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Montana Bureau of Mines and Geology
A Department of Montana Tech of The University of Montana

Potentiometric Surface Map of the Southern Part of the Flathead Lake Area, Lake, Missoula, Sanders Counties, Montana

by

John I. LaFave

Note - this map was originally published at a scale of 1:100,000 but the page sizes have been modified to fit the size of the paper in your printer. A full sized 36" X 48" colored print of this map can be ordered from the Office of Publications and Sales of the Montana Bureau of Mines and Geology, 1300 West Park Street, Butte, MT 59701.
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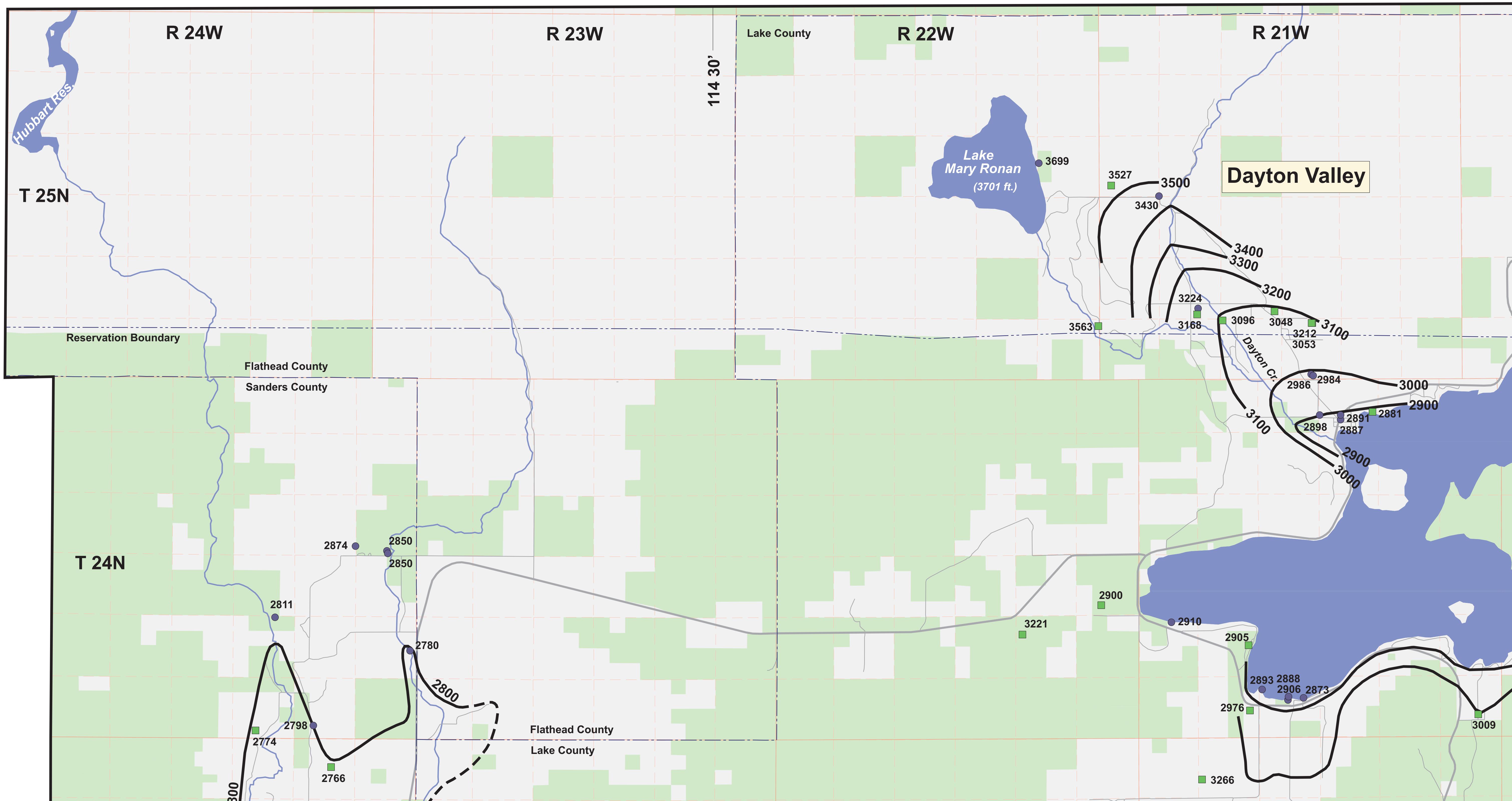

