Appendix A
Hydrogeologic Data

1.0 Purpose

The purpose of this appendix is to present the hydrogeologic data collected and summarized as part of the development of the South Platte Decision Support System (SPDSS) Alluvial Groundwater Model. Three separate tasks were conducted to identify, collect and summarize available hydrogeologic data within the SPDSS Alluvial Groundwater Study Area. Each of these tasks had a separate objective and were documented in the following technical memoranda.

- Task 42.3 South Platte Alluvium Region Aquifer Configuration Technical Memorandum
- Task 43.3 South Platte Alluvium Region Aquifer Property Technical Memorandum
- Task 44.3 South Platte Alluvium Region Water Level Technical Memorandum

The hydrogeologic data collected through these efforts were used to develop inputs and for calibration of the SPDSS Alluvial Groundwater Model. The information and data presented in these technical memoranda were used to:

1. *Define the extent of the alluvial aquifer within the SPDSS Study Area*
2. *Determine initial hydraulic conductivity, specific capacity in the alluvial aquifer*
3. *Compile the available water level data to be used for model calibration*

Copies of these technical memoranda are included in this Appendix A.

Task 42.3 South Platte Alluvium Region Aquifer Configuration Technical Memorandum

SPDSS Phase 3 Task 42.3 South Platte Alluvium Region Aquifer Configuration Technical Memorandum FINAL

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From: Camp Dresser and McKee Inc.
Donavon Paschall, Gordon McCurry, and Matt Bliss
Subject: SPDSS Groundwater Component Phase 3 Final Task 42.3
South Platte Alluvium Region Aquifer Configuration Technical Memorandum
Date: November 30, 2006

Introduction

The groundwater component of the South Platte Decision Support System (SPDSS) focuses on compiling and evaluating available relevant data to support the Decision Support System (DSS) for the South Platte River watershed and to add the data to HydroBase, the State of Colorado's hydrological database. The SPDSS groundwater study area is presented in Figure 1. For the purposes of the SPDSS, the groundwater study area is divided into two hydrologic regions. The Denver Basin Region includes the bedrock aquifers of the Denver Basin. The South Platte Alluvium Region consists of the unconsolidated deposits of the South Platte River mainstem, extending downstream from just below Chatfield Reservoir to the Nebraska state line at Julesburg, and consists of the unconsolidated deposits of the tributaries to the South Platte River. The South Platte Alluvium Region also includes the alluvial systems overlying the Denver Basin bedrock aquifers in Water Division 2.

The unconsolidated alluvial aquifers in the SPDSS study area consist of the South Platte River and its tributaries, as well as tributaries to the Arkansas River where they overlie the Denver Basin Region. From a hydrogeologic perspective, key tributaries overlying the SPDSS study area include East Plum Creek, Cherry Creek, Sand Creek, Clear Creek, Big Dry, St. Vrain Creek, Big Thompson River, Beebe Draw, Cache la Poudre River, Lonetree Creek, Crow Creek, Box Elder Creek, Lost Creek, Kiowa Creek, Bijou Creek, Badger Creek, Beaver Creek, Upper Black Squirrel Creek, and Upper Big Sandy Creek, the last two of which are located in Water Division 2 and drain into the Arkansas River. The eastern and southern portions of the Denver Basin have been divided into several Designated Basins for the purposes of water rights administration. The Designated Basins within the Denver Basin Region include the Lost Creek, Kiowa-Bijou, Upper Black Squirrel, and Upper Big Sandy Creek Designated Basins.

This task was undertaken for the Colorado Water Conservation Board (CWCB) and Division of Water Resources (DWR), under Tasks 31 and 42 of Phases 1, 2, and 3 of the SPDSS by Camp Dresser & McKee (CDM). Task 31 was undertaken in Phase 1 and included the collection of existing published aquifer configuration data. Task 42 was undertaken in Phases 1, 2, and 3 and included the collection of published data and the analysis and mapping of these configuration data. The objectives of these tasks are as follows:

1. *Compile existing aquifer configuration information and create a HydroBase-compatible database with data from the Denver Basin and South Platte Alluvium regions to enhance the understanding of the system.*
2. *Help identify additional data needs in these regions.*
3. *Support the design of the groundwater field program.*
4. *Enhance HydroBase with aquifer configuration data collected during the Phase 1 field activities.*
5. *Collect data to support future development and calibration of a groundwater model.*

This Technical Memorandum (TM) was undertaken under Task 42.3 of Phases 1, 2, and 3 of the SPDSS, and summarizes the compilation, analysis, and mapping of existing published alluvial aquifer configuration data for the South Platte Alluvium Region.

Approach

The following table summarizes the sections contained in this TM.

Section	Description
1.0	Aquifer Configuration Data Collection and Analysis
1.1	Sources of Data
1.2	Data Analysis and Processing
2.0	Aquifer Configuration Database
2.1	Database Structure
2.2	Database Quality Control
3.0	Results
3.1	Aquifer Bottom Elevations
3.2	Groundwater Level Elevations
3.3	Ground Surface Elevations
3.4	Saturated Thickness
3.5	Cross sections
4.0	Summary and Conclusions
5.0	Recommendations
6.0	References

1.0 Aquifer Configuration Data Collection and Analysis

Aquifer configuration data are used to describe the thickness and extent of the aquifer and includes the elevation of the aquifer bottom and the elevation of the top of the aquifer. For this TM, land surface will define the upper limit of the aquifer and a water table surface will define the saturated thickness of the aquifer. The difference between the bottom elevation and water table elevation will be used to calculate the saturated thickness of the alluvium. The following section describes the approach used to collect, analyze, and map aquifer configuration data for the South Platte Alluvium Region.

1.1 Sources of Data

Two types of available published data were collected to summarize the configuration of the South Platte Alluvial Aquifer. These include (1) published interpretive contour maps, and (2) individual values (referred to in the TM as "picks") representing the elevation of the bottom of the alluvium. Additionally a U.S. Geological Survey (USGS) 30-meter National Elevation Dataset (NED) grid is used to represent the ground surface.

Published geologic contour data were collected from Bjorklund and Brown (1957), Duke et al. (1966), Erker et al. (1967), Hurr and Schneider (1977, 1972a -1972f), NHPQ (1967), Robson (1996), Robson et al. (2000a – 2000d), Smith et al. (1964), and Willard Owens Associates (1971). All of these reports contain elevation contours for the bottom of alluvium and the groundwater level of the alluvium. These reports present a detailed interpretive analysis of the bottom of the alluvium with contour intervals of 20 feet, except for Willard Owens Associates and Duke et al. in the southern end of their report, which presents contour intervals of 100 feet. The groundwater level contours represent measurements from multiple historical time periods and are reported in contour intervals of 10, 20, and 100 feet. Even though the original data used to develop the contour maps are not available for al reports, these reports provide a basis for understanding the configuration of the alluvium. Figure 2 identifies the extent of the contours used from each source.

Point values for the bottom of alluvium elevations were gathered and evaluated from several sources, which include SPDSS Task 35, Smith et al. (1964), Bjorklund and Brown (1957), Weist (1964), DWR well permit images, and HydroBase. Under Phases 1 and 2 of Task 35 of the SPDSS, SPDSS alluvial well drilling used geophysical logging, which has the capacity to identify bedrock although it is not as reliable as a physical basis such as discrete coring or review of drill log cuttings. During SPDSS field work, bedrock was identified when the direct push probe encountered refusal accompanied by an increase in electroconductivity on the geophysical log indicating a higher clay lithology had been encountered. If the refusal was caused by coarse sands and gravels locking the direct push probe and not by a hard shale bedrock layer, then this would be in inaccurate determination of bedrock. Fourteen well drilling sites identified the depth to bedrock as described above in Phase 2, and five identified bedrock in Phase 1 (see Figure 2). Details on these wells and their drilling logs are provided in the Task 35 Alluvial Well Construction and Testing TM. Details for one of the Phase 1 wells cannot be found in the Task 35 TM since this well was drilled by the USGS for the SPDSS; the USGS report is pending.

Additional point values were obtained from the Smith et al. (1964) report, which provided data for the alluvium of Beebe Draw, Box Elder Creek, and the mainstem of the South Platte River from the northern edge of Denver County to Greeley (see Figure 2). These picks were compiled by Smith et al. (1964) and were used to develop the bottom of alluvium contours presented in their report. The picks are presented on a figure from the report, with approximately 1,072 points labeled with the bottom of alluvium elevations. The paper map was scanned, georeferenced, and the picks were digitized. Each digitized pick was electronically assigned its elevation value and its horizontal coordinates.

Bottom of alluvium elevation point data were gathered from Bjorklund and Brown (1957; see Figure 2). Bjorklund and Brown provided stratigraphic data in tabular format for the alluvium and bedrock from drill logs for wells in the area east of Greeley extending into Nebraska. Bjorklund and Brown reported data for 648 logs, although not all logs identified the bottom of alluvium and not all logs characterized the alluvium within the SPDSS study area.

The drill logs within the SPDSS study area were reviewed, and if the log identified the bottom of alluvium and provided a ground surface elevation, the data were added to an electronic spreadsheet. Additionally, for some drill logs, only a depth to the bottom of alluvium was provided. In selected geographic areas, bottom of alluvium data from these drill logs were added to an electronic spreadsheet. The 30-meter USGS NED (digital land surface elevation) was used to estimate a ground surface elevation for these data, from which the depth to bottom of alluvium was subtracted to calculate the elevation of the bottom of alluvium. Location information for each drill log was reported in Bjorklund and Brown using the Public Land Survey System (PLSS), including township, range, and section (down to quarter-quarter section), and sometimes included the distances from section lines. This information was used to estimate horizontal x and y coordinates that were also added to the electronic spreadsheet. A final set of picks were obtained from Bjorklund and Brown (1957) by digitizing values posted on their contour maps. The digitized picks represent original data not gathered from drill logs in the report.

It is presumed Hurr and Schneider (1972) used the data from the Bjorklund and Brown (1957) report to develop their contours, because both studies were conducted by the USGS and cover much of the same study area. A total of 412 bottom of alluvium picks were derived from Bjorklund and Brown (1957).

The Colorado Groundwater Basic Data Report 16 (Weist, 1964) was reviewed for drill logs that identified depth to bedrock. One value was obtained from this source. The x and y coordinates were estimated from PLSS information provided by the report, and a ground surface elevation was estimated with the USGS 30-meter NED and used to compute a bottom of alluvium elevation.

Another source of alluvial aquifer configuration were obtained from driller's logs included with the well permit images maintained by the DWR. Drill logs were gathered for areas across the South Platte Alluvium Region (see Figure 2). The drill logs were reviewed to identify the depth to bedrock. The x and y coordinates were estimated from PLSS information provided on the drill log, and ground surface elevation was estimated with the USGS 30-meter NED. This information was used to compute a bottom of alluvium elevation. Two-hundred sixty-five bottom of alluvium picks were obtained from DWR well permit image driller's logs.

One additional bottom of alluvium pick was available from HydroBase. This pick is identified in HydroBase as TH-DWR and summarized under the DWR data source in Table 1.

The sources of data used to define the configuration of the alluvial aquifer are summarized in Table 1 and shown spatially on Figure 2. As noted in the preceding discussion and in Table 1, a majority of the existing data sources provide only contoured surfaces of the bottom of alluvium

and water table. In these cases the data used to develop contours is not provided in the individual reports.

Table 1: Summary of Data Sources and Type of Data Provided

Data Source	Number of Picks	Contours
Bjorklund and Brown (1957)	412	Yes
Duke et al. (1966)	0	Yes
Erker et al. (1967)	0	Yes
Hurr and Schneider (1977)	0	Yes
Hurr and Schneider (1972a -1972f)	0	Yes
NHPQ (1967)	0	Yes
Robson (1996)	0	Yes
Robson et al. (2000a – 2000d)	0	Yes
Smith et al. (1964)	1,072	Yes
SPDSS Task 35	19	No
SPDSS Task 42	0	Yes
DWR	266	No
Weist (1964)	1	No
Willard Owens Associates (1971)	0	Yes
Total	1,770	

1.2 Data Analysis and Processing

1.2.1 Processing of Historical Bottom of Alluvium and Groundwater Level Contours

Two of the bottom-of-alluvium and groundwater level contour maps were available in electronic format, while the others were available only in hard copy format. Electronic contour maps were obtained from Robson, S.G., (1996) and Robson et al. (2000a to 2000d), while hard copy contour maps were obtained from Bjorklund and Brown (1957), Duke et al. (1966), Erker et al. (1967), Hurr and Schneider (1972a -1972f, 1977), NHPQ (1967), Smith et al. (1964), and Willard Owens Associates (1971). To convert the hard copy maps into a digital format, the bottom of alluvium and groundwater level contour maps were scanned, georeferenced, and then digitized to develop a series of electronic polyline contour maps for the South Platte Alluvium Region. In addition to bottom of alluvium and groundwater level contours, Bjorklund and Brown (1957), Duke et al. (1966), Erker et al. (1967), Hurr and Schneider (1972a -1972f, 1977), and NHPQ (1967) presented the extent of saturated thickness within their study area. The lines of 0 saturated thickness were also digitized.

Distortion of the data may be introduced in the georeferencing process. Imperfections in georeferencing are created because the hard copy maps are often folded, stretched, and sometimes drawn on low resolution base maps, which prevent a perfect matching of map points to real world points on a regional scale. However, the georeferencing is sufficiently accurate for the purposes of this TM.

1.2.2 Development of Contours in Areas not Covered by Historical Sources

Contoured data of the bottom of alluvium and the groundwater level were not available from historic reports for the alluvium of Crow Creek, Upper Box Elder Creek, Upper Beaver Creek, and the South Platte River just below Chatfield Reservoir. In these areas, picks from DWR well permit images and other sources were used in this task to manually draw contours of the bottom of the alluvium and groundwater level surfaces. Additionally, the contours from adjacent historic reports were used to guide the geometry of the contouring. These areas are identified as SPDSS Task 42 in Figure 2.

1.2.3 Merging of Contours

The contours obtained from historical reports and the contours created in this TM were merged together into one dataset. Contours from one report that overlapped or were adjacent to the contours of another report were evaluated to determine how well the contours agreed between the reports. In cases where there was not good agreement, the electronic contours were modified to seamlessly merge the historic report contours. If picks were present in the area of interest they were used to guide the merging, and where no picks existed then engineering judgment based on the trend of the contours was used. Contours from more recent reports were given preference over contours from more historic reports. The areas where contours were modified to merge the datasets are shown in Figure 3.

1.2.4 Gridding of Bottom of Alluvium and Groundwater Level Contours

Gridding is the process by which randomly scattered data are projected onto a uniformly spaced grid using an algorithm of choice. For the South Platte Alluvium Region sufficient data picks were not available to create an accurate grid for the entire study area. However, sufficient contour data from the historical reports and those contours created for this TM in the areas of Crow Creek, Upper Box Elder Creek, Upper Beaver Creek, and the South Platte River just below Chatfield Reservoir were available to accurately define the region.

Grids were created by first converting the contours into regularly spaced points along the contour line using GIS. This allowed the development of a horizontal coordinate (X,Y) and elevation value (Z) data set. The XYZ data set was used to grid a comprehensive bottom of the alluvium and groundwater level surface in Surfer® (version 8; Golden Software, Inc.) a software gridding package. A statistical analysis using kriging techniques was used to develop variograms for each surface. Variograms define the variation in data related to distance between pairs of data points. A function was then fit to each variogram, which was used to interpolate estimated elevation values onto a uniform grid.

For the bottom of alluvium, an exponential variogram model was applied with a sill of 17,800 and a range of 1,900. For the groundwater level data, the gridding was conducted with the kriging method using a linear variogram model with a slope of 1.40 and no nugget effect. The sill, range, and nugget are terms that describe the kriging nonlinear curve-fitting parameters and are defined in geostatistical textbooks and in the Surfer software manual. Both sets of data were gridded on a 100-meter spacing, which is sufficient to capture the detail of the narrowly incised paleochannels previous studies have shown to exist in the region.

After the grids were developed, contours lines were created by using Surfer® to fit lines of equal value to the grid cells values. These contour lines were imported into ArcGIS and compared to

the original source contour lines. The contours from the grids agreed very well with the original source contours, which indicates the grids are an accurate representation of the source data.

1.2.5 Grids Modifications with Ground Surface

As a final check of the bottom of alluvium and groundwater level grids, each was compared to ground surface (USGS 30-meter NED). It was found both grids extend above ground surface in isolated areas. Areas where the gridded bottom of alluvium extends above ground surface are limited to the southern (upstream) extents of mapped alluvial tributaries in the Kiowa-Bijou and to the Upper Big Sandy. These represent approximately one percent of the alluvial grid area.

The groundwater water table grid is higher than ground surface in small localized areas across the entire grid, immediately adjacent to the South Platte River from Greeley to Weldona, in the southern Kiowa-Bijou tributary areas and in the Upper Big Sandy. The total area where the water table elevation is greater than the ground surface elevation is approximately 5.6 percent of the alluvial grid area.

In areas where either of the grids exceeded ground surface, the grid values in those areas were set to ground surface. These areas of modification are shown in Figure 4. The areas modified for ground surface in the bottom of alluvium grid are limited to the fringes of the South Platte Alluvium and the adjustments made are considered appropriate based on available data and for the purpose of regional scale modeling. The groundwater level grid will be used for the purpose of helping to define the Task48 model domain, and therefore, the ground surface adjustment is a sufficient correction for that purpose. If more localized study or modeling is conducted, then additional data will be needed to perform more refined adjustments in these areas.

1.2.6 Development of the Saturated Thickness Grid

After the bottom of the alluvium and the groundwater level elevation grids were computed, the bottom of the alluvium grid was then subtracted from the groundwater level grid using Surfer® to calculate a saturated thickness grid for the alluvium.

Division 1 decreed wells and Division 8 (Designated Basins) wells with greater than 50 gallons per minute pumping capacity and with aquifer codes of "QAL" or "Groundwater" were plotted on this saturated thickness grid (see figure 5). In a few isolated areas, the saturated thickness grid indicated the alluvium was either unsaturated or showed very little saturated thickness where a cluster of wells existed. The contoured bottom of alluvium values obtained from historic reports were modified to agree with the bottom of alluvium picks gathered from the DWR well permit images in these areas. After these modifications were completed the bottom of alluvium was re-gridded and the saturated thickness grid was recalculated. The areas where modifications were performed are shown in Figure 6.

1.2.7 Comparison of Picks and the Bottom of Alluvium Grid

To verify how well the grid agrees with pick data, a residual was calculated as the difference between the pick value and its corresponding grid cell value. Residuals were calculated for individual picks shown in Figure 2. The results are summarized by source in Table 2, which includes the number of picks, 10th percentile, 50th percentile (median) and 90th percentile

residual values in feet. The 90th percentile rank indicates 90 percent of the picks have a residual of less than the number of feet indicated in the table. The counts in Table 2 are different than those in Table 1 because only the picks within the defined alluvial extent are included in Table 2.

Table 2: Summary of Absolute Values of Residuals between Picks and the Bottom of Alluvium Grid

	Count	10th Percentile (ft)	Median (ft)	90th Percentile (ft)
Bjorklund and Brown (1957)	315	1	5	20
DWR	235	1	7	19
Smith et al. (1964)	1,009	1	5	17
SPDSS	17	2	29	58
Weist (1964)	1	2	2	2
All Data Sources	1,577	1	6	18

The residual values for all data sources show that the median residual is six feet and the 90th percentile residual is 18 feet. These values are relatively low, less than the 20-feet contour interval of the historic reports, indicating the grid is in good agreement with the picks.

The residuals for the SPDSS picks are higher than the picks from other sources. SPDSS picks are derived from geophysical logging from direct-push drilling, which is a less accurate measure of the bedrock contact than the use of discrete cores samples and drill cuttings used by other sources. Another explanation is that the grid does not accurately reflect the base of the alluvium and therefore differs from the SPDSS pick value. Neither option can be validated because the SPDSS picks with high residuals mostly reside in areas with few to no picks nearby. Because of the lack of neighboring picks, there was not sufficient physical evidence to justify modifying the grid based on one pick of questionable confidence.

For example, in the Julesburg area, the SPDSS picks suggest the primary paleochannel could possibly be shifted slightly to the northwest. It was determined inappropriate to modify the bottom of alluvium grid based on only a few picks, because it is presumed the Hurr and Schneider (1972) contours in this area were developed with a larger pick data set, which is not available for evaluation. Furthermore additional pick data from other sources were not available in this area to evaluate a modification to the grid. For regional scale modeling, it is believed the current configuration sufficiently captures the overall trend and geometry of the base of the alluvium. If a more localized study is conducted in this area, it is recommended more data be gathered to evaluate the bottom of alluvium grid.

1.2.8 Comparison of 2005 Groundwater Level Data and the Groundwater Level Grid

March 2005 groundwater level data from 32 SPDSS alluvial monitoring wells were selected to provide a representation of current groundwater levels spanning the reach from Henderson to Julesburg. These measurements were used to assess how well groundwater levels digitized from the historical reports represent current levels. The time period of water level measurement for each historic source are shown in Table 3. Using GIS, a residual was calculated as the difference between the groundwater level grid value and the March 2005 groundwater level from the SPDSS wells. Ninety percent of the March 2005 measurements differed by less than 10

feet from the grid, and 50 percent differed by less than 4 feet. This indicates current groundwater level measurements are similar to groundwater levels reported in the historical reports. There were two measurements in the area near Weldona that indicated water level declines of approximately 20 feet since the development of the historical groundwater level contours in that area. This trend is in agreement with the water level mapping and analyses undertaken in Task 44 that indicates there are several areas where alluvial water levels have declined over time. For the purposes of developing a generalized saturated thickness map, the time-averaging of available data was determined to be an appropriate approach.

A minimum saturated thickness depth and width criteria will be used in Task 48 to define the alluvial model domain. Task 48 will use the saturated thickness created in this TM based on water level data from multiple historic time periods. This analysis validates the use of historic water levels since they have been found in most areas to be consistent with current water levels, and confirms that the model domain developed in Task 48 will sufficiently represent saturated alluvial areas over a range of time periods.

Table 3: Water Level Measurement Time Period for each Source

	Time Period
Bjorklund and Brown (1957)	November/December 1949
Duke et al. (1966)	Summer 1965
Erker et al. (1967)	Spring 1966
Hurr and Schneider (1972a -1972f)	March 1968
Hurr and Schneider (1977)	January 1975
NHPQ (1967)	Spring 1967
Robson (1996)	Multiple time periods
Robson et al. (2000a – 2000d)	Multiple time periods
Smith et al. (1964)	November 1957
SPDSS Task 42	Multiple time periods
Willard Owens Associates (1971)	March 1971

1.2.9 Development of the Alluvial Extent

The extent of the alluvium shown in Figure 1 was developed from multiple sources. A line of 0 saturated thickness was obtained from various historical reports including Bjorklund and Brown (1957), Duke et al. (1966), Erker et al. (1967), Hurr and Schneider (1977, 1972a -1972f), NHPQ (1967). These sources provided a basis for defining the extent of the alluvium for the mainstem of the South Platte River from Greeley to Julesburg, Beaver Creek, Badger Creek, Kiowa and Bijou Creeks, Lost Creek, and the Upper Black Squirrel Creek.

In the study areas of Robson, (1996) and Robson et al. (2000a – 2000d) as shown in Figure 2 , a saturated thickness extent was only presented in areas where those authors determined the water table to be well-defined. For the purposes of this TM, a saturated thickness grid was computed as indicated in Section 1.2.5, using the bottom of alluvium and water table data provided in the Robson reports. The saturated thickness contour line of approximately 10 feet, which is the minimum saturated thickness expected to be included in the Task 48 model domain, determined from the grid, was used to define the extent of the alluvium. The saturated thickness contour line of 0 feet produced a very discontinuous and fragmented alluvial extent.

Isolated areas of saturated thickness separated by extensive unsaturated zones were excluded from the extent. This new extent was merged with the extent presented in the Robson reports to generate a more comprehensive outline of the alluvium for the mainstem of the South Platte River from Denver to Greeley, the tributaries to the west of the South Platte River, portions of Beebe Draw and Box Elder Creek, and the Cache la Poudre River and its tributaries.

The Smith et al. (1964) report focused on the Box Elder Creek and Beebe Draw region but no saturated thickness limit was digitized from this report. The areal extents to which the water table contours and the bottom of alluvium contours were drawn were used to approximate the extent of the saturated alluvium and provide a basis for the outline in the Box Elder and Beebe Draw regions.

The Willard Owens Associates (1971) report focused on the Upper Big Sandy Designated Basin but no limit of the saturated thickness was defined in that report. In addition, the bottom of alluvium contours and the groundwater level contours are not of sufficient detail to estimate the extent of the saturated alluvium. The Colorado Geological Survey (CGS) developed a shapefile for the Groundwater Atlas of Colorado which maps the extent of alluvial deposits in Colorado (Topper et al. 2003). The CGS outline was used to map the alluvium in the Upper Big Sandy Designated Basin.

In areas of Crow Creek, Upper Beaver Creek, Upper Box Elder Creek, and just below Chatfield Reservoir on the South Platte , where contours were manually drawn for this TM (see Section 1.2.2), the CGS outline and data obtained from the DWR well permit images were used define the alluvium extent.

The final extent of alluvium was created by merging the boundaries obtained from each source identified above. Using ArcGIS software, the boundaries were clipped to the extent of the Denver Basin along the western, eastern, and southern margins. Finally, manual editing of the alluvial boundary was performed to fill in areas of alluvium between the various sources of data.

Division 1 decreed wells and Division 8 (Designated Basins) wells with greater than 50 gallons per minute pumping capacity and with aquifer codes of "QAL" or "Groundwater" are plotted on Figure 5. This figure illustrates the defined alluvial extent contains almost all of the high capacity wells. It should be noted some wells shown may be completed in aquifers other than the South Platte Alluvium because the aquifer code "Groundwater" may be used for aquifers such as the Denver Basin Bedrock Aquifer, the High Plains Aquifer, or other aquifers. This alluvial extent will be modified using a minimum saturated thickness depth and width criteria under Task 48 to develop the alluvial model domain.

2.0 Aquifer Configuration Database

One of the objectives of Tasks 31 and 42 was to create a HydroBase-compatible database with aquifer configuration data from the South Platte Alluvium Region. This section describes the HydroBase tables used to store configuration data. The picks gathered for this TM will be submitted in a HydroBase-compatible database using the format discussed in Section 2.1.

