MEMO

State of Idaho
Department of Water Resources
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Date: December 31, 2019

To: Gary Spackman, P.E., Director

Cc: Sean Vincent, P.G., Hydrology Section Manager

From: Jennifer Sukow, P.E., P.G., Hydrology Section JS

Subject: Response to expert report in the matter of designating the Eastern Snake Plain Aquifer Ground Water Management Area, Docket No. AA-GWMA-2016-001

One expert report was submitted in the matter of designating the Eastern Snake Plain Aquifer (ESPA) Ground Water Management Area (GWMA). Fremont Madison Irrigation District, Madison Ground Water District, and Idaho Irrigation District (collectively referred to as UV) submitted the report entitled *Technical Report Regarding Final Order Designating the ESPA GWMA*, dated December 5, 2019, by Bryce Contor, Senior Hydrologist at Rocky Mountain Environmental. This memorandum provides a technical review of the expert report.

The scope of the hearing for the above-referenced matter is limited to the following issue[1]:

> *"Whether areas outside of the ESPA area of common ground water supply, as defined by CM Rule 50 (IDAPA 37.03.11.050), but included within the ESPA GWMA, are located in tributary basins and are otherwise sufficiently remote or hydrogeologically disconnected from the ESPA to warrant exclusion from the ESPA GWMA."*

Contor's discussion of this issue is limited to one specific area, commonly referred to as the Rexburg Bench. The locations of the ESPA area of common ground water supply, the Eastern Snake Plain Aquifer Model Version 2.1 (ESPAM2.1) boundary[2], and the approximate location of the Rexburg Bench are shown in Figure 1. Contor does not explicitly delineate the boundaries of

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[1] *Deadline for IDWR's Submittal of Material; Order on Motion Practice; Notice of Hearing and Scheduling Order; Order Authorizing Discovery* dated September 25, 2019.

[2] In the vicinity of the Rexburg Bench, the ESPA GWMA boundary is coincident with the ESPAM2.1 boundary. *Order Designating the Eastern Snake Plain Aquifer Ground Water Management Area*, Idaho Department of Water Resources, November 2, 2016, Conclusions of Law 18 through 21.

the Rexburg Bench. For this memorandum, the extent of the Rexburg Bench delineated by Haskett (1972) was used in conjunction with the ESPA area of common ground water supply and ESPAM2.1 boundaries to identify the approximate extent of the Rexburg Bench.

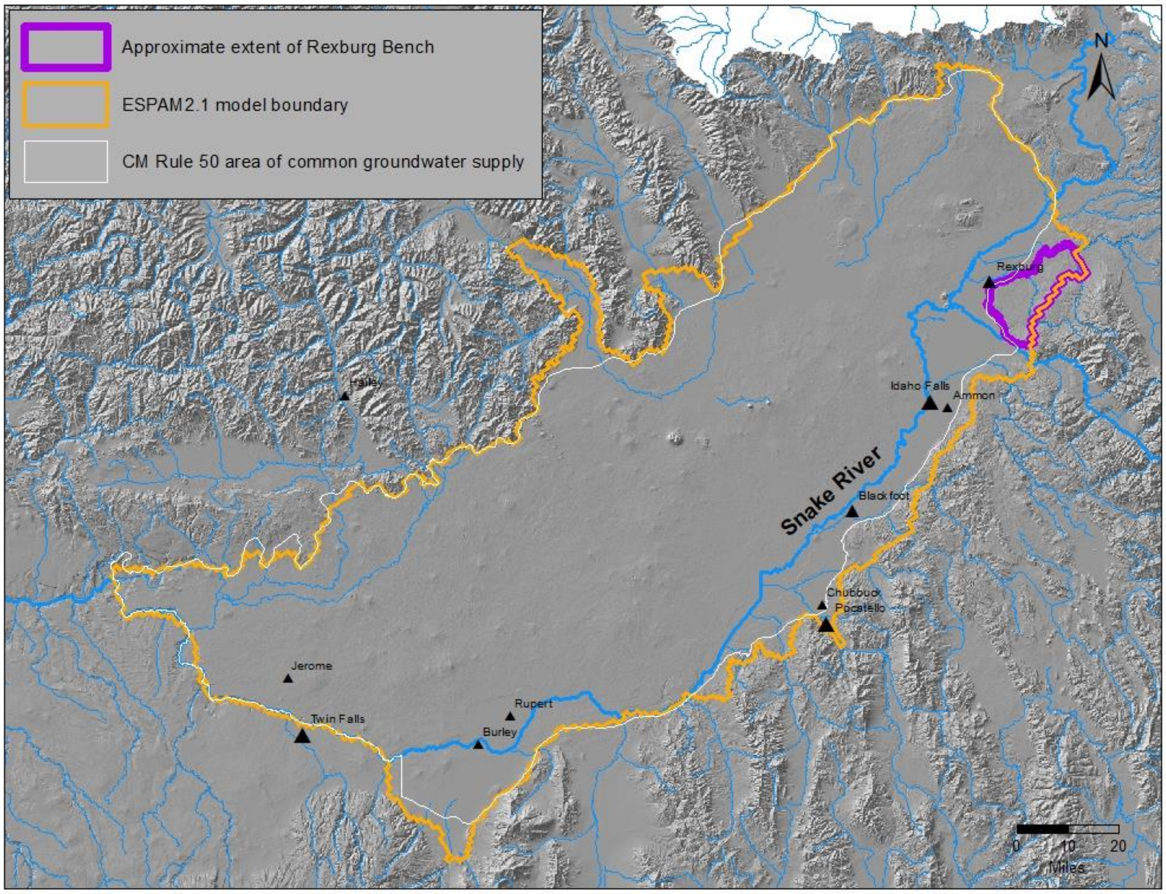

Figure 1. Location of the Rexburg Bench, ESPA area of common ground water supply, and ESPAM2.1 model boundary

Rather than directly addressing the issue identified above, Contor reformulates the issue, stating his report addresses the question, "*Do the Rexburg Bench and the Eastern Snake Plain Aquifer (ESPA) comprise a single groundwater basin*?" and argues if not, "*then the Bench is sufficiently remote or disconnected to warrant exclusion*." Contor discusses the definition of a groundwater basin, topography, geology and hydrogeology, static water levels in wells, the representation of the ESPA in numerical groundwater flow models, and comparison to areas not included in the GWMA. Contor concludes, "*the Rexburg Bench is located within a tributary basin. Because the Rexburg Bench and the Eastern Snake Plain Aquifer do not comprise a single groundwater basin[,] it is my professional opinion that the Rexburg Bench is sufficiently remote or* *hydrogeologically disconnected from the ESPA to warrant exclusion from the ESPA GWMA*." Contor's reformulation of the issue and his conclusion appear to rely on his interpretation of the definition of a groundwater basin, and do not appear to rely on a technical evaluation of remoteness or hydrogeological disconnection.

While I agree with Contor that the concept of sufficiency to warrant exclusion is a policy issue, I disagree with his reformulation of the issue. A technical evaluation of the degree of remoteness and hydrogeological disconnection can be presented without offering an opinion on sufficiency to warrant exclusion from the ESPA. Further, a technical evaluation of the degree of hydrogeological connection or disconnection should inform the delineation of a groundwater basin. This memorandum provides a technical review of the same topics reviewed by Contor, but focuses on the extent to which the Rexburg Bench is remote or hydrogeologically disconnected from the ESPA. The use of the phrase "tributary basin" in groundwater flow models representing the ESPA system is also discussed.

Definition of groundwater basin

Contor cites portions of the definition of groundwater basins from several sources, but omits other portions of these definitions. For example, Contor only mentions that the definition cited in the Order Designating the Eastern Snake Plain Aquifer Ground Water Management Area[3] indicates a groundwater basin has reasonably well-defined boundaries. The full definition cited in the order is, "*an aquifer or system of aquifers, whether basin-shaped or not, that has reasonably well-defined boundaries and more or less definite areas of recharge and discharge*." The concept of defining areas of aquifer recharge and aquifer discharge, and the hydrogeological connectivity between these areas, is an important consideration for the delineation of a groundwater basin.

Contor also cites a portion of a groundwater basin definition from the California Department of Water Resources (2003), "*lateral boundaries can be 'features…such as rock or sediments with very low permeability or a geologic structure such as a fault*'." The full definition reads, "*A groundwater basin is defined as an alluvial aquifer or a stacked series of alluvial aquifers with reasonably-defined boundaries in a lateral direction and a definable bottom. Lateral boundaries are features that significantly impede groundwater flow such as rock or sediments with very low permeability or a geologic structure such as a fault. Bottom boundaries would include rock or sediments of very low permeability if no aquifers occur below those sediments within the basin. In some cases, such as in the San Joaquin and Sacramento Valleys, the base of fresh water is*

[3] *Order Designating the Eastern Snake Plain Aquifer Ground Water Management Area*, Idaho Department of Water Resources, November 2, 2016, Conclusions of Law 12 through 17.

considered the bottom of the groundwater basin." Although aspects of this definition are specific to groundwater conditions in the State of California, the concept of lateral and vertical boundaries based on features that significantly impede groundwater flow is a general concept that can be applied in other areas. Note that faults and changes in rock type are only appropriate basin boundaries if they significantly impede groundwater flow.

Topography, Geology, and Hydrogeology

As mentioned by Contor, Haskett (1972) describes the topography, geology, and hydrogeology of the Rexburg Bench. Haskett described the Rexburg Bench as a broad apron extending northwest from the Big Hole Mountains to the margin of the Snake River Plain, with elevations ranging from approximately 6,500 feet at the base of the mountains to about 5,000 feet at the margin of the bench.

While the geology of the Rexburg Bench is complex, very productive wells have been developed in both the basalt and rhyolite underlying the Rexburg Bench. Haskett noted yields ranging from 925 to 3,500 gallons per minute (gpm) in wells developed in basalt and from 800 to 3,600 gpm in wells developed in rhyolite. High well yields are common in Quaternary basalt underlying the Eastern Snake Plain, but highly productive wells developed in rhyolite are less common. Haskett noted the rhyolite underlying the Rexburg Bench yields greater volumes of water than is usually obtained from rhyolite wells drilled "elsewhere about the Snake Plain." Haskett mentions jointing, the presence of fragmental tuffs, and faulting and associated fracturing as possible explanations for the relatively high permeability of rhyolite underlying the Rexburg Bench.

Haskett stated that in the early 1960s, there were concerns that groundwater development for irrigation on the Rexburg Bench would be limited by locally available recharge, but that by 1970, groundwater development had already exceeded expectations without indications of excessive water level declines. This suggests the Rexburg Bench has a strong hydrogeological connection to the regional Eastern Snake Plain aquifer system. Haskett discusses three possible sources of inflow to the Rexburg Bench from the regional Eastern Snake Plain aquifer system. For reference, Figure 2 shows rivers and other features mentioned by Haskett, and Attachment A provides a copy of Haskett's water table contour map.

> *"At the extreme north end of the Bench, in the vicinity of Newdale, some water lost from the Teton River reaches the regional water body. Gaging data by the USBR show that the Teton River has no loss in 8- or 10- mile reach above the damsite, but loses up to 50 cfs in the 5-mile reach downstream. The local gradient shows that some of this inflow may reach a few of the northernmost wells.*

A second possibility is suggested by the anamolous north and northwest directed gradient. Much of the flow of the regional water under the Rexburg Bench is from the south and southeast. It would appear that a reach of the Snake River in the vicinity of Heise loses water to the valley alluvium which is in contact with basalts and rhyolite extending under the Bench.

A third possible source is from the alluvium of the Henrys Fork Valley. During the pumping season on the Bench[,] the water table is locally pulled down 6 to 12 feet effecting a potential gradient reversal along the west margin of the Bench. This could allow great quantities of water to move eastward from the saturated alluvium of the Henrys Fork Valley to Rexburg Bench aquifers."

