HYDROGEOLOGIC ANALYSIS OF THE WATER SUPPLIES FOR THE COMMUNITIES OF BLOOMINGTON AND PARIS, BEAR LAKE COUNTY, IDAHO

PRELIMINARY DRAFT

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Technical Assistance for Rural Ground Water Development within Idaho

OVERVIEW

The IWRRI Community Water Project team met with the city councils of Bloomington and Paris, Idaho and agreed to provide the communities with assistance to: 1) evaluate the hydrology of the cities springs, 2) delineate recharge areas for these springs, 3) identify alternative ground water targets, 4) identify the recharge zones for the new targets, and 5) distribute results to the city, the city engineers, and the Idaho Department of Environmental Quality.

The dominant rock types in the Bear River Range consist of limestones and sandstones deposited in an ancient sea. Later the rocks were exposed at land surface, folded and then faulted, resulting in a north south oriented valley. Weathering and erosion then deposited additional sediment on the older rocks.

Our ground water conceptual model involves precipitation entering the hydrologic system primarily in the mountains, melting in the spring, flowing through the ground-water system and discharging in fracture-controlled springs in a limestone unit called the Bloomington Formation, which sits just above a shale. We think that the shale acts as a barrier to ground water flow forcing most of the ground water out of the limestone aquifer. The Brigham Quartzite (a well cemented sand), which lies just below the shale and sits on a thrust fault (fault due to compression of the earths crust), hosts numerous springs. We think the ground up rock material in the thrust fault acts as a barrier to ground water flow, forcing precipitation falling on the Brigham Quartzite to discharge in springs within the same formation.

Another interesting target is the Slat Lake Formation, an assortment of shales, silts, silty limes, sands and gravels. Gravels within the Salt Lake Formation hosts most of the high-yielding wells in the valley, thus our interest in it as a target.

Our study developed the following prioritized exploration targets. This list is based on our perception of the relative merit of each from an ease-of-discovery versus a risk-of-failure point of view. In descending order the targets are: 1) Salt Lake Formation, 2) Bloomington Formation, 3) Brigham Quartzite. The gravels within the Salt Lake Formation are close to both Paris and Bloomington and host high-yielding wells, but may be isolated from potential recharge areas. The Bloomington Formation contains high-volume springs and is in direct connection to a recharge area. However, fracture distribution controls ground-water flow so a well needs to intersect fractures to yield much water. We suspect a shale unit limits the amount of water available in the Brigham Quartzite.

We recommend drilling a test well to determine the suitability of a target aquifer and a routine water level monitoring plan.

INTRODUCTION

The communities of Bloomington and Paris, located along the west side of Bear Lake, derive their water from limestone cave-hosted springs sited several miles to the west (Figure 1). The springs serve 251 people in Bloomington and 576 people in Paris (Idaho Dept. of Commerce, 2001). The supply lines gravity-feed from the spring sources to the distribution lines in the communities.

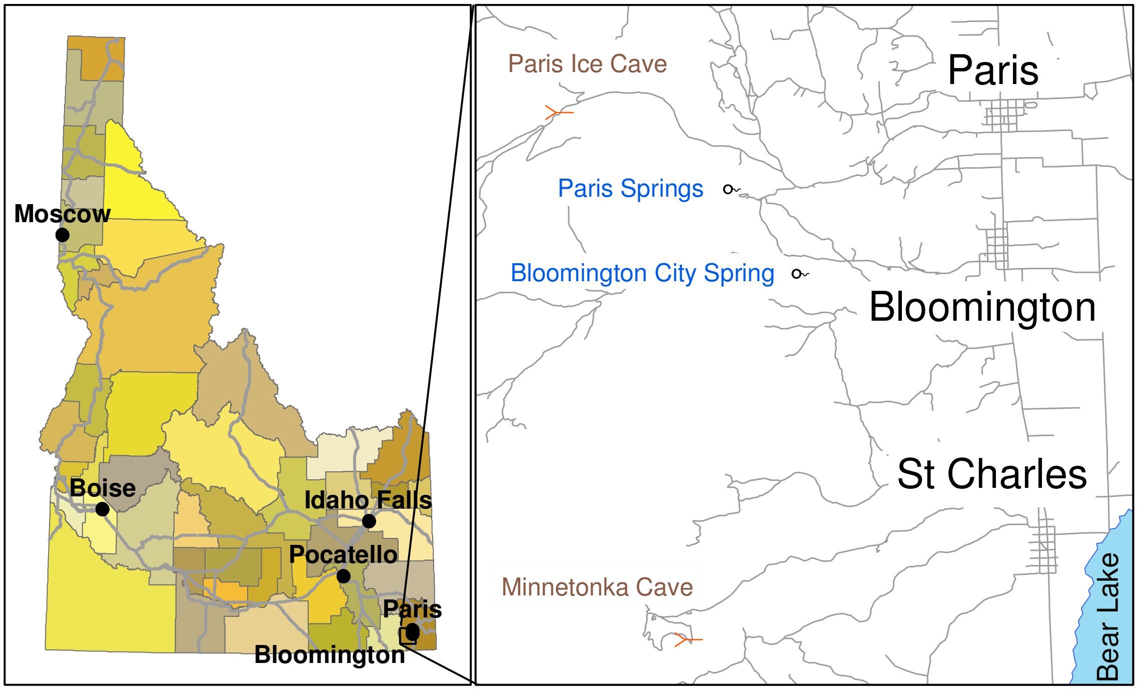

Figure 1. Map showing the location of the communities of Paris and Bloomington, Idaho.