2.1 Database Structure

The following paragraphs identify the key tables in HydroBase pertinent to aquifer configuration Data. Appendix A provides a more detailed summary of those tables and fields.

Four data tables contain data pertinent to an aquifer's configuration. These are named WELLS, GEOPHLOGS, AQUIFER_PICKS, REF_ELEV_ACCURACY and REF_LOC_ACCURACY.

The WELLS table contains the location, well elevation, permit number, well depth, and many other types of information about wells in the SPDSS study area. The WELLS table is the core table that links well information data with geophysical log, water level, and aquifer test data.

The GEOPHLOGS table of HydroBase contains the geophysical well log picks determined by the DWR. The GEOPHLOGS table contains the picks for the aquifer top and bottom elevations, and picks for the net sand thickness. For the alluvial aquifer, typically a pick for the bottom elevation of the aquifer is all that is stored in the GEOPHLOGS table. This table is linked to the WELLS table by the *well_id* field.

The AQUIFER_PICKS table of HydroBase contains the same type of aquifer configuration data as the GEOPHLOGS table. The picks are derived from sources such as geophysical logs, driller's logs, or historic reports, but the picks are not determined by the DWR. This table is linked to the WELLS table by the *well_id* field.

The REF_ELEV_ ACCURACY table includes comments indicating the source and accuracy of the elevation value.

The REF_LOC_ACCURACY table includes comments on the siting accuracy of the location (X,Y) data.

2.2 Database Quality Control

A series of quality control steps were undertaken to check the accuracy of the data analysis and processing.

Published contour data from Bjorklund and Brown (1957), Duke et al. (1966), Erker et al. (1967), Hurr and Schneider (1972a -1972f, 1977), NHPQ (1967), Smith et al. (1964) and Willard Owens Associates (1971) were scanned to a graphic image file and then digitized and assigned a contour value. The digitized contour values were analyzed for quality and accuracy by the following procedure. The digitized contours were overlain on the graphic image of the original contour map. One hundred percent of the digitized contours were verified for the appropriate contour interval and value by comparison with the contour graphic image. A similar procedure was used for the point values obtained from Bjorklund and Brown (1957) Smith et al. (1964). After the points were digitized, 100 percent of the assigned digitized values were checked against the value labeled on the image and found to be in agreement.

Numerical data from each of the sources external to HydroBase were initially entered into a Microsoft Excel® spreadsheet. Hand-entered data were then checked for accuracy by comparing 100 percent of the entered data to the original hard copy data. If errors in the data entry were found, the errors were corrected in the spreadsheet. The spreadsheet was then uploaded into

the SPDSS Groundwater Hydrobase-compatible database. This procedure was used to assure quality for all data added to the database.

3.0 Results

The following sections discuss the data analysis and mapping results for aquifer configuration of the South Platte Alluvium Region. The aquifer bottom elevations, groundwater level elevations, ground surface elevations, and saturated thickness grids will be provided to the CWCB in ArcGrid format as part of this TM. Additionally the picks presented in Figure 2 will be provided in shapefile format.

3.1 Aquifer Bottom Elevations

Figure 7 presents the grid and contours for the aquifer bottom elevations of the alluvium. As discussed in Section 1.2, the grid was created by digitizing contours from various reports, merging the contours together, modifying the contours based on new pick data, exploding the contours to points, gridding the points, and then limiting areas of the grid exceeding ground surface to ground surface. The color fill grid shows generally how the elevations change throughout the region. The bottom elevations in Division 1 range from a low of 3,254 feet near Julesburg at the state line to a high of 7,045 feet near at the southern end of the Kiowa Bijou designated basin. The bottom elevations in Division 2 range from a low of 5,486 feet at the outlet of the Upper Black Squirrel Creek drainage to a high of 7,044 feet in the north end of Upper Black Squirrel Creek drainage. Also shown are contours in intervals of 50 feet, which show the center of the paleochannels, as indicated by the v-shaped contours. The bottom of the alluvium is sufficiently characterized as depicted in Figure 7 to begin development of a groundwater model.

3.2 Groundwater Level Elevations

Figure 8 presents the grid and contours for the groundwater elevations in the alluvium. The gridding and contouring methods are discussed in Section 1.2 and summarized in Section 3.1. For the purposes of this study, the water table surface was used to define the saturated thickness. The groundwater elevations in Division 1 range from a low of 3,415 feet near Julesburg at the state line to a high of 6,902 feet near the southern end of the Kiowa Bijou designated basin. The groundwater elevations in Division 2 range from a low of 5,557 feet near the outlet of the Upper Black Squirrel Creek drainage to a high of 6,718 feet in the north end of the Upper Black Squirrel Creek drainage. Also shown are contours in intervals of 50 feet, which highlight the geometry of the water table. As discussed in Section 1.2.4, the historical groundwater surface shown is indicative of current groundwater levels.

3.3 Ground Surface Elevations

Figure 9 presents the ground surface elevation data from the USGS 30-meter NED. For the Task 48 modeling, ground surface will be used to define the upper limit of the alluvial aquifer. Within the alluvial extent, ground surface elevations in Division 1 range from 3,427 feet to 7,123 feet, while in Division 2 they range from 5,580 feet to 7,301 feet.

3.4 Saturated Thickness

Figure 10 presents the saturated thickness of the South Platte Alluvium calculated as the difference between the groundwater level and bottom of alluvium grids. Saturated thickness

ranges from zero to approximately 240 feet. The regions of greatest saturated thickness can be seen along the center of the paleochannel from Fort Morgan to Julesburg as indicated by the red color fill. Areas that show a color fill of black represent unsaturated areas and are generally confined to the edges of the alluvial extent, or between tributaries.

The saturated thickness in the areas of the Big Sandy Designated Basin and the southern end of the Kiowa Bijou Designated Basin are less accurate than other areas of saturated thickness. Saturated thickness is based on a subtraction of two grids and the accuracy is dependent on the accuracy of the source grids. The source data for these two basins, is of lower resolution (100-feet contour interval compared to 20-feet contour interval elsewhere) and, consequently, the saturated thickness estimated from the source data is less reliable. However, on a regional scale, the map presented provides a sufficient understanding of the geometry of saturated thickness for the South Platte Alluvium Region as a whole.

3.5 Cross sections

Figure 11 presents the locations of six cross sections developed for the South Platte Alluvium Region. The cross sections provide another means to visualize the alluvial aquifer configuration. From one cross section to the next, changes in elevation and lateral aquifer configuration from Henderson to the Nebraska state line are evident. Figures 12 through 17 show the cross sections with the elevation of the land surface, bottom of alluvium, and the water table surface. The bottom of alluvium and groundwater level data shown were based on the grids developed as discussed in Section 1.2. Land surface elevations were extracted from the 2001 USGS 30-meter NED. All cross sections are presented with a vertical exaggeration of a 23:1 vertical to horizontal ratio. This provides sufficient exaggeration to view the incised paleochannels, yet still reflect the broadness of the alluvium.

The configuration of the alluvial valley at each cross section provides insight into its creation and development. Each of the cross sections shows an incised river channel carved into the bedrock surface by the ancestral South Platte River. Down-cutting likely occurred near the end of successive glacial periods in Colorado's more recent geologic history. As glaciers near the Continental Divide receded, the increased melt water runoff had sufficient force to erode the bedrock surface and create relatively deep and narrow channels. As the last glacial melting event ended in the Quaternary Period, the flow in the ancestral South Platte River declined, as did the energy to erode into the bedrock. Decreasing river flow caused suspended sediment to settle out, gradually filling the former river channel up to the present day elevation. Cross sections A-A’ to F-F’ demonstrate this geologic history. Beginning at cross section A-A’, the paleochannel is shallow and broad but moving downstream the cross sections reveal paleochannels are more incised with steeper banks. Some of the cross sections reveal more than one paloechannel indicating the streams have meandered over time or the cross section may extend into a tributary paleochannel. The following paragraphs describe each cross section in more detail.

Cross section A-A', shown in Figure 12, is located near Brighton at the Henderson gaging station. The cross section lacks the V-shaped geometry that can be seen in the other cross sections. Along the western edge the bedrock surface is steeply dipping for 0.5 mile and then gradually rises to the east for 4.5 miles and generally parallels ground surface. Near the eastern

edge, there is a small channel located where the Beebe Draw Alluvium converges with the South Platte Alluvium.

Cross section B-B', shown in Figure 13, is located near Kersey at the Kersey gaging station. This cross section depicts more of an incised paleochannel than A-A' but still lacks the steep banks seen in downstream cross sections. The bedrock surface is nearly flat along the northern edge, rolls into the valley bottom, which extends for over a mile, and then rises steeply in the south.

Cross section C-C', shown in Figure 14, is located just upstream of Fort Morgan. The deepest part of the alluvial paleochannel is approximately one-half mile wide and then broadens out and extends for a total width of nearly 7 miles. On the left (north) side of the cross section, the bedrock surface at an elevation of approximately 4,175 feet and between distance markers 1 and 2 shows a smaller channel eroded into the bedrock surface. This likely represented the location of the ancestral South Platte River at an earlier time.

Cross section D-D', shown in Figure 15, is located downstream of Brush near the Balzac stream gage. It shows a narrow, incised valley bottom approximately 1 mile wide and deepens to 3,900 feet. Above an elevation of approximately 4,050 feet, but still almost 70 feet below the water table surface, on the south side of the valley bottom, the slope of the bedrock surface is nearly flat and extends out approximately 3 miles. This could represent the bottom elevation of the river channel at the end of a particular cycle of glaciation, when the river meandered into and eroded away the bedrock in the area of this bench. On the north side, the slope on the bedrock surface is much steeper and only extends approximately 1 mile from the valley bottom. The water table in this region is at approximately 4,100 feet.

Cross section E – E', shown in Figure 16, is located near the Town of Sterling. Compared to Cross section D-D', which is approximately 25 miles to the southwest, the valley bottom shows gentler side slopes. The elevation of the valley bottom has decreased by 200 feet from Cross section D-D' to approximately 3,700 feet, and the water table has also decreased by approximately 200 feet to 3,900 feet.

Cross section F-F', shown in Figure 17, is located between the Towns of Sterling and Julesburg in northeastern Logan County. At this location, the valley bottom is wider than at upstream locations, and contains a deep channel underneath a ground surface high. The slope of the bedrock surface on the south side of the valley bottom is much steeper than at Cross section D-D', whereas the slope on the north side is similar to Cross section E-E'. As with Cross section D-D', the bedrock surface is asymmetric, but the steeper side is on the south valley wall. The valley bottom and water table elevations again decreased by approximately 200 feet from Cross section E-E'.

4.0 Summary and Conclusions

CDM has completed SPDSS Tasks 31 and 42, the Phase 1, 2, and 3 collection, analysis, and mapping of aquifer configuration data for the South Platte Alluvium Region. This report examines the sources and types of available alluvial aquifer configuration data during Phases 1, 2, and 3 of the SPDSS. It describes the processing of the data used to generate a grid of the bottom of the alluvium, a grid of the water level surface, a grid of the saturated thickness, and a

grid of the ground surface. In addition, aquifer configuration pick data were processed to be HydroBase-compatible and will be submitted to the SPDSS project manager for inclusion in HydroBase. The data from this task were used to help identify additional data needs in the South Platte Alluvium Region and supported the design of the groundwater field programs in Phases 1, 2 and 3.

Below are conclusions from completion of these tasks.

General Conclusions

- The aquifer configuration data collected, analyzed, and presented in this TM represents a significant addition to the knowledge and characterization of the alluvial groundwater systems within the South Platte Alluvium Region. This task of the SPDSS has compiled a database of 1,770 alluvial aquifer bottom picks. In addition continuous grids of the aquifer bottom, water level surface, saturated thickness, and ground surface have been created and presented.

- Much of the data presented in this TM were available in previously published reports. However, many of the reports are out of print and limited to hard-copy maps. Through the work of this task, the historical data have been digitized, enhanced with new data, merged together, and converted to electronic formats that can be easily used for analysis.

- The integration of aquifer configuration data from a variety of sources has resulted in comprehensive databases and maps that represent the best available characterization of the alluvial aquifer configuration within the South Platte Alluvium Region study area.

- The alluvial aquifer configuration presented in this TM is sufficient for the purpose of commencing regional scale water resources planning and can be used directly as model input for the alluvial aquifer groundwater modeling under Task 48.

Specific Conclusions

- The Phase 1, 2, and 3 Tasks 31 and 42 activities satisfy the objectives of collecting available published aquifer configuration data, enhancing HydroBase with these data, guiding the Phase 1 and Phase 2 field investigations, and helping characterize the configuration of the alluvial aquifer in the South Platte Alluvium Region.

- A comparison of bottom of alluvium picks from the SPDSS drilling with the contouring from historical reports indicates the paleochannel in the mainstem of the South Platte River Alluvium near Julesburg, as represented by the historical contours, may need to be shifted. Modifications to the contours were not made at this time because sufficient data are not available to guide and validate contour modifications. However, the current characterization is sufficient for regional scale modeling. If more localized study or modeling is conducted in this area, additional bottom of alluvium elevation point data should be gathered to further evaluate the accuracy of the historical contours.

- The initial bottom of alluvium grid and groundwater level grid created for this TM both exceeded ground surface in isolated areas. These areas represented approximately one

percent and five percent, respectively, of the entire grid area. Both grids were revised so the bottom of alluvium and water table elevations greater than ground surface were set equal to ground surface. The modified areas in the bottom of alluvium grid are limited to the fringes of the South Platte alluvium and the adjustments made are considered appropriate based on available data and for the purpose of regional scale modeling. The groundwater level grid will be used to help define the alluvial model domain in Task 48, and therefore, the ground surface adjustment to the groundwater level grid is a reasonable correction for that purpose.

- The alluvial aquifer configuration of the Upper Big Sandy Designated Basin and the southern end of the Kiowa-Bijou Designated Basin is not characterized with as much certainty as is the remaining study area. The source data available for these areas are more sparse and of less confidence.

- The aquifer configuration picks discussed will be provided to the SPDSS project manager for inclusion into HydroBase.

5.0 Recommendations

The following additional data needs were identified based on this Phase 3 data analysis:

- The aquifer configuration data collected under Task 42 of the SPDSS and presented both in this TM and in HydroBase are the most comprehensive, readily available data and should be utilized by members of government agencies, water management groups and the public in water resources-related activities in the South Platte Alluvium Region.

- The configuration data for the Upper Big Sandy Designated Basin in Division 2 and the southern end of the Kiowa-Bijou Designated Basin is presented with less detail than other historical reports for other regions of the South Platte Alluvium. The SPDSS will not be including the Upper Big Sandy alluvial system and much of the southern end of the Kiowa-Bijou area in its Task 48 alluvial model, so no additional characterization is needed for the SPDSS. However, more data collection is recommended if localized groundwater modeling is conducted in the southern end of the Kiowa-Bijou, or if groundwater modeling is undertaken in the Upper Big Sandy for the future Arkansas River Decision Support System.

- The alluvial aquifer configuration information developed from digitized contour maps represents derived data. Therefore it should be retained in a database separate from HydroBase for use in conjunction with HydroBase data for future analysis, mapping, and modeling of the South Platte Alluvium Region.

- If more localized study is conducted in the areas where ground surface was used to adjust the grids or where the bottom of alluvium grid had a high residual compared to bottom of alluvium picks, then additional data should be gathered to refine the grids in those areas.

- When developing the model domain under Task 48, it is recommended that the alluvial extent be modified to include only areas with a minimum saturated thickness depth and width criteria and verify that the extent encompasses all high capacity wells to be modeled.

6.0 References

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_____. 1972b. Hydrogeologic Characteristics of the Valley-Fill Aquifer in the Greeley Reach of the South Platte River Valley, Colorado. USGS Open-File Report 73-124.

_____. 1972c. Hydrogeologic Characteristics of the Valley-Fill Aquifer in the Julesburg Reach of the South Platte River Valley, Colorado. USGS Open-File Report 73-125.

_____. 1972d. Hydrogeologic Characteristics of the Valley-Fill Aquifer in the Sterling Reach of the South Platte River Valley, Colorado. USGS Open-File Report 73-126.

_____. 1972e. Hydrogeologic Characteristics of the Valley-Fill Aquifer in the Weldona Reach of the South Platte River Valley, Colorado. USGS Open-File Report 73-127.

_____. 1972f. Hydrogeologic Characteristics of the Valley-Fill Aquifer in the Brighton Reach of the South Platte River Valley, Colorado. USGS Open-File Report 72-332.

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Robson, S.G., Heiny, J.S. and Arnold, L.R. 2000a. Geohydrology of the shallow Aquifers in the Greeley-Nunn area, Colorado. USGS Hydrologic Investigations Atlas HA-746A.
(Why not use the same approach as above for the next three entries, i.e., "_____." instead of the names?)
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Robson, S.G., Heiny, J.S. and Arnold, L.R. 2000c. Geohydrology of the shallow Aquifers in the Fort Lupton-Gilcrest area, Colorado. USGS Hydrologic Investigations Atlas HA-746C.

Robson, S.G., Heiny, J.S. and Arnold, L.R. 2000d, Geohydrology of the shallow Aquifers in the Boulder-Longmont area, Colorado. USGS Hydrologic Investigations Atlas HA-746D.

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Figure 1: SPDSS Study Area

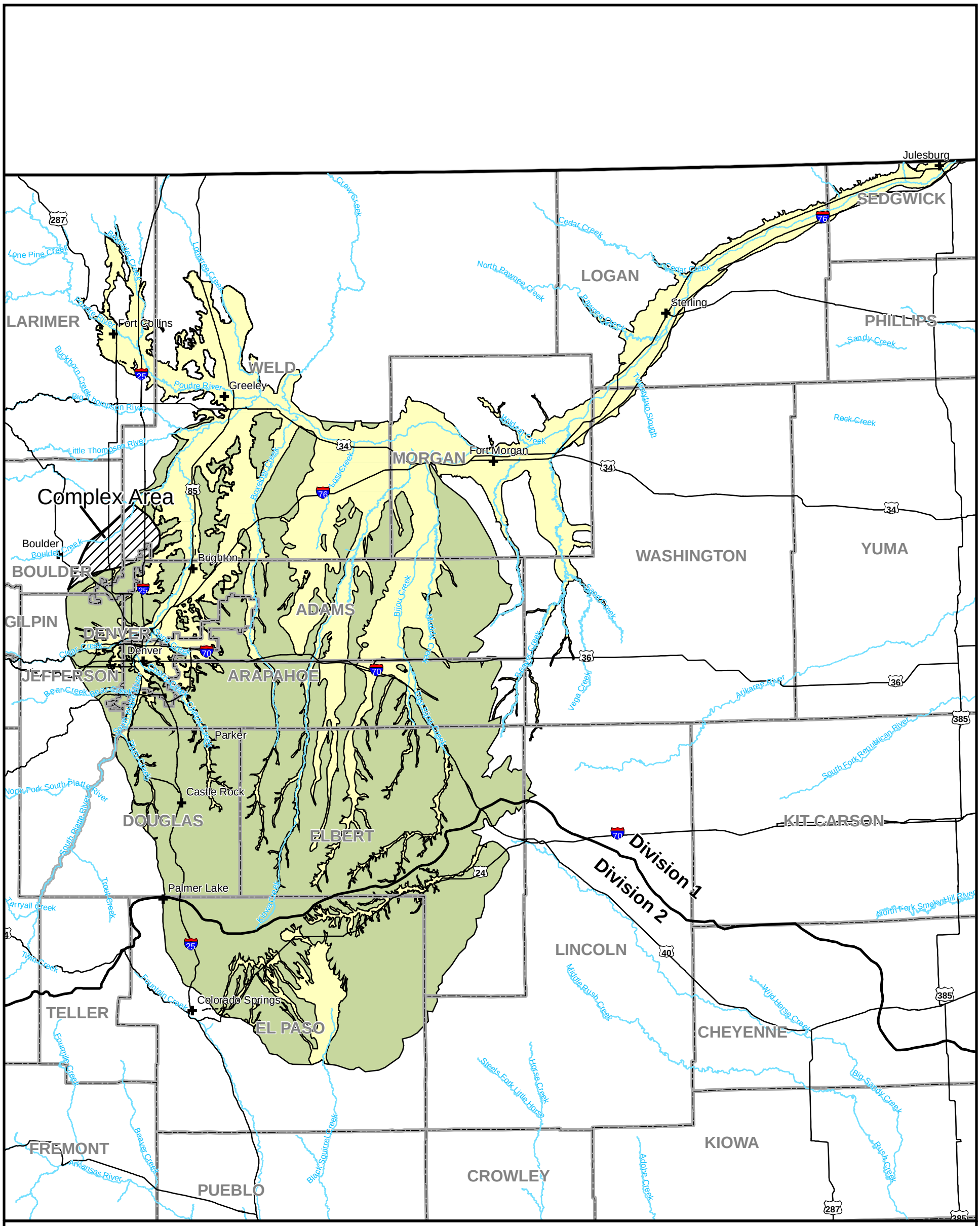

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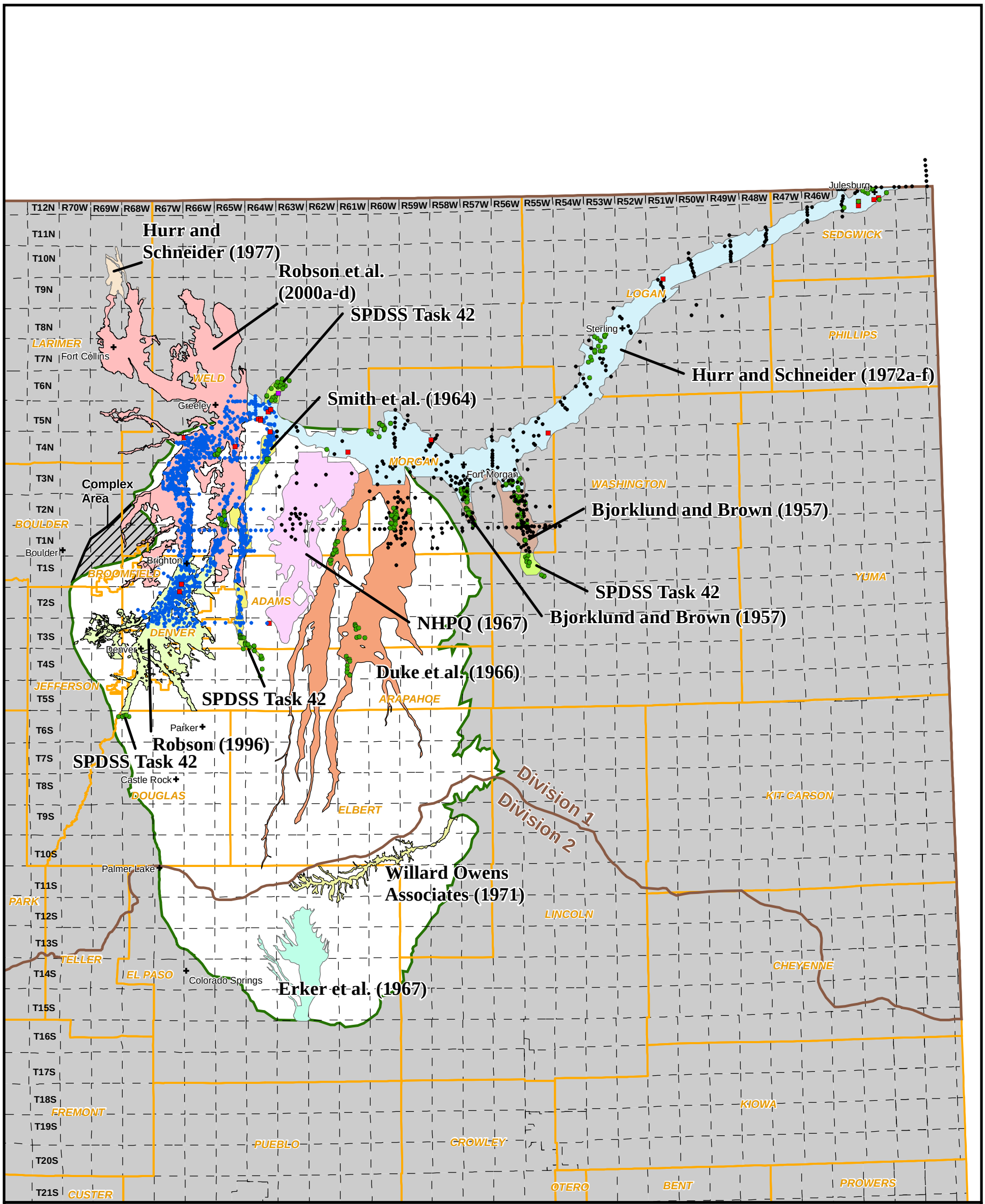
Figure 2: Alluvial Aquifer Configuration Data Sources



N
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Scale
1:1,200,000

0 5 10 20
Miles

NAD 1983 UTM Zone 13N

- City
- County
- Township
- Denver Basin Extent

Base of Alluvium Picks

- Bjorklund and Brown, 1957
- DWR
- SPDSS Task 35
- Smith et al., 1964
- Weist, 1964

Base of Alluvium Contour Sources

- Bjorklund and Brown (1957)
- Duke et al. (1966)
- Erker et al. (1967)
- Hurr and Schneider (1977)
- Hurr and Schneider (1972a-f)
- NHPQ (1967)
- Robson et al. (2000a-d)
- Robson (1996)
- Smith et al. (1964)
- SPDSS Task 42
- Willard Owens Associates (1971)

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Figure 3: Areas Where Contours from Histrorical Sources Were Modified to Seamlessly Merge the Contours