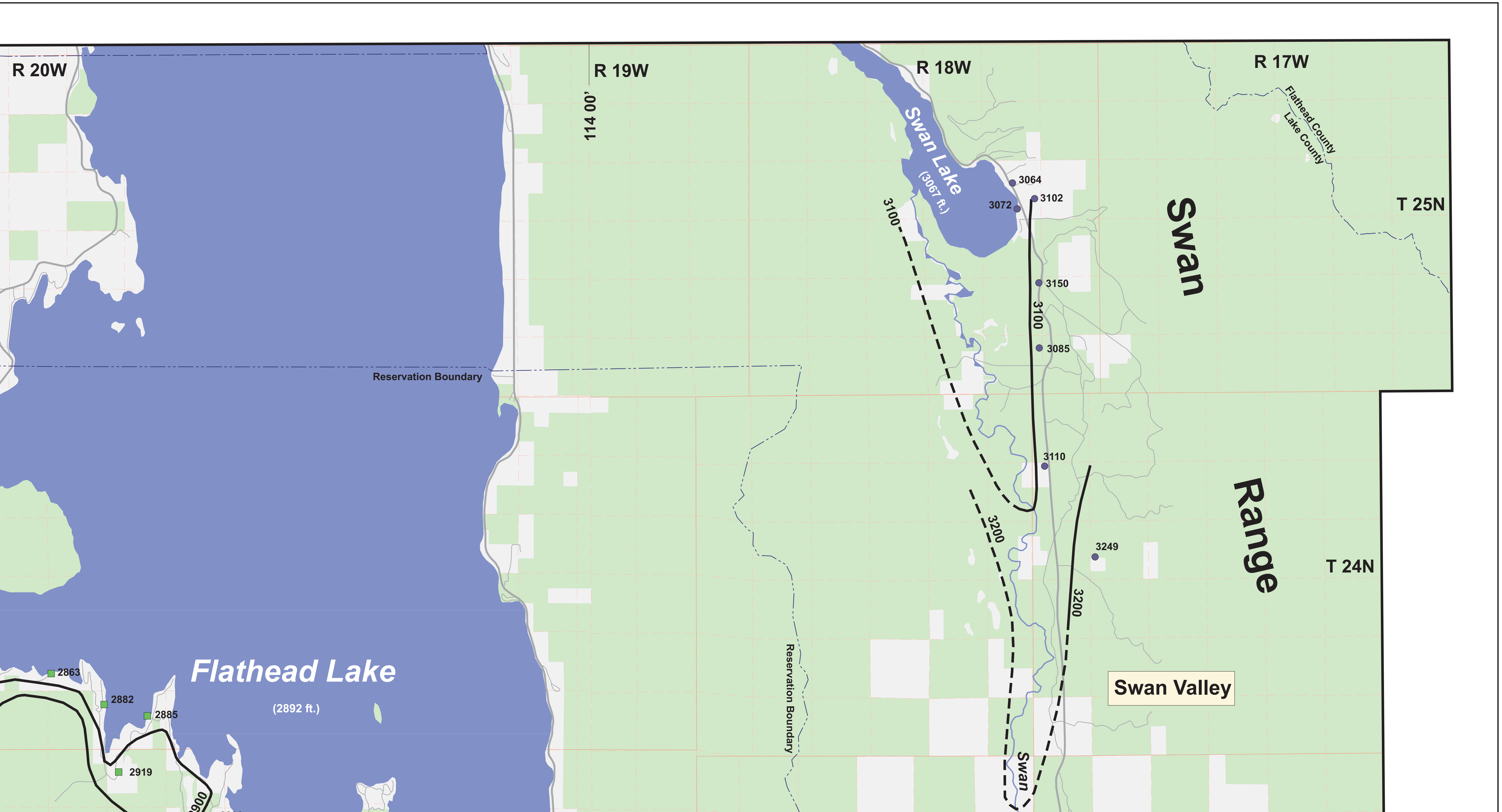
R 20W
R 19W
114 00'
R 18W
R 17W
Swan Lake
(3067 ft.)
Flathead County
Lake County
T 25N
T 24N
Swan
Range
Swan Valley
Reservation Boundary
Reservation Boundary
Flathead Lake
(2892 ft.)
3064
3102
3072
3150
3085
3110
3249
3100
3100
3200
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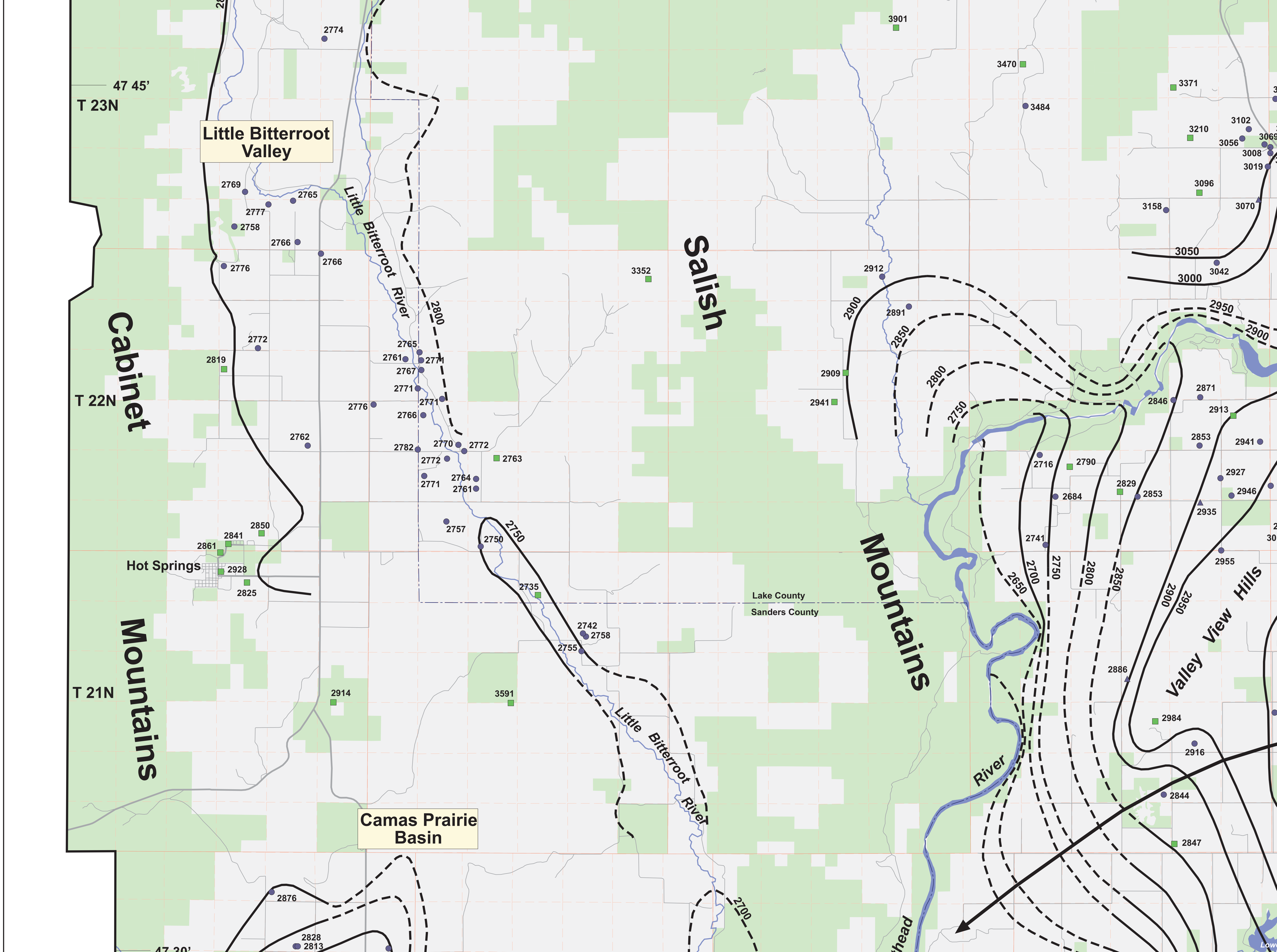
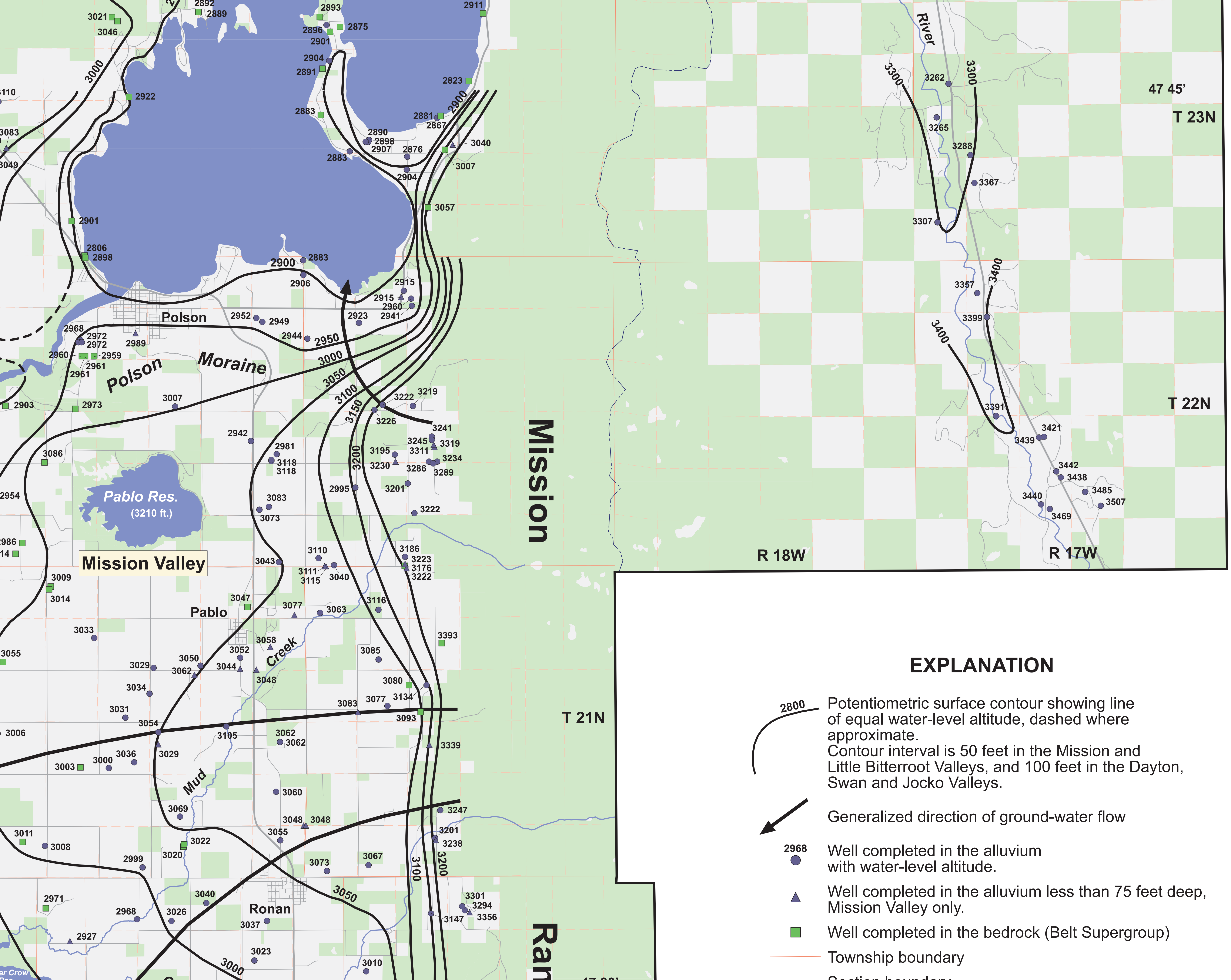
2882
2885
2919
Swan