STATEMENT OF PROBLEM

Though the springs historically produced adequate volumes of water, growth and the need for an alternate source requires that the communities seek additional supplies. The cities require an alternate source in case their primary water supply source fails.

This report describes the geologic controls for the springs supplying the communities of Paris and Bloomington, the ground water system that feeds the springs and alternatives for ground water development in the area. This paper does not address regulatory requirements or establish regulatory policy.

PURPOSE AND OBJECTIVES

IWRRI Community Water Project team members met with the city councils of Bloomington and Paris to discuss offering our technical hydrogeologic services. Subsequently we agreed to provide the communities with the following data and interpretations:

1. Evaluate the hydrology of the city springs.
2. Delineate recharge areas for these springs.
3. Identify alternative ground water targets available for potential development.
4. Delineate the recharge zones for the alternate targets.
5. Distribute results to the city, the city engineers, and the Idaho Department of Environmental Quality.

The following section provides an overview of ground water hydrology. In the following two major sections we discuss our understanding of the geology in the vicinity of the communities and then discuss our interpretations of the hydrogeology. The last two major sections, Discussion of Results and Recommendations, are where we place our findings in perspective.

GROUND WATER DEVELOPMENT CONCEPTS

Ground water occurs and moves through interconnected fractures and intergranular pore space in an aquifer. It moves under the force of gravity from higher elevation recharge areas to lower elevation discharge areas. Most recharge results from infiltration of precipitation, though some occurs from streams and lakes at elevations higher than the water table. Typical discharge areas include springs, streams and lakes. Ground water moves slowly, generally less than 10 feet per day.

Subsurface geology provides strong controls on water movement within an aquifer. Therefore, an understanding of the subsurface distribution of unlithified sediment, lithified rock, faults, and their physical properties generally leads to a commensurate understanding of ground water flow systems. Mapping surface rock outcrops and reviewing logs of material penetrated by wells helps interpret these features.

Sustainable well development requires less ground water use than aquifer recharge because removal of water results in some water level decline with an associated reduction in natural discharge. The basis for proper ground water development requires characterizing natural ground water discharge from springs and seeps, knowing the discharge of interconnected streams, and understanding the quantity and location of annual aquifer recharge. Additionally, municipal water supplies need a recharge zone protected from contamination because contaminants can mix with ground water and contaminate the municipal supply.

GEOLOGY

We find that to fully understand a ground water flow system we must first understand the geology. We start this section by first discussing the regional geologic setting and then we examine the project area geology. Following the geology section, the hydrogeologic section outlines ground water flow systems.

REGIONAL GEOLOGY

Bear Lake County resides within the Idaho-Wyoming-Montana overthrust belt, and also in the northern portion of the Basin and Range Province. Because it resides in the overlap of two geologic provinces, it includes both structural characteristics. Limestone and sandstone, the dominant types of rock exposed in the Bear River Mountain Range, originally formed by sedimentation in shallow seas during Paleozoic time. During Cretaceous time compressional forces folded and faulted these rock units forming the Idaho-Wyoming-Montana overthrust belt. Valleys in Bear Lake County formed primarily during Tertiary-age Basin and Range extensional faulting. As a result of this activity rocks identical to those exposed in the adjacent mountains occur at depth in the Bear Lake Valley. Because Bear Lake occupied much of the valley throughout the last several thousand years, these older rocks lie buried under lacustrine sediments.

PROJECT AREA GEOLOGY

This Project Area Geology section is divided into two sections, stratigraphy and structure. The stratigraphy section provides an overview of the hydrogeologically significant units exposed in this portion of the Bear River Range. The structure section discusses the hydrogeologically significant folds and faults.

STRATIGRAPHY

Strata exposed in the Bear River Range include a several-thousand-foot thick section of upper Proterozoic, Paleozoic and Tertiary age sedimentary rocks (Oriel and Platt, 1980). The Proterozoic and Paleozoic strata represent continuous deposition through time, with only a few minor erosional interruptions.

BRIGHAM QUARTZITE

The lowest strata exposed make up the Brigham Quartzite (PCcb in Plate 1). The Brigham Quartzite consists primarily of silicified sand with occasional small lenses of pebble conglomerate.

This lithology contains little hydraulic conductivity or porosity, two qualities necessary to form a good aquifer. However, the rock fractures readily during faulting, providing abundant avenues for water movement.

LEAD BELL SHALE

The Middle Cambrian age Lead Bell Shale (Cbl in Plate 1) lies above the Brigham Quartzite. The Lead Bell Shale consists primarily of green mudstone with some gray limestone and mudstone.

The Lead Bell Shale does not contain the characteristics required to make it a worthwhile aquifer. However, its location, between the Brigham Quartzite and the rest of the Bear River Mountain Range, makes the Lead Bell Shale hydrogeologically significant.

PALEOZOIC CARBONATE STRATA

Strata that occur above the Lead Bell Shale include a thick section of limestone, dolostone and interbedded quartzite (Plate 1). This sequence hosts some locally well-known caves such as Minnetonka Cave, within the Mississippian age Madison Limestone (Ml in Plate 1), and Paris Ice Cave, within the Ordovician Garden City Limestone (Og in Plate 1). Figure 1 locates these caves.

Limestone and dolostone host some of the most robust aquifers in the world, for example, the Floridian Aquifer in Florida and the Edwards Aquifer in Texas. However, carbonate rocks originally lack significant porosity and hydraulic conductivity. With dissolution along fractures due to water movement they develop into aquifers. Continued water movement through the fractures modifies them into caverns and caves by gradually dissolving the rock matrix. The Bloomington Formation (Cbo in Plate 1), located near the base of this carbonate sequence, hosts a well-developed system of interconnected caves and channels that provide pathways for water movement. These caves provide the avenue through which ground water easily passes and form the plumbing system for most of the large volume springs in the area. The community of Bloomington acquires water from a cave-hosted spring in the Bloomington Formation. Paris acquires water from a cave-hosted spring in the upper part of the Bloomington Formation or in the overlying Nounan Formation (Cn in Plate 1).

