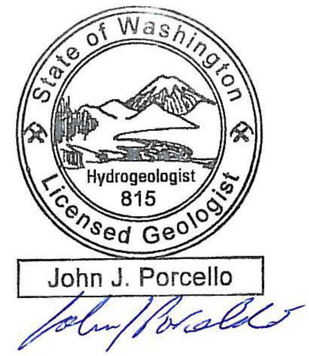
Water Solutions, Inc.

TECHNICAL MEMORANDUM

Groundwater Flow Model Development: Spokane Aquifer Joint Board (Spokane County, Washington)



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To:	Jeremy Jenkins, President/Spokane Aquifer Joint Board
From:	John Porcello, LHG (Washington)/GSI Water Solutions, Inc. Andy Lapostol, PG (California)/GSI Water Solutions, Inc.
CC:	Meagan Hayes, Program Manager/Spokane Aquifer Joint Board
Attachments:	Figures 1 through 18
Date:	December 12, 2025

Introduction

On behalf of the Spokane Aquifer Joint Board (SAJB), GSI Water Solutions, Inc. (GSI), has developed an updated three-dimensional numerical groundwater flow model of the Spokane Valley-Rathdrum Prairie (SVRP) Aquifer to support SAJB's groundwater protection programs. This model builds upon prior groundwater models developed by SAJB (CH2M HILL, 2000), the City of Spokane (CH2M HILL, 1998; GSI, 2012 and 2024) and the U.S. Geological Survey (USGS) (Hsieh et al., 2007). Figure 1 shows the geographic extent of the Spokane Valley-Rathdrum Prairie Aquifer (SVRP Aquifer), which is the sole source of municipal drinking water supply for the Spokane/Coeur d'Alene metropolitan region, including for the 21 SAJB members, who collectively provide all municipal drinking water supplies for the communities overlying the Washington portion of the SVRP Aquifer. The SVRP Aquifer encompasses an area of approximately 370 square miles (Kahle et al., 2005) and is present in portions of Spokane County, Washington, and portions of Kootenai and Bonner Counties in northern Idaho. As shown in Figure 1, two different versions of the aquifer boundary exist—the larger area (370 square miles) defined by the USGS during groundwater studies in the early 2000s, and a smaller area (of approximately 323 square miles) that was designated as a Sole Source Aquifer by the U.S. Environmental Protection Agency (EPA) in 1978.

SAJB's updated groundwater flow model uses the USGS software MODFLOW-USG (Panday et al., 2013; Panday, 2025) and replaces a model that was first developed during the mid-1990s (CH2M HILL, 1998 and 2000) using the European MicroFEM finite-element software (Hemker and de Boer, 2003 and 2017). SAJB's groundwater flow model builds upon an initial version of the MODFLOW-USG version of the model that was developed in 2024 for the City of Spokane (GSI, 2024). That version of the model and SAJB's new model each simulate the occurrence and movement of groundwater flow in the SVRP Aquifer. This regional aquifer system contains predominantly a thick sequence of highly permeable gravel, cobble, and sand deposits, but sandier and siltier deposits are present in tributary drainages and in deep portions of the aquifer along the Spokane River in the eastern portion of the City of Spokane. The model simulates groundwater flow processes and groundwater budgets in the SVRP Aquifer, as well as the aquifer's connection to the Spokane River, the Little Spokane River, and lakes that adjoin the outer boundaries of the aquifer. The model uses multiple layers to provide a three-dimensional representation of groundwater movement horizontally within individual model layers and vertically between model layers.

This technical memorandum describes the design and calibration of SAJB's new groundwater flow model and is organized into the following sections:

- **Section 1:** A description of the groundwater modeling software, including its benefits
- **Section 2:** Design of the model grid, both horizontally and vertically (i.e., its three-dimensional layering)
- **Section 3:** Boundary conditions and the groundwater system attributes they represent
- **Section 4:** Assignment of values for the SVRP Aquifer's hydraulic properties
- **Section 5:** Model calibration
- **Section 6:** Model applicability for groundwater resource management
- **Section 7:** Model limitations, and recommendations for model maintenance and improvements
- **Section 8:** A list of references cited in this technical memorandum

1. Description and Benefits of the MODFLOW-USG Groundwater Modeling Software

MODFLOW-USG was selected as the software code for the development of SAJB's new groundwater flow model because MODFLOW-USG (1) has particularly robust groundwater simulation capabilities, including detailed and flexible solvers; (2) is well-supported by graphical user interfaces (GUIs) that help the modeler visualize and manage the modeling process; (3) has the ability to communicate with other software packages such as Geographic Information System (GIS) software; and (4) has broad familiarity by—and support within—the groundwater modeling community. Although MicroFEM also had effective simulation capabilities, MODFLOW-USG offers the following benefits:

- It is part of the MODFLOW family of software tools, which are the most widely known models in the groundwater and hydrologic modeling community. These tools are widely used and are supported by multiple GUIs and visualization programs that facilitate the pre-processing, post-processing, information management, and visualization aspects of groundwater modeling efforts. The authors of MODFLOW-USG (the USGS and co-authors in the private sector) provide ongoing support and continued development of the MODFLOW family of modeling codes, and training programs and conferences are widely available through the USGS and other public and private entities.
- MODFLOW-USG provides a variety of flexible gridding methods and grid types that allow a grid to have high-spatial resolution where needed (such as the finite-element method built into MicroFEM), without adding more grid nodes/cells in places where higher resolution is unnecessary. These gridding methods also provide the capability to simulate the thinning and pinching out of model layers/geologic units in a more robust manner than is available with other software codes.
- MODFLOW-USG provides more detailed and sophisticated methods of representing stream/aquifer interactions than are available in MicroFEM, including in particular the ability to calculate flow rates and instream channel hydraulics during the groundwater solution process.
- MODFLOW-USG has a robust Connected Linear Network (CLN) package that greatly facilitates the process of simulating water levels in production wells. This package is similar to the Multi-Node Well (MNW2) package (Konikow et al., 2009) that is used in software codes that use structured grids. However, the CLN package allows for specification of well efficiency values, whereas MNW2 makes use of empirical well-loss coefficients that are often unmeasured or harder to derive from commonly used aquifer test analysis methods than well efficiency estimates. MicroFEM simulates water levels only in the aquifer formation adjacent to a pumping well, which requires that calculations of water levels in a pumping well must be conducted as a manual post-processing calculation procedure outside of the model simulation environment.

- MODFLOW-USG provides the capability to simulate the movement and concentration of inorganic (geochemical) constituents and organic chemicals in groundwater, using the Block-Centered Transport process documented by Panday (2025).

Version 9 of Groundwater Vistas (GV) is the GUI that was used to develop the model and manage the modeling process (ESI, 2024). GV is a popular and widely used program for managing model simulations and has an enhanced level of support for MODFLOW-USG. GV supports the entire family of MODFLOW codes for groundwater flow, particle-tracking, and solute transport. GV also supports certain codes developed by parties other than the USGS, including (1) the mod-PATH3DU particle-tracking code (Muffels et al., 2021) developed specifically for MODFLOW-USG and (2) the PEST suite of utilities for model calibration (Doherty and Hunt, 2010; Doherty et al., 2010a and 2010b). The simulations developed to date with the new regional model (using GV Version 9) are expected to be readily usable in newer versions of GV, based on its long record of compatibility importing existing models into new updated versions of the GV software.

2. Model Grid Design

The design of the spatial grid and the layering used in SAJB's groundwater flow model are discussed below.

2.1 Spatial Grid Design

The grid for SAJB's groundwater flow model has two components: (1) a parent grid composed of square cells having a 400-foot regular grid spacing regionally, and (2) imbedded grids that have refined (i.e., higher-resolution) spacing in the Washington portion of the SVRP Aquifer (except in the most downstream reaches of the Little Spokane River). The imbedded grids have 200-foot spacing in most areas, but with more refined spacing (50 feet) at and around each of the City of Spokane's eight high-capacity well stations. Figure 2 shows the active portion of the parent grid in the uppermost model layer (layer 1) across the entire SVRP Aquifer, before adding the refined grids. Figure 3 shows the imbedded grid in Spokane Valley (between the City of Spokane and the Washington/Idaho state line). Figure 4 shows the imbedded grid in and around the City of Spokane and the parent grid in the far northwestern corner of the SVRP Aquifer (along the Little Spokane River). These model grids are georeferenced to the Washington State Plane, North American Datum of 1983 (NAD83) High Accuracy Reference Network (HARN) coordinate system.

The areal extent of the active grid (i.e., the parent grid plus the imbedded grids) generally conforms to the SVRP Aquifer boundary delineated by the USGS (Kahle et al., 2005) and covers both the Washington and Idaho portions of the aquifer. Two notable aspects of the active portion of the model grid are as follows:

- As was the case with the USGS's numerical groundwater flow model (Hsieh et al., 2007), the SAJB model grid extends into the Hoodoo and Spirit Valleys in Bonner County, Idaho, but is inactive in both valleys. The USGS chose to inactivate the model grid cells in these valleys because of indications that (1) groundwater flow rates are limited in magnitude in both valleys and (2) groundwater likely flows northwards towards the Pend Oreille River rather than southwards to the SVRP Aquifer.
- North of Hayden and Hayden Lake in Idaho, the Chilco Channel is active in the SAJB model as is the case in the USGS model. The Chilco Channel lies along the eastern margin of the USGS-mapped portion of the SVRP Aquifer but is outside of the aquifer area that was mapped and designated as a Sole Source Aquifer by the EPA in 1978.

2.2 Layering (Vertical Discretization)

The model uses eight layers to represent the full saturated thickness of the SVRP Aquifer. The vertical datum is the North American Vertical Datum of 1988 (NAVD 88).

Because few wells, if any, penetrate the full saturated thickness of the SVRP Aquifer, the aquifer's thickness has been estimated primarily from (1) regional-scale and subregional-scale geophysical surveys and hydrogeologic studies (see Hsieh et al., 2007; Kahle and Bartolino, 2007), and (2) from exploratory drilling projects conducted by the City of Spokane (at its Havana Street and Well Electric well stations; see GSI et al., 2017, 2019a, and 2025a), and the Pasadena Park Irrigation District (PPID; see WNR Group, 2024). The 2012 version of the MicroFEM model (GSI, 2012) used three layers to represent the significant spatial variability in the aquifer's thickness, and also to represent the partially penetrating nature of groundwater production wells throughout most of the SVRP Aquifer. However, the use of three model layers was later deemed insufficient to support well condition assessments and capital improvement planning at three of the City of Spokane's well stations (Hoffman, Ray Street, and Well Electric). As discussed by GSI et al. (2019a and 2019b), the MicroFEM model was modified to be an eight-layer model to support studies at those well stations. The eight model layers have been carried over to SAJB's groundwater flow model, with the layering scheme being as follows:

- The upper two model layers (layers 1 and 2) are each 75 feet thick, and all existing pumping wells in the SVRP Aquifer are completed in one or both of these two layers. Together, these layers simulate the upper 150 feet of the SVRP Aquifer's saturated thickness, with the top of model layer 1 representing the historical average water table elevation at any given location. Because the ground surface is higher than the water table at most locations, the saturated thickness of model layer 1 is slightly greater than 75 feet when the water table is at its seasonal high level and slightly less than 75 feet when the water table is at its seasonal low level.
- Model layers 3 through 7 simulate the underlying system in 50-foot-thick layers, representing the depth interval of 150 feet to 400 feet below the water table. Model layer 8 simulates the remaining saturated thickness of the SVRP Aquifer wherever the base of the aquifer lies more than 400 feet below the water table.
- As with the three-layer model, at any given location in the eight-layer model where the saturated thickness is low enough that the aquifer does not penetrate into a particular model layer, that layer is inactive in the model at that location.

Currently, most production wells owned and operated by SAJB members penetrate less than 75 feet below the water table and hence are simulated in the model as pumping exclusively from the uppermost model layer (layer 1). In the Washington portion of the SVRP Aquifer, only 17 wells pump from deeper zones, and each of these wells are simulated as pumping from both model layers 1 and 2.[1]

3. Boundary Conditions

SAJB's new regional model uses no-flow boundary conditions to define inactive cells within the model grid. The model also uses the following MODFLOW-USG packages for boundary conditions that relate to specific hydrologic processes. These packages are the following:

- **Streamflow-Routing (SFR7) Package.** The SFR7 package uses head-dependent boundary conditions for computing groundwater/surface water exchanges in the Spokane River, specifying inflows to the river from the various outfalls for treated groundwater discharges, and routing the river's flow between model grid cells for water-balance tracking purposes. Streambed elevations were derived from digital elevation models. Streambed hydraulic conductivity values were initially derived from the MicroFEM model (GSI, 2012) and from the USGS-developed Bi-State groundwater flow model (Hsieh et al., 2007); these values

[1] These wells are the City of Millwood's New Park well; Consolidated Irrigation District's wellfields 4, 5, 6, 8, 9, 10, and 11; Model Irrigation District Well 6; Pasadena Park Irrigation District Well 2; the Riverside well; Spokane County Water District 3's Freeway&Vista well; and Vera Water and Power's wells 3, 9, 21, 22, and 33.

were then adjusted by GSI as needed during calibration of the new SAJB model. Monthly variations in flow rates at the headwaters of the Spokane River (the outlet from Coeur d'Alene Lake, near Post Falls, Idaho) are historical average flow rates since 1979 and are summarized in Table 1.[2] Table 2 lists inflows to the Spokane River from water reclamation facilities and from one major tributary (Latah Creek) that was programmed into the SFR7 package; these inflow rates were assumed to be constant throughout the year.

- **River (RIV) Package.** The RIV package uses head-dependent boundary conditions for computing groundwater/surface water exchanges in the Little Spokane River. Unlike the SFR7 package, the RIV package does not specify inflows to the river or route and calculate streamflow rates. Head values for the RIV package were assigned using digital elevation models for each grid cell containing the Little Spokane River.
- **Recharge (RCH) Package.** The RCH package uses specified-flux boundary conditions to represent deep percolation of rainfall, stormwater flows, and land-applied water (including infiltration from septic systems). Values for long-term average annual recharge rates were imported directly from the MicroFEM model (GSI, 2012); these rates were developed by the USGS for the period of 1991 through 2005 (Bartolino, 2007; Hsieh et al., 2007). For simulating the effects of climate change on groundwater resources, the average recharge rate was then translated into monthly-variable recharge rates using multipliers that range between zero in the summer months to values (during December and January) as high as 2.5 to 2.7 times the annual average recharge rate based on analyses for Spokane Airport published by the USGS; for further details, see Bartolino (2007) and Section 5.2 of this technical memorandum.
- **Well (WEL) Package.** The WEL package is primarily used in two manners:
  - To specify the rate of inflow into the SVRP Aquifer from lakes and from the tributary valleys of contributing watersheds that have stream systems flowing to the outer edges of the SVRP Aquifer. Inflow values from tributary valleys were varied month-by-month in conjunction with variations in long-term average annual precipitation. Inflow values from lakes were specified to be constant each month, with the rates of inflow adjusted slightly during calibration but targeted to be the same as the rates estimated by the USGS (Kahle and Bartolino, 2007) from data analyses conducted prior to the development of the Bi-State model.
  - To simulate pumping rates for all groundwater supply wells. The same wells and pumping rates used in the MicroFEM model were used in the MODFLOW-USG model; these rates are long-term average rates of groundwater pumping by municipal and private well owners, as derived from production records for 2012 and 2013 and from other data sources, as described by GSI (2012).
- **Connected Linear Network (CLN) Package.** The CLN package uses head-dependent boundary conditions to simulate flow exchanges between the aquifer matrix and the small number of groundwater production wells that span both of the upper two model layers.
- **Time-Variant Specified-Head (CHD) Package.** The CHD package uses specified-head boundary conditions to hold the groundwater elevation steady (at elevation 1,527 feet) where the SVRP Aquifer naturally discharges groundwater beneath Long Lake at the northwestern model boundary.

[2] These values were obtained in October 2022 from The Climate Toolbox website at https://climatetoolbox.org.

