:

- Complete displacement of ambient groundwater by infiltrated water was observed in some wells at the alluvial and basalt sites. In addition, water table increases and decreases did not necessarily indicate the arrival and departure of infiltrated water at a given location but rather provide evidence of the growth of a mound of infiltrated water under the basin which displaced ambient groundwater.
- At the combination alluvial/basalt site there was a discontinuous sedimentary interbed and the chemistries of water above and below it were the same, but chemical stratification occurred at a second location absent the interbed. Water table increases and decreases in that location did not evidence the arrival and departure of infiltrated water.

Geochemical processes impacting infiltrated water:

- An analysis of water quality samples indicated that a type of reverse cation exchange impacted the infiltrated water at the alluvial site in which a sediment preference of $Na^+ \approx Mg^{2+} > Ca^{2+}$ was inferred. Geochemical modeling predicted that the reactions were possible and would increase with additional sediment interaction.
- The precipitation of calcite would have minimal impact on the chemical evolution of infiltrated water.
- At the basalt site, no observable reactions impacted infiltrated water at two relatively close downgradient wells, but cation exchange processes probably impacted infiltrated water at a cross gradient well only when the closest basin to it was operating, highlighting the importance of heterogeneous fracture flow.

Additional findings synthesized with general applications for monitor well network designs:

- Hydrologic monitoring wells: All monitor wells at the basalt site, ranging between 100 ft (30 m) and 6,775 ft (2,065 m) from the basin, responded hydrologically to the substantial inflow events in the basin with locations closer to the basin showing larger water level increases. At the combination alluvial/basalt site the location 1,250 ft (380 m) from the basin responded hydrologically to the relatively small inflow event while wells 6,750 ft (2,060 m) from the basin apparently did not. Unsurprisingly, these results indicate that the hydrologic monitor well network designs should consider both volumes to-be infiltrated and distance from the basin.

- Chemical monitoring wells: At the alluvial site, an infiltrated water packet may have been elongated, moving faster in the direction of the regional gradient than orthogonal to it, and all wells, which were located between 100 ft (30 m) cross gradient and 620 ft (190 m) downgradient, were chemically impacted by the basin. At the basalt site, evidence of infiltrated water was observed at locations 600 ft (183 m) or less from the basin but not at locations 5,280 ft (1,609 m) or greater probably because preferential flow paths routed the large volume of infiltrated water away from the more distant locations. At the combination alluvial/basalt site, no chemical evidence of infiltrated water was observed in a well 1,250 ft (380 m) from the basin. Together these results offer some range on the distance of chemical impacts of the basins but more broadly demonstrate that local heterogeneities in the flow field should be considered when designing chemical monitor well networks.

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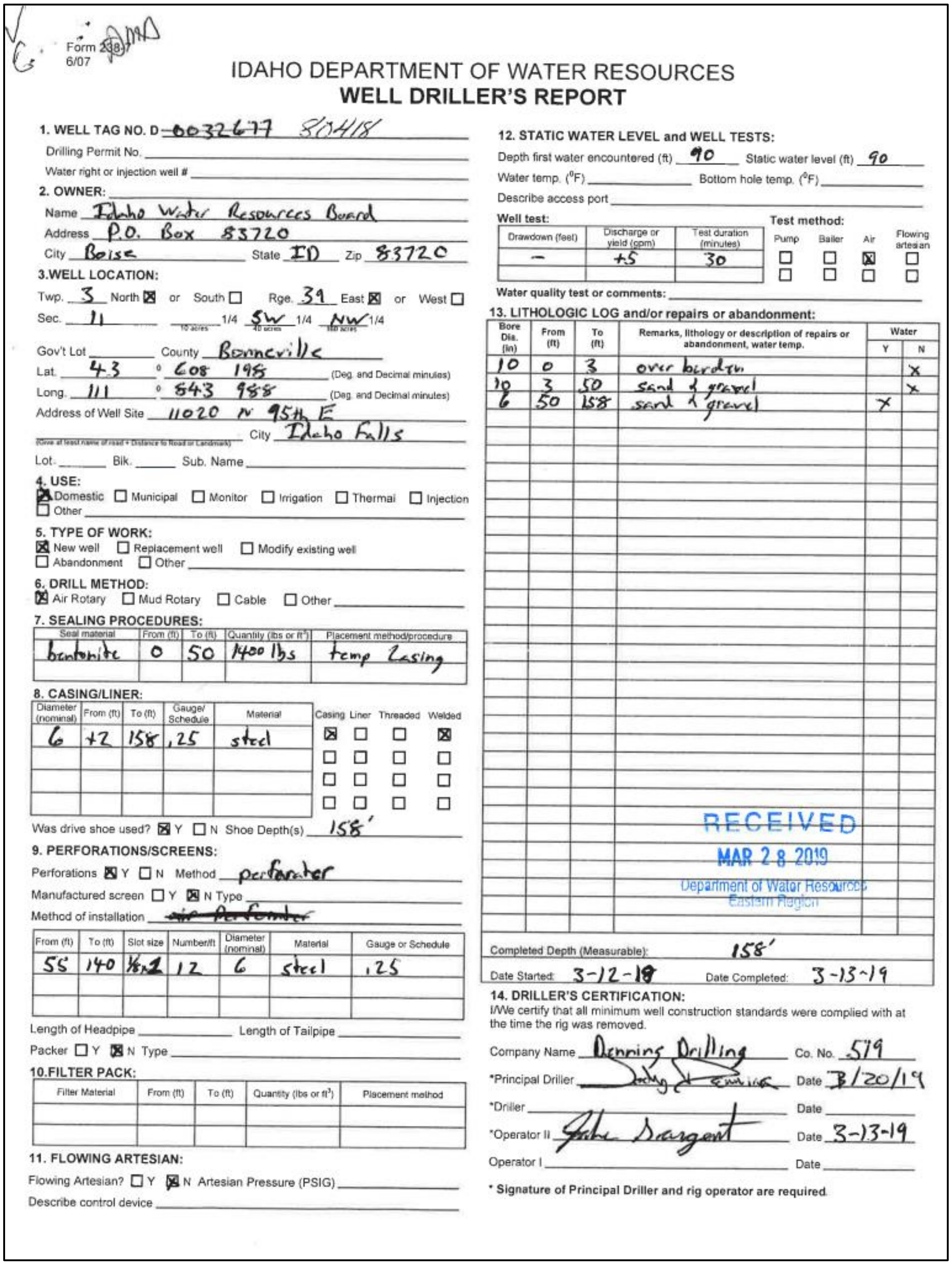
Appendix A – Alluvial Site Well Logs



Form 238-7
6/07

IDAHO DEPARTMENT OF WATER RESOURCES
WELL DRILLER'S REPORT

1. WELL TAG NO. D-0032677 80418

Drilling Permit No.

Water right or injection well #

2. OWNER:

Name Idaho Water Resources Board

Address P.O. Box 83720

City Boise State ID Zip 83720

3.WELL LOCATION:

Twp. 3 North ☒ or South ☐ Rge. 39 East ☒ or West ☐

Sec. 11 ___ 1/4 (10 acres) SW 1/4 (40 acres) NW 1/4 (160 acres)

Gov't Lot ___ County Bonneville

Lat. 43 ° 608 195 (Deg. and Decimal minutes)

Long. 111 ° 543 988 (Deg. and Decimal minutes)

Address of Well Site 11020 N 95th E

(Give at least name of road + Distance to Road or Landmark) City Idaho Falls

Lot. ___ Blk. ___ Sub. Name ___

4. USE:

☒ Domestic ☐ Municipal ☐ Monitor ☐ Irrigation ☐ Thermal ☐ Injection
☐ Other

5. TYPE OF WORK:

☒ New well ☐ Replacement well ☐ Modify existing well
☐ Abandonment ☐ Other

6. DRILL METHOD:

☒ Air Rotary ☐ Mud Rotary ☐ Cable ☐ Other

7. SEALING PROCEDURES:

Seal material	From (ft)	To (ft)	Quantity (lbs or ft³)	Placement method/procedure
bentonite	0	50	1400 lbs	temp Casing

8. CASING/LINER:

Diameter (nominal)	From (ft)	To (ft)	Gauge/ Schedule	Material	Casing	Liner	Threaded	Welded
6	+2	158	.25	steel	☒	☐	☐	☒
					☐	☐	☐	☐
					☐	☐	☐	☐
					☐	☐	☐	☐

Was drive shoe used? ☒ Y ☐ N Shoe Depth(s) 158'

9. PERFORATIONS/SCREENS:

Perforations ☒ Y ☐ N Method perforater

Manufactured screen ☐ Y ☒ N Type

Method of installation ~~air Perforater~~

From (ft)	To (ft)	Slot size	Number/ft	Diameter (nominal)	Material	Gauge or Schedule
55	140	1/8x2	12	6	steel	.25

Length of Headpipe ___ Length of Tailpipe ___

Packer ☐ Y ☒ N Type

10.FILTER PACK:

Filter Material	From (ft)	To (ft)	Quantity (lbs or ft³)	Placement method

11. FLOWING ARTESIAN:

Flowing Artesian? ☐ Y ☒ N Artesian Pressure (PSIG)

Describe control device

12. STATIC WATER LEVEL and WELL TESTS:

Depth first water encountered (ft) 90 Static water level (ft) 90

Water temp. (°F) ___ Bottom hole temp. (°F) ___

Describe access port

Well test:

Drawdown (feet)	Discharge or yield (gpm)	Test duration (minutes)
–	+5	30

Test method:

Pump	Bailer	Air	Flowing artesian
☐	☐	☒	☐
☐	☐	☐	☐

Water quality test or comments:

13. LITHOLOGIC LOG and/or repairs or abandonment:

Bore Dia. (in)	From (ft)	To (ft)	Remarks, lithology or description of repairs or abandonment, water temp.	Water Y	Water N
10	0	3	over burden		X
10	3	50	sand & gravel		X
6	50	158	sand & gravel	X	

RECEIVED
MAR 28 2019
Department of Water Resources
Eastern Region

Completed Depth (Measurable): 158'

Date Started: 3-12-19 Date Completed: 3-13-19

14. DRILLER'S CERTIFICATION:

I/We certify that all minimum well construction standards were complied with at the time the rig was removed.

Company Name Denning Drilling Co. No. 579

*Principal Driller ___ Date 3/20/19

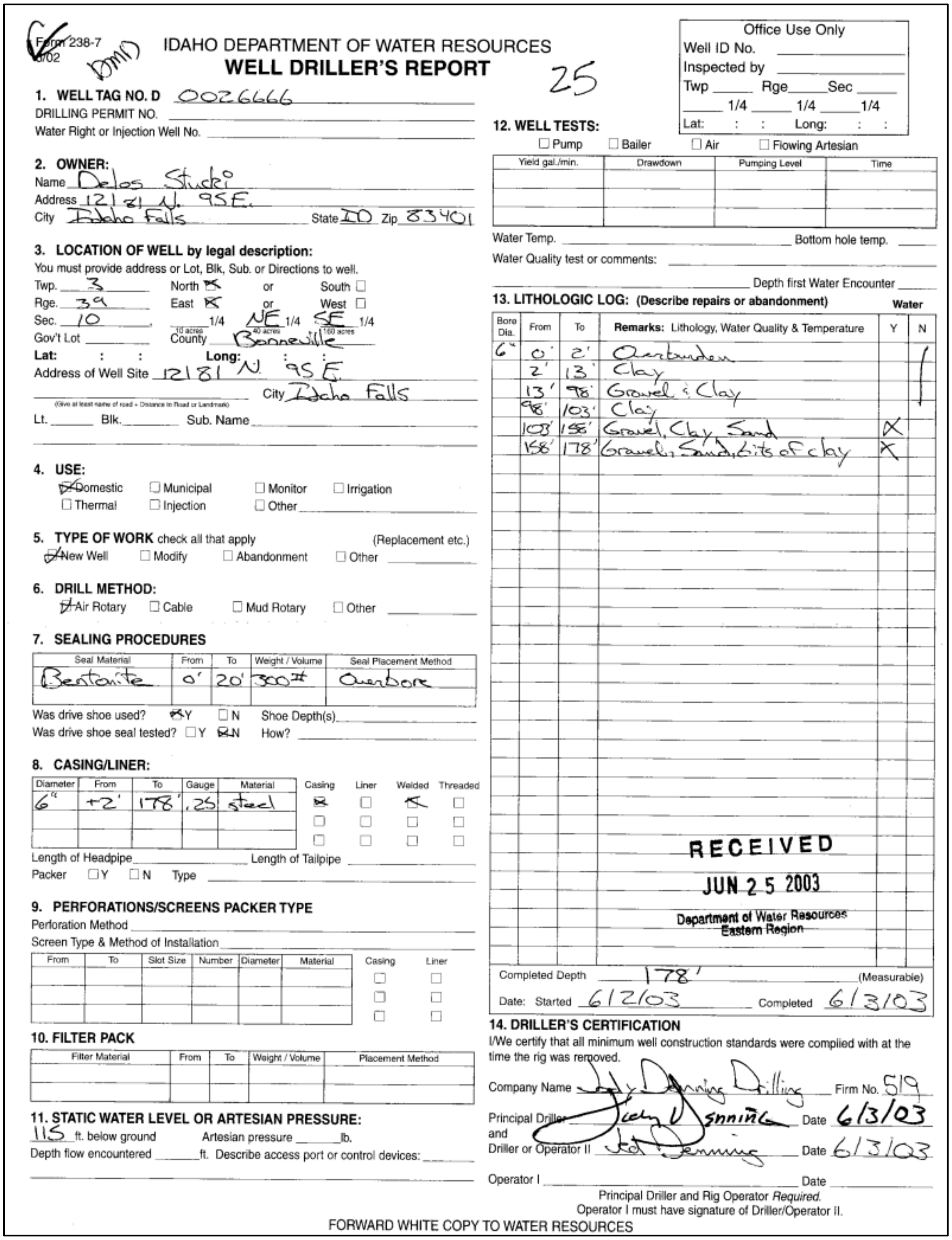
*Driller ___ Date ___

*Operator II John Sargent Date 3-13-19

Operator I ___ Date ___

*** Signature of Principal Driller and rig operator are required.**

IDWRMW



Form 238-7
6/02 DMD

IDAHO DEPARTMENT OF WATER RESOURCES

WELL DRILLER'S REPORT

25

Office Use Only
Well ID No. ______
Inspected by ______
Twp ___ Rge ___ Sec ___
___ 1/4 ___ 1/4 ___ 1/4
Lat: : : Long: : :

1. WELL TAG NO. D 0026666
DRILLING PERMIT NO. ______
Water Right or Injection Well No. ______

2. OWNER:
Name Delos Stucki
Address 12181 N. 95E.
City Idaho Falls State ID Zip 83401

3. LOCATION OF WELL by legal description:
You must provide address or Lot, Blk, Sub. or Directions to well.
Twp. 3 North ☒ or South ☐
Rge. 39 East ☒ or West ☐
Sec. 10, ___ 1/4 NE 1/4 SE 1/4
10 acres 40 acres 160 acres
Gov't Lot ___ County Bonneville
Lat: : : Long: : :
Address of Well Site 12181 N. 95 E.
City Idaho Falls
(Give at least name of road + Distance to Road or Landmark)
Lt. ___ Blk. ___ Sub. Name ___

4. USE:
☒ Domestic ☐ Municipal ☐ Monitor ☐ Irrigation
☐ Thermal ☐ Injection ☐ Other ___

5. TYPE OF WORK check all that apply (Replacement etc.)
☒ New Well ☐ Modify ☐ Abandonment ☐ Other ___

6. DRILL METHOD:
☒ Air Rotary ☐ Cable ☐ Mud Rotary ☐ Other ___

7. SEALING PROCEDURES

Seal Material	From	To	Weight / Volume	Seal Placement Method
Bentonite	0'	20'	300#	Overbore

Was drive shoe used? ☒ Y ☐ N Shoe Depth(s) ___
Was drive shoe seal tested? ☐ Y ☒ N How? ___

8. CASING/LINER:

Diameter	From	To	Gauge	Material	Casing	Liner	Welded	Threaded
6"	+2'	178'	.25	steel	☒	☐	☒	☐
					☐	☐	☐	☐
					☐	☐	☐	☐

Length of Headpipe ___ Length of Tailpipe ___
Packer ☐ Y ☐ N Type ___

9. PERFORATIONS/SCREENS PACKER TYPE
Perforation Method ___
Screen Type & Method of Installation ___

From	To	Slot Size	Number	Diameter	Material	Casing	Liner
						☐	☐
						☐	☐
						☐	☐

10. FILTER PACK

Filter Material	From	To	Weight / Volume	Placement Method

11. STATIC WATER LEVEL OR ARTESIAN PRESSURE:
115 ft. below ground Artesian pressure ___ lb.
Depth flow encountered ___ ft. Describe access port or control devices: ___

12. WELL TESTS:
☐ Pump ☐ Bailer ☐ Air ☐ Flowing Artesian

Yield gal./min.	Drawdown	Pumping Level	Time

Water Temp. ___ Bottom hole temp. ___
Water Quality test or comments: ___
___ Depth first Water Encounter ___

13. LITHOLOGIC LOG: (Describe repairs or abandonment)

Bore Dia.	From	To	**Remarks:** Lithology, Water Quality & Temperature	Water Y	Water N
6"	0'	2'	Overburden		
	2'	13'	Clay		
	13'	98'	Gravel & Clay		
	98'	103'	Clay		
	103'	158'	Gravel, Clay, Sand	X	
	158'	178'	Gravel, Sand, bits of clay	X	

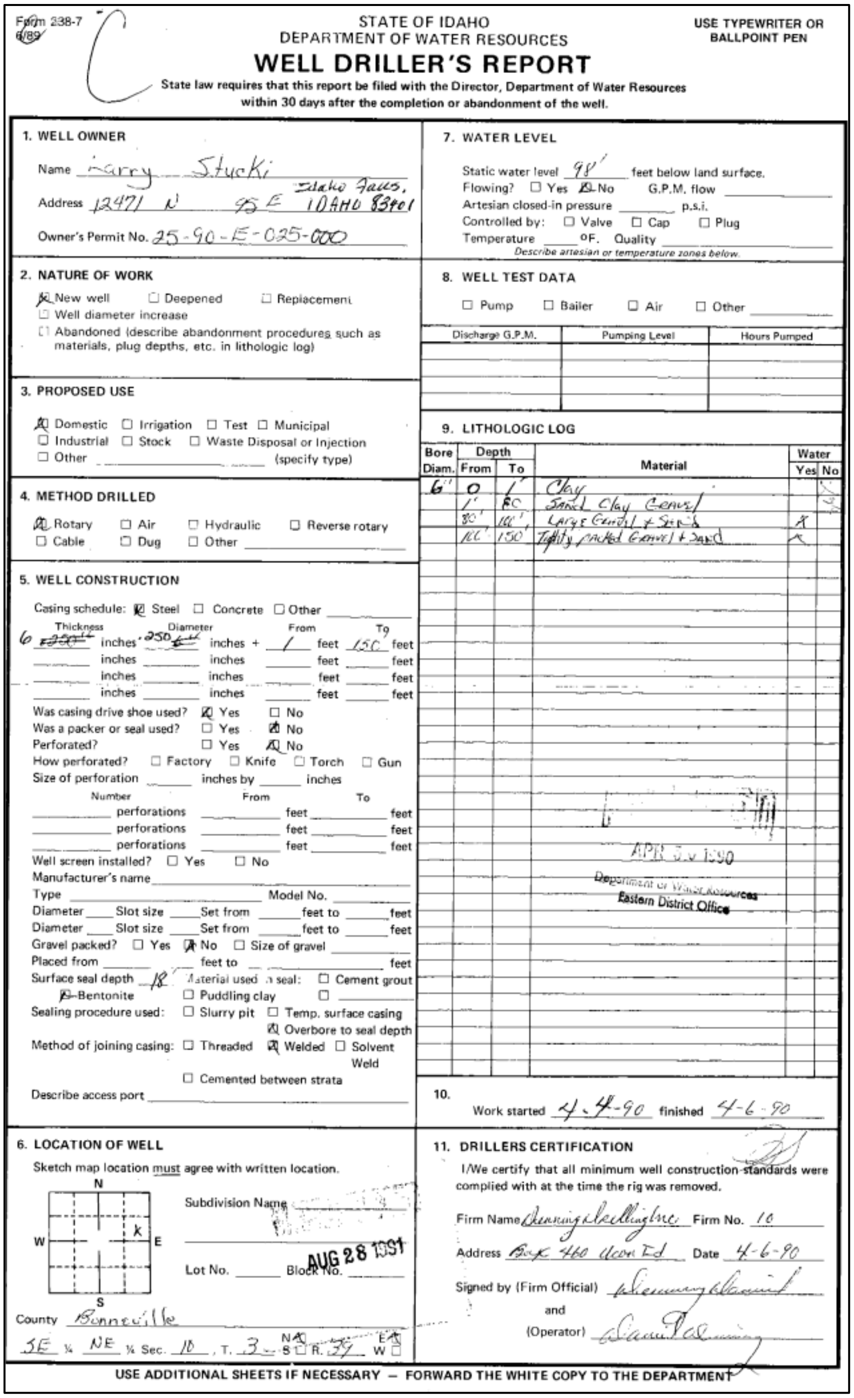
RECEIVED
JUN 25 2003
Department of Water Resources
Eastern Region

Completed Depth 178' (Measurable)
Date: Started 6/2/03 Completed 6/3/03

14. DRILLER'S CERTIFICATION
I/We certify that all minimum well construction standards were complied with at the time the rig was removed.
Company Name Judy Denning Drilling Firm No. 519
Principal Driller Judy V Denning Date 6/3/03
and
Driller or Operator II Ted Denning Date 6/3/03
Operator I ___ Date ___
Principal Driller and Rig Operator *Required.*
Operator I must have signature of Driller/Operator II.