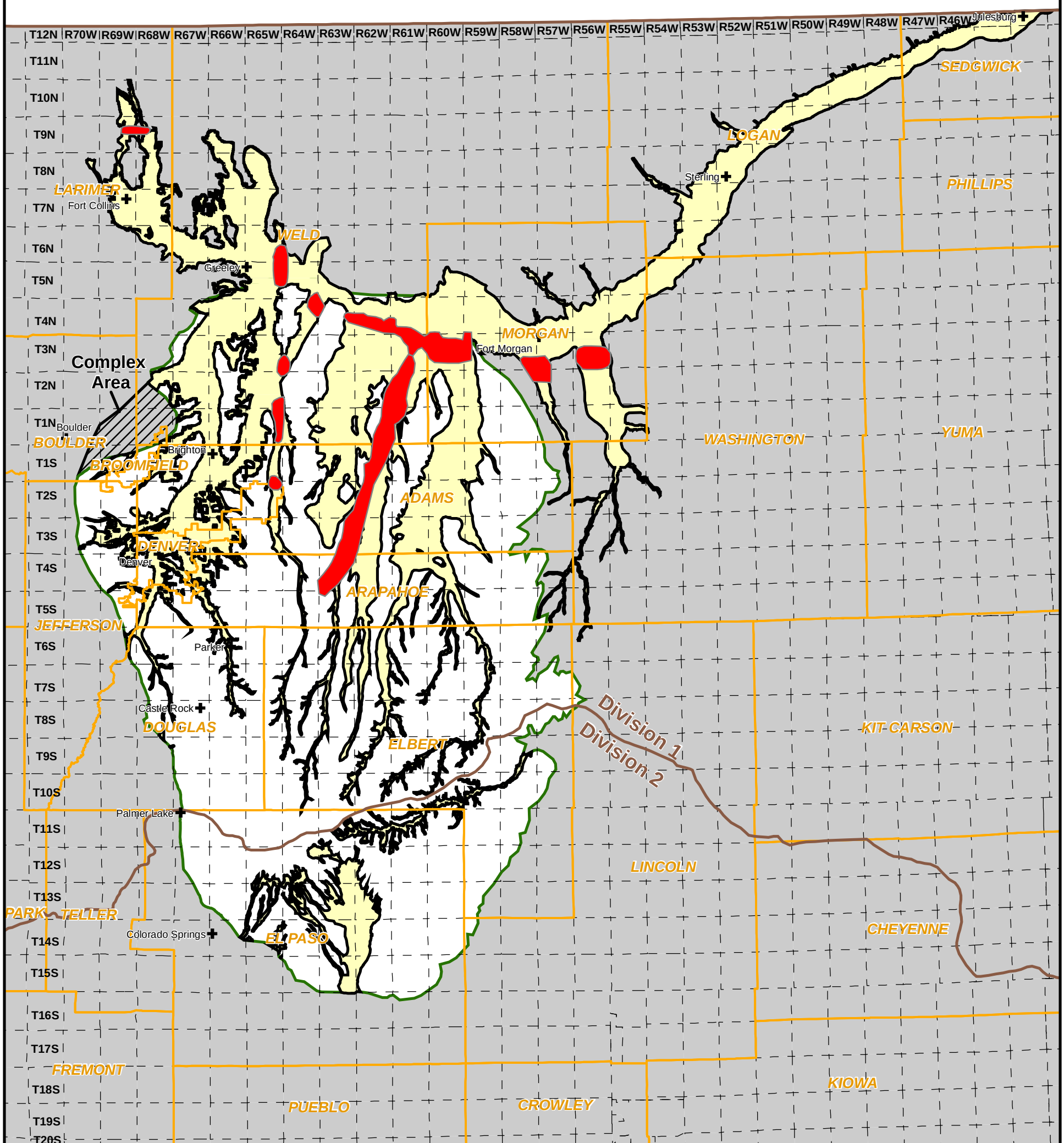

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Figure 4: Areas Where Bottom of Alluvium and Groundwater Level Grids Were Truncated to Ground Surface

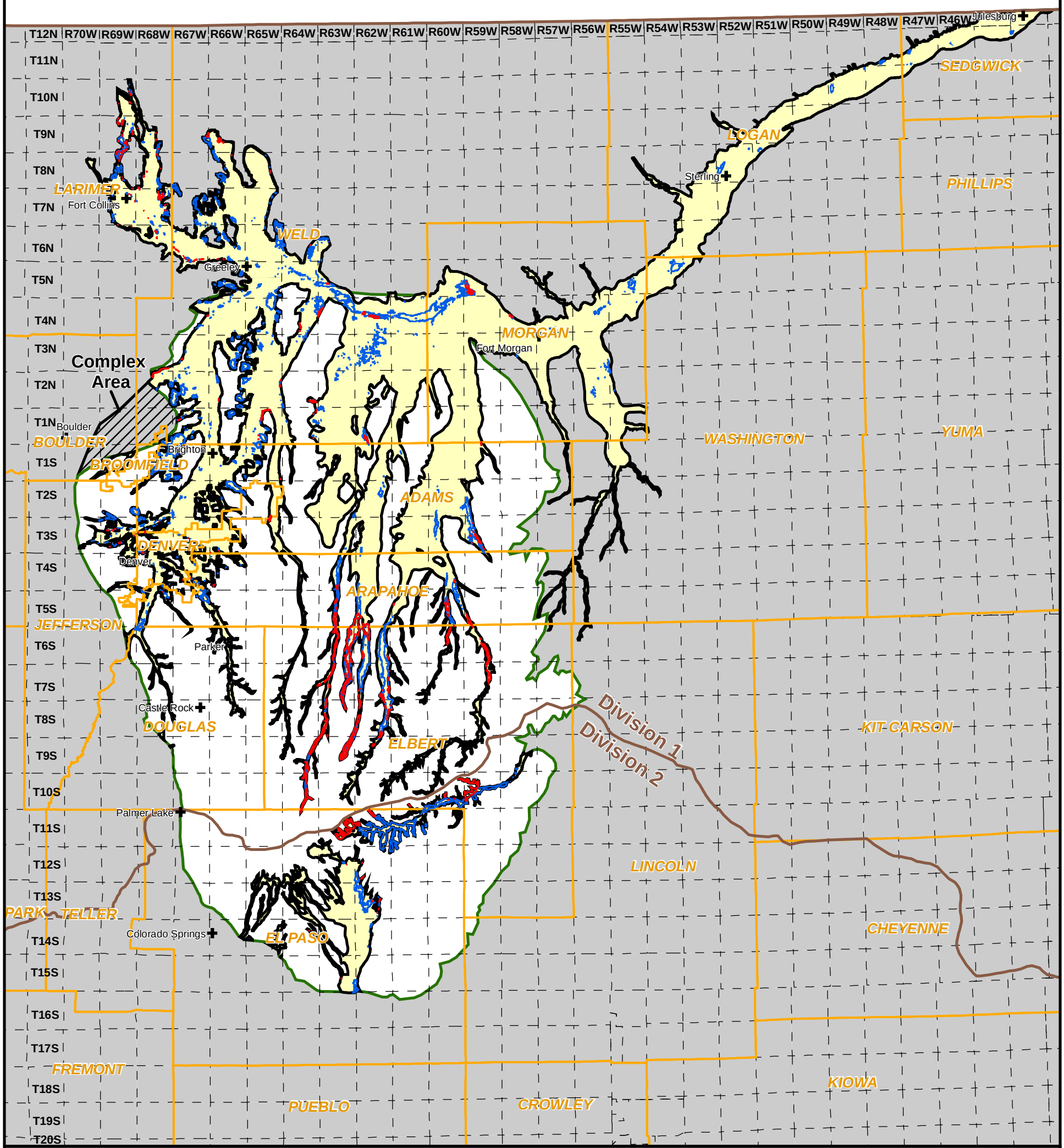

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Figure 5: Location of Division 1 Decreed and Division 8 Permitted Wells > 50 gpm Compared with the SPDSS Alluvial Extent

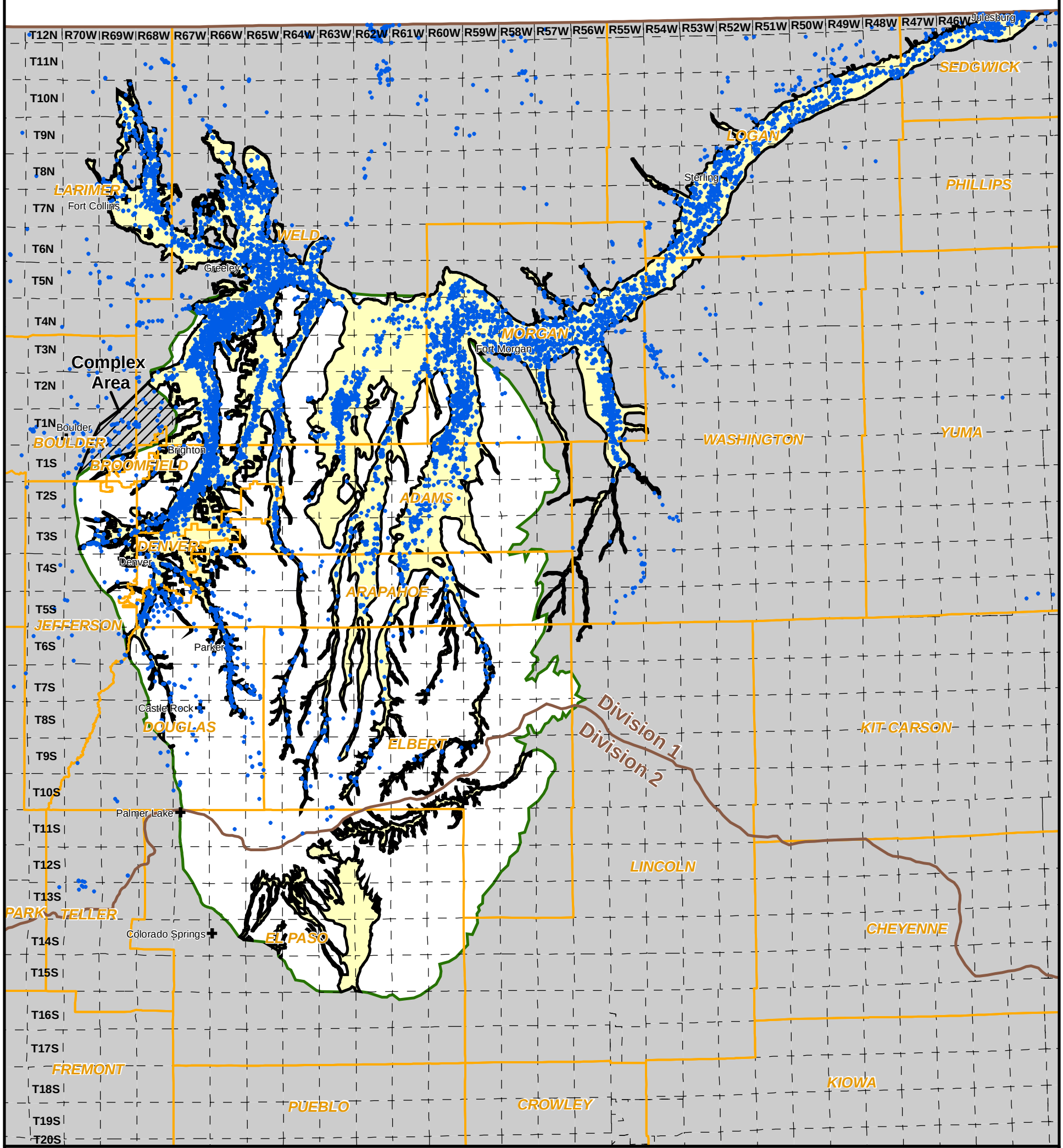

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Figure 6: Areas Where Historical Bottom of Alluvium Contours Were Modified with Picks

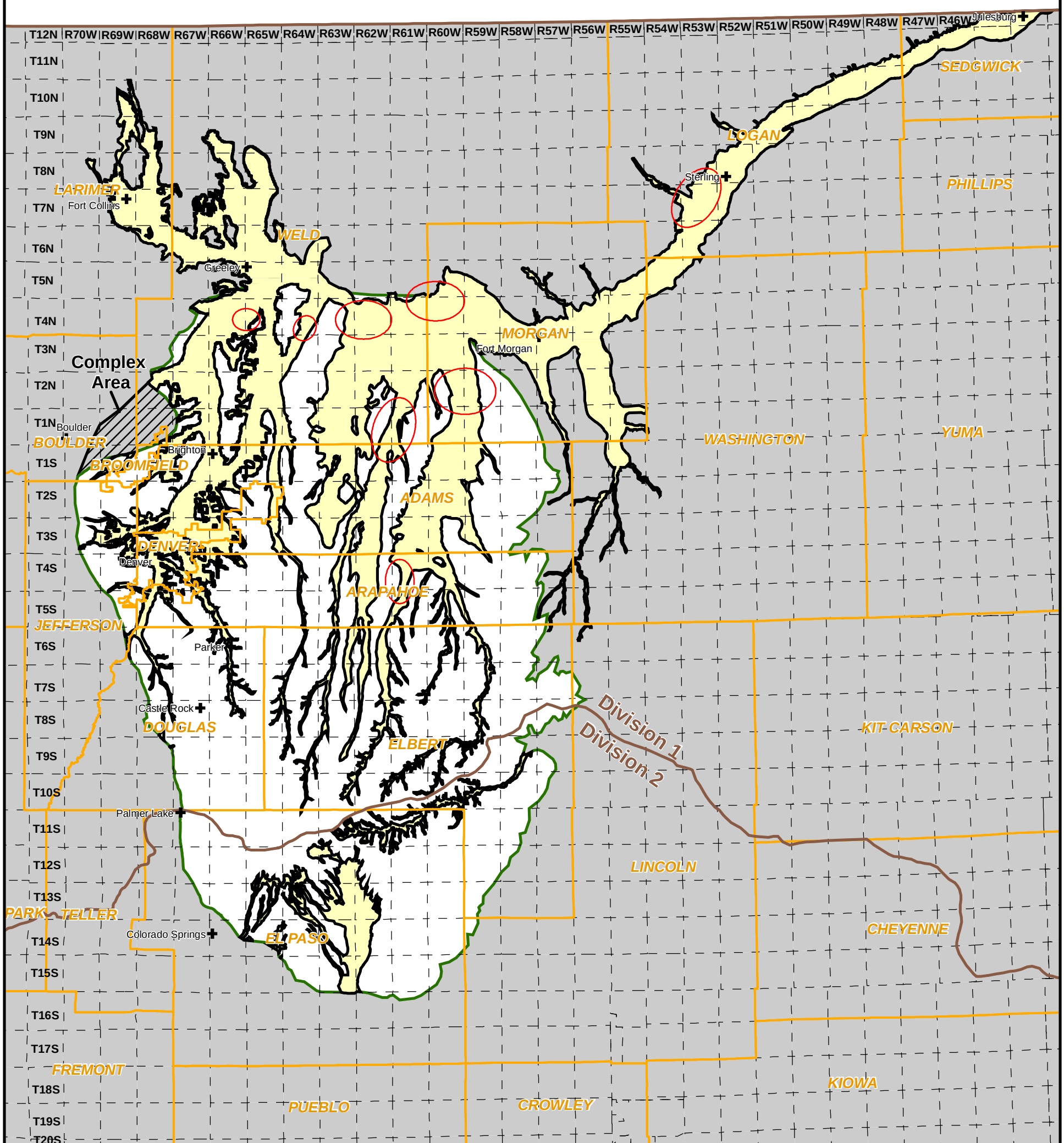

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Figure 7: Bottom Elevations of the Alluvial Aquifer

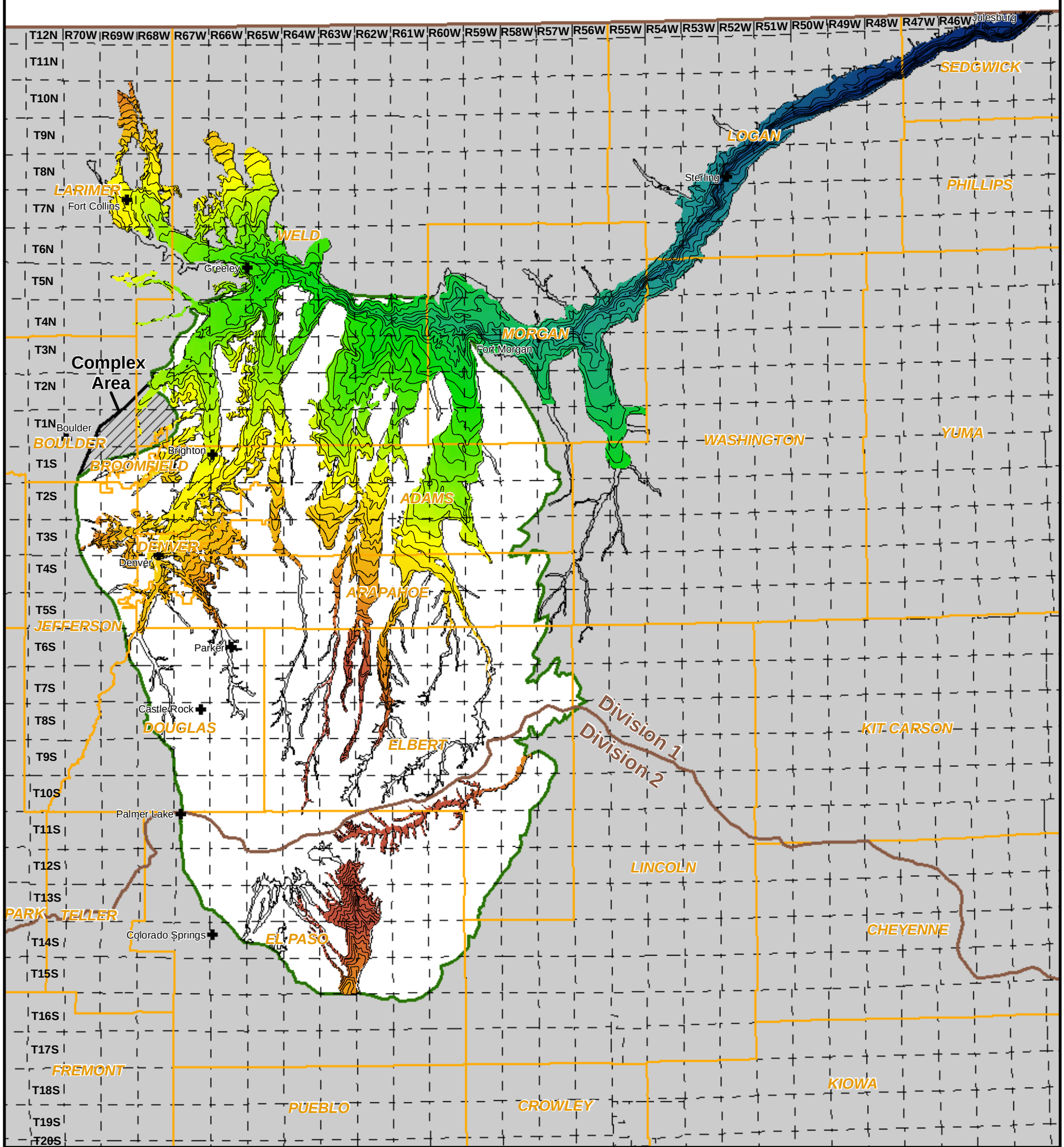

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Figure 8: Groundwater Level Elevations of the Alluvial Aquifer

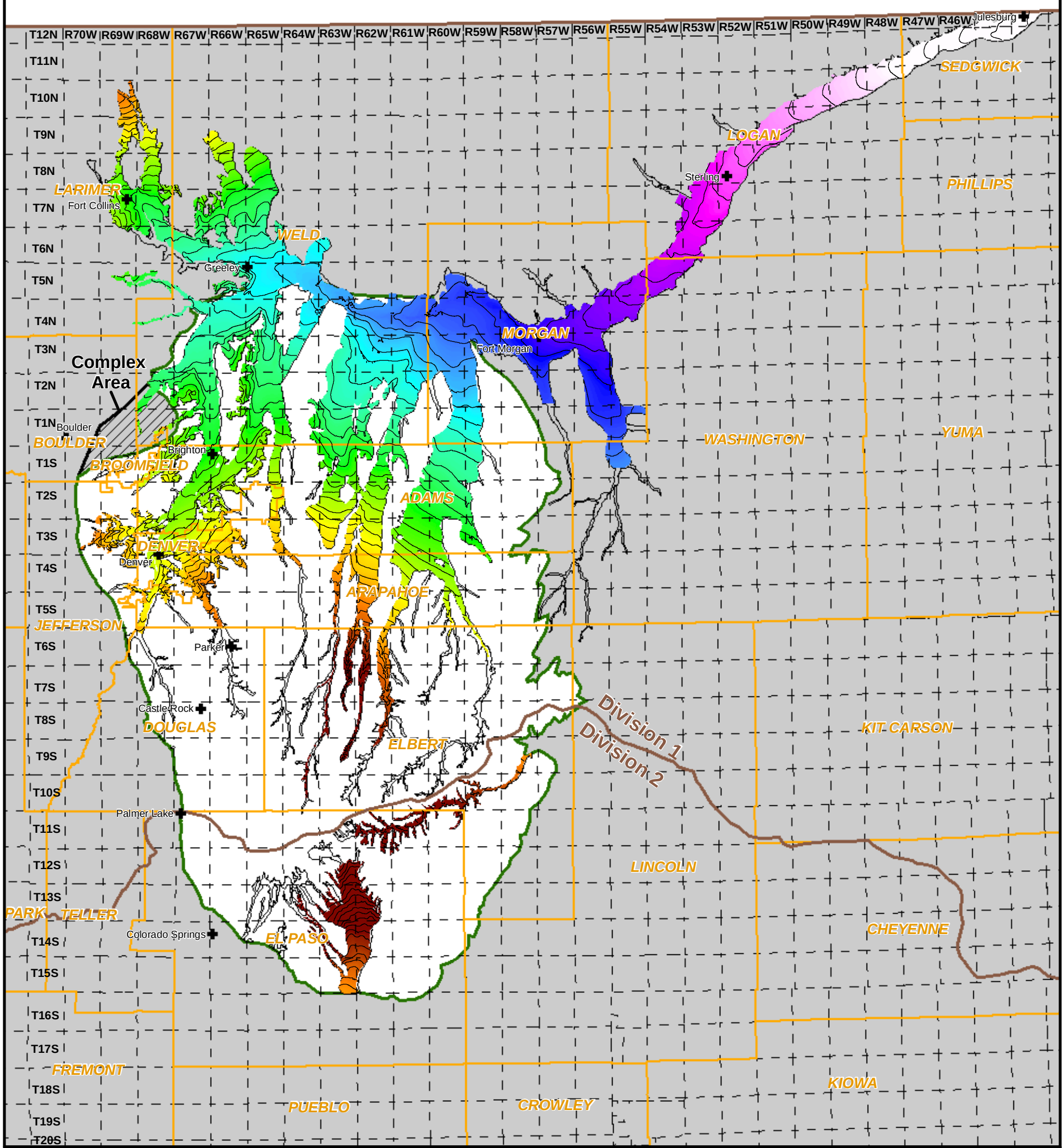

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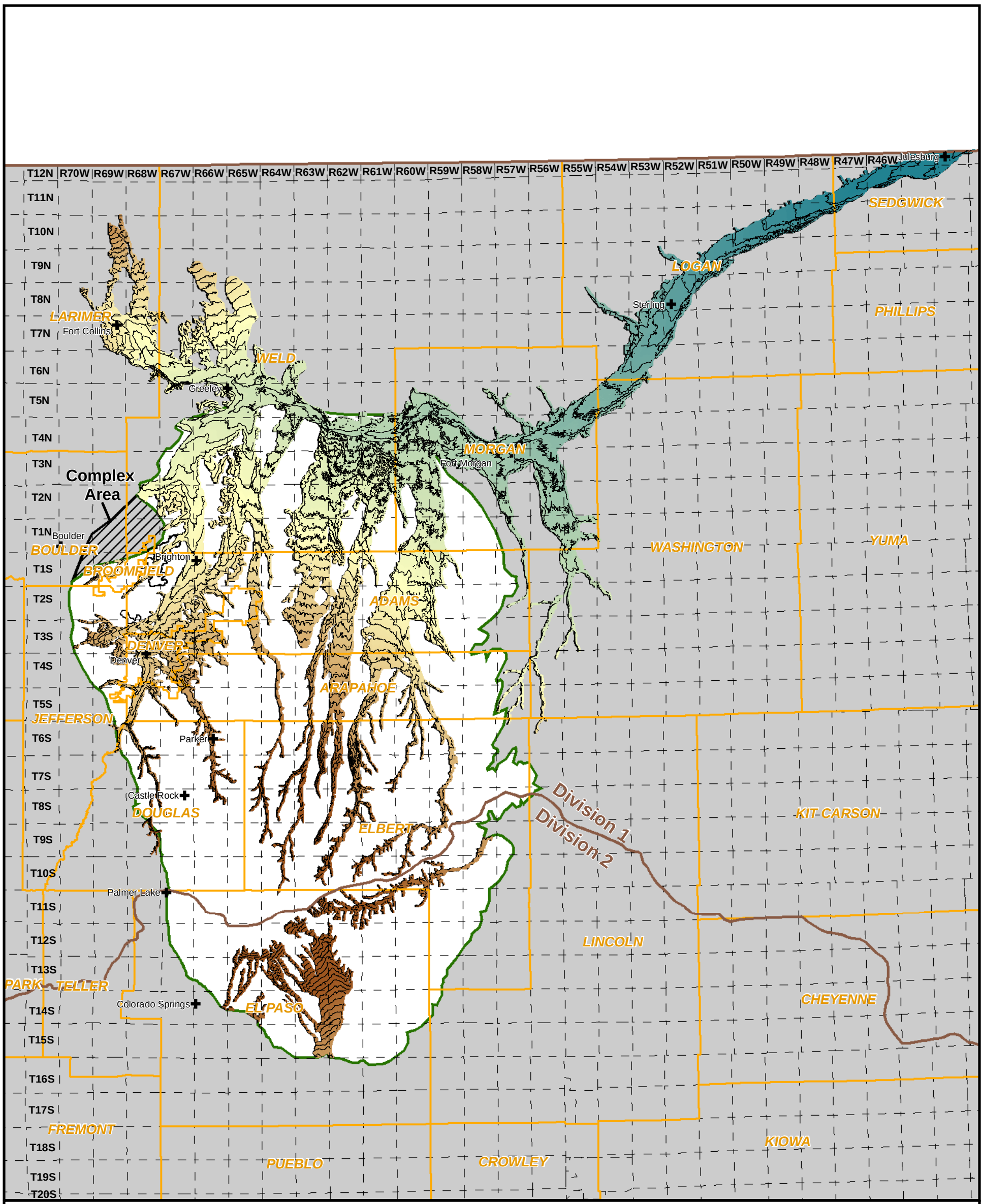
Figure 9: Ground Surface Elevations within the Alluvial Extent



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Scale
1:1,100,000

0 5 10 20
Miles

NAD 1983 UTM Zone 13N

City
County
Township
Alluvial Aquifer Extent
Denver Basin Extent

Ground Surface Elevation (ft)
High : 7301
Low : 3427
Elevation Contour (50-ft interval)