47 45'
T 23N
Little Bitterroot Valley
Little Bitterroot River
Salish
Mountains
Cabinet
Mountains
T 22N
T 21N
Hot Springs
Lake County
Sanders County
Camas Prairie Basin
Valley View Hills
River
47 30'
2800
2750
2700
2650
2850
2900
2950
3000
3050



EXPLANATION

2800 Potentiometric surface contour showing line of equal water-level altitude, dashed where approximate. Contour interval is 50 feet in the Mission and Little Bitterroot Valleys, and 100 feet in the Dayton, Swan and Jocko Valleys.

Generalized direction of ground-water flow

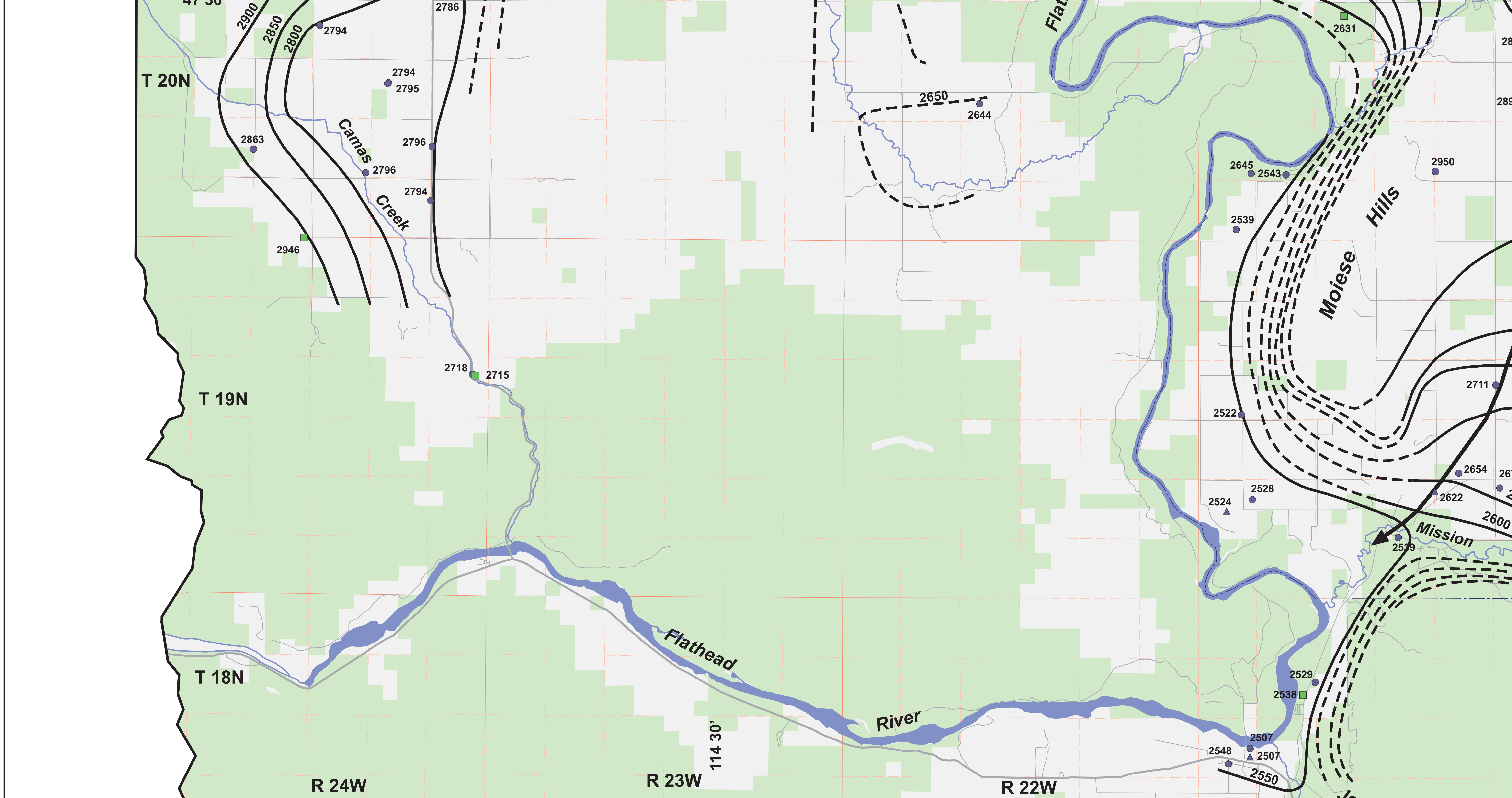
2968 Well completed in the alluvium with water-level altitude.

Well completed in the alluvium less than 75 feet deep, Mission Valley only.

Well completed in the bedrock (Belt Supergroup)

Township boundary

Section boundary



Potentiometric Surface Map of the Southern Part of the Flathead Lake Area, Lake, Sanders, and Missoula Counties, Montana

by
John I. LaFave

Author's Note: This map is part of the Montana Bureau of Mines and Geology (MBMG) Ground-Water Assessment Atlas for the Flathead Lake Area ground-water characterization. It is intended to stand alone and describe a single hydrogeologic aspect of the study area, although many of the area's hydrogeologic features are interrelated. For an integrated view of the hydrogeology of the Flathead Lake Area the reader is referred to Part A (descriptive overview) and other Part B maps of the Montana Ground-Water Assessment

surface topography and ground-water flow is away from the mountains along the valley margins toward the streams that drain the valleys. The ground-water flow systems in the valleys are strongly controlled by topography and the distribution of permeable layers within the valley-fill deposits. Summaries for the individual valleys for which the potentiometric surface was mapped are presented below.

