POWDER BASIN WELL LOGS REPORT

Oregon Watershed Enhancement Board

Grant Number 220-5043-17407

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POWDER BASIN WATERSHED COUNCIL

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Monitoring Questions and Objectives

Groundwater resources provide a significant source of water for drinking, irrigation, stock, municipal, and industrial uses in the Powder Basin of Northeastern Oregon. Unfortunately, much less attention has been paid to this important water source compared to surface water resources in the basin. To address some of these concerns, the Powder Basin Watershed Council (PBWC), the Oregon Water Resources Department (OWRD), and the Oregon Department of Geology and Mineral Industries (DOGAMI) detailed the geology and hydrology related to groundwater resources using information collected from 579 wells in the basin. The well log data suggests that there is some evidence of groundwater depletion in the basin related to withdrawals, with declining groundwater elevations found for wells in upland and terrace features in the Baker Valley. The analysis also finds bedrock elevation and composition under the Baker Valley consistent with nearby geology, although the depths of these wells were not enough to understand processes under the deeper sediments in the valley. While this report does find some concerning trends in groundwater elevations, it is only a first step in understanding groundwater processes, with more advanced analyses needed to fully understand the hydrological and geological processes and their impacts on groundwater hydrology.

Introduction to the Powder Basin Watershed

The Powder Basin Watershed covers 8,970 km^2 of Northeastern Oregon including all of Baker County and parts of Union, Wallowa, and Malheur Counties. (Figure 1.) The watershed is composed of 3 HUC 8 sub-watersheds: The Powder, Burnt and Brownlee subbasins. The watershed is defined by the Elkhorn and Wallowa Mountain ranges which heavily influence the hydrology, geography, and climate in the watershed. The higher elevations of these ranges are primarily composed of alpine meadows and conifer forests with average annual precipitation ranging between 50” to 60”, mostly coming in the form of snow between October and May. Lower elevation forests are dominated by mixed conifer forests and Ponderosa Pine, with a mix of rain and snow as the dominant forms of precipitation. The lower elevation regions are primarily composed of sagebrush and bunchgrasses, where average annual precipitation is less than 20” per year (NWPCC 2004).

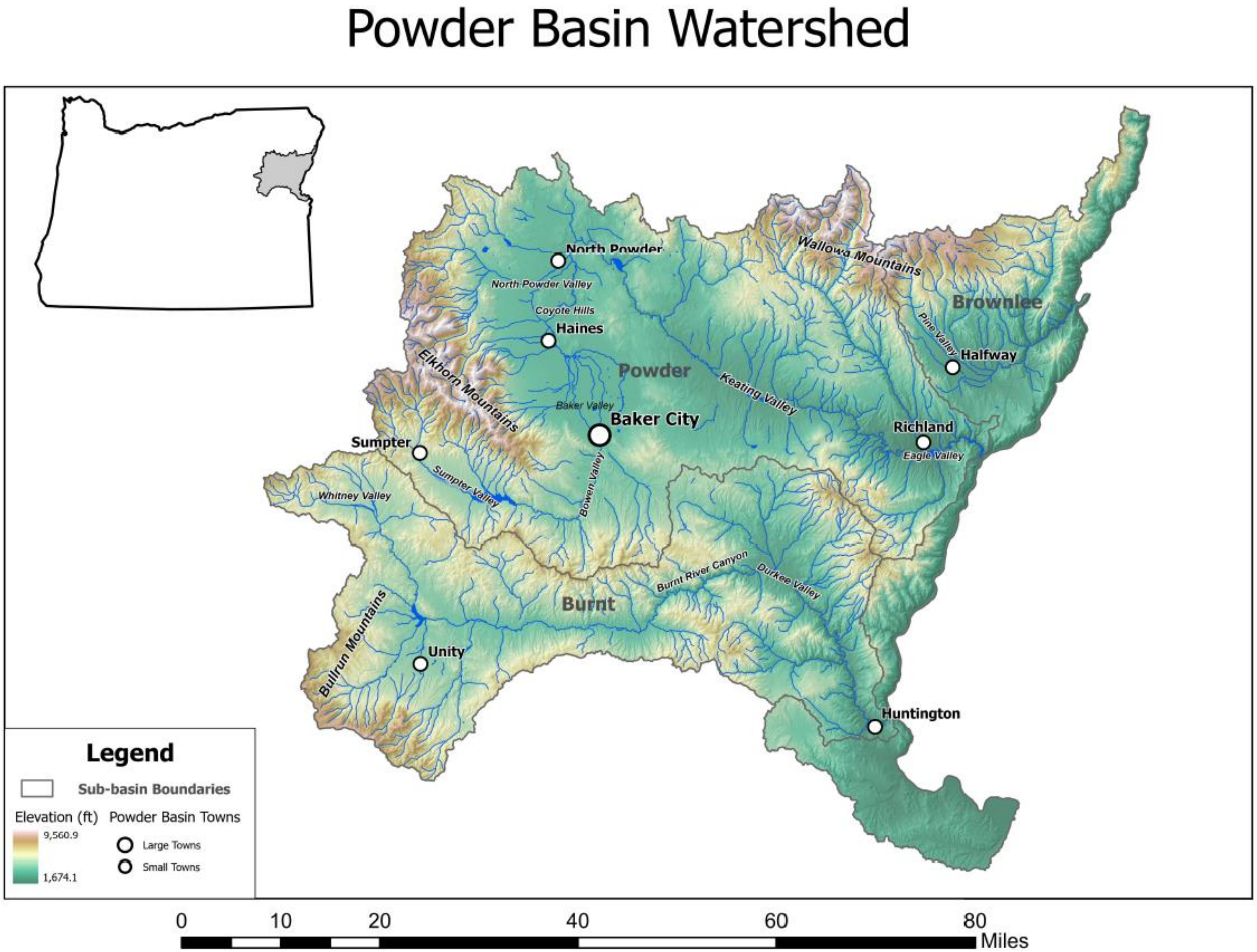

Figure 1. Map of the Powder Basin with major subbasins, population centers, waterbodies, streams, and landform features (in italics)

Agriculture and ranching are significant economic and land use activities in the region, with 674 km^2 of irrigated crop and pastureland alongside 811 km^2 of non-irrigated pastureland (ODEQ 2013). The lower depositional valleys were historically composed of wetlands and tall grass meadows but have largely been converted into agricultural and developed land, the largest among these being the Baker Valley. Other important depositional valleys include the Sumpter, Bowen, Keating, and Eagle Valleys in the Powder sub-basin, Whitney and Durkee Valleys in the Burnt sub-basin, and the Pine Valley in the Brownlee subbasin. Agricultural practices have had a large influence on the hydrology of the region through the use of irrigation diversions and reservoirs, resulting in shifts in stream flow and temperature compared to pre-settlement conditions.

Surface water resources are well studied in the basin, with ongoing monitoring of water temperature, water chemistry, bacteria, nutrients, and algae undertaken by several organizations, including the Powder Basin Watershed Council (PBWC). The PBWCs most recent water quality monitoring efforts include grab sample monitoring for pH, conductivity, turbidity, dissolved oxygen, and temperature at 56 sites throughout the basin, as well as E. coli and phosphorus monitoring at 5 sites in the Burnt River sub-basin. 604 miles of streams and rivers in the basin are listed as 303d impaired according to DEQ, with temperature, dissolved oxygen, bacteria, and nutrients as major impairments of concern (NRCS 2006).

Although there is a large amount of information regarding surface waters throughout the basin, far less information is available on groundwater resources. Several reports issued by the State of Oregon and the United State Geological Survey were issued in the 1960's detailing trends in water usage in the basin, but no known studies since have explored trends in groundwater levels (Ducret and Anderson 1965, Sceva and Debow 1965, Lystrom et al. 1967). The best source of current information on aquifer status and trends comes from well logs recorded during the drilling of groundwater wells. These well logs include valuable information that can be used for further analysis, including date of drilling, geology, depth of groundwater bearing zones, and groundwater flow rates.

Nearby basins demonstrate the importance of tracking groundwater issues, particularly regarding trends in groundwater elevations. Further south in the Harney basin, several groundwater issues have emerged as major concerns, including high levels of arsenic (>10 µg/L) related to underlying geology and widespread declines in groundwater throughout the basin, with some locations seeing declines in water levels as much by as 100 feet (Smitherman 2015, Gingerich et al. 2024). Similar issues can be found in the Umatilla basin to the northwest of the Powder Basin, where groundwater declines of ~3 ft/year have been seen in various basalt and depositional aquifers, with some locations showing declines up to 200 ft over the recorded period (Herrera et al. 2017). Lower in the

Umatilla basin, groundwater nitrate contamination has resulted in state and federal investigations and input (ODEQ et al. 2024).

Given these issues, a better understanding of groundwater hydrology in the Powder Basin is warranted. One of the most important informational needs this report details is determining trends in groundwater usage over time and by location to identify areas where groundwater declines may be present. There is also a need to understand the underlying geology of the area, particularly the depositional valleys where overlying sediments obscure the bedrock geology. Climate change is expected to shift precipitation and temperature patterns that may result in stress to groundwater resources. Understanding the processes related to groundwater hydrology will help mitigate the impacts of these changes and ensure continued benefits. Finally, this report hopes to establish the next steps needed to better understand groundwater processes in the basin, particularly the interaction between groundwater and surface water resources. More complex models, alongside improved understanding of trends, will improve our understanding of factors impacting groundwater and help better manage this resource.

Geology and Groundwater Hydrology of the Powder Basin

The geology of the Powder Basin Watershed, along with much of the broader Pacific Northwest, has been heavily influenced by the collision of the Pacific and North American tectonic plates and the resulting volcanism and faulting associated with it. The rock strata found in the Powder Basin, the Blue Mountain Geological Province, provides an useful case study in how terrane accretion, volcanism, faulting, and glaciofluvial processes influence the surface geology and groundwater flows in the region (Figures 2. and 3.). Much of the information related to the geological history of the Blue Mountains comes from the book Geology of the Pacific Northwest (Orr and Orr 1996), which provides an excellent account of the formation and distribution of rock types in the area.

Era	Period	Epoch	Start	End	Powder Basin Geological Events
PreCambrian			4300	541	
Paleozoic	Cambrian		541	485.4	
	Ordovician		485.4	443.8	
	Silurian		443.8	419.2	
	Devonian		419.2	358.9	
	Carboniferous		358.9	298.9	Baker Terrane accretion
	Permian		298.9	251.9	Wallowa Terrane accretion
Mesozoic	Triassic		251.9	201.3	Olds Ferry Terrane accretion; Izze Terrane accretion
	Jurassic		201.3	145	Granitic batholith formation
	Cretaceous		145	66	
Cenozoic	Paleogene	Paleocene	66	56	Rhyolitic volcanism, caldera formation
		Eocene	56	33.9	
		Oligocene	33.9	23.03	
	Neogene	Miocene	23.03	5.333	Columbia River Basalt volcanism
		Pliocene	5.333	2.58	Baker Valley formation, glaciation
	Quaternary	Pleistocene	2.58	0.012	
		Holocene	0.012	Present	

Figure 2. Geological time scale with important Powder Basin events highlighted.