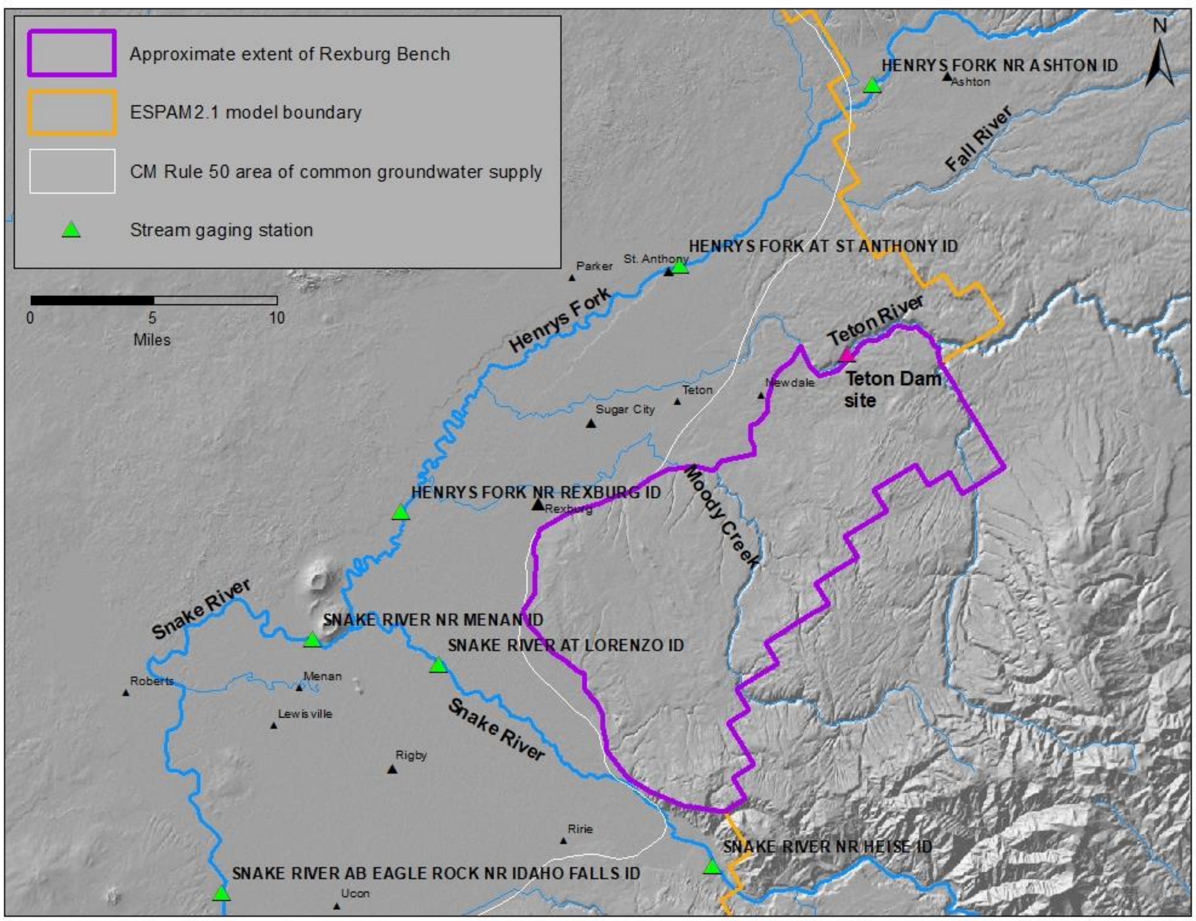

Figure 2. Location of rivers and other features mentioned by Haskett

Considerable groundwater development has occurred on the Rexburg Bench since Haskett's study. Records of groundwater rights developed for irrigation use on the Rexburg Bench show that groundwater development for irrigation has almost doubled since the end of the 1970 irrigation season. On the Rexburg Bench, licensed and decreed water rights developed solely for irrigation with priority dates of 1970 or earlier have a total authorized diversion rate of approximately 418 cfs, while those with priority dates of 1971 or later have a total authorized diversion rate of approximately 384 cfs. Groundwater irrigation water rights on the Rexburg Bench have a mean authorized diversion rate per well of approximately 540 gpm and a maximum authorized diversion rate per well of 3,870 gpm. These values are consistent with the well yields reported by Haskett and support the conclusion that groundwater beneath the Rexburg Bench has a strong hydrogeological connection with the regional Eastern Snake Plain aquifer system. While not all of the geologic materials beneath the Rexburg Bench have high permeability, substantial portions of the basalt and rhyolite rocks have very high permeability, and the highly permeable deposits are well-connected with each other and with highly permeable sediment and basalt deposits outside of the Rexburg Bench. The distribution of groundwater development in the Rexburg Bench area is shown in Figure 3.

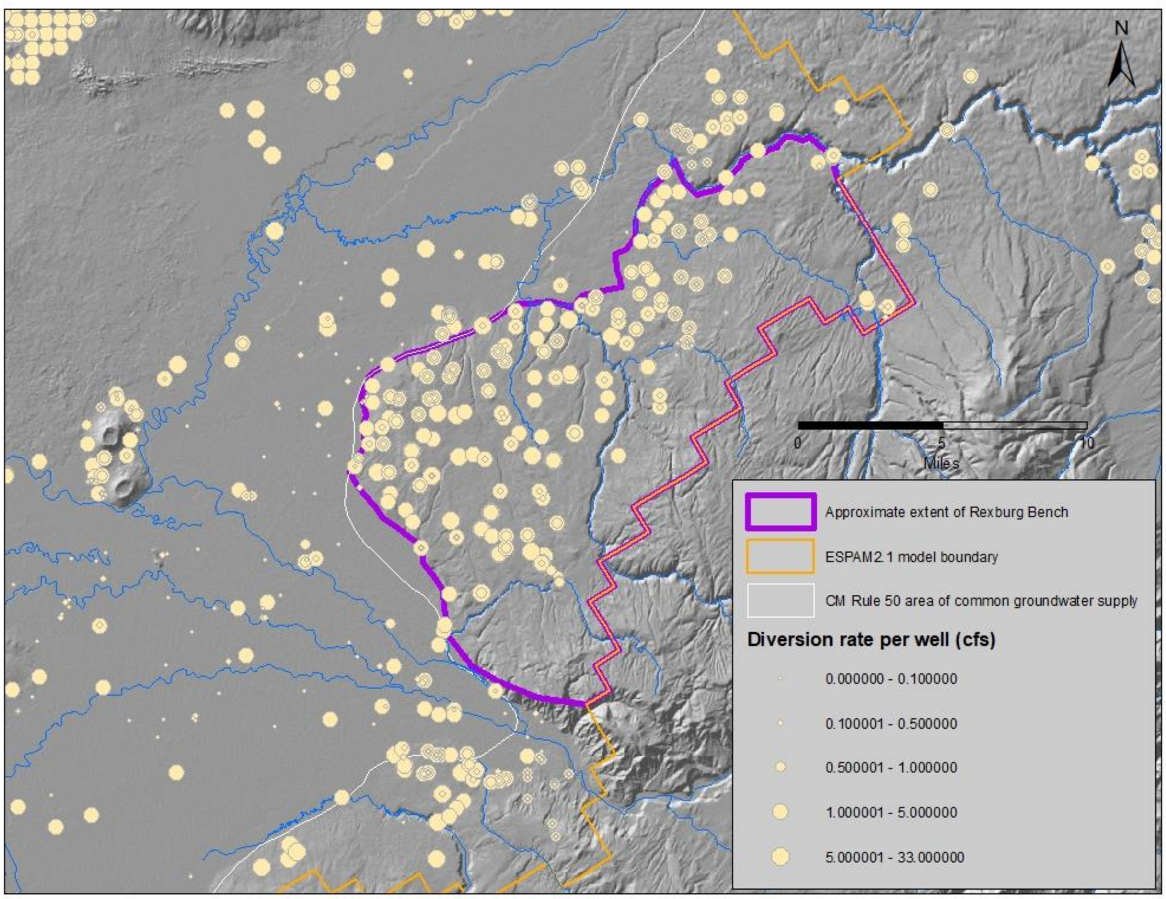

Figure 3. Diversion rate per well for licensed and decreed groundwater rights developed for irrigation use

Static Water Levels in Wells

Contor's analysis of static water levels relied on data obtained from well drillers' logs. Well drillers' logs can be a valuable source of information, but determining groundwater elevations based on a large number of well drillers' logs may be unreliable without substantial effort to verify each well location and the corresponding ground surface elevation. Well drillers' log data sets also include a large number of single-residence domestic wells, which only need very small yields and may or may not be connected to the regional aquifer system in which the irrigation wells are developed. Water level measurements collected by the U.S. Geological Survey, Bureau of Reclamation, or other water management agencies are generally better sources of data for evaluating groundwater levels.

Haskett presented water level data collected from wells on the Rexburg Bench by the U.S. Geological Survey, Bureau of Reclamation, pump contractors, and well drillers. Contor's static water level analysis is inconsistent with water level information presented by Haskett. Attachment A includes Haskett's water level contour map with water levels from the fall of 1970. Attachment B includes cross-sections from Haskett's report showing water levels and Haskett's interpretation of the perched and regional water table. Perched groundwater occurs locally where clay layers are present. When recharge exceeds pumping in perched aquifers, water will drain to the regional water table at the margins of the clay layers. Haskett shows the regional water table extending from beneath the Rexburg Bench to adjoining areas underlying the Teton River and Eastern Snake Plain. Haskett's contour map shows groundwater flowing from underneath the Eastern Snake Plain to underneath the Rexburg Bench along the northern and southern margins of the bench, and from underneath the Rexburg Bench to underneath the Eastern Snake Plain along the western margin of the bench.

More recent water level measurements are generally consistent with water level information presented by Haskett and do not suggest the Rexburg Bench is hydrogeologically disconnected from the ESPA. Water level elevations measured during the spring of 2013 on the Rexburg Bench and the Snake River Plain are shown in Figure 4. Within the Rexburg Bench, water level elevations are highest in wells closest to the Big Hole Mountains and generally decrease towards the outer margins of the Rexburg Bench. Local groundwater gradients vary in steepness and direction because of the locations of recharge sources and the geometry of the Big Hole Mountain front relative to the Henrys Fork and Snake River valleys. There is not a sharp transition or steep gradient between water level elevations near the edge of the Rexburg Bench and water level elevations in the adjacent Henrys Fork and Snake River valleys, which indicates there is not a geologic feature significantly impeding groundwater flow between the Rexburg Bench and the Snake River Plain. This is consistent with Haskett's characterization of the connection between groundwater in the alluvium of Henrys Fork and Snake River valleys and groundwater underlying the Rexburg Bench, which was discussed in the previous section of this memorandum.