Table 1. Monthly Streamflow Rates for the Spokane River from Coeur d'Alene Lake (Historical Average for 1950–2005)

Month	Specified Flow Rate at Post Falls, Idaho (cfs)
January	5,236
February	7,463
March	8,941
April	15,394
May	17,408
June	9,118
July	2,381
August	877
September	798
October	1,368
November	2,903
December	4,646

Note

cfs = cubic feet per second

Table 2. Specified Inflows into the Spokane River from Point Sources

Source of Inflow	Segment Number in SFR7 Package	Specified Flow Rate (mgd)	Specified Flow Rate (cfs)
Liberty Lake Sewer & Water District WRF	3	1.8	2.8
Kaiser Trentwood Outfall	7	2.4	3.7
Inland Empire Paper Outfall	10	5.7	8.8
Spokane County WRF	13	8.0	12.4
Latah Creek	19	151.9	235
City of Spokane WRF	21	29.1	45.0

Notes

cfs = cubic feet per second
mgd = millions of gallons per day
WRF = water reclamation facility

4. Aquifer Hydraulic Properties

Following are discussions of the assignments of the primary hydraulic properties for the SVRP Aquifer system in the model. Sections 4.1 and 4.2 examine the horizontal and vertical hydraulic conductivity, and Section 4.3 examines the storage coefficients (the specific yield and the specific storage).

4.1 Horizontal Hydraulic Conductivity

Figures 5 through 11 show the spatial distribution of horizontal hydraulic conductivity and the geographic extent of the SVRP Aquifer in each model layer. The horizontal hydraulic conductivity in each model layer increases in an eastward direction in the Washington portion of the SVRP Aquifer and is highest at the state line and in much of the Idaho portion of the aquifer (between the state line and Lake Pend Oreille). Notable exceptions to the use of high hydraulic conductivity values occur at four locations:

- **North of the City of Spokane, in Hillyard Trough.** In this area, a clay layer is known to bifurcate the SVRP Aquifer into an upper section and a lower section (CH2M HILL, 1998; Kahle and Bartolino, 2007). This clay layer is simulated as being present in model layer 2 (see Figure 6), with a horizontal (and vertical) hydraulic conductivity value of 1×10^{-8} feet per day (ft/day) based on the USGS Bi-State model's calibration (Hsieh et al., 2007). Beneath this clay layer, in model layers 3 through 8, the horizontal hydraulic conductivity is set at 1,500 ft/day in Hillyard Trough and along the Little Spokane River, based on the calibration process for the new SAJB model.
- **Along the North Side of Spokane Valley.** Along the north side of the Spokane River, the area extending from Upriver Dam through the service area for PPID contains 100 to 150 feet of high-permeability gravel/cobble/boulder-dominated deposits that are underlain by a thick sequence of predominantly sandy deposits with little to no gravel content. This deep sand unit has been identified in exploratory boreholes, test wells, and production wells installed by the City of Spokane (GSI, 2025a) and in two new production wells installed by PPID (WNR Group, 2024). Constant-rate aquifer tests and groundwater model calibration activities indicate that the horizontal hydraulic conductivity of this deep sand unit ranges from approximately 100 to 1,500 ft/day, depending on location.
- **Adjacent to Coeur d'Alene Lake and Hayden Lake.** Well logs show that the southern portion of the City of Coeur d'Alene is underlain by predominantly sand deposits, rather than the gravel/cobble/boulder-dominated deposits that are typical of the more interior portions of the SVRP Aquifer. Similarly, sand-dominated deposits and steep hydraulic gradients are present adjacent to the western shore of Hayden Lake. The model simulates hydraulic conductivity values ranging between 100 and 500 ft/day in these areas.
- **In the Round Mountain Area (including West, Middle, and Chilco Channels).** In these areas (located south of Athol and north of Rathdrum), the USGS (Kahle and Bartolino, 2007; see Plate 1) identified that most wells are completed in bedrock or fine-grained deposits, rather than high-permeability SVRP Aquifer deposits. In this area, USGS mapping of well locations in SVRP Aquifer sediments versus other deposits suggests that most groundwater flowing from the north likely passes through the West Channel, with less flow (reduced thickness and likely reduced permeability) in the Middle and Chilco Channels. Based on GSI's calibration efforts during 2025, the SAJB model simulates hydraulic conductivity values of 1,500 ft/day in the West Channel and 150 ft/day in the Middle and Chilco Channels. However, the calibration process suggests these values and the simulated aquifer transmissivity may be too high.

The hydraulic conductivity values used in the new SAJB model are generally higher than those used in the earlier MicroFEM models and have the same general order of magnitude as the values used in the USGS Bi-State model. Summaries of these distinctions in the Washington and Idaho portions of the SVRP Aquifer are as follows:

- **Washington Portion of the SVRP Aquifer.** Horizontal hydraulic conductivity values in the MicroFEM model (GSI, 2012) progressed in an upgradient direction from 1,000 ft/day in the northern and northwestern portions of the SVRP Aquifer to 7,000 ft/day at the Washington/Idaho state line. These values were based on limited single-well tests conducted at certain City of Spokane well stations during and before the 1990s. In the gravel/cobble/boulder-dominated deposits, the horizontal hydraulic conductivity now ranges between 1,000 and 22,100 ft/day in much of the Washington portion of the SVRP Aquifer, which is similar to the values used in the USGS Bi-State model. These values have been derived from the following recent studies:
  - Hydrogeologic investigations at four of the City of Spokane's well stations between 2016 and 2025 have included more sophisticated multi-well tests (using test wells and monitoring wells) that identified much higher values for the hydraulic conductivity of the gravel/cobble/boulder-dominated deposits penetrated by the City of Spokane's shallow well stations.
    - A 5-day controlled aquifer test from a test well at the Havana Street Well Station resulted in a hydraulic conductivity estimate of 15,000 ft/day along the southern margin of the aquifer (GSI et al., 2017).
    - Performance testing at the Ray Street Well Station in fall 2017 produced a similar estimate.
    - Performance testing of two caisson wells at the Well Electric Well Station in fall 2017 resulted in hydraulic conductivity estimates for the gravel/cobble/boulder-dominated deposits that range between 12,500 and 31,000 ft/day, based on analytical and numerical modeling of the test results.
  - For the deep sand unit:
    - On land parcels north and south of the Spokane River near Well Electric, constant-rate aquifer tests in test wells completed in deeper sand-dominated materials have resulted in horizontal hydraulic conductivity estimates ranging between 400 and 1,500 ft/day, based on analytical and numerical modeling of the test results (GSI, 2025a).
    - Production well testing by PPID (WNR Group, 2024) at a location just north of the Spokane River and east of N. Argonne Road in Spokane Valley produced horizontal hydraulic conductivity estimates for the deep sand unit ranging between approximately 100 and 380 ft/day.
- **Idaho Portion of the SVRP Aquifer.** Horizontal hydraulic conductivity values in the MicroFEM model (GSI, 2012) decreased in an upgradient direction from 9,100 ft/day near the state line, to 5,005 ft/day in central Rathdrum Prairie, 7,085 ft/day in the West (Main) Channel, and between 2,500 and 5,400 ft/day from there to Lake Pend Oreille. The effort to calibrate SAJB's new MODFLOW-USG model has resulted in hydraulic conductivity values that are higher notably than in the MicroFEM model and generally of the same magnitude as used in the USGS Bi-State model (Hsieh et al., 2007).

4.2 Vertical Hydraulic Conductivity

Through the full thickness of the SVRP Aquifer, the vertical connection between model layers is represented using a vertical hydraulic conductivity that is one-tenth of the horizontal hydraulic conductivity value at any given location. This vertical anisotropy ratio of 10:1 (the ratio of horizontal-to-vertical hydraulic conductivity) was used in the MicroFEM model (GSI, 2012) and was found to not warrant adjustment in either the upper (gravel/cobble/boulder-dominated) or the lower (sand-dominated) portions of the SVRP Aquifer during calibration of SAJB's MODFLOW-USG model. As discussed by GSI et al. (2019a), vertical anisotropy ratios of 10:1 or less were found to replicate observed vertical hydraulic gradients at the City of Spokane's Well Electric Well Station during a several-month period of continuous water level monitoring in wells constructed in the shallow (gravel/cobble/boulder-dominated) and deep (sand-dominated) depth intervals of the SVRP Aquifer.

4.3 Storage Coefficients (Specific Yield and Specific Storage)

The specific yield of the SVRP Aquifer's sediments is set at 0.35, based on the prevalence of gravels and cobbles with large pore spaces. This value is used to calculate groundwater levels in the uppermost saturated layer of the model (layer 1), representing water table conditions in this uppermost layer of the model. The model is assigned a specific storage value of 0.00001 (1×10^{-5}) in each underlying model layer to simulate groundwater levels in fully saturated layers, where the groundwater level is a pressure-based head that lies above the top of the model layer. The specific yield is a dimensionless coefficient (i.e., it has no unit of measurement). The specific storage has dimensions of 1/foot (ft^{-1}); multiplying the specific storage by the thickness of the model layer in a given model grid cell produces the dimensionless storage coefficient for that grid cell. Both the specific yield and the specific storage were found to not warrant adjustment during model calibration.

The specific yield of 0.35 is also used in all model layers to conduct particle-tracking analyses with the mod-PATH3DU software, which is used to delineate groundwater capture zones for SAJB-member-owned production wells.

5. Model Calibration

The calibration process consisted of constructing a 5-year simulation that varied natural and human-based recharge terms, groundwater pumping, and Spokane River flows on a monthly basis (using the same set of monthly variations from one year to the next). This simulation was used to conduct a general check of the model's ability to simulate two sets of conditions during the summer low-flow season: (1) regional groundwater elevations, as displayed in Figure 12 (from Kahle and Bartolino, 2007), and (2) Spokane River gains and losses as reported by the USGS (Kahle and Bartolino, 2007; Hsieh et al., 2007) and as derived from unpublished data provided by Spokane County (during SAJB's development of its wellhead protection program during the late 1990s).

Adjustments to horizontal hydraulic conductivity values in the SVRP Aquifer and to streambed hydraulic conductivity values for the Spokane River were made to improve the initial model fit to these data sets. Additionally, during the course of the calibration process, lake inflow rates were changed significantly in the model to address calibration difficulties and the discovery of large differences in the inflow rates between the USGS's Bi-State model and estimates the USGS had derived prior to development of the Bi-State model.

Following are discussions of the inflow rates specified in SAJB's updated model from lakes (Section 5.1) and other tributary valleys (Section 5.2); a comparison of modeled versus historically measured summer-low groundwater elevations and the groundwater flow directions interpreted from field data and prior studies (Section 5.3); the rates of Spokane River gains and losses computed by the model (Section 5.4); and a comparison of the aquifer-wide groundwater budgets from the USGS's conceptual and numerical models and the new SAJB model (Section 5.5).

5.1 Lake Inflow Rates

During the initial phases of checking the model's calibration, GSI noticed that summer-low groundwater levels could not be simulated without deviating significantly from published estimates of the rates of Spokane River gains and losses. In particular, considerable difficulty was encountered reducing summer-low groundwater levels in the eastern portion of Spokane Valley and in much of the Idaho portion of the SVRP Aquifer, and this difficulty persisted even when lowering groundwater recharge rates in the losing reaches of the Spokane River to unreasonably low values between Post Falls and the City of Spokane. Figure 13 presents a map comparing three sets of summer-low groundwater elevations in this area: (1) USGS-published elevations for September 2004 in black contours (from Kahle and Bartolino, 2007), (2) the initial SAJB model in pink contours, and (3) the final SAJB model in blue contours.

To evaluate possible solutions to this dilemma, GSI decided to review the USGS's conceptual model report (Kahle and Bartolino, 2007) and compare that report's published lake inflow rates with the rates simulated in the USGS's final numerical model (which was the basis for the rates being used in the SAJB model). This comparison identified that the USGS model (and the initial version of the SAJB model) were using notably higher lake inflow rates than had been published in the USGS's conceptual model report. As shown in Figure 14, the USGS's numerical model simulated 101 cubic feet per second (cfs) greater inflow from Coeur d'Alene Lake (138 cfs) than the estimate from the USGS's conceptual model report (37 cfs), and inflow from all lakes bounding the SVRP Aquifer was 147 cfs higher in the USGS's numerical model (434 cfs) than the total lake inflow published in the USGS's conceptual model report (287 cfs). In summary, inflows from each of the nine lakes bordering the SVRP Aquifer were higher in the USGS's numerical model (and hence in the initial version of the SAJB model) than those published in the USGS's conceptual model report.

As a result, GSI modified the boundary conditions along each lake—particularly Coeur d'Alene Lake—to provide inflows that more closely match the USGS's conceptual model report. As part of that effort, GSI also adjusted the model's horizontal hydraulic conductivity values in the aquifer to improve the simulation of typical summer-season low groundwater levels in Idaho, as shown in Figures 12 and 13. Table 3 and Figure 15 compare the two USGS estimates of lake inflow rates and the rates now specified in the SAJB model. As shown in Table 3 and Figure 15, the lake inflows in the SAJB model total to 270 cfs, which is similar to the 287 cfs of lake inflow estimated in the USGS's conceptual model report (Kahle and Bartolino, 2007). The only notable difference between the SAJB model and the USGS's conceptual model report is a modest difference at Coeur d'Alene Lake, where the SAJB model simulates 20 cfs of inflow versus the USGS estimate of 37 cfs.

Table 3. Specified Lake Inflows Rates into the SVRP Aquifer

Lake	USGS Conceptual Model (2007)	USGS Numerical Model (2007)	SAJB Model (2025)
Lake Pend Oreille	50	67	50
Spirit Lake	48	55	48
Twin Lakes	35	40	35
Hayden Lake	62	70	62
Fernan Lake	13	15	13
Coeur d'Alene Lake	37	138	20
Hauser Lake	17	20	17
Newman Lake	20	23	20
Liberty Lake	5	6	5
Total	**287**	**434**	**270**

Note

All values are in units of cfs (cubic feet per second).

5.2 Inflows from Other Tributary Watersheds

Besides inflows from lakes, the USGS identified and simulated inflows to the SVRP Aquifer from 71 other tributaries that drain water to the outer boundary of the aquifer and then infiltrate this runoff into the aquifer along its outer margins (at the locations of the black dots shown in Figure 16). A specified-flux type of boundary condition was used in the USGS model—and continues to be used in the SAJB model—to specify the inflow rates from these tributary valleys (contributing watersheds). This type of boundary condition is specified using MODFLOW-USG's WEL package.

These subsurface inflows from the 71 tributary watersheds vary on a monthly basis in the SAJB model, based on an analysis by Bartolino (2007), who tabulated monthly precipitation and estimated recharge rates on a monthly basis for the period 1990 through 2005 at five locations in and near the SVRP Aquifer (Spokane Airport and Newport in Washington, and Bayview, Coeur d'Alene, and the Priest River Experiment Station in Idaho). GSI used these tabulations to calculate the ratio of the recharge rate in a given month to the long-term average daily recharge rate during this 16-year period of record at the Spokane Airport and at Bayview; calculations were also conducted at Coeur d'Alene but were concluded to be unreliable because of significant data gaps (missing records). As shown in Table 4, during the summer months, the ratio of monthly recharge to long-term average daily recharge is zero at Spokane and 0.26 at Bayview. The highest ratios occur during the winter months (December through February) and range between 1.7 and 2.7 at the Spokane Airport and 1.3 to 2.8 at Bayview. The SAJB model applies the Spokane Airport's monthly ratios to all tributaries entering the basin, given that the records at this station are the most complete and its ratios are similar to those at Bayview (the station with the next most complete set of records).

Table 4. Ratios of Monthly Average Recharge Rates to Long-Term Average Daily Recharge Rates

Month	Spokane Airport, Washington	Bayview, Idaho
January	2.523	2.329
February	1.676	1.289
March	1.009	0.776
April	0.383	0.444
May	0.244	0.282
June	0.198	0.230
July	0.195	0.226
August	0	0.259
September	0	0.267
October	0.841	1.035
November	2.26	2.139
December	2.691	2.847

Note

These ratios are calculated by GSI Water Solutions, Inc., from data listed in Tables 10 and 11 of Bartolino (2007).