Terrane Accretion and Upland Groundwater Hydrology

The core of the Blue Mountain Province is the result of sedimentation and volcanic activity associated with the formation of island chains in the Pacific Ocean off the coast of North American plate during the Paleozoic through Jurassic period (538.8 – 201.3 mya). Four major terranes are associated with rocks formed from the accretion, or welding, of these island chains to the North American Plate during subsequent periods.

The Baker Terrane comprises the largest area of exposed terrane rocks in the Powder Basin. These terrane rocks were formed during the Paleozoic through early Triassic (299-201 mya), along an offshore subduction zone where sediments and volcanic rocks, alongside some oceanic crust, were accreted to the North American plate. Currently, these rocks compose large sections of the southern Elkhorn mountains and rocks found east of the Baker Valley. Baker Terrane rocks also underlay much of the Burnt River Canyon, which is primarily composed of Limestone formed during the Devonian through Permian, and moderately metamorphosed sedimentary rocks known as schist. Along with these sedimentary rocks, some remnants of oceanic crust known as ophiolites can be found further east of Keating Valley, which are characterized by several layers of volcanic rock, including pillow lavas and underlying, slow cooling volcanic rock known as gabbro.

North of the Baker Terrane, throughout much of the southern Wallowa Mountains and sections of the Coyote Hills, lie the rocks of the Wallowa Terrane. These rocks were formed during the same period between the Permian and Early Triassic, but unlike the Baker Terrane, were primarily formed in an interoceanic basin between the North American plate and an island arc chain. Much of the Wallowa Terrane contains similar sedimentary rock formations, particularly limestone and argillite, which is formed from fine grained oceanic sediments. Underlying these sedimentary rocks are clastic volcanic rocks formed from explosive volcanic eruptions from the nearby island chains.

The rocks of the Olds Ferry Terrane are found south of the Baker Terrane just north of Huntington. These rocks were formed during the Late Triassic to Middle Jurassic (237-163.5 mya) and are primarily composed of clastic volcanic rocks. Composing small parts of the Bullrun Mountains are the rocks of the Izee Terrane, the youngest of the four terrane features in the Powder basin. Formed between the Middle Triassic and Late Jurassic (245-144 mya), the Izee is primarily composed of argillite and limestone, the result of shallow ocean conditions between the volcanic island arc systems of the Wallowa and Olds Ferry Terranes.

Volcanic activity associated with the subduction of the Pacific Plate and accretion of the exotic terranes to the North American Plate during the Jurassic to early Cretaceous periods (160 – 120 mya) produced extensive intrusive batholiths. Originally the magma chambers deep underneath the volcanic island chains, these rocks invaded the surrounding sedimentary and volcanic rocks, and then cooled forming granite, quartz, and diorite. These batholiths now form the base of Elkhorn and Wallowa Mountains as well as the Coyote Hills.

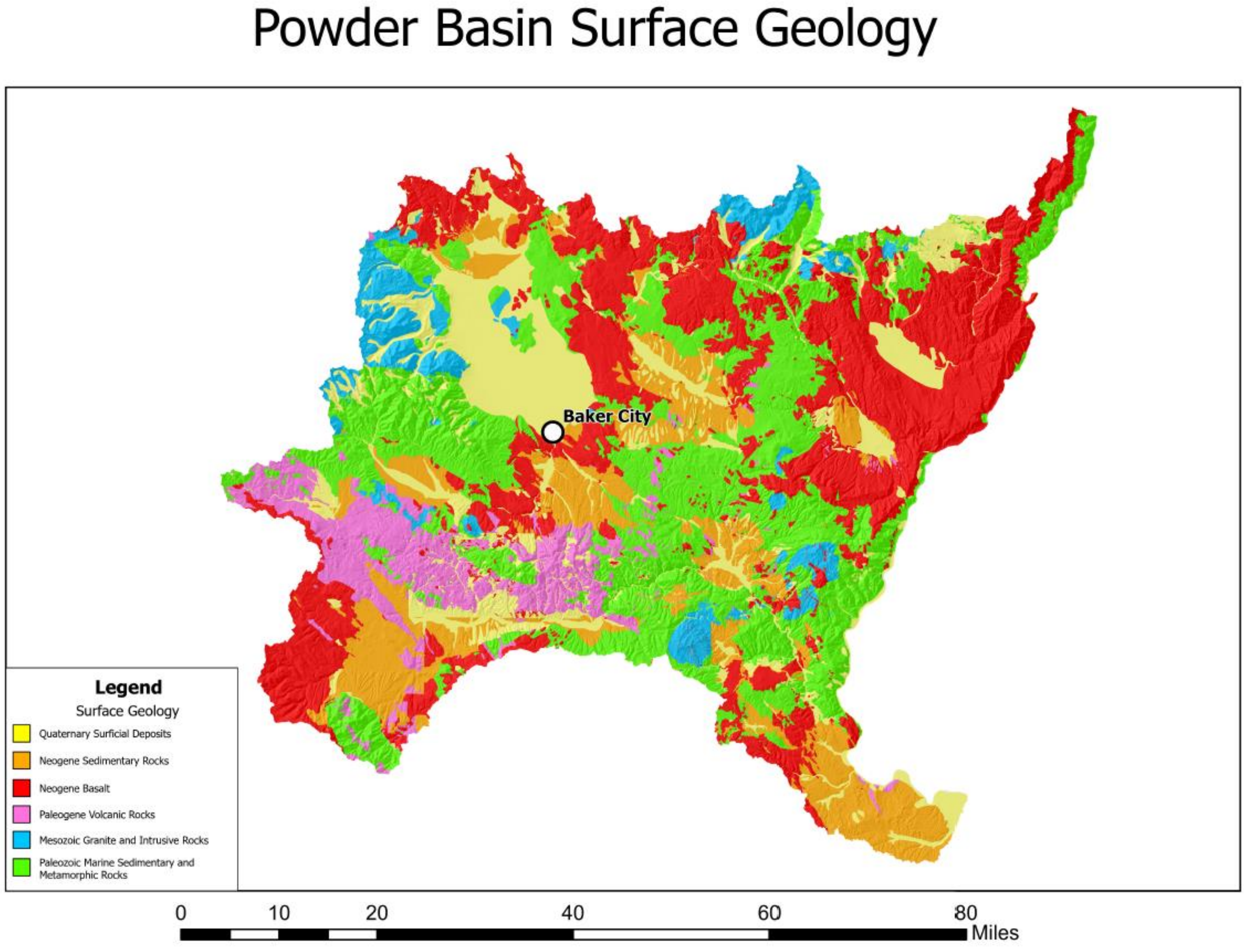

Figure 3. Surface Geology of the Powder Basin with rocks colored according to geological composition and age. Source: Franczyk et al. (2023)

These older rocks are most commonly found in the upland areas of the Powder basin and generally tend to be very low in hydraulic permeability except for some fracture zones and faults. As a result, most of the precipitation that falls in these areas eventually ends up as surface flow in streams, springs, wetlands, and meadows, with the rest ending up as groundwater. Around 28% of flows into lowland aquifers result from groundwater sourced from upland reaches, with the hydrological head created by high levels of precipitation and gravity driving these flows into the lower areas of the basin. These upland flows are often slow due to the low permeability of the rock and can take thousands of years to flow into the lowlands (Gingerich et al. 2024).

Cenozoic Volcanism and Columbia River Basalt Aquifers

As the terranes were further accreted to the North American Plate, they were severely distorted along fault lines in a NW-SE axis. Further volcanism associated with this faulting and uplift resulted in the formation of volcanic vents throughout much of the region beginning in Paleogene era (66 – 27.82 mya). Thick layers of rhyolite, andesite, and tuff indicating volcanic mud and debris flows from caldera eruptions occur throughout these strata. These eruptions resulted in the smoothing of the terrain and the preservation of numerous Paleogene plants and animals. The Clarno Formation, found between the western boundary of the Powder and Burnt River sub-basins, is the largest collection of these rocks in the Powder basin.

Volcanism in the basin was not limited to clastic eruptive activity during the Paleogene period. The largest source of volcanism during the subsequent Miocene epoch (part of Neogene period, 23.03-5.333 mya) was the eruption of lava flows associated with the Columbia River Basalt. These eruptions resulted from fissures located north and south of the Wallowa Mountains and further west near Monument, OR. Layer upon layer of these basalts erupted in over three hundred distinct flows over 11 million years, with individual flows ranging from 5 to 200 feet in thickness. Over time, these lava flows accumulated to produce the basalt formations common to the Powder Basin. In some areas of the Umatilla basin, these flows can reach as much as 6,800 feet deep, with similar depths also likely to be found in the Powder basin.

The largest of these flows, representing 90% of the total volume of Columbia River Basalts, was the result of the Grande Ronde volcanics occurring between 16.5 to 16.1 mya. Currently, Grande Ronde Basalt can be found on the eastern edge of the Wallowa Mountains. Other major flows in the Powder basin include the Strawberry volcanics west of Unity in the Bullrun Mountains which started with rhyolitic volcanic activity 16.16 mya followed by basalt lava flows 15.57 mya. The youngest of the major basalt flows in the Powder basin, the Powder River Volcanics from 13.38 to 13.1 mya, includes ridges east of Baker City and locations to the north of Baker Valley in Ladd Canyon.

While the rhyolite associated with the Powder River volcanics created bedrock low in permeability similar to the earlier schist, argillite, and granite, the layered basalt provided a much more suitable environment for groundwater flow. Despite individual flows of basalt being low in permeability to water flow, outgassing produced vesicular, broken, and angular (brecciated) fragments at the tops and bottoms of the flow. In addition to these crevices, eroded sediment accumulated between flows with longer periods between eruptions, providing significant avenues for flow connectivity and permeability (Herrera et al. 2017). Alongside these processes was continued uplift and faulting, resulting in fractures in the basalt layers, further increasing vertical hydrological connectivity between the layers. Over time, surface water was able to infiltrate and fill these faults and fissures, resulting in the formation of the Columbia River Basalt aquifer.

These aquifers provide a significant source of groundwater for upland areas away from streams and other surface water resources. The upper most layers of these basalt aquifers generally have high hydrologic connectivity to alluvial aquifers and surface water from streams, resulting in high recharge rates in the upper 90-150 meters of the strata, while connectivity is lower in the deeper basalt strata resulting in longer recharge times. Although wells drilled into these deeper strata may produce large quantities of water during initial pumping, continued withdrawals can result in large declines in water levels (Herrera et al. 2017).

The Columbia River Basalt aquifers also have high potential for Aquifer Storage and Recovery (ASR) due to their high hydrologic connectivity, separation from surface water sources, and ease of access. It’s estimated that there is about 650 million gallons of estimated storage capacity for the Powder Basin basalt aquifers, which are primarily found north of Baker City (Woody 2009). Two ASR wells provide municipal water supplies for Baker City, with the first constructed in 1977 and the second in 2021 with support from the Oregon Water Resources Department. These two wells have an estimated capacity of 200 million gallons, although they typically store 70-80 million gallons (O’Conner 2024).