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Figure 10: Saturated Thickness of the Alluvial Aquifer

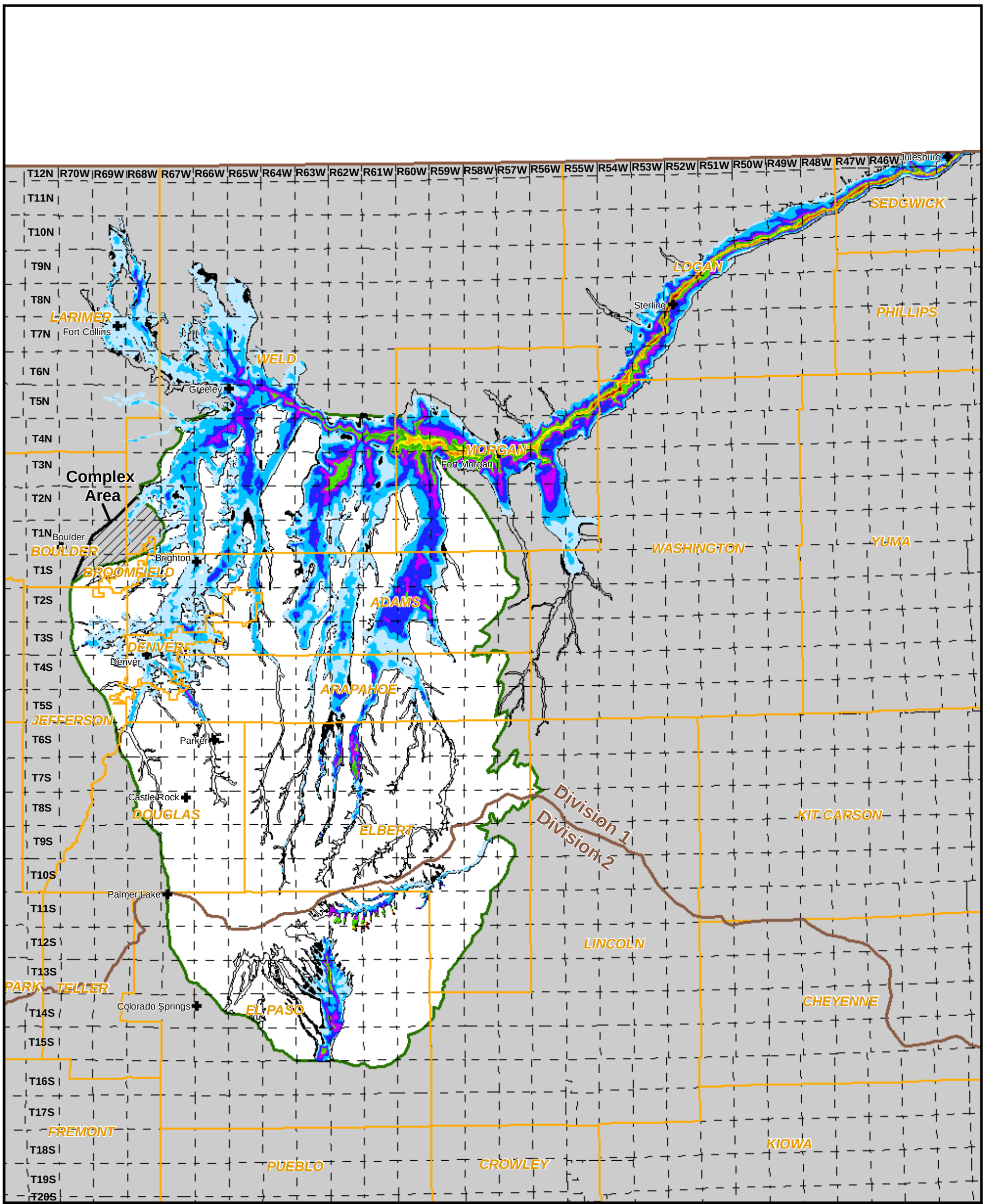

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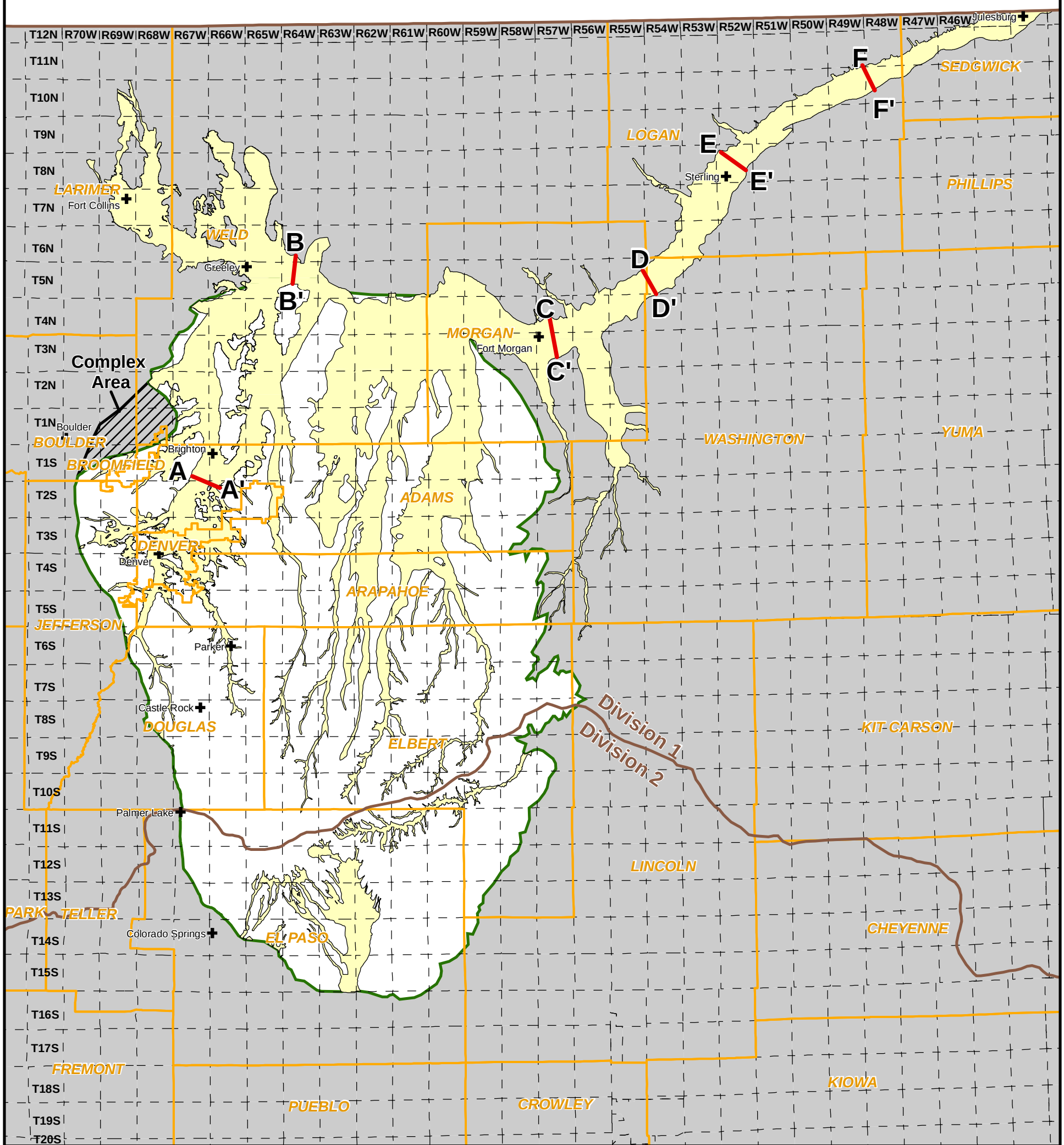
Figure 11: Plan View of Cross Sections for the Alluvial Aquifer



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Scale
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0 5 10 20
Miles

NAD 1983 UTM Zone 13N

City
County
Township
Alluvial Aquifer Extent
Denver Basin Extent
Cross Section

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Figure 12: Cross Section A-A'

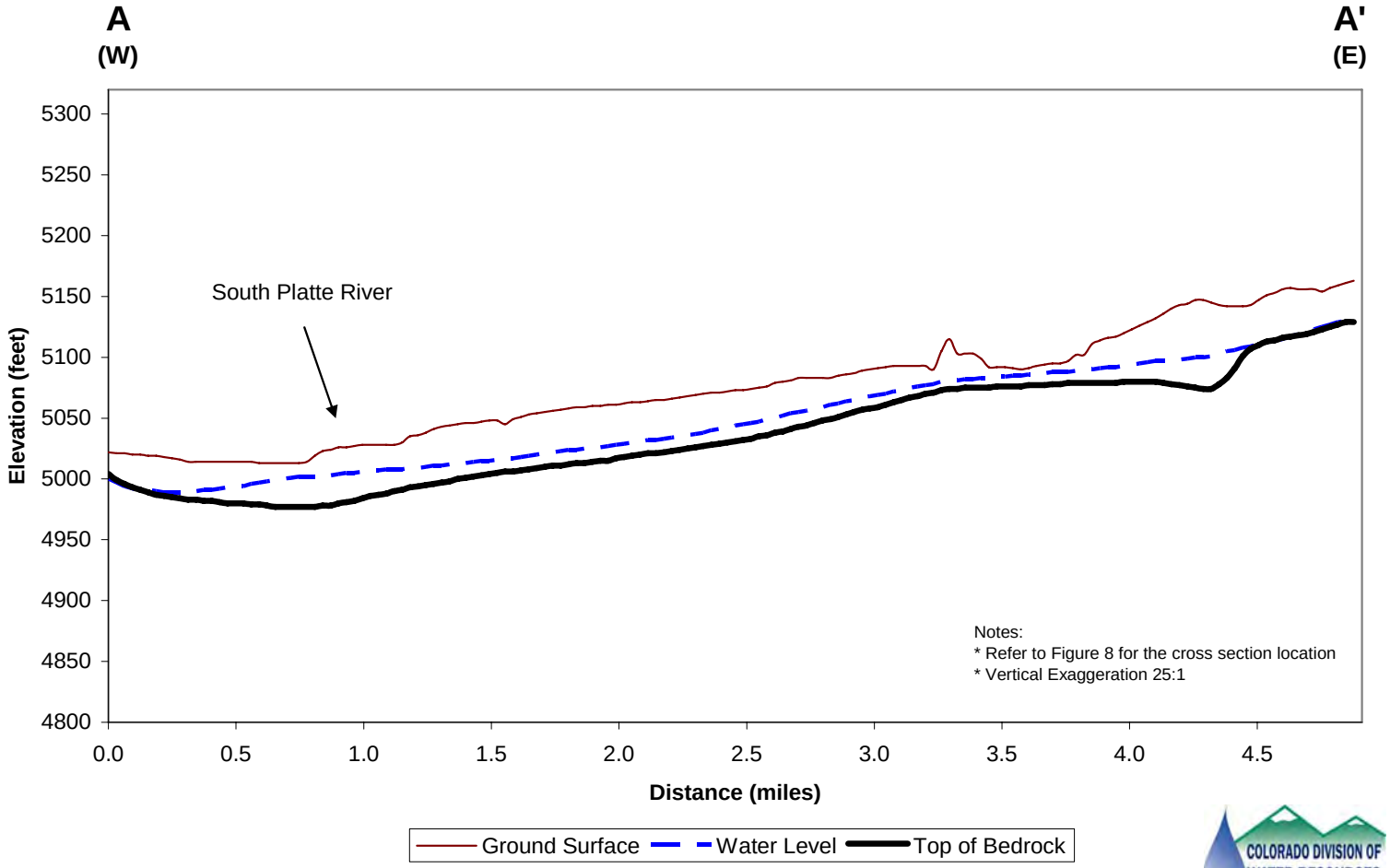

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Figure 13: Cross Section B-B'

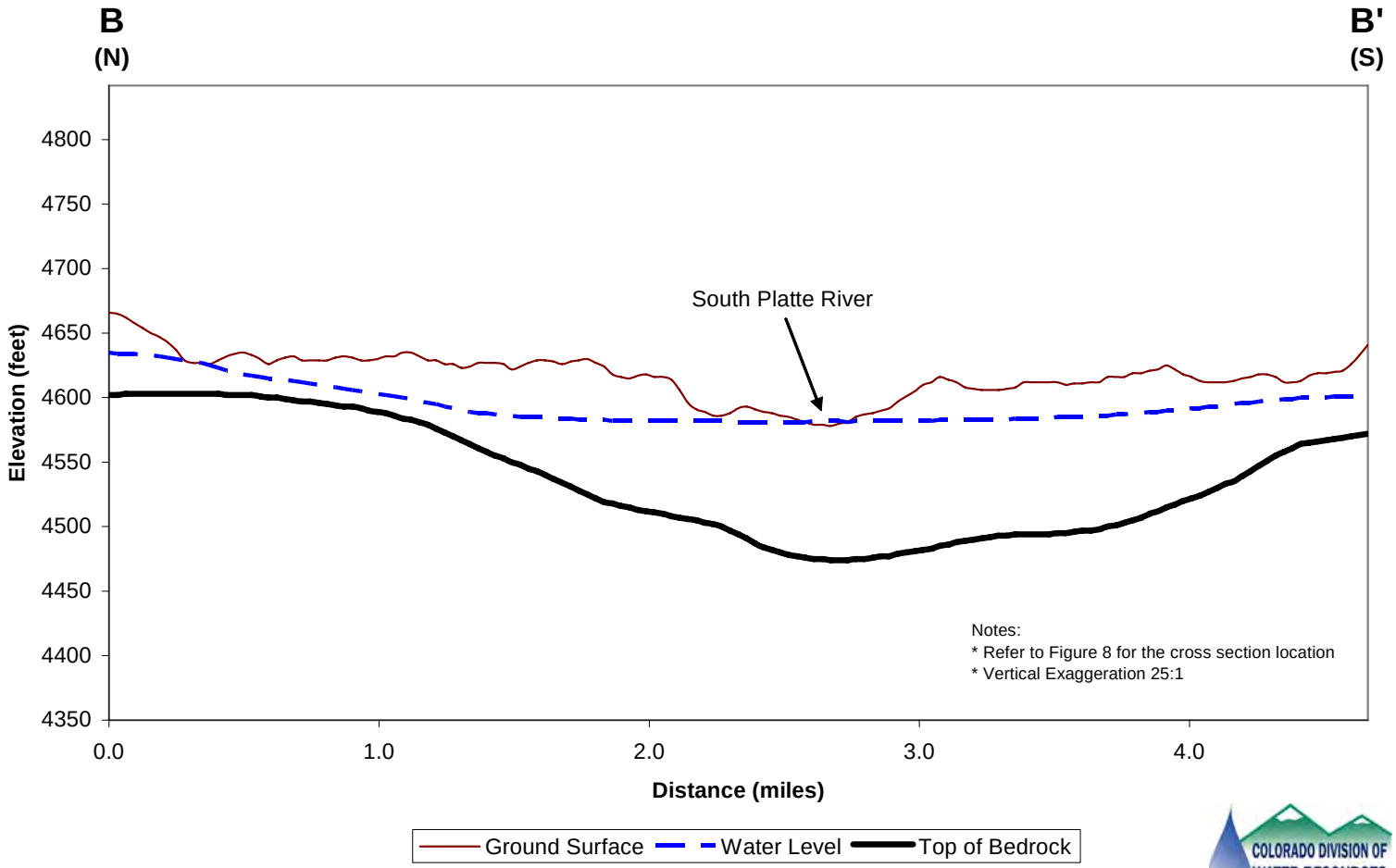

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Figure 14: Cross Section C-C'

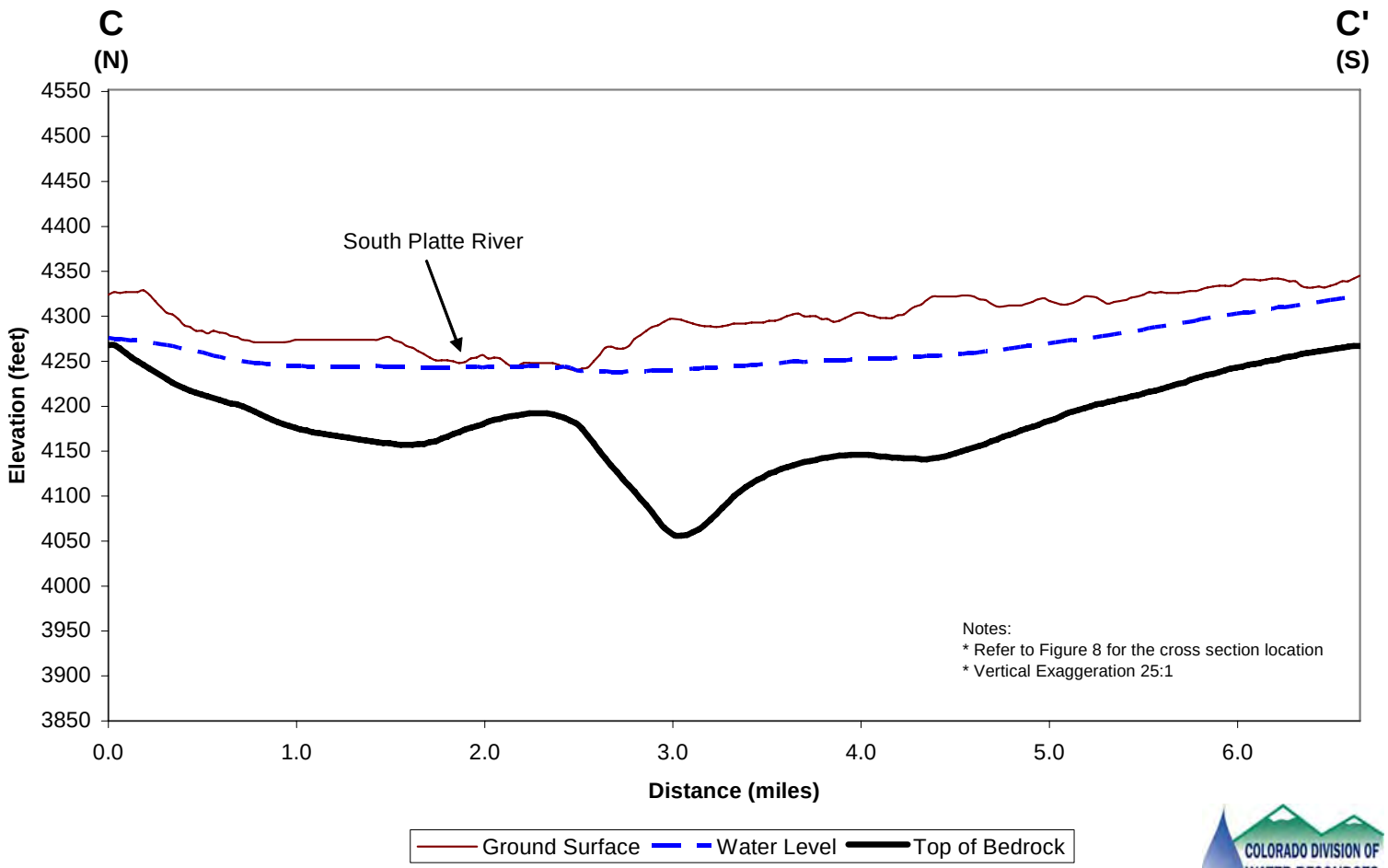

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Figure 15: Cross Section D-D'

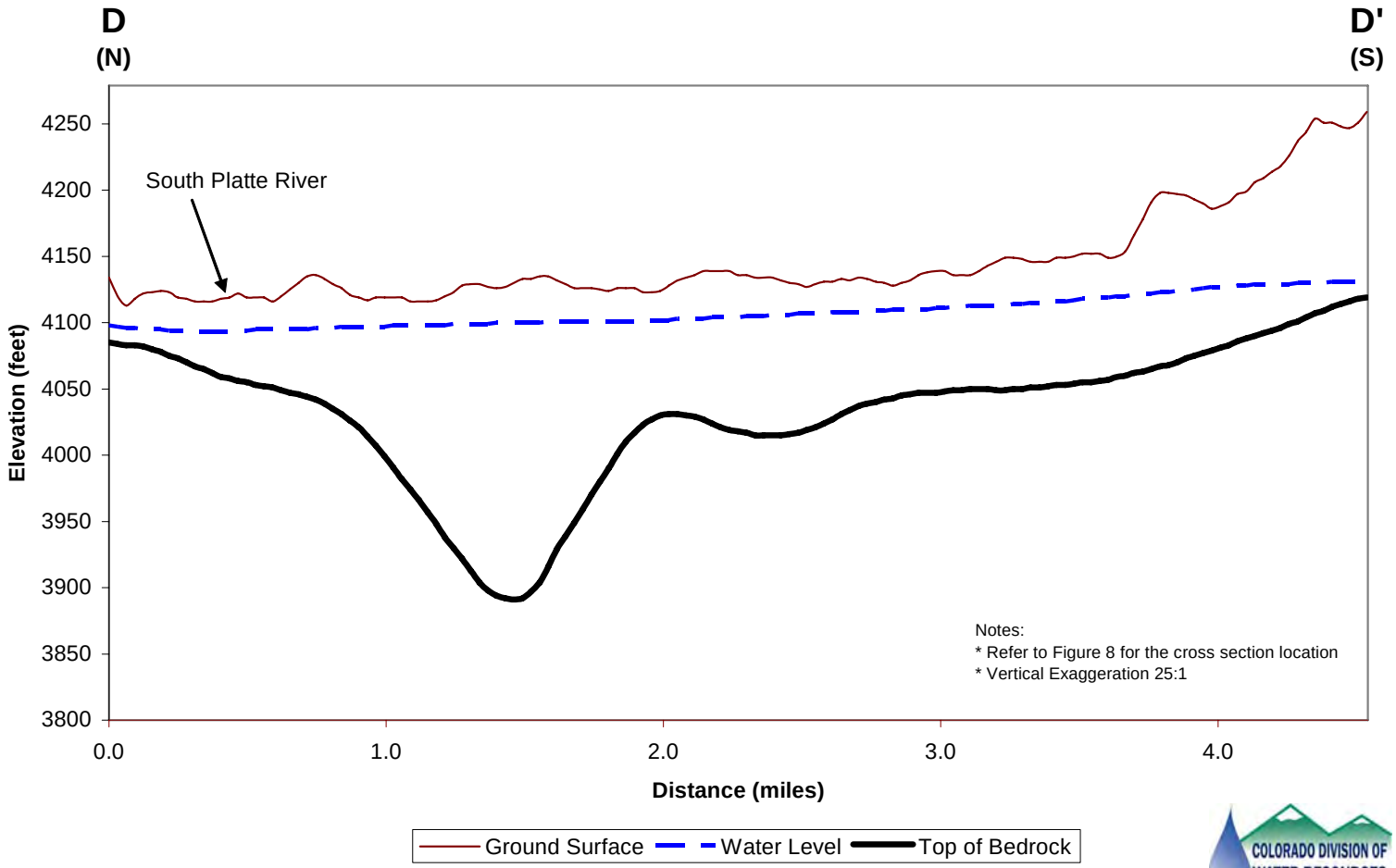

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Figure 16: Cross Section E-E'