5.3 Groundwater Elevations and Flow Directions

For the entire SVRP Aquifer, Figures 13 and 17 compare the simulated seasonal-low groundwater levels from the final SAJB model against the September 2004 seasonal-low groundwater elevation contour map published by the USGS (Kahle and Bartolino, 2007). As discussed earlier, Figure 13 focuses this comparison in eastern Spokane Valley and in Idaho, with the initial and final SAJB model simulations shown in the pink and blue contours, respectively. Figure 17 shows this comparison for the final version of the SAJB model across the entire SVRP Aquifer.

Figures 13 and 17 show that groundwater flow directions are reasonably well matched throughout the SVRP Aquifer. The shapes of the groundwater elevation contours are similar, and groundwater elevations are generally similar except for slight over-predictions of groundwater levels just east of the state line and extending upgradient roughly to a point halfway between the state line and Lake Pend Oreille. Groundwater elevations are generally well-matched near Coeur d'Alene and Hayden Lakes in Idaho and in the Washington portion of the SVRP Aquifer. Figures 13 and 17 also show that the calibration process—particularly the revisions to the lake inflow rates—produced a reasonable simulation of the groundwater elevation contours in Washington and in the southern part of the Idaho portion of the SVRP Aquifer. Summer-low groundwater elevations are still simulated slightly higher than observed during September 2004 in the eastern portion of Spokane Valley and in the southern part of the Idaho portion of the SVRP Aquifer; however, these differences are small considering the uncertainties that arise from the 20-year difference between the time period being simulated (recent historical conditions) versus the September 2004 date of the field measurements.

Further upgradient, the area north of Hayden Lake shows simulated groundwater elevations that are much higher than the USGS-published contours for September 2004; this difference arose from the need to introduce a zone of low transmissivity (low hydraulic conductivity) in the various aquifer flow channels situated near Twin Lakes and Round Mountain to reduce groundwater elevations south of this area. Although this results in over-prediction of groundwater levels at and north of the Twin Lakes/Round Mountain area, no work was undertaken during this project to resolve conditions in this farthest upgradient end of the SVRP Aquifer, given that the portion of the aquifer near Twin Lakes and Round Mountain lies approximately 17 miles upgradient of the Washington/Idaho state line (far upgradient of the water service areas for SAJB members).

5.4 Spokane River Gains/Losses

Table 5 compares the simulated and field-measured estimates of the rates of Spokane River gains and losses for three major reaches of the river across the SVRP Aquifer. Values are shown in units of cubic feet per second (cfs).

Table 5. Model Calibration to Spokane River Gains/Losses (Summer-Low and Annual-Average Conditions)

Reach	Spokane County Unpublished Data (Late 1990s)	USGS Field Measurements (Sept. 2004)	USGS Model (Annual Average)	SAJB Model (Summer Low)	SAJB Model (Annual Average)
Post Falls to Sullivan Road	-207 to -319	-606	-651	-356	-781
Sullivan Road to Monroe Street	+478 to +659	+481	+623	+766	+463
Monroe St. to Nine Mile Falls	-57 to +108[1]	+268	+283	+331	+311
Total	**+379 to +448**	**+143**	**+255**	**+741**	**-7**

Notes

[1] This is a combination of estimates from Broom (1951) and unpublished data provided by Spokane County during the late 1990s.

All values are in units of cubic feet per second.

USGS = U.S. Geological Survey

In general, the model provides a reasonable representation of the gaining versus losing nature of each of these three reaches of the Spokane River, but some noteworthy differences exist between the various models and data sets. Specific observations from Table 5 are:

- In the prominent upper losing reach of the Spokane River (extending from Post Falls to Sullivan Road), the SAJB model simulates a loss rate that is similar to Spokane County's late-1990s estimates for the summer season but below the USGS's field-based summer estimates. The SAJB model's annual average loss rate is slightly greater than the loss rate simulated by the USGS model, but of the same general order of magnitude.
- From Sullivan Road to Monroe Street, the modeled streamflow gains during the summer season are slightly to moderately higher than the other available estimates. On an average annual basis, the modeled gains (463 cfs) are somewhat less than the gains estimated by the USGS model (623 cfs).
- From Monroe Street to Nine Mile Falls, the available studies generally identify gaining conditions. The model simulates slightly higher gain rates than the USGS estimates. Spokane County estimated the uppermost portion of this reach (from Monroe Street to the USGS downtown gage) to be slightly losing (-57 to -80 cfs) but did not quantify stream gains and losses downstream of the USGS gage. The earliest study of this reach (Broom, 1951) estimated a net gain of 108 cfs from Monroe Street to Nine Mile Falls.

- For the entire reach of the Spokane River:
  - During the summer, conditions are net gaining according to each field and model estimate. The Spokane County estimate (379 to 448 cfs) and the SAJB model estimate (741 cfs) are notably higher than the field-based estimate by the USGS (143 cfs); this distinction arises because during the summer season the USGS estimates higher streamflow losses above Sullivan Road and lower streamflow gains between Sullivan Road and Monroe Street compared with the other estimates.
  - On an annual average basis, the USGS model estimated a net gaining condition (255 cfs) whereas the SAJB model estimates a nearly net-zero condition. Based on water budget analyses presented in Section 5.5, this difference appears to arise from the much greater lake inflow in the USGS model than in the SAJB model.

During late August 2025, the Spokane River was observed to be dry in an approximately 1-mile reach between Barker and Sullivan Roads in Spokane Valley. According to press reports and independent observers, this is the first known event in which a portion of the Spokane River was observed to have no flow. At that time, the river's streamflow rate upstream of the dry reach was 500 cfs (at Post Falls, USGS gaging station 12419000), while the downstream gaging station in downtown Spokane (USGS gaging station 12422500) showed nominally 700 cfs of flow. This event provides the first distinct measurements of the streamflow gain and loss rates in specific reaches of the river that are separated by a dry reach. Compared with the SAJB model's gain/loss rates, the observed conditions were as follows:

- In the losing reach between Post Falls and Sullivan Road, the model simulates 356 cfs of streamflow loss compared with the reported 500 cfs of flow at the Post Falls gage, which suggests the model may slightly underestimate streamflow loss rates in this reach.
- In the gaining reach that extends from Sullivan Road to downtown Spokane, the observed flow rate of 700 cfs is thought to have consisted of approximately 25 cfs of point-source flows into the river and 675 cfs of groundwater discharges into the river over this reach. The resulting stream-gage-based estimate of 675 cfs for the groundwater contribution to streamflow at the downtown Spokane gage is 100 cfs lower than (but of the same general order of magnitude as) the 776 cfs of groundwater contribution that is estimated by the SAJB model to occur between Sullivan Road and downtown Spokane at the end of a typical summer.

5.5 Aquifer-Wide Groundwater Budget

Figure 18 compares the aquifer-wide groundwater budget terms on an average annual basis for the SAJB model and the USGS's Bi-State numerical model (Hsieh et al., 2007) and also shows the summer-season water budget for August 2005 as reported in the USGS's conceptual model report (Kahle and Bartolino, 2007). Key observations from these three data sets are as follows:

- The SAJB model has 75 cfs more groundwater pumpage than the two USGS data sets, reflecting the use of pumping rates obtained from records collected from SAJB members for the years 2012 and 2013 in the Washington portion of the aquifer.
- All data sets show net losses of groundwater to rivers, in the cases of both the Spokane River and the Little Spokane River:
  - For the Spokane River, the net exchange is much smaller in the SAJB model than in the USGS's numerical model, primarily because the SAJB model has notably lower lake inflow rates than the USGS's numerical model.
  - For the Little Spokane River, the net exchanges are similar between the three data sets.

- Tributary and lake recharge rates in the SAJB model are similar to (though slightly lower than) those in the USGS's conceptual model but noticeably lower than those in the USGS's numerical model.
- Areal recharge over the aquifer's footprint is similar between the three data sets.
- Subsurface outflow is notably higher in the two USGS data sets than in the SAJB model, despite the limited cross-sectional area through which groundwater can move laterally across the delineated northwestern boundary of the SVRP Aquifer (near the mouth of the Little Spokane River, downstream of Nine Mile Dam).

6. Model Applicability for Groundwater Resource Management

SAJB's new groundwater flow model (like previous models) has been created through a detailed process of planning, construction, and calibration, which has resulted in a model that is well-suited for a variety of applications related to wellfield evaluation and planning and aquifer resource management. The new model is constructed using the MODFLOW-USG groundwater modeling software, which is an improvement over SAJB's prior groundwater model because of the flexible gridding capabilities of this software, the more robust numerical solvers for computing groundwater elevations and groundwater budgets, and the more sophisticated method of simulating groundwater/surface water interactions.

Additionally, SAJB's new model incorporates the results of recent controlled multi-well aquifer tests, which are a type of test that had not been conducted in the SVRP Aquifer until recently. The data from these controlled multi-well aquifer tests have significantly improved the understanding of the general order of magnitude of hydraulic conductivity values in the SVRP Aquifer. In addition, unlike most previous models, which used either one or three layers to simulate the aquifer system, SAJB's new model uses eight layers, which provides greater vertical resolution for (1) simulating the direction and magnitudes of vertical gradients in the aquifer at any given location, and (2) more accurately representing the exchanges between the shallowest portions of the aquifer system and the Spokane River. The model also provides good replication of the important attributes of the system, including groundwater elevations, groundwater flow directions, and the rates and locations of Spokane River gains and losses.

From a calibration perspective, the primary limitation in the model is in Idaho, where groundwater pumping and land use data are from the 1990s and hence are out of date because of the significant growth that has occurred since that time in Kootenai County. Additionally, the model's simulation capability is limited in the Idaho portion of the SVRP Aquifer in two respects. First, the model significantly overestimates groundwater elevations between Lake Pend Oreille and Twin Lakes. Second, after the SAJB model was developed, data evaluations by the Idaho Washington Aquifer Collaborative (IWAC) identified that portions of the SVRP Aquifer are affected by significant seasonal fluctuations in lake levels at Lake Pend Oreille and to a lesser extent by Coeur d'Alene Lake. (See GSI, 2025b for details.) IWAC is currently conducting an update of the pumping and land use information in Idaho and will be conducting calibration activities to account for the seasonal influences of lakes on the aquifer system and to simulate historically observed fluctuations in groundwater levels across the Idaho portion of the SVRP Aquifer. The calibration effort will also examine stream gains/losses in the Spokane River in light of the occurrence of dry conditions in a portion of the river in late August 2025 (as discussed previously in Section 5.3). The model resulting from IWAC's work in Idaho is anticipated to be completed in mid to late 2026.

7. Model Limitations and Recommended Maintenance and Improvements

Despite its detail and the in-depth nature of the calibration and validation process, SAJB's new groundwater flow model is a simplification of a complex hydrogeologic system and has been designed with certain built-in assumptions. Like any model, it is not perfect and should be used with care. Predictive simulation results should be examined by qualified and experienced hydrogeologists and water resource managers. Future modeling analyses, interpretations, and conclusions should not be viewed as absolute results and could change as the model is refined in the future as new data becomes available.

Additionally, SAJB has developed this model with the intention of beginning a process to improve groundwater modeling tools and capabilities in the SVRP Aquifer. SAJB does not view this model as the final model of the aquifer system, but rather a first step in building an updated model across the region. This model development effort did not alter several hydrologic inputs to the model in Idaho—in particular, the spatial distribution and magnitude of areal recharge, which is controlled by precipitation, evaporation, septic system discharges, and deep percolation from irrigated agricultural areas and irrigated urban landscapes. However, certain boundary conditions such as inflows from lakes and tributary valleys are now simulated in a more realistic manner than in prior models yet are understood to require further evaluation in light of more data sets that have recently become available in Idaho. As discussed in Section 6, IWAC is now embarking on updates to the hydrologic inputs in Idaho and detailed calibration to long-term groundwater-level data in Idaho—efforts that will update and enhance the simulation capabilities of the new SAJB model.

Continued maintenance of the model is recommended, to ensure that it will continue to be useful for future groundwater resource planning and wellfield evaluation needs. Maintenance activities should be determined by SAJB and its individual members based on how the model will be used to support long-term programs (such as water supply planning, capital improvements planning, and groundwater resource protection) and to support near-term decision making on matters such as wellfield operations, site development impacts on groundwater, or other specific resource management topics. Maintenance activities could include one or more of the following activities:

- **Updating and Checking Calibration as New Data Becomes Available.** This can be thought of as a "calibration check" process, for which the objective is to evaluate the model's ability to simulate new water use and hydrologic information that is collected as time progresses. Events that could warrant an extension of the calibration period include not only the continued collection of information at existing wells and existing monitoring locations in the aquifer and in the river systems, but also (1) the collection of data at new locations and (2) the occurrence of different groundwater conditions than those experienced in the past (e.g., if the onset of an extended drought were to cause notably decreased pumping at certain production wells and/or unusually low groundwater levels). Additionally, whenever new production wells are installed, long-term water-level monitoring should commence in the well, and controlled pumping tests should be conducted to provide quantitative estimates of aquifer properties—particularly in areas where wells have not been recently constructed and tested. Incorporating new data sets into the model provides opportunities to incorporate refinements to the model-specified hydraulic parameters that are used in localized areas for the aquifer and/or the Spokane River.
- **Upgrades to Model Software.** New versions of the MODFLOW family of software tools periodically become available that add/improve existing MODFLOW packages and/or improve solver capabilities and reduce model run times. These updates can occur every few years. Additionally, updates to the GUI (GV) occur frequently, although major upgrades in its features occur only every few years. Updates to MODFLOW and GV do not need to be conducted on a regular schedule for the model to remain functional and suitable for its desired uses. If municipal water providers elect to use the model in an updated version of MODFLOW or under a major update of GV, the model should be run with the new software to confirm that it converges and runs properly, and to check that simulation results are similar to those obtained from the earlier software.
- **Model-Sharing and Cooperative Efforts with Local Stakeholders and Other Government Agencies.** When a municipality or water provider has developed a detailed numerical groundwater model of a regional aquifer system, it is common to receive requests for the model from local landowners/stakeholders or other government agencies.

Keeping the model updated with recent software and a calibration that is not several years old is helpful for increasing the confidence of groundwater users and other stakeholders, and for providing the model's keepers with opportunities to ensure that the model is being used correctly. Accordingly, GSI and SAJB recommend that SAJB and other SVRP groundwater users work together to further update and improve the model in the coming years to support planning activities occurring at both local and regional scales.