Quaternary Glaciation and Unconsolidated Basin-fill Aquifers

Faulting and compression continued after the Miocene, partially brought on by the immense weight of the prior basaltic lava flows as well as continued movement of the Pacific and North American plates. This faulting resulted in the formation the Baker Valley Graben, a lowered fault block feature resulting in 3,280 feet of displacement from the surrounding features (Ferns et al. 2017). Cooler and wetter climates during the Quaternary (2.58 mya – present) resulted in in significant glaciation in the Elkhorn and Wallowa Mountains, carving out deep, U-shaped valleys and transporting large amounts of material from the uplands to valley bottoms. This glaciation, along with other erosional processes in upland areas resulted in coarser grained sediments near the valley edges with higher levels of hydrological connectivity. In contrast, fine grained, semi-consolidated sediments associated with fluvial (stream) and lacustrine (lake) related processes accumulated in the centers of the valleys, resulting in lower hydrological connectivity in these areas. In total, 452 km^2 of surficial deposits would eventually accumulate in this graben.

The resulting basin-fill produced the most important and easily accessible sources of groundwater in the region, with the accumulated sediments and gravels providing an ideal system for water to percolate through. In the Powder Valley, this groundwater primarily resulted from surface flow associated with streams, rivers, and wetlands. These processes, alongside similar human mediated activities such as infiltration from irrigation, currently account for 72% of flows into similar basin-fill aquifers such as the Harney basin. Most of the water in the deeper aquifers can be sourced from 5,000 to 30,000 years when the climate was cooler and wetter (Gingerich et al. 2024). For these deeper groundwater aquifers, sediment size, fill depth, and presence of bedrock material resulted in a mosaic of groundwater bearing zones throughout the valley.

For near-surface aquifers, surface flows have been the primary driver in determining groundwater depths, with shallower groundwater systems closely associated with the Powder River and its major tributaries as well as the extensive wetlands that used to exist in the southeastern section of the valley (Figure 4). Major sources of outflows from these basins primarily come from evapotranspiration from surface vegetation and surface water discharge. In the Harney basin, evapotranspiration and losses to surface waters account for 128,000 acre/feet per year in flows out of the aquifer (with 1 acre foot equivalent to the volume of water covering one acre one foot deep, or 325,851 gallons), or 45% of discharges in this heavily used aquifer (Gingerich et al. 2024).

Given the reliance of these aquifers on surface flows and processes, there are strong seasonal patterns in groundwater levels in these basins. Most recharge occurs during the winter period (Jan-Mar) with smaller but still significant amounts in spring (Apr-May). Infiltration from irrigation is also an important source of recharge during the Summer and fall months (June-Oct) although the amount of recharge is only 0.3% of the total volume of recharge from precipitation throughout the basin (Herrera et al. 2017). Seasonal patterns are quite noticeable in historical hydrographs of wells in the area, with higher levels in spring and early summer when stream flows and precipitation area and decreasing levels throughout the summer through winter period (Ducret and Anderson 1965, Sceva and Debow 1965).

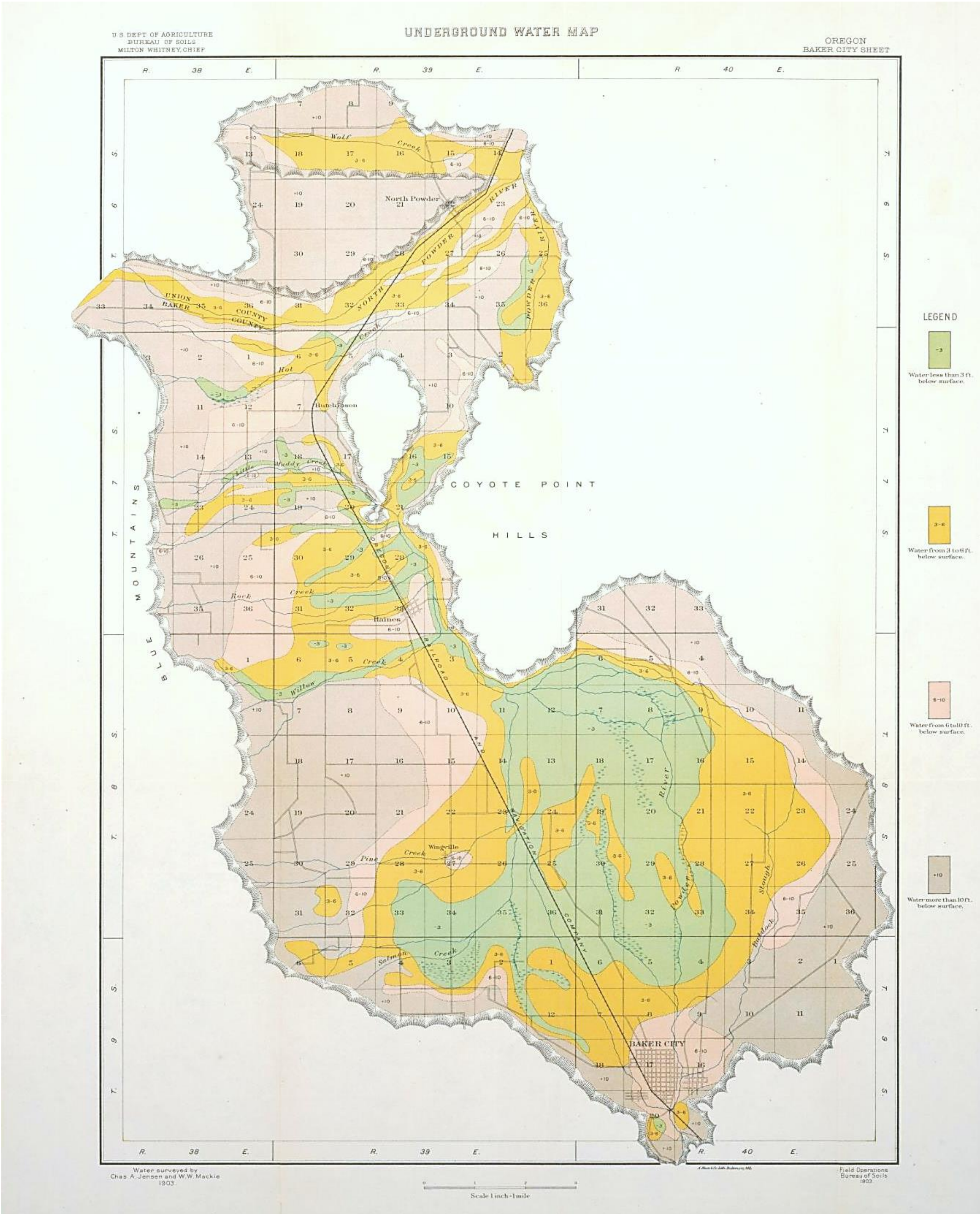

Figure 4. Map of groundwater depths in the Baker and North Powder Valleys c. 1900. Note the relationship between presence of streams and rivers and groundwater depth, particularly for the southern Baker Valley. Source: United States Bureau of Soils (1903)

Groundwater Use and Other Issues

Given the diverse geology and landscape of the Powder basin, there are a variety of sources and factors in how human use influences groundwater resources in the area. Changes to groundwater hydrology from single wells are generally seen on a local level (< 300 m). If the amount of water pumped from the well is in excess of the flow rate of water into the aquifer, a cone of depression around the well is formed. The size and depth of this cone is related to the rate of pumping, permeability of the aquifer and duration of pumping, with higher rates of pumping and higher permeability associated with larger and deeper cones of depression (Arthur et al. 2024).

When the cones of depression from two or more wells overlap, well interference can occur. In these instances, the rate of drawdown is accelerated, altering the hydrological head of the aquifer for kilometers around the wells. Aside from aquifer depletion, this can result in changes to surface flow, particularly for streams and wetlands where groundwater provides a significant source of discharge, resulting in lower flows or seasonal drying (Arthur et al. 2024). This issue can be clearly seen in studies of nearby watersheds, particularly the Harney Basin. Here groundwater levels have seen significant declines since the 1980’s, with some locations seeing declines of more than 100 feet. Groundwater models of the Harbey Basin find consistent over withdrawals from lowland aquifers in the basin by approximately 110,000 acre/feet per year, 38.8% higher than estimated inflows from surface flow and upland groundwater recharge (Gingerich et al. 2024).

Another major issue facing aquifers is the leaching of solutes from underlying geology and sediments alongside contamination from surface water pollutants. The high degree of connectivity between the shallow lowland aquifers and surface water flows can make these groundwater sources particularly susceptible to contamination from human sources. Nitrate pollution is a particularly pervasive issue in some aquifers caused by nitrogen rich runoff from agricultural practices. Nitrate concentrations above 10 mg/L can result in health issues such as reduced blood oxygen levels and are particularly harmful to infants. Nitrate groundwater contamination is a particularly pervasive issue in the Umatilla basin, with 48% of wells exceeding the 10 mg/L drinking water standard set by the US Environmental Protection Agency (ODEQ et al. 2024). Addressing the issue has been a high priority for state and federal agencies, although limited progress has been made in reducing concentrations.

Groundwater contamination also comes from arsenic, a common heavy metal that can result in hyperkeratosis, Type II Diabetes, low birth weight, and stroke, alongside skin, lung, bladder, and kidney cancers. These health effects are particularly notable at concentrations over 10 µg/L, but no concentration exists where adverse effects do not occur. While anthropogenic sources such as pesticides, herbicides, and industrial effluents can result in arsenic contamination, in Eastern Oregon it is primarily found in volcanic rocks, particularly tuff, rhyolite, and basalt, where it is associated with other minerals, primarily iron oxides (Murray et al. 2023, Smitherman 2015). Dry environments are especially at risk of groundwater arsenic contamination due to the concentrated amounts found in alkaline brine lakes that can dissolve into groundwater sources. Arsenic groundwater contamination is widespread in the Harney basin, with 21% of wells with arsenic concentrations between 11 and 50 µg/L and 11% of wells with concentration above 51 µg/L (Smitherman 2015). Addressing arsenic issues is particularly difficult since it can be found in many rock types, but testing can improve knowledge of its distribution and allow well users to make proper plans to address exposure.

Finally, climate change has already influenced the hydrology of both ground and surface water resources in the region. This issue is particularly noticeable in upland areas where precipitation has shifted from snow dominated systems to systems where rain and rain on snow are the primary sources of precipitation. On average, snowpack at five SNOTEL sites in the Powder Basin have declined by 39.9% since 1955, with further declines of 40% expected by 2049 (USDA 2024, OWEB 2023). Shifts in the seasonal distribution of precipitation are also expected, with more precipitation anticipated for the winter and spring and less precipitation during the summer and fall, which has resulted in a 21-28% decrease in summer stream flows for Blue Mountain streams between 1949 and 2010 (OWEB 2023). These changes primarily impact areas where groundwater recharge is currently highest, such as in upland areas and from streams and rivers in depositional valleys. Given the changes in precipitation, seasonal and regional patterns in groundwater dynamics will be heavily impacted, particularly for upland areas, while the impacts on lowland aquifers will likely be more muted (Waibel et al. 2013).