On this map ground-water flow appears to be horizontal, but there also are important vertical components. Vertical ground-water flow is indicated by differing water-level altitudes in closely spaced wells that are completed at different depths. Vertical flow may be upward or downward depending on position in the flow system, and the geologic framework. Recharge areas, discharge areas, and places where low permeability layers separate more permeable units are settings where vertical flow can occur. Typically, in recharge areas (such as along the mountain fronts) shallow wells have higher water levels; this indicates a downward gradient and downward flow. Upward flow occurs in the

feet. The distribution of well depths is variable; between Mission and Post Creeks west of Highway 93 and in the alluvium associated with Mud Creek near Pablo, well depths are generally less than 75 feet. Where well depths are less than 75 feet, ground water occurs under unconfined conditions. In the center of the valley west of Highway 93 well depths are typically greater than 250 feet; east of Highway 93 toward the Mission Mountain front, well depths are typically less than 250 feet. The median well depth for the valley is 154 ft (figure 1).

Across the rest of the valley, most water-bearing units are buried by layers of silt and/or clay and ground water is under semi-confined to fully confined conditions. In a wedge-shaped area between Ronan and Pablo west of Highway 93, well depths are 300 to 500 feet below land surface, but the potentiometric surface is within about 20 feet of land surface and there are some flowing wells.

Well yields were reported for about 1,600 wells in the Mission valley and range from less than

over a distance of about 20 miles along the axis of the valley. The relatively flat gradient reflects the low relief of the surface topography in the Little Bitterroot Valley as well as the high transmissivity of the Lone Pine aquifer.

Records from GWIC indicate that there are at least 482 wells completed in the Little Bitterroot Valley; 262 of them are completed in the Lone Pine aquifer. Yields from wells in the Lone Pine aquifer are relatively high compared to other valleys and are reportedly as much as 1,100 gpm, with a median of 60 gpm (figure 2). Most wells completed in the Lone Pine aquifer are between 200 and 330 feet deep (figure 1). There are records of 76 wells completed in the Belt bedrock; most of the bedrock wells are located in and near the town of Hot Springs and along the valley margin. Bedrock well depths and yields are more variable. Most of the bedrock wells are between 50 and 570 feet deep and well yields range from less than 1 up to 500 gpm with a median of 25 gpm.

Swan valley

fill deposits consist of Tertiary (?) alluvial deposits overlying the bedrock, and Quaternary alluvium and lacustrine deposits; there is no evidence of glacial till in the valley (Kendy and Tresch, 1996). The deepest well in the valley penetrated 725 feet of valley-fill material without encountering bedrock.

Records from GWIC indicate that there are at least 72 wells completed in the valley that supply domestic and stock water. Most wells are completed in the valley-fill deposits; some are in the surficial alluvium (less than 50 feet deep) but most are in alluvium that is buried by lacustrine silts and clays. Around the valley margin there are 17 wells completed in Belt bedrock. Most wells are less than 200 feet deep, and the median well depth is 80 feet (figure 1). Reported yields are generally less than 30 gpm; the median reported yield is 10 gpm (figure 2). Ground water flows away from the valley margins toward Camas Creek in the middle of the valley.

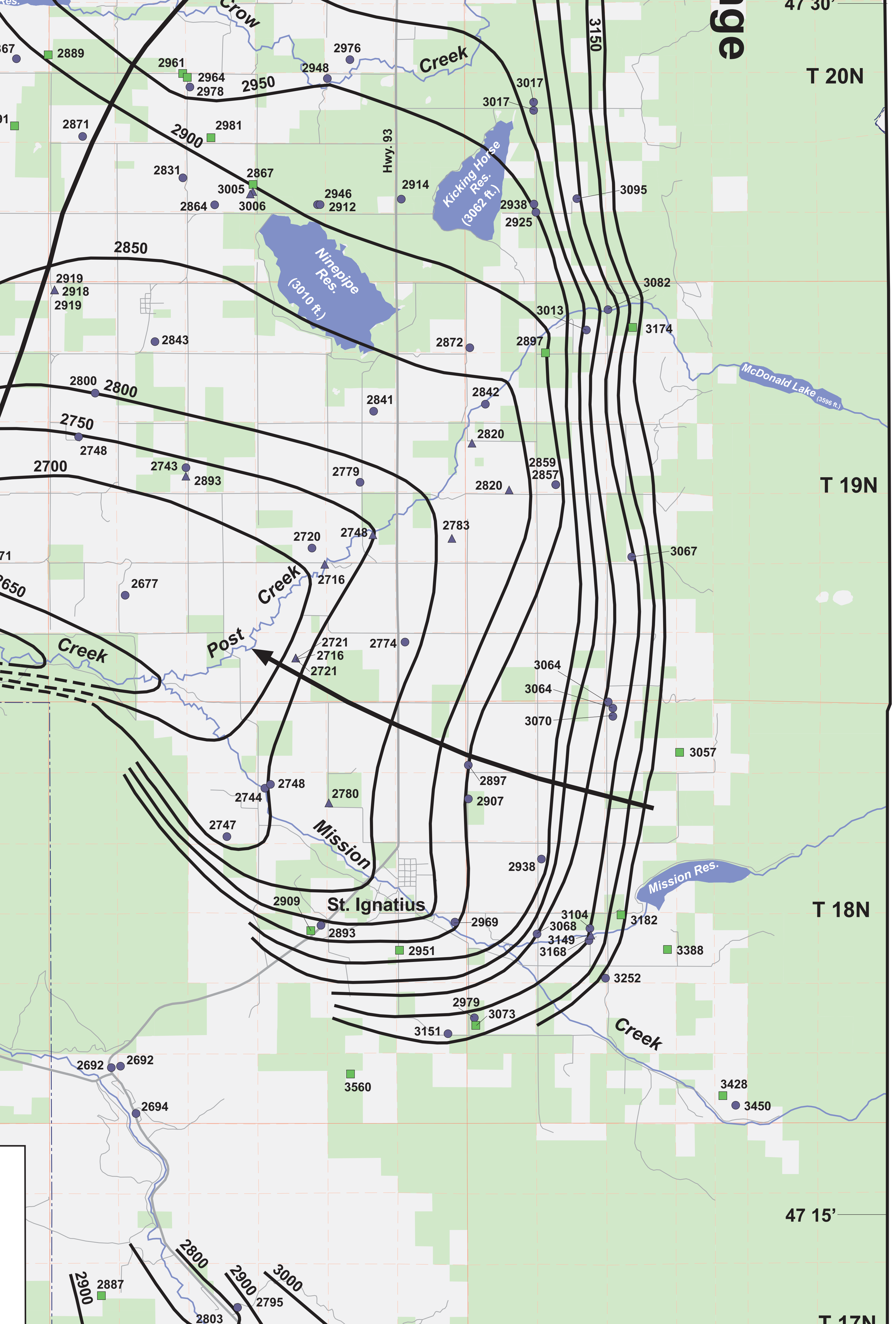
USE OF THIS MAP

This potentiometric surface map is useful for

REFERENCES

Abdo, G., 1997, Reappraisal of hydrogeology of the Little Bitterroot Valley, northwestern Montana: Montana Bureau of Mines and Geology Open File Report 350, 43 p.