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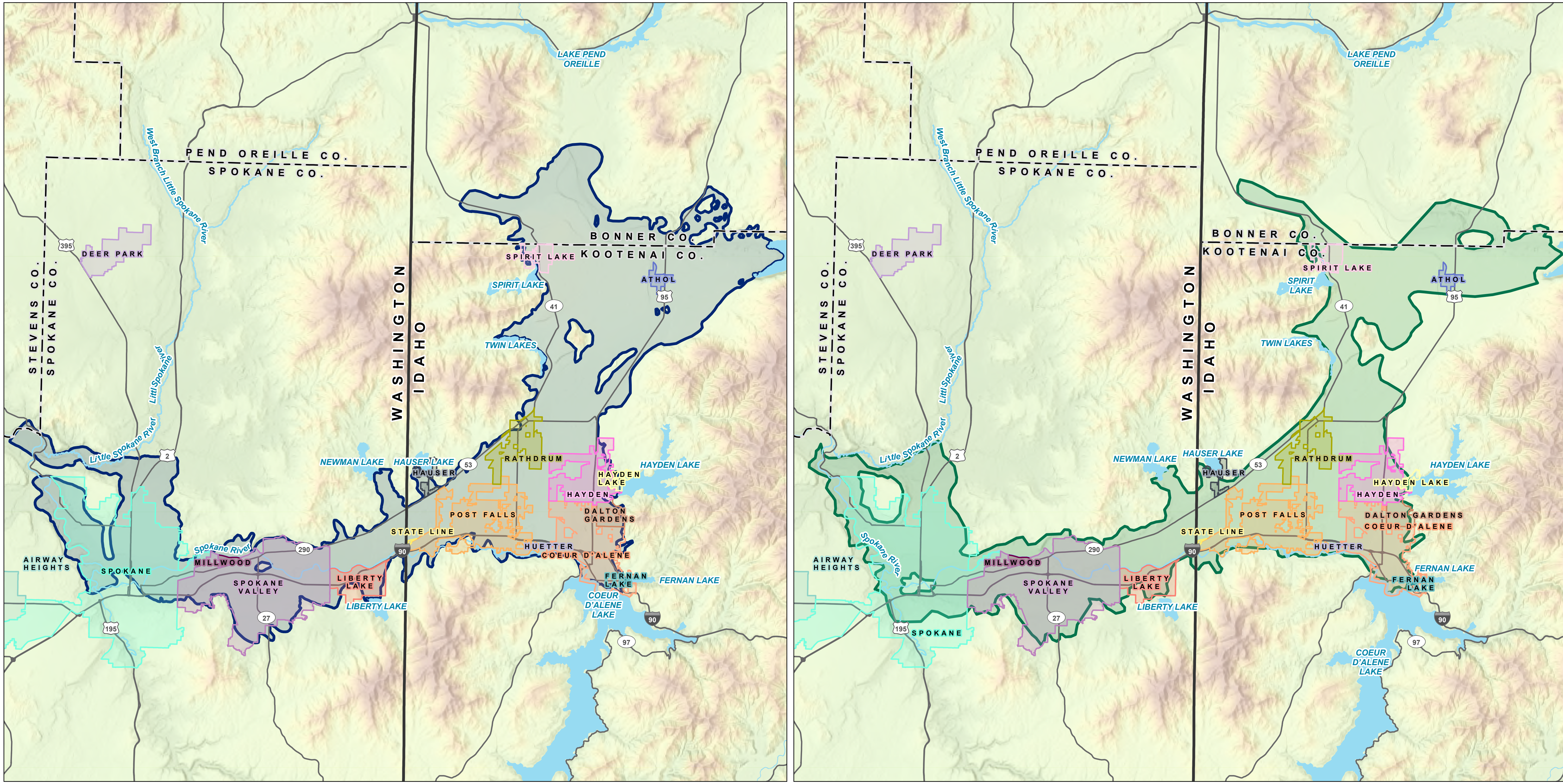
Figures



LEGEND

- USGS Aquifer Boundary (2005)
- EPA Sole Source Aquifer Boundary (1987)

All Other Features

- County Boundary
- State Boundary
- Major Road
- Watercourse
- Waterbody

NOTES

EPA: U.S. Environmental Protection Agency
USGS: U.S. Geological Survey

Date: October 24, 2025
Data Sources: BLM, ESRI, ODOT, USGS, Imagery (2022)

FIGURE 1

Location and Areal Extent of the Spokane Valley-Rathdrum Prairie Aquifer

Groundwater Flow Model Development:
Spokane Aquifer Joint Board
(Spokane County, Washington)

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GSI Water Solutions, Inc.

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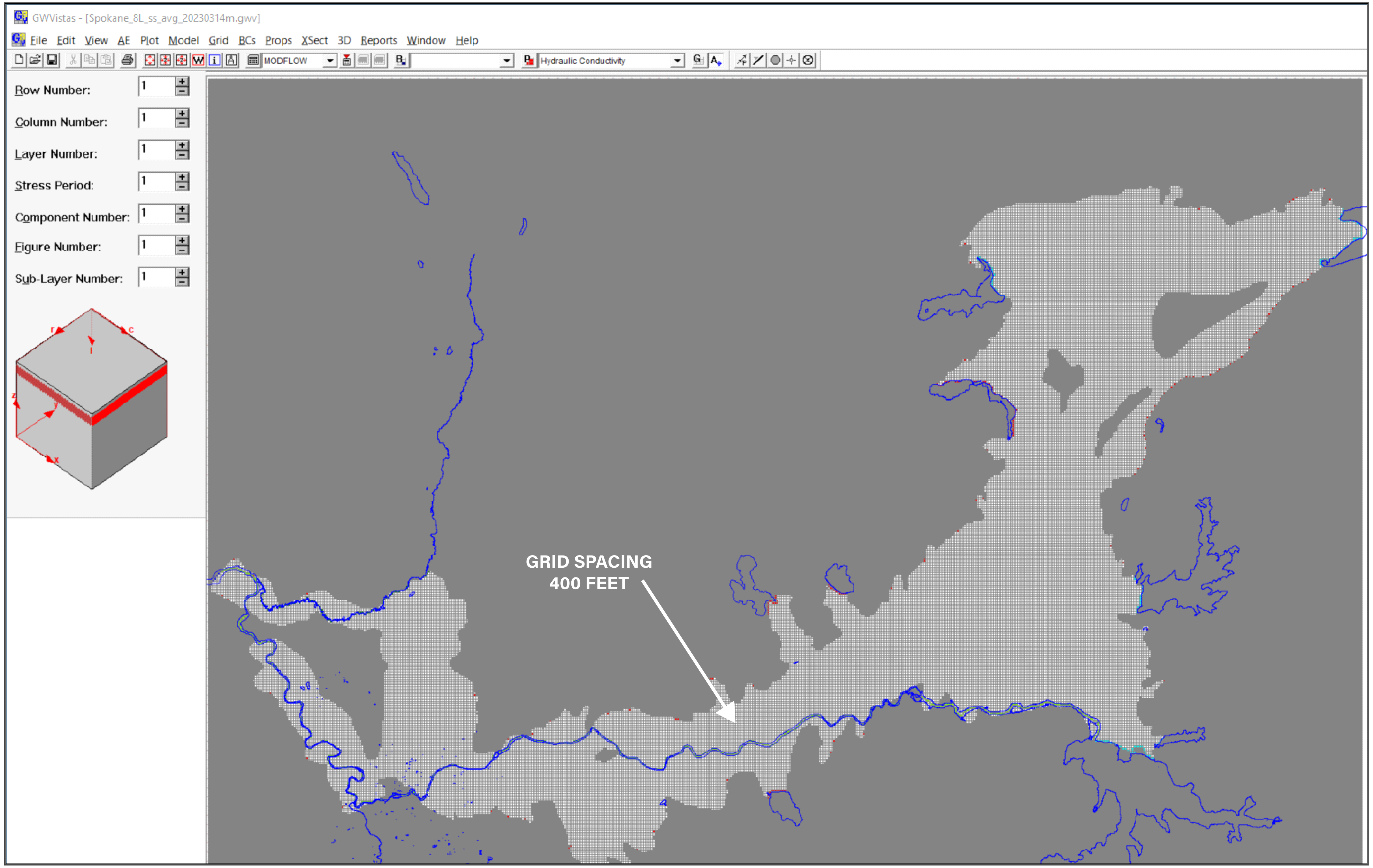

FIGURE 2

Parent Model Grid for Entire SVRP Aquifer

Groundwater Flow Model Development:
Spokane Aquifer Joint Board
(Spokane County, Washington)

GSI Water Solutions, Inc.

NOTE
SVRP: Spokane Valley-Rathdrum Prairie

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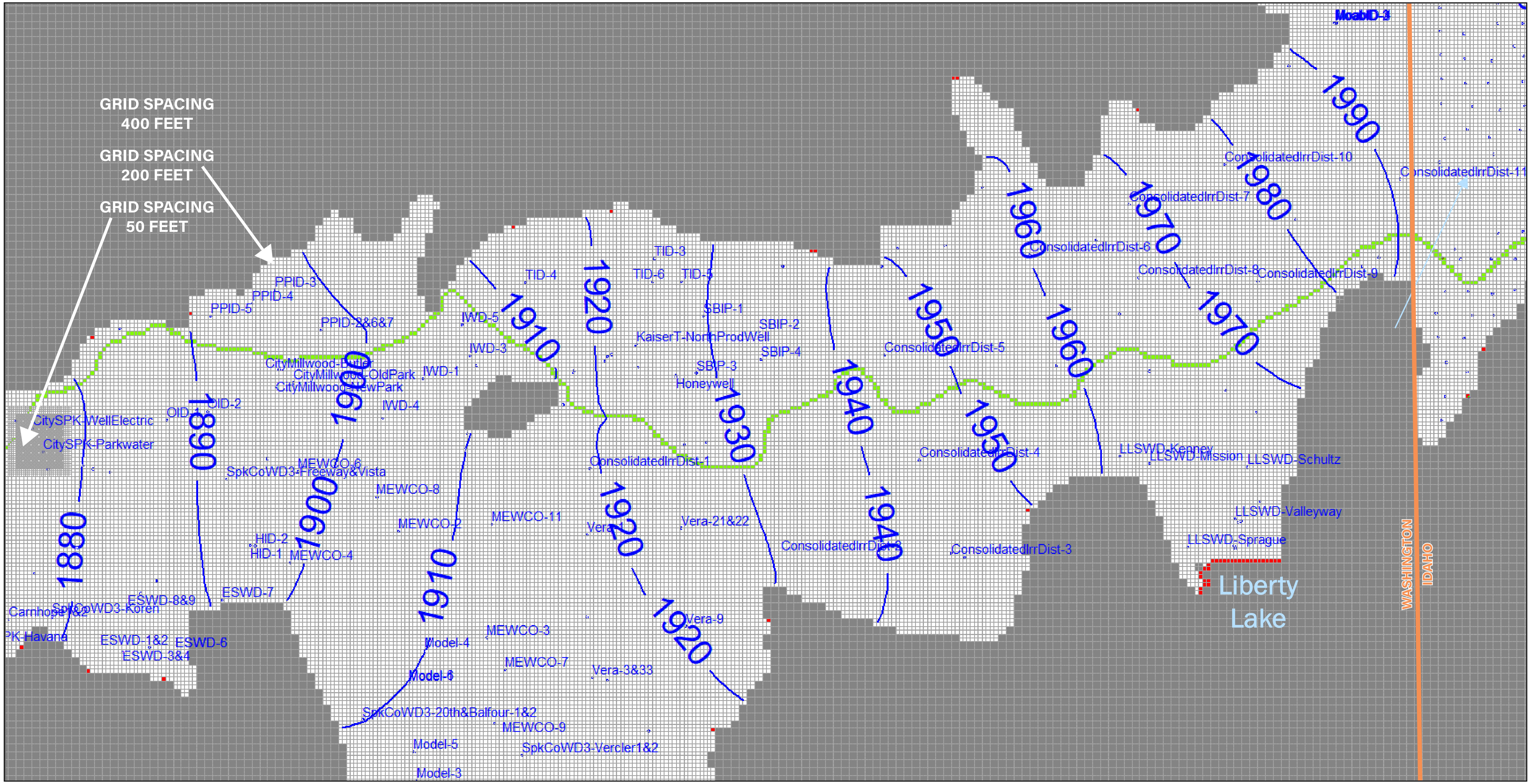

FIGURE 3

View of Irregular Grid Imbedded Inside the Parent Grid (Spokane Valley)

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Spokane Aquifer Joint Board
(Spokane County, Washington)

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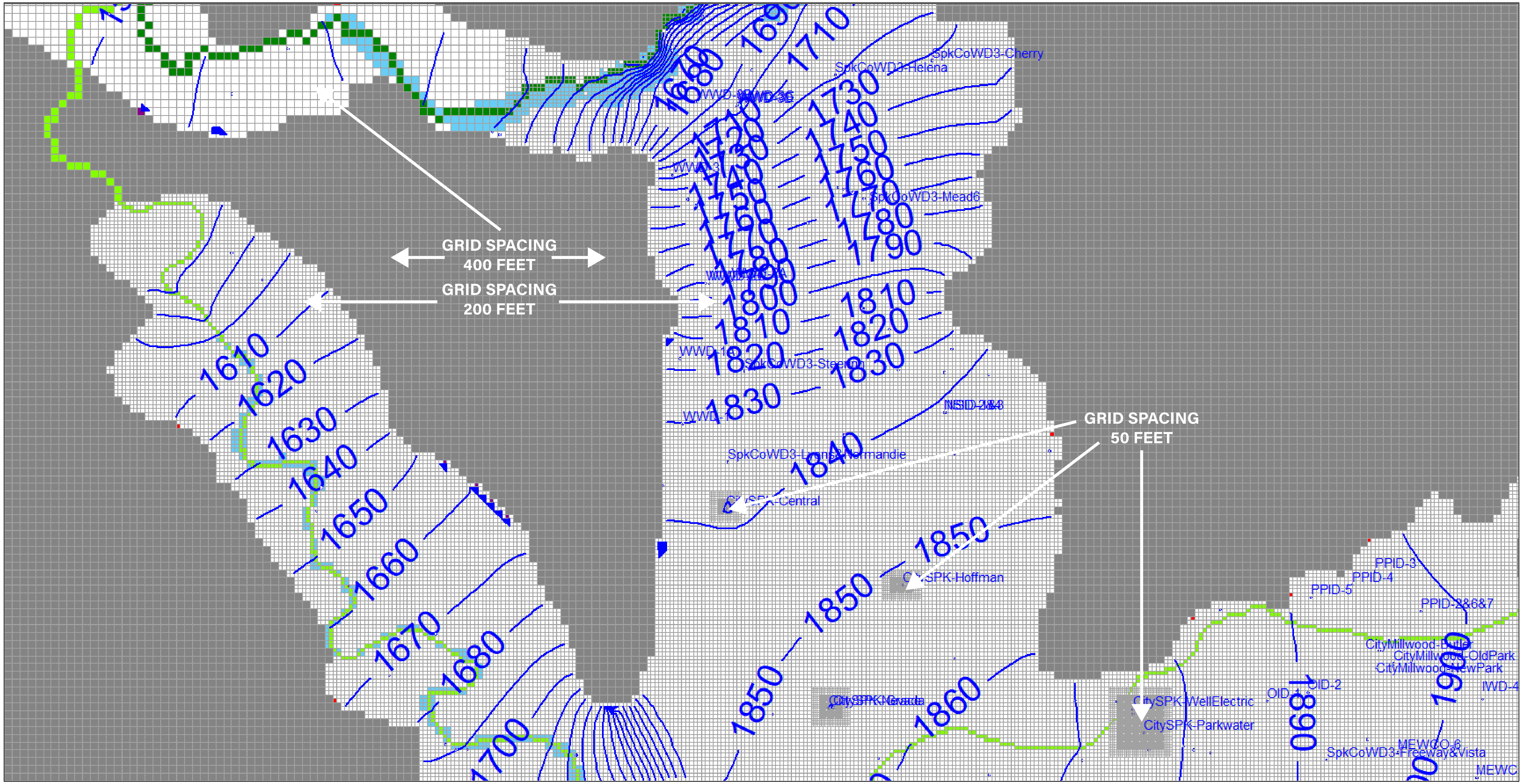

LEGEND

Model-Simulated Average Groundwater Elevations (feet NAVD 88) in August 10-foot Contour Interval

NOTE

NAVD 88: North American Vertical Datum of 1988

FIGURE 4

View of Irregular Grid Imbedded Inside the Parent Grid (City of Spokane and Hillyard Trough)

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Spokane Aquifer Joint Board
(Spokane County, Washington)

GSI Water Solutions, Inc.