Groundwater Concerns in the Powder Basin

Past studies of groundwater usage in the Baker Valley have identified several historic trends in groundwater elevations in the region. A study commissioned by the USGS in 1965 showed stable groundwater levels at sites located in the alluvial fill areas in the basin between 1936 and 1965 (Sceva and Debow 1965). Similarly, groundwater monitoring in the Baker Valley from 1956 to 1965 also identified stable water levels over the study period. The same study found rising groundwater elevations at a well in the North Powder Valley over the 1963-1965 period (Ducret and Anderson 1965). Another study found several patterns in groundwater chemistry in the basin, with high salinity and medium to high alkalinity in central portion of valley southeast of Coyote Hills along with areas of medium alkalinity and salinity north of Haines (Lystrom et al. 1967) (Figure 5.).

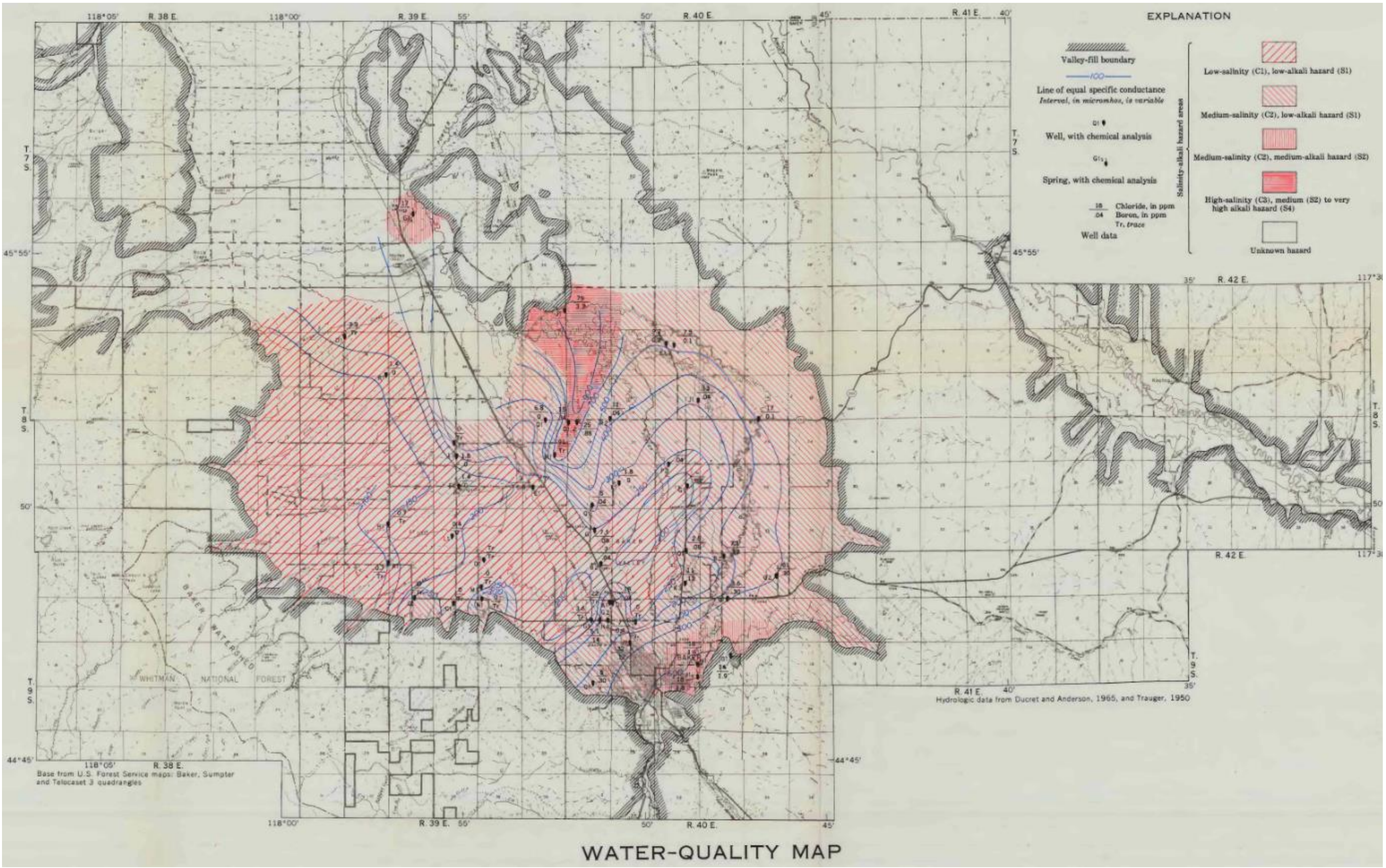

Figure 5. Map of salinity in the Baker Valley with higher hashmark densities associated with higher salinity/conductivity measurements. Source: Lystrom et al. 1967

The development of groundwater resources since these studies leaves many questions, particularly for aquifers in the glacial fill deposits in the western Baker Valley and in upland regions. Despite detailed water chemistry associated with some well reports, the lack of a single database or published study on them makes determining trends in water chemistry and potential contamination difficult. In addition, the risk of aquifer depletion is high in the Powder basin, especially in the Baker Valley, where some wells produce up to 2,000 gallons per minute for irrigation (Ducret and Anderson 1965). Better knowledge of groundwater trends and processes is crucial to determining the presence and extent of groundwater depletion and addressing any concerns related to groundwater contamination in the Powder.

Methods

Well records were obtained from the OWRD Well Report Query (link: https://apps.wrd.state.or.us/apps/gw/well_log/Default.aspx). Wells logs were found by using the first four letters of the county and well log number. Drill date, coordinates (in UTM and Township, Range, Section), Elevation (ft), Use, Lithology, Water bearing zone elevations, and well construction information was copied from well records. Elevations and UTM coordinates were found using well log coordinates and Google Earth to identify features such as pads, pumps, or other well infrastructure. Other information used as metadata for the project included ownership, tax lot, and location confidence (m).

The data from the wells logs was collated into a database using the well log number and county as the linking fields. The database was composed of 6 tables: A master table with well log metadata, a table with detailed lithology, a table containing construction information, a table with groundwater depths and water bearing zones, a table describing lithologies, fabrics, and color classes for data entry in the lithology table, and a table describing lithology and groundwater codes for the groundwater table.

A total of 579 records were queried during this project (Figure 6). Twenty-nine locations did not have associated lithology data and were not included in the final dataset. In addition to these sites, 18 locations that did not have any records, including springs, proposed wells, or locations with no well log information, were excluded from the final dataset. Well logs with lithology data were located in three counties in the Powder Basin watershed: Baker County (488 records), Union County (35 records), and Malheur County (9 records).

Analysis focused on four major questions:

- How does bedrock type change throughout the Basin and in Baker Valley?
- Does bedrock geology align with current maps of surface geology?
- What patterns exist in bedrock depths in Baker Valley?
- What are trends in groundwater depth and are there any associations with geology?

To answer questions related to bedrock geology, depth, and relation surface geology, bedrock type and elevation was found for each well log using classes identified by DOGAMI. The main bedrock types were Shale associated with Paleozoic marine sedimentary rock, Diorite and Granite associated with Mesozoic intrusive volcanic rocks, Rhyolite and Tuff associated with Paleogene volcanic rocks, Basalt, Lava, Cinders, and Scoria associated with Neogene Volcanic Rocks, and Conglomerate, Sandstone, and Claystone associated with Neogene sedimentary rocks. Bedrock geology was overlaid alongside surface geology from the Oregon Geologic Data Compilation, release 7 (OGDC-7) (Franczyk et al. 2023). Bedrock geology was colored similarly to surface geology to better identify patterns. Alongside bedrock geology, bedrock elevations were also plotted against surface elevations.

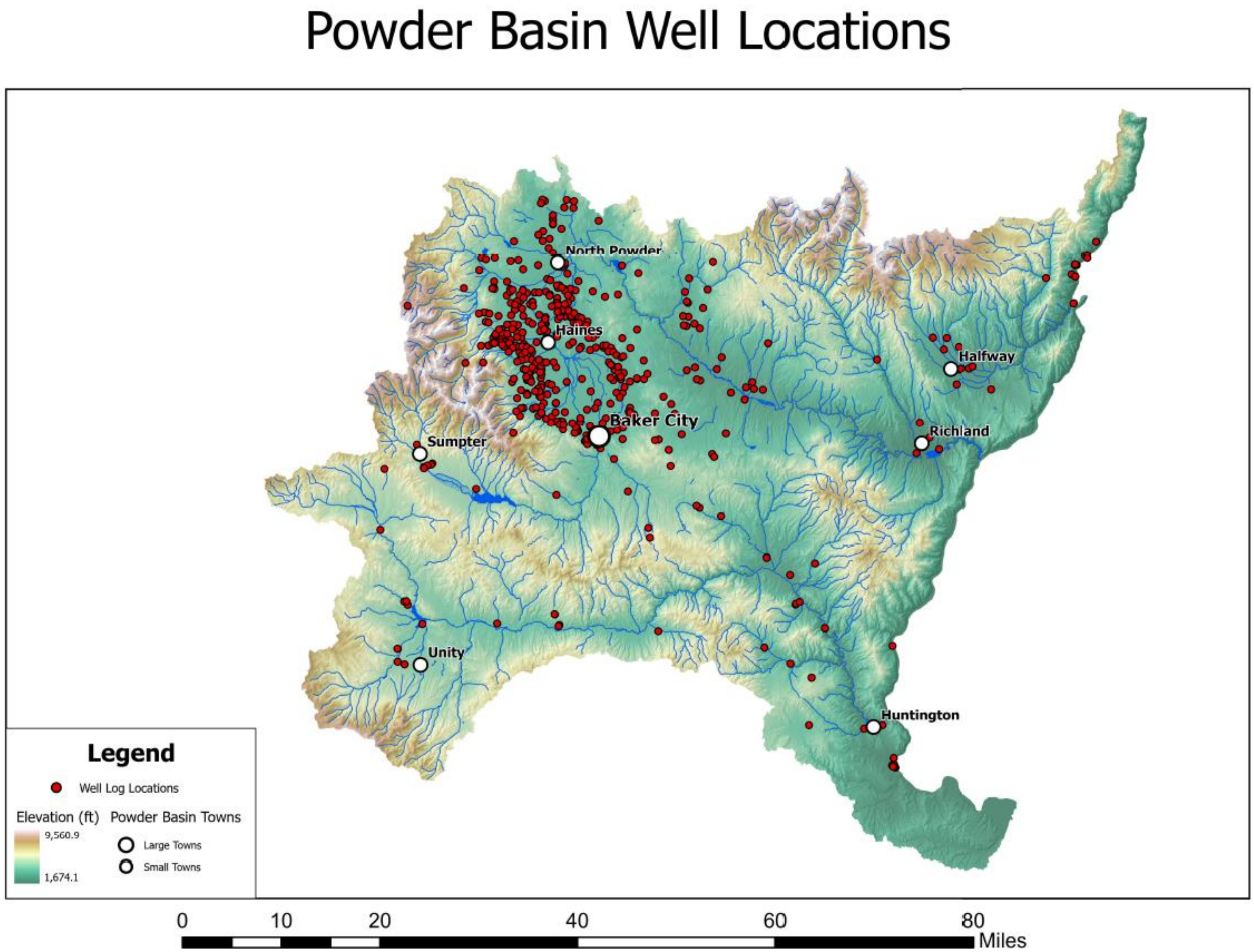

Figure 6. Map of locations for well logs included in this report.