Boettcher, A.J., 1982, Ground-water resources in the central part of the Flathead Indian



Section boundary

Major road

Secondary road

Flathead Indian Reservation boundary

County boundary

Stream

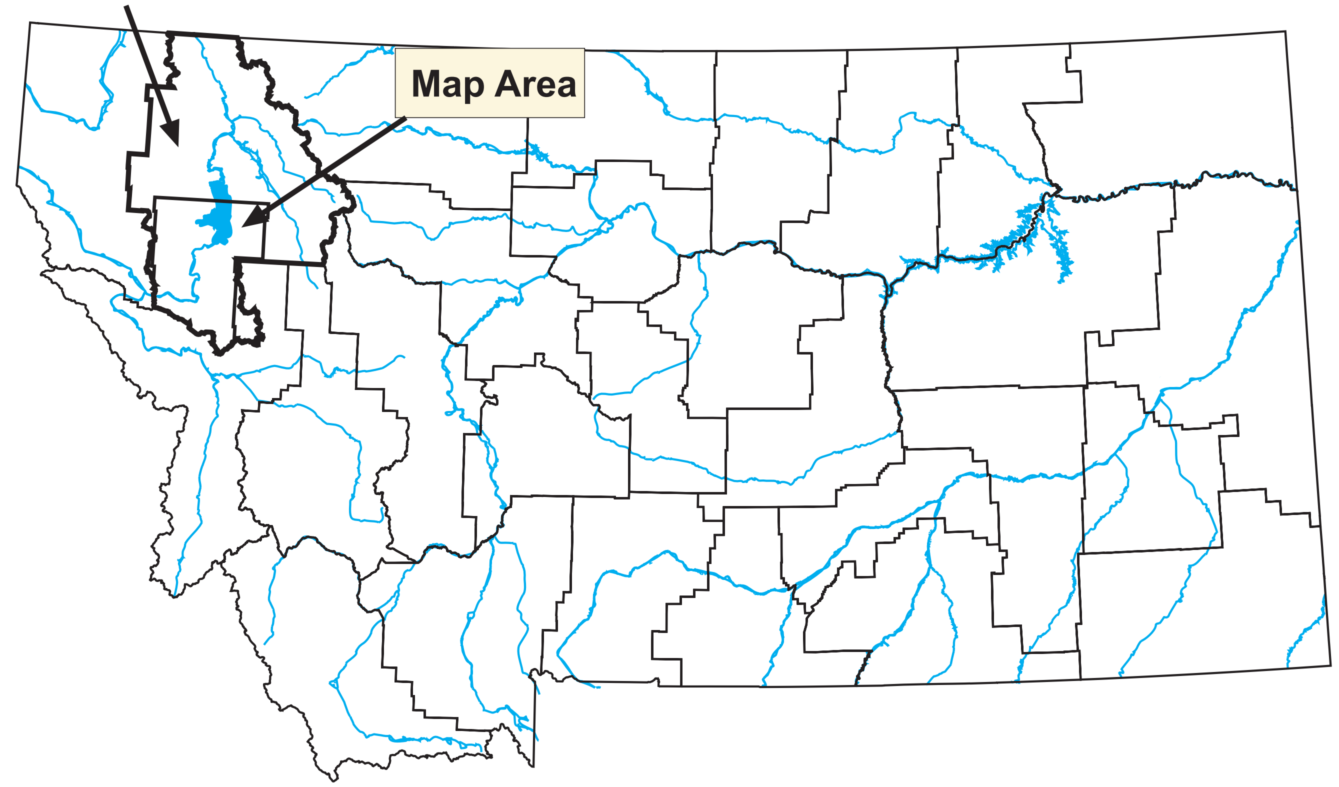
Federal/Tribal/State lands

Other lands

N
W E
S

2 0 2 4 6 Miles

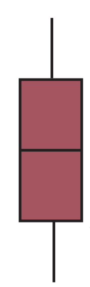
Scale 1:100,000
UTM Projection Zone 11 NAD27

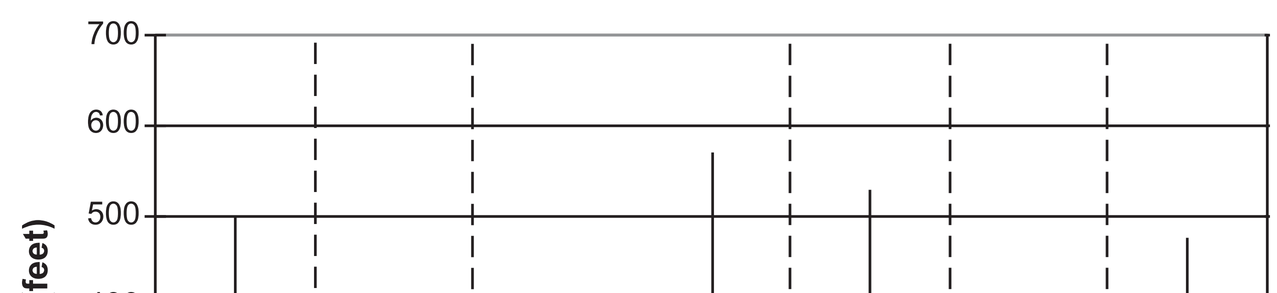


Ground-Water Characterization Program Study Areas

Explanation

n = number of samples





Atlas No. 2.

INTRODUCTION

This map presents the potentiometric surface of the major valley-fill aquifers in the southern part of the Flathead Lake Ground Water Characterization Study Area. The area is characterized by a series of north-northwest trending, structurally controlled intermontane basins that are bounded by mountains formed mostly of metamorphosed sedimentary rocks of the Proterozoic Belt Supergroup (bedrock). The valleys are filled with consolidated to unconsolidated, Tertiary and Quaternary sediment; most of the surficial valley-fill deposits are of glacial or glaciolacustrine origin. The Flathead River and its tributaries drain the valleys in the mapped area. Ground water in the valley-fill sediment and the fractured bedrock along the valley margins is an important source of municipal, domestic, irrigation and stock water.

Overviews of the area's geology are presented in Smith (2002a, 2002b), and Tuck and others (1996). The hydrogeology of various parts of the study area are presented in Kendy and Tresch (1996), Briar and others (1996), Slagle (1988), Makepeace (1994), Donovan (1985), Boettcher (1982), Thompson (1988) and Abdo (1997).

Aquifers are saturated geologic materials that yield sufficient water to supply wells and springs. Non-aquifer materials (also known as confining beds) also may be saturated, but have low permeability and do not produce usable amounts of water to wells or springs. The permeable layers of sand and gravel that form most of the aquifers are composed of alluvium (silt, sand, and gravel most likely deposited by glacial meltwater streams), and are covered and/or interfinger with glacial till (poorly sorted clayey gravel deposited directly by glaciers), and glaciolacustrine deposits (clay and silt deposited in glacial lakes). The depth, continuity, and character of these permeable layers vary from valley to valley reflecting the variable depositional history of each valley.