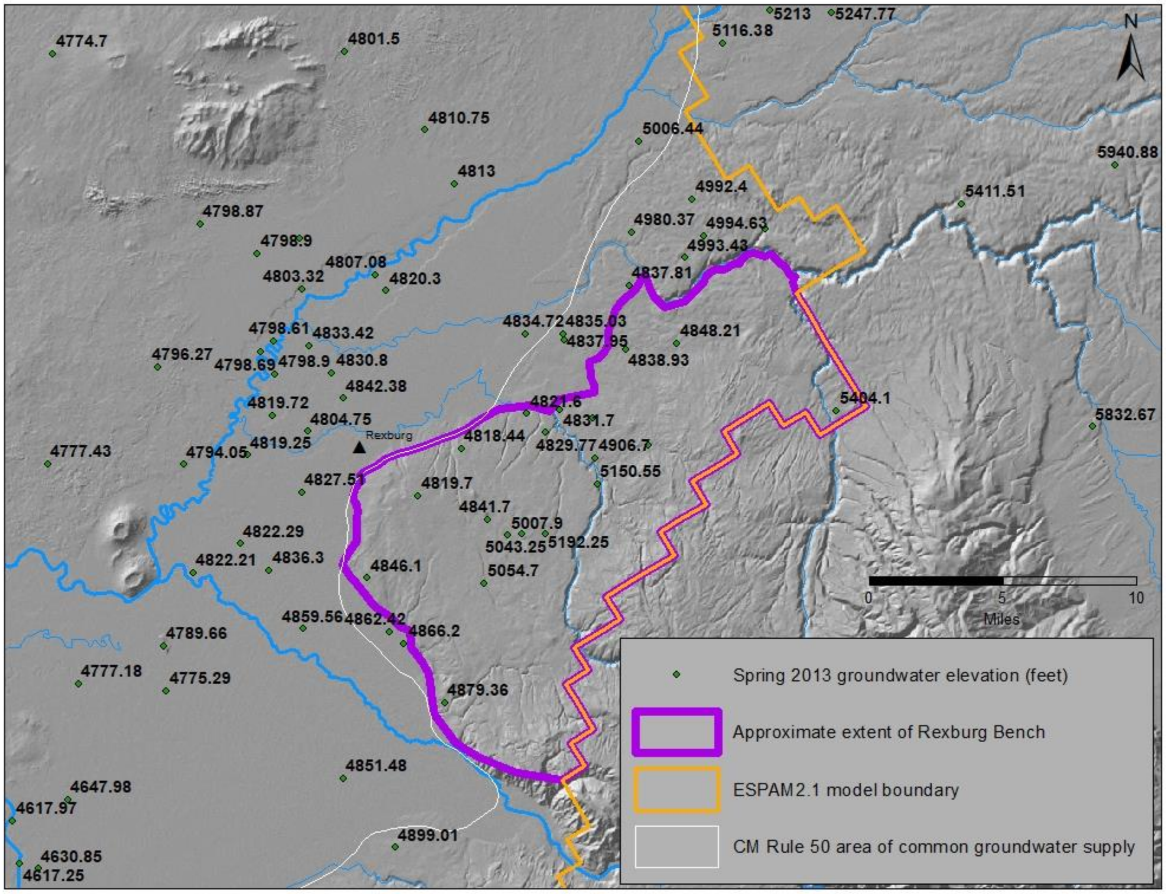

Figure 4. Water level elevations measured during the spring of 2013

Representation of the EPSA in Numerical Groundwater Flow Models

The locations of the Rexburg Bench, the ESPA area of common ground water supply, and the ESPA GWMA are shown in Figure 1. The ESPA area of common ground water supply was defined by CM Rule 50 in 1994 as "*the aquifer underlying the Eastern Snake River Plain as the aquifer is defined in the report, Hydrology and Digital Simulation of the Regional Aquifer System, Eastern Snake River Plain, Idaho, USGS Professional Paper 1408-F, 1992 excluding areas south of the Snake River and west of the line separating Sections 34 and 35, Township 10 South, Range 20 East, Boise Meridian*." This report was one of a series of seven reports published by the USGS on the Snake River Plain Regional Aquifer-System Analysis (RASA) and the boundary is commonly referred to as the RASA boundary.

The RASA boundary is the basis for the area of common ground water supply boundary in the vicinity of the Rexburg Bench. The RASA boundary delineated in Garabedian (1992) and other reports in the RASA series is referred to as the "boundary of Eastern Snake River Plain" and is not referred to as a "basin" boundary. Multiple figures in these reports show the delineation of the Eastern Snake River Plain boundary within the larger Snake River Basin boundary, Figure 5 is an example from Garabedian (1992).

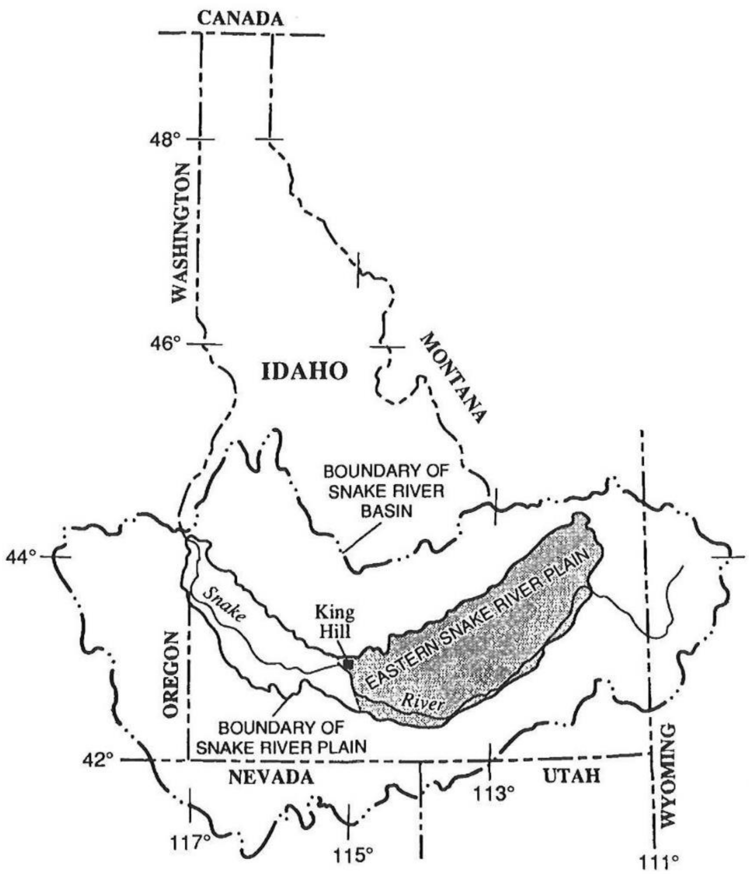

FIGURE 1.—Location of study area.

Figure 5. Delineation of Eastern Snake River Plain and Snake River Basin in RASA study (from Garabedian, 1992)

Whitehead (1992) described the RASA boundary as follows:

> "*Areal extent of the Snake River Plain, as defined in this study, is based on geology and topography. Generally, the boundary of the plain is at the land-surface contact between the Tertiary and older rocks that border the plain and the Quaternary sedimentary and volcanic rocks. In some areas, an arbitrary boundary was selected on the basis of topographic relief, even though the younger rocks extend beyond the boundary*."

Attachment C shows the geologic map from the RASA report (Whitehead, 1992, plate 2). In this map, the Rexburg Bench is mapped as Quaternary Basalt of the Snake River Group (Qb) and Quaternary silicic and volcanic rocks (Qsv) of the Yellowstone Group and Plateau Rhyolite. Since the RASA boundary in the vicinity of the Rexburg Bench is not at a mapped land-surface contact between Quaternary and Tertiary or older rocks, and younger rocks extend beyond the boundary, Whitehead's description of an "arbitrary boundary selected on the basis of topographic relief" appears to be applicable to the RASA boundary in this area. I found no indication in the RASA reports that the delineation of the RASA boundary was intended to delineate the entirety of a groundwater basin.

Groundwater flow models often do not represent an entire groundwater basin and many groundwater flow models represent groundwater inflow from tributary areas as a specified flux along the model boundary. This is often referred to as tributary underflow or boundary flux. In the RASA groundwater flow model, boundary flux was modeled at 27 locations along the model boundary, including the Rexburg Bench. While the boundary flux is referred to as "underflow from tributary drainage basins", the tributary drainage basins are all located within the Snake River Basin boundary. The RASA reports describe the importance of surface water and groundwater inflow from tributary drainage basins to water supply. Lindholm (1994) describes the pre-development water supply in the Eastern Snake Plain aquifer system as follows:

> "*Before large areas were irrigated, total average annual recharge to and discharge from the ground-water system in the main part of the eastern plain was about 3.9 million acre-feet. About 60 percent of the total recharge was from tributary drainage basins, 25 percent was from Snake River losses, and 15 percent was from precipitation on the plain.*"

Goodell (1988) describes the impact of agricultural development in tributary drainage basins on water supply in the Eastern Snake Plain aquifer system as follows:

> "*In some tributary basins, agricultural development and consequent crop evapotranspiration of surface and ground water have reduced available water flowing to the plain. Most water available to the Snake River Plain originates as surface-water inflow and ground-water underflow from tributary basins. Kjelstrom (1984) estimated available water flowing from tributary basins to the eastern and western plain on the basis of (1) present irrigation development and (2) no development or reservoir storage in tributary basins. According to his figures, on the average, agricultural development in tributary basins has reduced annual available water flowing to the eastern plain by about 7 percent (10.972 MAF to 10.215 MAF)…for water years 1934-1980*."

Garabedian (1992) used the RASA model to simulate the effect of changes in boundary flux (underflow from tributary drainage basins) on aquifer heads and aquifer discharge to the Snake River. For example, Figure 6 shows the predicted head response at a well located approximately 10 miles from the Rexburg Bench resulting from a 50% increase or a 50% decrease in boundary flux. Change in consumptive use of groundwater for irrigation within a tributary drainage basin is one example of a change in boundary flux. Garabedian's simulations illustrate that changes in consumptive use of water outside of the RASA boundary affect aquifer heads within the RASA boundary.

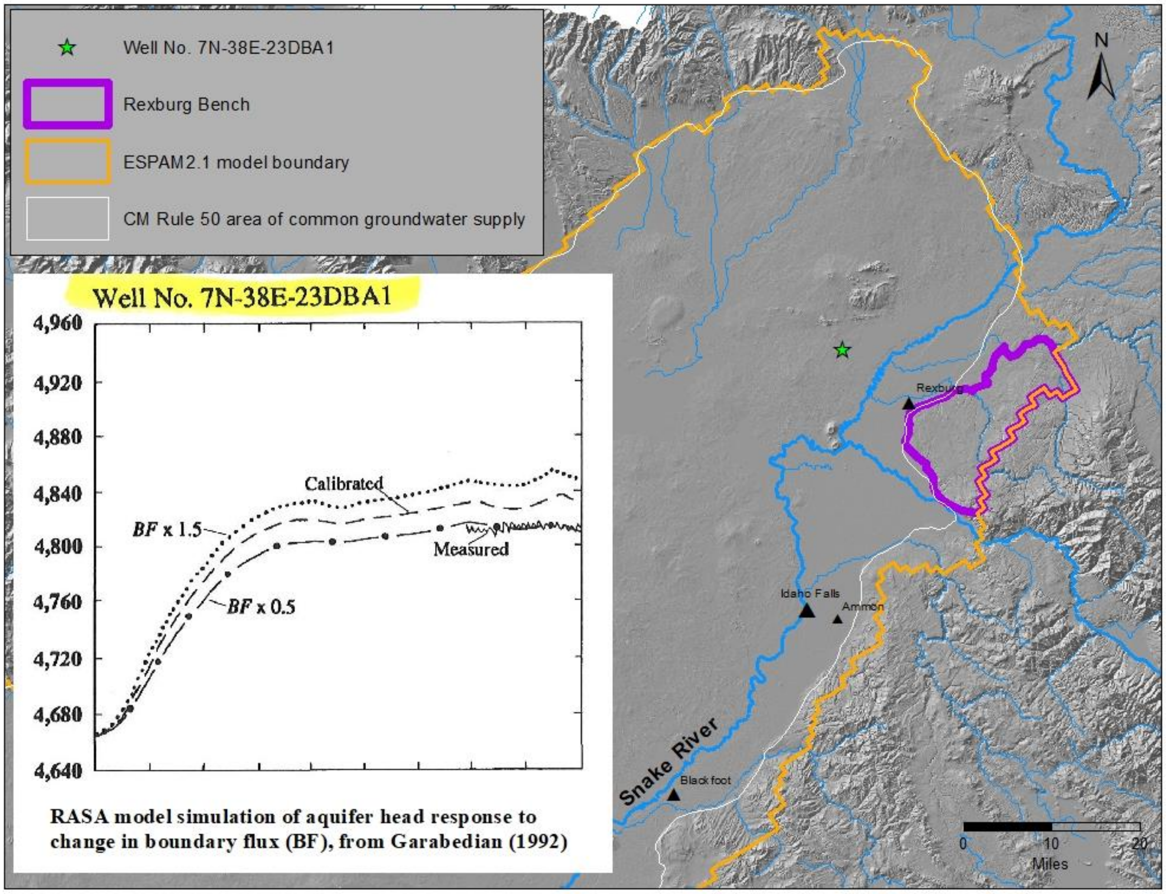

Figure 6. Example from Garabedian (1992) showing impact of changes in underflow from tributary drainage basins (including the Rexburg Bench) on aquifer head within the RASA boundary.