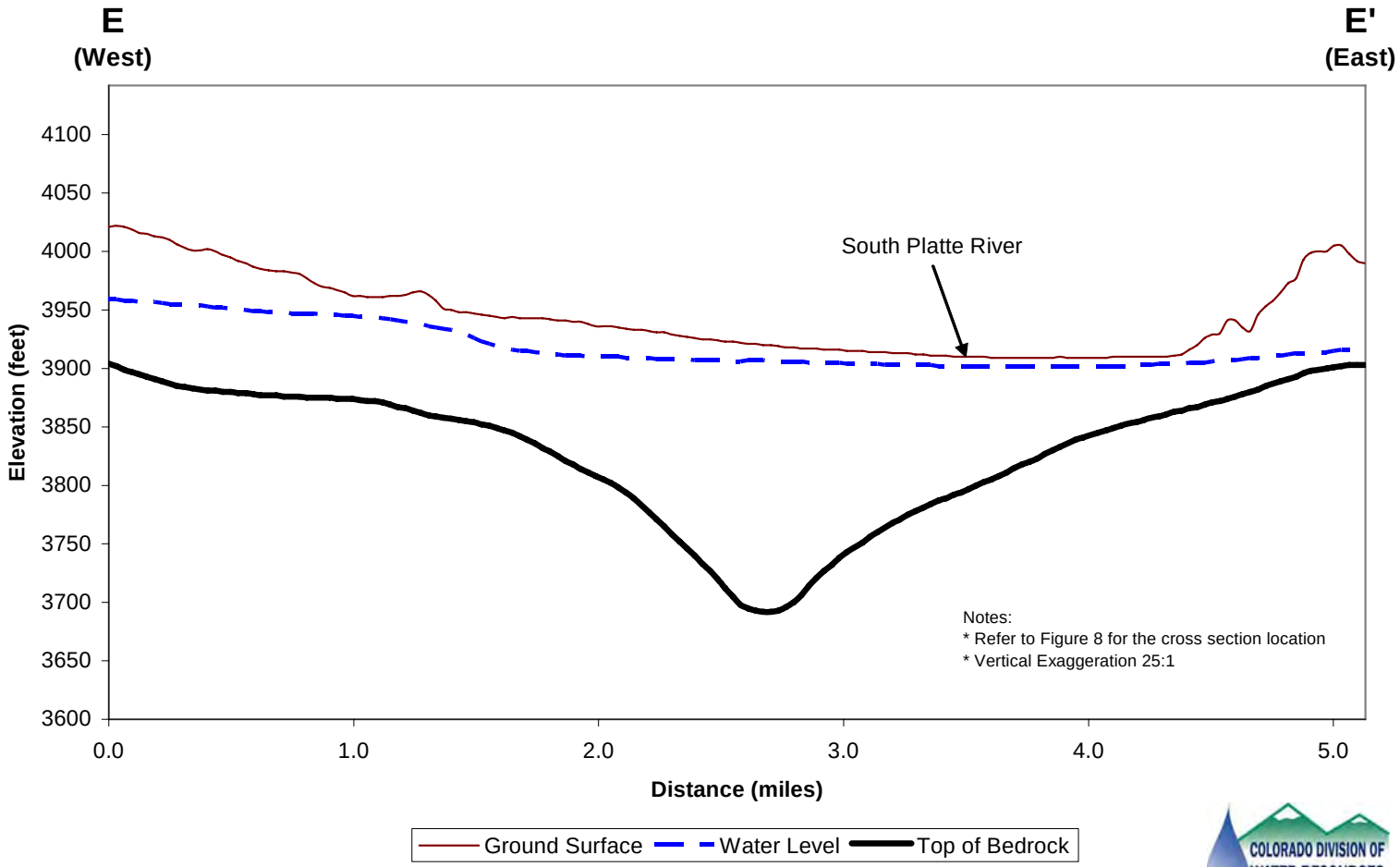

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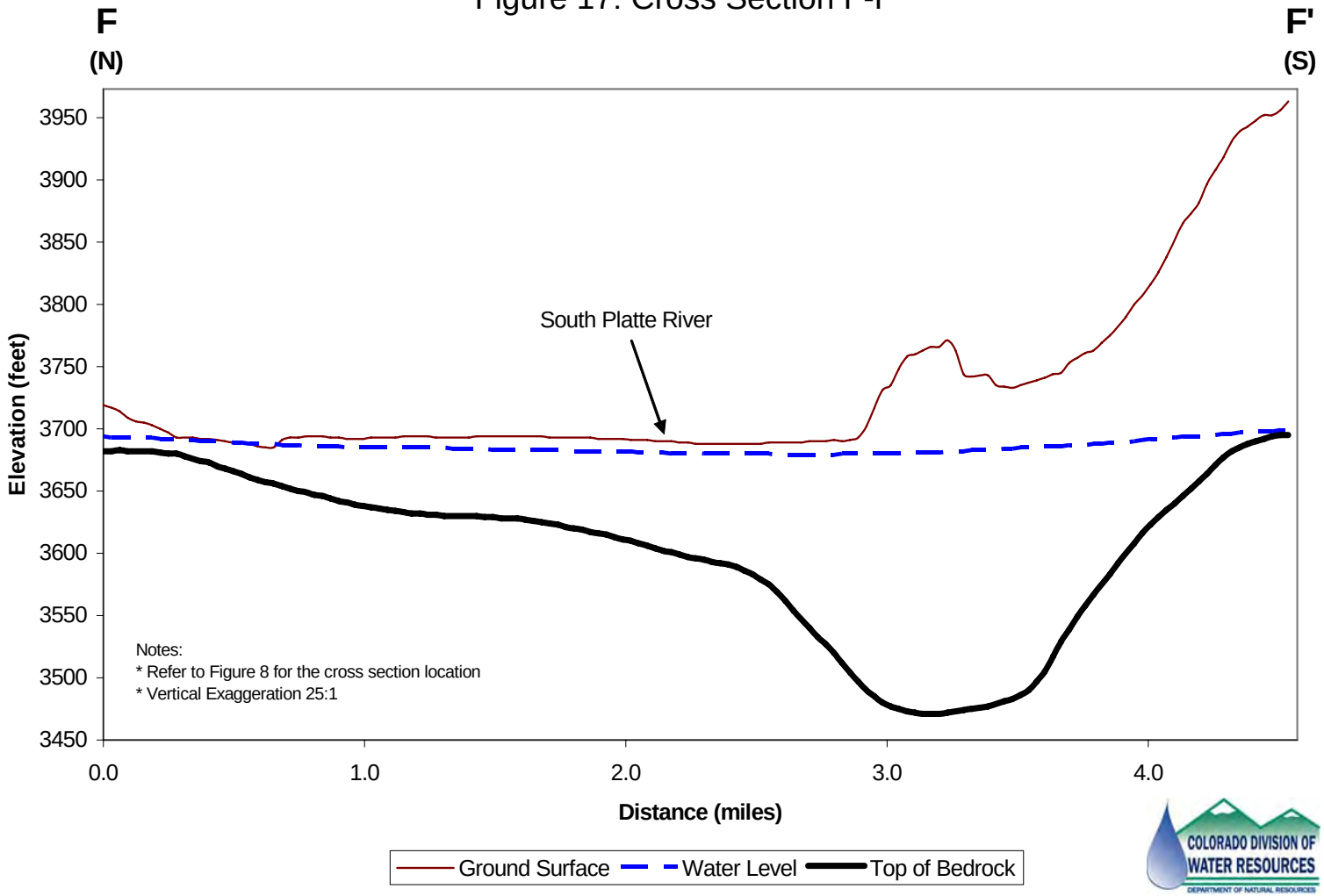
Figure 17: Cross Section F-F'



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Appendix A

Phase 3 Task 42.3, Data Directory for Aquifer Configuration Data in HydroBase

Appendix A
Data Directory for Aquifer Configuration Data in HydroBase

Table Name: *WELLS*	**Task:** Task 42, 43 and 44 of the SPDSS
Description: The core table in the database containing key information on wells including location, permit number, receipt, name, depth, aquifer tapped, and perforated interval.	
Field Name	**Field Description**
well_id	Well identifier.
well_name	Name of the well.
div	SEO Division number.
wd	SEO Water district.
receipt	Unique identifer. Generated by cash register.
permitno	Well permit number.
permitsuf	Well suffix code.
permitrpl	Well replacement code. Contains an 'A' for exempt, and 'R' for non-exempt.
locnum	USBR location identifier string.
Site_ID	USGS site identifier.
basin	Designated basin code.
md	Management district code.
cty	County code.
PM	Principle meridian.
ts	Township number
tsa	Half township indicator.
tdir	Township direction.
rng	Range number.
rnga	Half range indicator.
rdir	Range direction.
sec	Section number.
seca	Upper section indicator.
q160	160 acre quarter section indicator.
q40	40 acre quarter section indicator.
q10	10 acre quarter section indicator.
coordsns	Distance from north/south section line (feet).
coordsns_dir	Direction of measurement from north/south section line.
coordsew	Distance from east/west section line (feet).
coordsew_dir	Direction of measurement from east/west section line.
utm_x	The x (Easting) component of the Universal Transverse Mercator system. NAD83 Zone 13.
utm_y	The y (Northing) component of the Universal Transverse Mercator system. NAD83 Zone 13.
latdecdeg	Latitude (decimal degrees).
longdecdeg	Longitude (decimal degrees).
loc_accuracy	Horizontal location accuracy indicator.
gs_elev	Ground surface elevation.
elev_accuracy	Vertical location accuracy indicator.
well_depth	Completed depth of well (feet).
log_depth	Geophysical log measurement depth
log_type	Geophysical log measurement method.
log_SWL	Geophysical log measurement surface water level.
log_date	Geophysical log measurement date of measurement.
aquifer1	Aquifer in which well is located.

Appendix A
Data Directory for Aquifer Configuration Data in HydroBase

Table Name: *WELLS*	**Task:** Task 42, 43 and 44 of the SPDSS
aquifer2	If well is located in two aquifers, name of second aquifer.
aquifer_comment	Any comments associated with the aquifer(s) that the well transverses.
tperf	Depth to top of first perforated casing. (FEET)
bperf	Depth to base of last perforated casing. (FEET)
yield	Actual pumping rate. (GPM)
bedrock_elev	Elevation of bedrock.
sat_1965	
remarks1	Generic remarks.
remarks2	Generic remarks.
owner	Owner's fullname.
address	Address of owner.
city	City.
st	State abbreviation.
zip	Zip code.
phone	Phone number.
cell_phone	Cell phone number.
email	E-mail address or internet address.
collection_order	Water level collection number. Used to indicate route to gather WL measurements.
data_source_id	A unique identifer of the data. Either the Site_ID or the locnum string.
data_source	Source of data.
publish?	Boolean indicating if well is part of DWR's water level publications.
geoplog?	Boolean indicating if well is part of DWR's geophysical log archive.
modified	Date the record was last modified.
user	User who last modified the record.
cdm_id	TEMPORARY - Identifer originally given to well by CDM in SPDSS project.
cmd_modified	TEMPORARY - Date the record was last modified by CDM.

Table Name: *GEOPHLOGS*	**Task:** Task 42 of the SPDSS
Description: Table containing geophysical log picks determined by the DWR. This data is entered into the database such that for each log a separate record is used for each aquifer's picks.	
Field Name	**Field Description**
well_id	Well identifier.
aquifer	Aquifer.
logid	[Not Used]
glogtop	Upper elevation of the specified aquifer. (feet above sea level)
glogbase	Lower elevation of the specified aquifer. (feet above sea level)
glogthickness	Thickness of the sand. (feet)
Orig_1986	Boolean used to indicate if the well was used in the 1986 study.
Excl_glogtop	TEMPORARY - Flag used indicate if CDM was using the GLOGTOP value in the DSS.
Excl_glogbase	TEMPORARY - Flag used indicate if CDM was using the GLOGBASE value in the DSS.
Excl_glogthickness	TEMPORARY - Flag used indicate if CDM was using the GLOGTHICKNESS value in the DSS.
Comment	Comment field

Appendix A
Data Directory for Aquifer Configuration Data in HydroBase

Table Name: *GEOPHLOGS*	**Task:** Task 42 of the SPDSS
modified	Date record was last modified.
user	User who last modified the record.
cdm_modified	Date CDM last modified the record.

Table Name: *AQUIFER_PICKS*	**Task:** Task 42 of the SPDSS
Description: Table containing aquifer picks not determined by the DWR. This data is entered into the database such that for each log a separate record is used for each aquifer's picks.	
Field Name	**Field Description**
well_id	Well identifier.
aquifer	Aquifer.
top	Upper elevation of the specified aquifer. (feet above sea level)
base	Lower elevation of the specified aquifer. (feet above sea level)
thickness	Thickness of the sand. (feet)
Comment	Comment field
data_source	Source of data
modified	Date record was last modified.
user	User who last modified the record.
cdm_modified	Date CDM last modified the record.

Table Name: *REF_ELEV_ACCURACY*	**Task:** Task 42, 43 and 44 of the SPDSS
Description: Table containing lookup values for elevation accuracy codes.	
elev_accuracy_num	**Description**
1	Original database
2	USGS 30-meter DEM
3	Surveyed

Table Name: *REF_ELEV_ACCURACY*	**Task:** Task 42, 43 and 44 of the SPDSS
Description: Table containing lookup values for location accuracy codes.	
loc_accuracy_num	**Description**
1	Spotted from PLSS quarters
2	Spotted from PLSS distances from section lines
3	Surveyed
4	Digitized
5	Original database
6	GPS

Task 43.3 South Platte Alluvium Region Aquifer Property Technical Memorandum

SPDSS Phase 3 Task 43.3 South Platte Alluvium Region Aquifer Property Technical Memorandum
FINAL

To: Ray Alvarado, CWCB
From: Camp Dresser and McKee Inc.
Matt Bliss, Donavon Paschall, and Gordon McCurry
Subject: SPDSS Groundwater Component, Phase 3 Final Task 43.3
South Platte Alluvium Region Aquifer Property Technical Memorandum
Date: December 6, 2006

Introduction

The groundwater component of the South Platte Decision Support System (SPDSS) includes compiling and evaluating available relevant data to support the Decision Support System (DSS) for the South Platte River watershed, to add the data to HydroBase, the State of Colorado's hydrological database, and to present initial aquifer property model inputs for the alluvial groundwater model of the South Platte basin that is being undertaken in Task 48. The SPDSS study area is presented in Figure 1. For the purposes of the SPDSS, the groundwater study area is divided into two hydrologic regions. The Denver Basin Region includes the bedrock aquifers of the Denver Basin. The South Platte Alluvium Region consists of the unconsolidated deposits of the South Platte River mainstem, extending downstream from just below Chatfield Reservoir to the Nebraska state line near Julesburg. The South Platte Alluvium Region also includes the alluvium overlying the Denver Basin bedrock aquifers in Water Divisions 1 and 2.

The unconsolidated alluvial aquifers in the SPDSS study area consist of the South Platte River and its tributaries, as well as tributaries to the Arkansas River where they overlie the Denver Basin Region. From a hydrogeologic perspective, key tributaries in the SPDSS study area include East Plum Creek, Cherry Creek, Sand Creek, Clear Creek, Big Dry Creek, St. Vrain Creek, Big Thompson River, Beebe Draw, Cache la Poudre River, Lonetree Creek, Crow Creek, Box Elder Creek, Lost Creek, Kiowa Creek, Bijou Creek, Badger Creek, Beaver Creek, Upper Black Squirrel Creek, and Upper Big Sandy Creek, the last two of which are located in Water Division 2 and drain into the Arkansas River. The eastern and southern portions of the Denver Basin have been divided into several Designated Basins for the purposes of water rights administration. The Designated Basins within the Denver Basin Region include the Lost Creek, Kiowa-Bijou, Upper Black Squirrel, and Upper Big Sandy Creek Designated Basins.

This task was undertaken for the Colorado Water Conservation Board (CWCB) and Division of Water Resources (DWR), under Task 43 of Phases 1, 2 and 3 of the SPDSS by Camp Dresser & McKee (CDM). Task 43 of the SPDSS includes the collection, analysis, and mapping of existing published aquifer property data. The objectives of this task are as follows:

1. *Compile aquifer property information and create a HydroBase compatible database with data from the South Platte Alluvium Region.*
2. *Identify additional data needs in this region.*
3. *Enhance HydroBase with aquifer property data collected during the SPDSS field activities.*
4. *Analyze and map the aquifer property data obtained.*
5. *Collect data to support future development and calibration of a groundwater model.*

This Technical Memorandum (TM) summarizes the compilation, analysis, and mapping of existing published aquifer property data for the alluvial aquifer systems in the South Platte Alluvium Region that were undertaken in Task 43.1. In addition, initial aquifer properties model inputs were generated and are presented in this document. A draft final version of this TM has been reviewed by a technical Peer Review Committee; their comments are reflected in this final version.

Approach

The following table summarizes the sections contained in this TM and identifies which section pertains to the objectives outlined above.

Section	Description
1.0	Aquifer Property Data Collection and Analysis:
1.1	Sources of Data
1.2	Data Analysis and Processing
2.0	Aquifer Property Database
2.1	Database Structure
2.2	Database Quality Control
3.0	Results
3.1	Hydraulic Conductivity Data
3.2	Transmissivity Data
3.3	Specific Yield and Storage Coefficient Data
4.0	Summary and Conclusions
5.0	Recommendations
6.0	References

1.0 Aquifer Property Data Collection and Analysis

Aquifer properties are the key parameters that describe the potential for groundwater flow and the water bearing capacity of an aquifer. These are transmissivity, hydraulic conductivity, and storage coefficient (S). Transmissivity (T) defines the flow potential through a unit width of the entire saturated thickness (b) of an aquifer under a unit hydraulic gradient. T measures the ability of the aquifer to transmit groundwater throughout its entire saturated thickness (b). Typical units of measurement are gallons

per day per foot of drawdown (gpd/ft) and square feet per day (ft^2/day). Hydraulic conductivity (K) defines the flow potential through a unit area of an aquifer, perpendicular to the direction of flow. K can be calculated by dividing T by b. Typical units of measurement of K are feet per day (ft/day). The storage coefficient (S) defines the amount of water that a unit volume of an aquifer can supply under a unit change in groundwater level. For unconfined aquifers, such as exist in most of the South Platte Alluvium Region, S is called the specific yield (S_y). Specific yield represents the drainable water volume of a unit volume of an unconfined the aquifer. S and S_y parameters are unitless, and typical values for an alluvial aquifer range from 0.01 for a clay to 0.30 for a coarse sand (Freeze and Cherry 1979, Driscoll 1986).

Data Flow Process

Throughout this task, aquifer property data were obtained from HydroBase and newly identified data sets were added to a temporary HydroBase-compatible SPDSS database used for this study. This SPDSS database was queried for aquifer property data and analyzed. The data in this TM are presented in several forms to depict spatial aquifer property trends. The HydroBase-compatible SPDSS database will be submitted to the State's SPDSS project manager upon completion of this task so that all new data can be incorporated into HydroBase by the DWR.

The following section describes the approach used to collect, analyze, and map aquifer property data for the South Platte Alluvium Region.

1.1 Sources of Data

Alluvial aquifer property data available for the South Platte Alluvium Region were obtained from a variety of published and unpublished sources requiring varying degrees of analysis. Published sources include data reports by the CWCB, the U.S. Geological Survey (USGS), and conference proceedings related to the South Platte. Unpublished sources include DWR well permit data and consultant reports provided to the SPDSS by cooperating entities.

Alluvial aquifer property data collected through this task include aquifer tests from Wilson (1965), Smith et al. (1964), McConaghy et al. (1964), Bjorklund and Brown (1957), DWR well permit database, and Hurr and Schneider (1972 a-f). The Wilson (1965) report contains information on aquifer T and K at specific locations determined from aquifer tests that were conducted during the 1950s and early 1960s. T, K and Sy data was obtained from two additional sites from an aquifer test conducted at the Tamarack Ranch Wildlife Area located in Logan County (Fox , 2003). In addition to these two aquifer property data points, Fox also references a streambed conductance value that will be included in the upcoming SPDSS Phase 3 Task 34 Streambed Conductance TM. The Hurr and Schneider reports (1972a-f) are a significant source of contoured T data for the South Platte Alluvium Region and were digitized for use in this task. Field data and solicited data from various entities were also collected and are described in greater detail in the Phase 2 Task 35 (SPDSS alluvial field program) and Task 37 (aquifer test solicitation) data collection TMs (CDM 2005a, CDM 2005b). Under Task 37 (CDM 3005b), aquifer tests were solicited from the State of Colorado Division of Wildlife (CDOW 2003), municipalities, and private entities who provided data and results from 30 aquifer

tests. Aquifer test results obtained from municipalities and private entities were generally received in the form of consultant's reports, which are listed in the Task 37 TM. Data obtained in Task 37 were subjected to a screening process described in the Task 37 TM (CDM 2005b).

The alluvial groundwater model domain developed under Task 48 does not include Upper Black Squirrel and Big Sandy Creeks, as they are in Water Division 2. Data collected in these drainages was not used in the analysis or contouring of aquifer properties presented in this TM.

Sources of data vary in their level of supporting documentation. Table 1 provides a summary of the sources used and the total number of individual aquifer property data points (tests) obtained. A summary of the data screened from use in this report is provided in Appendix A.

Table 1: Alluvial Aquifer Property Data Points by Test Type and Data Source

	Aquifer Pumping Test			Specific Capacity	Lab		
Source	**T**	**K**	**S/Sy**	**T**	**K**	**Sy**	**Total**
Basic Data Report 16 (Weist, 1964)	0	0	0	4	0	0	4
Bjorklund and Brown, 1957	8	8	8	0	0	0	24
Fox, 2003	2	2	2	0	0	0	6
McConaghy et al., 1964	0	0	0	220	73	63	356
McGovern, 1964	1	1	0	0	0	0	2
Nelson et al., 1967	5	5	0	0	0	0	10
Schneider, 1962	0	0	0	21	0	0	21
SEO Well Permit Database	0	0	0	449	0	0	449
Smith et al., 1964	41	41	20	0	0	0	102
South Metro Study (Mulhern, 2003)	1	1	0	0	0	0	2
SPDSS Task 35	13	13	13	0	0	0	39
SPDSS Task 37 (CDM, 2005b)	27	27	9	0	0	0	63
Tamarack Groundwater Model (CDOW, 2003)	3	3	3	0	0	0	9
Thornton Northern Project Study (RMC, 1991)	4	4	4	0	0	0	12
Wilson, 1965	69	69	4	0	0	0	142
TOTAL	174	174	63	694*	73	63	1241

*Note: Saturated thickness was not available for 40 of the 694 specific capacity tests. K was not calculated at these locations.

Alluvial aquifer property data have been categorized in this TM into four types, according to their source: aquifer pumping tests, specific capacity tests, previously contoured data, and laboratory geotechnical analyses. The general reliability of aquifer property data decreases in order of aquifer pumping tests, specific capacity tests, contoured data, and lab tests for the reasons presented below.

Aquifer pumping tests, as defined in this TM, are generally performed by collection of multiple water level measurements during drawdown and recovery as a well is pumped and after cessation of pumping, respectively. The pumping period may be on the order

of hours to several days, resulting in a high-resolution data set that may consist of hundreds of data points measured with automated high-precision equipment. The longer a well pumps, the more extensive its radius of influence becomes and thus the volume of aquifer tested becomes greater and more representative of bulk aquifer conditions than a shorter duration test. Additionally, potential bias due to well-bore storage will diminish with time. The detailed pumping data are then subjected to analysis during which any interference or potential biases can be determined and accounted for during the interpretation. For these reasons, results from aquifer pumping tests provide the highest level of certainty relative to the other types of data presented here.

A total of 13 alluvial aquifer pumping tests were conducted as part of the SPDSS Task 35. These tests were performed in each case with a high capacity irrigation well used as the pumping well, and drawdown was monitored in a nearby observation well. The observation well was either installed under the Phase 1 Task 35.1 field investigation or was an existing well available for use as an observation well. An additional 27 aquifer test results conducted in the alluvial aquifers of the study area were acquired from cooperating entities under Task 37 in Phase 2 (CDM 2005b). Additional sources of pumping test data are presented in Table 1.

Specific capacity test values, expressed in terms of pumping rate divided by drawdown, were obtained from the DWR well permit database and other sources (see Table 1), for a total of 694 tests within the study area. Specific capacity data can be converted to aquifer T, as described in Section 1.2.1. During a specific capacity test, water level measurements are usually collected only at the beginning and end of a generally shorter-duration test lasting on the order of several hours. Due to the shorter test duration (often 1 to 4 hours), the volume of aquifer tested is typically less than that of a longer-term aquifer pumping test so the tests results are representative of a smaller portion of the aquifer than are results from a longer pumping test. In addition, drawdown measured at the pumping well as part of a specific capacity test are influenced by well inefficiency, which is not accounted for in this analysis. As described above, tests of longer duration provide data that are more representative of the surrounding aquifer and provide water levels more representative of equilibrium conditions. For this reason, tests lasting longer than 2 hours were selected for analysis. While considered to be an acceptable approximation of the aquifer T, this specific capacity methodology has a lower level of certainty than an aquifer pumping test. Specific capacity test data were used to supplement the limited number of aquifer test-derived data points available and provide a broader distribution of data. Since specific capacity data are considered less reliable than aquifer pumping tests, additional analysis was performed on the specific capacity data set to identify which of these data should be included for further evaluation and mapping. This analysis is presented in section 1.2.4

A third category of aquifer property data used in this report is contoured data for which the underlying point values are not available. Contoured T data from Henderson to the Colorado-Nebraska state line were obtained from the series of reports by Hurr and Schneider (1972a-f), hereafter referred to as the Hurr and Schneider reports. The source data used to generate the contours presented in these reports are not available, the

methods used to calculate the source data are unknown, and efforts to contact others who worked on the project have been unsuccessful. It is assumed that aquifer test data available in previous reports (Wilson 1965, Smith et al. 1964, McConaghy et al. 1964, Bjorklund and Brown 1957) were used in preparation of the Hurr and Schneider reports. In addition to aquifer test-derived T values, it is assumed that Hurr and Schneider (1972a-f) used well-specific capacity data to estimate T values. Regardless of how the T values were calculated during preparation of the reports, the data would have been smoothed and contours would have been interpolated from the data points. Comparison of the Hurr and Schneider T values to aquifer test-derived data points have been performed and the results determined to be acceptable (CDM, 2005a). The Hurr and Schneider T contours are compared to the T data collected, analyzed and mapped under this task and is presented in Section 3.2.1

The final category of aquifer property data, laboratory testing of aquifer materials, directly examines the physical properties of a sample of the aquifer material. Laboratory data obtained during SPDSS Phase 1 field work have been presented (CDM, 2004a and CDM, 2004b), and were determined not to be representative of large-scale aquifer properties, and are not presented herein. Laboratory-derived data are of a lower level of confidence than other values due to either the potential for degradation of the sample due to inadequate methods of collection, preservation, and analysis; or that core samples may represent a very small portion of a heterogeneous aquifer. In a heterogeneous aquifer consisting of interbedded clay, silt, sand, and gravel, a core sample could represent the properties of any one of these materials rather than the bulk aquifer property. Aquifer property values obtained from core samples, in conjunction with drilling logs such as those presented in CDM, 2005a, have been useful in developing a conceptual understanding of the South Platte Alluvial Aquifer's interbedded nature and will assist in assigning an anisotropy value in a groundwater model. Lab data are also useful for determining the range of aquifer property values anticipated to exist within an aquifer. In general, the aquifer property values of interest to the regional groundwater modeler will be the bulk aquifer properties rather than the properties associated with individual beds within the aquifer.

Aquifer property values obtained from each of the different data types are indicated in the SPDSS database, which will be incorporated into HydroBase and categorized by type in the 'pt_type' field of the pumping_test table. Data obtained from contoured data are not provided in the SPDSS database but will instead be included as separate GIS shapefiles.

1.2 Data Analysis and Processing

Data collected throughout this task have been used in the aquifer property analysis and mapping presented in this TM. Data came from a variety of sources, resulting in the aquifer T or K data being reported in several different types of units or needing to be calculated from the information provided. In addition, a majority of the aquifer property data was derived from specific capacity data. To create a consistent basis for evaluating and presenting the data, aquifer T or K data were converted to consistent units of feet for length and days for time. This section describes the methods used to obtain an internally

consistent aquifer property data set. The queries used to obtain the final data set are provided in Appendix A.

1.2.1 Specific Capacity Data Analysis

In order to analyze specific capacity data obtained from scanned images in the DWR well permit database, a linear regression equation was developed by plotting specific capacity values and T values derived from the same aquifer test. Only tests conducted in the unconfined alluvial aquifers of the South Platte River and its tributaries from Denver to Julesburg were used in the analysis. Development of the linear regression is detailed below.

Data from the following sources were combined to provide a total of 122 data points with both specific capacity and aquifer test data at a given location: Bjorklund and Brown, (1957); McGovern, (1964); Nelson et al., (1967); Smith et al., (1964) and Wilson, (1965). The majority of the data are from Wilson, (1965), which reports 24-hour specific capacity values along with pumping test data. The specific capacity tests from Smith et al. (1964) and Nelson et al. (1967) are of varied duration but exceed two hours to minimize the influence of rapid drawdown in the early stages of a test.

Note that T varies with changes in water levels and that T values from different time periods were used together in the linear regression. An analysis of water levels for the South Platte alluvium conducted under Task 44 indicates that aquifer water levels have changed relatively little in most areas since the 1960s. Therefore, T values computed at different times can in this case be combined into a single database with little error.