FORWARD WHITE COPY TO WATER RESOURCES

D. Stucki



Form 238-7
6/89

STATE OF IDAHO
DEPARTMENT OF WATER RESOURCES

USE TYPEWRITER OR BALLPOINT PEN

WELL DRILLER'S REPORT

State law requires that this report be filed with the Director, Department of Water Resources within 30 days after the completion or abandonment of the well.

1. WELL OWNER

Name Larry Stucki
Address 12471 N 95 E Idaho Falls, IDAHO 83401
Owner's Permit No. 25-90-E-025-000

2. NATURE OF WORK

☒ New well ☐ Deepened ☐ Replacement
☐ Well diameter increase
☐ Abandoned (describe abandonment procedures such as materials, plug depths, etc. in lithologic log)

3. PROPOSED USE

☒ Domestic ☐ Irrigation ☐ Test ☐ Municipal
☐ Industrial ☐ Stock ☐ Waste Disposal or Injection
☐ Other ______ (specify type)

4. METHOD DRILLED

☒ Rotary ☐ Air ☐ Hydraulic ☐ Reverse rotary
☐ Cable ☐ Dug ☐ Other ______

5. WELL CONSTRUCTION

Casing schedule: ☒ Steel ☐ Concrete ☐ Other ______

Thickness		Diameter		From		To	
6 ~~.250"~~	inches	.250 ~~6"~~	inches +	1	feet	150	feet
	inches		inches		feet		feet
	inches		inches		feet		feet
	inches		inches		feet		feet

Was casing drive shoe used? ☒ Yes ☐ No
Was a packer or seal used? ☐ Yes ☒ No
Perforated? ☐ Yes ☒ No
How perforated? ☐ Factory ☐ Knife ☐ Torch ☐ Gun
Size of perforation ______ inches by ______ inches

Number		From		To	
	perforations		feet		feet
	perforations		feet		feet
	perforations		feet		feet

Well screen installed? ☐ Yes ☐ No
Manufacturer's name ______
Type ______ Model No. ______
Diameter ____ Slot size ____ Set from ______ feet to ______ feet
Diameter ____ Slot size ____ Set from ______ feet to ______ feet
Gravel packed? ☐ Yes ☒ No ☐ Size of gravel ______
Placed from ______ feet to ______ feet
Surface seal depth 18' Material used in seal: ☐ Cement grout ☒ Bentonite ☐ Puddling clay ☐ ______
Sealing procedure used: ☐ Slurry pit ☐ Temp. surface casing ☒ Overbore to seal depth
Method of joining casing: ☐ Threaded ☒ Welded ☐ Solvent Weld ☐ Cemented between strata
Describe access port ______

6. LOCATION OF WELL

Sketch map location must agree with written location.

N W E S
k

Subdivision Name ______
Lot No. ______ Block No. ______

AUG 28 1991

County Bonneville
SE ¼ NE ¼ Sec. 10, T. 3 N☒ S☐ R. 39 E☒ W☐

7. WATER LEVEL

Static water level 98' feet below land surface.
Flowing? ☐ Yes ☒ No G.P.M. flow ______
Artesian closed-in pressure ______ p.s.i.
Controlled by: ☐ Valve ☐ Cap ☐ Plug
Temperature ______ °F. Quality ______
Describe artesian or temperature zones below.

8. WELL TEST DATA

☐ Pump ☐ Bailer ☐ Air ☐ Other ______

Discharge G.P.M.	Pumping Level	Hours Pumped

9. LITHOLOGIC LOG

Bore Diam.	Depth From	Depth To	Material	Water Yes	Water No
6"	0	1'	Clay		✓
	1'	80	Sand Clay Gravel		✓
	80'	100'	Large Gravel + Sand	X	
	100'	150'	Tightly packed Gravel + Sand	X	

APR [illegible] 1990
Department of Water Resources
Eastern District Office

10.

Work started 4-4-90 finished 4-6-90

11. DRILLERS CERTIFICATION

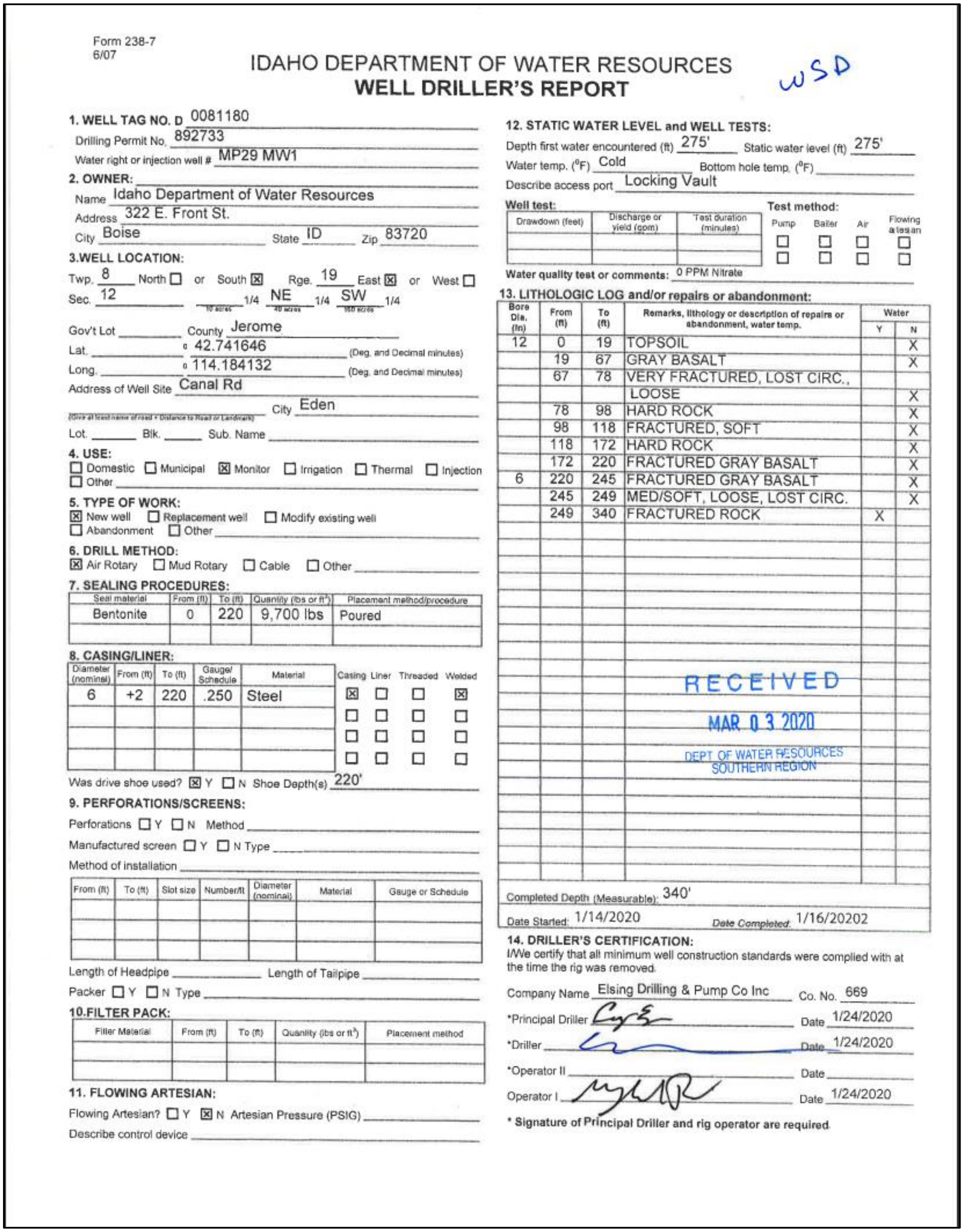
I/We certify that all minimum well construction standards were complied with at the time the rig was removed.

Firm Name Denning Drilling Inc. Firm No. 10
Address Box 460 Ucon Id Date 4-6-90
Signed by (Firm Official)
and
(Operator)

USE ADDITIONAL SHEETS IF NECESSARY — FORWARD THE WHITE COPY TO THE DEPARTMENT

J. Stucki

Appendix B – Basalt Site Well Logs



Form 238-7
6/07

IDAHO DEPARTMENT OF WATER RESOURCES
WELL DRILLER'S REPORT

WSD

1. WELL TAG NO. D 0081180

Drilling Permit No. 892733

Water right or injection well # MP29 MW1

2. OWNER:

Name Idaho Department of Water Resources

Address 322 E. Front St.

City Boise State ID Zip 83720

3.WELL LOCATION:

Twp. 8 North ☐ or South ☒ Rge. 19 East ☒ or West ☐

Sec. 12 ____ 1/4 (10 acres) NE 1/4 (40 acres) SW 1/4 (160 acres)

Gov't Lot ____ County Jerome

Lat. ° 42.741646 (Deg. and Decimal minutes)

Long. ° 114.184132 (Deg. and Decimal minutes)

Address of Well Site Canal Rd

(Give at least name of road + Distance to Road or Landmark) City Eden

Lot. ____ Blk. ____ Sub. Name ____

4. USE:
☐ Domestic ☐ Municipal ☒ Monitor ☐ Irrigation ☐ Thermal ☐ Injection
☐ Other ____

5. TYPE OF WORK:
☒ New well ☐ Replacement well ☐ Modify existing well
☐ Abandonment ☐ Other ____

6. DRILL METHOD:
☒ Air Rotary ☐ Mud Rotary ☐ Cable ☐ Other ____

7. SEALING PROCEDURES:

Seal material	From (ft)	To (ft)	Quantity (lbs or ft³)	Placement method/procedure
Bentonite	0	220	9,700 lbs	Poured

8. CASING/LINER:

Diameter (nominal)	From (ft)	To (ft)	Gauge/ Schedule	Material	Casing	Liner	Threaded	Welded
6	+2	220	.250	Steel	☒	☐	☐	☒
					☐	☐	☐	☐
					☐	☐	☐	☐
					☐	☐	☐	☐

Was drive shoe used? ☒ Y ☐ N Shoe Depth(s) 220'

9. PERFORATIONS/SCREENS:

Perforations ☐ Y ☐ N Method ____

Manufactured screen ☐ Y ☐ N Type ____

Method of installation ____

From (ft)	To (ft)	Slot size	Number/ft	Diameter (nominal)	Material	Gauge or Schedule

Length of Headpipe ____ Length of Tailpipe ____

Packer ☐ Y ☐ N Type ____

10.FILTER PACK:

Filter Material	From (ft)	To (ft)	Quantity (lbs or ft³)	Placement method

11. FLOWING ARTESIAN:

Flowing Artesian? ☐ Y ☒ N Artesian Pressure (PSIG) ____

Describe control device ____

12. STATIC WATER LEVEL and WELL TESTS:

Depth first water encountered (ft) 275' Static water level (ft) 275'

Water temp. (°F) Cold Bottom hole temp. (°F) ____

Describe access port Locking Vault

Well test:

Drawdown (feet)	Discharge or yield (gpm)	Test duration (minutes)

Test method:

Pump	Bailer	Air	Flowing artesian
☐	☐	☐	☐
☐	☐	☐	☐

Water quality test or comments: 0 PPM Nitrate

13. LITHOLOGIC LOG and/or repairs or abandonment:

Bore Dia. (in)	From (ft)	To (ft)	Remarks, lithology or description of repairs or abandonment, water temp.	Water Y	Water N
12	0	19	TOPSOIL		X
	19	67	GRAY BASALT		X
	67	78	VERY FRACTURED, LOST CIRC.,		
			LOOSE		X
	78	98	HARD ROCK		X
	98	118	FRACTURED, SOFT		X
	118	172	HARD ROCK		X
	172	220	FRACTURED GRAY BASALT		X
6	220	245	FRACTURED GRAY BASALT		X
	245	249	MED/SOFT, LOOSE, LOST CIRC.		X
	249	340	FRACTURED ROCK	X	

RECEIVED
MAR 0 3 2020
DEPT OF WATER RESOURCES
SOUTHERN REGION

Completed Depth (Measurable): 340'

Date Started: 1/14/2020 Date Completed: 1/16/20202

14. DRILLER'S CERTIFICATION:

I/We certify that all minimum well construction standards were complied with at the time the rig was removed.

Company Name Elsing Drilling & Pump Co Inc Co. No. 669

*Principal Driller ____ Date 1/24/2020

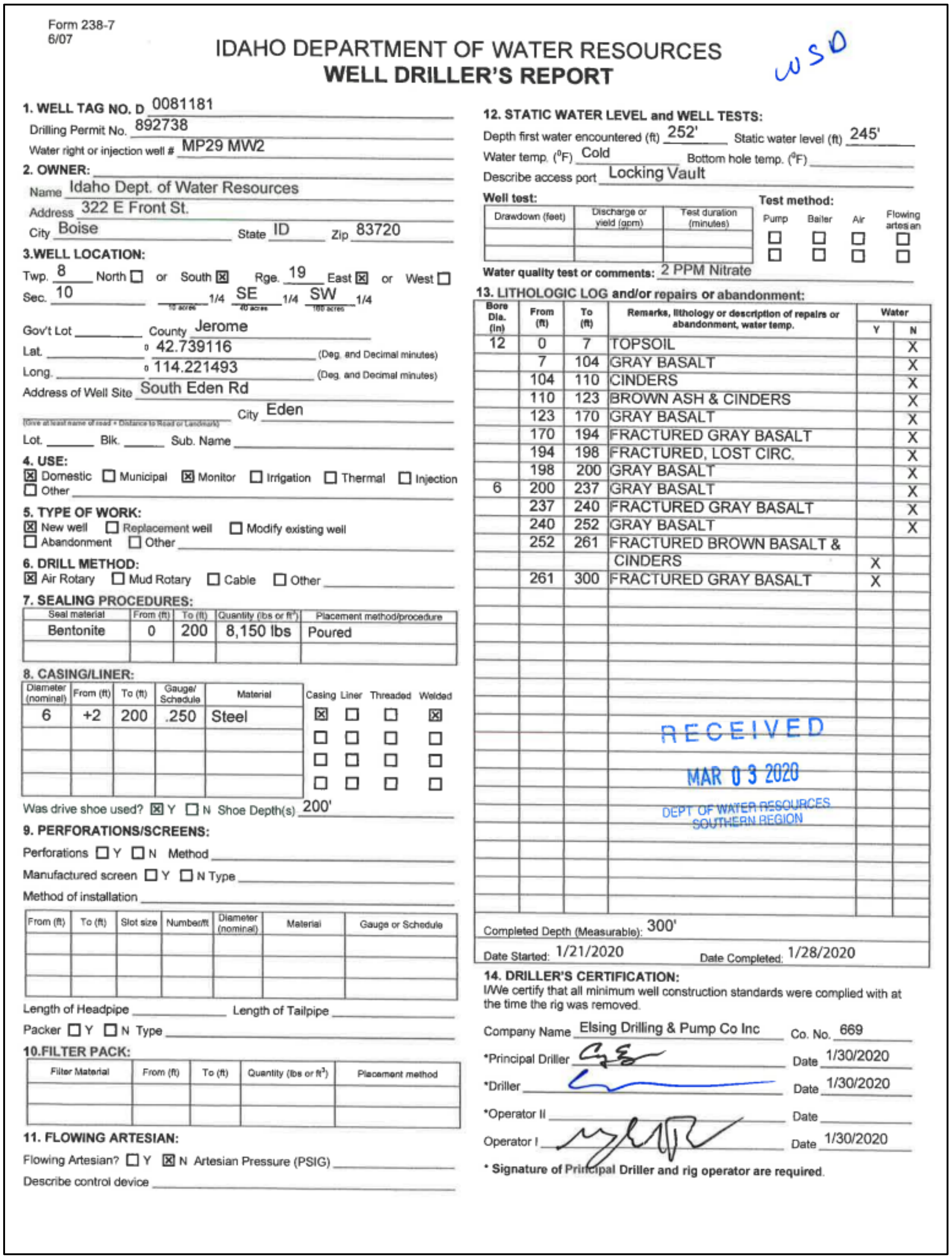
*Driller ____ Date 1/24/2020

*Operator II ____ Date ____

Operator I ____ Date 1/24/2020

*** Signature of Principal Driller and rig operator are required.**

MW1



Form 238-7
6/07

IDAHO DEPARTMENT OF WATER RESOURCES
WELL DRILLER'S REPORT

wsD

1. WELL TAG NO. D 0081181
Drilling Permit No. 892738
Water right or injection well # MP29 MW2

2. OWNER:
Name Idaho Dept. of Water Resources
Address 322 E Front St.
City Boise State ID Zip 83720

3.WELL LOCATION:
Twp. 8 North ☐ or South ☒ Rge. 19 East ☒ or West ☐
Sec. 10 ____ 1/4 (10 acres) SE 1/4 (40 acres) SW 1/4 (160 acres)
Gov't Lot ____ County Jerome
Lat. ____ ° 42.739116 (Deg. and Decimal minutes)
Long. ____ ° 114.221493 (Deg. and Decimal minutes)
Address of Well Site South Eden Rd
(Give at least name of road + Distance to Road or Landmark) City Eden
Lot. ____ Blk. ____ Sub. Name ____

4. USE:
☒ Domestic ☐ Municipal ☒ Monitor ☐ Irrigation ☐ Thermal ☐ Injection
☐ Other ____

5. TYPE OF WORK:
☒ New well ☐ Replacement well ☐ Modify existing well
☐ Abandonment ☐ Other ____

6. DRILL METHOD:
☒ Air Rotary ☐ Mud Rotary ☐ Cable ☐ Other ____

7. SEALING PROCEDURES:

Seal material	From (ft)	To (ft)	Quantity (lbs or ft^3)	Placement method/procedure
Bentonite	0	200	8,150 lbs	Poured

8. CASING/LINER:

Diameter (nominal)	From (ft)	To (ft)	Gauge/ Schedule	Material	Casing	Liner	Threaded	Welded
6	+2	200	.250	Steel	☒	☐	☐	☒
					☐	☐	☐	☐
					☐	☐	☐	☐
					☐	☐	☐	☐

Was drive shoe used? ☒ Y ☐ N Shoe Depth(s) 200'

9. PERFORATIONS/SCREENS:
Perforations ☐ Y ☐ N Method ____
Manufactured screen ☐ Y ☐ N Type ____
Method of installation ____

From (ft)	To (ft)	Slot size	Number/ft	Diameter (nominal)	Material	Gauge or Schedule

Length of Headpipe ____ Length of Tailpipe ____
Packer ☐ Y ☐ N Type ____

10.FILTER PACK:

Filter Material	From (ft)	To (ft)	Quantity (lbs or ft^3)	Placement method

11. FLOWING ARTESIAN:
Flowing Artesian? ☐ Y ☒ N Artesian Pressure (PSIG) ____
Describe control device ____

12. STATIC WATER LEVEL and WELL TESTS:
Depth first water encountered (ft) 252' Static water level (ft) 245'
Water temp. (°F) Cold Bottom hole temp. (°F) ____
Describe access port Locking Vault

Well test:

Drawdown (feet)	Discharge or yield (gpm)	Test duration (minutes)

Test method:

Pump	Bailer	Air	Flowing artesian
☐	☐	☐	☐
☐	☐	☐	☐

Water quality test or comments: 2 PPM Nitrate

13. LITHOLOGIC LOG and/or repairs or abandonment:

Bore Dia. (in)	From (ft)	To (ft)	Remarks, lithology or description of repairs or abandonment, water temp.	Water Y	Water N
12	0	7	TOPSOIL		X
	7	104	GRAY BASALT		X
	104	110	CINDERS		X
	110	123	BROWN ASH & CINDERS		X
	123	170	GRAY BASALT		X
	170	194	FRACTURED GRAY BASALT		X
	194	198	FRACTURED, LOST CIRC.		X
	198	200	GRAY BASALT		X
6	200	237	GRAY BASALT		X
	237	240	FRACTURED GRAY BASALT		X
	240	252	GRAY BASALT		X
	252	261	FRACTURED BROWN BASALT & CINDERS	X	
	261	300	FRACTURED GRAY BASALT	X	

RECEIVED
MAR 03 2020
DEPT OF WATER RESOURCES
SOUTHERN REGION

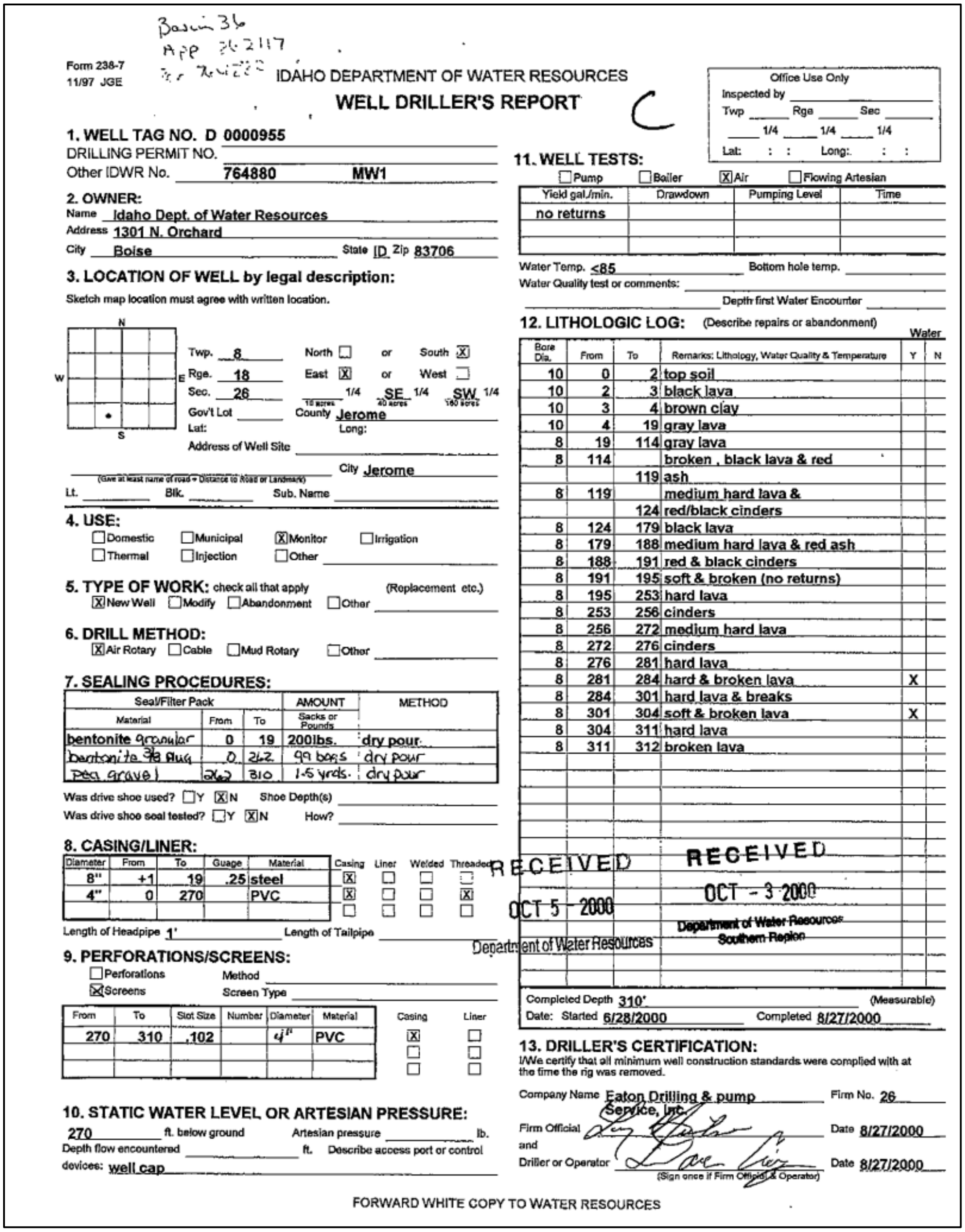
Completed Depth (Measurable): 300'
Date Started: 1/21/2020 Date Completed: 1/28/2020

14. DRILLER'S CERTIFICATION:
I/We certify that all minimum well construction standards were complied with at the time the rig was removed.