The Belt Supergroup bedrock, which occurs around the fringe of the valleys, generally contains sufficient fracture permeability (the primary openings through which water moves in the rocks are fractures or "cracks") to yield water to wells and is included as part of the valley-fill aquifers because it appears, based on the potentiometric surface(s), to be in hydraulic communication with the valley-fill deposits. It should be noted, that ground water in the Belt bedrock occupies and moves through fractures and voids within the rock, rather than through intergranular spaces as in the sand and gravel deposits. Because of the irregular distribution of fractures within the bedrock, ground-water occurrence in the bedrock can be unpredictable, and well yields can vary widely between locations.

The potentiometric surface represents the altitudes to which water will rise in wells penetrating an aquifer. Ground water moves down the slope of the potentiometric surface, from higher altitude to lower altitude, perpendicular to the contours. This map shows the potentiometric surfaces of the valley-fill aquifers based on water-level measurements from the summer and fall of 1996 (Smith and others, 2002). In most of the valleys, the potentiometric surface generally reflects the

downward flow. Upward flow occurs in the discharge areas which generally coincide with the valley bottoms. In these areas water-level altitudes increase with depth, indicating an upward component of ground-water flow.

Mission valley

The Mission valley occupies part of a north-trending, intermontane basin that is bounded by the Salish Mountains to the west, the Mission Range to the east and the Jocko Hills to the south; Flathead Lake marks the northern boundary. The Flathead River drains the Mission Valley and marks most of its western boundary. Drainage within the valley has been modified by an extensive network of irrigation canals and reservoirs (Boettcher, 1982; Kendy and Tresch, 1996). The valley floor generally slopes to the south-southwest away from the Polson moraine (maximum altitude 3,487 ft) on the north end of the valley, toward the Flathead River and to where the Flathead River exits the valley (altitude 2,600 ft). The Valley View Hills and The Moiese Hills, which are cored by Belt bedrock, protrude from the western part of the valley floor.

The Polson moraine marks the southern extent of valley-filling ice during the last glacial maximum (Levish, 1997). South of the moraine the valley has been filled with up to 800 feet of proglacial deposits and lacustrine sediments of glacial Lake Missoula. The subsurface stratigraphy is a complicated sequence of silt, clay, sand and gravel deposits. Ground water in the Mission valley occurs in discontinuous layers of permeable sand and gravel that are separated by low permeability layers of lacustrine silt and clay. Most of the permeable layers are buried at depths greater than 75 feet below the land surface. Locally, shallow sand and gravel also may support surficial aquifers at depths less than 75 feet below land surface, the most notable examples being the alluvium associated with Mud Creek near Pablo and the area between Post and Mission Creeks (Smith, 2002b; Makepeace, 1994). Although the permeable units are generally not contiguous over large areas (Slagle, 1988) there is sufficient hydraulic continuity between the sand and gravel layers to be considered a single entity in terms of ground-water flow on a valley-wide scale.

This map presents the potentiometric surface for the ground-water flow system in the Mission Valley; although data are presented from wells completed at various depths, more weight was given to those completed at depths greater than 75 feet below the land surface when contouring. Ground-water flow is generally away from the Mission Mountains, which serve as the major recharge area, westward toward the Flathead River. North of the Polson moraine, ground water flows towards Flathead Lake. The Moiese and Valley View Hills, which are bedrock highs, divert ground-water flow in the western part of the valley; ground-water flow from the north part of the valley converges toward lower Crow Creek, while ground-water flow in the southern part of the valley converges toward lower Mission Creek.

Records from the Montana Bureau of Mines and Geology's Ground-Water Information Center (GWIC) data base show that of about 1,900 wells completed in the Mission valley with reported well depths, approximately 1,400 (roughly 74 percent) are completed at depths greater than 75

in the Mission valley and range from less than 1.0 gallon per minute (gpm) up to 2,400 gpm, the median yield is 20 gpm (figure 2). Most of the high capacity wells (yields > 200 gpm) occur in the center of the valley north of Post Creek, south of the Pablo Reservoir and west of Highway 93.

Jocko valley

The Jocko valley occupies a northwest trending intermontane basin in the southernmost part of the study area. The northwest flowing Jocko River and its tributaries drain the valley, and the surface drainage has been modified by more than 60 miles of irrigation canals (Thompson, 1988). Ground water in the valley-fill and the bedrock around the valley margin supplies all the drinking water within the Jocko valley (Kendy and Tresch, 1996).

Records from GWIC indicate that there are at least 570 wells completed in the valley; the median well depth is 100 feet (figure 1), and wells are generally shallower (less than 75 feet) in the northern part of the valley, north of Arlee. Most of the wells are completed in alluvial deposits associated with the Jocko River and its tributaries and in the Belt bedrock surrounding the valley, however a few wells along the northern margin flanking the Jocko Hills, appear to be completed in Tertiary sediments. Reported well yields range from 1.0 up to 400 gpm with a median of 15 gpm (figure 2).

Ground water generally occurs under unconfined conditions. Ground-water flow follows the surface topography to the northwest, gradients are steeper in the southern part of the valley and along the valley margins.

Little Bitterroot valley

The Little Bitterroot valley is a northwest-trending intermontane basin that is bounded by the Salish Mountains on the east and north, and the Cabinet Mountains to the west. The southeast flowing Little Bitterroot River and its tributaries drain the valley. The valley-fill deposits consist of fine-grained, Tertiary sandstone, siltstone and clay that are overlain by a layer of Pleistocene sand and gravel that varies from as little as 7 to as much as 60 feet in thickness. The sand and gravel layer, which is capped by 200 to 350 feet of lacustrine silt and clay, forms what is informally referred to as the Lone Pine aquifer (Donovan, 1985). Shallow alluvial gravels, thin sand lenses within the lacustrine deposits, and fractured bedrock also supply water to wells, however ground water from the Lone Pine aquifer supplies most of the domestic, stock and irrigation water in the valley (Abdo, 1997).

The potentiometric surface portrayed on the map is based on data from wells completed in the Lone Pine aquifer and wells completed in the fractured bedrock. Water-level data from Abdo (1997) collected in 1993 and 1994 were used to supplement data collected by the Ground-Water Characterization program. Ground water in the Lone Pine aquifer is under artesian conditions with flowing wells common in the center of the valley near the Little Bitterroot River. Ground-water flow is away from the valley margins toward the center of the valley and the Little Bitterroot River. What is striking about the potentiometric surface in the Lone Pine aquifer is the relatively flat hydraulic gradient. The ground-water altitude decreases only 150 feet

Swan valley

The Swan valley is a relatively narrow north-trending intermontane basin that is bounded by the Mission Range on the west and the Swan Range on the east. The north-flowing Swan River and its tributaries drain the valley and empty into Swan Lake. The mapped area includes only that part of the valley between the Missoula County line and Swan Lake. Normal faults have down-dropped the valley floor relative to the mountains and the valley-fill sediments are as much as 5,000 feet thick (Kendy and Tresch, 1996). Most of the valley floor is covered with glacial till; glacial outwash and alluvium are present near some of the tributaries to the Swan River. Ground water from the glacial sediments supplies most of the residents in the valley.

Records from GWIC indicate at least 100 wells are completed in the mapped part of the valley. Most of the wells are between about 50 and 120 feet deep (figure 1) and completed in permeable layers of sand and gravel buried in till. Ground water flows from the valley margins toward the center of the valley and appears to be under unconfined to semi-confined conditions; flowing wells are present in the valley bottoms. The highest reported well yield in the valley is 100 gpm; most yields are less than 30 gpm with a median of 20 gpm (figure 2).