SALT LAKE FORMATION

The Salt Lake Formation (Tslc in Plate 1) overlies the older limestone and sandstone sequence. The Salt Lake Formation consists of mostly fine-grained claystone and silty limestone with interspersed sand and gravel lenses. The base of the Salt Lake Formation is marked by a laterally extensive gravel.

The claystone and silty limestone in the Salt Lake Formation generally act as confining layers inhibiting ground water movement. However, when the sand and gravel lenses are large enough, they form aquifers. Additionally, the regionally extensive gravel unit at the base of the formation looks like a particularly robust aquifer.

UNCONSOLIDATED SEDIMENTS

In the Bear Lake area, much of the unconsolidated material filling the valleys consists of sands and gravels deposited from flowing streams, and fine-grained mud deposited from lakes (Qal in Plate 1). The sands and gravels lie in canyons incised into the mountains. Clay beds deposited from an ancient lake fill much of the central part of the Bear Lake Valley.

Unconsolidated sands and gravels deposits form good aquifers and the river or stream that deposited them represents a good source of recharge. Unfortunately this intimate contact with a surface water body also tends to render these aquifers vulnerable to contamination.

STRUCTURE

Rocks in the Bear Lake area display structures created during at least two tectonic events. Cretaceous tectonism includes folds and associated thrust faults caused from compression. The younger, Tertiary-age, event consists primarily of normal faults that formed in response to extension during development of the Basin and Range Province.

CRETACEOUS-AGE FEATURES

Cretaceous age tectonism produced the syncline that forms the core of the Bear River Range. Cross section UTM 4,672,181 N in Plate 1 shows our interpretation of this structure. Road cuts along Highway 36 between Ovid and Preston expose the same rocks illustrated in this section. The other major Cretaceous age tectonic feature exposed in the Bear River Range is the Bloomington Thrust Fault. The cross-section shows the Bloomington thrust placing the Precambrian age Brigham Quartzite above Paleozoic strata.

The folding that produced the syncline and movement along the Bloomington Thrust Fault fractured the adjacent overlying and underlying rocks, greatly enhancing their hydraulic conductivity. Movement along the Bloomington Thrust also likely produced fault gouge. Fault gouge may inhibit ground-water flow.

TERTIARY-AGE FEATURES

Basin and Range faulting further modified the landscape, displacing the valleys downward and the mountain ranges upward, producing the Bear Lake Valley. The normal faults on the east side of the Bear River Range all trend north and generally displace strata down to the east. We mapped several normal faults along the east front of the Bear River Range.

These steeply dipping faults cause concern because they can offset aquifers. Occasionally either the up-thrown or the downthrown segment of an aquifer becomes isolated from any source of recharge. Without recharge, the aquifer simply dries up with use.

HYDROGEOLOGY

All water in the Bear River drainage basin originated as precipitation. Most of the precipitation within this high elevation valley comes as snow during the winter months. Thus the entire hydrogeologic system is sensitive to snow-pack accumulations. Figure 2 contains an average annual precipitation map for the area (modified from Daly and Taylor, 2001). Notice that the vast majority of the precipitation falls on the mountains.

REGIONAL AREA HYDROGEOLOGY

The hydrogeologic conceptual model consists of water accumulating during the winter months in the mountains as snow. When the snow melts in the spring some of the water flows across the land surface contributing to flow in streams and rivers, some evaporates, some infiltrates the soil and is used by plants, and some infiltrates the soil and recharges the ground water system.

The cross-section shown in Plate 1 illustrates our conceptual model for the hydrological system. It shows precipitation entering the system primarily in the mountains, flowing through the largely carbonate rocks and discharging as springs primarily in the Bloomington Formation and Brigham Quartzite. The Lead Bell Shale probably acts as a barrier to ground water flow and forces most of the ground water out of the limestone aquifers in springs such as Jarvis Spring, Paris Springs, and the Bloomington City spring. Some water seeps through the shale into the Brigham Quartzite. The Brigham lies above the Bloomington Thrust fault, which we think contains fault gouge and acts as a barrier to ground water flow. This barrier forces ground water out into the surface water system through springs in the Brigham Quartzite.

PROJECT AREA HYDROGEOLOGY

In this section we discuss the flow systems for the city springs and for potential targets. Figure 2 contains an average annual precipitation map for the Bear River Range near Paris and Bloomington. The color scale alongside the map assigns precipitation values to the different colors. The contour lines in the figure indicate ground water elevation. We inferred the ground water elevations from well logs on file with the Idaho Department of Water Resources, spring elevations, and elevations of hydraulically connected rivers and streams. Ground water, like surface water, flows down hill, knowledge that enables hydrogeologists to use maps like this to infer ground water flow directions. This analysis indicates that ground water flows easterly from the mountainous recharge area to the municipal springs.