The linear trend of specific capacity versus aquifer test-derived T values suggested there was no need to differentiate between tests performed in the South Platte mainstem alluvial aquifer and its tributaries (Figure 2). A relationship was developed between T and specific capacity using linear regression techniques applied to the data, with a straight-line fit forced through the origin. The regression analysis resulted in the following equation :

$$T = 1.64 \times \text{Specific Capacity}$$

that has an R-squared value of 0.74. The R-squared value indicates how closely the data fits the trend line. An R-squared value of 1 is a perfect trend line fit.

Several data points were evaluated further because the regression equation did not fit these points well. Based on analysis of the pumping curves and other supporting documentation, none of these data points were excluded from the regression curve or the R-squared value provided above.

The R-squared of this linear regression line is 0.74, a reasonable fit considering the varying locations, test duration, and sources of data. No points originally identified for use in the regression analysis were excluded, even if the value differed from the general trends seen in the rest of the data set. Figure 2 presents the specific capacity data and trend line fit. All data used to develop the trend line are contained in HydroBase. This

linear regression equation was then used to calculate T values for the specific capacity tests obtained from the DWR Well Permit database and other sources of specific capacity data (see Table 1).

1.2.2 Conversion of Transmissivity Data to Hydraulic Conductivity Values

Many sources of data present only T results. T is the parameter that is provided from analytical equations used for aquifer pumping tests and also from specific capacity data. T is the product of two physical characteristics of an aquifer: hydraulic conductivity (K) and saturated thickness (b). K characterizes the potential for flow through a unit volume of the aquifer material. K is also used as a direct input to groundwater flow models, so it is necessary to convert all of the T data into K values for use in groundwater modeling.

T values, expressed in units of gpd/ft, were converted to K values by converting T data into units of ft^2/day and dividing by b. Explicit well data were used to estimate b where available (i.e., b was given in the source report, screened interval length was given, or a calculation could be made using water level elevation minus well depth elevation). Saturated thickness was estimated from Task 42 aquifer configuration saturated thickness maps for those wells without explicit saturated thickness data. Although the time period represented in the aquifer configuration maps may differ from the specific capacity test date, fairly consistent year-to-year water levels throughout the alluvial SPDSS study area (as shown in the SPDSS Task 44.3 TM) make this a reasonable method for estimating b. For solicited aquifer tests, either b was provided with the data or an explicit value for K was given.

1.2.3 Identification and Screening of Anomalous Data

Aquifer T or K values that did not appear reasonable or were located outside the saturated alluvium in the study area were screened from further analysis. Examples of unreasonable data include 1) a drawdown greater than the b reported in the Task 42.2 TM; and 2) an unlikely drawdown, such as less than 1 foot per 400 gpm (or a specific capacity of over 400 gpm/ft) reported on well driller's logs. This threshold was selected because the highest specific capacity value derived from alluvial aquifer pumping tests in the South Platte Basin is 328 gpm/ft. Data that have been eliminated from further analysis are summarized in Table 2 and tabulated in Appendix A.

Table 2: Summary of Alluvial Aquifer Property Data Points Excluded from Analysis

	Aquifer Pumping Test			Specific Capacity	Lab		
Reason for Exclusion	**T**	**K**	**S/Sy**	**T**	**K**	**Sy**	**Total**
Depth to Water > Well Depth	0	0	0	1	0	0	1
Duplicate Test	4	4	1	2	0	0	11
Outside SPDSS Study Area	3	3	1	0	0	0	7
Specific Capacity > 400 gpm/ft	0	0	0	28	0	0	28
Screened Interval Below Bottom of Well	0	0	0	4	0	0	4
Test Drawdown > Saturated Thickness	0	0	0	67	0	0	67
Test Duration < 2 Hours	0	0	0	23	0	0	23
Test Duration Not Provided	0	0	0	3	0	0	3
TOTAL	7	7	2	128	0	0	144

1.2.4 Generation of Contouring Data Set

To present the data in mapped format and to prepare for modeling of the alluvial aquifer system, aquifer properties were processed, gridded and contoured. Data processing included analysis of specific capacity tests, further evaluation of extreme data values, and evaluation of the spatial variability of the data. Gridding is the process by which randomly scattered data are projected onto a uniformly spaced grid using an interpolation algorithm. Gridding is required to provide a data set that can be contoured and to provide groundwater models with aquifer property data at each model cell. Smoothing of highly variable data was undertaken during the gridding process by specifying the interpolation method and by the addition of engineering control points to areas of sparse data and, in some cases, near alluvial boundaries.

Specific capacity data is much more abundant than aquifer pumping test data due to the significantly lower cost of specific capacity tests. However, the data is generally considered less reliable than aquifer pumping test data. Therefore, additional analysis was performed to substantiate the usefulness of the specific capacity data set. This analysis resulted in a subset of specific capacity data to be used in gridding and contouring.

Figure 3 presents box plots showing the minimum, lower quartile (Q1), median, upper quartile (Q3), and maximum of different subsets of K data, Examination of the quartiles reveals that specific capacity-based K values are biased low relative to the more reliable aquifer pumping tests. Since both specific capacity tests and aquifer pumping tests measure the same alluvial aquifer system, the bias in the specific capacity data warranted further investigation.

It was hypothesized that the duration of the specific capacity test, or even the manner in which the saturated thickness was calculated at a given well could account for the low bias. However, a statistical analysis performed on these parameters showed no conclusive bias in the tests.

The data was then analyzed by test flow rate, comparing specific capacity tests on high capacity wells to those on low capacity wells. High capacity wells are defined as wells with flows of greater than 50 gpm used during the specific capacity test. The high capacity wells (360 tests) have a K distribution similar to the aquifer pumping tests, while the low capacity wells (166 tests), in general, have much smaller K values. The smaller K values in the low capacity wells suggest that these tests were performed on wells that are likely to have less efficient communication with the aquifer and thus under-represent aquifer K. The low capacity wells are distributed throughout the alluvial aquifer and generally in the vicinity of high capacity wells or pumping test sites, so it is unlikely that the smaller K values are due to the aquifer having a lower K in locations corresponding to those wells. The specific capacity tests performed on low capacity wells were excluded from the gridding data set. A list of these tests can be found in Appendix B.

After excluding the specific capacity tests from low capacity wells, the data set was evaluated for extreme values. Inclusion of inaccurate data can have large impacts when gridding and contouring the data. Data points with K greater than 2000 ft/day are considered extreme and physically improbable given the geologic makeup of the South Platte alluvial aquifer. Inclusion of data that is most likely inaccurate can have severe impacts when gridding and contouring the data. A total of 13 data points were excluded from the gridding data set based on this criterion. A list of these exclusions can be found in Appendix B.

Engineering control points were introduced to the data set in areas where little or no data exist and also along key alluvial boundaries. Engineering control points constrain the gridding process to reasonable values and reduce errors caused by the numerical algorithms involved in gridding. Control points in areas of little or no data allow the gridding process to assign aquifer properties to each grid cell in those areas where no actual data exist. The Kiowa and Bijou basins are examples of where this type of engineering control points were used, as only one pumping test exists in these basins.

Control points were also placed along alluvial boundaries of basins that are located adjacent to other basins having different hydrogeologic properties. This was done to prevent one basin's properties from inadvertently influencing the properties of neighboring basins during the gridding process. An example of this type of control point is near the confluences of the western tributaries and the South Platte River. The available data indicates that the alluvial aquifer in the mainstem of the South Platte River has higher values of K than its tributaries; therefore engineering control points were added in locations to minimize the influence of one area's hydraulic properties on the other. Control points were not placed in alluvial channels adjacent to other channels with similar properties. This decreases the number of control points used, but allows influence from the adjacent channel.

A total of 320 engineering control points were added to the K data set prior to gridding. Values for the control points were determined by calculating the median value of K from available data for each specific basin or from averages presented in published reports. A summary of these values, counts and locations is presented in Appendix B.

The final gridding data set for K consists of 826 points, of which 156 are pumping tests, 350 are specific capacity tests and 320 are engineering control points. The engineering control points are shown on the detailed maps of K and T presented in Section 3. The data is log-normally distributed, so in order to use linear interpolation methods the data needed to be converted to log space, gridded and then converted back to linear space. Data was gridded onto a regular grid with 1000-meter spacing using a kriging algorithm. Due to the highly variable nature of the data, a 'nugget' was used in kriging. The nugget allows the kriging algorithm to smooth data as it interpolates to each grid location. The gridded values were then contoured, the contours were saved as a shapefile, used for figures and included as a final product of this TM. The gridded data will be used as input in the Task 48 groundwater modeling. Further details of the gridding algorithm using kriging, the data exclusions and engineering control points are presented in Appendix B.

Transmissivity contours were then generated by multiplying the K grid by the saturated thickness grid. The saturated thickness grid was developed in Task 42.3 with modification by CDM in limited areas where data was provided by the USGS as part of their Denver Basin groundwater model (in progress as of date of this TM). This is an example where the State and USGS have cooperated in an effort to develop models that are consistent in the areas where the models overlap. T data was not explicitly gridded because, unlike K, it depends on two variables (saturated thickness and K) rather than just one.

Specific yield (Sy) values are less abundant than K and T data. Due to the limited number of data values and the elevated level of uncertainty associated with interpreting Sy data as being representative of bulk aquifer properties, the Sy data are not contoured but are shown as point values.

1.2.5 Aquifer Property Mapping

Aquifer K, T, and Sy data maps were prepared to present the aquifer property data in graphical format. Analysis steps taken to prepare these figures are presented in this section, while discussion of the results can be found in section 3.

Both K and T data are each mapped in a series of six figures. Figure 4 is a spatial index to each figure's location. The first figure in each series shows the contoured K or T results for the entire alluvial study area. Color-coded point data is presented along with aquifer property contours in these figures. The presentation of smoothed contour lines with the raw data provides a useful tool for users to evaluate regional aquifer property trends against local heterogeneity that can exist at any given location. This presentation fulfills two primary objectives of this TM; to analyze and map the aquifer property data obtained, and collect data to support future development and calibration of a groundwater model.

Figures 5a-f present K maps. K point data are color-coded by quartile, each quartile grouping containing an equal number of data points, with each grouping based on the numeric range of K. This grouping was done to help distinguish the major trends in aquifer K. The data groupings are defined with blue representing K values greater than the 75th percentile (the highest 25 percent), green representing the 50th to the 75th percentile values, orange representing the 25th to the 50th percentile, and red representing values less than the 25th percentile. The contour interval used on these maps is 50 ft/day. The first map in this set shows K for the entire study area. As presented in Section 1.2.4, the gridded K data will be used as model input in the Task 48 alluvial modeling.

Figures 6a-f present T maps. T data is not color-coded by quartiles, but according to the contour intervals presented in the Hurr and Schneider maps. This color scheme facilitates comparison of point values with the Hurr and Schneider contoured values. Due to the historical importance of the Hurr and Schneider T maps to river management, and for ease of comparison, the contour intervals used on these maps are

identical to those used by Hurr and Schneider. The first map in this set shows T for the entire study area.

Transmissivity values generated as a part of this TM are compared with the area that the Hurr and Schneider T contours cover. Figures 7a-c display a color-fill map of the SPDSS T contours overlain by Hurr and Schneider's T contours. These figures show areas where the T values developed under this task are in agreement with or differ from the Hurr and Schneider T maps. Discussion of the comparison can be found in section 3.2.

The S and Sy values are posted and labeled as point values in Figures 8a-c.

All point K and T and S/Sy data and contoured K and T data are contained in ArcGIS shapefiles and raster files that will be included electronically as part of the Final TM.

2.0 Aquifer Property Database

This section describes the procedures used to catalogue and compile all the data sources into the appropriate HydroBase formats. The data directory for the alluvial aquifer property database is provided in Appendix C.

2.1 Database Structure

Four HydroBase tables contain information pertinent to aquifer property data for the Denver Basin Region. These are the WELLS, PUMPING_TEST, REF_ELEV_ACCURACY and REF_LOC_ACCURACY tables.

The WELLS table contains the well name and permit number, well location, and other information about a well's characteristics. The WELLS table is the core table that links well information data with geophysical log, water level, and aquifer properties data.

The core of the aquifer properties data is stored in the PUMPING_TEST table. This includes information such as test date, test type, and test results, including T, K, and S values.

The REF_ELEV_ ACCURACY table includes comments indicating the source and accuracy of the elevation value.

The REF_LOC_ACCURACY table includes comments on the siting accuracy of the location (X,Y) data.

All aquifer property data collected through this task were combined and placed in the appropriate tables.

HydroBase does not have a table that is specifically designed to store laboratory data. This limits HydroBase in its ability to store data collected from multiple horizons within a single borehole.

2.2 Database Quality Control

A series of quality control steps were undertaken once Task 43.3 data were compiled into a common electronic format. These steps were performed to check the accuracy of the data before submitting it to the State for uploading into HydroBase.

Numerical data from each of the sources external to HydroBase were initially entered into a Microsoft Excel® spreadsheet. Hand-entered data were then checked for accuracy by comparing 100 percent of the entered data to the original hard copy data. Data received in electronic format from sources other than HydroBase were checked for data importation accuracy by manual verification of 10-percent of the values imported into a HydroBase-compatible table against the original electronic source data. If errors in the data entry were found, the error was corrected in the spreadsheet. The spreadsheet containing new data collected under Task 43.3 was then uploaded into the SPDSS database, augmenting HydroBase data, before analyses were performed.

3.0 Results

This section presents the findings of the Task 43.3 aquifer property data collection, analysis, and reporting. Figures 5 through 8 show the spatial distribution of the aquifer property data for hydraulic conductivity (K), transmissivity (T), the comparison of T data to Hurr and Schneider T contours, and storage coefficient and/or specific yield (S/Sy), respectively . Figure 4 is a spatial index for the K and T maps. These figures break the South Platte Alluvium Region into sub-regions to facilitate a clearer and more detailed visual presentation of the data. All data will also be provided to the State in ArcGIS shapefiles and raster files as part of this TM. Table 3 provides a statistical summary (including count, minimum, maximum, and median) for the K, T, and S/Sy data used in the analyses and maps.

This TM is intended to analyze and present raw field data and data used as initial groundwater model inputs. It should be fully understood that some of the data collected for analysis in this TM, in particular data obtained from specific capacity and lab test results, may appear anomalous compared to what can realistically be expected from the South Platte alluvial aquifer. As described in section 1.2.4, several of these data points were excluded before generating K and T contours. The contours represent a processed, smoothed surface which captures regional trends. The contoured data will be used as initial model inputs to the alluvial groundwater model being developed in Task 48 while point data highlights the highly variable nature of aquifer properties in the South Platte alluvial aquifer.

The results described in the K and T sections pertain only to those data used to generate the contours. Additional discussion and presentation of data excluded from contouring (see section 1.2.4) can be found in Appendix B.

Contours of both T and K generated in this task will be used as initial model inputs to the groundwater model. These values will be modified during model calibration and should not be considered final until that time.

Table 3: Summary of Aquifer Property Data (from all sources)

Data Type	Aquifer Test Property Values				Figure
	Count	Min	Max	Median	
Hydraulic Conductivity (ft/day)	506	18.0	1946.8	425.4	5a-f
Transmissivity (ft^2/day)[1]	506	414	102,603	16,388	N/A
Transmissivity (gpd/ft)	506	3,100	767,520	122,594	6a-f
Specific Yield/Storativity (dimensionless)	124	0.0001	0.3660	0.1730	8a-c

Note 1) T presented in ft^2/day for comparison purposes only; it is not mapped because HydroBase format requires T in units of gpd/ft.

3.1 Hydraulic Conductivity Data

Hydraulic conductivity (K) data for the South Platte Alluvium Region are presented in Figures 5a-f, which represent different sub-regions of the study area as shown in Figure 4, the spatial index for the K and T maps. Figure 5a shows the K distribution for the entire study area. Point data is color-coded by quartile and is presented along with contoured data. The contour interval is 50 ft/day.

The 506 K values used in the analysis range from 18 to 1946.8 ft/day, with a median of 425.4 ft/day. The lowest and highest values are derived from pumping test data and specific capacity, respectively. Only two specific capacity test values used in contouring fall outside of the range of pumping test values. As discussed in section 1.2.4, specific capacity and aquifer pumping tests measure the same aquifer property, and have a similar statistical distribution. Therefore, specific capacity tests are generally considered to provide an acceptable estimate of K where aquifer pumping test data are not available.

K values obtained from aquifer pumping tests range from a minimum of 18 ft/day to a maximum of 1872.0 ft/day with a median value of 489.0 ft/day. These values are consistent with literature values for medium to coarse sand and gravel deposits that characterize much of the South Platte alluvium (Heath 1983). There are three tests with resulting K values greater than 2000 ft/day, which were excluded from the gridding data set. These K values range from 2005 to 2558 ft/day and are abnormally high based on other data from the region and engineering judgment. These three aquifer pumping tests were excluded from contouring, as discussed in section 1.2.4.

The K data are presented in color-coded quartile groups with the ranges defined on Figures 5b-f. The range in values shown on these figures (such as between Fort Morgan and Sterling, for example), is indicative of the localized heterogeneity in the South Platte alluvial aquifer system. A few spatial trends in the data can also be observed by clusters of data points with a majority of similarly colored symbols found in various reaches of the South Platte alluvium. For example, in the reaches between Denver and Brighton and between Sterling and Julesburg, there is a predominance of K data in the 425 to 680 ft/day range (50th to 75th percentile) and a significant number of data points indicating K values greater than 680.0 ft/day (>75th percentile). The alluvium along the Cache la Poudre shows a preponderance of higher K values above the median, while most other tributaries to the South Platte do not show such consistently high K values.

3.2 Transmissivity Data

Transmissivity (T) data derived from specific capacity data and aquifer pumping tests are presented in Figures 6a-f. Figure 6a shows the T distribution for the entire study area. These figures also present the contoured T data, which were generated from K contours and saturated thickness maps. Due to the historical importance of the Hurr and Schneider T maps to the administration and evaluation of water resources in the region, and for ease of comparison, the contour intervals used on these maps are identical to those used by Hurr and Schneider, and point values are color-coded according to the contour intervals (< 50,000 gpd/ft, 50,000 to 100,000 gpd/ft, 100,000 to 200,000 gpd/ft, 200,000 to 400,000 gpd/ft and > 400,000 gpd/ft). Point values of T obtained from all sources and used for contouring range from approximately 3,100 to 767,520 gpd/ft, with a median value of 122,600 gpd/ft. As would be expected, areas of high T correspond to areas of high aquifer thickness (b). Based on the median values of T and K presented in Section 3.1, the median aquifer b is approximately 39 feet. This value is consistent with the alluvial aquifer saturated thickness presented in the Task 42.3 TM.

Figures 7a-c present the SPDSS T and the Hurr and Schneider T contours. The SPDSS T values are shown as a color fill map, with the different colors corresponding to the contour intervals used in the Hurr and Schneider maps.

The comparison with Hurr and Schneider shows relatively good agreement in most areas, while isolated areas show large differences. For example, the SPDSS T values are very similar to Hurr and Schneider from Sterling to Julesburg and through large portions of Weld County. However, there are areas where there are significant differences. One area showing a large difference is just east of Greeley in T5N-R65W, where SPDSS T is lower than Hurr and Schneider in the central portion of the township, but much higher in the northeastern corner of the township. Areas where differences in T are large can be accounted for by the larger data set used to generate the SPDSS T values compared to data available to Hurr and Schneider; the SPDSS T maps better reflect the aquifer T because of the larger data set used.

3.3 Specific Yield and Storage Coefficient Data

Published Sy/S data for the South Platte Alluvium Region are presented in Figures 8a-c. Locations with more than one value assigned to them are those at which more than one sample was obtained from a single borehole. According to well drilling logs obtained from the Phase 1 and 2 SPDSS Task 35 field investigations, some of the upper saturated portions of the South Platte Alluvium contain layers of silt and clay. These create localized zones of confined to semi-confined conditions along with the unconfined conditions present throughout most of the alluvial aquifer. The degree and extent of confining conditions in the aquifer have a direct influence on the aquifer S. Accordingly, values representing both Sy and S are presented together in Figures 5a-c.

Sy and S point values range from approximately 0.0001 to 0.3660 with a median value of 0.17. The majority of values greater than 0.17 are from laboratory analyses. Aquifer pumping tests yielded values from 0.0001 to 0.25 with a median of 0.07, while lab data produced values ranging from 0.096 to 0.0366 with a median value of 0.27. Values

ranging from approximately 0.05 to 0.30 are expected in unconfined alluvial aquifers with deposits similar to the South Platte Alluvium. Lower Sy values may be the result of delayed gravity drainage, semi-confined or confined aquifer conditions. As discussed in section 1.2.4, the median laboratory value of Sy was adopted as constant throughout the model domain. Values of Sy in any geographic location are subject to change through the calibration process.

4.0 Summary and Conclusions

CDM has completed SPDSS Task 43.3: the analysis and mapping of aquifer property data for the South Platte Alluvium Region. The Task 43.1 and 43.3 activities satisfy the objectives of collecting available published aquifer property data, enhancing HydroBase with these data, guiding the field investigations through data gap identification (Tasks 35 and 37), characterizing the hydrogeologic properties of the South Platte Alluvium Region, and supporting development of an alluvial groundwater model. Aquifer property data from multiple sources have been combined and converted to consistent reporting units, and are presented here in graphical format and in a readily available report and format suitable for inclusion in the State's hydrologic database (HydroBase). The data were used to help identify additional data needs in the South Platte alluvium and to support the design of the SPDSS groundwater field data collection programs in earlier phases. Data was then analyzed, summarized and used to develop initial model inputs for an alluvial groundwater model.

This TM is not anticipated to be updated with data collected in future phases of the SPDSS; however, any aquifer property data received by CDM will be evaluated for usefulness in upcoming SPDSS tasks and forwarded to the State.

Below are conclusions from completion of these tasks.

<u>General Conclusions</u>

- The aquifer properties data collected, analyzed, and presented in this TM represent an important addition to the knowledge and characterization of the groundwater system within the South Platte Alluvium Region. The information presented here includes a depiction of the variable nature of aquifer properties within the study area, a smoothed, regional representation of the data for initial input into a groundwater model, and a comparison with the historical and widely used Hurr and Schneider reports. This task of the SPDSS compiled a database of aquifer property measurements from 15 historical reports and numerous non-published data, resulting in 1241 aquifer property measurements.

- Many of these data are being presented in this Task 43 TM for the first time in a publicly accessible report and electronic database (HydroBase). The aquifer property data and mapping are the most comprehensive results currently available. The data collected and presented in this TM represents an 86% increase in the number of aquifer property data points (574 records) over

previously published reports, and should be considered a significant update to existing mapping.

- The aquifer properties presented in the TM are generally consistent with those presented in the earlier reports by Hurr and Schneider (1972). However, the source data from those reports is not available so the hydraulic conductivity and transmissivity maps in this TM represent the best data-supported representation of the alluvial aquifer hydraulic properties available. A comparison map was generated to show the differences from the Hurr and Schneider maps.

- The aquifer properties presented in this TM are sufficient to develop initial model inputs for the alluvial aquifer groundwater model which is being developed under Task 48 of the SPDSS.

Specific Conclusions

- Analysis of specific capacity data in this TM substantiates the validity for estimating bulk aquifer properties with data derived from tests at high capacity (> 50 gpm) wells. 350 of 526 specific capacity data points were included for contouring in addition to 156 pumping tests for this analysis.

- The hydraulic conductivity and transmissivity contours and the comparison with Hurr and Schneider maps (Figures 5, 6 and 7) were generated using a smoothed interpretation of the data that will be the initial model inputs to the alluvial groundwater model being developed in Task 48. These maps will be revised after model calibration is achieved.

- The simultaneous presentation of the processed, smoothed contour lines and the raw point data provides a useful tool for users to evaluate regional aquifer property trends against local heterogeneity.

- The aquifer properties of the Kiowa-Bijou Designated Basin and western tributaries (Clear, Big Dry, Boulder, and St. Vrain Creeks, and the Big Thompson River) are not characterized with as much certainty as is the remaining study area due to minimal amounts of data in these drainages.

5.0 Recommendations

- The aquifer properties data collected under Task 43 of the SPDSS and presented both in this TM and in HydroBase are the most comprehensive currently available and should be utilized in water resources-related activities.

- The maps of hydraulic conductivity, transmissivity, the Hurr and Schneider T comparison, and specific yield, should be republished once model calibration is achieved in Task 48.

- Specific capacity-derived K and T values should be considered representative of bulk aquifer properties only when the well is tested at a rate of at least 50 gpm.

- The aquifer property data for the Upper Big Sandy and Upper Black Squirrel Designated Basins in Division 2 were not presented in this TM since the Task 48 alluvial groundwater model does not include these areas. However, more data collection is recommended if groundwater modeling is undertaken in these areas.

- Additional data collection efforts should be focused in areas where aquifer property data is sparse, such as in the western tributaries to the the South Platte River and in Kiowa, Bijou, upper Lost, and upper Boxelder Creeks.

- When aquifer property data are collected by well owners as part of their routine well installation and testing, the State should request, if available, aquifer pumping test results and other aquifer property data, such as core sample analyses, as part of the well permitting process. These data are often obtained as part of installation and testing programs for municipal, industrial, and commercial high-capacity wells and are often readily available from consultant's reports. HydroBase should be populated with these data.

- Specific capacity, depth-to-water, and depth-to-bedrock data should be entered into HydroBase upon receipt of new well construction and testing reports.

- HydroBase should be modified to be accommodate multiple data entries from different stratum within a single borehole. This could be accomplished by adding an additional field to the WELLS table and populating it with an aquifer code identifying the stratum from which a sample was taken, while still maintaining the 'aquifer1' and 'aquifer2' fields as the screened interval.