Middle Powder Landform Zones

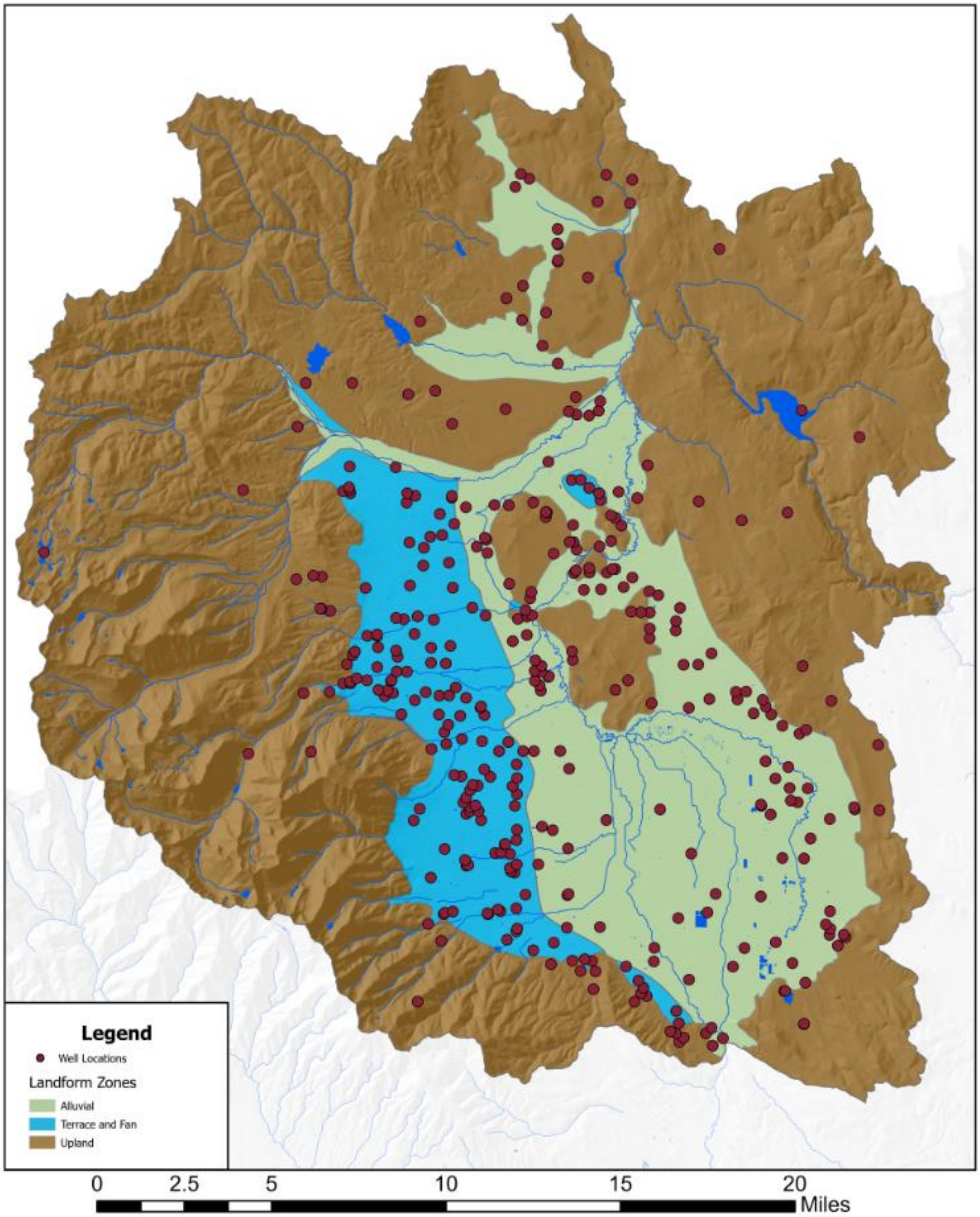

Figure 7. Map of Middle Powder well locations and landform zones. Zones delineated based on shapefiles from the Oregon Geologic Data Compilation, Release 7 (Franczyk et al. 2023).

To assess trends in groundwater depth over time, the data for wells located in the Middle Powder basin was separated into three categories based on landform and deposition type using the OGDC-7 dataset. (Figure 7.). The lowest of the three categories includes wells located within the Alluvial deposits of the Powder River and its largest tributaries, where groundwater depths are likely influenced by surface water infiltration. The next highest zone included wells located in sediments representing older terrace and alluvial fan deposits where infiltration from precipitation or from uphill sources plays a larger role in groundwater depths than those from the alluvial aquifer. The highest up are upland areas located in the Elkhorn Mountains, Coyote Hills, and other foothills regions bordering the Valley where groundwater depths are influenced by bedrock features or factors other than nearby alluvial aquifers. Sediment size also differs among these landform types affecting groundwater infiltration, retention, and flow, with finer sediments found in the alluvial landforms, while coarser sediments are found in the terrace and fan landforms.

Results

Well Information

Most locations (94.5%) were drilled after 1960. Noticeable peaks in drilling activity were found centered around 1980 and 2015, likely due to drought occurrence during these time periods (Figure 8)

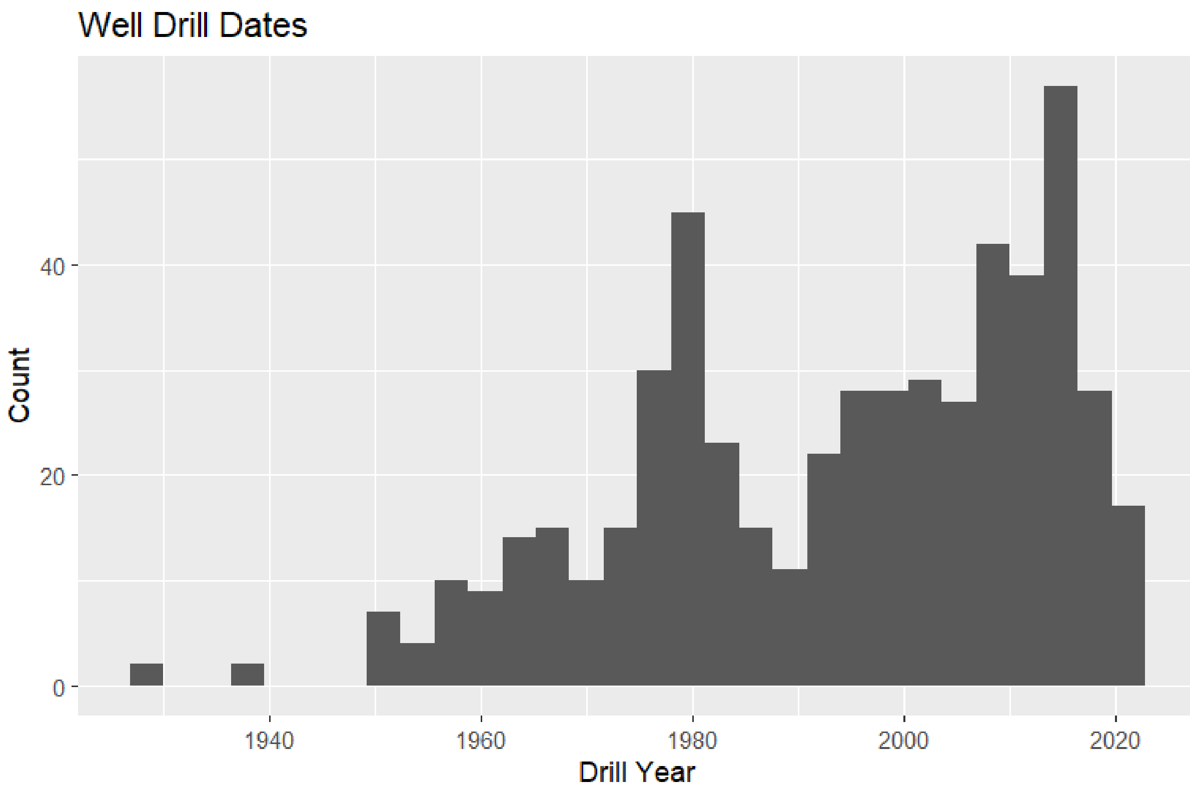

Figure 8. Histogram of drill dates for the wells included in this project

Primary uses for wells were for Domestic (44.4%), Irrigation (31.0%), and Livestock (9.0%) uses. Other uses (Community, Industrial, Monitoring, Test Wells, etc..) composed 11.3% of uses, while wells with multiple uses constituted 4.3% of all records.

Of the 530 records with well depths, 528 (99.6%) were less than 1000 feet deep, 398 (75.1%) were less than 500 feet deep, and 98 (18.5%) were less than 100 feet deep (Figure 9). Well depths differed by use. Average depths for Domestic wells were 222 feet, while depths for industrial and irrigation wells were 368 and 432 feet, respectively (Figure 10).

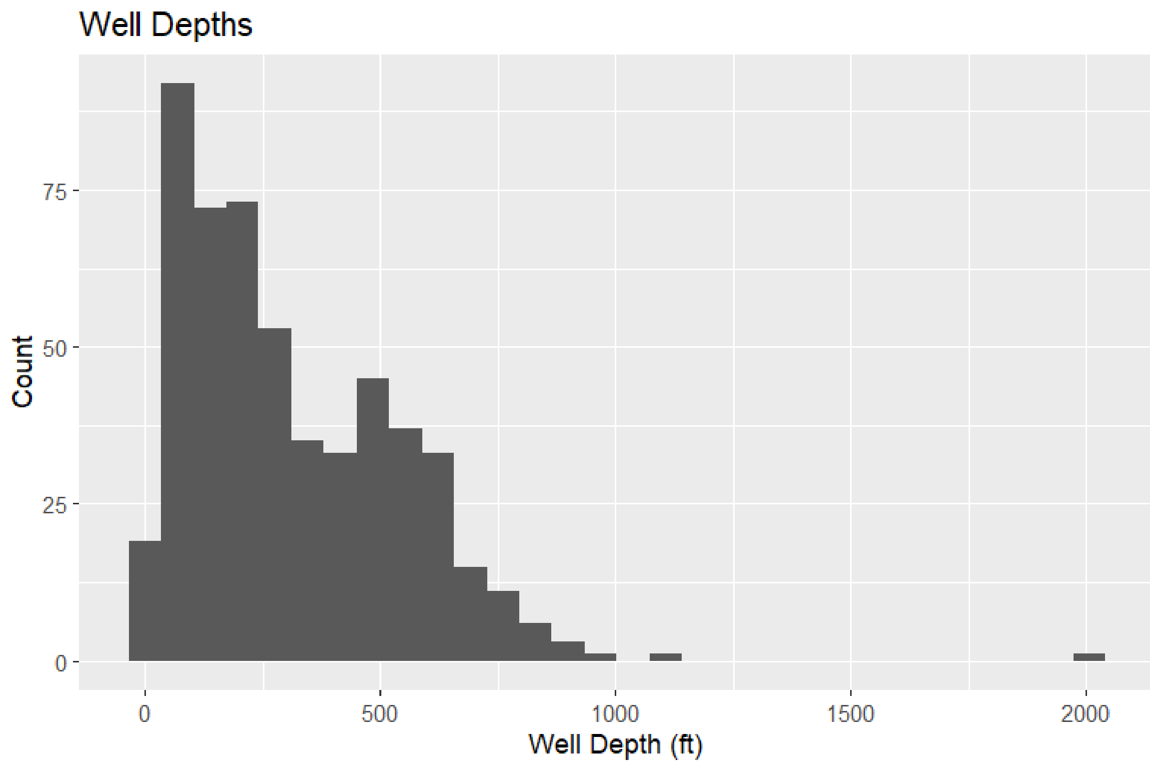

Figure 9. Histogram of maximum well depths for the wells included in this project.