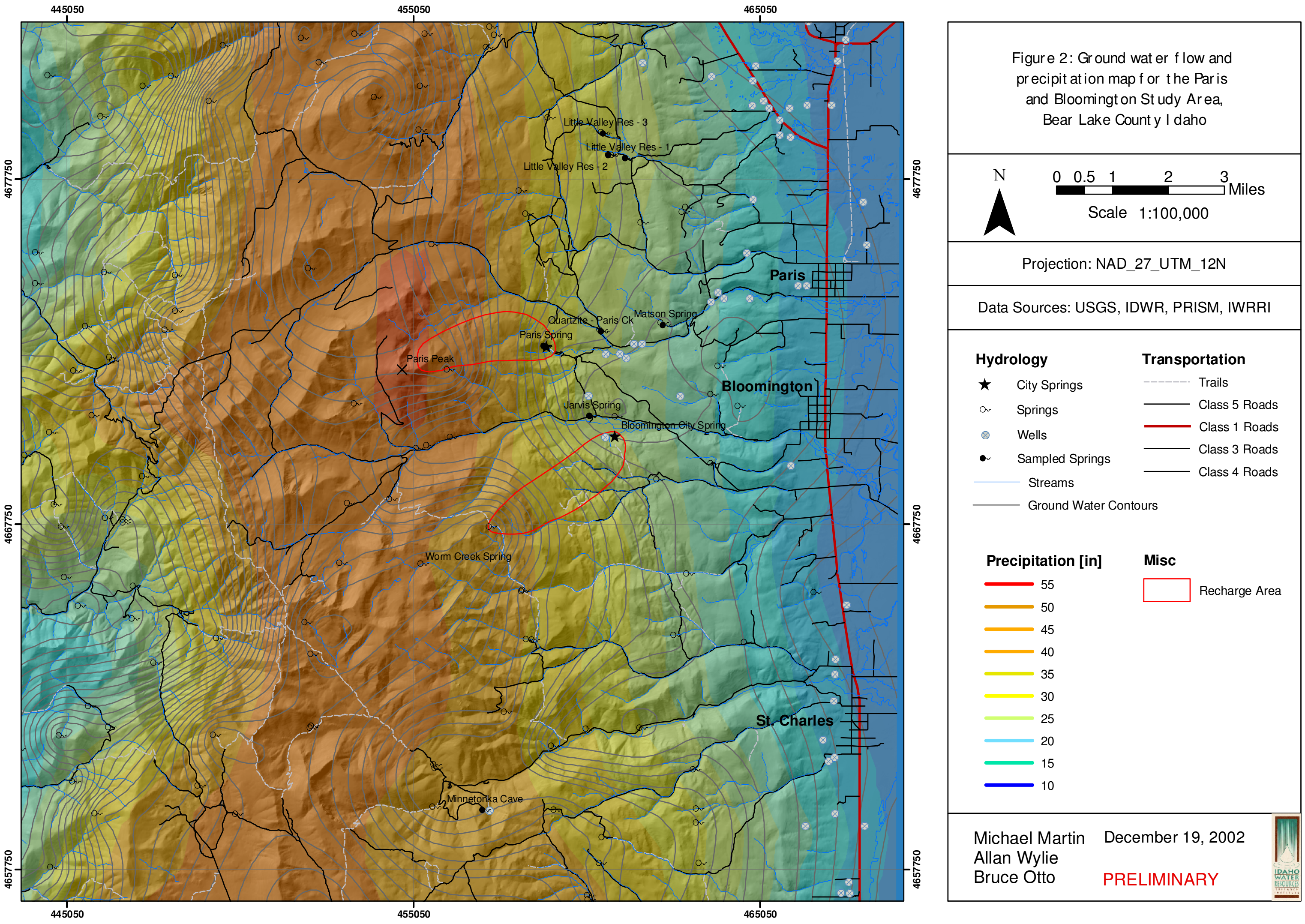

Figure 2. . Ground water flow and precipitation map.

GROUND WATER FLOW SYSTEM IN THE BRIGHAM QUARTZITE

The Brigham Quartzite hosts several springs and some wells indicating that it stores and transmits water (Plate 1). However, our conceptual model of the ground water flow system suggests that the Lead Bell Shale acts as a barrier limiting the volume of water that leaks through into the Brigham Quartzite. The Brigham Quartzite in-turn rests on the Bloomington Thrust Fault. Fault gauge within the Bloomington Thrust Fault forms another hydrologic barrier forcing ground water to discharge in the Brigham Quartzite.

GROUND WATER FLOW SYSTEMS IN CARBONATE ROCKS

Paris Springs and Bloomington City Spring discharge within or near the Bloomington Formation. As mentioned above, we suspect the many springs at this geologic horizon exist because the Lead Bell Shale restricts ground water flow, forcing water out of the aquifer and into the surface water system.

Paris Spring

Precipitation enters the system on or near Paris Peak, flows through the carbonate rocks and discharges at Paris Springs. Figure 2 shows the inferred recharge area. We suspect that the Lead Bell Shale acts as a barrier forcing most of the ground water out of the aquifer at Paris Spring. Figure 2 also shows the average annual precipitation. Paris Peak, the highest point in the Bear River Range, receives the highest average annual precipitation in the Bear River Range. More elevation provides more storage and more precipitation provides more recharge. We think these factors explain why Paris Springs maintain a more consistent discharge than many other springs.

Bloomington City Spring

Precipitation enters the system in the general vicinity of Worm-Creek Springs, flows through the carbonate rocks and discharges at the Bloomington City Spring. Figure 2 shows the inferred recharge area. We suspect that the Lead Bell Shale acts as a barrier to ground water flow, and forces most of the ground water out of the aquifer at Bloomington City Spring. Figure 2 also shows the average annual precipitation. The Worm Creek Spring area is much lower in elevation than Paris Peak, less elevation translates into less storage, and less precipitation results in less recharge, consequently Bloomington City Spring exhibits less consistent discharges than Paris Springs.