Company Name Elsing Drilling & Pump Co Inc Co. No. 669
*Principal Driller ____ Date 1/30/2020
*Driller ____ Date 1/30/2020
*Operator II ____ Date ____
Operator I ____ Date 1/30/2020

*** Signature of Principal Driller and rig operator are required.**

MW2



Basin 36
App 36-2117
[illegible]

Form 238-7
11/97 JGE

IDAHO DEPARTMENT OF WATER RESOURCES

WELL DRILLER'S REPORT

C

Office Use Only
Inspected by ______
Twp ______ Rge ______ Sec ______
______ 1/4 ______ 1/4 ______ 1/4
Lat: : : Long: : :

1. WELL TAG NO. D 0000955
DRILLING PERMIT NO. ______
Other IDWR No. 764880 MW1

2. OWNER:
Name Idaho Dept. of Water Resources
Address 1301 N. Orchard
City Boise State ID Zip 83706

3. LOCATION OF WELL by legal description:
Sketch map location must agree with written location.

Twp. 8 North ☐ or South ☒
Rge. 18 East ☒ or West ☐
Sec. 26 ______ 1/4 (10 acres) SE 1/4 (40 acres) SW 1/4 (160 acres)
Gov't Lot ______ County Jerome
Lat: Long:
Address of Well Site ______
(Give at least name of road + Distance to Road or Landmark) City Jerome
Lt. ______ Blk. ______ Sub. Name ______

4. USE:
☐ Domestic ☐ Municipal ☒ Monitor ☐ Irrigation
☐ Thermal ☐ Injection ☐ Other ______

5. TYPE OF WORK: check all that apply (Replacement etc.)
☒ New Well ☐ Modify ☐ Abandonment ☐ Other ______

6. DRILL METHOD:
☒ Air Rotary ☐ Cable ☐ Mud Rotary ☐ Other ______

7. SEALING PROCEDURES:

Seal/Filter Pack			AMOUNT	METHOD
Material	From	To	Sacks or Pounds	
bentonite granular	0	19	200lbs.	dry pour
bentonite 3/8 plug	0	262	99 bags	dry pour
Pea gravel	262	310	1.5 yrds.	dry pour

Was drive shoe used? ☐ Y ☒ N Shoe Depth(s) ______
Was drive shoe seal tested? ☐ Y ☒ N How? ______

8. CASING/LINER:

Diameter	From	To	Guage	Material	Casing	Liner	Welded	Threaded
8"	+1	19	.25	steel	☒	☐	☐	☐
4"	0	270		PVC	☒	☐	☐	☒
					☐	☐	☐	☐

Length of Headpipe 1' Length of Tailpipe ______

9. PERFORATIONS/SCREENS:
☐ Perforations Method ______
☒ Screens Screen Type ______

From	To	Slot Size	Number	Diameter	Material	Casing	Liner
270	310	.102		4"	PVC	☒	☐
						☐	☐
						☐	☐

10. STATIC WATER LEVEL OR ARTESIAN PRESSURE:
270 ft. below ground Artesian pressure ______ lb.
Depth flow encountered ______ ft. Describe access port or control devices: well cap

11. WELL TESTS:
☐ Pump ☐ Bailer ☒ Air ☐ Flowing Artesian

Yield gal./min.	Drawdown	Pumping Level	Time
no returns			

Water Temp. <85 Bottom hole temp. ______
Water Quality test or comments: ______
Depth first Water Encounter ______

12. LITHOLOGIC LOG: (Describe repairs or abandonment)

Bore Dia.	From	To	Remarks: Lithology, Water Quality & Temperature	Water Y	Water N
10	0	2	top soil		
10	2	3	black lava		
10	3	4	brown clay		
10	4	19	gray lava		
8	19	114	gray lava		
8	114		broken , black lava & red		
		119	ash		
8	119		medium hard lava &		
		124	red/black cinders		
8	124	179	black lava		
8	179	188	medium hard lava & red ash		
8	188	191	red & black cinders		
8	191	195	soft & broken (no returns)		
8	195	253	hard lava		
8	253	256	cinders		
8	256	272	medium hard lava		
8	272	276	cinders		
8	276	281	hard lava		
8	281	284	hard & broken lava	X	
8	284	301	hard lava & breaks		
8	301	304	soft & broken lava	X	
8	304	311	hard lava		
8	311	312	broken lava		

RECEIVED
OCT 5 - 2000
Department of Water Resources

RECEIVED
OCT - 3 2000
Department of Water Resources
Southern Region

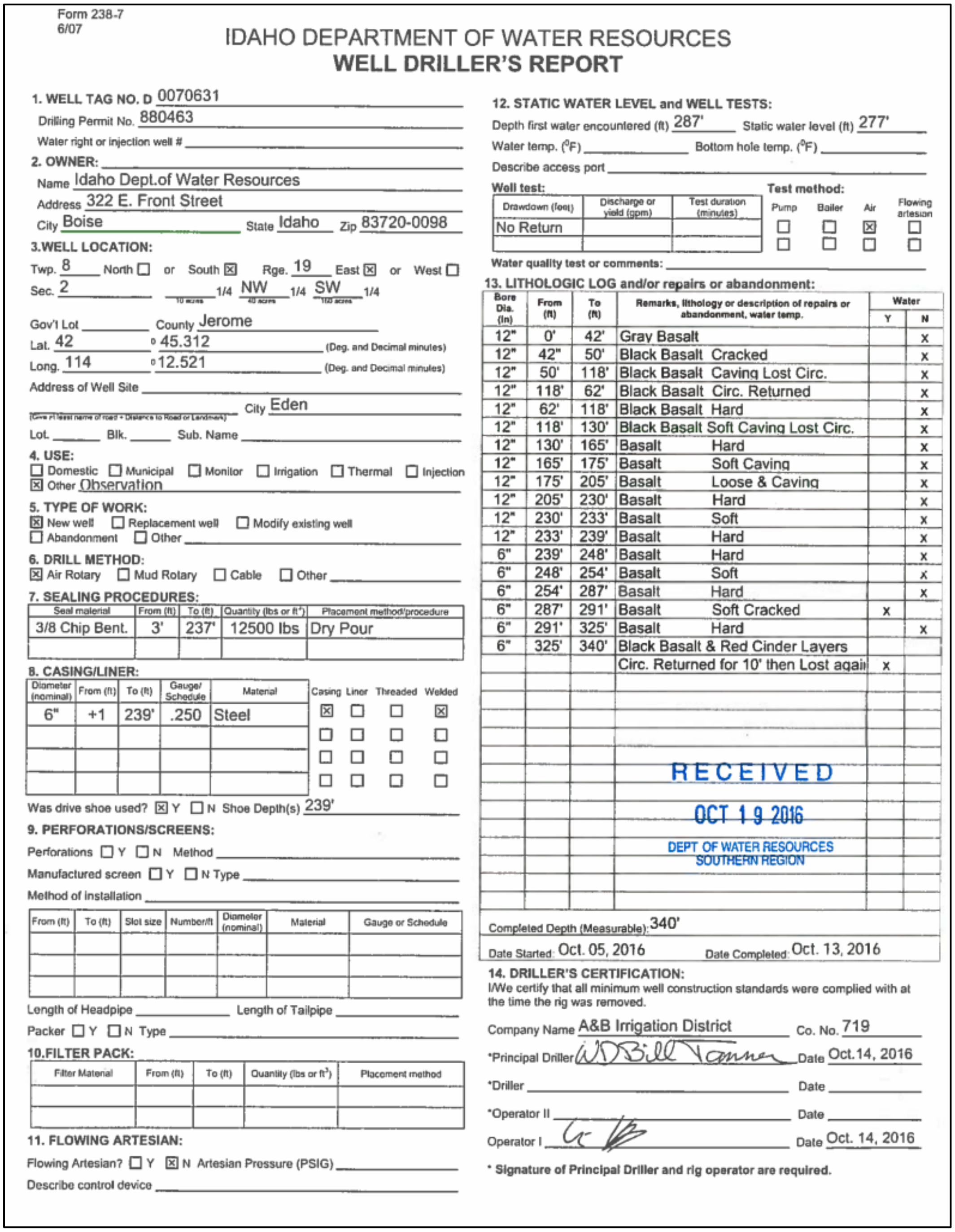
Completed Depth 310' (Measurable)
Date: Started 6/28/2000 Completed 8/27/2000

13. DRILLER'S CERTIFICATION:
I/We certify that all minimum well construction standards were complied with at the time the rig was removed.

Company Name Eaton Drilling & pump Service, Inc. Firm No. 26
Firm Official ______ Date 8/27/2000
and
Driller or Operator ______ Date 8/27/2000
(Sign once if Firm Official & Operator)

FORWARD WHITE COPY TO WATER RESOURCES

East Well



Form 238-7
6/07

IDAHO DEPARTMENT OF WATER RESOURCES
WELL DRILLER'S REPORT

1. WELL TAG NO. D 0070631
Drilling Permit No. 880463
Water right or injection well # ____

2. OWNER:
Name Idaho Dept.of Water Resources
Address 322 E. Front Street
City Boise State Idaho Zip 83720-0098

3.WELL LOCATION:
Twp. 8 North ☐ or South ☒ Rge. 19 East ☒ or West ☐
Sec. 2 ____ 1/4 (10 acres) NW 1/4 (40 acres) SW 1/4 (160 acres)
Gov't Lot ____ County Jerome
Lat. 42 ° 45.312 (Deg. and Decimal minutes)
Long. 114 ° 12.521 (Deg. and Decimal minutes)
Address of Well Site ____
(Give at least name of road + Distance to Road or Landmark) City Eden
Lot. ____ Blk. ____ Sub. Name ____

4. USE:
☐ Domestic ☐ Municipal ☐ Monitor ☐ Irrigation ☐ Thermal ☐ Injection
☒ Other Observation

5. TYPE OF WORK:
☒ New well ☐ Replacement well ☐ Modify existing well
☐ Abandonment ☐ Other ____

6. DRILL METHOD:
☒ Air Rotary ☐ Mud Rotary ☐ Cable ☐ Other ____

7. SEALING PROCEDURES:

Seal material	From (ft)	To (ft)	Quantity (lbs or ft³)	Placement method/procedure
3/8 Chip Bent.	3'	237'	12500 lbs	Dry Pour

8. CASING/LINER:

Diameter (nominal)	From (ft)	To (ft)	Gauge/ Schedule	Material	Casing	Liner	Threaded	Welded
6"	+1	239'	.250	Steel	☒	☐	☐	☒
					☐	☐	☐	☐
					☐	☐	☐	☐
					☐	☐	☐	☐

Was drive shoe used? ☒ Y ☐ N Shoe Depth(s) 239'

9. PERFORATIONS/SCREENS:
Perforations ☐ Y ☐ N Method ____
Manufactured screen ☐ Y ☐ N Type ____
Method of installation ____

From (ft)	To (ft)	Slot size	Number/ft	Diameter (nominal)	Material	Gauge or Schedule

Length of Headpipe ____ Length of Tailpipe ____
Packer ☐ Y ☐ N Type ____

10.FILTER PACK:

Filter Material	From (ft)	To (ft)	Quantity (lbs or ft³)	Placement method

11. FLOWING ARTESIAN:
Flowing Artesian? ☐ Y ☒ N Artesian Pressure (PSIG) ____
Describe control device ____

12. STATIC WATER LEVEL and WELL TESTS:
Depth first water encountered (ft) 287' Static water level (ft) 277'
Water temp. (°F) ____ Bottom hole temp. (°F) ____
Describe access port ____

Well test:

Drawdown (feet)	Discharge or yield (gpm)	Test duration (minutes)
No Return		

Test method:

Pump	Bailer	Air	Flowing artesian
☐	☐	☒	☐
☐	☐	☐	☐

Water quality test or comments: ____

13. LITHOLOGIC LOG and/or repairs or abandonment:

Bore Dia. (in)	From (ft)	To (ft)	Remarks, lithology or description of repairs or abandonment, water temp.	Water Y	Water N
12"	0'	42'	Gray Basalt		x
12"	42"	50'	Black Basalt Cracked		x
12"	50'	118'	Black Basalt Caving Lost Circ.		x
12"	118'	62'	Black Basalt Circ. Returned		x
12"	62'	118'	Black Basalt Hard		x
12"	118'	130'	Black Basalt Soft Caving Lost Circ.		x
12"	130'	165'	Basalt Hard		x
12"	165'	175'	Basalt Soft Caving		x
12"	175'	205'	Basalt Loose & Caving		x
12"	205'	230'	Basalt Hard		x
12"	230'	233'	Basalt Soft		x
12"	233'	239'	Basalt Hard		x
6"	239'	248'	Basalt Hard		x
6"	248'	254'	Basalt Soft		x
6"	254'	287'	Basalt Hard		x
6"	287'	291'	Basalt Soft Cracked	x	
6"	291'	325'	Basalt Hard		x
6"	325'	340'	Black Basalt & Red Cinder Layers		
			Circ. Returned for 10' then Lost agai	x	

RECEIVED
OCT 19 2016
DEPT OF WATER RESOURCES
SOUTHERN REGION

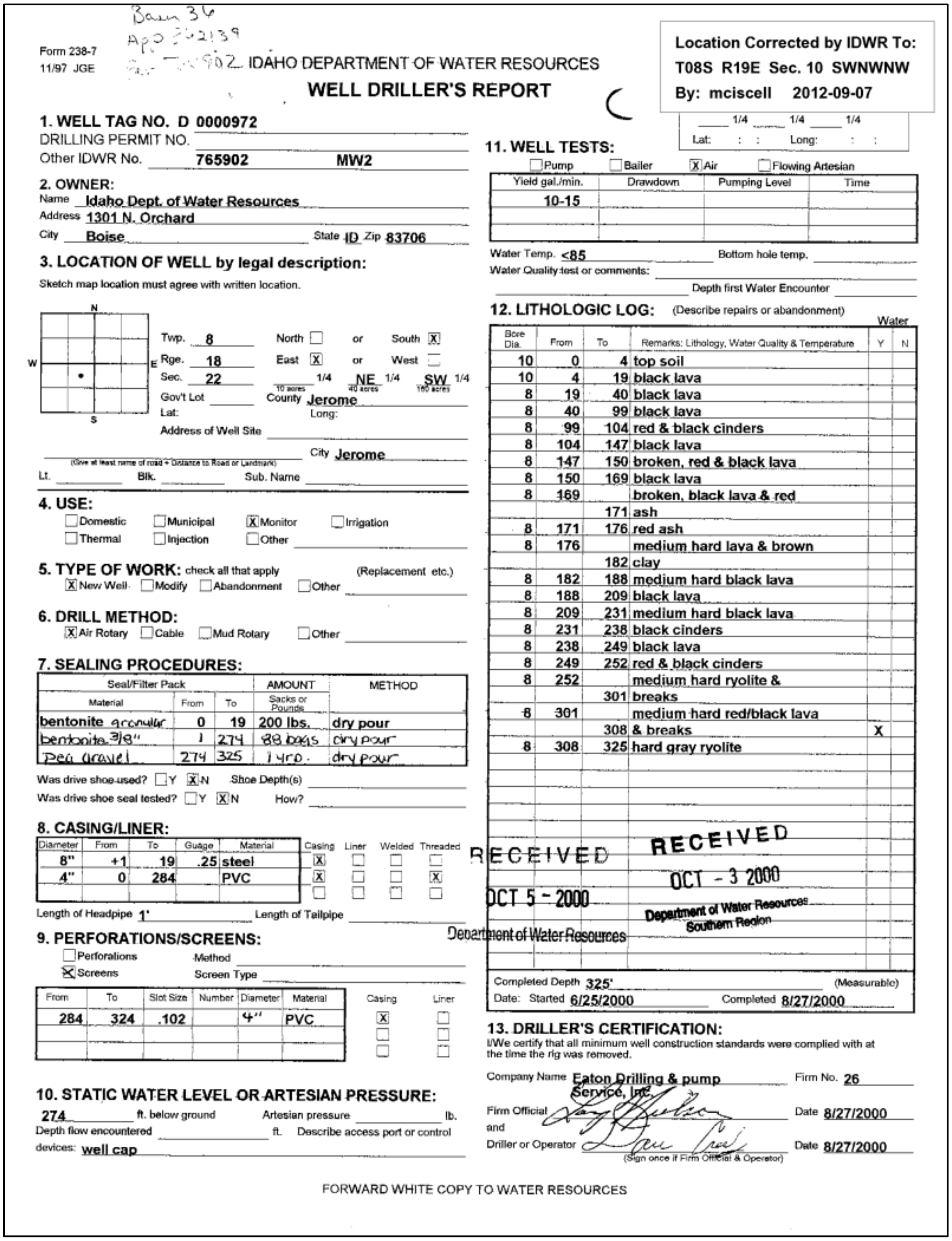
Completed Depth (Measurable): 340'
Date Started: Oct. 05, 2016 Date Completed: Oct. 13, 2016

14. DRILLER'S CERTIFICATION:
I/We certify that all minimum well construction standards were complied with at the time the rig was removed.

Company Name A&B Irrigation District Co. No. 719
*Principal Driller W D Bill Tanner Date Oct.14, 2016
*Driller ____ Date ____
*Operator II ____ Date ____
Operator I ____ Date Oct. 14, 2016

* **Signature of Principal Driller and rig operator are required.**

Central Well



Basin 36
App 36-2139
[illegible] 902

Form 238-7
11/97 JGE

IDAHO DEPARTMENT OF WATER RESOURCES

WELL DRILLER'S REPORT

Location Corrected by IDWR To:
T08S R19E Sec. 10 SWNWNW
By: mciscell 2012-09-07

1. WELL TAG NO. D 0000972
DRILLING PERMIT NO.
Other IDWR No. 765902 MW2

2. OWNER:
Name Idaho Dept. of Water Resources
Address 1301 N. Orchard
City Boise State ID Zip 83706

3. LOCATION OF WELL by legal description:
Sketch map location must agree with written location.

N W E S

Twp. 8 North ☐ or South ☒
Rge. 18 East ☒ or West ☐
Sec. 22 ___ 1/4 NE 1/4 SW 1/4 (10 acres, 40 acres, 160 acres)
Gov't Lot ___ County Jerome
Lat: Long:
Address of Well Site
(Give at least name of road + Distance to Road or Landmark) City Jerome
Lt. ___ Blk. ___ Sub. Name ___

4. USE:
☐ Domestic ☐ Municipal ☒ Monitor ☐ Irrigation
☐ Thermal ☐ Injection ☐ Other

5. TYPE OF WORK: check all that apply (Replacement etc.)
☒ New Well ☐ Modify ☐ Abandonment ☐ Other

6. DRILL METHOD:
☒ Air Rotary ☐ Cable ☐ Mud Rotary ☐ Other

7. SEALING PROCEDURES:

Seal/Filter Pack			AMOUNT	METHOD
Material	From	To	Sacks or Pounds	
bentonite granular	0	19	200 lbs.	dry pour
bentonite 3/8"	1	274	88 bags	dry pour
Pea gravel	274	325	1 yrd.	dry pour

Was drive shoe used? ☐ Y ☒ N Shoe Depth(s)
Was drive shoe seal tested? ☐ Y ☒ N How?