As mentioned by Contor, other groundwater flow models of the Eastern Snake Plain aquifer system were developed after the completion of the RASA project and the promulgation of CM Rule 50. Model boundaries were different for each model, but all of the models used specified flux to represent underflow of groundwater from tributary valleys outside of the model boundary. The Snake River Plain Aquifer Model (SRPAM) developed by Cosgrove and others (1999) described the Eastern Snake Plain as follows:

> *"The eastern plain is bounded structurally by faulting on the northwest and downwarping and faulting on the southeast (Whitehead, 1986). The plain is bounded by Yellowstone Group rhyolite in the northeast and Idavada volcanics in the southwest. Granitic rocks of the Idaho batholith, along with pre-Cretaceous sedimentary and metamorphic rocks, border the plain to the northwest (Garabedian, 1992)."*

Cosgrove and others (1999) did not describe the SRPAM model boundary as a delineation of a groundwater basin. Conversely, they stated, "*The Snake River Plain aquifer, underlying the eastern Snake River Plain, is hosted in layered basalts and interbedded sediments and is an integral part of the basin water resources.*" Cosgrove and others specifically acknowledged that the SRPM model was not a basin-wide model and identify this as a limitation of the SRPAM. Cosgrove and others recommended:

> *"At some time in the future, it may be desirable to develop a basin-wide model representing the Snake River Plain aquifer and the major tributaries. This would allow prediction of impacts on the Snake River from scenarios incorporating changes in water management in both the plain and in tributary valleys."*

During development of the first version of the Enhanced Snake Plain Aquifer Model (ESPAM), the model domain was expanded into areas not included in previous models (Wylie, 2004; Cosgrove, 2006). Both the first version of ESPAM and the current version, ESPAM2.1, were developed to serve as a tool for the conjunctive administration of groundwater and surface-water resources, thus efforts to expand the model domain into hydraulically-connected areas were focused on areas with significant irrigated acreage (IDWR, 2013). This is consistent with the recommendation of Cosgrove and others mentioned in the previous paragraph. While, the ESPAM2.1 model domain is still smaller than a basin-wide model, the expansion of the model domain into hydraulically-connected areas with significant irrigated acreage lessens the limitation described by Cosgrove and others. While the usefulness of the model as an administrative tool was considered in delineation of the model boundary for ESPAM, the expansion of the model into hydraulically-connected areas outside of the SRPAM and RASA model boundaries, including the Rexburg Bench, was scientifically sound and followed the recommendation of previous researchers.

Comparison to Areas Not Included in the GWMA

Contor identified 21 tributary basins (or portions of tributary basins) that are not included in the GWMA and states these areas are "*presumably sufficiently distinct from the ESPA to warrant exclusion. Sixteen of these areas are less or similarly distinct from the ESPA than is the Rexburg Bench."* This presumption is inconsistent with the order designating the GWMA[4], which clearly states these areas were excluded from the GWMA because they are outside of the ESPAM2.1 model boundary:

[4] *Order Designating the Eastern Snake Plain Aquifer Ground Water Management Area*, Idaho Department of Water Resources, November 2, 2016, Conclusions of Law 18 through 21.

> "*The ESPAM2.1 boundary is a reasonable administrative area because the Department currently lacks similar modeling tools and hydrologic data to administer outside the ESPAM2.1 model boundary, except for the Big Wood River Basin. Moreover, most of the ground-water irrigated land within the upper Snake River basin is located within the model boundary or, in the case of the Big Wood River and Raft River basins, in established management areas outside the model boundary.*"

Figure 7 shows groundwater development for irrigation within the ESPAM2.1 model domain and within tributary valleys outside of the model domain. Groundwater development was quantified by summing authorized water right diversion rates of licensed and decreed water rights developed solely for irrigation use. By this measure, groundwater development in the Rexburg Bench is approximately 4% of the total groundwater development within the model domain. The only area outside the model boundary with more groundwater development than the Rexburg Bench is the Raft River drainage area, and the majority of this area is already designated as a Critical Ground Water Area (CGWA). Other areas identified by Contor as being "*less or similarly distinct from the ESPA than is the Rexburg Bench*" have considerably less groundwater development than the Rexburg Bench.

As discussed previously, the ESPAM2.1 is not a basin-wide model and groundwater use in tributary areas does affect groundwater and/or surface water inflow to the Eastern Snake Plain. From a technical standpoint, consumptive water use in all of the excluded areas identified by Contor has an effect on groundwater and surface water availability within the Snake River Plain. This issue was acknowledged and discussed in Findings of Fact 13 through 17 in the order designating the GWMA. Conclusions of law 17 through 21 acknowledge that the GWMA designation only includes part of the groundwater basin and explain the reasoning for the delineation of the GWMA boundary.

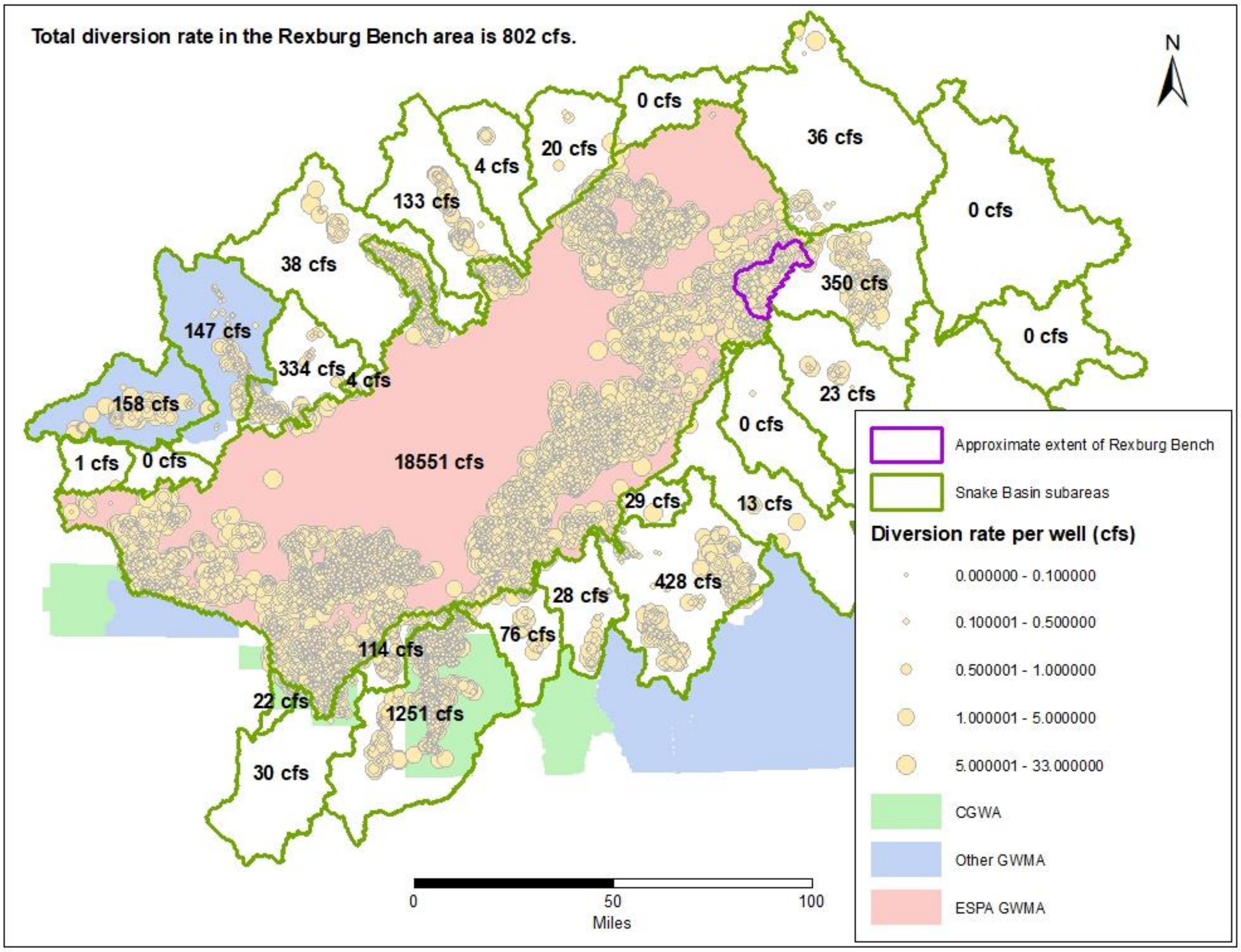

Figure 7. Groundwater points of diversion developed for irrigation use in the ESPAM2.1 model domain and tributary drainage areas within the Snake River basin

Conclusions

Although there are topographic, geologic, and structural differences between the Rexburg Bench and the Eastern Snake Plain, formal geologic work indicates there is a strong hydrogeological connection between groundwater underlying the bench and groundwater underlying the plain. Faulting and the presence of different geologic materials do not make an area hydrogeologically distinct from an adjacent area unless they significantly impede groundwater flow or result in a significantly different bulk permeability. High yields in wells developed in multiple rock types underlying the Rexburg Bench were documented by Haskett, and also are evident in the subsequent development of groundwater rights for irrigation. Water level information and the extent of groundwater development achieved on the Rexburg Bench indicate the water-bearing rocks underlying the Rexburg Bench are well-connected to both each other and the highly permeable deposits underlying the Eastern Snake Plain.

Groundwater development on the Rexburg Bench extends to the margin of the bench, immediately adjacent to the Eastern Snake Plain, indicating groundwater underlying the bench is not remote from the Eastern Snake Plain aquifer system.

The presence of perched aquifers is not unique to the Rexburg Bench, perched aquifers also occur locally in areas underlying the Eastern Snake Plain. Perched aquifers are limited in areal extent and drain to the regional aquifer system.

Various models of the Eastern Snake Plain aquifer system have either excluded or included the Rexburg Bench in the active model domain. Models which excluded the Rexburg Bench from the active model domain simulated underflow from the Rexburg Bench as a specified boundary flux, and model developers acknowledged that activities occurring outside of the active model domain do impact the boundary flux and affect aquifer heads within the model boundary. The developers of the SRPAM, which was the most recent model that excluded the Rexburg Bench from the active domain, specifically identified this as a limitation of the model and recommended a "basin-wide" model be developed in the future to allow predictions of impacts on the Snake River resulting from changes in water management in areas which affect the boundary flux. More recent models of the Eastern Snake Plain aquifer system were expanded to partially address the recommendation of the SRPAM developers. The expansion of the active model domain included the Rexburg Bench and other areas that are hydraulically connected with the ESPA system.