The extent to which the Lead Bell Shale isolates the flow system in the Brigham Quartzite from the carbonate flow system is a critical question. The shale could isolate the Brigham flow system from the carbonate system, separating the Brigham from the most significant flow system in the area. To evaluate the extent of mixing between the carbonate aquifer system and the Brigham aquifer system we collected samples from several springs in both flow systems (Figure 3). Figure 2 shows the sampling locations and Table 1 contains the analytical results. We collected a Little Valley Res 1 sample from a rather stagnant spring that we decided not to use after locating several more active Brigham Quartzite springs. We present our interpretation of these analyses later in the Discussion of Results section.

Figure 3. Sampling for common ions in springs near Bloomington and Paris, Idaho.

GROUND WATER FLOW SYSTEMS IN THE SALT LAKE FORMATION

The Salt Lake Formation lies beneath the communities of both Bloomington and Paris (see cross-section UTM 4,672181 in Plate 1) and hosts high-yielding wells. We examined well logs and talked with a driller that installed several wells in the area. The evidence we gathered suggests that laterally extensive gravels lie at the bottom of the formation.

We were unable to locate a source of recharge for these gravels. The lack of wells deep enough to define the distribution of the gravels and the number of faults between Paris and Bloomington and potential recharge areas, i.e. Bear River Range and Bear Lake, may indicate that the gravels do not connect to a source of recharge. If these gravels lack recharge, they will eventually run out of water.

Table 1. Spring sample analysis.

Location (Aquifer system)	Date	Alkalinity ($CaCO_3$) (mg/L)	Ca (mg/L)	Mg (mg/L)	Si (mg/L)	K (mg/L)	Na (mg/L)	Sulfate (mg/L)
Little Valley Res 2 (Brigham Qtz)	8/21/02	14	5.3	1.2	6.68	0.7	2.2	2.52
Little Valley Res 3 (Brigham Qtz)	8/21/02	16	6.1	1.2	6.71	0.7	2.3	2.46
Quartzite-Paris Ck (Brigham Qtz)	8/21/02	18	4.8	1	6.17	0.6	1.9	<2.00
Matson Spring (Brigham Qtz)	8/22/02	37	9.9	2.4	10.8	0.7	3	3.09
Paris Spring (Carbonate)	8/21/02	161	43.9	11.3	5.15	0.5	1.8	2.31
Jarvis Spring (Carbonate)	8/21/02	175	44.1	15.5	5.13	0.6	1.9	2.92
Minnetonka Cave (Carbonate)	8/21/02	215	54.4	19.4	5.12	0.5	2	5.23

DISCUSSION OF RESULTS

We identified three potential targets to explore for additional sources of water:

1) The Brigham Quartzite,
2) The Bloomington Formation,
3) Gravels within the Salt Lake Formation.

The following sections discuss advantages and disadvantages (from a hydrogeological perspective) of each of the three targets.

BRIGHAM QUARTZITE

The advantages of the Brigham Quartzite are that it is known to contain water, there is no development in its recharge area, and wells may not require an engineered well screen. Several springs and some wells exist in the Brigham Quartzite indicating that it stores and transmits water. No hazardous material handling or storage takes place or is ever likely to take place in the recharge area for the Brigham Quartzite, and therefore little risk exists of aquifer contamination from human activity. Because the sand grains in the Brigham Quartzite are cemented together, wells drilled in it may not require an engineered well screen designed to efficiently keep the aquifer material out of the well while allowing ground water in.

The disadvantages of the Brigham Quartzite are that it will likely be a difficult drilling environment, none of the springs or wells we found in this formation yield significant quantities of water and the available evidence indicates that recharge may be limited. Quartzite is a hard rock to drill and fractured-rock drilling environments pose there own set of drilling problems. We expect any drilling program in this formation to encounter both hard rock and fractured rock problems. A more significant detractor is that none of the wells or springs we located in the Brigham yield more than 20 gpm.

Our conceptual model suggests that the Lead Bell Shale limits recharge to the Brigham Quartzite. To evaluate the extent to which the Lead Bell Shale limits mixing between the carbonate aquifer flow system and the flow system in the Brigham Quartzite, we sampled springs in both flow systems. Figure 2 depicts the sampling locations and Figure 3 contains a ternary diagram illustrating the results. Note the two clusters on the ternary diagram. The samples from within the carbonate aquifer system plot on the calcium rich side of the diagram, while the samples from within the Brigham Quartzite plot on the silica rich side. If the flow systems mixed, the data points would scatter along a line indicating a transitional zone existed between the two systems. We interpret this to mean that the majority of water in the Brigham Quartzite originates from precipitation falling directly the formation outcrops. We think the low elevation of the Brigham Quartzite limits the annual precipitation rendering the available supply inadequate for either Bloomington or Paris.