8. CASING/LINER:

Diameter	From	To	Guage	Material	Casing	Liner	Welded	Threaded
8"	+1	19	.25	steel	☒	☐	☐	☐
4"	0	284		PVC	☒	☐	☐	☒
					☐	☐	☐	☐

Length of Headpipe 1' Length of Tailpipe

9. PERFORATIONS/SCREENS:
☐ Perforations Method
☒ Screens Screen Type

From	To	Slot Size	Number	Diameter	Material	Casing	Liner
284	324	.102		4"	PVC	☒	☐
						☐	☐
						☐	☐

10. STATIC WATER LEVEL OR ARTESIAN PRESSURE:
274 ft. below ground Artesian pressure ___ lb.
Depth flow encountered ___ ft. Describe access port or control devices: well cap

11. WELL TESTS:
Lat: : : Long: : :
☐ Pump ☐ Bailer ☒ Air ☐ Flowing Artesian

Yield gal./min.	Drawdown	Pumping Level	Time
10-15			

Water Temp. <85 Bottom hole temp.
Water Quality test or comments:
Depth first Water Encounter

12. LITHOLOGIC LOG: (Describe repairs or abandonment)

Bore Dia.	From	To	Remarks: Lithology, Water Quality & Temperature	Water Y	Water N
10	0	4	top soil		
10	4	19	black lava		
8	19	40	black lava		
8	40	99	black lava		
8	99	104	red & black cinders		
8	104	147	black lava		
8	147	150	broken, red & black lava		
8	150	169	black lava		
8	169		broken, black lava & red		
		171	ash		
8	171	176	red ash		
8	176		medium hard lava & brown		
		182	clay		
8	182	188	medium hard black lava		
8	188	209	black lava		
8	209	231	medium hard black lava		
8	231	238	black cinders		
8	238	249	black lava		
8	249	252	red & black cinders		
8	252		medium hard ryolite &		
		301	breaks		
8	301		medium hard red/black lava		
		308	& breaks	X	
8	308	325	hard gray ryolite		

RECEIVED
OCT 5 - 2000
Department of Water Resources

RECEIVED
OCT - 3 2000
Department of Water Resources
Southern Region

Completed Depth 325' (Measurable)
Date: Started 6/25/2000 Completed 8/27/2000

13. DRILLER'S CERTIFICATION:
I/We certify that all minimum well construction standards were complied with at the time the rig was removed.

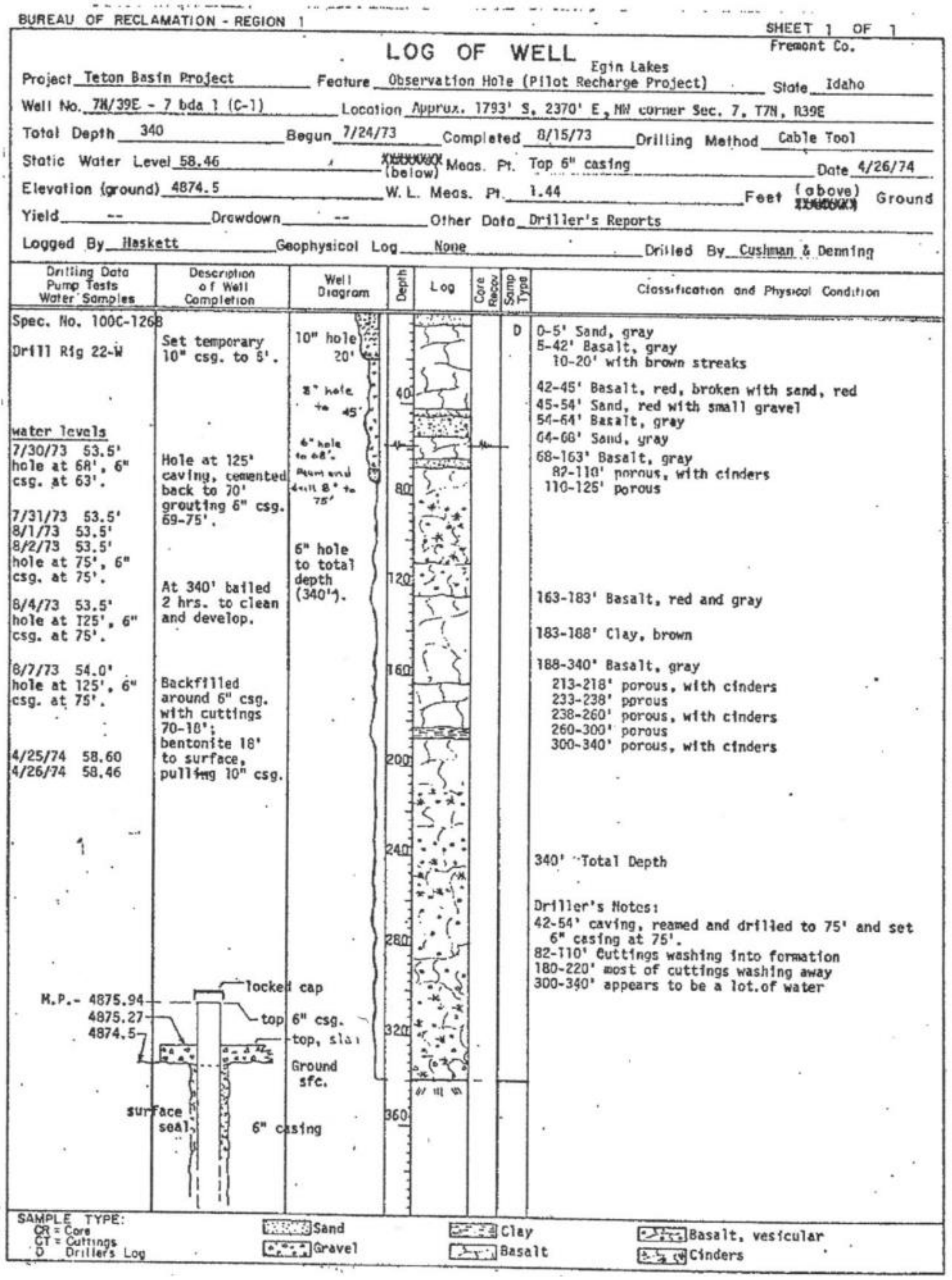
Company Name Eaton Drilling & pump Service, Inc. Firm No. 26
Firm Official Date 8/27/2000
and
Driller or Operator Date 8/27/2000
(Sign once if Firm Official & Operator)

FORWARD WHITE COPY TO WATER RESOURCES

West Well (corrected from MW2 as listed)

Appendix C – 07N 39E 07 BDA1 Well Log

A-2



BUREAU OF RECLAMATION - REGION 1

SHEET 1 OF 1

Fremont Co.

LOG OF WELL

Project Teton Basin Project Feature Observation Hole (Pilot Recharge Project) Egin Lakes State Idaho
Well No. 7N/39E - 7 bda 1 (C-1) Location Approx. 1793' S, 2370' E, NW corner Sec. 7, T7N, R39E
Total Depth 340 Begun 7/24/73 Completed 8/15/73 Drilling Method Cable Tool
Static Water Level 58.46 XXXXXXX (below) Meas. Pt. Top 6" casing Date 4/26/74
Elevation (ground) 4874.5 W. L. Meas. Pt. 1.44 Feet (above) XXXXXX Ground
Yield -- Drawdown -- Other Data Driller's Reports
Logged By Haskett Geophysical Log None Drilled By Cushman & Denning

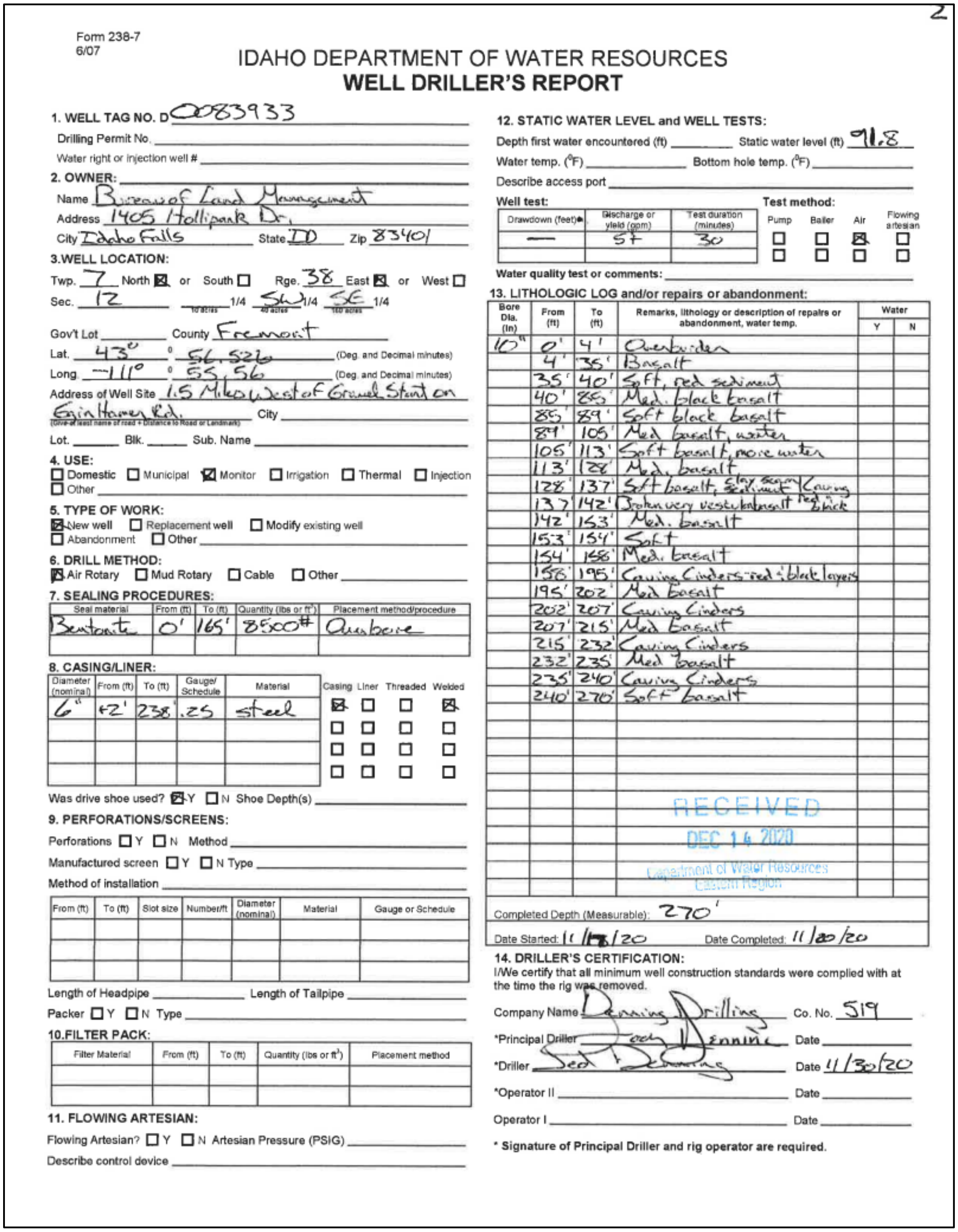
Drilling Data Pump Tests Water Samples	Description of Well Completion	Well Diagram	Samp Type	Classification and Physical Condition
Spec. No. 100C-1268 Drill Rig 22-W	Set temporary 10" csg. to 5'.	10" hole 20' 8" hole to 45' 6" hole to 68'. Ream and drill 8" to 75'	D	0-5' Sand, gray 5-42' Basalt, gray 10-20' with brown streaks 42-45' Basalt, red, broken with sand, red 45-54' Sand, red with small gravel 54-64' Basalt, gray 64-68' Sand, gray 68-163' Basalt, gray 82-110' porous, with cinders 110-125' porous
water levels 7/30/73 53.5' hole at 68', 6" csg. at 63'. 7/31/73 53.5' 8/1/73 53.5' 8/2/73 53.5' hole at 75', 6" csg. at 75'.	Hole at 125' caving, cemented back to 70' grouting 6" csg. 69-75'.	6" hole to total depth (340').		
8/4/73 53.5' hole at 125', 6" csg. at 75'.	At 340' bailed 2 hrs. to clean and develop.			163-183' Basalt, red and gray 183-188' Clay, brown
8/7/73 54.0' hole at 125', 6" csg. at 75'. 4/25/74 58.60 4/26/74 58.46	Backfilled around 6" csg. with cuttings 70-18'; bentonite 18' to surface, pulling 10" csg.			188-340' Basalt, gray 213-218' porous, with cinders 233-238' porous 238-260' porous, with cinders 260-300' porous 300-340' porous, with cinders
				340' Total Depth

Driller's Notes:
42-54' caving, reamed and drilled to 75' and set 6" casing at 75'.
82-110' Cuttings washing into formation
180-220' most of cuttings washing away
300-340' appears to be a lot.of water

SAMPLE TYPE:
CR = Core
CT = Cuttings
D Drillers Log

▨ Sand
▨ Gravel
▨ Clay
▨ Basalt
▨ Basalt, vesicular
▨ Cinders

Appendix D – Combination Alluvial/Basalt Site Deep Well Logs



2

Form 238-7
6/07

IDAHO DEPARTMENT OF WATER RESOURCES
WELL DRILLER'S REPORT

1. WELL TAG NO. D 00839333
Drilling Permit No.
Water right or injection well #

2. OWNER:
Name Bureau of Land Management
Address 1405 Hollipark Dr.
City Idaho Falls State ID Zip 83401

3. WELL LOCATION:
Twp. 7 North ☒ or South ☐ Rge. 38 East ☒ or West ☐
Sec. 12 ___ 1/4 (10 acres) SW 1/4 (40 acres) SE 1/4 (160 acres)
Gov't Lot ___ County Fremont
Lat. 43° 56.526 (Deg. and Decimal minutes)
Long. -111° 55.56 (Deg. and Decimal minutes)
Address of Well Site 1.5 Miles West of Gravel Start on Egin Hamer Rd. (Give at least name of road + Distance to Road or Landmark) City
Lot. ___ Blk. ___ Sub. Name

4. USE:
☐ Domestic ☐ Municipal ☒ Monitor ☐ Irrigation ☐ Thermal ☐ Injection
☐ Other

5. TYPE OF WORK:
☒ New well ☐ Replacement well ☐ Modify existing well
☐ Abandonment ☐ Other

6. DRILL METHOD:
☒ Air Rotary ☐ Mud Rotary ☐ Cable ☐ Other

7. SEALING PROCEDURES:

Seal material	From (ft)	To (ft)	Quantity (lbs or ft³)	Placement method/procedure
Bentonite	0'	165'	8500#	Overbore

8. CASING/LINER:

Diameter (nominal)	From (ft)	To (ft)	Gauge/ Schedule	Material	Casing	Liner	Threaded	Welded
6"	+2'	238'	.25	steel	☒	☐	☐	☒
					☐	☐	☐	☐
					☐	☐	☐	☐
					☐	☐	☐	☐

Was drive shoe used? ☒ Y ☐ N Shoe Depth(s)

9. PERFORATIONS/SCREENS:
Perforations ☐ Y ☐ N Method
Manufactured screen ☐ Y ☐ N Type
Method of installation

From (ft)	To (ft)	Slot size	Number/ft	Diameter (nominal)	Material	Gauge or Schedule

Length of Headpipe ___ Length of Tailpipe
Packer ☐ Y ☐ N Type

10. FILTER PACK:

Filter Material	From (ft)	To (ft)	Quantity (lbs or ft³)	Placement method

11. FLOWING ARTESIAN:
Flowing Artesian? ☐ Y ☐ N Artesian Pressure (PSIG)
Describe control device

12. STATIC WATER LEVEL and WELL TESTS:
Depth first water encountered (ft) ___ Static water level (ft) 91.8
Water temp. (°F) ___ Bottom hole temp. (°F)
Describe access port

Well test:

Drawdown (feet)	Discharge or yield (gpm)	Test duration (minutes)
—	5+	30

Test method:

Pump	Bailer	Air	Flowing artesian
☐	☐	☒	☐
☐	☐	☐	☐

Water quality test or comments:

13. LITHOLOGIC LOG and/or repairs or abandonment:

Bore Dia. (in)	From (ft)	To (ft)	Remarks, lithology or description of repairs or abandonment, water temp.	Water Y	Water N
10"	0'	4'	Overburden		
	4'	35'	Basalt		
	35'	40'	Soft, red sediment		
	40'	85'	Med. black basalt		
	85'	89'	Soft black basalt		
	89'	105'	Med basalt, water		
	105'	113'	Soft basalt, more water		
	113'	128'	Med. basalt		
	128'	137'	Soft basalt, clay seam sediment Caving		
	137'	142'	Broken very vesticular basalt red & black		
	142'	153'	Med. basalt		
	153'	154'	Soft		
	154'	158'	Med. basalt		
	158'	195'	Caving Cinders-red & black layers		
	195'	202'	Med Basalt		
	202'	207'	Caving Cinders		
	207'	215'	Med Basalt		
	215'	232'	Caving Cinders		
	232'	235'	Med basalt		
	235'	240'	Caving Cinders		
	240'	270'	Soft basalt		

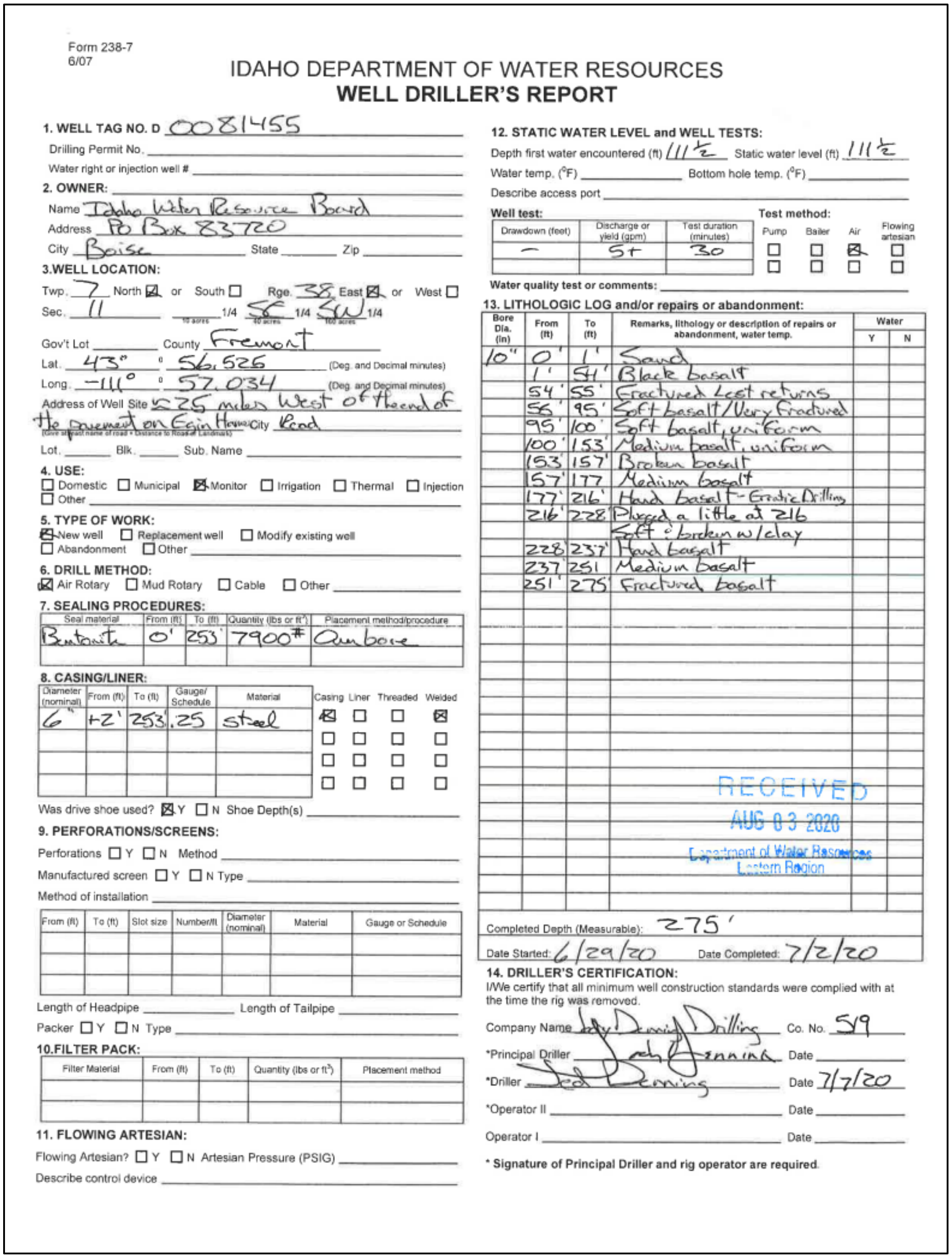
RECEIVED
DEC 14 2020
Department of Water Resources
Eastern Region

Completed Depth (Measurable): 270'
Date Started: 11/18/20 Date Completed: 11/20/20

14. DRILLER'S CERTIFICATION:
I/We certify that all minimum well construction standards were complied with at the time the rig was removed.
Company Name Denning Drilling Co. No. 519
*Principal Driller [illegible] Denning Date
*Driller Jed Denning Date 11/30/20
*Operator II ___ Date
Operator I ___ Date

*** Signature of Principal Driller and rig operator are required.**

Easement Well Deep



Form 238-7
6/07

IDAHO DEPARTMENT OF WATER RESOURCES
WELL DRILLER'S REPORT

1. WELL TAG NO. D 0081455

Drilling Permit No.