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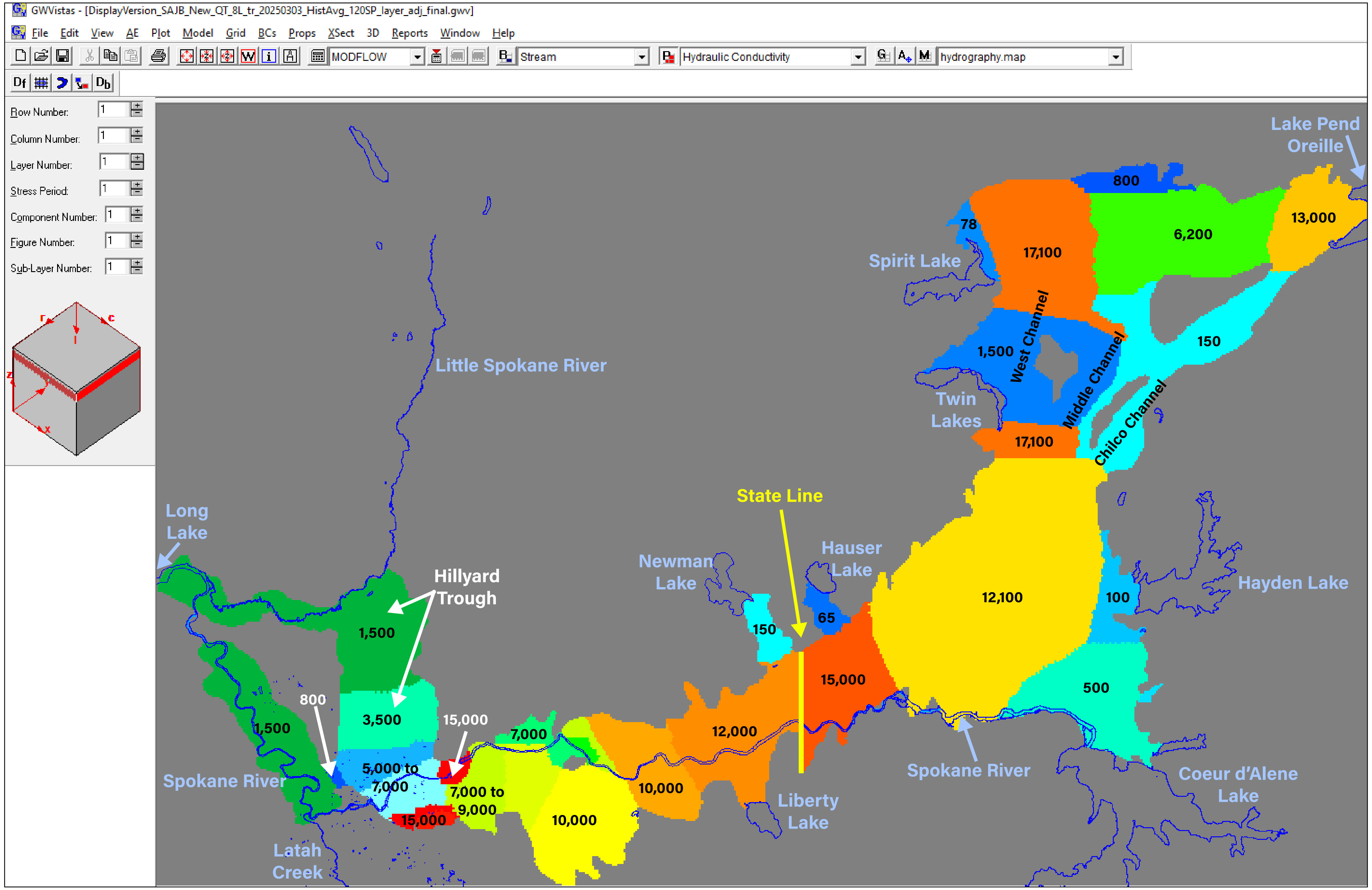

FIGURE 5

Spatial Distribution of Horizontal Hydraulic Conductivity (feet/day) in Model Layer 1

Groundwater Flow Model Development:
Spokane Aquifer Joint Board
(Spokane County, Washington)

GSI Water Solutions, Inc.

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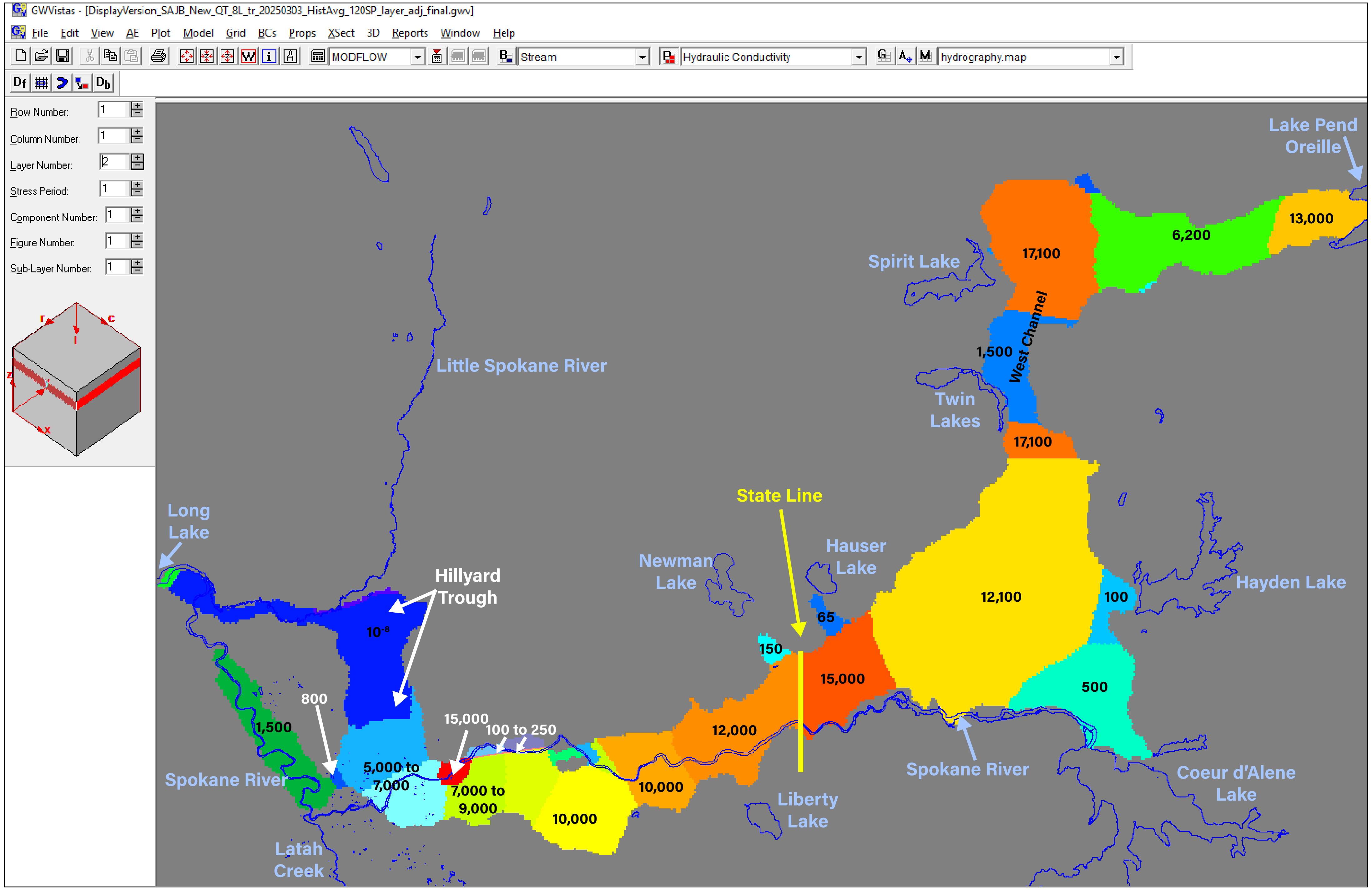

FIGURE 6

Spatial Distribution of Horizontal Hydraulic Conductivity (feet/day) in Model Layer 2

Groundwater Flow Model Development:
Spokane Aquifer Joint Board
(Spokane County, Washington)

GSI Water Solutions, Inc.

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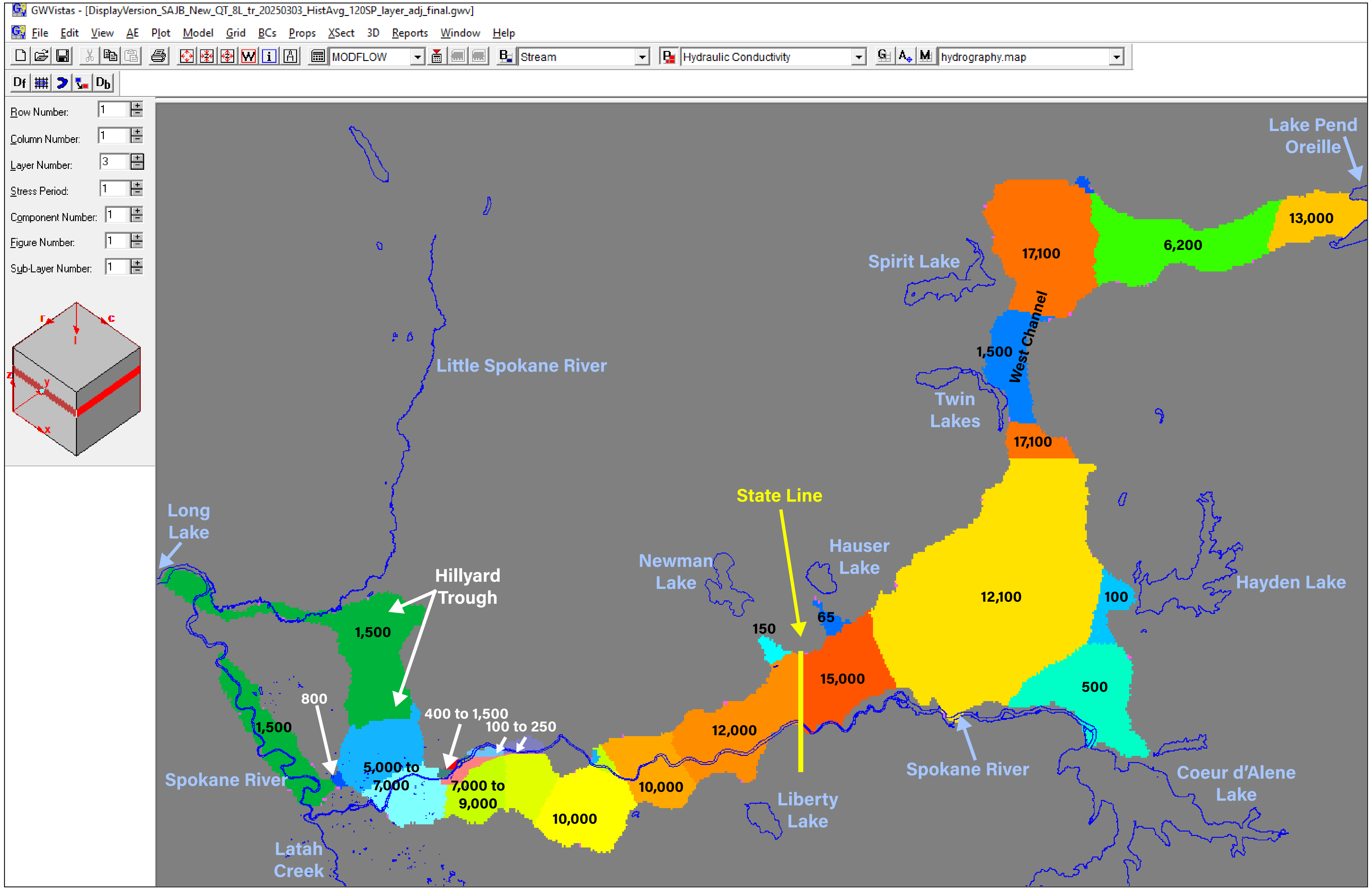

FIGURE 7

Spatial Distribution of Horizontal Hydraulic Conductivity (feet/day) in Model Layers 3 and 4

Groundwater Flow Model Development:
Spokane Aquifer Joint Board
(Spokane County, Washington)

GSI Water Solutions, Inc.

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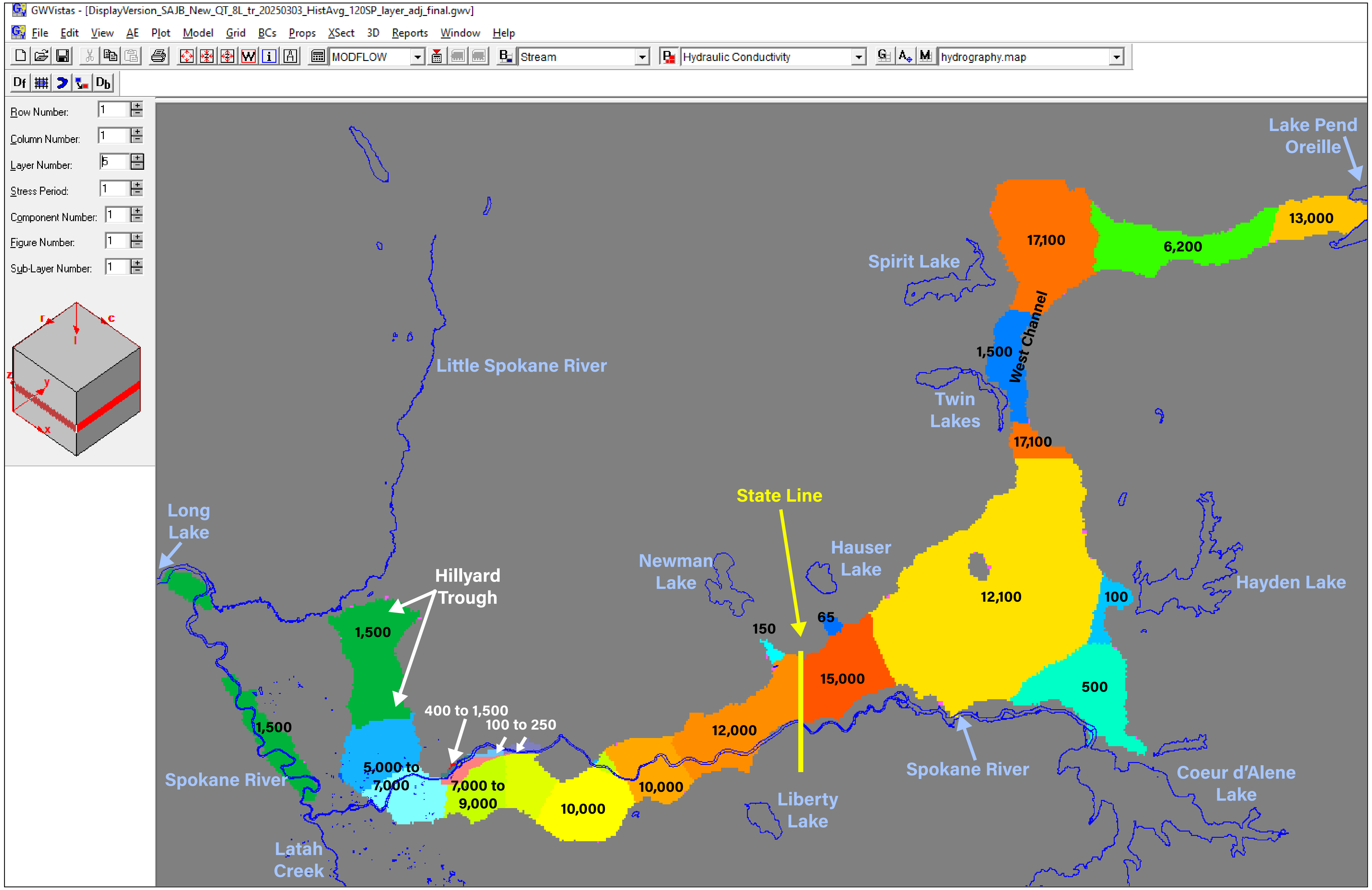


FIGURE 8

Spatial Distribution of Horizontal Hydraulic Conductivity (feet/day) in Model Layer 5

Groundwater Flow Model Development:
Spokane Aquifer Joint Board
(Spokane County, Washington)