In my professional opinion, references to the Rexburg Bench and other areas as "tributary drainage basins" or "tributary basins" in model development reports do not exclude them from being part of a larger groundwater basin. It simply means they are tributary to the active model domain, which does not represent an entire groundwater basin. Further, the Rexburg Bench is located within the active model domain in recent models of the Eastern Snake Plain aquifer system and is not represented as a "tributary basin" in models developed within the last 20 years.

In my professional opinion, available technical evidence indicates the Rexburg Bench is neither remote nor hydrogeologically disconnected from the ESPA. In my professional opinion, the technical evidence indicates groundwater underlying the Rexburg Bench is hydrogeologically connected to groundwater underlying the Eastern Snake Plain, and both areas are located within the same groundwater basin.

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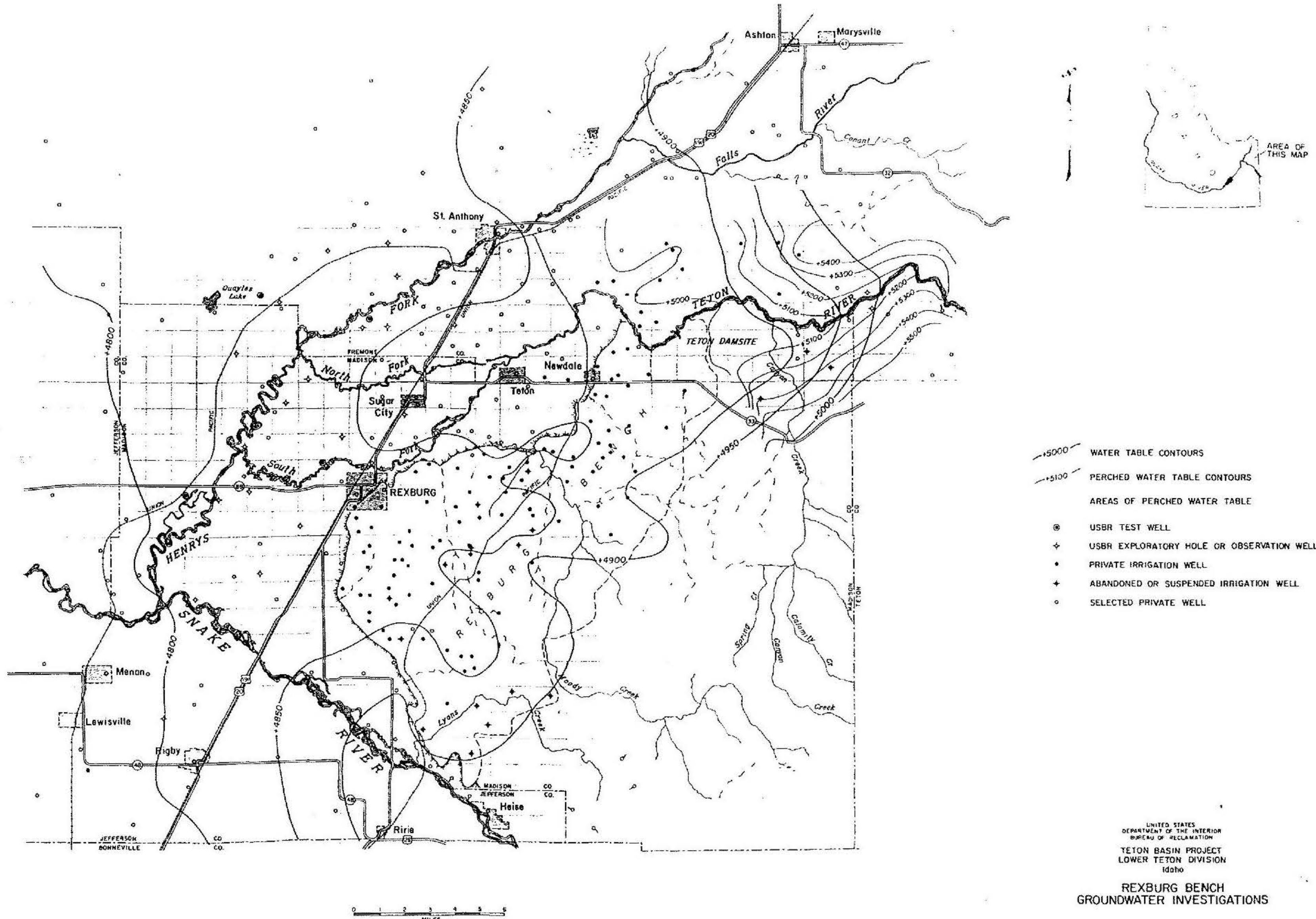
ATTACHMENT A.
Water table contour map from Haskett (1972)