Water right or injection well #

2. OWNER:

Name Idaho Water Resource Board

Address PO Box 83720

City Boise State Zip

3.WELL LOCATION:

Twp. 7 North ☑ or South ☐ Rge. 38 East ☒ or West ☐

Sec. 11 1/4 (10 acres) SE 1/4 (40 acres) SW 1/4 (160 acres)

Gov't Lot County Fremont

Lat. 43° ° 56.526 (Deg. and Decimal minutes)

Long. -111° ° 57.034 (Deg. and Decimal minutes)

Address of Well Site ≈ 25 miles West of the end of the pavement on Egin Hamer City Road

(Give at least name of road + Distance to Road or Landmark)

Lot. Blk. Sub. Name

4. USE:

☐ Domestic ☐ Municipal ☒ Monitor ☐ Irrigation ☐ Thermal ☐ Injection
☐ Other

5. TYPE OF WORK:

☒ New well ☐ Replacement well ☐ Modify existing well
☐ Abandonment ☐ Other

6. DRILL METHOD:

☒ Air Rotary ☐ Mud Rotary ☐ Cable ☐ Other

7. SEALING PROCEDURES:

Seal material	From (ft)	To (ft)	Quantity (lbs or ft³)	Placement method/procedure
Bentonite	0'	253'	7900#	Down bore

8. CASING/LINER:

Diameter (nominal)	From (ft)	To (ft)	Gauge/ Schedule	Material	Casing	Liner	Threaded	Welded
6"	+2'	253'	.25	steel	☒	☐	☐	☒
					☐	☐	☐	☐
					☐	☐	☐	☐
					☐	☐	☐	☐

Was drive shoe used? ☒ Y ☐ N Shoe Depth(s)

9. PERFORATIONS/SCREENS:

Perforations ☐ Y ☐ N Method

Manufactured screen ☐ Y ☐ N Type

Method of installation

From (ft)	To (ft)	Slot size	Number/ft	Diameter (nominal)	Material	Gauge or Schedule

Length of Headpipe Length of Tailpipe

Packer ☐ Y ☐ N Type

10.FILTER PACK:

Filter Material	From (ft)	To (ft)	Quantity (lbs or ft³)	Placement method

11. FLOWING ARTESIAN:

Flowing Artesian? ☐ Y ☐ N Artesian Pressure (PSIG)

Describe control device

12. STATIC WATER LEVEL and WELL TESTS:

Depth first water encountered (ft) 111 ½ Static water level (ft) 111 ½

Water temp. (°F) Bottom hole temp. (°F)

Describe access port

Well test:

Drawdown (feet)	Discharge or yield (gpm)	Test duration (minutes)
–	5+	30

Test method:

Pump	Bailer	Air	Flowing artesian
☐	☐	☒	☐
☐	☐	☐	☐

Water quality test or comments:

13. LITHOLOGIC LOG and/or repairs or abandonment:

Bore Dia. (in)	From (ft)	To (ft)	Remarks, lithology or description of repairs or abandonment, water temp.	Water Y	Water N
10"	0'	1'	Sand		
	1'	54'	Black basalt		
	54'	55'	Fractured Lost returns		
	56'	95'	Soft basalt/Very Fractured		
	95'	100'	Soft basalt, uniform		
	100'	153'	Medium basalt, uniform		
	153'	157'	Broken basalt		
	157'	177	Medium basalt		
	177'	216'	Hard basalt - Erratic Drilling		
	216'	228'	Plugged a little at 216		
			Soft & broken w/clay		
	228'	237'	Hard basalt		
	237'	251	Medium basalt		
	251'	275'	Fractured basalt		

RECEIVED
AUG 03 2020
Department of Water Resources
Eastern Region

Completed Depth (Measurable): 275'

Date Started: 6/29/20 Date Completed: 7/2/20

14. DRILLER'S CERTIFICATION:

I/We certify that all minimum well construction standards were complied with at the time the rig was removed.

Company Name Jay Denning Drilling Co. No. 519

*Principal Driller Jack Denning Date

*Driller Jed Denning Date 7/7/20

*Operator II Date

Operator I Date

*** Signature of Principal Driller and rig operator are required.**

West Well Deep

Appendix E – Additional Headgate SC values from the alluvial site – The Jones Pit

Appendix E -- Weekly SC Measurements		
Sample Location	Date	Electrical conductivity
		uS/cm
Headgate at the alluvial site -- The Jones Pit	9/12/2019	253
	9/20/2019	229
	9/27/2019	299
	10/3/2019	290
	10/11/2019	309
	10/17/2019	345
	10/25/2019	347
	10/31/2019	367

Appendix F – Assessment of uncertainties for various constituents, endmember mixing fractions (f_1) and $\sum Cation_{excess}$

The relative uncertainty in the concentrations of groundwater constituents was estimated from seven samplings of the West and MW2 wells (Table 5) at MP29/31 located 5,930 and 6,775 ft (1,810 and 2,065 m) from the basin over a period of 227 days. The composition of water samples from both these wells appeared to be minimally influenced by MAR activities. The relative standard deviations for each constituent as well as that for the sodium adsorption ratio (SAR) and the equivalence base sulfate to chloride ratio calculated for each well are given in Table F.1. The average of the two relative standard deviations for each constituent or ratio was used as an estimate of the relative uncertainties associated with sampling, analytical methods, and spatial variations at a given location (i.e., different locations may have different concentrations on the same date).

Table F.1 -- The relative standard deviations among different constituents and ratios from the West Well and MW2 at the basalt site – MP29/31, and their average which was used to estimate the relative uncertainties associated with repeated samplings.

Constituent/Ratio	Relative Standard Deviation		
	West	MW2	Average
Ca^{2+}	2.8%	2.6%	2.7%
Mg^{2+}	3.0%	4.0%	3.5%
Na^{+}	2.4%	2.1%	2.2%
K^{+}	1.6%	1.1%	1.4%
Cl^{-}	2.6%	2.0%	2.3%
SO_4^{2-}	2.6%	1.9%	2.3%
Alkalinity	2.4%	7.5%	5.0%
SAR	2.5%	2.0%	2.2%
SO_4^{2-}/Cl^{-}	2.4%	2.4%	2.4%

Uncertainties associated with mixing calculations were estimated from a simulated normally distributed random population of 10,200 samples calculated using Microsoft Excel. The simulated sample population had the same mean concentrations as the Scenario 4 (mixing, cation exchange, and calcite precipitation) Jones Pit GWB modeling results for mixture of 50% ambient groundwater and 50% infiltrated surface water and relative standard deviations given in Table F.1The mixing fractions and $[species]_{excess}$ values were then calculated for each of the simulated samples the absolute uncertainties (Table F.2) estimated from the population standard deviations are given in Table F.2.

Table F.2 – Uncertainties for various constituents, endmember mixing fractions (f_1) and $\sum Cation_{excess}$.

	Absolute Uncertainty (±1 St. Dev.)	Units
f_1	0.12	None
Na^+	0.04	meq/L
Ca^{2+}	0.09	meq/L
Mg^{2+}	0.09	meq/L
Alkalinity	0.10	meq/L
$\sum \mathrm{Cation}_{\mathrm{excess}}$	0.12	meq/L

Although the estimated uncertainties are specific to Jones Pit water composition, they are not particularly sensitive to the actual water composition as long as the difference between the concentration of the conserved ion used in the mixing calculations. As such these estimated uncertainties are applicable for all three sites.

Appendix G – Modeling results for the alluvial site – The Jones Pit for Six Scenarios

Scenario 1 -- Mixing								
Carbonate alkalinity	Ca++	Cl-	HCO3-	K+	Mg++	NO3-	Na+	SO4--
meq_acid/l	mmol/l	mmol/l	mmol/l	mmol/l	mmol/l	mmol/l	mmol/l	mmol/l
3.6823246	1.584	0.2331	3.847656	0.05627	0.576	0.02278	0.4143	0.42995
3.6553461	1.575434	0.243031	3.812825	0.056266	0.575956	0.021875	0.422041	0.435069
3.6294205	1.567212	0.252564	3.779388	0.056262	0.575913	0.021005	0.429472	0.439983
3.6045053	1.559318	0.261717	3.747288	0.056258	0.575872	0.020171	0.436607	0.444701
3.5805594	1.551739	0.270503	3.716472	0.056254	0.575833	0.01937	0.443455	0.44923
3.5575438	1.544464	0.278937	3.686889	0.05625	0.575795	0.018601	0.45003	0.453577
3.5354207	1.53748	0.287035	3.658489	0.056246	0.575759	0.017863	0.456342	0.457751
3.5141542	1.530775	0.294808	3.631225	0.056243	0.575725	0.017154	0.462402	0.461758
3.4937098	1.524339	0.302271	3.605051	0.05624	0.575691	0.016474	0.468219	0.465605
3.4740545	1.518159	0.309435	3.579925	0.056237	0.575659	0.015821	0.473803	0.469297
3.4551565	1.512227	0.316312	3.555803	0.056234	0.575629	0.015193	0.479164	0.472843
3.4369857	1.506533	0.322914	3.532646	0.056231	0.575599	0.014592	0.48431	0.476246
3.419513	1.501066	0.329253	3.510416	0.056228	0.575571	0.014014	0.489251	0.479513
3.4027108	1.495818	0.335337	3.489075	0.056225	0.575544	0.013459	0.493994	0.482649
3.3865525	1.490779	0.341179	3.468587	0.056223	0.575518	0.012926	0.498547	0.48566
3.3710127	1.485942	0.346786	3.448919	0.05622	0.575492	0.012415	0.502919	0.488551
3.3560673	1.481299	0.35217	3.430038	0.056218	0.575468	0.011924	0.507115	0.491326
3.3416931	1.476842	0.357338	3.411912	0.056216	0.575445	0.011453	0.511143	0.49399
3.3278678	1.472562	0.362299	3.39451	0.056214	0.575423	0.011001	0.515011	0.496547
3.3145702	1.468454	0.367062	3.377805	0.056212	0.575402	0.010567	0.518724	0.499002
3.3017802	1.46451	0.371634	3.361769	0.05621	0.575382	0.01015	0.522288	0.501359
3.2894781	1.460724	0.376024	3.346373	0.056208	0.575362	0.009749	0.525709	0.503622
3.2776456	1.45709	0.380238	3.331594	0.056206	0.575343	0.009365	0.528994	0.505794
3.2662646	1.4536	0.384283	3.317405	0.056204	0.575325	0.008996	0.532147	0.507879
3.2553182	1.450251	0.388167	3.303784	0.056202	0.575308	0.008642	0.535175	0.509881
3.24479	1.447035	0.391895	3.290708	0.056201	0.575291	0.008303	0.538081	0.511802
3.2346643	1.443948	0.395474	3.278155	0.056199	0.575275	0.007976	0.540871	0.513647
3.2249259	1.440985	0.39891	3.266104	0.056198	0.57526	0.007663	0.543549	0.515418
3.2155605	1.438139	0.402208	3.254535	0.056196	0.575245	0.007362	0.54612	0.517119
3.2065541	1.435408	0.405375	3.243429	0.056195	0.575231	0.007074	0.548588	0.518751
3.1978932	1.432786	0.408415	3.232767	0.056194	0.575217	0.006796	0.550958	0.520318
3.1895651	1.430269	0.411333	3.222532	0.056192	0.575204	0.00653	0.553233	0.521822
3.1815572	1.427853	0.414135	3.212706	0.056191	0.575192	0.006275	0.555417	0.523266
3.1738577	1.425533	0.416824	3.203273	0.05619	0.57518	0.00603	0.557513	0.524652
3.1664551	1.423306	0.419406	3.194217	0.056189	0.575168	0.005794	0.559526	0.525983
3.1593383	1.421168	0.421885	3.185524	0.056188	0.575157	0.005568	0.561458	0.527261
3.1524966	1.419116	0.424264	3.177178	0.056187	0.575146	0.005351	0.563312	0.528487

3.1459197	1.417145	0.426548	3.169166	0.056186	0.575136	0.005143	0.565093	0.529665
3.1395977	1.415254	0.428741	3.161475	0.056185	0.575127	0.004943	0.566802	0.530795
3.133521	1.413438	0.430847	3.154091	0.056184	0.575117	0.004751	0.568443	0.53188
3.1276804	1.411695	0.432868	3.147003	0.056183	0.575108	0.004567	0.570019	0.532922
3.122067	1.410022	0.434808	3.140198	0.056182	0.575099	0.00439	0.571531	0.533922
3.1166722	1.408415	0.43667	3.133665	0.056181	0.575091	0.00422	0.572983	0.534882
3.1114877	1.406873	0.438458	3.127394	0.05618	0.575083	0.004057	0.574377	0.535804
3.1065056	1.405392	0.440175	3.121374	0.05618	0.575075	0.003901	0.575715	0.536689
3.1017182	1.403971	0.441823	3.115594	0.056179	0.575068	0.003751	0.576999	0.537538
3.097118	1.402606	0.443405	3.110045	0.056178	0.575061	0.003606	0.578233	0.538354
3.092698	1.401296	0.444923	3.104719	0.056178	0.575054	0.003468	0.579416	0.539136
3.0884512	1.400039	0.446381	3.099605	0.056177	0.575048	0.003335	0.580553	0.539888
3.0843709	1.398832	0.447781	3.094696	0.056176	0.575041	0.003207	0.581644	0.540609
3.0804509	1.397673	0.449125	3.089984	0.056176	0.575035	0.003085	0.582691	0.541302
3.076685	1.39656	0.450414	3.08546	0.056175	0.57503	0.002967	0.583697	0.541967
3.0730671	1.395492	0.451653	3.081116	0.056175	0.575024	0.002854	0.584662	0.542605
3.0695917	1.394467	0.452841	3.076947	0.056174	0.575019	0.002746	0.585589	0.543218
3.0662531	1.393482	0.453983	3.072944	0.056174	0.575014	0.002642	0.586478	0.543806
3.0630462	1.392537	0.455078	3.069102	0.056173	0.575009	0.002542	0.587332	0.544371
3.0599657	1.39163	0.45613	3.065413	0.056173	0.575004	0.002446	0.588152	0.544913
3.0570068	1.390759	0.45714	3.061872	0.056172	0.575	0.002354	0.588939	0.545433
3.0541648	1.389923	0.458109	3.058472	0.056172	0.574995	0.002266	0.589695	0.545933
3.0514351	1.389121	0.459039	3.055209	0.056171	0.574991	0.002181	0.59042	0.546413
3.0488133	1.38835	0.459933	3.052075	0.056171	0.574987	0.002099	0.591116	0.546873
3.0462953	1.387611	0.46079	3.049068	0.056171	0.574983	0.002021	0.591785	0.547315
3.0438769	1.386901	0.461614	3.04618	0.05617	0.57498	0.001946	0.592426	0.54774
3.0415542	1.386219	0.462404	3.043408	0.05617	0.574976	0.001874	0.593042	0.548147
3.0393236	1.385564	0.463163	3.040747	0.05617	0.574973	0.001805	0.593634	0.548538
3.0371814	1.384936	0.463891	3.038193	0.056169	0.57497	0.001739	0.594202	0.548914
3.0351241	1.384333	0.46459	3.03574	0.056169	0.574966	0.001675	0.594747	0.549274
3.0331485	1.383754	0.465261	3.033386	0.056169	0.574963	0.001614	0.59527	0.54962
3.0312512	1.383198	0.465906	3.031126	0.056168	0.574961	0.001555	0.595772	0.549952
3.0294293	1.382665	0.466525	3.028956	0.056168	0.574958	0.001498	0.596254	0.550271
3.0276797	1.382152	0.467118	3.026873	0.056168	0.574955	0.001444	0.596717	0.550577
3.0259996	1.381661	0.467689	3.024873	0.056168	0.574953	0.001392	0.597162	0.550871
3.0243863	1.381189	0.468236	3.022953	0.056167	0.57495	0.001342	0.597588	0.551153
3.022837	1.380735	0.468761	3.021111	0.056167	0.574948	0.001295	0.597998	0.551424
3.0213494	1.3803	0.469266	3.019341	0.056167	0.574945	0.001249	0.598391	0.551684
3.019921	1.379883	0.46975	3.017643	0.056167	0.574943	0.001204	0.598769	0.551934
3.0185493	1.379482	0.470215	3.016012	0.056167	0.574941	0.001162	0.599131	0.552173
3.0172323	1.379097	0.470661	3.014447	0.056166	0.574939	0.001121	0.599479	0.552403
3.0159676	1.378727	0.47109	3.012945	0.056166	0.574937	0.001082	0.599813	0.552624
3.0147533	1.378372	0.471501	3.011502	0.056166	0.574936	0.001045	0.600134	0.552836

3.0135874	1.378032	0.471896	3.010117	0.056166	0.574934	0.001009	0.600441	0.55304
3.0124678	1.377705	0.472275	3.008788	0.056166	0.574932	0.000974	0.600737	0.553235
3.0113929	1.377391	0.472639	3.007512	0.056166	0.57493	0.000941	0.60102	0.553423
3.0103608	1.37709	0.472988	3.006286	0.056165	0.574929	0.000909	0.601293	0.553603
3.0093698	1.376801	0.473323	3.00511	0.056165	0.574927	0.000879	0.601554	0.553775
3.0084183	1.376523	0.473645	3.003981	0.056165	0.574926	0.000849	0.601805	0.553941
3.0075048	1.376256	0.473954	3.002897	0.056165	0.574925	0.000821	0.602046	0.554101
3.0066276	1.376	0.474251	3.001856	0.056165	0.574923	0.000794	0.602277	0.554254
3.0057855	1.375755	0.474536	3.000857	0.056165	0.574922	0.000768	0.602499	0.5544
3.0049769	1.375519	0.474809	2.999898	0.056165	0.574921	0.000743	0.602712	0.554541
3.0042005	1.375292	0.475072	2.998978	0.056164	0.57492	0.000719	0.602917	0.554677
3.0034551	1.375075	0.475324	2.998094	0.056164	0.574918	0.000696	0.603113	0.554807
3.0027395	1.374866	0.475566	2.997245	0.056164	0.574917	0.000674	0.603302	0.554931
3.0020524	1.374666	0.475798	2.996431	0.056164	0.574916	0.000653	0.603483	0.555051
3.0013927	1.374474	0.476021	2.995649	0.056164	0.574915	0.000633	0.603657	0.555166
3.0007594	1.374289	0.476235	2.994898	0.056164	0.574914	0.000613	0.603824	0.555276
3.0001513	1.374112	0.47644	2.994177	0.056164	0.574913	0.000594	0.603984	0.555382
2.9995675	1.373942	0.476638	2.993485	0.056164	0.574913	0.000576	0.604138	0.555484
2.999007	1.373778	0.476827	2.992821	0.056164	0.574912	0.000559	0.604285	0.555581
2.9984689	1.373622	0.477009	2.992184	0.056164	0.574911	0.000543	0.604427	0.555675
2.9979522	1.373471	0.477183	2.991572	0.056164	0.57491	0.000527	0.604563	0.555765
Scenario 2 -- Mixing and Calcite Precipitation								
Carbonate alkalinity	Ca++	Cl-	HCO3-	K+	Mg++	NO3-	Na+	SO4--
meq_acid/l	mmol/l	mmol/l	mmol/l	mmol/l	mmol/l	mmol/l	mmol/l	mmol/l
3.6823246	1.584	0.2331	3.847656	0.05627	0.576	0.02278	0.4143	0.42995
3.6523582	1.573891	0.243031	3.811282	0.056266	0.575956	0.021875	0.422041	0.435069
3.619642	1.562154	0.252564	3.774331	0.056262	0.575913	0.021005	0.429473	0.439983
3.5881375	1.550839	0.261717	3.738809	0.056258	0.575872	0.020171	0.436607	0.444701
3.5578036	1.539932	0.270503	3.704665	0.056254	0.575833	0.01937	0.443456	0.44923
3.5286004	1.529421	0.278937	3.671846	0.05625	0.575796	0.018601	0.45003	0.453578
3.500489	1.519293	0.287035	3.640302	0.056247	0.575759	0.017863	0.456342	0.457751
3.4734315	1.509535	0.294808	3.609986	0.056243	0.575725	0.017154	0.462402	0.461758
3.4473914	1.500137	0.302271	3.58085	0.05624	0.575692	0.016474	0.468219	0.465605
3.4223328	1.491084	0.309435	3.552851	0.056237	0.57566	0.015821	0.473803	0.469298
3.3982213	1.482367	0.316312	3.525944	0.056234	0.575629	0.015193	0.479164	0.472843
3.3750231	1.473973	0.322915	3.500088	0.056231	0.575599	0.014592	0.484311	0.476246
3.3527057	1.465892	0.329253	3.475244	0.056228	0.575571	0.014014	0.489251	0.479513
3.3312377	1.458113	0.335338	3.451372	0.056225	0.575544	0.013459	0.493995	0.48265
3.3105882	1.450625	0.341179	3.428435	0.056223	0.575518	0.012926	0.498548	0.485661
3.2907279	1.443419	0.346787	3.406398	0.05622	0.575493	0.012415	0.502919	0.488551
3.2716278	1.436485	0.35217	3.385225	0.056218	0.575469	0.011924	0.507116	0.491326