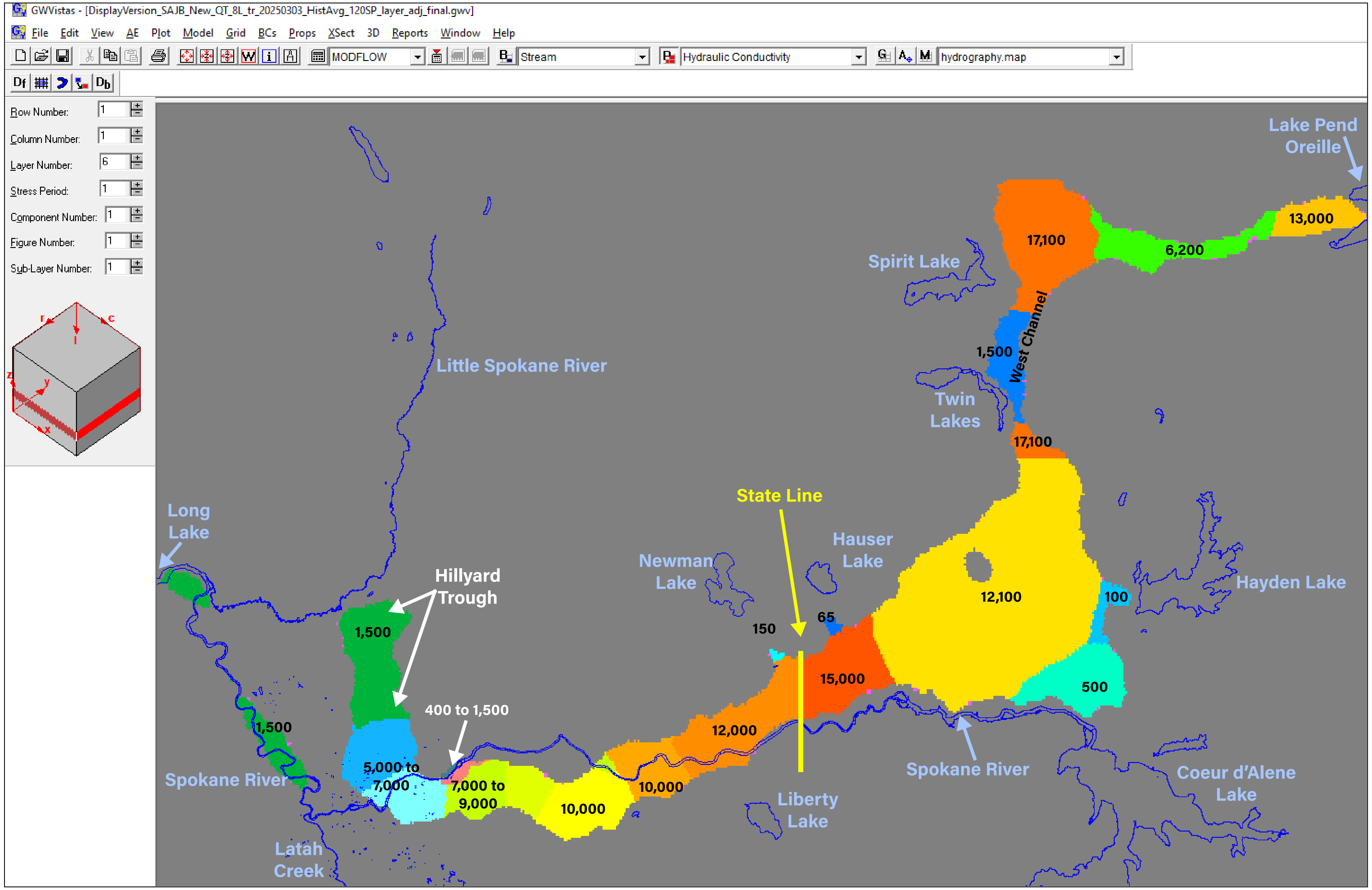


FIGURE 9

Spatial Distribution of Horizontal Hydraulic Conductivity (feet/day) in Model Layer 6

Groundwater Flow Model Development:
Spokane Aquifer Joint Board
(Spokane County, Washington)

GSI Water Solutions, Inc.

\\VMS\GIS_Files\0516_Spokane_Aquifer_Joint_Board\Source_Figures\004_WHP\GW_Flow_Model

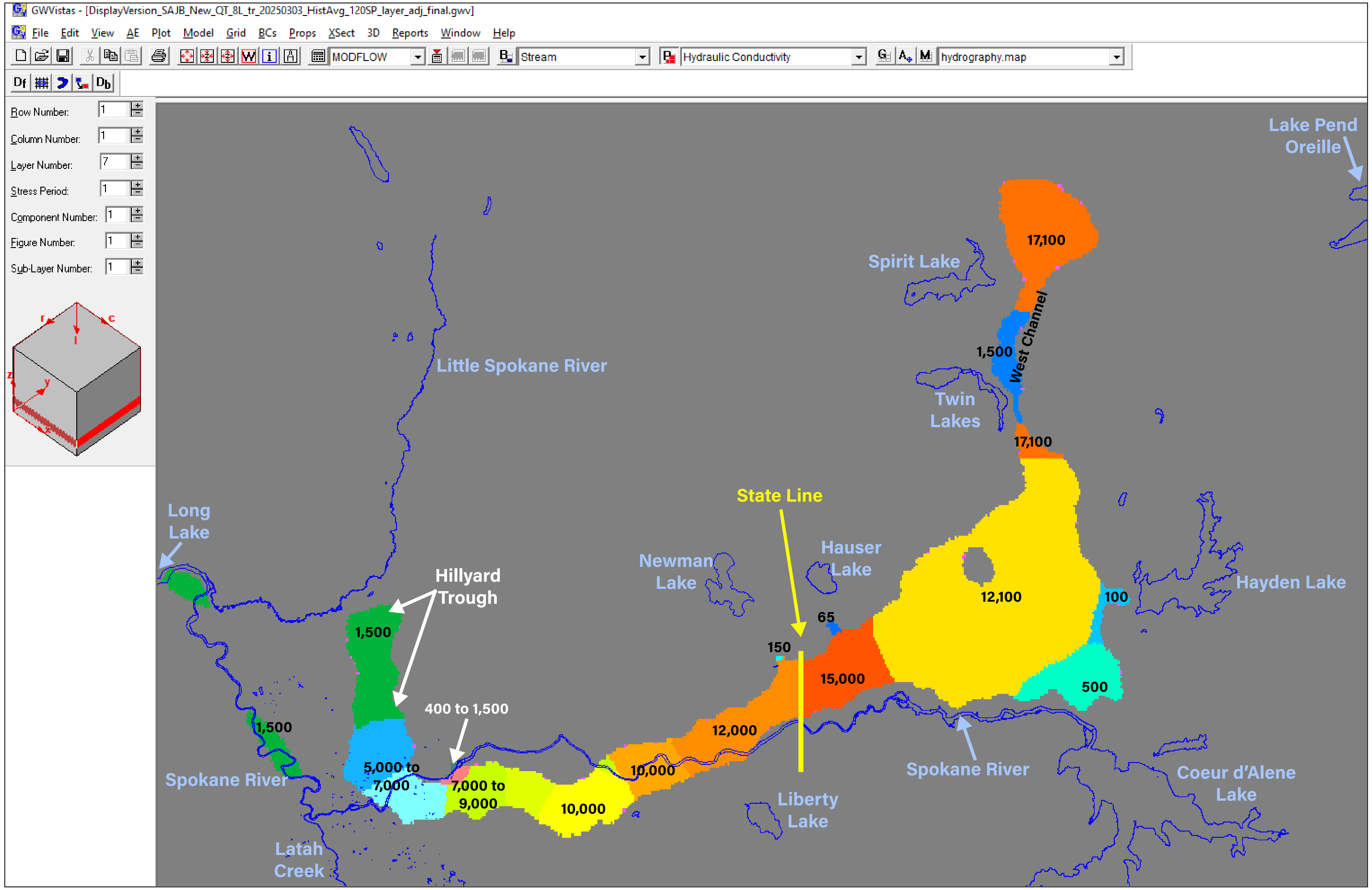


FIGURE 10

Spatial Distribution of Horizontal Hydraulic Conductivity (feet/day) in Model Layer 7

Groundwater Flow Model Development:
Spokane Aquifer Joint Board
(Spokane County, Washington)

GSI Water Solutions, Inc.

\\VMS\GIS_Files\0516_Spokane_Aquifer_Joint_Board\Source_Figures\004_WHP\GW_Flow_Model

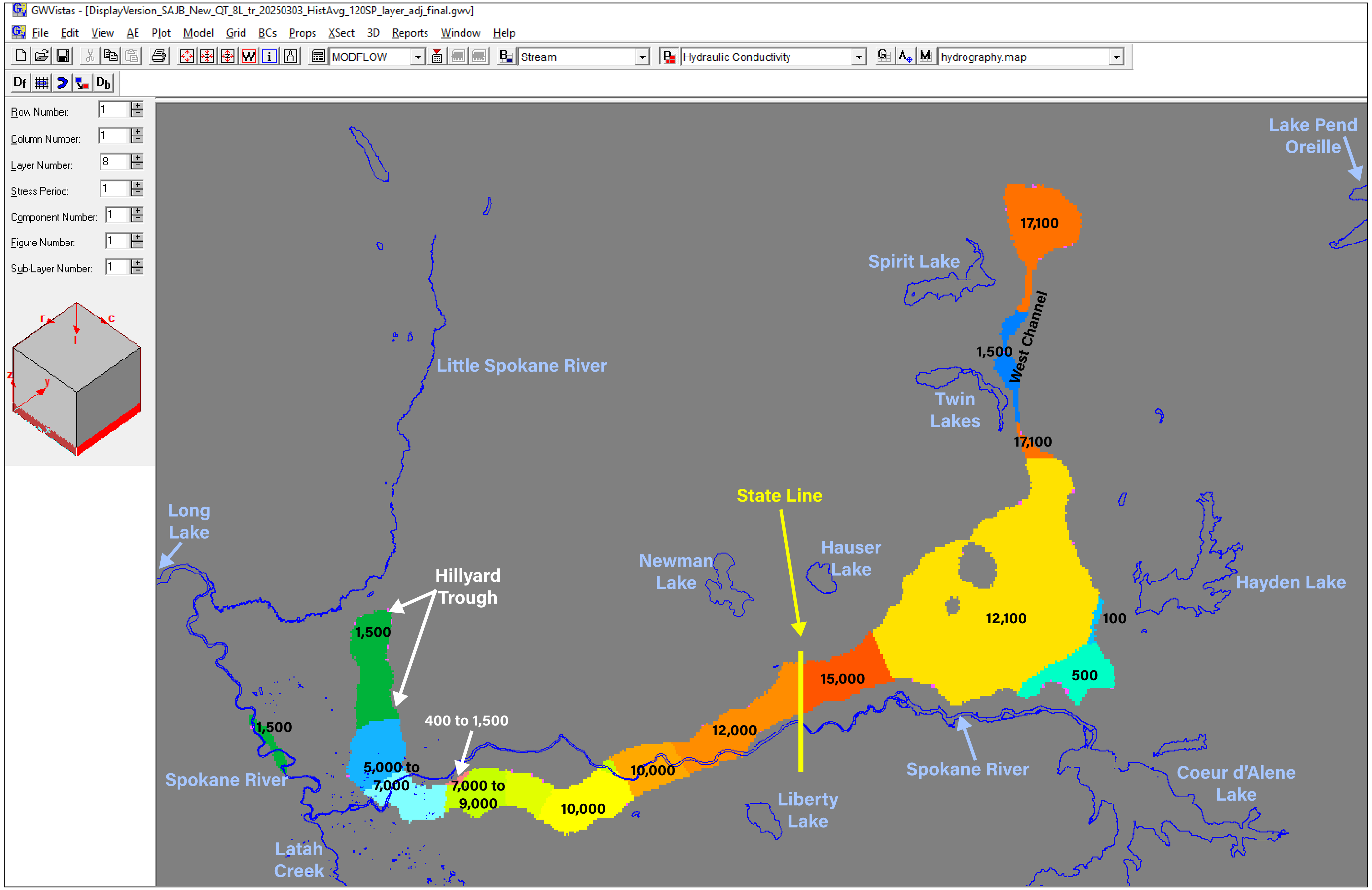


FIGURE 11

Spatial Distribution of Horizontal Hydraulic Conductivity (feet/day) in Model Layer 8

Groundwater Flow Model Development:
Spokane Aquifer Joint Board
(Spokane County, Washington)

GSI Water Solutions, Inc.

\\VMS\GIS_Files\0516_Spokane_Aquifer_Joint_Board\Source_Figures\004_WHP\GW_Flow_Model