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

TETON BASIN PROJECT
LOWER TETON DIVISION
Idaho

REXBURG BENCH
GROUNDWATER INVESTIGATIONS

WATER TABLE CONTOURS

NOVEMBER, 1971

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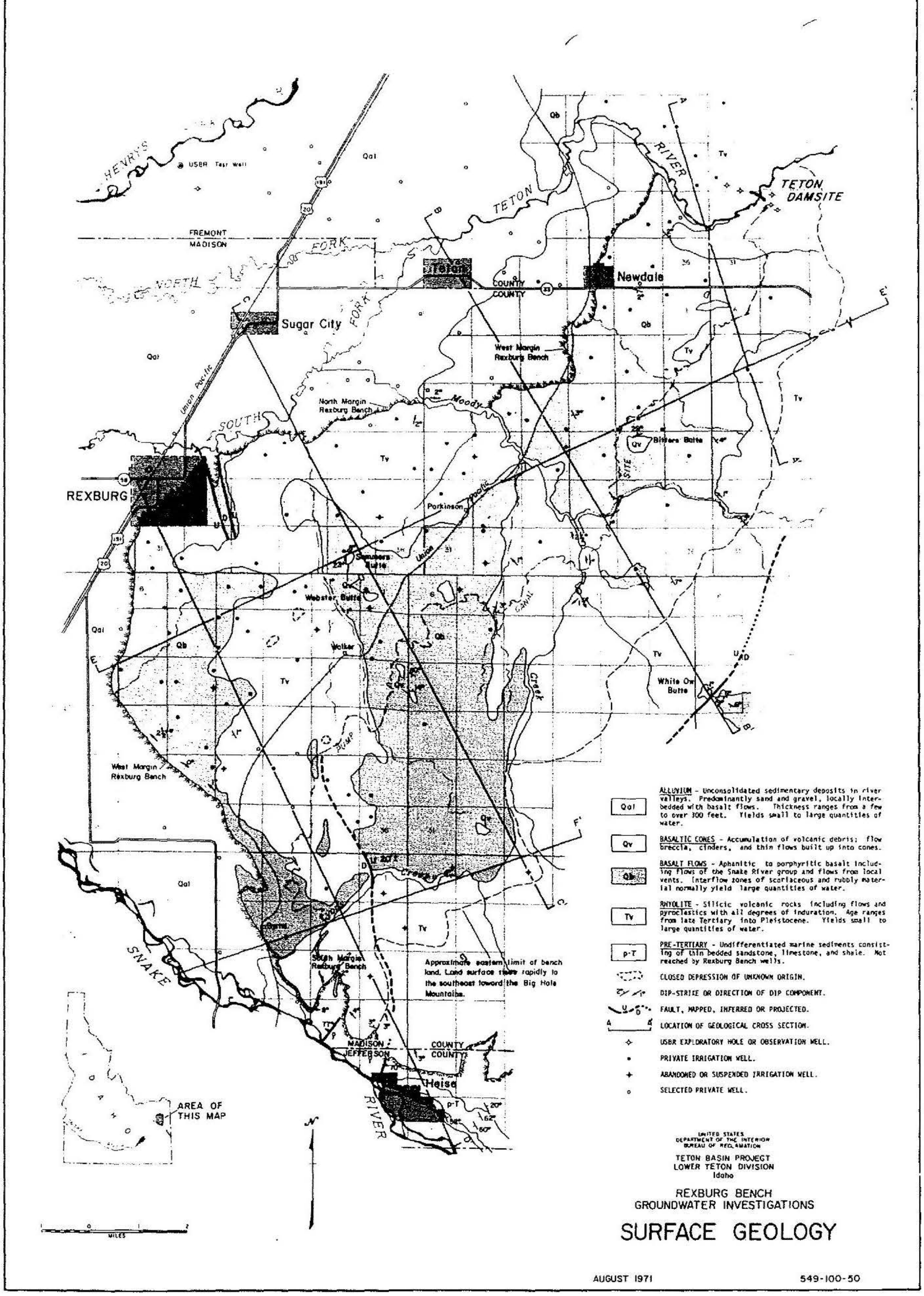
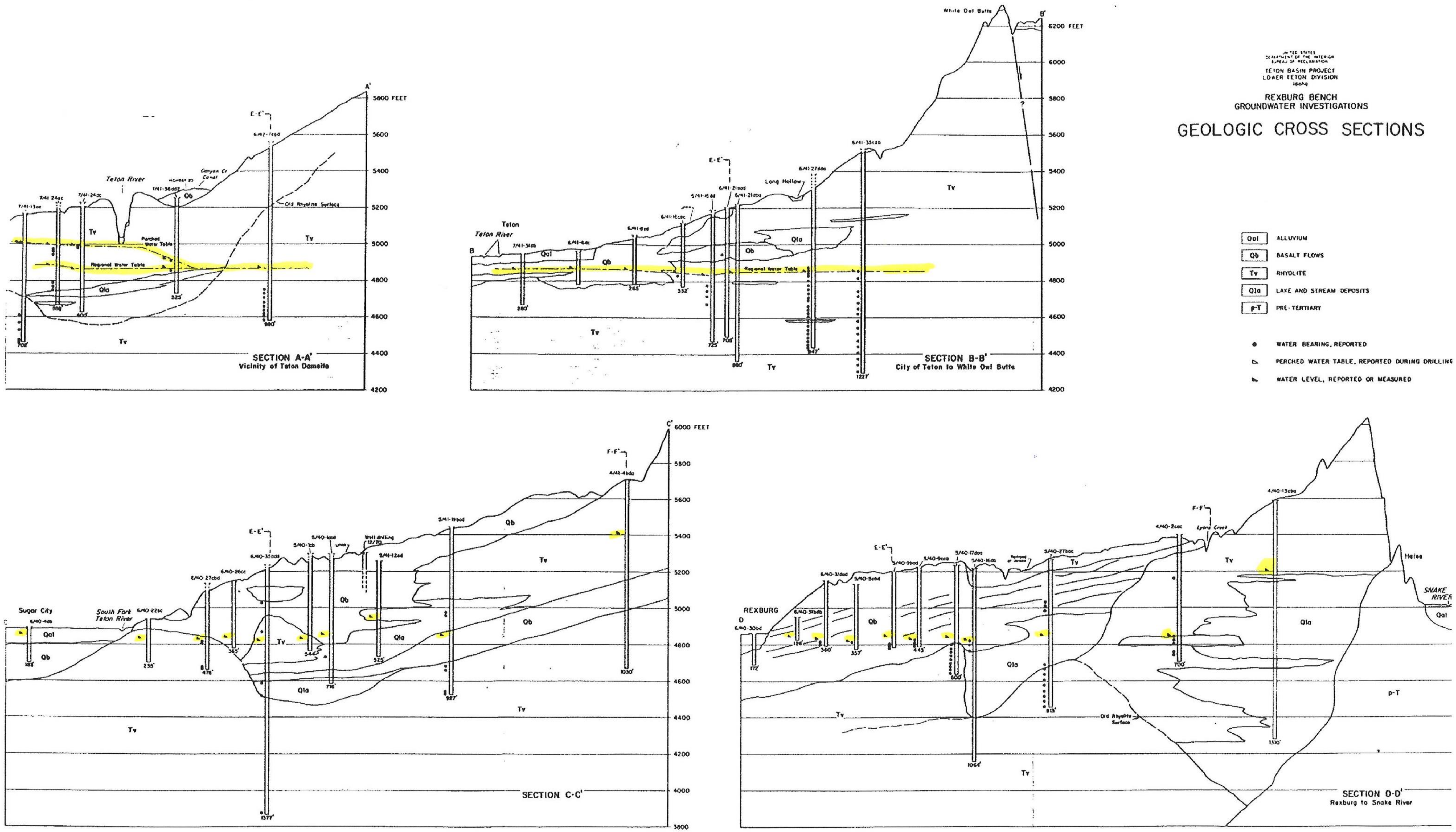
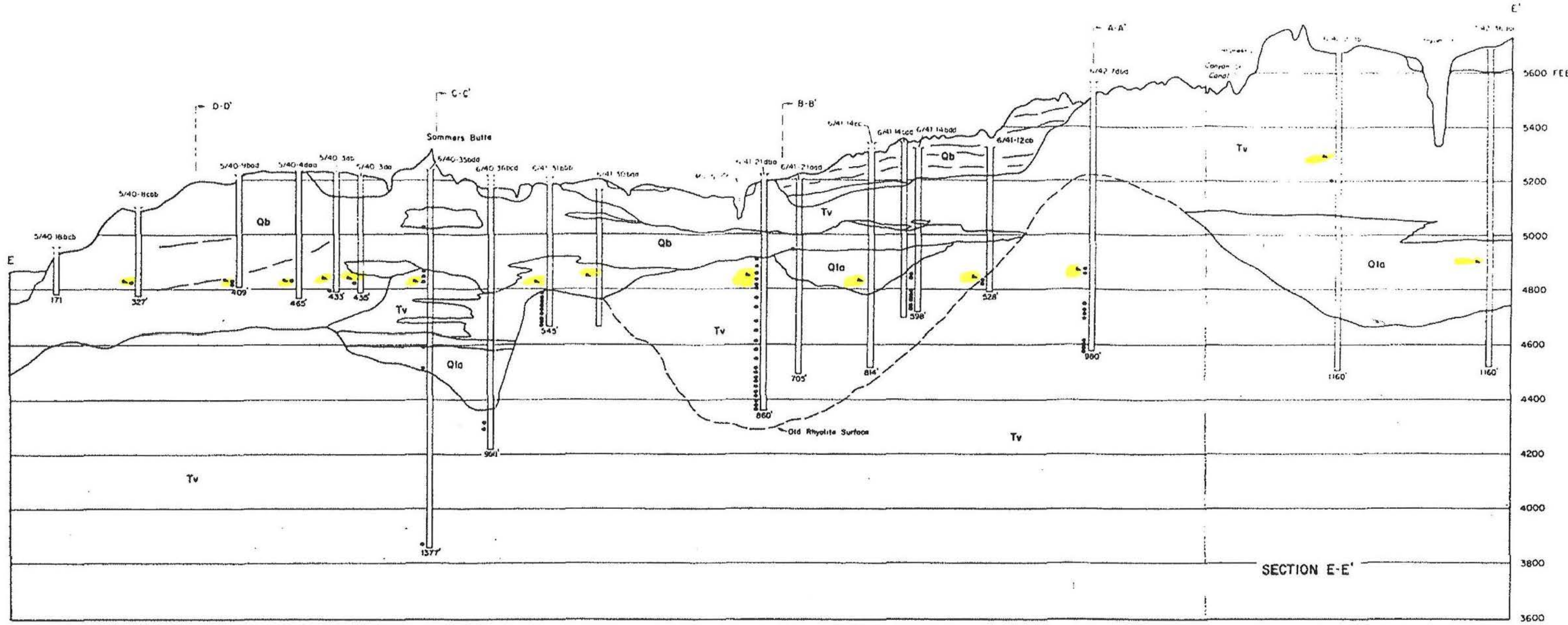
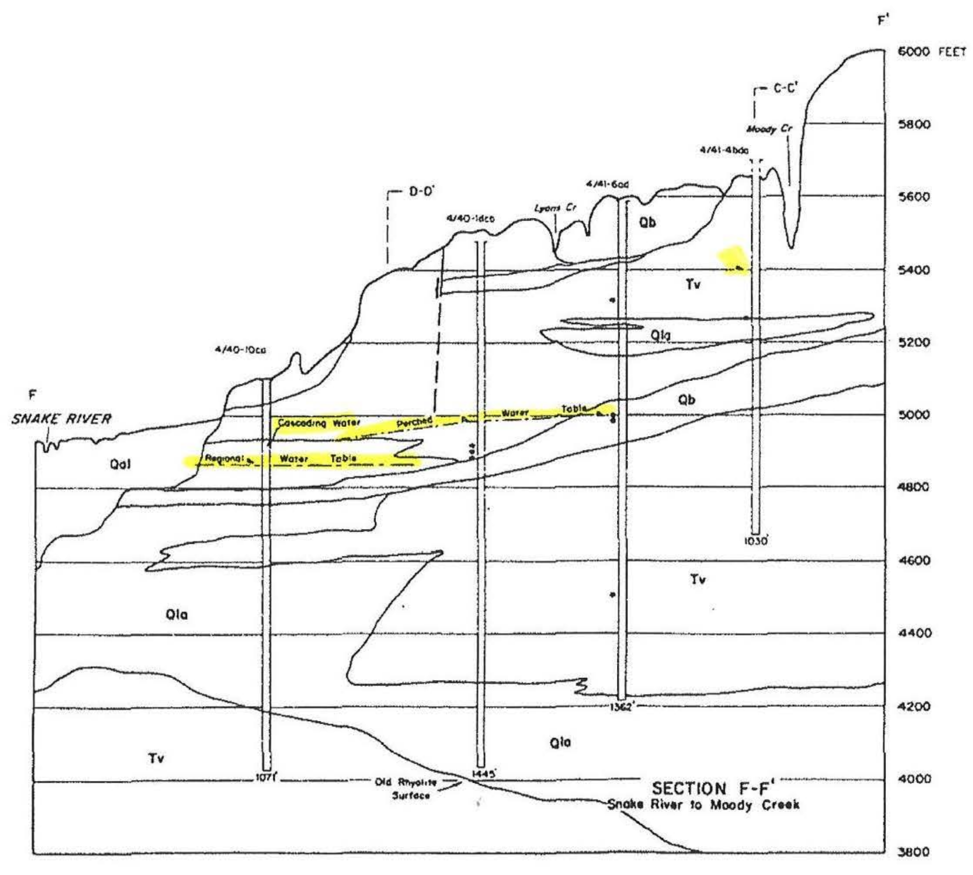
ATTACHMENT B.
Geologic cross sections from Haskett (1972)


HENRYS
USBR Test Well
Qal
TETON
RIVER
TETON DAMSITE
FREMONT
MADISON
NORTH FORK
FORK
Teton
COUNTY
COUNTY
Newdale
Sugar City
Qb
Tv
West Margin Rexburg Bench
Union Pacific
North Margin Rexburg Bench
Moody
SOUTH
Qv
Bitters Butte
REXBURG
Parkinson
Union Pacific
Sambers Butte
Webster Butte
Walker
Canal
Creek
White Owl Butte
West Margin Rexburg Bench
Pump
Creek
South Margin Rexburg Bench
Approximate eastern limit of bench land. Land surface rises rapidly to the southeast toward the Big Hole Mountains.
SNAKE
MADISON
JEFFERSON
COUNTY
COUNTY
Heise
p-T
RIVER
IDAHO
AREA OF THIS MAP
MILES
Qal
ALLUVIUM - Unconsolidated sedimentary deposits in river valleys. Predominantly sand and gravel, locally interbedded with basalt flows. Thickness ranges from a few to over 300 feet. Yields small to large quantities of water.
Qv
BASALTIC CONES - Accumulation of volcanic debris: flow breccia, cinders, and thin flows built up into cones.
Qb
BASALT FLOWS - Aphanitic to porphyritic basalt including flows of the Snake River group and flows from local vents. Interflow zones of scoriaceous and rubbly material normally yield large quantities of water.
Tv
RHYOLITE - Silicic volcanic rocks including flows and pyroclastics with all degrees of induration. Age ranges from late Tertiary into Pleistocene. Yields small to large quantities of water.
p-T
PRE-TERTIARY - Undifferentiated marine sediments consisting of thin bedded sandstone, limestone, and shale. Not reached by Rexburg Bench wells.
CLOSED DEPRESSION OF UNKNOWN ORIGIN.
DIP-STRIKE OR DIRECTION OF DIP COMPONENT.
FAULT, MAPPED, INFERRED OR PROJECTED.
LOCATION OF GEOLOGICAL CROSS SECTION.
USBR EXPLORATORY HOLE OR OBSERVATION WELL.
PRIVATE IRRIGATION WELL.
ABANDONED OR SUSPENDED IRRIGATION WELL.
SELECTED PRIVATE WELL.
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
TETON BASIN PROJECT
LOWER TETON DIVISION
Idaho
REXBURG BENCH
GROUNDWATER INVESTIGATIONS
SURFACE GEOLOGY
AUGUST 1971
549-100-50


UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION
TETON BASIN PROJECT
LOWER TETON DIVISION
IDAHO
REXBURG BENCH
GROUNDWATER INVESTIGATIONS
GEOLOGIC CROSS SECTIONS
Qal ALLUVIUM
Qb BASALT FLOWS
Tv RHYOLITE
Qla LAKE AND STREAM DEPOSITS
p-T PRE-TERTIARY
WATER BEARING, REPORTED
PERCHED WATER TABLE, REPORTED DURING DRILLING
WATER LEVEL, REPORTED OR MEASURED
SECTION A-A'
Vicinity of Teton Damsite
Teton River
Perched Water Table
Regional Water Table
Old Rhyolite Surface
SECTION B-B'
City of Teton to White Owl Butte
White Owl Butte
Long Hollow
Regional Water Table
SECTION C-C'
Sugar City
South Fork Teton River
SECTION D-D'
Rexburg to Snake River
REXBURG
Old Rhyolite Surface
Heise
SNAKE RIVER