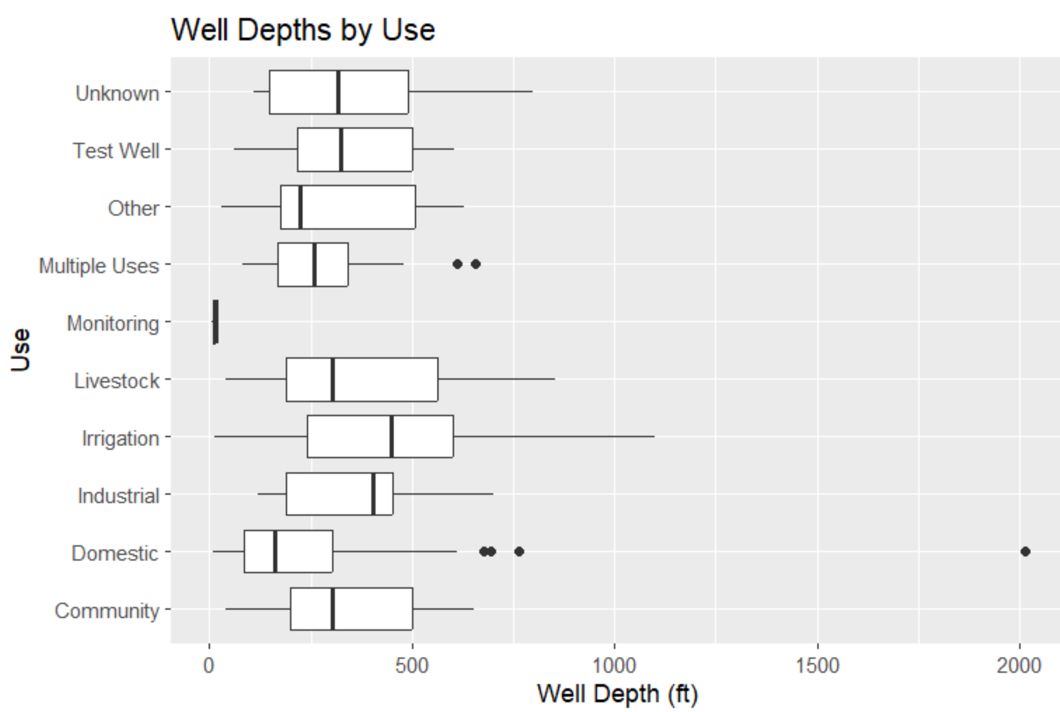

Figure 10. Boxplots of maximum well depths by well use.

Well Bedrock Geology and Elevation

Information on bedrock type, depth, and elevation was present for 274 sites from the query. This information was used to map bedrock attributes and to identify patterns in bedrock depth, elevation, and groundwater presence. Of these sites, 197 (71.9%) were located in the Middle Powder basin, with most of these sites in the wide, depositional Baker Valley. Of the remaining sites, 21 sites were located in depositional valleys by the Main stem Burnt River, while 31 sites were located in the Lower Powder, primarily in the Keating Valley.

The presence of Bedrock elevation data in the Baker Valley was primarily located on the edges of the valley and around the Coyote Hills (Figures 13 and 14). Few wells had bedrock elevation data in the middle of the southern Baker Valley, most likely due to the deep layers of sediment above bedrock in this part of the Valley. Elevational gradients of bedrock in the Powder Valley showed increasing elevations from east to west, likely due to faulting in the area along the flank of the Elkhorns on the west side of the basin and along the hills on the east side of the basin.

Of the sites with bedrock information, 244 well logs had more detailed data on bedrock types. The primary rock types found in the well logs were basalt and granite, further evidence of the region's volcanic history (Figure 11). In the Baker Valley, the basalt is located primarily on the eastern edge of valley with significant amounts also found around the Coyote Hills in conjunction with large amounts of Cinder (Figure 14). Granite was located mostly on the western edge in the valley by the northern extent of the Elkhorn Range and by the Coyote Hills. Sedimentary bedrock types (Conglomerate, sandstone, and claystone) were primarily found in the flatter, depositional areas of Valley. The bedrock types aligned well with surface geology in most areas. Of particular interest was the bedrock in the North Powder section of Baker Valley, highlighting the presence of granitic rocks near the Elkhorn Mountains and Basalt in the basin east of the Coyote Hills. Another interesting pattern of note was the presence of basalt bedrock in the southern Elkhorn foothills, indicating the presence of overlaying volcanic rock on top of the Paleozoic terrane rocks in this area that have been covered by overlying alluvial and glacial sediments.

Powder Basin Well Bedrock Types

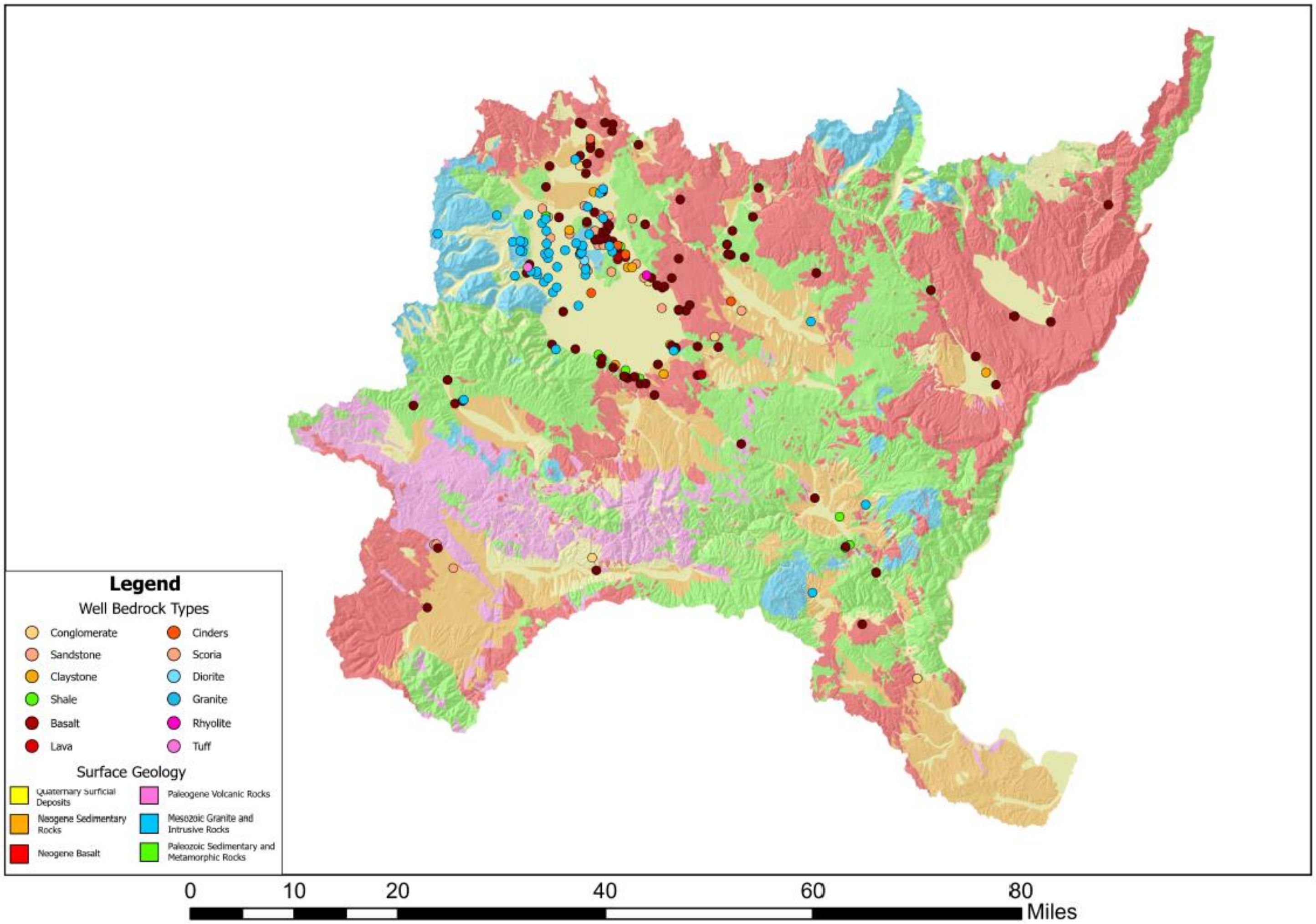

Figure 11. Bedrock geology for wells in Powder Basin with surface geology in the background for reference. Bedrock types color-coded to match surface geology symbology.