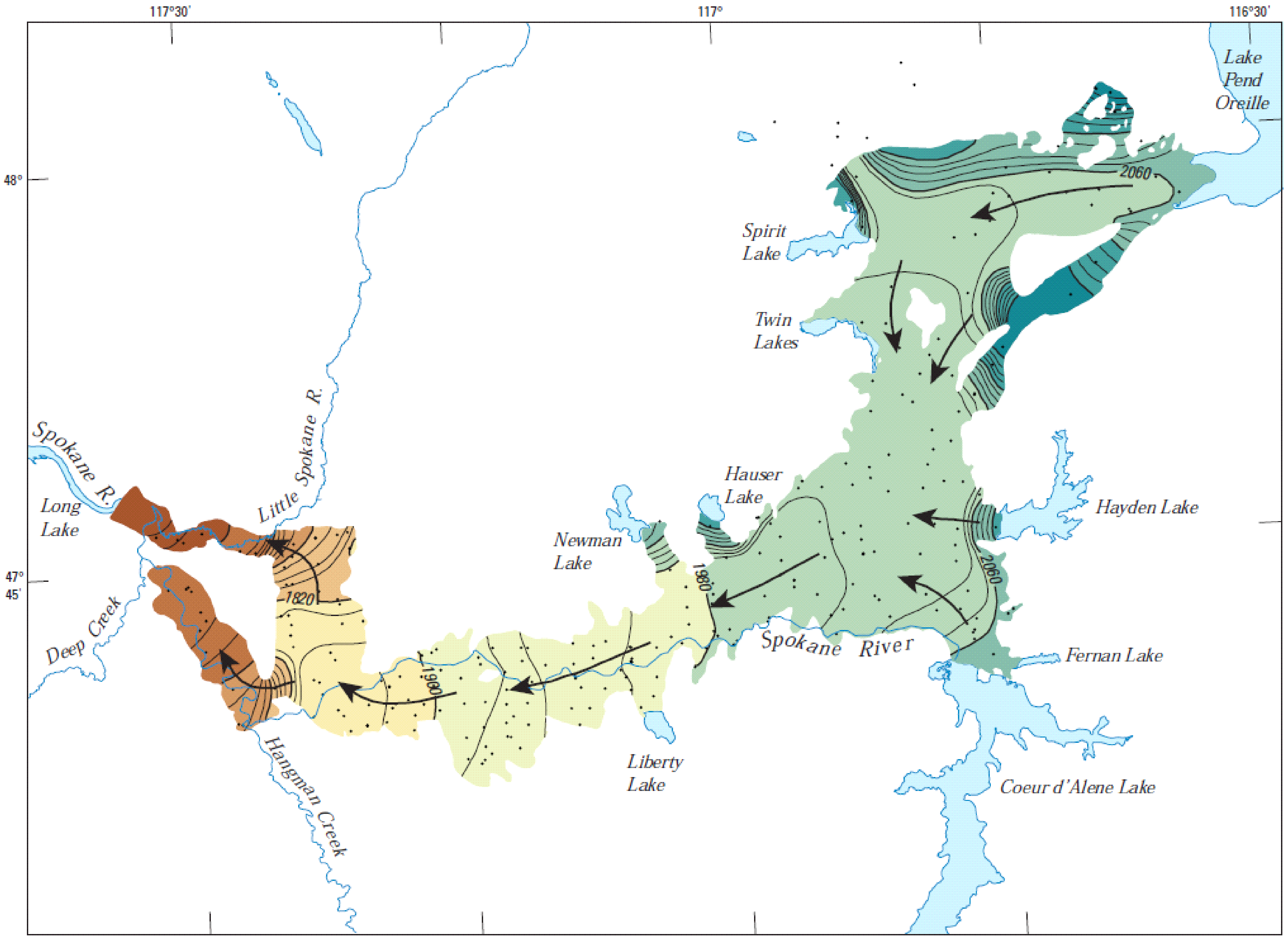


FIGURE 12

Contours of Seasonal-Low Groundwater Elevations Measured in September 2004

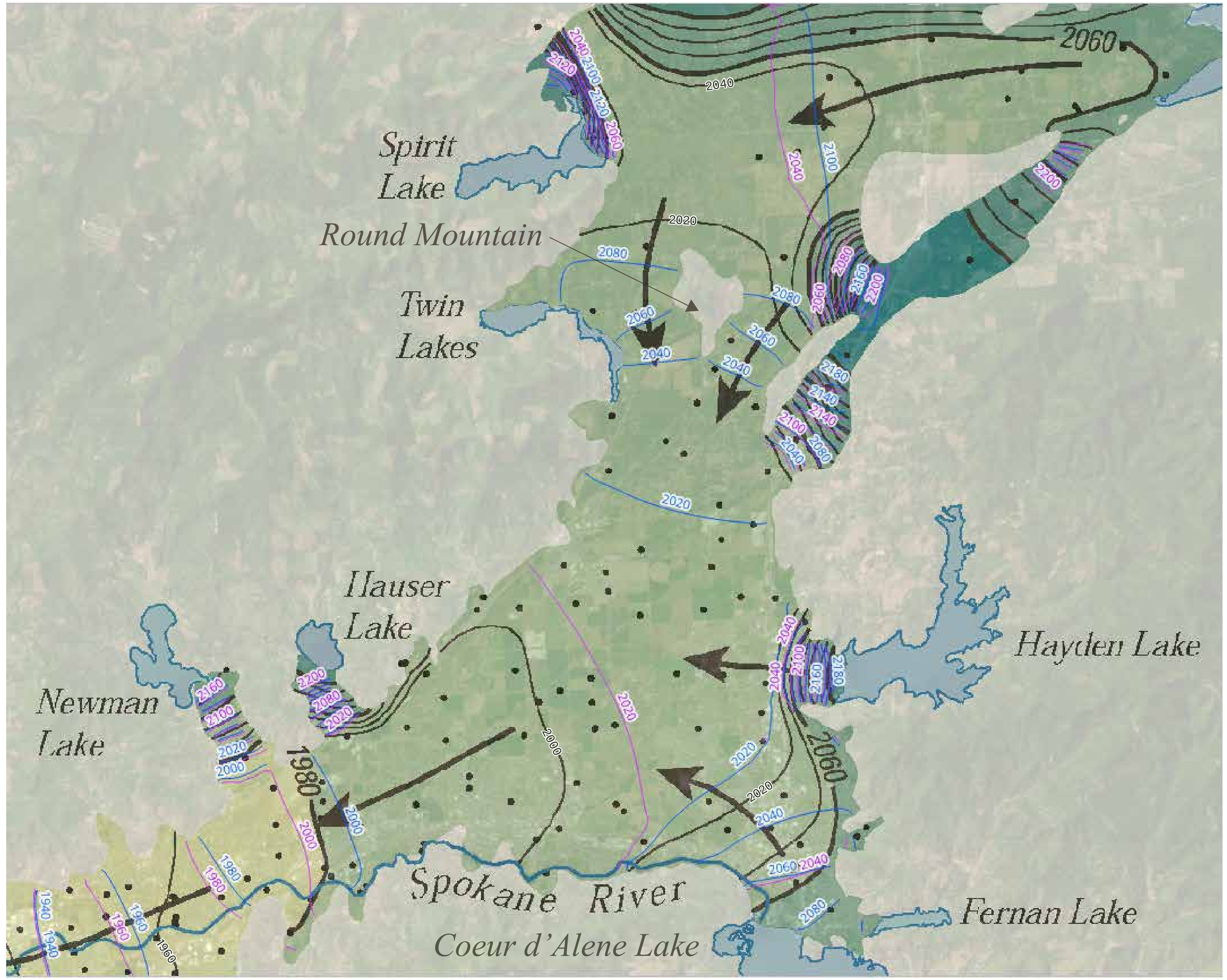
Groundwater Flow Model Development:
Spokane Aquifer Joint Board
(Spokane County, Washington)

NOTE
Colors in the map of measured groundwater elevations represent the spatial distribution of groundwater elevations (with the highest values in green and the lowest values in brown).

Data Sources:
Kahle, S.C., and Bartolino, J.R., 2007.
Hydrogeologic Framework and Ground-Water Budget of the Spokane Valley-Rathdrum Prairie Aquifer, Spokane County, Washington, and Bonner and Kootenai Counties, Idaho.
U.S. Geological Survey Scientific Investigations Report 2007-5041, 48 p., 2 pls.

GSI Water Solutions, Inc.

\\VMS\GIS_Files\0516_Spokane_Aquifer_Joint_Board\Source_Figures\004_WHP\GW_Flow_Model



LEGEND

- Measured Groundwater Elevation (September 2004)
- Average Summer-Low Groundwater Elevation (Initial SAJB Model)
- Average Summer-Low Groundwater Elevation (Final SAJB Model)

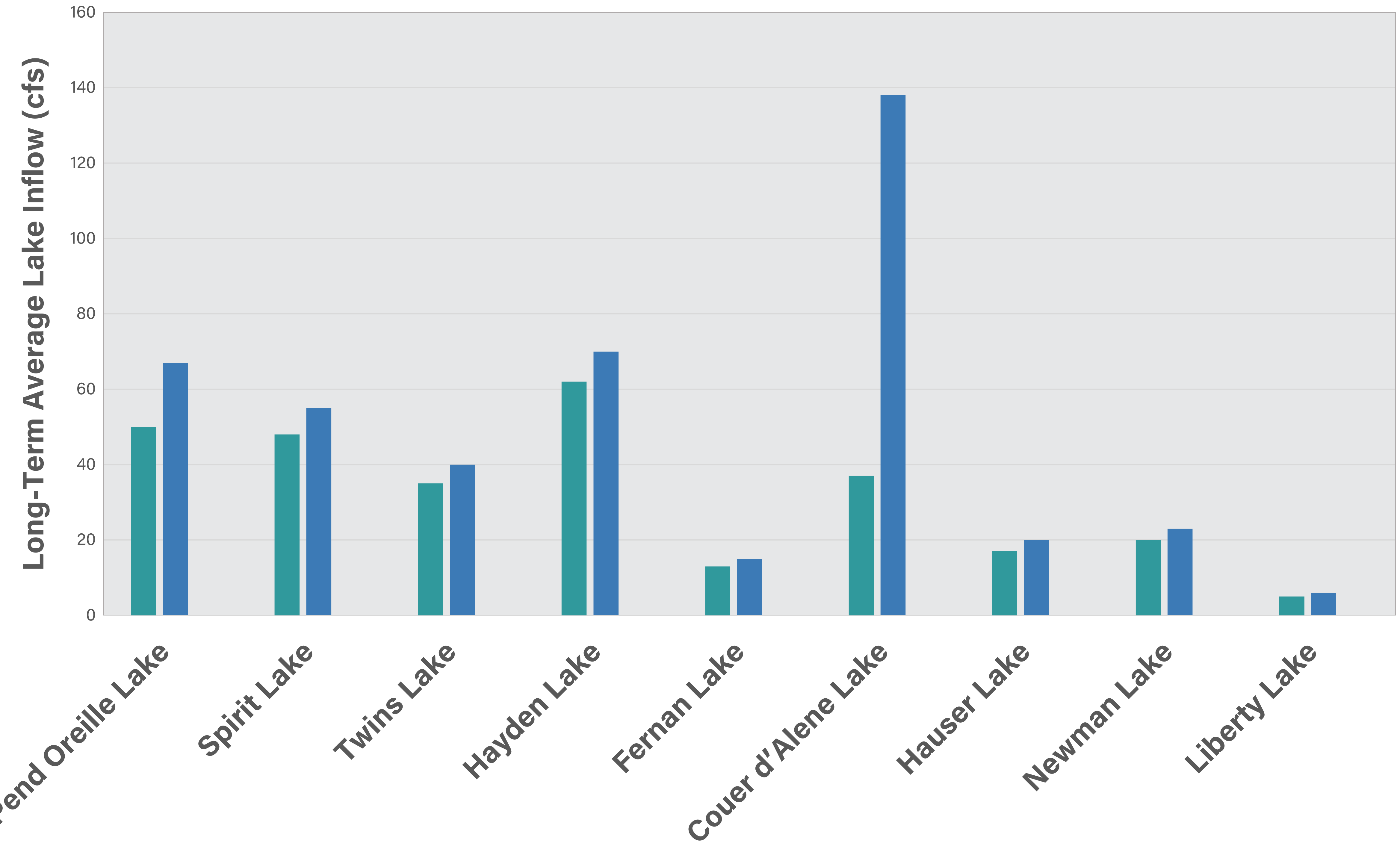
FIGURE 13

Comparison of Measured and Modeled Summer-Low Groundwater Elevations

Groundwater Flow Model Development:
Spokane Aquifer Joint Board
(Spokane County, Washington)

GSI Water Solutions, Inc.

\\VMS\GIS_Files\0516_Spokane_Aquifer_Joint_Board\Source_Figures\004_WHP\GW_Flow_Model



LEGEND

USGS Data Analysis (Total = 287 cfs)

USGS Flow Model (Total = 434 cfs)

NOTES

SVRP: Spokane Valley–Rathdrum Prairie

USGS: United States Geological Survey

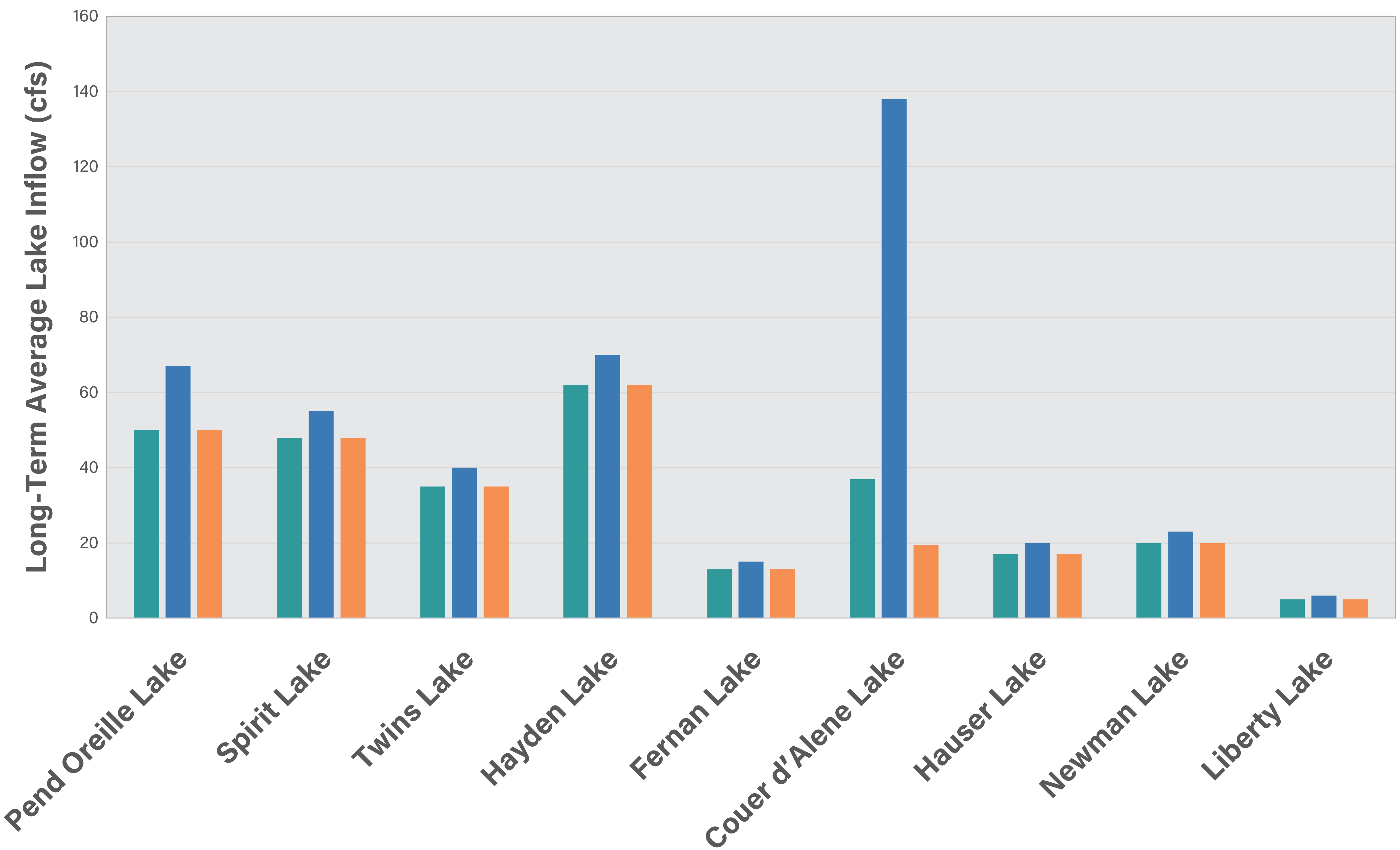
\\VMS\GIS_Files\0516_Spokane_Aquifer_Joint_Board\Source_Figures\004_WHP\GW_Flow_Model

FIGURE 14

USGS 2007 Interpretations of Long-Term Average Rates of Lake Inflows to the SVRP Aquifer System

Groundwater Flow Model Development:
Spokane Aquifer Joint Board
(Spokane County, Washington)

GSI Water Solutions, Inc.



LEGEND

- USGS Data Analysis (Total = 287 cfs)
- USGS Flow Model (Total = 434 cfs)
- SAJB Flow Model (Total = 270 cfs)

NOTES

cfs: cubic feet per second
SAJB: Spokane Aquifer Joint Board
SVRP: Spokane Valley–Rathdrum Prairie
USGS: United States Geological Survey

FIGURE 15

Comparison of USGS 2007 and SAJB 2025 Interpretations of Long-Term Average Rates of Lake Inflows to the SVRP Aquifer System

Groundwater Flow Model Development:
Spokane Aquifer Joint Board
(Spokane County, Washington)

GSI Water Solutions, Inc.