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SPDSS Phase 3 Task 43.3

Figure 1: SPDSS Study Area

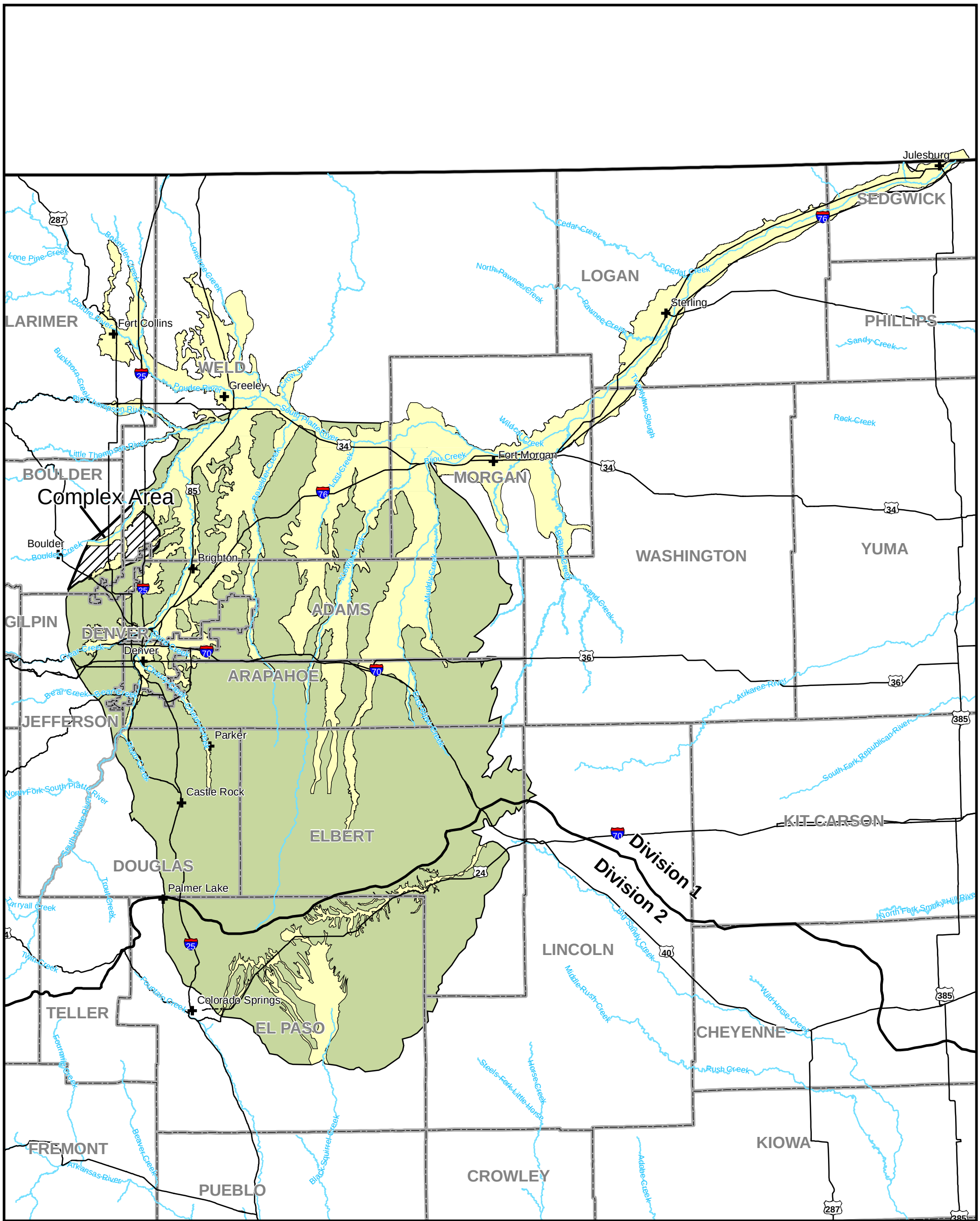

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Figure 2: Comparison of Alluvial Aquifer Tests Transmissivity and Specific Capacity Data in the SPDSS Study Area

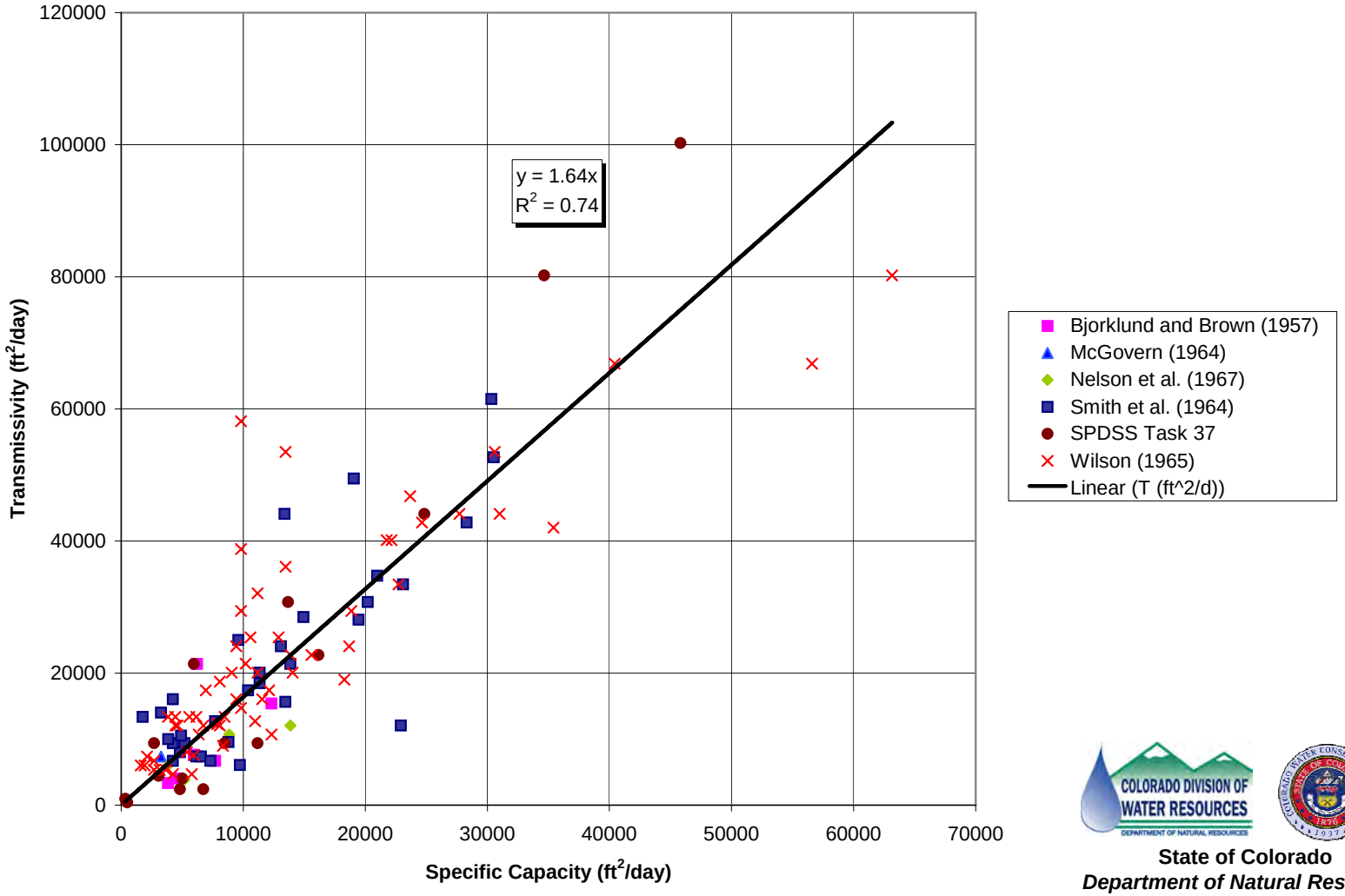

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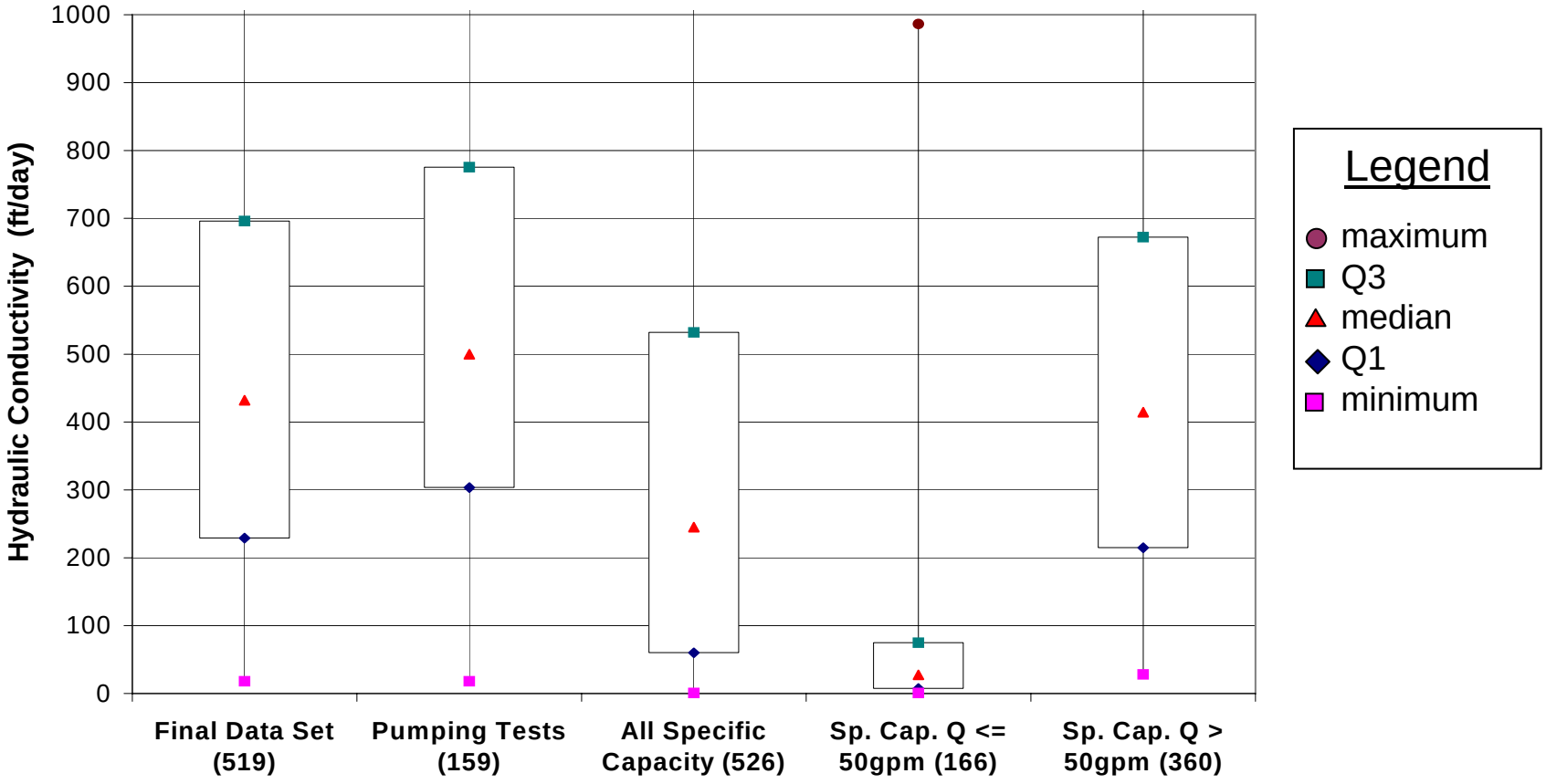
Figure 3: Specific Capacity Analysis by Test Flow Rate



Notes: Number of tests in parentheses.
Q1 and Q3 represent the 25th and 75th percentiles, respectively.
Values of greater than 2000ft/day removed from Final Data Set (see section 1.2.4).

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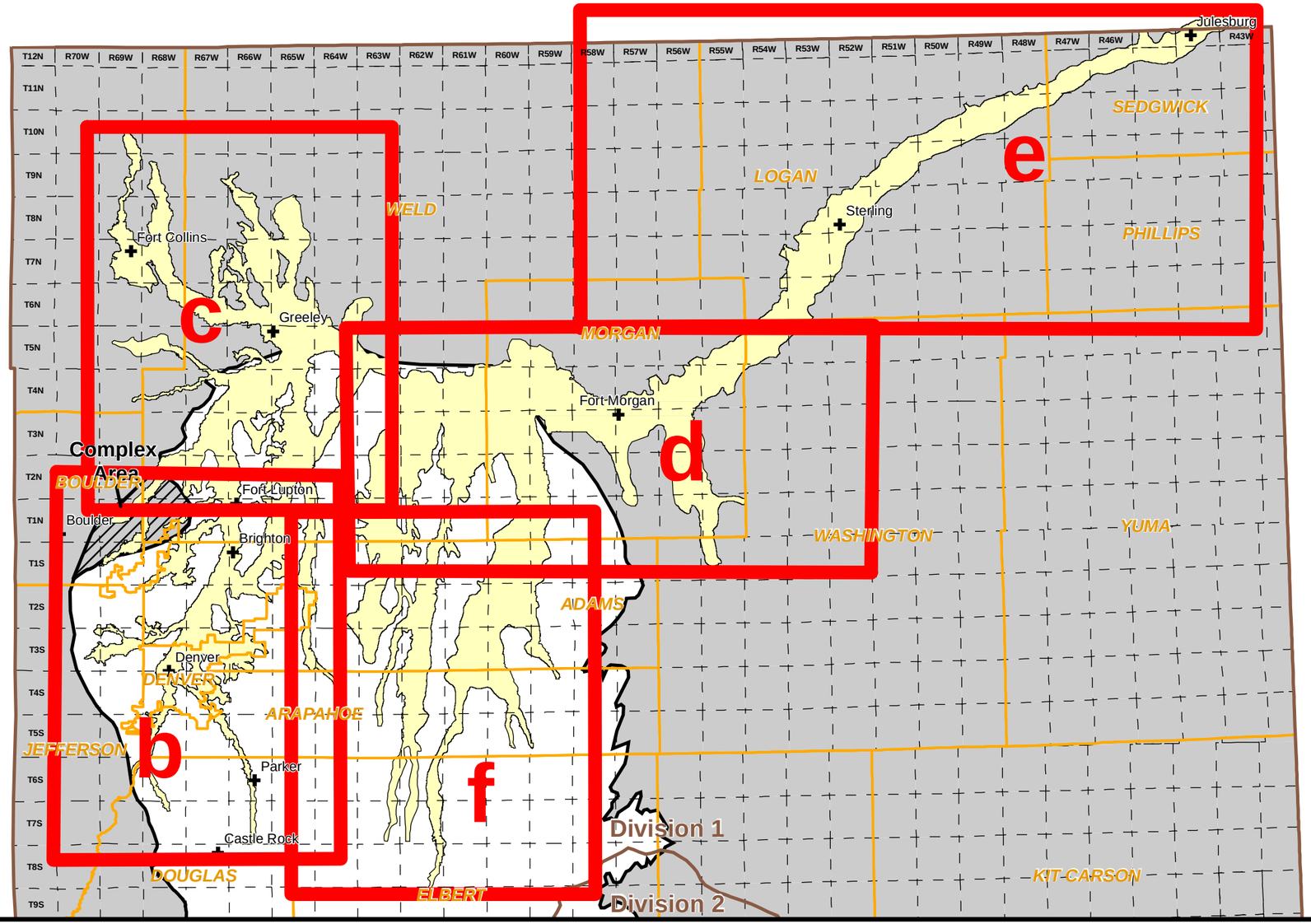
Figure 4: Spatial Index for K and T Maps



N
W
E
S

Scale
1:1,100,000

0 10 20 40 Miles

NAD 1983 UTM Zone 13N

Highway
Streams
City
County
Township
Denver Basin Extent
Alluvial Model Domain
c Indicates area of detail shown in Figures 5c and 6c

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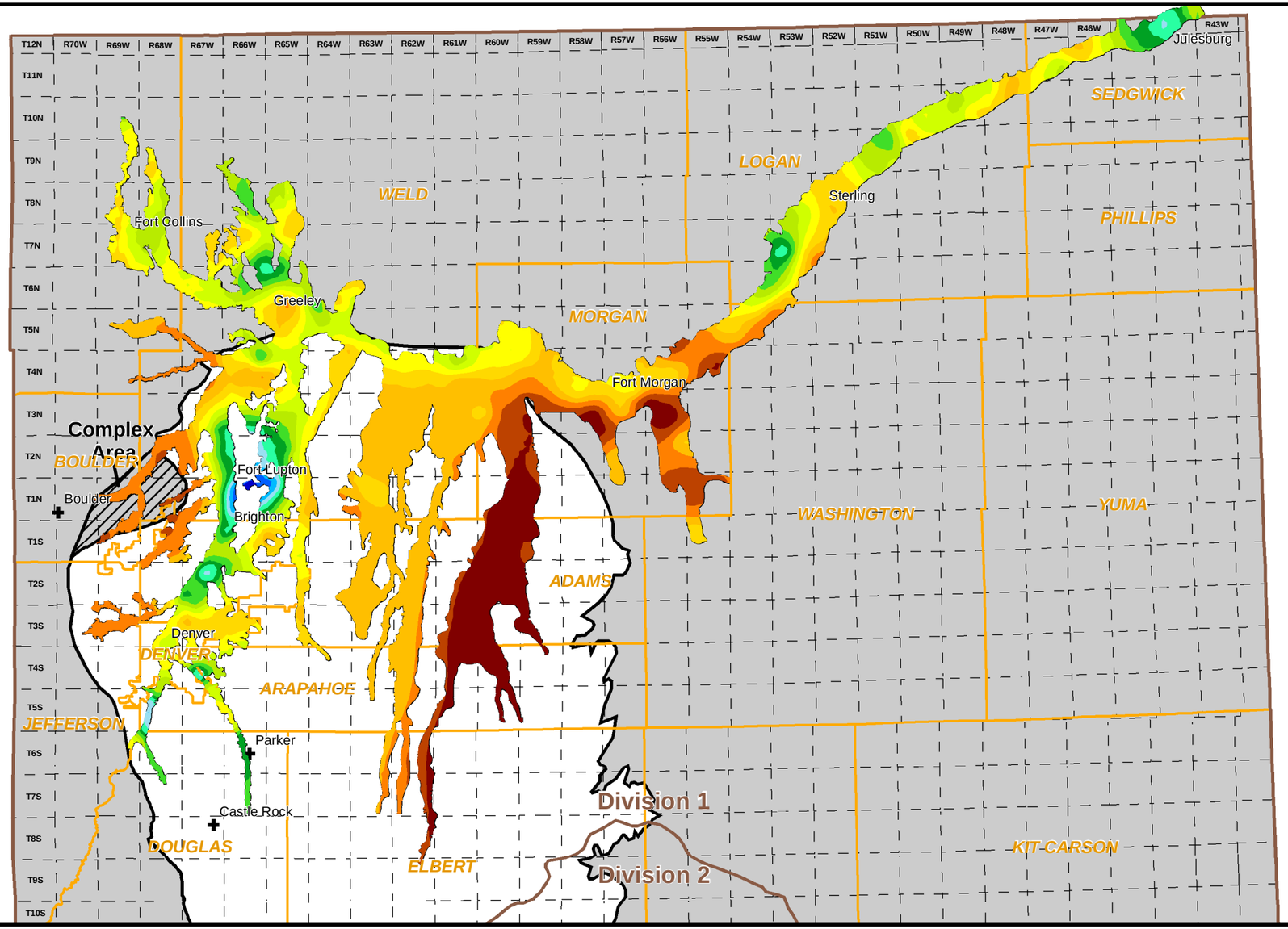
Figure 5a: Hydraulic Conductivity (K) Distribution, SPDSS Alluvial Groundwater Model Extent



N
W E
S

Scale
1:1,100,000

0 10 20 40 Miles

NAD 1983 UTM Zone 13N

- City
- County
- Township
- Denver Basin Extent

Hydraulic Conductivity (ft/day)

- < 150
- 150 - 200
- 200 - 250
- 250 - 300
- 300 - 350
- 350 - 400
- 400 - 450
- 450 - 500
- 500 - 550
- 550 - 600
- 600 - 650
- 650 - 700
- 700 - 750
- 750 - 800
- > 800

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Figure 5b: Hydraulic Conductivity (K) Distribution, Denver to Ft. Lupton

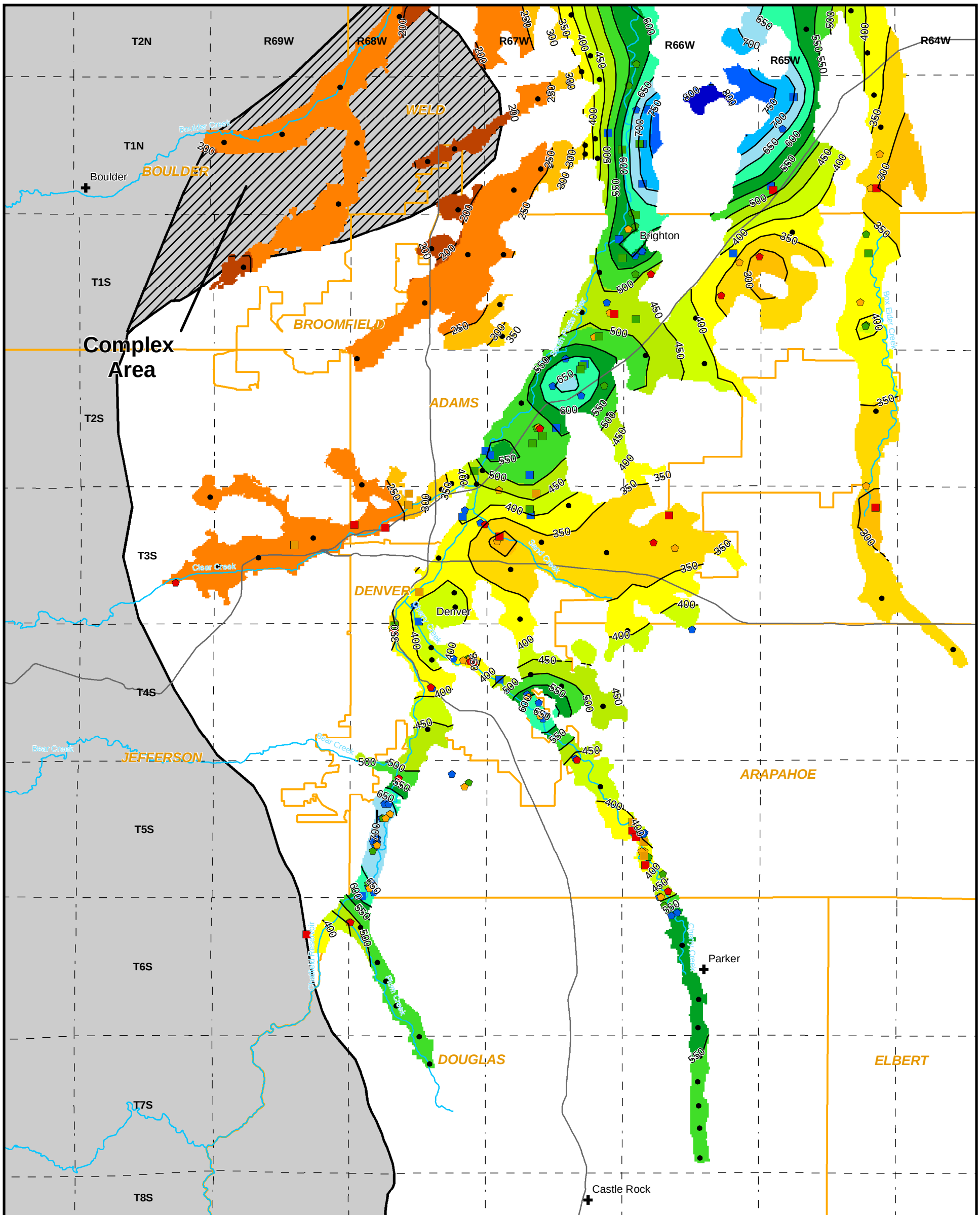

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Figure 5c: Hydraulic Conductivity (K) Distribution, Ft. Lupton to Greeley and Poudre River