Powder Basin Well Bedrock Elevations

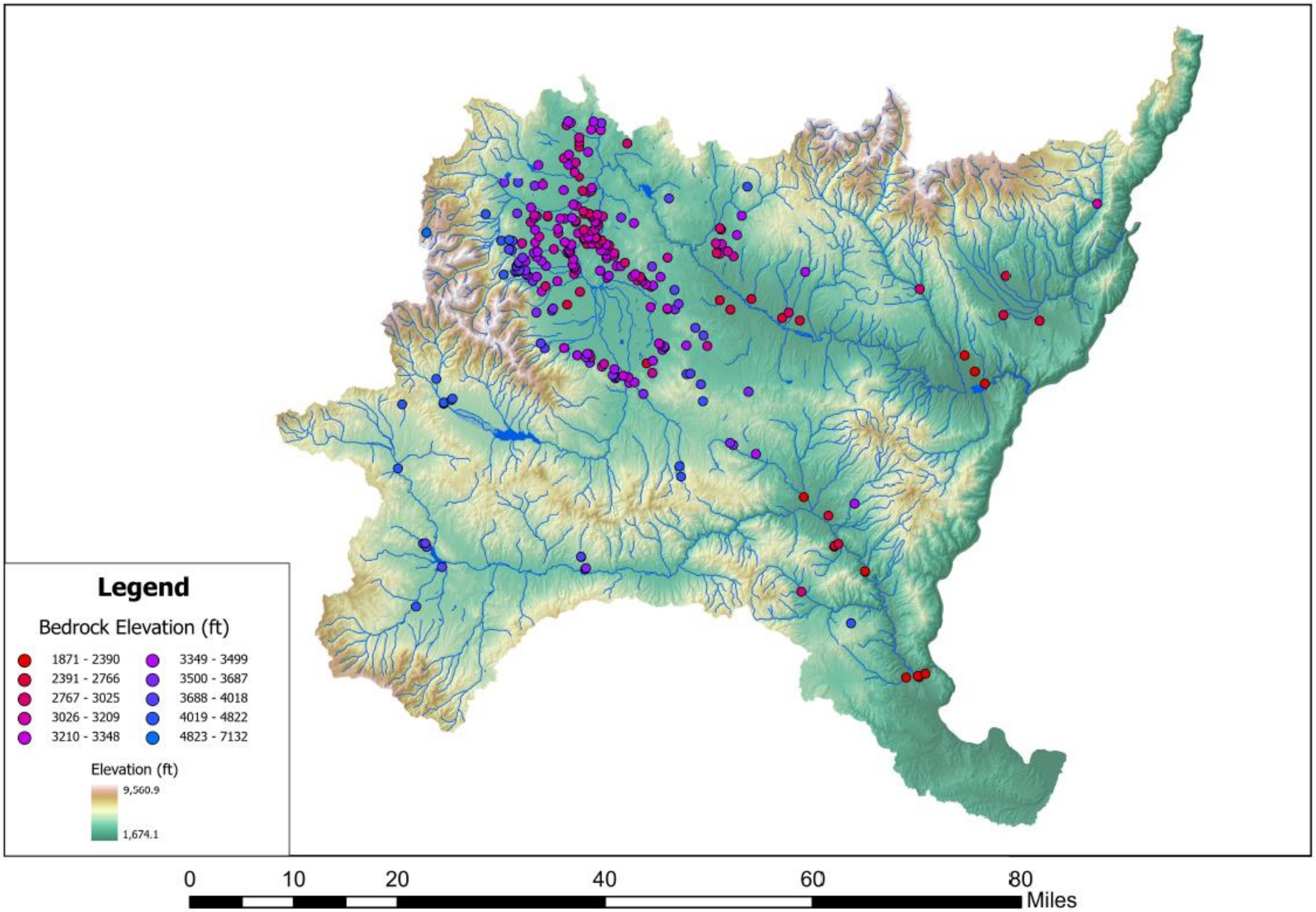

Figure 12. Well bedrock elevations for the Powder Basin with stream and waterbodies in blue.

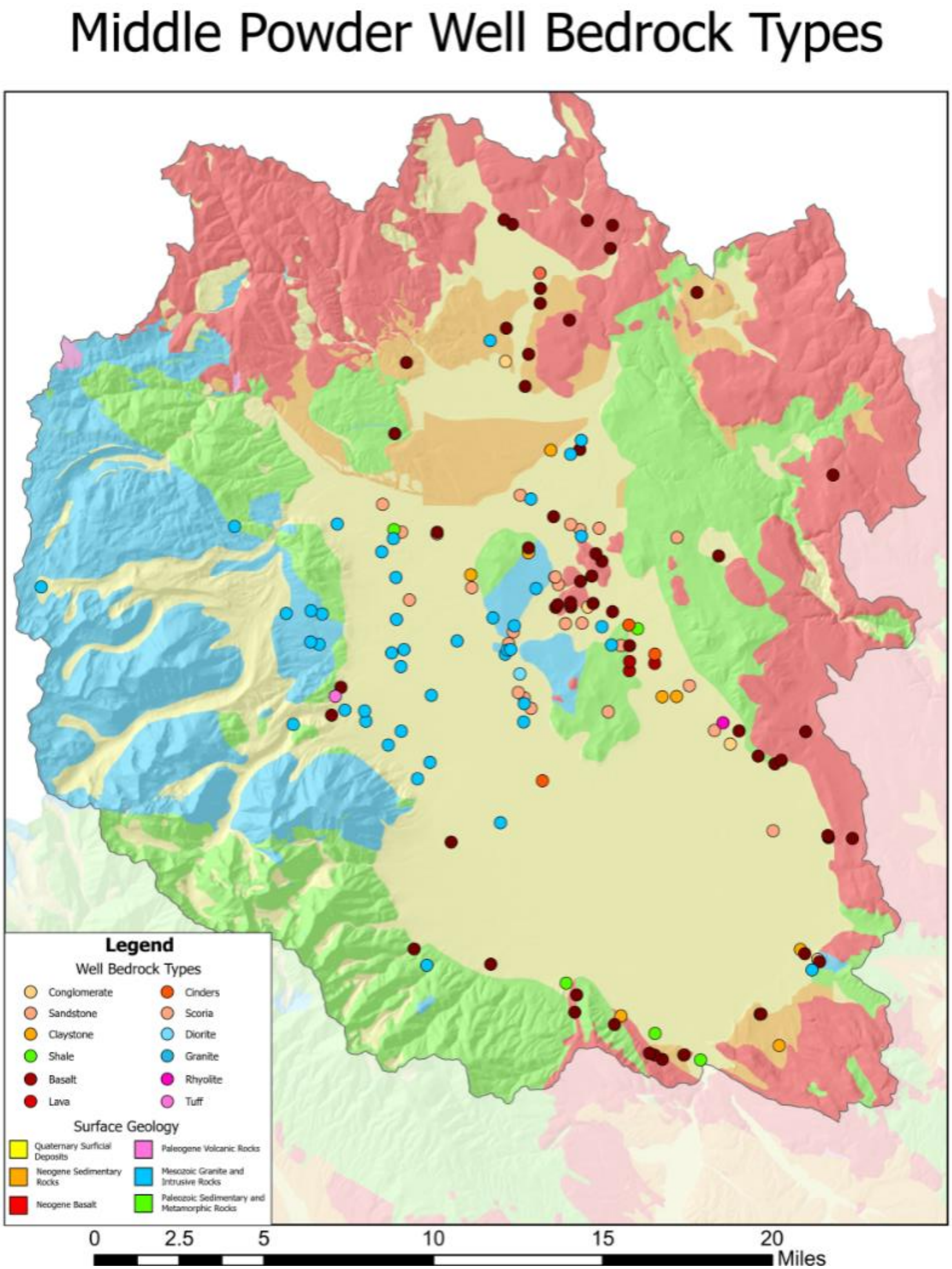

Figure 13. Close-up of well bedrock geology in the Middle Powder basin with surface geology in the background for reference.

Middle Powder Well Bedrock Elevations

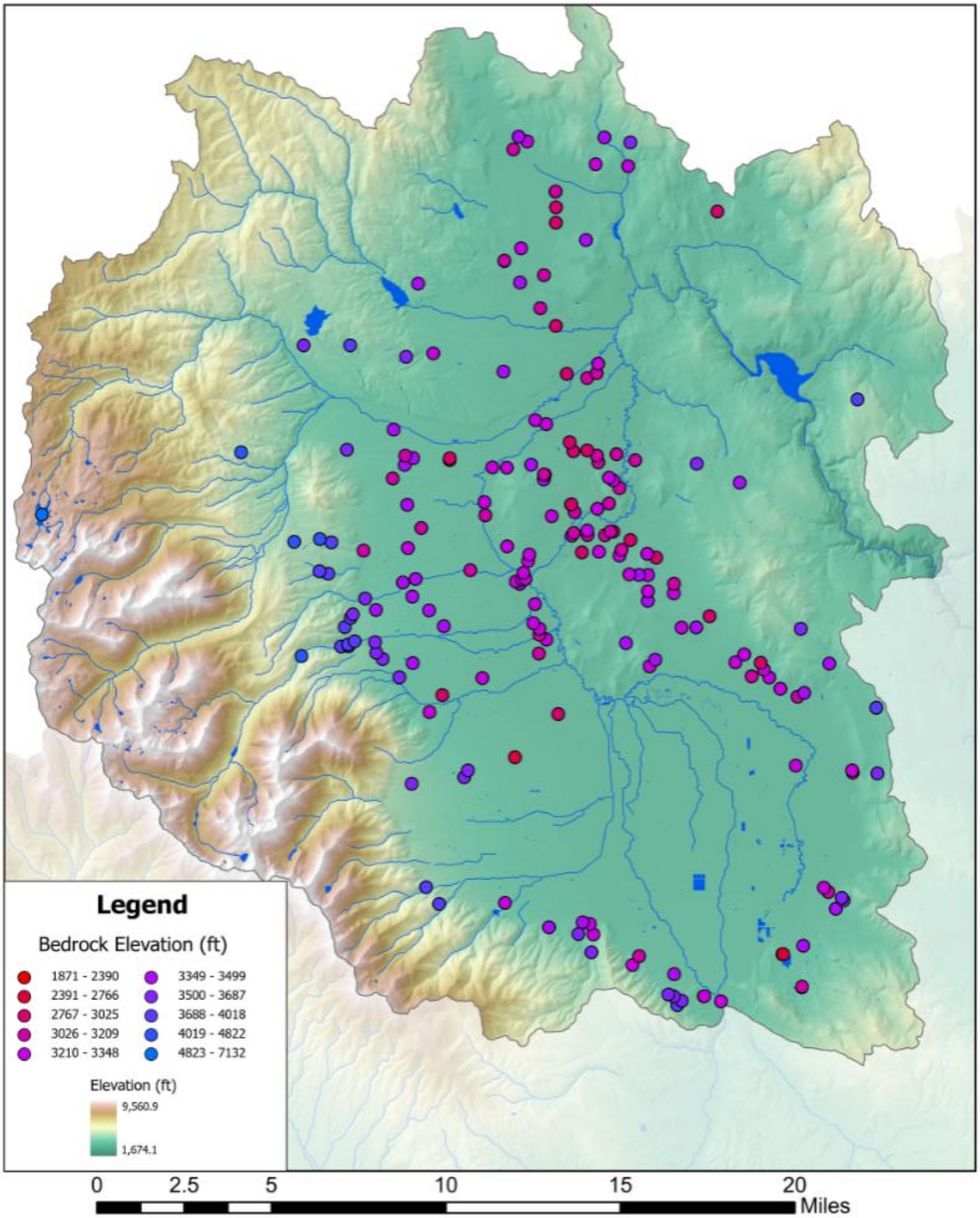

Figure 14. Close-up of well bedrock elevations in the Middle Powder basin with stream and waterbodies in blue.

Groundwater Depths and Geology

470 well logs contained information on depth of first water (i.e. groundwater depth). Groundwater depths were mapped and plotted to assess spatial patterns and temporal trends. Analysis focused on the Middle Powder and Baker Valley region due to heavy groundwater usage in this area (364 records or 77.4% of records with groundwater data).