Qal	ALLUVIUM
Qb	BASALT FLOWS
Tv	RHYOLITE
Qla	LAKE AND STREAM DEPOSITS

- • WATER BEARING, REPORTED
- ▷ PERCHED WATER TABLE, REPORTED DURING DRILLING
- ▶ WATER LEVEL, REPORTED OR MEASURED

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

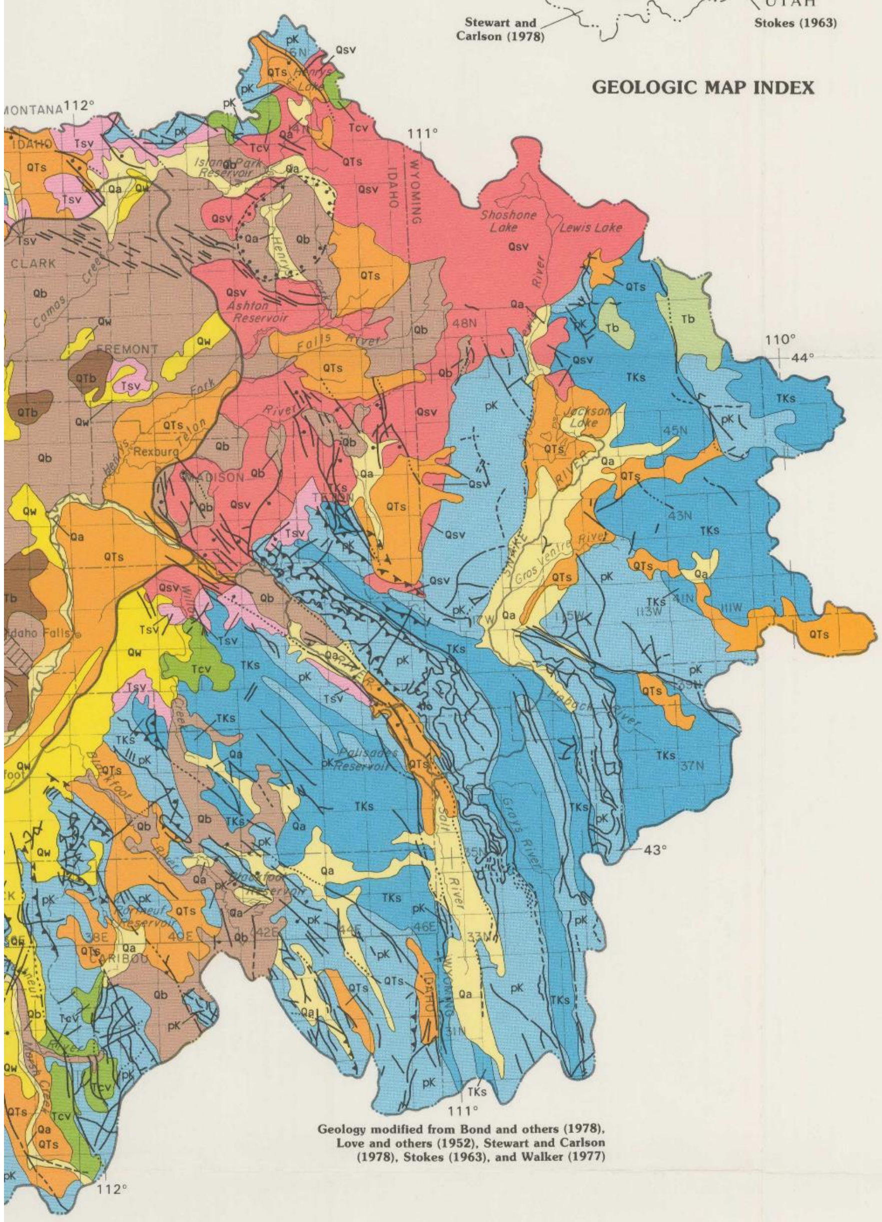
TETON BASIN PROJECT
LOWER TETON DIVISION
Idaho

REXBURG BENCH
GROUNDWATER INVESTIGATIONS

GEOLOGIC CROSS SECTIONS

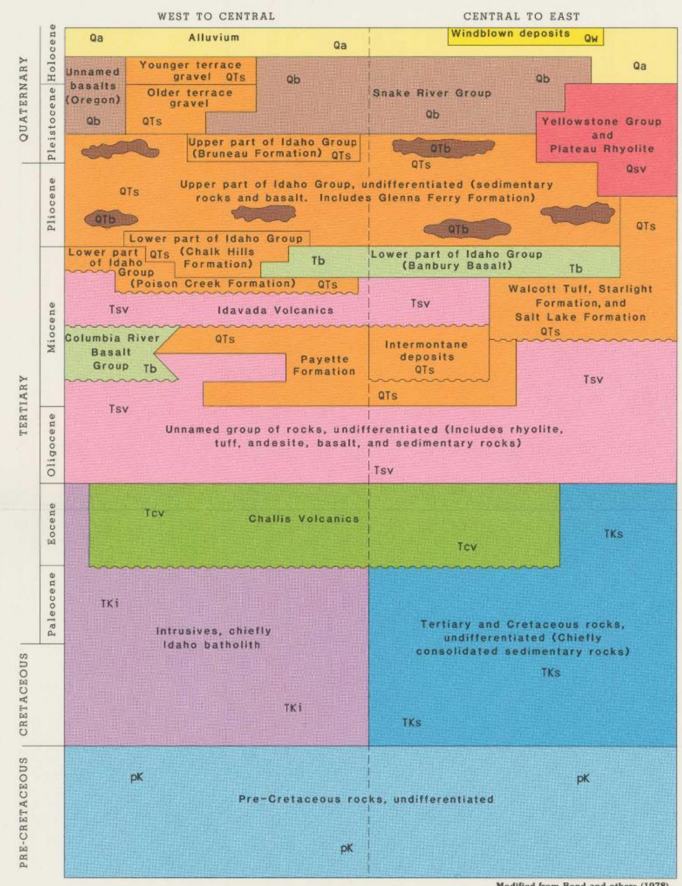
ATTACHMENT C.
Excerpt from Whitehead (1992) geologic map

GEOLOGIC MAP INDEX



Geology modified from Bond and others (1978), Love and others (1952), Stewart and Carlson (1978), Stokes (1963), and Walker (1977)

GENERALIZED STRATIGRAPHY OF THE SNAKE RIVER BASIN



Modified from Bond and others (1978), Malde and Powers (1962), and Malde (1982)

EXPLANATION AND DESCRIPTION OF MAP UNITS

System	Series	Rock unit and map symbol	Physical characteristics and areal distribution	Water-yielding characteristics	Known thickness (ft)
QUATERNARY	Holocene	**Alluvium** Qa	Chiefly flood-plain deposits. May contain some glacial deposits and colluvium in the uplands. Clay, silt, sand, gravel, and boulders; unconsolidated to well compacted; unstratified to well stratified. Alluvium floors the tributary valleys and flood plains of the main streams and forms fans at mouths of some valleys.	Hydraulic conductivity variable, moderately high in coarse-grained deposits. Sandy and gravelly alluvium yields moderate to large quantities of water to wells. Transmissivity ranges from about 16,000 to more than 160,000 ft^2/d (Nace and others, 1957, p. 55). Specific capacities commonly range from 20 to 100 (gal/min)/ft. An important aquifer.	<250 (?)
		Windblown deposits Qw	Chiefly windblown deposits, include some lake and glacial-flood deposits; mantle much of the lowland areas; include active sand dunes in places, generally in northern Owyhee County and in northern part of eastern plain.	Generally above the water table.	<100 (?)
	Pleistocene	**Younger basalt** Qb	Olivine basalt, dense to vesicular, aphanitic to porphyritic; irregular to columnar jointing; thickness of individual flows variable, but averages about 20-25 ft (Mundorff and others, 1964, p. 143). Includes beds of basaltic cinders, rubbly basalt, and interflow sedimentary rocks. Chiefly basalt of the Snake River Group. Crops out in much of Snake River Plain; mantled in many places with alluvium, terrace gravel, and windblown deposits.	Hydraulic conductivity variable but extremely high in places; formational conductivity high because of jointing and rubbly contacts between numerous flows; rock conductivity low. Unit constitutes the Snake River Plain aquifer east of King Hill (Mundorff and others, 1964, p. 8). Specific capacities of 500-1,000 (gal/min)/ft are common. Transmissivity determined from aquifer tests ranges from about 100,000 to more than 1,000,000 ft^2/d in much of the Snake River Plain (Mundorff and others, 1964, p. 159; Nace and others, 1957, p. 55).	>4,000 Includes QTb below
		Younger silicic volcanic rocks Qsv	Rhyolitic ash-flow tuff, occurs as thick flows and blankets of welded tuff with associated fine- to coarse-grained ash and pumice beds. Include rocks of upper part of the Yellowstone Group and Plateau Rhyolite. Mantle much of Yellowstone Plateau in northeastern part of basin.	Hydraulic conductivity generally unknown but may be high as indicated by rapid percolation of surface runoff (Whitehead, 1978, p. 10). Tightly welded in places. Specific capacities range from 2 to 60 (gal/min)/ft. An important aquifer locally.	>3,000
QUATERNARY AND TERTIARY	Pleistocene, Pliocene, and Miocene	**Basalt** QTb	Olivine basalt similar to Qb above. Included as part of the Snake River Plain aquifer. Tentatively assigned to upper part of Idaho Group. Exposures generally have well-developed soil cover.	Hydraulic conductivity slightly lower than Qb above. It decreases with increasing age.	Included with Qb above
		Older alluvium QTs	Subaerial and lake deposits of clay, silt, sand, and gravel. Compacted to poorly consolidated; poorly to well stratified; beds somewhat lenticular and intertongued; contains beds of ash and intercalated basalt. Widespread tuffaceous sedimentary rocks and tuff in western part of basin. Includes upper part of Idaho Group and Payette and Salt Lake Formations. In places, underlies the older basalt (Tb).	Hydraulic conductivity highly variable; generally contains water under confined conditions; yields to wells range from a few gallons per minute from clayey beds to several hundred gallons per minute from sand and gravel. Specific capacities range from 5 to 60 (gal/min)/ft. In places, an important aquifer.	>5,500
TERTIARY	Pliocene and Miocene	**Older basalt** Tb	Flood-type basalt, dense, columnar jointing in many places; folded and faulted (except for the Banbury Basalt); may include some rhyolitic and andesitic rocks; some flows of vesicular olivine basalt (Banbury), interbedded locally with minor amounts of stream and lake deposits. Includes Columbia River Basalt Group or equivalent (Miocene) and the Banbury Basalt of the Idaho Group (Miocene).	Hydraulic conductivity variable, may be high in places. Locally yields small to moderate amounts of water to wells from fractures and faults; some interbedded zones of sand and silt yield good supplies of water under confined or unconfined conditions. Specific capacities range from 3 to 900 (gal/min)/ft. An important aquifer.	>7,000 (The Banbury Basalt is generally <1,000. The older basalt may be >7,000 in the western plain)
	Pliocene to Oligocene	**Older silicic volcanic rocks** Tsv	Rhyolitic, latitic, and andesitic rocks, massive and dense; jointing ranges from platy to columnar; occur as thick flows and blankets of welded tuff with associated fine- to coarse-grained ash and pumice beds (commonly reworked by flowing water) and as clay, silt, sand, and gravel; locally folded, tilted, and faulted. Include Idavada Volcanics.	Hydraulic conductivity highly variable. Joints and fault zones in flows and welded tuff and interstices in coarse-grained ash, sand, and gravel yield small to moderate, and rarely large, amounts of water to wells. Commonly contain thermal water under confined conditions. Specific capacities range from 1 to >2,000 (gal/min)/ft and are generally <400 (gal/min)/ft. An important aquifer.	>3,000
	Eocene and Paleocene	**Volcanic rocks, undifferentiated** Tcv	Extrusive rocks range in composition from rhyolite to basalt; include welded tuff, pyroclastic, tuffaceous, and other clastic and sedimentary rocks. Chiefly Challis Volcanics; mainly crop out in mountains and foothills north of the eastern plain; may include some intrusive rocks.	Hydraulic conductivity generally low. Little information available on yields to wells. May be an important aquifer locally for domestic and stock use.	>5,000

EXPLANATION

Volcanic rift zone (Kuntz, 1978)