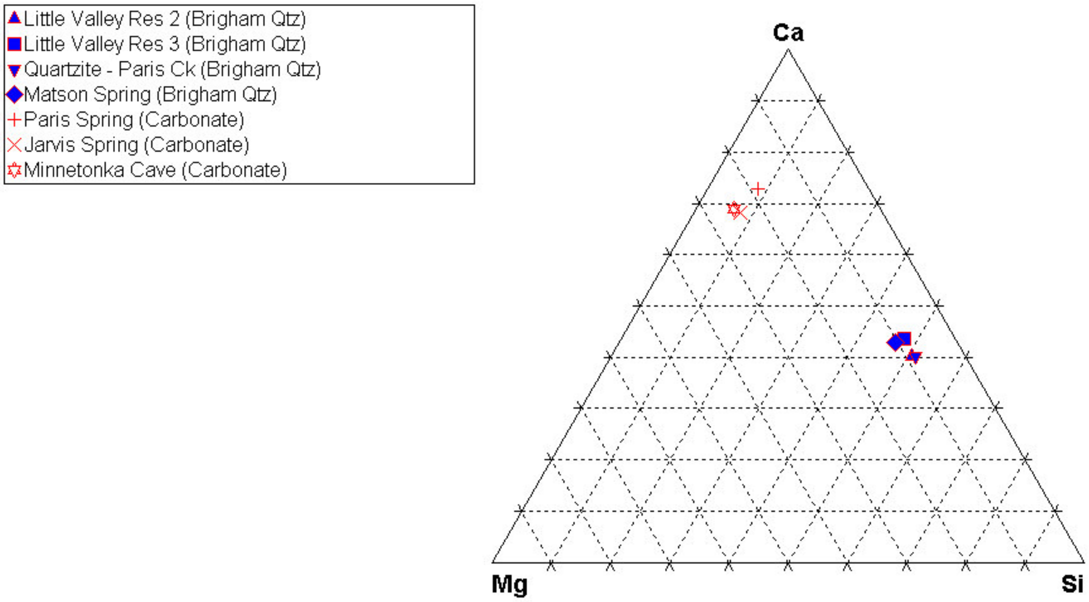

Figure 4. Plot illustrating the chemical composition of water from springs in the carbonate flow system and springs in the Brigham Quartzite flow system.

BLOOMINGTON FORMATION

The advantages of the Bloomington Formation are that it contains several high volume springs, it is directly connected to a recharge area, there is no development in its recharge area, and it may not require an engineered well screen. The number of high-volume springs indicates that this formation yields large volumes of water. Equally as important, our conceptual model suggests that this aquifer possess a direct connection to a recharge area. No hazardous material handling or storage takes place or is ever likely to take place in the recharge area for the Bloomington Formation, and therefore little risk of aquifer contamination exists. Because the Bloomington Formation consists of solid rock, wells in it may not require an engineered well screen.

The disadvantage of the Bloomington Formation is aquifer complexity. The aquifer rock matrix consists of small interlocking crystals, nearly eliminating natural porosity and hydraulic conductivity, therefore, most water movement and storage takes place in fractures, caves, and along bedding plains. Because these features are not equally distributed the success of a drilling program depends largely on luck, and hours of detailed geologic mapping and air photo analysis.

GRAVELS WITHIN SALT LAKE FORMATION

The advantages of the gravels within the Sale Lake Formation are that it lies beneath both Bloomington and Paris, it hosts high-yielding wells, and there is a thick sequence of shale and marl insulating the gravels from surface activities. We located high-yielding wells drilled in the Salt Lake Formation and talked with a driller that drilled some of the wells. The evidence suggests that the gravels are at the bottom of the formation and are laterally extensive. Since the gravels lie below a thick sequence of shale and marl there is little risk of contaminants making their way into the gravel aquifer.

A disadvantage of the gravels within the Salt Lake Formation is that they may lack a direct connection to a source of aquifer recharge. The lack of wells deep enough to map the gravels and the number of faults between Paris and Bloomington and potential recharge areas, i.e. Bear River Range and Bear Lake, leave us concerned that some of the gravels may not be connected to a source of recharge. We mapped several faults within the Salt Lake Formation and suspect these faults could limit ground water movement. We have no way of knowing how effectively (if at all) recharge reaches the gravels. This could mean that a new well might produce from an aquifer receiving no recharge. Therefore, if either Paris or Bloomington accept the Salt Lake Formation as a target, the city should put a plan in place to routinely monitor water levels in the new well. Another disadvantage is that the gravels within the Salt Lake Formation don’t appear to be cemented, therefore, a well will require an engineered screen to efficiently allow water into the well while keeping fine-grained material out.

RECOMMENDATIONS

Prior to drilling a new production well we recommend drilling test wells, conducting hydraulic tests, and collecting water samples to determine the suitability of the target aquifer(s).

The city should implement a routine water-level monitoring plan once it places a ground water well on line. Monitoring establishes seasonal and long-term trends for use during city-water-supply planning sessions.

The following list prioritizes exploration targets for additional ground water sources. We based the list on our perception of the relative merit of each target from an ease-of-discovery versus a risk-of-failure point of view (recognition of the possibility of failure in any exploration program should be kept close at hand). The list assumes acceptable chemical quality of all target aquifers. It does not address requirements that may be imposed by regulatory or administrative agencies.

1. Salt Lake Formation
2. Bloomington Formation
3. Brigham Quartzite

ACKNOWLEDGEMENTS

The authors accept responsibility for the interpretations expressed in this document. These views do not necessarily reflect those of the United States Environmental Protection Agency, the University of Idaho or any other institution. Rather, they reflect our opinions as shaped by our observations and experiences in the field, interpretation of the scientific and technical literature and our understanding of input provided by our colleagues and representatives from Paris and Bloomington, Idaho. We, the authors, accept full responsibility for any omissions or misinterpretations of facts.

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REFERENCES CITED

Daly, C. and G. Taylor. 2001: PRISM Precipitation Maps, Oregon State University Spatial Climate Analysis Service and State of Oregon Climate Service. (http://www.ocs.orst.edu/prism/prism_new.html)

Oriel, S.S. and Platt, L.B. 1980, Geologic map of the Preston 1° X 2° Quadrangle, Southeastern Idaho and Western Wyoming: U.S. Geological Survey Map I-1127, scale 1:250.000.