3.2532604	1.429812	0.357338	3.364884	0.056216	0.575446	0.011453	0.511144	0.49399
3.2355988	1.423392	0.3623	3.345343	0.056214	0.575424	0.011001	0.515011	0.496548
3.2186169	1.417216	0.367063	3.32657	0.056212	0.575403	0.010567	0.518724	0.499003
3.2022897	1.411275	0.371635	3.308536	0.05621	0.575382	0.01015	0.522288	0.50136
3.1865929	1.405561	0.376024	3.291212	0.056208	0.575363	0.00975	0.52571	0.503622
3.1715031	1.400065	0.380238	3.274571	0.056206	0.575344	0.009365	0.528995	0.505794
3.1569977	1.394779	0.384284	3.258586	0.056204	0.575326	0.008996	0.532148	0.50788
3.1430547	1.389696	0.388167	3.243232	0.056202	0.575309	0.008642	0.535175	0.509882
3.129653	1.384808	0.391896	3.228484	0.056201	0.575292	0.008303	0.538082	0.511803
3.1167724	1.380109	0.395475	3.214318	0.056199	0.575276	0.007976	0.540871	0.513648
3.1043931	1.37559	0.398911	3.200713	0.056198	0.575261	0.007663	0.54355	0.515419
3.0924962	1.371246	0.402209	3.187645	0.056196	0.575246	0.007362	0.546121	0.51712
3.0810634	1.36707	0.405376	3.175094	0.056195	0.575232	0.007074	0.548589	0.518752
3.070077	1.363056	0.408416	3.16304	0.056194	0.575218	0.006796	0.550959	0.520319
3.0595201	1.359198	0.411334	3.151464	0.056192	0.575205	0.00653	0.553234	0.521823
3.0493762	1.355489	0.414135	3.140345	0.056191	0.575193	0.006275	0.555418	0.523267
3.0396296	1.351925	0.416825	3.129668	0.05619	0.575181	0.00603	0.557514	0.524653
3.030265	1.348499	0.419407	3.119413	0.056189	0.575169	0.005794	0.559527	0.525984
3.0212678	1.345207	0.421885	3.109566	0.056188	0.575158	0.005568	0.561459	0.527262
3.0126238	1.342043	0.424265	3.100109	0.056187	0.575148	0.005351	0.563314	0.528489
3.0043194	1.339003	0.426549	3.091027	0.056186	0.575137	0.005143	0.565094	0.529666
2.9963416	1.336081	0.428742	3.082305	0.056185	0.575128	0.004943	0.566804	0.530796
2.9886777	1.333274	0.430847	3.073931	0.056184	0.575118	0.004751	0.568445	0.531882
2.9813156	1.330577	0.432868	3.065888	0.056183	0.575109	0.004567	0.57002	0.532923
2.9742435	1.327986	0.434809	3.058165	0.056182	0.575101	0.00439	0.571532	0.533923
2.9674503	1.325496	0.436671	3.05075	0.056181	0.575092	0.00422	0.572984	0.534884
2.960925	1.323104	0.438459	3.043629	0.056181	0.575084	0.004057	0.574378	0.535805
2.9546573	1.320806	0.440176	3.036791	0.05618	0.575077	0.003901	0.575716	0.53669
2.9486371	1.318598	0.441824	3.030225	0.056179	0.575069	0.003751	0.577001	0.537539
2.9428548	1.316477	0.443406	3.02392	0.056178	0.575062	0.003606	0.578234	0.538355
2.9373011	1.31444	0.444924	3.017866	0.056178	0.575056	0.003468	0.579418	0.539138
2.931967	1.312483	0.446382	3.012053	0.056177	0.575049	0.003335	0.580554	0.539889
2.9268441	1.310603	0.447782	3.006472	0.056176	0.575043	0.003207	0.581645	0.540611
2.9219239	1.308798	0.449126	3.001112	0.056176	0.575037	0.003085	0.582693	0.541303
2.9171986	1.307063	0.450416	2.995966	0.056175	0.575031	0.002967	0.583698	0.541968
2.9126605	1.305397	0.451654	2.991026	0.056175	0.575026	0.002854	0.584663	0.542606
2.9083023	1.303797	0.452843	2.986281	0.056174	0.57502	0.002746	0.58559	0.543219
2.9041168	1.302261	0.453984	2.981726	0.056174	0.575015	0.002642	0.58648	0.543808
2.9000974	1.300785	0.455079	2.977353	0.056173	0.57501	0.002542	0.587334	0.544372
2.8962375	1.299367	0.456131	2.973154	0.056173	0.575006	0.002446	0.588153	0.544914
2.8925308	1.298006	0.457141	2.969122	0.056172	0.575001	0.002354	0.58894	0.545435
2.8889713	1.296698	0.45811	2.965251	0.056172	0.574997	0.002266	0.589696	0.545934
2.8855531	1.295442	0.459041	2.961534	0.056172	0.574993	0.002181	0.590421	0.546414

2.8822707	1.294236	0.459934	2.957965	0.056171	0.574989	0.002099	0.591118	0.546875
2.8791188	1.293078	0.460792	2.954539	0.056171	0.574985	0.002021	0.591786	0.547317
2.8760922	1.291966	0.461615	2.95125	0.05617	0.574981	0.001946	0.592428	0.547741
2.8731858	1.290898	0.462405	2.948091	0.05617	0.574978	0.001874	0.593044	0.548148
2.8703951	1.289872	0.463164	2.945059	0.05617	0.574974	0.001805	0.593635	0.548539
2.8677154	1.288887	0.463892	2.942148	0.056169	0.574971	0.001739	0.594203	0.548915
2.8651423	1.287941	0.464591	2.939352	0.056169	0.574968	0.001675	0.594748	0.549275
2.8626716	1.287033	0.465263	2.936669	0.056169	0.574965	0.001614	0.595272	0.549621
2.8602992	1.286161	0.465907	2.934092	0.056169	0.574962	0.001555	0.595774	0.549954
2.8580213	1.285323	0.466526	2.931619	0.056168	0.574959	0.001498	0.596256	0.550272
2.8558341	1.284519	0.46712	2.929244	0.056168	0.574957	0.001444	0.596719	0.550579
2.853734	1.283747	0.46769	2.926964	0.056168	0.574954	0.001392	0.597163	0.550872
2.8517176	1.283006	0.468237	2.924775	0.056168	0.574952	0.001342	0.59759	0.551155
2.8497815	1.282294	0.468763	2.922673	0.056167	0.574949	0.001295	0.598	0.551425
2.8479225	1.28161	0.469267	2.920655	0.056167	0.574947	0.001249	0.598393	0.551685
2.8461377	1.280953	0.469751	2.918718	0.056167	0.574945	0.001204	0.59877	0.551935
2.8444239	1.280323	0.470216	2.916858	0.056167	0.574943	0.001162	0.599133	0.552175
2.8427785	1.279718	0.470662	2.915073	0.056167	0.574941	0.001121	0.599481	0.552405
2.8411987	1.279137	0.471091	2.913358	0.056166	0.574939	0.001082	0.599815	0.552626
2.8396819	1.278579	0.471502	2.911713	0.056166	0.574937	0.001045	0.600135	0.552838
2.8382256	1.278043	0.471897	2.910133	0.056166	0.574935	0.001009	0.600443	0.553041
2.8368274	1.277529	0.472276	2.908616	0.056166	0.574934	0.000974	0.600738	0.553236
2.8354849	1.277035	0.47264	2.90716	0.056166	0.574932	0.000941	0.601022	0.553424
2.834196	1.276561	0.472989	2.905761	0.056166	0.57493	0.000909	0.601294	0.553604
2.8329585	1.276105	0.473325	2.904419	0.056165	0.574929	0.000879	0.601556	0.553777
2.8317704	1.275668	0.473647	2.903131	0.056165	0.574927	0.000849	0.601807	0.553943
2.8306297	1.275248	0.473956	2.901893	0.056165	0.574926	0.000821	0.602048	0.554102
2.8295346	1.274846	0.474252	2.900706	0.056165	0.574925	0.000794	0.602279	0.554255
2.8284831	1.274459	0.474537	2.899566	0.056165	0.574923	0.000768	0.602501	0.554402
2.8274737	1.274087	0.474811	2.898471	0.056165	0.574922	0.000743	0.602714	0.554543
2.8265045	1.273731	0.475073	2.89742	0.056165	0.574921	0.000719	0.602919	0.554678
2.825574	1.273388	0.475325	2.896411	0.056164	0.57492	0.000696	0.603115	0.554808
2.8246807	1.273059	0.475567	2.895443	0.056164	0.574919	0.000674	0.603304	0.554933
2.823823	1.272744	0.475799	2.894513	0.056164	0.574918	0.000653	0.603485	0.555053
2.8229996	1.272441	0.476022	2.89362	0.056164	0.574917	0.000633	0.603659	0.555167
2.8222091	1.27215	0.476236	2.892763	0.056164	0.574916	0.000613	0.603825	0.555278
2.8214501	1.27187	0.476442	2.89194	0.056164	0.574915	0.000594	0.603986	0.555384
2.8207215	1.271602	0.476639	2.89115	0.056164	0.574914	0.000576	0.604139	0.555485
2.8200219	1.271345	0.476828	2.890392	0.056164	0.574913	0.000559	0.604287	0.555583
2.8193503	1.271098	0.47701	2.889664	0.056164	0.574912	0.000543	0.604429	0.555677
2.8187056	1.27086	0.477185	2.888965	0.056164	0.574912	0.000527	0.604565	0.555767
Scenario 3 -- Mixing and Cation Exchange								

Carbonate alkalinity	Ca++	Cl-	HCO3-	K+	Mg++	NO3-	Na+	SO4--
meq_acid/l	mmol/l	mmol/l	mmol/l	mmol/l	mmol/l	mmol/l	mmol/l	mmol/l
3.6823246	1.584	0.2331	3.847656	0.05627	0.576	0.02278	0.4143	0.42995
3.6553197	1.579961	0.243031	3.812825	0.056197	0.574551	0.021875	0.415865	0.435069
3.6293684	1.576066	0.252564	3.779388	0.056126	0.573152	0.021005	0.417423	0.439983
3.6044278	1.572307	0.261717	3.747288	0.056057	0.5718	0.020171	0.418974	0.444701
3.580457	1.56868	0.270503	3.716472	0.05599	0.570493	0.01937	0.420517	0.44923
3.5574167	1.56518	0.278937	3.686889	0.055926	0.569231	0.018601	0.422052	0.453577
3.5352695	1.561801	0.287035	3.658489	0.055863	0.568011	0.017863	0.423579	0.457751
3.5139791	1.558541	0.294808	3.631225	0.055803	0.566831	0.017154	0.425099	0.461758
3.493511	1.555392	0.302271	3.605051	0.055744	0.56569	0.016474	0.42661	0.465605
3.4738323	1.552353	0.309435	3.579925	0.055687	0.564586	0.015821	0.428113	0.469297
3.4549112	1.549417	0.316312	3.555803	0.055632	0.563518	0.015193	0.429607	0.472843
3.4367175	1.546582	0.322914	3.532646	0.055579	0.562485	0.014592	0.431093	0.476246
3.4192222	1.543844	0.329253	3.510416	0.055527	0.561484	0.014014	0.43257	0.479513
3.4023977	1.541198	0.335337	3.489075	0.055476	0.560516	0.013459	0.434038	0.482649
3.3862173	1.538641	0.341179	3.468587	0.055427	0.559579	0.012926	0.435497	0.48566
3.3706557	1.536169	0.346786	3.448919	0.05538	0.558671	0.012415	0.436948	0.488551
3.3556889	1.53378	0.35217	3.430038	0.055334	0.557792	0.011924	0.438389	0.491326
3.3412934	1.531471	0.357338	3.411911	0.055289	0.55694	0.011453	0.439822	0.49399
3.3274473	1.529237	0.362299	3.39451	0.055246	0.556115	0.011001	0.441246	0.496547
3.3141293	1.527076	0.367062	3.377805	0.055203	0.555316	0.010567	0.44266	0.499002
3.3013192	1.524985	0.371634	3.361768	0.055163	0.554541	0.01015	0.444066	0.501359
3.2889975	1.522962	0.376024	3.346373	0.055123	0.553791	0.009749	0.445462	0.503622
3.2771457	1.521003	0.380238	3.331593	0.055084	0.553063	0.009365	0.44685	0.505794
3.265746	1.519106	0.384283	3.317405	0.055047	0.552357	0.008996	0.448228	0.507879
3.2547812	1.51727	0.388167	3.303784	0.05501	0.551674	0.008642	0.449597	0.509881
3.2442352	1.51549	0.391895	3.290708	0.054975	0.551011	0.008303	0.450957	0.511802
3.2340921	1.513765	0.395474	3.278155	0.054941	0.550368	0.007976	0.452309	0.513647
3.2243368	1.512094	0.39891	3.266104	0.054908	0.549744	0.007663	0.453651	0.515418
3.214955	1.510473	0.402208	3.254535	0.054875	0.54914	0.007362	0.454984	0.517119
3.2059327	1.508901	0.405375	3.243429	0.054844	0.548554	0.007074	0.456309	0.518751
3.1972565	1.507375	0.408415	3.232767	0.054814	0.547985	0.006796	0.457624	0.520318
3.1889135	1.505895	0.411333	3.222532	0.054785	0.547433	0.00653	0.458931	0.521822
3.1808913	1.504458	0.414135	3.212706	0.054756	0.546899	0.006275	0.460228	0.523266
3.173178	1.503062	0.416824	3.203273	0.054728	0.54638	0.00603	0.461517	0.524652
3.1657622	1.501706	0.419406	3.194217	0.054702	0.545876	0.005794	0.462797	0.525983
3.1586326	1.500388	0.421885	3.185524	0.054676	0.545388	0.005568	0.464068	0.527261
3.1517786	1.499107	0.424264	3.177178	0.054651	0.544914	0.005351	0.46533	0.528487
3.14519	1.497862	0.426548	3.169166	0.054626	0.544454	0.005143	0.466584	0.529665
3.1388567	1.49665	0.428741	3.161475	0.054603	0.544008	0.004943	0.467828	0.530795
3.1327692	1.495472	0.430846	3.154091	0.05458	0.543575	0.004751	0.469064	0.53188

3.1269184	1.494324	0.432867	3.147003	0.054558	0.543155	0.004567	0.470292	0.532922
3.1212952	1.493207	0.434808	3.140198	0.054536	0.542747	0.00439	0.47151	0.533922
3.115891	1.492119	0.43667	3.133665	0.054515	0.542351	0.00422	0.47272	0.534882
3.1106977	1.49106	0.438458	3.127394	0.054495	0.541967	0.004057	0.473921	0.535804
3.1057072	1.490027	0.440175	3.121373	0.054476	0.541593	0.003901	0.475114	0.536689
3.1009119	1.48902	0.441823	3.115594	0.054457	0.541231	0.003751	0.476297	0.537538
3.0963042	1.488038	0.443405	3.110045	0.054439	0.540879	0.003606	0.477472	0.538354
3.091877	1.48708	0.444923	3.104719	0.054421	0.540537	0.003468	0.478639	0.539136
3.0876235	1.486146	0.446381	3.099605	0.054404	0.540205	0.003335	0.479797	0.539888
3.0835371	1.485233	0.447781	3.094696	0.054388	0.539883	0.003207	0.480946	0.540609
3.0796112	1.484343	0.449125	3.089983	0.054372	0.539569	0.003085	0.482087	0.541302
3.0758397	1.483473	0.450414	3.085459	0.054357	0.539265	0.002967	0.483219	0.541967
3.0722167	1.482624	0.451653	3.081116	0.054342	0.538969	0.002854	0.484342	0.542605
3.0687365	1.481793	0.452841	3.076947	0.054327	0.538681	0.002746	0.485457	0.543218
3.0653935	1.480982	0.453983	3.072944	0.054314	0.538402	0.002642	0.486563	0.543806
3.0621825	1.480188	0.455078	3.069102	0.0543	0.53813	0.002542	0.487661	0.544371
3.0590983	1.479412	0.45613	3.065413	0.054287	0.537866	0.002446	0.488751	0.544913
3.056136	1.478653	0.45714	3.061872	0.054275	0.537609	0.002354	0.489832	0.545433
3.0532908	1.47791	0.458109	3.058472	0.054262	0.537359	0.002266	0.490904	0.545933
3.0505583	1.477183	0.459039	3.055208	0.054251	0.537115	0.002181	0.491968	0.546413
3.047934	1.476471	0.459933	3.052075	0.054239	0.536879	0.002099	0.493024	0.546873
3.0454137	1.475773	0.46079	3.049067	0.054228	0.536648	0.002021	0.494071	0.547315
3.0429933	1.47509	0.461614	3.04618	0.054218	0.536424	0.001946	0.49511	0.54774
3.0406689	1.474421	0.462404	3.043408	0.054208	0.536206	0.001874	0.49614	0.548147
3.0384368	1.473765	0.463163	3.040747	0.054198	0.535994	0.001805	0.497162	0.548538
3.0362933	1.473122	0.463891	3.038192	0.054188	0.535787	0.001739	0.498176	0.548913
3.0342351	1.472491	0.46459	3.03574	0.054179	0.535586	0.001675	0.499182	0.549274
3.0322586	1.471872	0.465261	3.033385	0.05417	0.535389	0.001614	0.50018	0.54962
3.0303608	1.471265	0.465906	3.031125	0.054161	0.535198	0.001555	0.501169	0.549952
3.0285384	1.47067	0.466524	3.028955	0.054153	0.535012	0.001498	0.50215	0.550271
3.0267887	1.470085	0.467118	3.026872	0.054145	0.534831	0.001444	0.503123	0.550577
3.0251086	1.469511	0.467688	3.024873	0.054137	0.534654	0.001392	0.504088	0.550871
3.0234954	1.468947	0.468236	3.022953	0.05413	0.534482	0.001342	0.505045	0.551153
3.0219466	1.468394	0.468761	3.02111	0.054123	0.534314	0.001295	0.505994	0.551424
3.0204595	1.46785	0.469266	3.019341	0.054116	0.53415	0.001249	0.506935	0.551684
3.0190317	1.467315	0.46975	3.017643	0.054109	0.53399	0.001204	0.507867	0.551934
3.0176609	1.46679	0.470215	3.016012	0.054103	0.533834	0.001162	0.508793	0.552173
3.0163448	1.466273	0.470661	3.014447	0.054096	0.533682	0.001121	0.50971	0.552403
3.0150812	1.465765	0.471089	3.012944	0.05409	0.533534	0.001082	0.510619	0.552624
3.0138682	1.465266	0.471501	3.011502	0.054085	0.533389	0.001045	0.511521	0.552836
3.0127036	1.464774	0.471896	3.010117	0.054079	0.533248	0.001009	0.512415	0.55304
3.0115855	1.464291	0.472275	3.008787	0.054074	0.53311	0.000974	0.513301	0.553235
3.0105122	1.463815	0.472639	3.007511	0.054069	0.532975	0.000941	0.514179	0.553422

3.0094818	1.463347	0.472988	3.006286	0.054064	0.532844	0.000909	0.51505	0.553603
3.0084926	1.462886	0.473323	3.00511	0.054059	0.532716	0.000879	0.515913	0.553775
3.007543	1.462432	0.473645	3.003981	0.054054	0.53259	0.000849	0.516769	0.553941
3.0066314	1.461985	0.473954	3.002897	0.05405	0.532468	0.000821	0.517618	0.554101
3.0057564	1.461544	0.474251	3.001856	0.054045	0.532348	0.000794	0.518459	0.554254
3.0049163	1.46111	0.474536	3.000857	0.054041	0.532231	0.000768	0.519292	0.5544
3.00411	1.460683	0.474809	2.999898	0.054037	0.532117	0.000743	0.520118	0.554541
3.0033359	1.460262	0.475072	2.998977	0.054033	0.532006	0.000719	0.520937	0.554677
3.0025929	1.459846	0.475324	2.998093	0.05403	0.531896	0.000696	0.521749	0.554807
3.0018797	1.459437	0.475566	2.997245	0.054026	0.53179	0.000674	0.522553	0.554931
3.0011951	1.459033	0.475798	2.99643	0.054023	0.531686	0.000653	0.523351	0.555051
3.000538	1.458635	0.476021	2.995648	0.05402	0.531584	0.000633	0.524141	0.555166
2.9999073	1.458243	0.476235	2.994898	0.054016	0.531484	0.000613	0.524924	0.555276
2.9993018	1.457856	0.47644	2.994177	0.054013	0.531386	0.000594	0.5257	0.555382
2.9987207	1.457474	0.476638	2.993485	0.054011	0.531291	0.000576	0.52647	0.555484
2.998163	1.457097	0.476827	2.992821	0.054008	0.531198	0.000559	0.527232	0.555581
2.9976276	1.456725	0.477009	2.992183	0.054005	0.531107	0.000543	0.527988	0.555675
2.9971138	1.456357	0.477183	2.991571	0.054003	0.531017	0.000527	0.528736	0.555765
Scenario 4 -- Mixing, cation exchange, and calcite precipitation								
Carbonate alkalinity	Ca++	Cl-	HCO3-	K+	Mg++	NO3-	Na+	SO4--
meq_acid/l	mmol/l	mmol/l	mmol/l	mmol/l	mmol/l	mmol/l	mmol/l	mmol/l
3.6823246	1.584	0.2331	3.847656	0.05627	0.576	0.02278	0.4143	0.42995
3.6514762	1.578526	0.243031	3.810842	0.056176	0.574072	0.021875	0.415747	0.435069
3.6178369	1.57175	0.252564	3.773428	0.056064	0.571715	0.021005	0.417068	0.439983
3.5854701	1.565197	0.261717	3.737475	0.055956	0.569438	0.020171	0.41839	0.444701
3.5543306	1.558862	0.270503	3.702926	0.055852	0.567238	0.01937	0.419711	0.44923
3.5243746	1.552736	0.278937	3.669729	0.05575	0.565113	0.018601	0.421033	0.453578
3.4955596	1.546813	0.287035	3.637832	0.055653	0.56306	0.017863	0.422355	0.457751
3.4678445	1.541087	0.294808	3.607185	0.055558	0.561078	0.017154	0.423676	0.461758
3.4411894	1.535552	0.302271	3.57774	0.055467	0.559163	0.016474	0.424997	0.465605
3.415556	1.530201	0.309435	3.54945	0.055379	0.557315	0.015821	0.426317	0.469298
3.3909068	1.525028	0.316312	3.522272	0.055294	0.55553	0.015193	0.427637	0.472843
3.3672058	1.520028	0.322915	3.496163	0.055212	0.553807	0.014592	0.428955	0.476246
3.3444181	1.515194	0.329253	3.471081	0.055132	0.552144	0.014014	0.430272	0.479513
3.3225101	1.510522	0.335338	3.446986	0.055056	0.550538	0.013459	0.431587	0.48265
3.3014491	1.506006	0.341179	3.423841	0.054982	0.548988	0.012926	0.432901	0.485661
3.2812037	1.50164	0.346787	3.401608	0.05491	0.547491	0.012415	0.434213	0.488551
3.2617435	1.497419	0.35217	3.380253	0.054841	0.546047	0.011924	0.435522	0.491326
3.2430391	1.493339	0.357338	3.35974	0.054775	0.544653	0.011453	0.43683	0.49399
3.2250622	1.489395	0.3623	3.340038	0.054711	0.543307	0.011001	0.438134	0.496548
3.2077854	1.485581	0.367063	3.321115	0.054649	0.542008	0.010567	0.439436	0.499003