\\VMS\GIS_Files\0516_Spokane_Aquifer_Joint_Board\Source_Figures\004_WHP\GW_Flow_Model

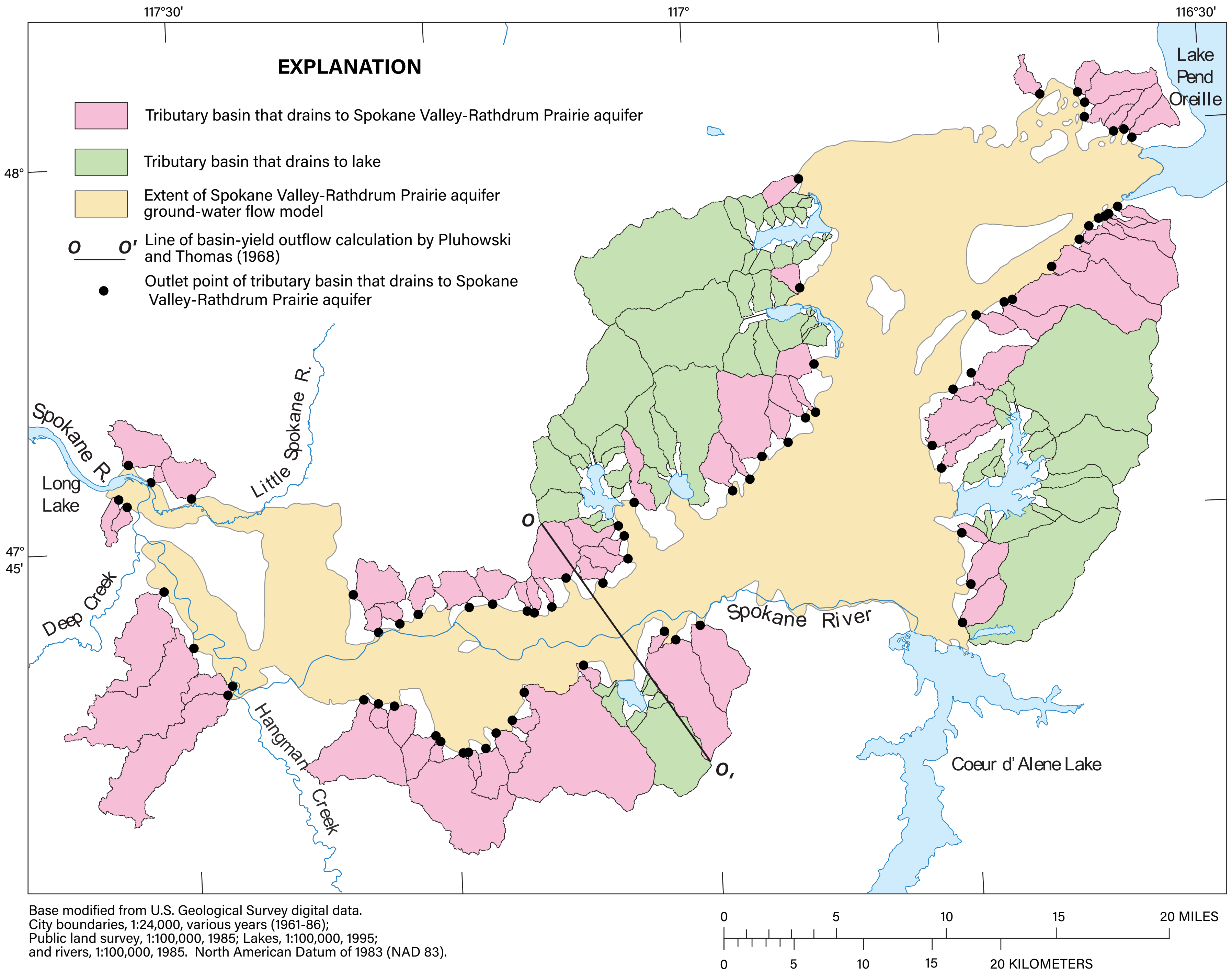


Figure 10. Tributary basins that drain to the Spokane Valley-Rathdrum Prairie aquifer and to seven lakes that border the aquifer, Washington and Idaho.

FIGURE 16

Tributary Basins Draining to the SVRP Aquifer

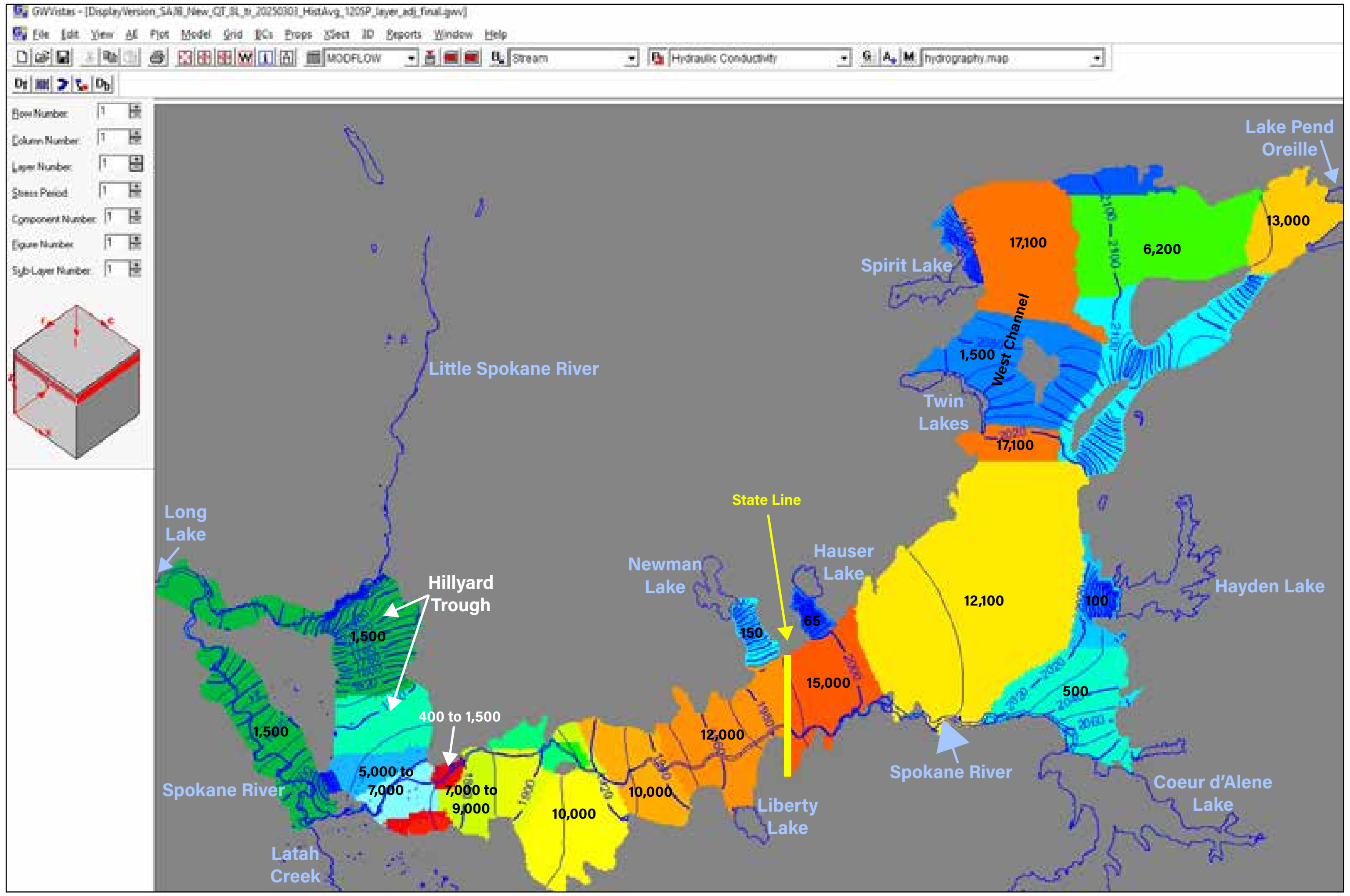
Groundwater Flow Model Development:
Spokane Aquifer Joint Board
(Spokane County, Washington)

NOTE

SVRP: Spokane Valley-Rathdrum Prairie

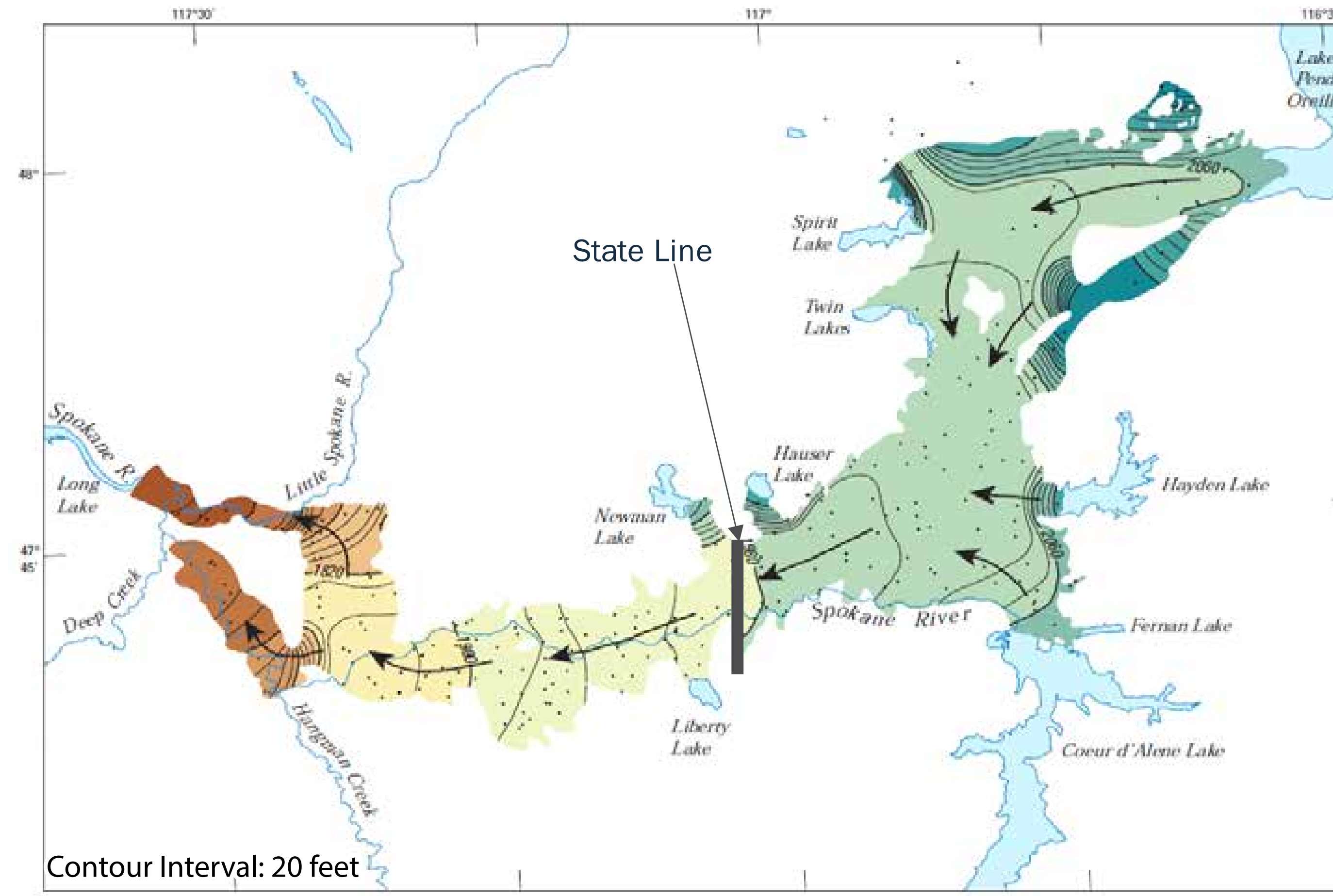
Data Sources:
Hsieh, P.A., M.E. Barber, B.A. Contor, Md. A. Hossain, G.S. Johnson, J.L. Jones, and A.H. Wylie. 2007. Ground-Water Flow Model for the Spokane Valley-Rathdrum Prairie Aquifer, Spokane County, Washington, and Bonner and Kootenai Counties, Idaho. U.S. Geological Survey Scientific Investigations Report 2007-5044, 78 p.

Modeled Groundwater Elevations (Average Conditions in August)



NOTE
Colors in the map of modeled groundwater elevations represent zones showing the differences in the spatial distribution of the aquifer's hydraulic conductivity.

Measured Groundwater Elevations (September 2004)



NOTE
Colors in the map of measured groundwater elevations represent the spatial distribution of groundwater elevations (with the highest values in green and the lowest values in brown).

SOURCE
Kahle, S.C., and Bartolino, J.R., 2007.
Hydrogeologic Framework and Ground-Water Budget of the Spokane Valley-Rathdrum Prairie Aquifer, Spokane County, Washington, and Bonner and Kootenai Counties, Idaho.
U.S. Geological Survey Scientific Investigations Report 2007-5041, 48 p., 2 pls.

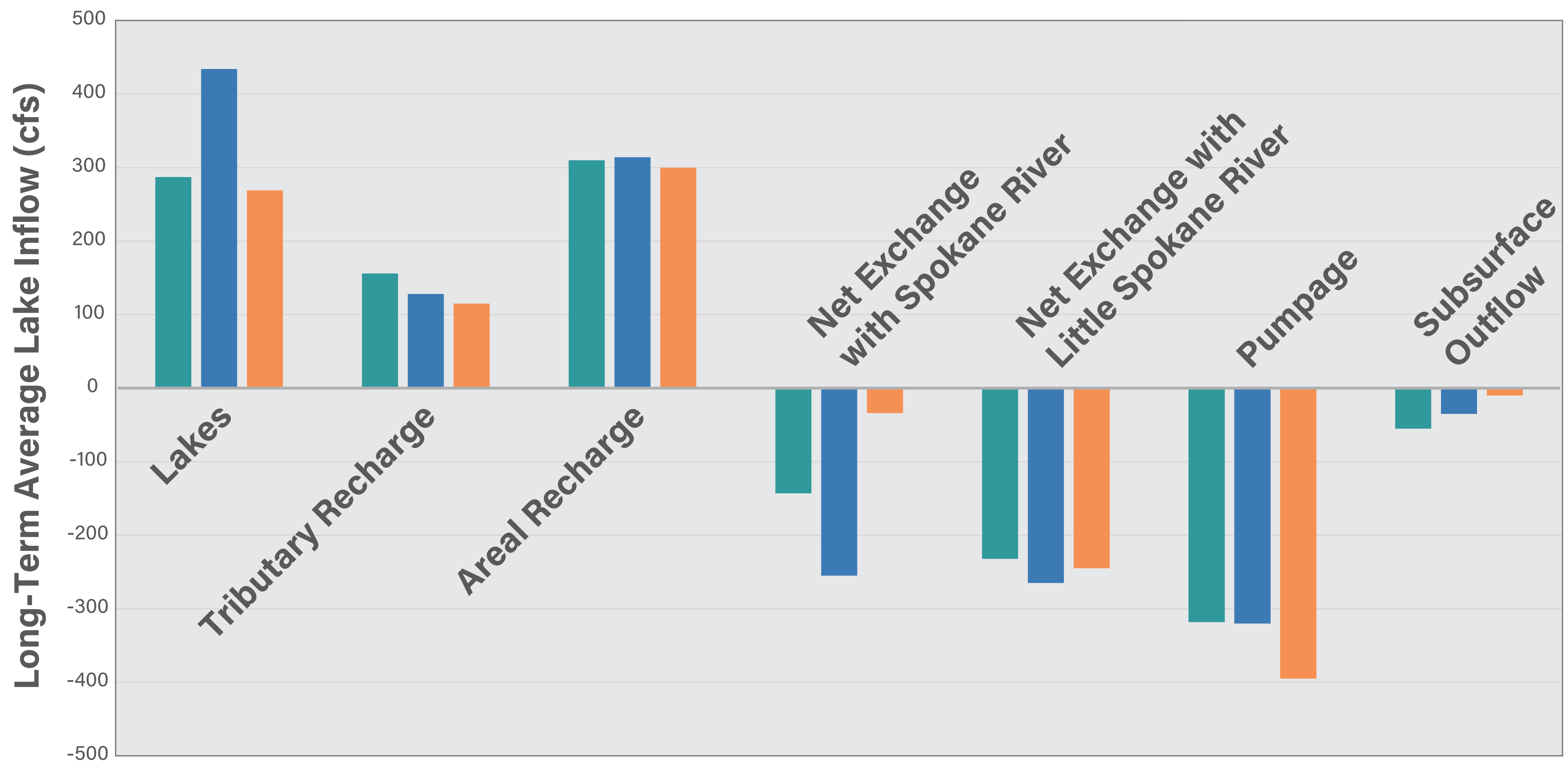
FIGURE 17

Modeled and Measured Groundwater Elevation Contours for Seasonal-Low Conditions

Groundwater Flow Model Development:
Spokane Aquifer Joint Board
(Spokane County, Washington)

GSI Water Solutions, Inc.

\\VMS\GIS_Files\0516_Spokane_Aquifer_Joint_Board\Source_Figures\004_WHP\GW_Flow_Model



LEGEND

- USGS Data Analysis (August 2005)
- USGS Model (Annual Average for 1990-2005)
- SAJB Model (Annual Average for Current/Recent Conditions)

NOTES

csf: cubic feet per second
SAJB: Spokane Aquifer Joint Board
SVRP: Spokane Valley-Rathdrum Prairie
USGS: United States Geological Survey

FIGURE 18

Long-Term Average Inflows and Outflows for the SVRP Aquifer

Groundwater Flow Model Development:
Spokane Aquifer Joint Board
(Spokane County, Washington)

GSI Water Solutions, Inc.