Idaho Dept. of Commerce. 2001, http://www.idoc.state.id.us/

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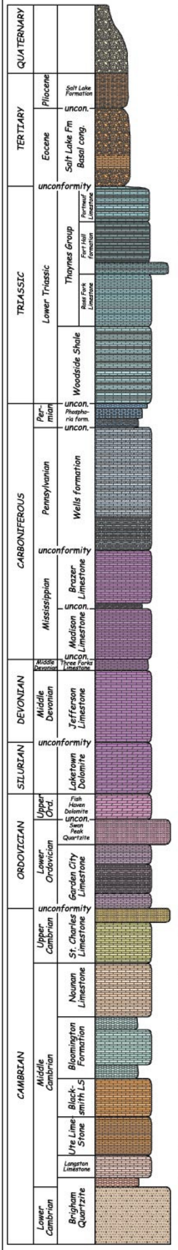
EXPLANATION



Stratigraphic column from Mansfield, 1927

Qal; Alluvium - Well to poorly sorted unconsolidated gravel, sand and silt in channels and flood plains. Up to 20 meters thick.

Qtg; Terrace gravels - Unconsolidated coarse to fine gravel; occurs along range front at different topographic levels due to post-depositional faulting. As much as 100 meters thick.

Qd; Colluvium - Unconsolidated and unstratified angular debirs on hillsides.

Qdm; Diamicton - Unconsolidated, strikingly unsorted clastic material that ranges from clay and silt to large blocks of quartzite. Deposited as mudslides, rock glaciers and Hill wash. Up to 200 meters thick.

Tsl; White, gray, and green tuff, calcareous siltstone, sandstone and conglomerate; grades into red-weathering diamictite near exposures of older rocks. Reaches thickness of several thousand meters near Preston.

QTc; Conglomerate; occurs at base of Salt Lake Formation, variable thickness, variably lithified. Several thousand meters thick near Preston.

TRt; Thaynes Limestone (lower Triassic) Gray limestone and brown-weathering gray, calcareous siltstone; dark-gray shale and limestone abundant in lower part. Thins eastward from 500 to 300 meters.

TRd; Dinwoody Formation (lower Triassic) Gray limestone and olive to greenish- brown siltstone. Thins eastward from 500 to 75 meters.

Pp: Phosphoria Formation (Permian) Upper part dark- to light-gray chert and shale; lower part brown-weathering phosphatic shale and limestone. Thins eastward from 110 to 70 meters.

Ppw; Wells Formation (Permian and Pennsylvanian) Interbedded gray limestone and pale-yellow calcareous sandstone; minor gray dolomite; cherty in lower part. Thins eastward from 600 to 180 meters.

Ml; Lodgepole Limestone (Lower Mississippian) Blue to dark-gray thin to medium-bedded fossiliferous cherty limestone. Thins eastward from 250 to 110 meters.

Du; Devonian sedimentary rocks undivided. Primarily limestone.

Db; Beirdneau formation; Thin-bedded dolomitic limestone and tan sandy dolomite in upper part; pink sandstone and gray limestone in lower part. 250 meters thick.

Dh; Hyrum Dolomite (Middle and Upper Devonian) Finely crystalline light to dark gray thin-bedded dolomite. In southwestern part of quadrangle includes Lower Dev. Water Canyon Formation. Thins eastward from 500 to 350 meters.

Of; Fish Haven Dolomite (Upper Ordovician) Dark-gray, brown-weathering, thin-bedded dolomite with bioclastic beds. Thins eastward from 150 to 80 meters.

Os; Swan Peak Quartzite (Middle Ordovician) White, tan, and pink, well sorted, well-rounded fine- to medium-grained massive quartzite. Thins eastward from 350 to 200 meters.

Og; Garden City Limestone (Middle and Lower Ordovician) Dark-gray limestone; minor dolomite. Abundant bioclastic and intraformational conglomerate and chert increasing toward top. 360 meters thick.

Csw; Worm Creek Quartzite Member (Upper Cambrian) Gray to tan arkosic quartzite; some sandy dolomite beds in lower part. Thins eastward from 200 to 100 meters.

Cs; St. Charles Limestone (Upper Cambrian) Medium-gray crystalline limestone containing intraformational conglomerate and chert; some thin-bedded dolomite near top. 300 meters thick.

Cn: Nounan Limestone (Upper and Middle Cambrian) Gray and blue-gray thin-bedded crystalline dolomite; minor dark-gray silty limestone and limestone conglomerate. 200 meters thick.

Cbo; Bloomington Formation (Middle Cambrian) Green mudstone containing partly nodular siltstone beds in upper part and limestone in lower part. 300 meters thick. This formation hosts at least 34 springs in the Bear River Range, and could potentially be a significant source of domestic water.