3.1911824	1.481894	0.371635	3.30294	0.054589	0.540755	0.01015	0.440735	0.50136
3.1752276	1.478329	0.376025	3.285485	0.054532	0.539545	0.00975	0.442031	0.503622
3.1598966	1.474882	0.380238	3.26872	0.054476	0.538377	0.009365	0.443323	0.505794
3.1451657	1.471548	0.384284	3.25262	0.054423	0.53725	0.008996	0.444612	0.50788
3.131012	1.468323	0.388167	3.237158	0.054371	0.536162	0.008642	0.445897	0.509882
3.1174135	1.465205	0.391896	3.222308	0.054321	0.535112	0.008303	0.447178	0.511803
3.104349	1.462188	0.395475	3.208048	0.054273	0.534098	0.007976	0.448455	0.513648
3.0917981	1.45927	0.398911	3.194354	0.054227	0.533119	0.007663	0.449727	0.515419
3.079741	1.456446	0.402209	3.181204	0.054183	0.532175	0.007362	0.450995	0.51712
3.0681588	1.453714	0.405376	3.168576	0.05414	0.531263	0.007074	0.452258	0.518752
3.0570333	1.45107	0.408416	3.15645	0.054098	0.530383	0.006796	0.453517	0.520319
3.0463467	1.448511	0.411334	3.144806	0.054059	0.529533	0.00653	0.45477	0.521823
3.0360822	1.446034	0.414135	3.133625	0.05402	0.528713	0.006275	0.456018	0.523267
3.0262235	1.443636	0.416825	3.122889	0.053983	0.527921	0.00603	0.457261	0.524653
3.0167548	1.441314	0.419407	3.11258	0.053947	0.527156	0.005794	0.458499	0.525984
3.007661	1.439065	0.421885	3.102682	0.053913	0.526417	0.005568	0.459731	0.527262
2.9989276	1.436887	0.424265	3.093178	0.05388	0.525704	0.005351	0.460957	0.528489
2.9905405	1.434778	0.426549	3.084053	0.053848	0.525015	0.005143	0.462177	0.529666
2.9824862	1.432734	0.428742	3.075291	0.053817	0.52435	0.004943	0.463392	0.530796
2.9747519	1.430753	0.430847	3.066879	0.053788	0.523707	0.004751	0.4646	0.531882
2.9673249	1.428834	0.432868	3.058802	0.053759	0.523087	0.004567	0.465802	0.532923
2.9601934	1.426973	0.434809	3.051048	0.053732	0.522487	0.00439	0.466998	0.533923
2.9533457	1.42517	0.436671	3.043603	0.053706	0.521908	0.00422	0.468188	0.534884
2.9467707	1.42342	0.438459	3.036455	0.05368	0.521348	0.004057	0.469371	0.535805
2.9404579	1.421724	0.440176	3.029593	0.053656	0.520807	0.003901	0.470547	0.53669
2.9343968	1.420078	0.441824	3.023005	0.053632	0.520285	0.003751	0.471717	0.537539
2.9285776	1.418481	0.443406	3.01668	0.05361	0.51978	0.003606	0.47288	0.538355
2.9229907	1.416932	0.444924	3.010608	0.053588	0.519291	0.003468	0.474036	0.539138
2.9176272	1.415428	0.446382	3.004778	0.053567	0.51882	0.003335	0.475185	0.539889
2.9124781	1.413968	0.447782	2.999182	0.053547	0.518363	0.003207	0.476327	0.540611
2.9075351	1.41255	0.449126	2.99381	0.053527	0.517922	0.003085	0.477462	0.541303
2.90279	1.411172	0.450416	2.988653	0.053509	0.517496	0.002967	0.47859	0.541968
2.898235	1.409834	0.451654	2.983702	0.053491	0.517083	0.002854	0.479711	0.542606
2.8938626	1.408534	0.452843	2.97895	0.053473	0.516685	0.002746	0.480825	0.543219
2.8896656	1.407271	0.453984	2.974388	0.053457	0.516299	0.002642	0.481931	0.543808
2.8856371	1.406042	0.455079	2.970008	0.053441	0.515926	0.002542	0.483031	0.544372
2.8817704	1.404848	0.456131	2.965804	0.053425	0.515565	0.002446	0.484122	0.544914
2.8780591	1.403686	0.457141	2.961769	0.053411	0.515215	0.002354	0.485207	0.545435
2.874497	1.402556	0.45811	2.957895	0.053396	0.514877	0.002266	0.486284	0.545934
2.8710783	1.401456	0.459041	2.954177	0.053383	0.51455	0.002181	0.487354	0.546414
2.8677973	1.400386	0.459934	2.950608	0.05337	0.514234	0.002099	0.488416	0.546875
2.8646485	1.399344	0.460792	2.947183	0.053357	0.513927	0.002021	0.489471	0.547317
2.8616266	1.398329	0.461615	2.943894	0.053345	0.513631	0.001946	0.490518	0.547741

2.8587267	1.397341	0.462405	2.940738	0.053333	0.513343	0.001874	0.491558	0.548148
2.8559438	1.396378	0.463164	2.937709	0.053322	0.513065	0.001805	0.49259	0.548539
2.8532734	1.395439	0.463892	2.934801	0.053311	0.512796	0.001739	0.493615	0.548915
2.8507109	1.394525	0.464591	2.932011	0.053301	0.512535	0.001675	0.494632	0.549275
2.8482521	1.393633	0.465263	2.929332	0.053291	0.512282	0.001614	0.495642	0.549621
2.8458929	1.392763	0.465907	2.926761	0.053282	0.512037	0.001555	0.496644	0.549954
2.8436293	1.391915	0.466526	2.924294	0.053273	0.5118	0.001498	0.497638	0.550272
2.8414574	1.391087	0.46712	2.921926	0.053264	0.51157	0.001444	0.498625	0.550579
2.8393736	1.390279	0.46769	2.919653	0.053256	0.511347	0.001392	0.499605	0.550872
2.8373745	1.38949	0.468237	2.917472	0.053248	0.511131	0.001342	0.500577	0.551155
2.8354566	1.38872	0.468763	2.915379	0.05324	0.510922	0.001295	0.501541	0.551425
2.8336167	1.387967	0.469267	2.91337	0.053233	0.510719	0.001249	0.502498	0.551685
2.8318517	1.387232	0.469751	2.911442	0.053226	0.510522	0.001204	0.503448	0.551935
2.8301586	1.386514	0.470216	2.909592	0.053219	0.510331	0.001162	0.50439	0.552175
2.8285345	1.385812	0.470662	2.907817	0.053213	0.510146	0.001121	0.505324	0.552405
2.8269768	1.385125	0.471091	2.906113	0.053206	0.509967	0.001082	0.506251	0.552626
2.8254826	1.384453	0.471502	2.904478	0.053201	0.509792	0.001045	0.507171	0.552838
2.8240495	1.383796	0.471897	2.902909	0.053195	0.509623	0.001009	0.508083	0.553041
2.8226751	1.383154	0.472276	2.901403	0.05319	0.50946	0.000974	0.508988	0.553236
2.8213569	1.382524	0.47264	2.899959	0.053185	0.5093	0.000941	0.509886	0.553424
2.8200928	1.381908	0.472989	2.898573	0.05318	0.509146	0.000909	0.510776	0.553604
2.8188806	1.381305	0.473325	2.897242	0.053175	0.508996	0.000879	0.511659	0.553777
2.8177182	1.380714	0.473646	2.895966	0.053171	0.508851	0.000849	0.512535	0.553943
2.8166036	1.380135	0.473956	2.894742	0.053166	0.508709	0.000821	0.513403	0.554102
2.8155349	1.379568	0.474252	2.893567	0.053162	0.508572	0.000794	0.514264	0.554255
2.8145103	1.379011	0.474537	2.89244	0.053159	0.508439	0.000768	0.515119	0.554402
2.813528	1.378466	0.474811	2.891358	0.053155	0.50831	0.000743	0.515965	0.554543
2.8125862	1.377931	0.475073	2.89032	0.053152	0.508184	0.000719	0.516805	0.554678
2.8116834	1.377406	0.475325	2.889325	0.053149	0.508062	0.000696	0.517638	0.554808
2.810818	1.376892	0.475567	2.88837	0.053146	0.507944	0.000674	0.518464	0.554933
2.8099886	1.376386	0.475799	2.887454	0.053143	0.507829	0.000653	0.519283	0.555053
2.8091935	1.37589	0.476022	2.886575	0.05314	0.507717	0.000633	0.520094	0.555167
2.8084316	1.375403	0.476236	2.885732	0.053137	0.507608	0.000613	0.520899	0.555278
2.8077014	1.374925	0.476442	2.884923	0.053135	0.507502	0.000594	0.521697	0.555384
2.8070017	1.374455	0.476639	2.884148	0.053133	0.5074	0.000576	0.522488	0.555485
2.8063312	1.373993	0.476828	2.883403	0.053131	0.5073	0.000559	0.523273	0.555583
2.8056888	1.373539	0.47701	2.88269	0.053129	0.507203	0.000543	0.52405	0.555677
2.8050733	1.373093	0.477185	2.882005	0.053127	0.507109	0.000527	0.524821	0.555767
Scenario 5 -- Mixing and Cation Exchange * 10								
Carbonate alkalinity	Ca++	Cl-	HCO3-	K+	Mg++	NO3-	Na+	SO4--

meq_acid/l	mmol/l	mmol/l	mmol/l	mmol/l	mmol/l	mmol/l	mmol/l	mmol/l
3.6823246	1.584	0.2331	3.847656	0.05627	0.576	0.02278	0.4143	0.42995
3.6553143	1.580657	0.243031	3.812825	0.056204	0.574747	0.021875	0.414075	0.435069
3.6293575	1.577449	0.252564	3.779388	0.056141	0.57354	0.021005	0.413866	0.439983
3.6044114	1.574368	0.261717	3.747288	0.05608	0.572378	0.020171	0.413672	0.444701
3.580435	1.571412	0.270503	3.716472	0.05602	0.571258	0.01937	0.413494	0.44923
3.557389	1.568573	0.278937	3.686889	0.055963	0.57018	0.018601	0.413329	0.453577
3.5352359	1.565849	0.287035	3.658489	0.055908	0.569141	0.017863	0.413178	0.457751
3.5139396	1.563234	0.294808	3.631225	0.055854	0.568141	0.017154	0.41304	0.461758
3.4934655	1.560725	0.302271	3.605051	0.055802	0.567176	0.016474	0.412915	0.465605
3.4737806	1.558316	0.309435	3.579925	0.055752	0.566246	0.015821	0.412801	0.469297
3.4548532	1.556003	0.316312	3.555803	0.055703	0.56535	0.015193	0.4127	0.472843
3.4366531	1.553784	0.322914	3.532646	0.055656	0.564486	0.014592	0.412609	0.476246
3.4191513	1.551654	0.329253	3.510416	0.05561	0.563652	0.014014	0.412529	0.479513
3.4023201	1.54961	0.335337	3.489075	0.055566	0.562848	0.013459	0.412459	0.482649
3.3861329	1.547648	0.341179	3.468587	0.055523	0.562073	0.012926	0.412399	0.48566
3.3705645	1.545764	0.346786	3.448919	0.055482	0.561325	0.012415	0.412349	0.488551
3.3555906	1.543956	0.35217	3.430038	0.055442	0.560603	0.011924	0.412307	0.491326
3.3411881	1.542221	0.357338	3.411912	0.055403	0.559907	0.011453	0.412275	0.49399
3.3273348	1.540555	0.362299	3.394511	0.055365	0.559235	0.011001	0.412251	0.496547
3.3140096	1.538956	0.367062	3.377805	0.055328	0.558586	0.010567	0.412236	0.499002
3.3011921	1.53742	0.371634	3.361769	0.055293	0.55796	0.01015	0.412228	0.501359
3.288863	1.535946	0.376024	3.346373	0.055258	0.557355	0.009749	0.412229	0.503622
3.2770037	1.53453	0.380238	3.331594	0.055225	0.556772	0.009365	0.412237	0.505794
3.2655964	1.53317	0.384283	3.317405	0.055192	0.556209	0.008996	0.412252	0.507879
3.254624	1.531864	0.388167	3.303784	0.055161	0.555666	0.008642	0.412274	0.509881
3.2440703	1.530609	0.391895	3.290708	0.055131	0.555141	0.008303	0.412304	0.511802
3.2339195	1.529403	0.395474	3.278155	0.055101	0.554634	0.007976	0.412339	0.513647
3.2241566	1.528245	0.39891	3.266104	0.055073	0.554145	0.007663	0.412382	0.515418
3.2147671	1.527132	0.402208	3.254535	0.055045	0.553673	0.007362	0.412431	0.517119
3.205737	1.526061	0.405375	3.243429	0.055018	0.553217	0.007074	0.412486	0.518751
3.1970531	1.525032	0.408415	3.232767	0.054992	0.552778	0.006796	0.412547	0.520318
3.1887023	1.524043	0.411333	3.222532	0.054967	0.552353	0.00653	0.412614	0.521822
3.1806724	1.523091	0.414135	3.212706	0.054943	0.551943	0.006275	0.412686	0.523266
3.1729515	1.522175	0.416824	3.203273	0.054919	0.551547	0.00603	0.412765	0.524652
3.1655279	1.521294	0.419406	3.194217	0.054897	0.551165	0.005794	0.412848	0.525983
3.1583906	1.520446	0.421885	3.185524	0.054875	0.550796	0.005568	0.412937	0.527261
3.151529	1.51963	0.424264	3.177178	0.054853	0.55044	0.005351	0.41303	0.528487
3.1449327	1.518843	0.426548	3.169166	0.054833	0.550097	0.005143	0.413129	0.529665
3.1385918	1.518086	0.428741	3.161475	0.054813	0.549765	0.004943	0.413233	0.530795
3.1324968	1.517357	0.430847	3.154091	0.054793	0.549445	0.004751	0.413341	0.53188
3.1266384	1.516654	0.432868	3.147003	0.054775	0.549136	0.004567	0.413453	0.532922
3.1210077	1.515977	0.434808	3.140198	0.054757	0.548837	0.00439	0.41357	0.533922

3.1155961	1.515324	0.43667	3.133665	0.054739	0.548549	0.00422	0.413691	0.534882
3.1103954	1.514694	0.438458	3.127394	0.054723	0.548271	0.004057	0.413816	0.535804
3.1053976	1.514087	0.440175	3.121374	0.054706	0.548003	0.003901	0.413945	0.536689
3.1005949	1.5135	0.441823	3.115594	0.054691	0.547743	0.003751	0.414078	0.537538
3.09598	1.512935	0.443405	3.110045	0.054675	0.547493	0.003606	0.414215	0.538354
3.0915457	1.512389	0.444923	3.104719	0.054661	0.547251	0.003468	0.414355	0.539136
3.0872851	1.511861	0.446381	3.099605	0.054646	0.547018	0.003335	0.414499	0.539888
3.0831915	1.511352	0.447781	3.094696	0.054633	0.546792	0.003207	0.414646	0.540609
3.0792587	1.51086	0.449125	3.089984	0.05462	0.546574	0.003085	0.414796	0.541302
3.0754803	1.510384	0.450414	3.08546	0.054607	0.546364	0.002967	0.414949	0.541967
3.0718504	1.509924	0.451653	3.081117	0.054594	0.546161	0.002854	0.415105	0.542605
3.0683634	1.50948	0.452841	3.076947	0.054583	0.545964	0.002746	0.415264	0.543218
3.0650137	1.509049	0.453983	3.072944	0.054571	0.545774	0.002642	0.415426	0.543806
3.061796	1.508633	0.455078	3.069102	0.05456	0.545591	0.002542	0.41559	0.544371
3.0587052	1.50823	0.45613	3.065413	0.054549	0.545414	0.002446	0.415757	0.544913
3.0557364	1.50784	0.45714	3.061872	0.054539	0.545242	0.002354	0.415926	0.545434
3.0528848	1.507462	0.458109	3.058472	0.054529	0.545077	0.002266	0.416098	0.545933
3.0501458	1.507096	0.459039	3.055209	0.054519	0.544916	0.002181	0.416272	0.546413
3.0475152	1.506741	0.459933	3.052075	0.05451	0.544761	0.002099	0.416448	0.546873
3.0449886	1.506397	0.46079	3.049068	0.054501	0.544611	0.002021	0.416627	0.547315
3.0425621	1.506063	0.461614	3.04618	0.054492	0.544466	0.001946	0.416807	0.54774
3.0402316	1.505739	0.462404	3.043408	0.054483	0.544326	0.001874	0.416989	0.548147
3.0379935	1.505425	0.463163	3.040747	0.054475	0.54419	0.001805	0.417173	0.548538
3.0358441	1.50512	0.463891	3.038193	0.054467	0.544058	0.001739	0.417359	0.548914
3.0337799	1.504824	0.46459	3.03574	0.05446	0.543931	0.001675	0.417546	0.549274
3.0317976	1.504536	0.465261	3.033386	0.054452	0.543807	0.001614	0.417735	0.54962
3.029894	1.504256	0.465906	3.031126	0.054445	0.543688	0.001555	0.417926	0.549952
3.028066	1.503984	0.466525	3.028956	0.054438	0.543572	0.001498	0.418118	0.550271
3.0263106	1.503719	0.467118	3.026873	0.054432	0.54346	0.001444	0.418311	0.550577
3.024625	1.503461	0.467689	3.024873	0.054425	0.543351	0.001392	0.418506	0.550871
3.0230064	1.503211	0.468236	3.022953	0.054419	0.543245	0.001342	0.418702	0.551153
3.0214522	1.502966	0.468761	3.021111	0.054413	0.543143	0.001295	0.4189	0.551424
3.0199597	1.502729	0.469266	3.019341	0.054407	0.543044	0.001249	0.419098	0.551684
3.0185267	1.502497	0.46975	3.017643	0.054401	0.542947	0.001204	0.419298	0.551934
3.0171507	1.502271	0.470215	3.016013	0.054396	0.542853	0.001162	0.419499	0.552173
3.0158295	1.502051	0.470661	3.014447	0.054391	0.542763	0.001121	0.419701	0.552403
3.0145609	1.501836	0.47109	3.012945	0.054386	0.542674	0.001082	0.419903	0.552624
3.0133429	1.501626	0.471501	3.011502	0.054381	0.542588	0.001045	0.420107	0.552836
3.0121733	1.501421	0.471896	3.010117	0.054376	0.542505	0.001009	0.420311	0.55304
3.0110504	1.501221	0.472275	3.008788	0.054371	0.542424	0.000974	0.420517	0.553235
3.0099723	1.501025	0.472639	3.007512	0.054367	0.542345	0.000941	0.420723	0.553423
3.0089372	1.500834	0.472988	3.006286	0.054362	0.542268	0.000909	0.42093	0.553603
3.0079433	1.500647	0.473323	3.00511	0.054358	0.542194	0.000879	0.421137	0.553775