Dayton valley

The Dayton valley is a relatively small, northwest-trending intermontane basin about 6 miles long and less than 2 miles wide. The valley's topography has been shaped by glacial features. The arc-shaped ridge on the northwest part of the valley dams Lake Mary Ronan, and is the terminal moraine of the Dayton Lobe of the Flathead glacier. The broad valley surface slopes toward Flathead Lake and is covered by till, glaciolacustrine deposits and meltwater alluvium. The valley is drained by the southeast-flowing Dayton Creek and its tributaries. Belt bedrock of the Salish Mountains surrounds and underlies the valley; some Tertiary deposits (reported on drillers logs as "light gray rock" or "soft gray rock") may overlie the bedrock. At the crest of the moraine the valley-fill deposits may be up to 700 feet thick, but are generally less than 300 feet thick in other parts of the valley.

Records from GWIC indicate that there are at least 84 wells completed in the valley. Wells supply domestic, stock and public water supplies. About half the wells are completed in the Belt bedrock but the rest of the wells are completed in surficial sand and gravel (mostly near Flathead Lake), and in alluvium buried by various amounts of lacustrine silt and clay, and/or till. Well depths are as much as 622 feet with a median of 227 feet (figure 1). Most reported yields are relatively low, and the median reported yield is 12 gpm (figure 2). Ground-water flow is away from the valley margins and to the southeast toward Flathead Lake.

Camas Prairie basin

The Camas Prairie basin is a small north-trending graben bounded by normal faults on the east and southwest (Kendy and Tresch, 1996). The valley is broad, about 6-miles wide, and flat in its middle but narrows to less than a mile wide on its southern end. The valley is surrounded by the Salish and Cabinet Mountains, and is drained by the south-flowing Camas Creek. Belt bedrock surrounds and underlies the valley. The valley-

This potentiometric surface map is useful for estimating the general direction of ground-water flow, identifying areas where flowing artesian wells might occur, and estimating the water-level altitude in a non-flowing well. Ground water flows from high altitude to low altitude. If the approximate land-surface altitude at a location is known (for example, determined from a topographic map), the corresponding point on the potentiometric surface map can be found and the altitude of the potentiometric surface estimated. Subtracting the potentiometric surface altitude from the land surface altitude yields the approximate level at which water will stand in a well. It may also show that the altitude of the potentiometric surface is above land surface at a given location and a flowing well could be expected.

MAP CONSTRUCTION

This map was constructed by hand-contouring water-level altitudes measured in wells between May 1996 and November 1996. In the Little Bitterroot Valley, data were supplemented by measurements from Abdo (1997) made in 1993-1994. Map accuracy is affected by data distribution, field measurement errors, accuracy of well locations, and errors in interpretation. Points at which water levels have been measured are distributed unevenly across the map, and map accuracy is greater near points of measurement. Well locations are accurate to the 2.5-acre level (+/- about 300 feet). Land-surface altitudes at well locations were interpreted from U.S. Geological Survey (USGS) 1:24,000 topographic maps and are generally accurate to +/- 5 to 10 ft (based on 10 and 20 ft contour intervals). The potentiometric surface contour intervals are either 50 or 100 feet, depending upon the valley. The potentiometric contours are expected to be accurate to within one-half of the contour interval (+/- 25 ft, or +/- 50 ft depending on the valley).

ACKNOWLEDGMENTS

Well owners who allowed collection of the data necessary for the map, and the people who collected the data are all gratefully acknowledged. Reviews of this report by Tom Patton, Wayne Van Voast, improved its clarity.

SOURCES OF DATA

Geographic Features:

Population centers and roads are from 1:100,000-scale USGS Digital Line Graph files available from the Natural Resources Information System (NRIS) at the Montana State Library, Helena, Montana. Hydrography has been simplified from the 1:100,000 Digital Line Graph files. Township boundaries are from the U.S. Forest Service. The land ownership base was modified from 1:100,000-scale land ownership data available from NRIS.

Point Data:

Well-location and water-level altitude data were obtained by Ground-Water Characterization Program and personnel from the Confederated Salish and Kootenai Tribes; altitudes of the points were determined from USGS 1:24,000 topographic maps. All point data used on this map are available from the Ground-Water Information Center (GWIC) at the Montana Bureau of Mines and Geology, Montana Tech of The University of Montana, Butte, Montana. Lake level altitudes were obtained from USGS 1:24,000 topographic maps.

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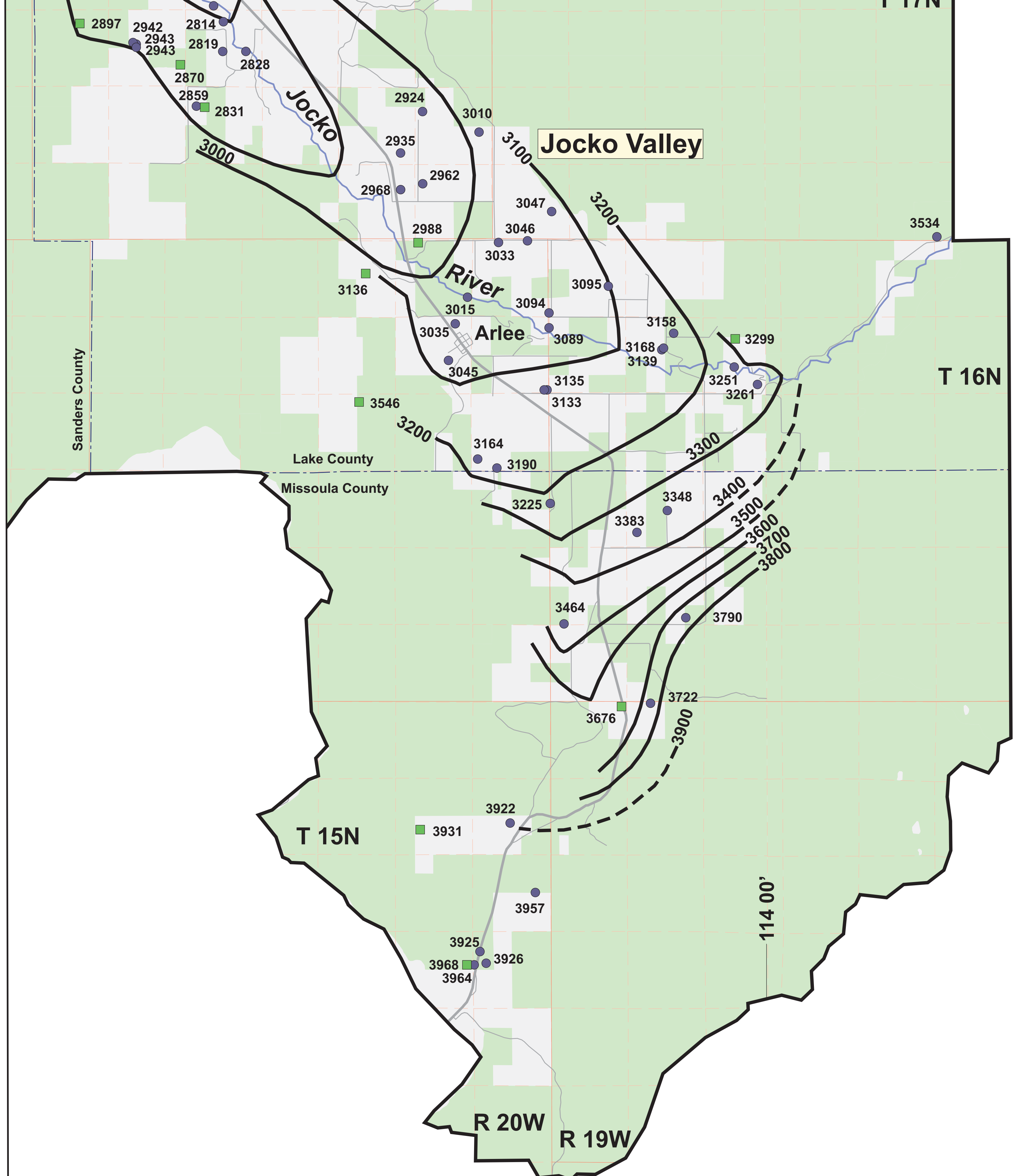