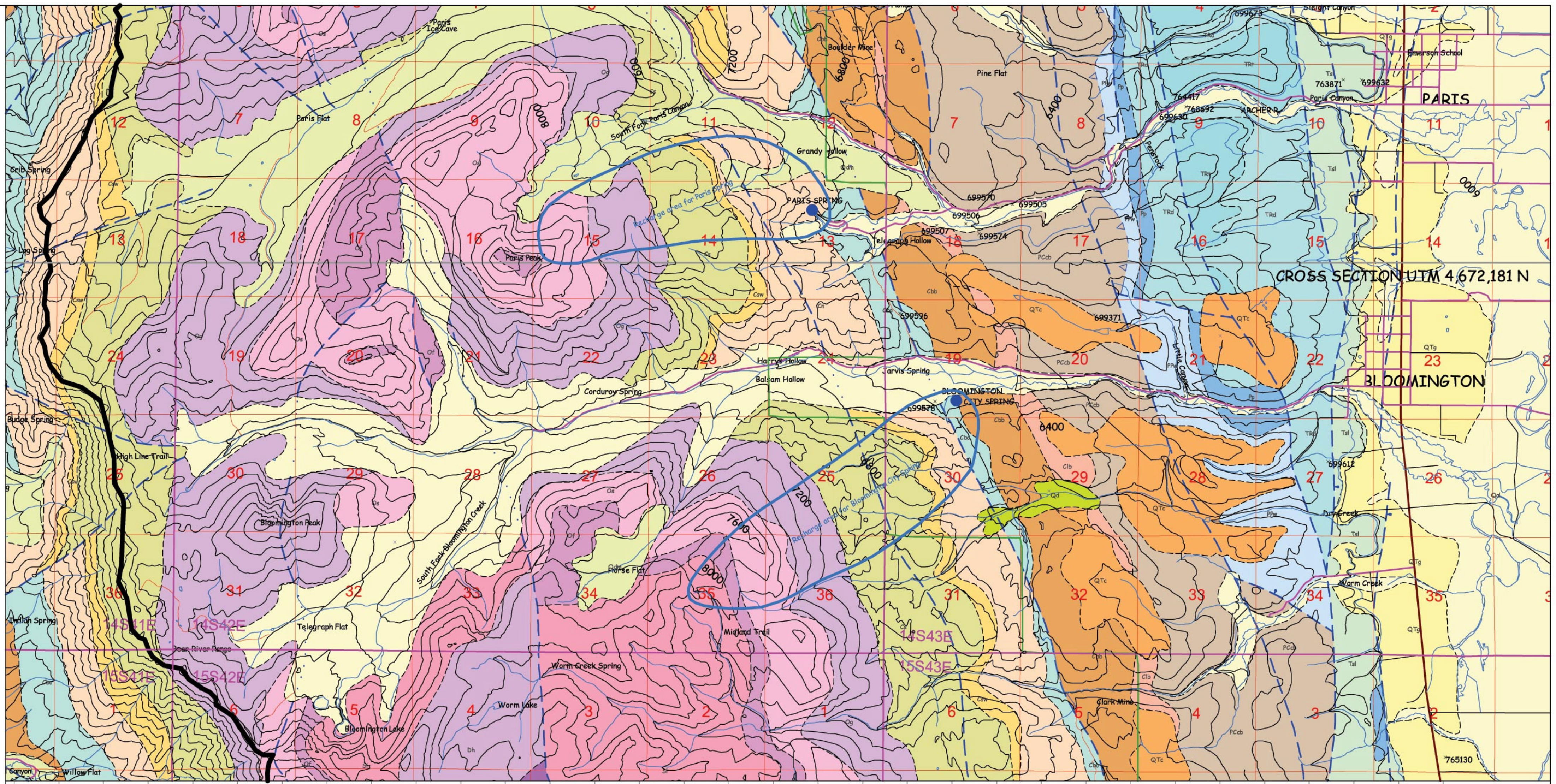
Cbb; Blacksmith, Bancroft and Ute Limestone (Middle Cambrian) Thin- to medium-bedded medium-gray oolitic and crystalline limestone. 400 meters thick.

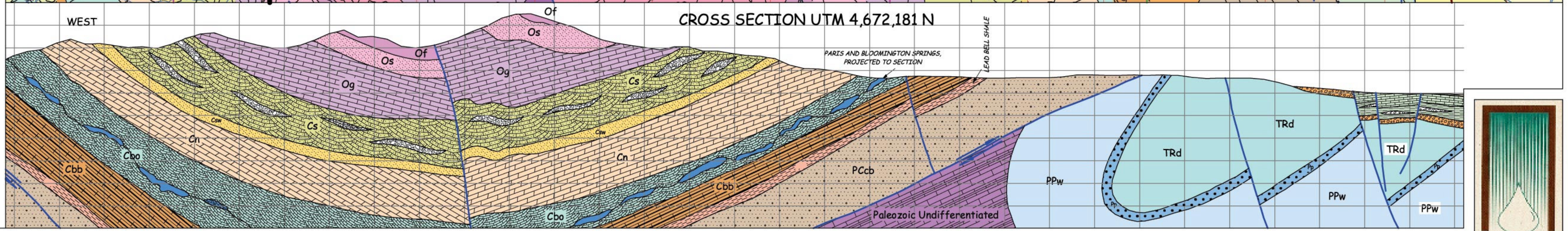
Cl; Langston Dolomite (Middle Cambrian) Very light gray dolomite that weathers pale red to yellowish brown; some thin-bedded, dark-gray limestone and green mudstone. 150 meters thick.

Clb; Lead Bell Shale (Middle Cambrian) Green mudstone; some medium-gray limestone and dark-gray mudstone in lower part. Locally includes the Twin Knobs Formation, a limestone facies of the Langston Dolomite. 300 meters thick.

pCCb; Brigham Quartzite (Middle and Lower Cambrian and Precambrian) Poorly sorted, white, buff, purple, and pink quartzite; minor conglomerate and phyllite. At least 3000 meters thick; base faulted. These sands host at least 32 springs in the Bear River Range, and potentially be a source of domestic water

Stratigraphic descriptions modified from Oriel and Platt, 1980





IWRRI

SCALE : 1:63,360

0 0.5 1.0 2.0
Miles

File: Bear Lake Geology_Draft_9-02-02.dwg
Projection: NAD 27 Zone 12 N
Data sources: USGS, BRO, AW, IDSL, IGS
Compilation and CADwork by B. R. Otto

PLATE 1: GEOLOGY OF THE BEAR RIVER RANGE
Modified from Oriel and Platt, 1980

GRID NORTH

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