3.0069891	1.500463	0.473645	3.003981	0.054354	0.542121	0.000849	0.421345	0.553941
3.006073	1.500284	0.473954	3.002897	0.05435	0.54205	0.000821	0.421554	0.554101
3.0051935	1.500109	0.474251	3.001856	0.054346	0.541981	0.000794	0.421764	0.554254
3.004349	1.499937	0.474536	3.000857	0.054342	0.541914	0.000768	0.421974	0.5544
3.0035383	1.499769	0.474809	2.999898	0.054338	0.541848	0.000743	0.422184	0.554541
3.00276	1.499603	0.475072	2.998978	0.054335	0.541784	0.000719	0.422395	0.554677
3.0020127	1.499442	0.475324	2.998094	0.054331	0.541722	0.000696	0.422607	0.554807
3.0012954	1.499283	0.475566	2.997245	0.054328	0.541661	0.000674	0.422819	0.554931
3.0006066	1.499127	0.475798	2.996431	0.054325	0.541601	0.000653	0.423031	0.555051
2.9999454	1.498974	0.476021	2.995649	0.054322	0.541543	0.000633	0.423244	0.555166
2.9993107	1.498823	0.476235	2.994898	0.054318	0.541487	0.000613	0.423457	0.555276
2.9987013	1.498675	0.47644	2.994177	0.054315	0.541431	0.000594	0.42367	0.555382
2.9981163	1.49853	0.476638	2.993485	0.054312	0.541377	0.000576	0.423884	0.555484
2.9975547	1.498387	0.476827	2.992821	0.05431	0.541324	0.000559	0.424098	0.555582
2.9970156	1.498246	0.477009	2.992184	0.054307	0.541272	0.000543	0.424312	0.555675
2.996498	1.498108	0.477183	2.991572	0.054304	0.541221	0.000527	0.424527	0.555765
Scenario 6 -- Mixing, cation exchange, and calcite preciptiation * 10								
Carbonate alkalinity	Ca++	Cl-	HCO3-	K+	Mg++	NO3-	Na+	SO4--
meq_acid/l	mmol/l	mmol/l	mmol/l	mmol/l	mmol/l	mmol/l	mmol/l	mmol/l
3.6823246	1.584	0.2331	3.847656	0.05627	0.576	0.02278	0.4143	0.42995
3.6513535	1.579199	0.243031	3.810781	0.056183	0.57425	0.021875	0.413918	0.435069
3.6175928	1.573109	0.252564	3.773307	0.056076	0.572064	0.021005	0.4134	0.439983
3.5851093	1.567234	0.261717	3.737297	0.055974	0.569955	0.020171	0.412909	0.444701
3.5538577	1.561568	0.270503	3.702693	0.055875	0.567922	0.01937	0.412442	0.44923
3.5237937	1.556103	0.278937	3.669443	0.055779	0.565961	0.018601	0.412	0.453578
3.4948747	1.550835	0.287035	3.637494	0.055686	0.56407	0.017863	0.411581	0.457751
3.4670593	1.545755	0.294808	3.606798	0.055597	0.562248	0.017154	0.411186	0.461758
3.4403074	1.540859	0.302271	3.577305	0.055511	0.560491	0.016474	0.410813	0.465605
3.4145804	1.536139	0.309435	3.548969	0.055428	0.558798	0.015821	0.410462	0.469298
3.3898407	1.531591	0.316312	3.521746	0.055347	0.557166	0.015193	0.410132	0.472843
3.3660521	1.527208	0.322915	3.495593	0.05527	0.555594	0.014592	0.409822	0.476246
3.3431796	1.522985	0.329253	3.470469	0.055195	0.55408	0.014014	0.409533	0.479513
3.3211892	1.518916	0.335338	3.446334	0.055123	0.552621	0.013459	0.409262	0.48265
3.3000482	1.514996	0.341179	3.423149	0.055054	0.551215	0.012926	0.40901	0.485661
3.2797251	1.51122	0.346787	3.400878	0.054987	0.549862	0.012415	0.408776	0.488551
3.2601892	1.507582	0.35217	3.379485	0.054922	0.548558	0.011924	0.408559	0.491326
3.2414112	1.504079	0.357338	3.358936	0.05486	0.547302	0.011453	0.408359	0.49399
3.2233625	1.500704	0.3623	3.339199	0.0548	0.546093	0.011001	0.408175	0.496548
3.2060157	1.497454	0.367063	3.320241	0.054742	0.544929	0.010567	0.408007	0.499003
3.1893443	1.494325	0.371635	3.302032	0.054686	0.543808	0.01015	0.407855	0.50136
3.1733228	1.491311	0.376025	3.284544	0.054633	0.542729	0.00975	0.407716	0.503622

3.1579265	1.488408	0.380238	3.267747	0.054581	0.54169	0.009365	0.407592	0.505794
3.1431316	1.485613	0.384284	3.251615	0.054531	0.54069	0.008996	0.407482	0.50788
3.1289153	1.482922	0.388167	3.236121	0.054483	0.539727	0.008642	0.407385	0.509882
3.1152555	1.480331	0.391896	3.221242	0.054437	0.5388	0.008303	0.4073	0.511803
3.1021308	1.477836	0.395475	3.206952	0.054392	0.537907	0.007976	0.407228	0.513648
3.0895209	1.475433	0.398911	3.193228	0.054349	0.537048	0.007663	0.407168	0.515419
3.0774058	1.47312	0.402209	3.180049	0.054308	0.536222	0.007362	0.407119	0.51712
3.0657667	1.470893	0.405376	3.167393	0.054268	0.535426	0.007074	0.407081	0.518752
3.0545851	1.468748	0.408416	3.155239	0.05423	0.53466	0.006796	0.407054	0.520319
3.0438435	1.466683	0.411334	3.143568	0.054193	0.533923	0.00653	0.407037	0.521823
3.0335248	1.464694	0.414135	3.13236	0.054158	0.533213	0.006275	0.40703	0.523267
3.0236127	1.46278	0.416825	3.121597	0.054123	0.53253	0.00603	0.407032	0.524653
3.0140914	1.460936	0.419407	3.111263	0.05409	0.531872	0.005794	0.407043	0.525984
3.0049457	1.459161	0.421886	3.101339	0.054059	0.531239	0.005568	0.407063	0.527262
2.9961611	1.457451	0.424265	3.091809	0.054028	0.53063	0.005351	0.407092	0.528489
2.9877236	1.455804	0.426549	3.082659	0.053999	0.530044	0.005143	0.407129	0.529666
2.9796196	1.454219	0.428742	3.073872	0.05397	0.529479	0.004943	0.407173	0.530796
2.9718361	1.452691	0.430848	3.065436	0.053943	0.528936	0.004751	0.407225	0.531882
2.9643606	1.451221	0.432869	3.057335	0.053917	0.528413	0.004567	0.407285	0.532923
2.9571811	1.449804	0.434809	3.049557	0.053892	0.52791	0.00439	0.407351	0.533923
2.9502861	1.448439	0.436671	3.042088	0.053867	0.527425	0.00422	0.407424	0.534884
2.9436643	1.447124	0.438459	3.034917	0.053844	0.526958	0.004057	0.407504	0.535805
2.9373051	1.445858	0.440176	3.028032	0.053822	0.526509	0.003901	0.407589	0.53669
2.9311982	1.444637	0.441824	3.021421	0.0538	0.526076	0.003751	0.407681	0.53754
2.9253337	1.443462	0.443406	3.015074	0.053779	0.525659	0.003606	0.407778	0.538355
2.9197021	1.442328	0.444924	3.00898	0.053759	0.525258	0.003468	0.407881	0.539138
2.9142942	1.441236	0.446382	3.003128	0.05374	0.524872	0.003335	0.407989	0.539889
2.9091013	1.440184	0.447782	2.99751	0.053721	0.5245	0.003207	0.408103	0.540611
2.9041148	1.43917	0.449126	2.992117	0.053703	0.524141	0.003085	0.408221	0.541303
2.8993267	1.438192	0.450416	2.986938	0.053686	0.523796	0.002967	0.408343	0.541968
2.8947291	1.437249	0.451654	2.981966	0.053669	0.523464	0.002854	0.408471	0.542607
2.8903145	1.43634	0.452843	2.977193	0.053653	0.523143	0.002746	0.408602	0.543219
2.8860757	1.435463	0.453984	2.97261	0.053638	0.522835	0.002642	0.408738	0.543808
2.8820058	1.434618	0.455079	2.96821	0.053623	0.522537	0.002542	0.408878	0.544372
2.8780981	1.433802	0.456131	2.963985	0.053608	0.522251	0.002446	0.409021	0.544914
2.8743461	1.433015	0.457141	2.95993	0.053595	0.521974	0.002354	0.409168	0.545435
2.8707438	1.432256	0.45811	2.956036	0.053581	0.521708	0.002266	0.409319	0.545935
2.8672852	1.431523	0.459041	2.952298	0.053569	0.521452	0.002181	0.409473	0.546414
2.8639646	1.430816	0.459934	2.94871	0.053556	0.521204	0.002099	0.40963	0.546875
2.8607766	1.430134	0.460792	2.945264	0.053544	0.520966	0.002021	0.40979	0.547317
2.8577158	1.429475	0.461615	2.941957	0.053533	0.520735	0.001946	0.409953	0.547741
2.8547774	1.428839	0.462405	2.938782	0.053522	0.520514	0.001874	0.410119	0.548148
2.8519563	1.428224	0.463164	2.935733	0.053511	0.5203	0.001805	0.410288	0.54854

2.8492481	1.42763	0.463892	2.932807	0.053501	0.520093	0.001739	0.410459	0.548915
2.8466481	1.427057	0.464592	2.929997	0.053491	0.519894	0.001675	0.410633	0.549275
2.8441521	1.426503	0.465263	2.9273	0.053482	0.519702	0.001614	0.410809	0.549621
2.841756	1.425967	0.465907	2.924711	0.053472	0.519516	0.001555	0.410988	0.549954
2.8394558	1.425449	0.466526	2.922226	0.053464	0.519337	0.001498	0.411168	0.550273
2.8372476	1.424948	0.46712	2.91984	0.053455	0.519164	0.001444	0.411351	0.550579
2.8351279	1.424464	0.46769	2.917549	0.053447	0.518997	0.001392	0.411535	0.550873
2.8330932	1.423996	0.468237	2.91535	0.053439	0.518835	0.001342	0.411722	0.551155
2.8311399	1.423542	0.468763	2.913239	0.053431	0.51868	0.001295	0.41191	0.551425
2.829265	1.423104	0.469267	2.911213	0.053424	0.518529	0.001249	0.4121	0.551686
2.8274653	1.422679	0.469751	2.909268	0.053417	0.518383	0.001204	0.412292	0.551935
2.8257377	1.422267	0.470216	2.907401	0.05341	0.518243	0.001162	0.412486	0.552175
2.8240795	1.421869	0.470662	2.905608	0.053403	0.518107	0.001121	0.41268	0.552405
2.8224879	1.421483	0.471091	2.903887	0.053397	0.517975	0.001082	0.412877	0.552626
2.8209602	1.421109	0.471502	2.902236	0.05339	0.517848	0.001045	0.413074	0.552838
2.8194938	1.420747	0.471897	2.90065	0.053384	0.517725	0.001009	0.413273	0.553041
2.8180864	1.420395	0.472276	2.899128	0.053379	0.517606	0.000974	0.413473	0.553237
2.8167355	1.420054	0.47264	2.897667	0.053373	0.517491	0.000941	0.413675	0.553424
2.815439	1.419723	0.472989	2.896265	0.053368	0.517379	0.000909	0.413877	0.553604
2.8141947	1.419402	0.473325	2.894919	0.053362	0.517271	0.000879	0.414081	0.553777
2.8130004	1.41909	0.473647	2.893627	0.053357	0.517166	0.000849	0.414285	0.553943
2.8118542	1.418788	0.473956	2.892387	0.053352	0.517065	0.000821	0.414491	0.554102
2.8107542	1.418494	0.474252	2.891196	0.053348	0.516966	0.000794	0.414697	0.554255
2.8096986	1.418208	0.474537	2.890053	0.053343	0.516871	0.000768	0.414904	0.554402
2.8086854	1.41793	0.474811	2.888957	0.053339	0.516779	0.000743	0.415112	0.554543
2.8077132	1.41766	0.475073	2.887904	0.053334	0.516689	0.000719	0.415321	0.554678
2.8067802	1.417397	0.475325	2.886893	0.05333	0.516602	0.000696	0.415531	0.554808
2.8058848	1.417142	0.475567	2.885923	0.053326	0.516517	0.000674	0.415741	0.554933
2.8050257	1.416893	0.475799	2.884992	0.053322	0.516435	0.000653	0.415952	0.555053
2.8042012	1.416651	0.476022	2.884099	0.053318	0.516356	0.000633	0.416164	0.555168
2.8034101	1.416415	0.476236	2.883241	0.053315	0.516278	0.000613	0.416376	0.555278
2.802651	1.416185	0.476442	2.882418	0.053311	0.516203	0.000594	0.416589	0.555384
2.8019226	1.415961	0.476639	2.881628	0.053308	0.51613	0.000576	0.416802	0.555485
2.8012238	1.415742	0.476828	2.88087	0.053304	0.516059	0.000559	0.417016	0.555583
2.8005532	1.415529	0.47701	2.880142	0.053301	0.51599	0.000543	0.41723	0.555677
2.7999099	1.415321	0.477185	2.879444	0.053298	0.515922	0.000527	0.417445	0.555767

Appendix H – Modeled changes in aquifer sediments for Scenario Six (mixing, cation exchange, and calcite precipitation) at the alluvial site – The Jones Pit

Mass reacted, H2O	Ca++	K+	Mg++	Na+	Mass reacted, H2O	Calcite_ESRPA	Porosity	0.41
kg	meq/l	meq/l	meq/l	meq/l	kg	mg	CEC (meq/g rock)	0.21
Mass reacted, H2O	Ca++	K+	Mg++	Na+				
0	0	0	0	0	0			
0.04	-0.0099	8.57E-05	0.003666	0.006996	0.04	0.1739		
0.08	-0.02101	0.000196	0.008483	0.014108	0.08	0.58267		
0.12	-0.03213	0.000308	0.01332	0.021182	0.12	0.995034		
0.16	-0.04326	0.00042	0.018175	0.028217	0.16	1.410715		
0.2	-0.05441	0.000532	0.023048	0.035215	0.2	1.829453		
0.24	-0.06556	0.000646	0.027938	0.042174	0.24	2.251009		
0.28	-0.07671	0.00076	0.032843	0.049094	0.28	2.675163		
0.32	-0.08787	0.000874	0.037763	0.055977	0.32	3.101708		
0.36	-0.09904	0.000989	0.042697	0.062821	0.36	3.530458		
0.4	-0.1102	0.001104	0.047645	0.069626	0.4	3.961235		
0.44	-0.12136	0.00122	0.052604	0.076394	0.44	4.393879		
0.48	-0.13252	0.001336	0.057576	0.083122	0.48	4.82824		
0.52	-0.14367	0.001453	0.062559	0.089813	0.52	5.26418		
0.56	-0.15482	0.00157	0.067554	0.096465	0.56	5.701571		
0.6	-0.16596	0.001687	0.072558	0.103079	0.6	6.140295		
0.64	-0.17709	0.001805	0.077573	0.109655	0.64	6.580244		
0.68	-0.18822	0.001923	0.082597	0.116193	0.68	7.021317		
0.72	-0.19933	0.002041	0.08763	0.122693	0.72	7.463421		
0.76	-0.21043	0.00216	0.092672	0.129155	0.76	7.90647		
0.8	-0.22152	0.002278	0.097723	0.135579	0.8	8.350386		
0.84	-0.2326	0.002397	0.102783	0.141966	0.84	8.795094		
0.88	-0.24366	0.002517	0.10785	0.148315	0.88	9.240529		
0.92	-0.25471	0.002636	0.112925	0.154626	0.92	9.686626		
0.96	-0.26574	0.002756	0.118008	0.1609	0.96	10.13333		
1	-0.27676	0.002876	0.123098	0.167137	1	10.58059		
1.04	-0.28776	0.002996	0.128195	0.173338	1.04	11.02835		
1.08	-0.29874	0.003116	0.133299	0.179501	1.08	11.47657		
1.12	-0.30971	0.003237	0.138411	0.185627	1.12	11.92521		
1.16	-0.32066	0.003358	0.143529	0.191717	1.16	12.37423		
1.2	-0.33159	0.003479	0.148653	0.197771	1.2	12.82359		

1.24	-0.3425	0.0036	0.153784	0.203788	1.24	13.27326		
1.279999	-0.3534	0.003721	0.158922	0.209769	1.279999	13.72322		
1.319999	-0.36427	0.003842	0.164066	0.215714	1.319999	14.17343		
1.359999	-0.37512	0.003963	0.169216	0.221623	1.359999	14.62387		
1.399999	-0.38596	0.004085	0.174372	0.227497	1.399999	15.07451		
1.439999	-0.39677	0.004207	0.179534	0.233335	1.439999	15.52533		
1.479999	-0.40756	0.004329	0.184702	0.239138	1.479999	15.97632		
1.519999	-0.41833	0.004451	0.189875	0.244906	1.519999	16.42746		
1.559999	-0.42909	0.004573	0.195055	0.25064	1.559999	16.87872		
1.599999	-0.43981	0.004695	0.20024	0.256338	1.599999	17.33009		
1.639999	-0.45052	0.004817	0.205431	0.262002	1.639999	17.78156		
1.679999	-0.46121	0.00494	0.210628	0.267631	1.679999	18.23312		
1.719999	-0.47187	0.005062	0.21583	0.273226	1.719999	18.68474		
1.759999	-0.48252	0.005185	0.221037	0.278788	1.759999	19.13643		
1.799999	-0.49314	0.005308	0.22625	0.284315	1.799999	19.58817		
1.839999	-0.50373	0.00543	0.231469	0.289809	1.839999	20.03995		
1.879999	-0.51431	0.005553	0.236692	0.295269	1.879999	20.49177		
1.919999	-0.52486	0.005676	0.241921	0.300696	1.919999	20.94361		
1.959999	-0.53539	0.0058	0.247156	0.30609	1.959999	21.39546		
1.999999	-0.5459	0.005923	0.252395	0.311452	1.999999	21.84733		
2.039999	-0.55639	0.006046	0.25764	0.31678	2.039999	22.2992		
2.079999	-0.56685	0.006169	0.26289	0.322076	2.079999	22.75106		
2.119999	-0.57729	0.006293	0.268145	0.327339	2.119999	23.20293		
2.159999	-0.58771	0.006416	0.273405	0.332571	2.159999	23.65478		
2.199999	-0.59811	0.00654	0.27867	0.33777	2.199999	24.10661		
2.239999	-0.60848	0.006663	0.28394	0.342938	2.239999	24.55842		
2.279999	-0.61883	0.006787	0.289215	0.348074	2.279999	25.01021		
2.319999	-0.62916	0.006911	0.294495	0.353178	2.319999	25.46197		
2.359999	-0.63946	0.007035	0.299779	0.358252	2.359999	25.91371		
2.399999	-0.64974	0.007159	0.305069	0.363294	2.399999	26.3654		
2.439999	-0.66	0.007283	0.310364	0.368305	2.439999	26.81707		
2.479999	-0.67024	0.007407	0.315663	0.373286	2.479999	27.26869		
2.519999	-0.68045	0.007531	0.320967	0.378236	2.519999	27.72028		
2.559999	-0.69064	0.007655	0.326276	0.383156	2.559999	28.17182		
2.599999	-0.70081	0.007779	0.331589	0.388046	2.599999	28.62332		
2.639999	-0.71096	0.007903	0.336907	0.392906	2.639999	29.07477		
2.679999	-0.72108	0.008028	0.34223	0.397736	2.679999	29.52617		
2.719999	-0.73118	0.008152	0.347558	0.402536	2.719999	29.97753		
2.759999	-0.74126	0.008277	0.35289	0.407307	2.759999	30.42883		
2.799999	-0.75131	0.008401	0.358226	0.412048	2.799999	30.88009		
2.839999	-0.76135	0.008526	0.363567	0.416761	2.839999	31.33129		
2.879999	-0.77136	0.00865	0.368913	0.421445	2.879999	31.78244		
2.919999	-0.78135	0.008775	0.374263	0.4261	2.919999	32.23354		

2.959999	-0.79131	0.0089	0.379617	0.430726	2.959999	32.68458		
2.999999	-0.80126	0.009024	0.384976	0.435324	2.999999	33.13557		
3.039999	-0.81118	0.009149	0.390339	0.439894	3.039999	33.5865		
3.079999	-0.82108	0.009274	0.395706	0.444436	3.079999	34.03738		
3.119999	-0.83096	0.009399	0.401078	0.448949	3.119999	34.4882		
3.159999	-0.84082	0.009524	0.406454	0.453436	3.159999	34.93896		
3.199999	-0.85065	0.009649	0.411834	0.457894	3.199999	35.38967		
3.239999	-0.86047	0.009774	0.417219	0.462326	3.239999	35.84031		
3.279999	-0.87026	0.009899	0.422607	0.46673	3.279999	36.29091		
3.319999	-0.88003	0.010024	0.428	0.471107	3.319999	36.74144		
3.359999	-0.88978	0.010149	0.433397	0.475457	3.359999	37.19191		
3.399999	-0.89951	0.010274	0.438798	0.47978	3.399999	37.64233		
3.439999	-0.90921	0.010399	0.444203	0.484077	3.439999	38.09269		
3.479999	-0.9189	0.010524	0.449612	0.488348	3.479999	38.54299		
3.519999	-0.92856	0.010649	0.455025	0.492592	3.519999	38.99323		
3.559999	-0.9382	0.010775	0.460441	0.496811	3.559999	39.44342		
3.599999	-0.94783	0.0109	0.465862	0.501003	3.599999	39.89354		
3.639999	-0.95743	0.011025	0.471287	0.50517	3.639999	40.34361		
3.679999	-0.96701	0.011151	0.476715	0.509311	3.679999	40.79362		
3.719999	-0.97657	0.011276	0.482148	0.513427	3.719999	41.24357		
3.759998	-0.98611	0.011401	0.487584	0.517517	3.759998	41.69347		
3.799998	-0.99563	0.011527	0.493024	0.521582	3.799998	42.1433		
3.839998	-1.00512	0.011652	0.498467	0.525623	3.839998	42.59308		
3.879998	-1.0146	0.011778	0.503914	0.529638	3.879998	43.0428		
3.919998	-1.02406	0.011903	0.509365	0.533629	3.919998	43.49247		
3.959998	-1.0335	0.012029	0.51482	0.537596	3.959998	43.94207		
3.999998	-1.04291	0.012154	0.520278	0.541538	3.999998	44.39162		