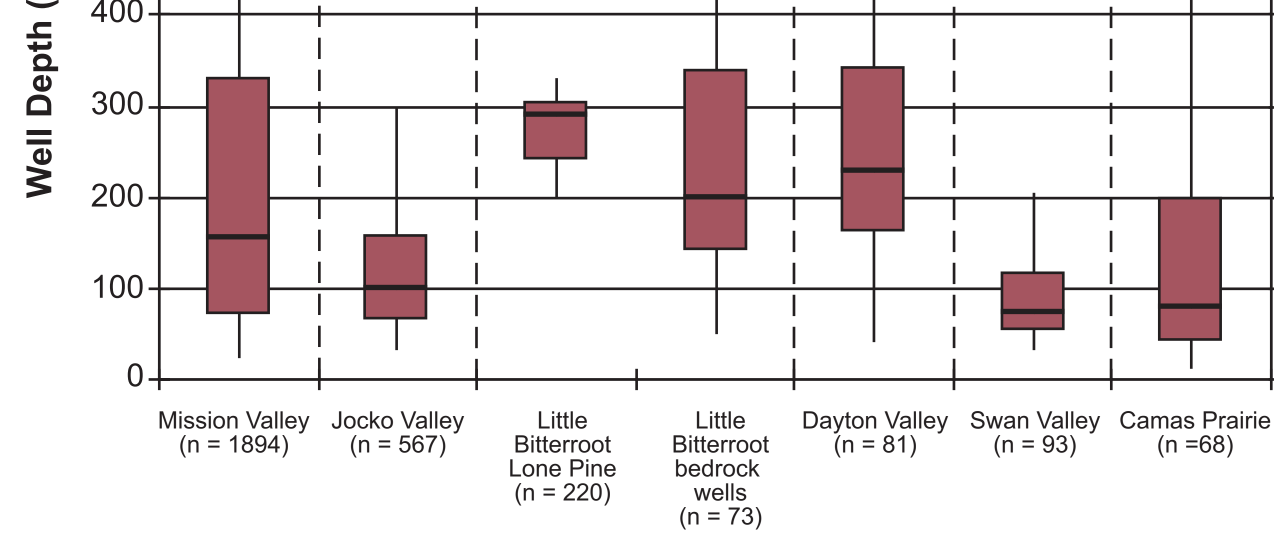

Figure 1. Summary of well depths.

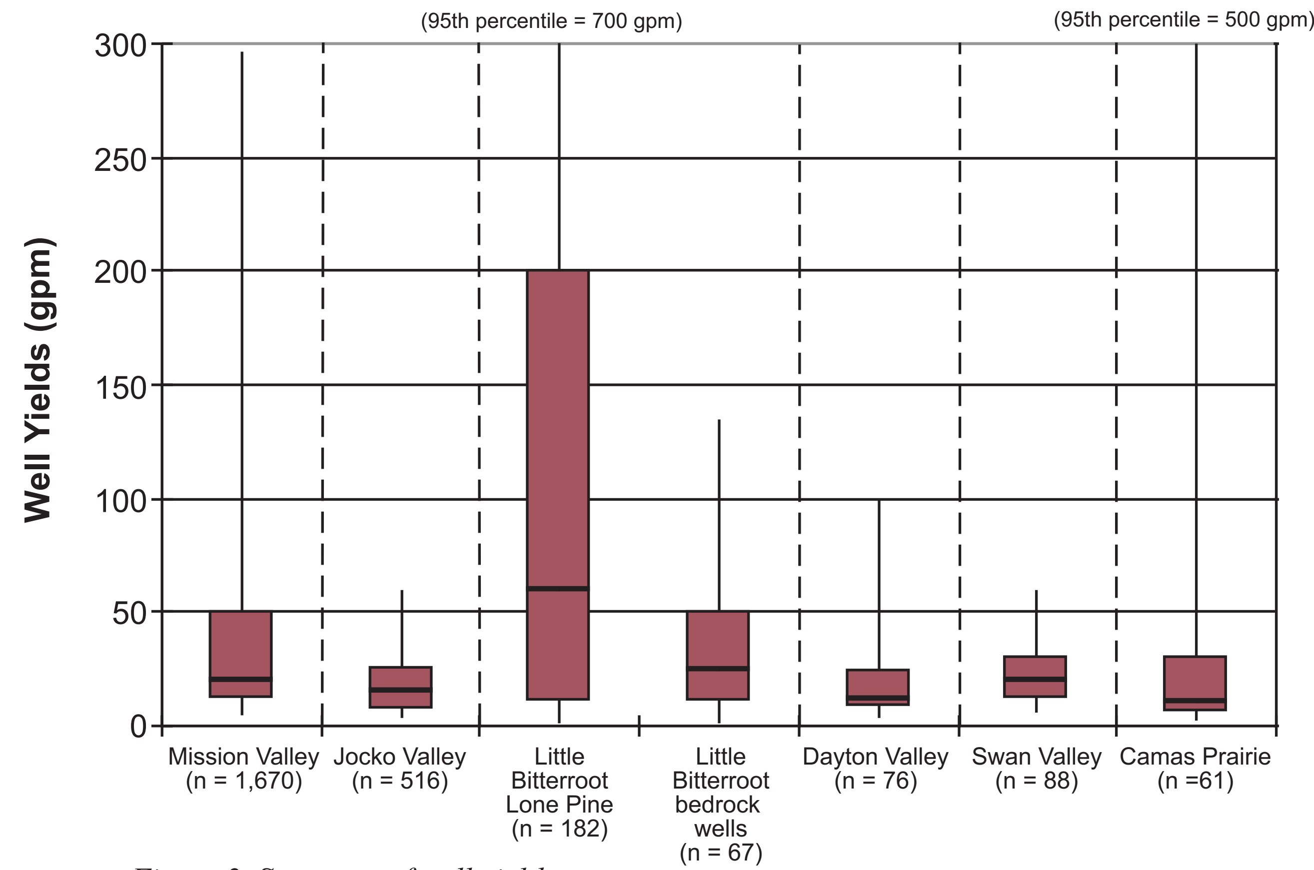

Figure 2. Summary of well yields.