Thrust fault—Sawteeth on upper plate

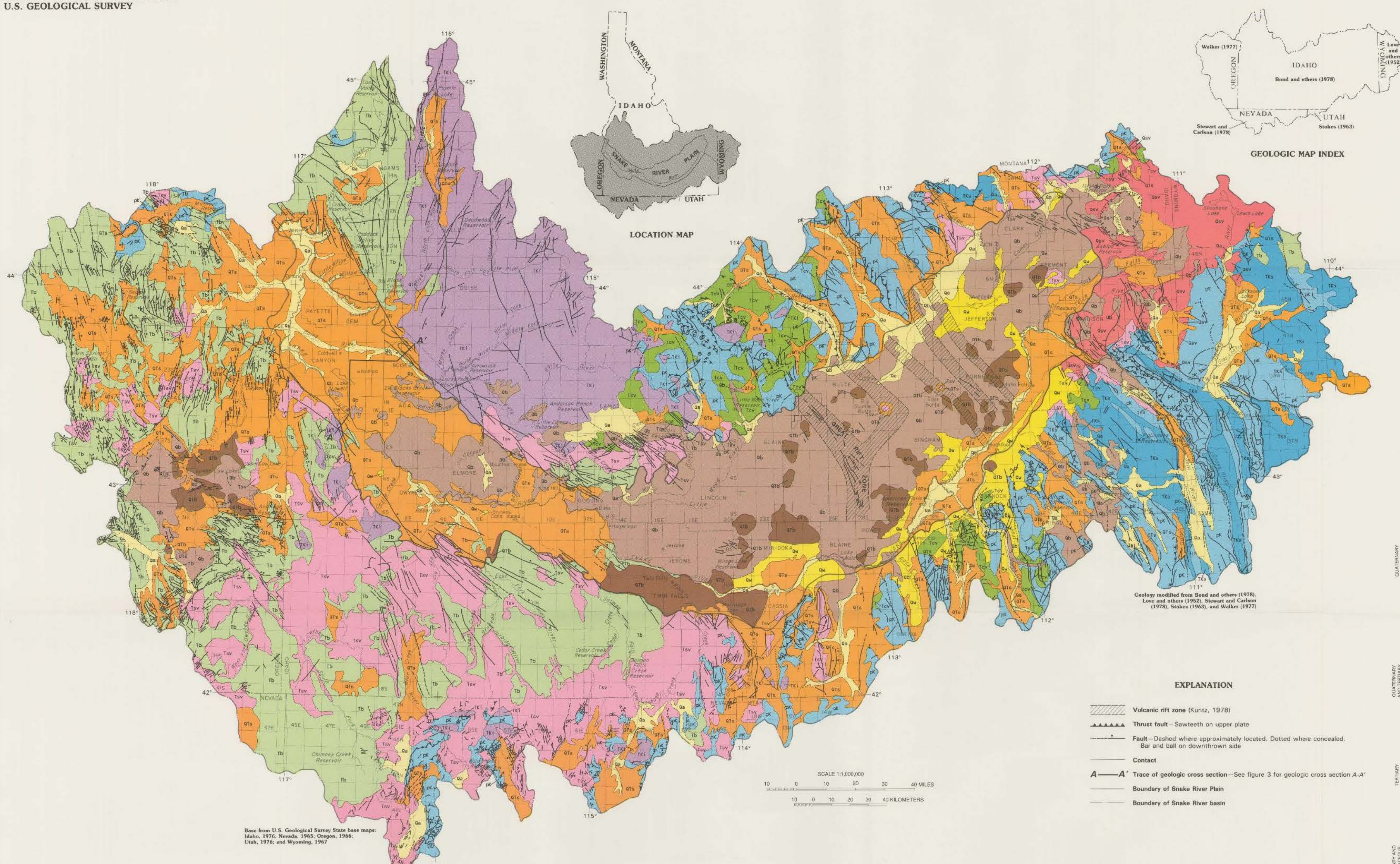
Fault—Dashed where approximately located. Dotted where concealed. Bar and ball on downthrown side

Contact

A——*A'* **Trace of geologic cross section**—See figure 3 for geologic cross section *A-A'*

Boundary of Snake River Plain

Boundary of Snake River basin

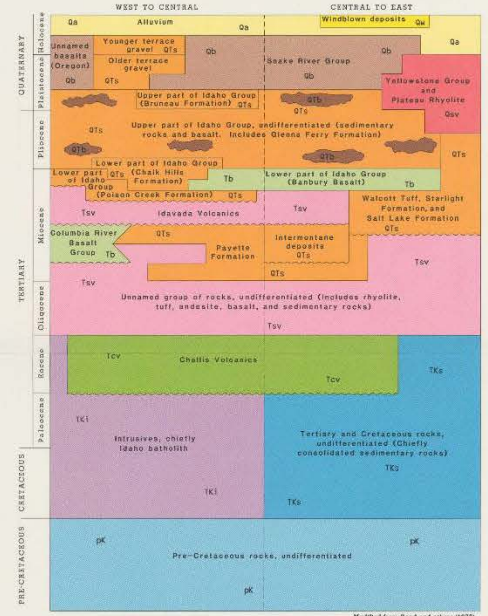


EXPLANATION

- **Volcanic rift zone** (Kuntz, 1978)
- **Thrust fault**—Sawteeth on upper plate
- **Fault**—Dashed where approximately located. Dotted where concealed. Bar and ball on downthrown side
- **Contact**
- A——A′ **Trace of geologic cross section**—See figure 3 for geologic cross section *A-A′*
- **Boundary of Snake River Plain**
- **Boundary of Snake River basin**

GENERALIZED GEOLOGIC MAP OF THE SNAKE RIVER BASIN, IDAHO AND EASTERN OREGON

GENERALIZED STRATIGRAPHY OF THE SNAKE RIVER BASIN



Modified from Bond and others (1978), Malde and Powers (1962), and Malde (1982)

EXPLANATION AND DESCRIPTION OF MAP UNITS

System	Series	Rock unit and map symbol	Physical characteristics and areal distribution	Water-yielding characteristics	Known thickness (ft)
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	Holocene	**Windblown deposits** Qw	Chiefly windblown deposits, include some lake and glacial-flood deposits; mantle much of the lowland areas; include active sand dunes in places, generally in northern Owyhee County and in northern part of eastern plain.	Generally above the water table.	<100 (?)
	Holocene–Pleistocene	**Younger basalt** Qb	Olivine basalt, dense to vesicular, aphanitic to porphyritic; irregular to columnar jointing; thickness of individual flows variable, but averages about 20-25 ft (Mundorff and others, 1964, p. 143). Includes beds of basaltic cinders, rubbly basalt, and interflow sedimentary rocks. Chiefly basalt of the Snake River Group. Crops out in much of Snake River Plain; mantled in many places with alluvium, terrace gravel, and windblown deposits.	Hydraulic conductivity variable but extremely high in places; formational conductivity high because of jointing and rubbly contacts between numerous flows, rock conductivity low. Unit constitutes the Snake River Plain aquifer east of King Hill (Mundorff and others, 1964, p. 8). Specific capacities of 500-1,000 (gal/min)/ft are common. Transmissivity determined from aquifer tests ranges from about 100,000 to more than 1,000,000 ft²/d in much of the Snake River Plain (Mundorff and others, 1964, p. 159; Nace and others, 1957, p. 55).	>4,000 includes QTb below
	Pleistocene	**Younger silicic volcanic rocks** Qsv	Rhyolitic ash-flow tuff, occurs as thick flows and blankets of welded tuff with associated fine- to coarse-grained ash and pumice beds. Include rocks of upper part of the Yellowstone Group and Plateau Rhyolite. Mantle much of Yellowstone Plateau in northeastern part of basin.	Hydraulic conductivity generally unknown but may be high as indicated by rapid percolation of surface runoff (Whitehead, 1978, p. 10). Tightly welded in places. Specific capacities range from 2 to 60 (gal/min)/ft. An important aquifer locally.	>3,000
QUATERNARY AND TERTIARY	Pleistocene, Pliocene, and Miocene	**Basalt** QTb	Olivine basalt similar to Qb above. Included as part of the Snake River Plain aquifer. Tentatively assigned to upper part of Idaho Group. Exposures generally have well-developed soil cover.	Hydraulic conductivity slightly lower than Qb above. It decreases with increasing age.	Included with Qb above
		Older alluvium QTs	Subaerial and lake deposits of clay, silt, sand, and gravel. Compacted to poorly consolidated, poorly to well stratified; beds somewhat lenticular and intertongued; contains beds of ash and intercalated basalt. Widespread tuffaceous sedimentary rocks and tuff in western part of basin. Includes upper part of Idaho Group and Payette and Salt Lake Formations. In places, underlies the older basalt (Tb).	Hydraulic conductivity highly variable; generally contains water under confined conditions; yields to wells range from a few gallons per minute from clayey beds to several hundred gallons per minute from sand and gravel. Specific capacities range from 5 to 60 (gal/min)/ft. In places, an important aquifer.	>5,500
TERTIARY	Pliocene and Miocene	**Older basalt** Tb	Flood-type basalt, dense, columnar jointing in many places; folded and faulted (except for the Banbury Basalt), may include some rhyolitic and andesitic rocks; some flows of vesicular olivine basalt (Banbury). Interbedded locally with minor amounts of stream and lake deposits. Includes Columbia River Basalt Group or equivalent (Miocene) and the Banbury Basalt of the Idaho Group (Miocene).	Hydraulic conductivity variable, may be high in places. Locally yields small to moderate amounts of water to wells from fractures and faults; some interbedded zones of sand and silt yield good supplies of water under confined or unconfined conditions. Specific capacities range from 3 to 900 (gal/min)/ft. An important aquifer.	>7,000 (The Banbury Basalt is generally <1,000. The older basalt may be >7,000 in the western plain)
	Pliocene to Oligocene	**Older silicic volcanic rocks** Tsv	Rhyolitic, latitic, and andesitic rocks, massive and dense; jointing ranges from platy to columnar; occur as thick flows and blankets of welded tuff with associated fine- to coarse-grained ash and pumice beds (commonly reworked by flowing water) and as clay, silt, sand, and gravel; locally folded, tilted, and faulted. Include Idavada Volcanics.	Hydraulic conductivity highly variable. Joints and fault zones in flows and welded tuff and interstices in coarse-grained ash, sand, and gravel yield small to moderate, and rarely large, amounts of water to wells. Commonly contain thermal water under confined conditions. Specific capacities range from 1 to >2,000 (gal/min)/ft and are generally <400 (gal/min)/ft. An important aquifer.	>3,000
	Eocene and Paleocene	**Volcanic rocks, undifferentiated** Tcv	Extrusive rocks range in composition from rhyolite to basalt; include welded tuff, pyroclastic, tuffaceous, and other clastic and sedimentary rocks. Chiefly Challis Volcanics; mainly crop out in mountains and foothills north of the eastern plain; may include some intrusive rocks.	Hydraulic conductivity generally low. Little information available on yields to wells. May be an important aquifer locally for domestic and stock use.	>5,000
TERTIARY AND CRETACEOUS		**Sedimentary rocks, undifferentiated** TKs	Undifferentiated shale, siltstone, sandstone, and freshwater limestone of Tertiary and Cretaceous age. Younger rocks composed chiefly of breccia, conglomerate, and sandstone. Exposed in eastern part of basin. May include a few small outcrops of Jurassic age.	Hydraulic conductivity generally low. Little information available on yields to wells; weathered zones and fractures may yield moderate quantities of water to wells; large yields may be obtained in places. May be an important aquifer locally.	>10,000
		Intrusive rocks TKi	Chiefly granitic rocks of the Idaho batholith; include older and younger crystalline rocks; crop out in a few places south of Snake River in Idaho and northern Nevada.	Hydraulic conductivity generally low. Faults, fractures, and weathered zones may yield small quantities of water to wells. Not an important aquifer.	Unknown
PRE-CRETACEOUS		**Pre-Cretaceous rocks, undifferentiated** pK	Well-indurated sedimentary and metamorphic rocks that have been folded, faulted, and intruded by igneous rocks. Crop out in mountainous areas. Include extrusive rocks of Permian and Triassic age in western part of basin. May include Cretaceous or younger sedimentary rocks.	Hydraulic conductivity low. Faults, fractures, and weathered zones may yield small quantities of water to wells. Little information available on yields to wells. Not an important aquifer.	>12,000