Trends in groundwater depth over time for the Baker Valley/Middle Powder varied depending on landform type. An increasing trend was found between drill date and depth to first water for all zones, although the trend was not significant at the p = 0.05 level for wells in the Alluvial zone (x = 0.6165 ft. per year, SE = 0.3788, p = 0.106) (Figure 15). Trends were much higher in the Terrace zone (x = 2.5871 ft. per Year, SE = 0.6098, p = < 0.001) (Figure 16) and in the Upland zone (x = 2.4622 ft. per year, SE = 0.6271, p = <0.001) (Figure 17), likely indicating a drop in groundwater depths in these zones over time.

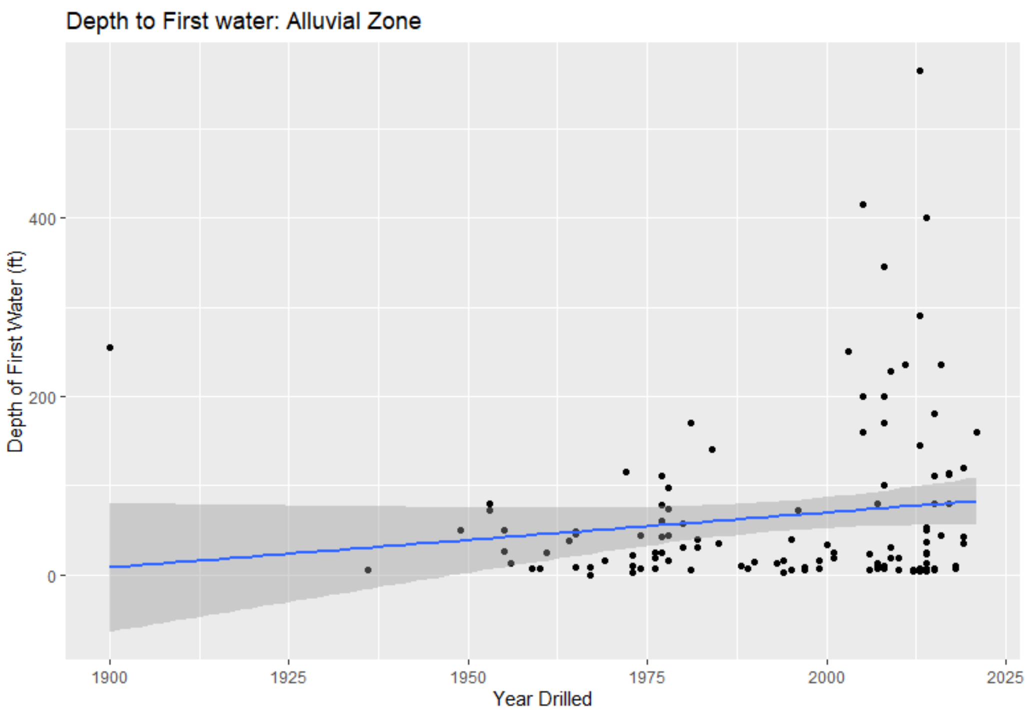

Figure 15. Plot of depth to First water (in ft. below surface) over time based on drill year for wells located in the Alluvial Zone of the Baker Valley with linear regression best fit (blue line) and 95% error (shaded).

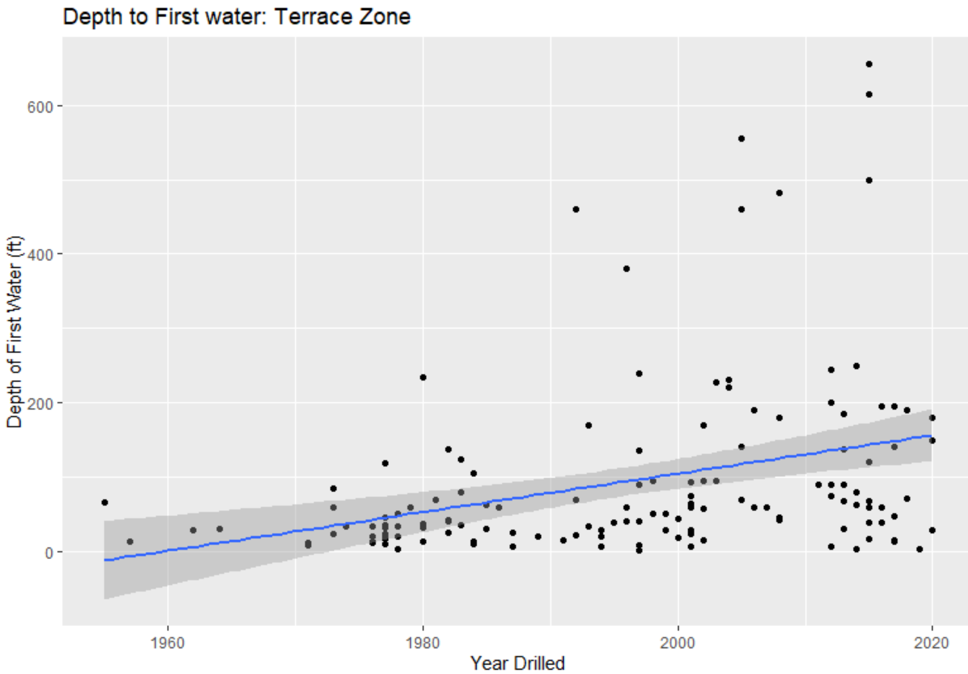

Figure 16. Plot of depth to First water (in ft. below surface) over time based on drill year for wells located in the Terrace and Fan Zone of the Baker Valley with linear regression best fit (blue line) and 95% error (shaded).

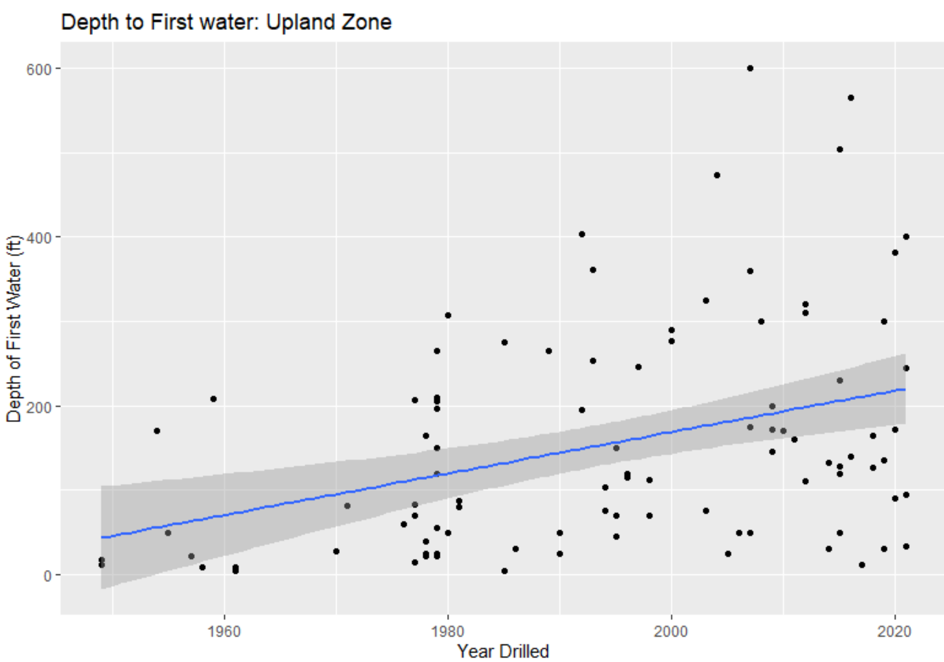

Figure 17. Plot of depth to First water (in ft. below surface) over time based on drill year for wells located in the Upland Zone of the Baker Valley with linear regression best fit (blue line) and 95% error (shaded).

However, the distribution of well depths for all zones was not equal over time, with greater variation in the data found during later years vs. earlier years. The linear regression also failed to explain much of the variance in the data for all zones, as indicated by low R^2 values from the regressions ($R^2 < 0.15$) limiting the utility of the analysis to assess if groundwater depths are increasing over time due to overuse. Seasonal patterns are another important component that cannot be ruled out as a factor contributing to the observed trends in groundwater depth over time, since groundwater depths can vary up to up to 10 feet over the course of the year (Ducret and Anderson 1965).

Discussion

Better knowledge of the lithology of the Powder Valley was useful for the PBWC in assessing trends in groundwater usage and depths. The data suggests there might be groundwater depletion in the Middle Powder region, particularly for terrace and upland depositional zones where longer-term processes are more important in determining aquifer recharge and storage. While simplified geological correlations such as the method used in this report can help understand some trends, more detailed models, such as the numerical groundwater-flow models used in the Harney and Umatilla basins will likely be required to better understand groundwater processes in the basin. Improved understanding of these processes will be incredibly useful in improving management of groundwater resources in the region. Data from monitoring wells outside of the shallow alluvial aquifer in the Main Baker Valley would be useful to assess if the observed trends in maximum wells depths over time in the Terrace is an artifact of better data and/or increased well drilling during later periods (1970's to present).

Moving forward, the PBWC hopes to continue to use well logs as a way to track groundwater use. Better use of existing well log data, particularly from currently continuously monitored locations, will be critical in assessing trends in groundwater resources throughout the basin. Future reports should also look into trends at these sites in relation to bedrock/substrate type and water chemistry. Previous monitoring of public groundwater sources identified 6 wells with arsenic levels above the 10 µg/L recommended level and 10 sites with nitrate levels above the 10mg/L recommended level. These include wells for Baker City, Huntington, and Durkee as well as water sources for several state parks and campgrounds (ODEQ 2013). More widespread groundwater chemistry monitoring including private groundwater wells, if possible, may be useful in identifying associations with geology and groundwater usage and help mitigate potential public health issues.

The data collected as part of this project will complement other data collected by DOGAMI to generate reports and products that will explore Baker County geology, including geochemical samples, orientation points, magnetic polarity and samples from volcanic vents. Of particular interest to DOGAMI is evidence of past volcanism in the region using similar methods used to understand clastic volcanic activity in the Prineville area. The presence of Rhyolitic rocks indicates the presence of several large-scale eruptions between 29.7 and 27.6 million years ago, alongside similar rocks indicating earlier, smaller eruptions around 41.8 million years ago. Similar rock formations of rhyolite associated with the John Day and Clarno Formations exist throughout the mountain ranges between the Powder and Burnt River sub-basins, indicating pyroclastic and andesitic volcanic activity in the area. Better geologic maps of this region will improve our understanding of the processes related to these calderas, identify locations where they were likely present, and the timeline these eruptions occurred.

This project will also complement DOGAMI's assessment of the underlying geology of the Baker Valley. While the well log data will be useful in understanding the geology of the North Powder section of Baker Valley due to the shallower bedrock depths, they were unable to determine bedrock composition for the deeper sediments of the main Valley. More information is needed to determine how deep these sediments go, what processes might result in patterns of groundwater presence, and how current use compares to rates of outflows and recharge. Combining the well-bedrock data with other methods will better determine the geology and groundwater dynamics in this area of the basin.

Acknowledgements

This project was completed in collaboration with Jason McClaughry from DOGAMI and Phil Marcy from OWRD, who provided guidance, financial support, and review.

This project was funded by OWEB (Grant #220-5043-1740)

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