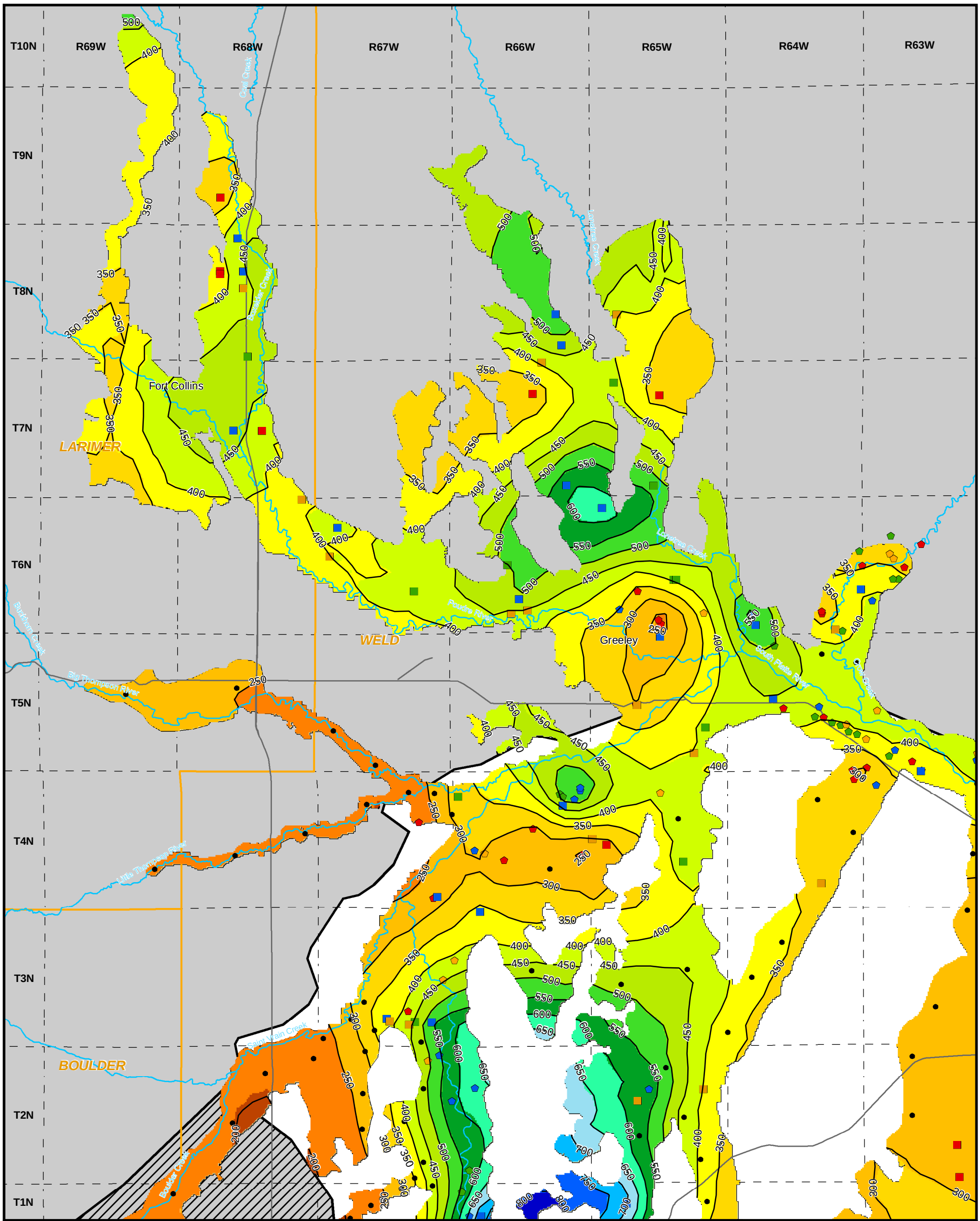

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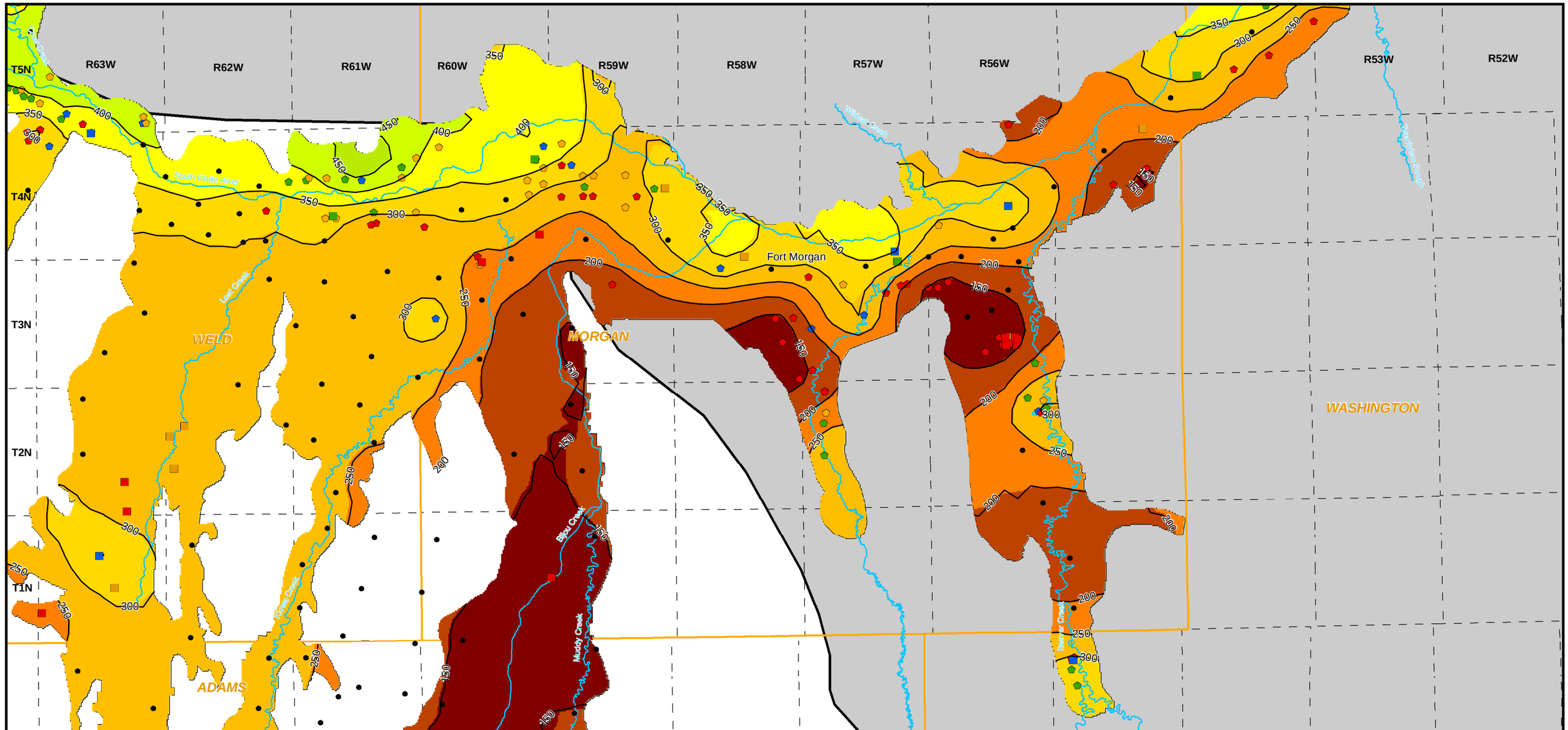
Figure 5d: Hydraulic Conductivity (K) Distribution, Greeley to Beaver Creek



N
W E
S

Scale
1:290,000

0 2.5 5 10 Miles

NAD 1983 UTM Zone 13N

- Highway
- Stream
- City
- County
- Township
- Denver Basin Extent
- Engineering Control Point
- Hydraulic Conductivity Contour (50 ft/day interval)

Hydraulic Conductivity (ft/day)

- < 150
- 150 - 200
- 200 - 250
- 250 - 300
- 300 - 350
- 350 - 400
- 400 - 450
- 450 - 500
- 500 - 550
- 550 - 600
- 600 - 650
- 650 - 700
- 700 - 750
- 750 - 800
- > 800

Pumping Test K (ft/day)

- < 220
- 220 - 425
- 425 - 680
- > 680

Specific Capacity K (ft/day)

- < 220
- 220 - 425
- 425 - 680
- > 680

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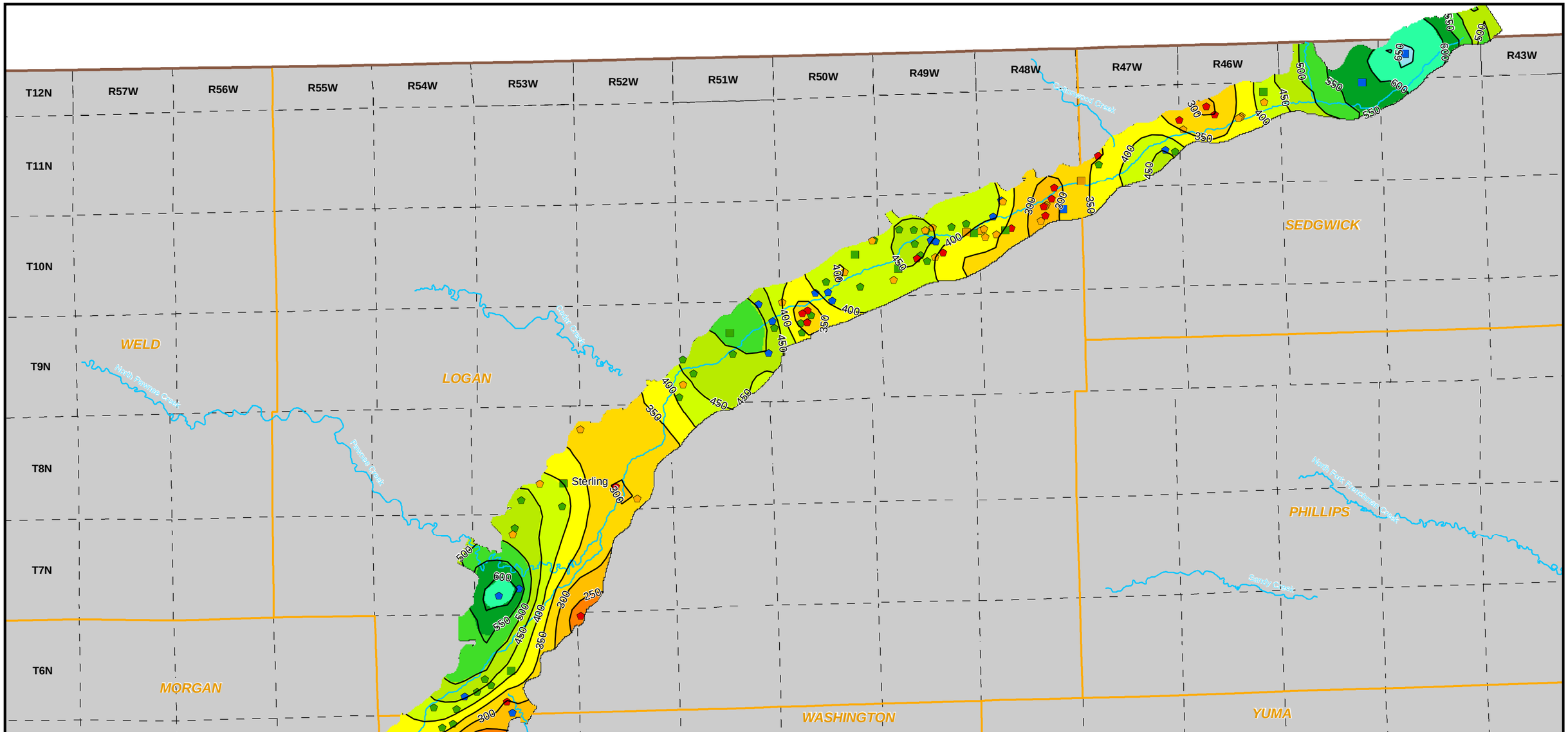
Figure 5e: Hydraulic Conductivity (K) Distribution, Sterling to Julesburg



Scale
1:370,000

0 3 6 12 Miles

NAD 1983 UTM Zone 13N

- Highway
- Stream
- City
- County
- Township
- Denver Basin Extent
- Engineering Control Point
- Hydraulic Conductivity Contour (50 ft/day interval)

Hydraulic Conductivity (ft/day)

- < 150
- 150 - 200
- 200 - 250
- 250 - 300
- 300 - 350
- 350 - 400
- 400 - 450
- 450 - 500
- 500 - 550
- 550 - 600
- 600 - 650
- 650 - 700
- 700 - 750
- 750 - 800
- > 800

Pumping Test K (ft/day)

- < 220
- 220 - 425
- 425 - 680
- > 680

Specific Capacity K (ft/day)

- < 220
- 220 - 425
- 425 - 680
- > 680

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Figure 5f: Hydraulic Conductivity (K) Distribution, Upper Kiowa-Bijou and Lost Creek Designated Basins and Boxelder Creek

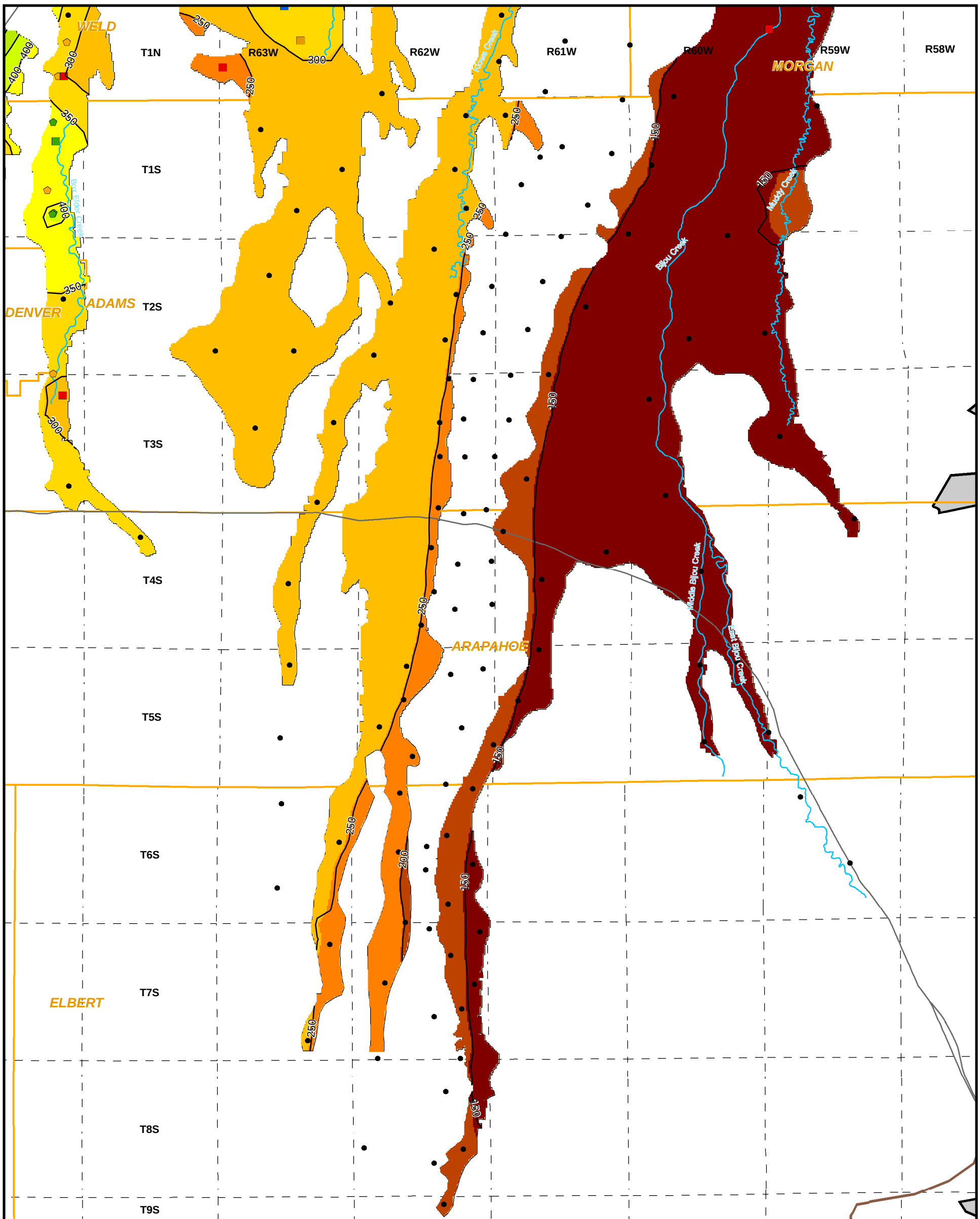

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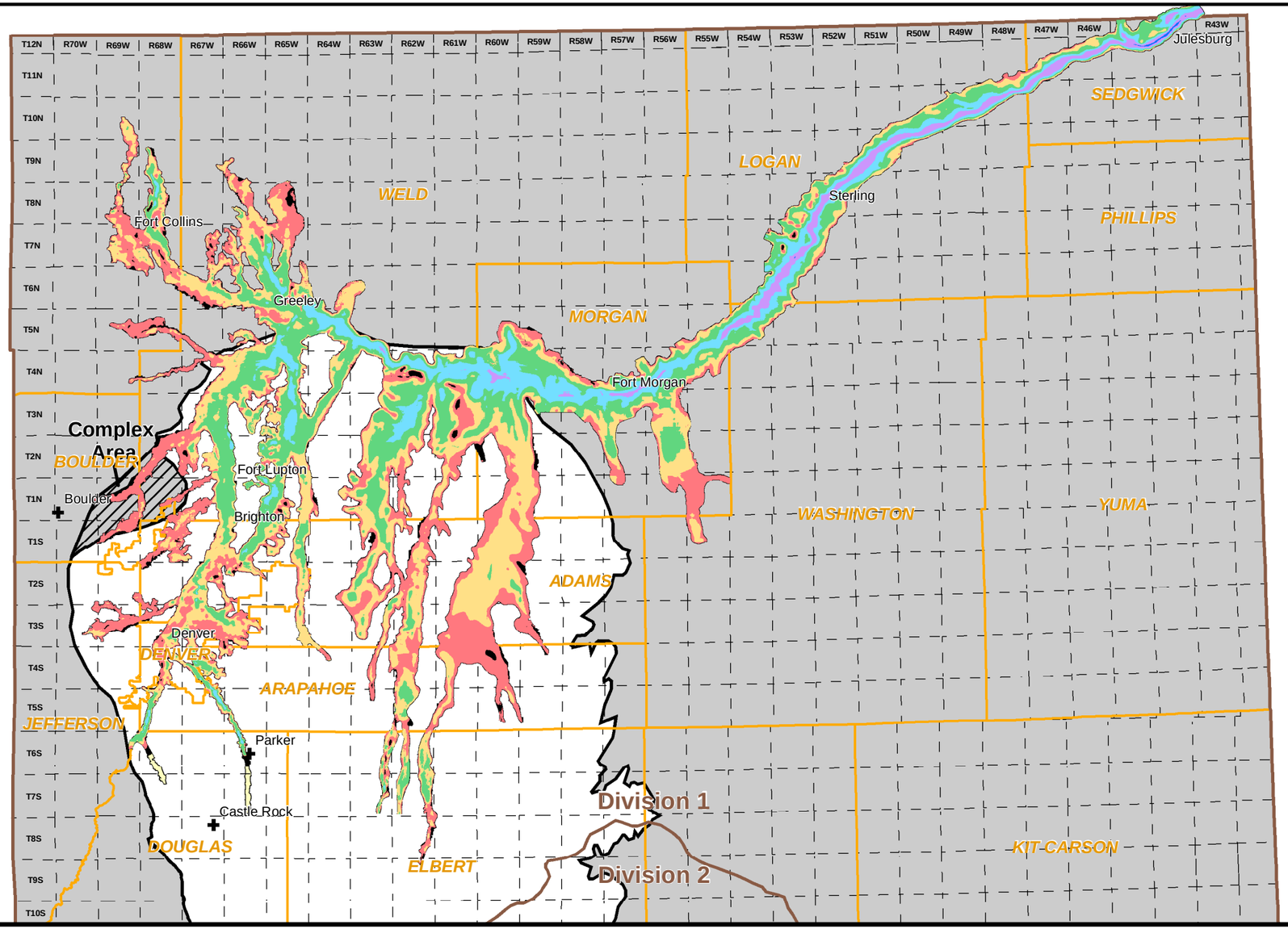
Figure 6a: Transmissivity (T) Distribution, SPDSS Alluvial Groundwater Model Extent



N
W
E
S

Scale
1:1,100,000

0 10 20 40 Miles

NAD 1983 UTM Zone 13N

City
County
Township
Denver Basin Extent

Transmissivity
(1000's gpd/ft)
Bedrock High
0 - 50
50 - 100
100 - 200
200 - 400
400 - 800
> 800

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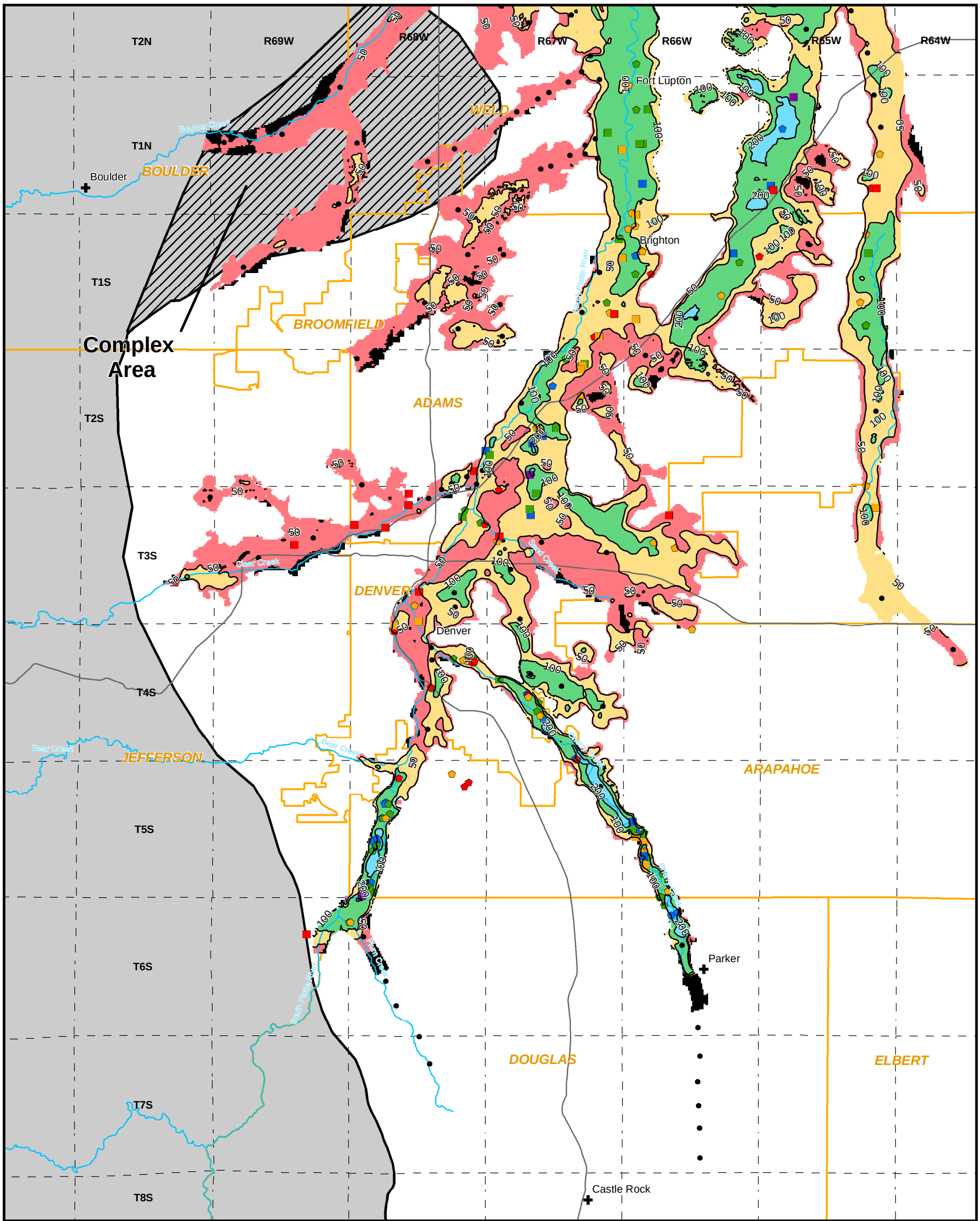
Figure 6b: Transmissivity (T) Distribution, Denver to Ft. Lupton



N
W E
S

Scale
1:270,000

0 2.5 5 10 Miles

NAD 1983 UTM Zone 13N

- Highway
- Stream
- City
- County
- Township
- Denver Basin Extent
- Engineering Control Point
- Transmissivity Contour (1000's gpd/ft)

Transmissivity (1000's gpd/ft)	Pumping Test T (1000's gpd/ft)	Specific Capacity T (1000's gpd/ft)
Bedrock High	< 50	< 50
0 - 50	50 - 100	50 - 100
50 - 100	100 - 200	100 - 200
100 - 200	200 - 400	200 - 400
200 - 400	> 400	> 400
400 - 800		
> 800		

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Figure 6c: Transmissivity (T) Distribution, Ft. Lupton to Greeley and Poudre River

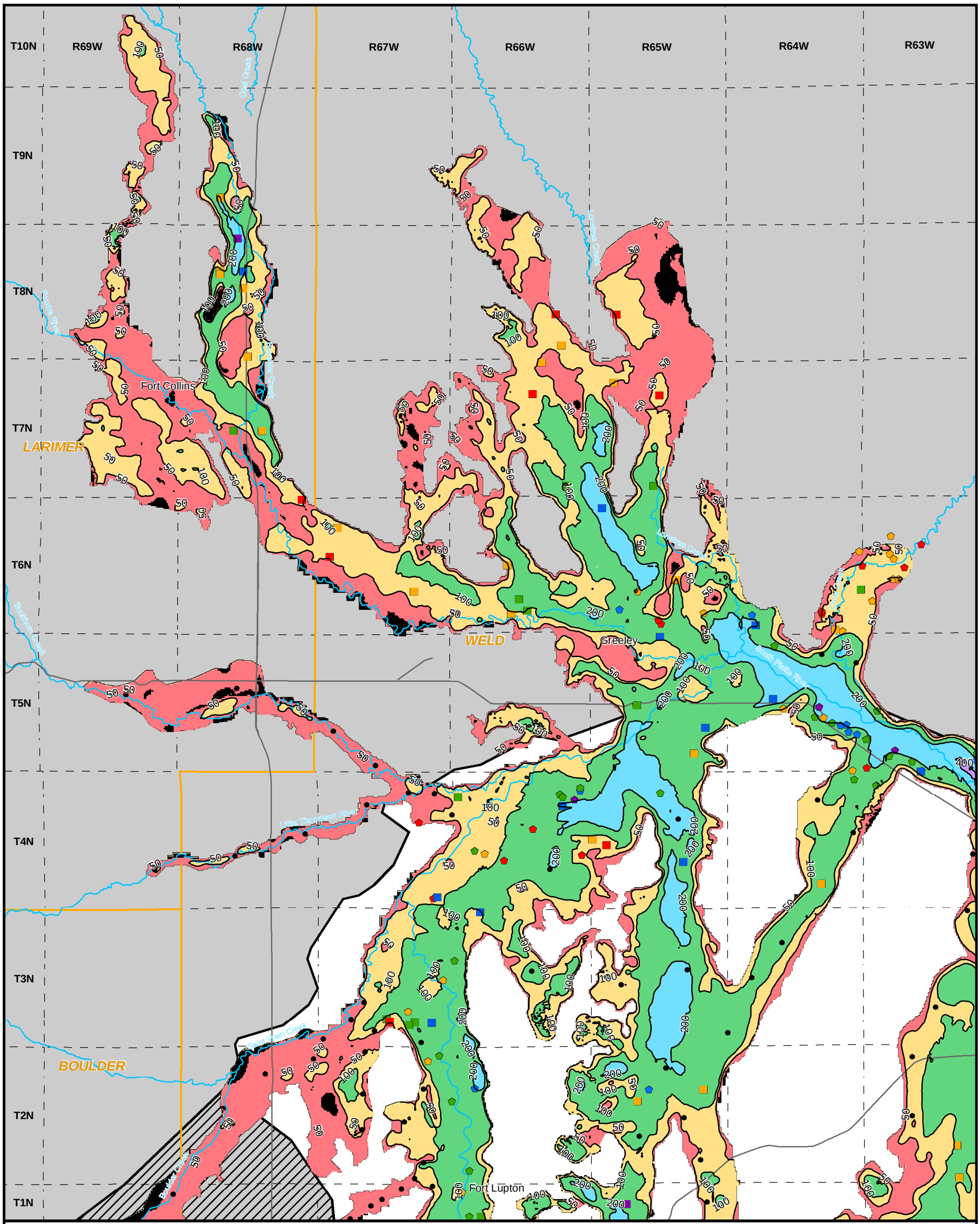

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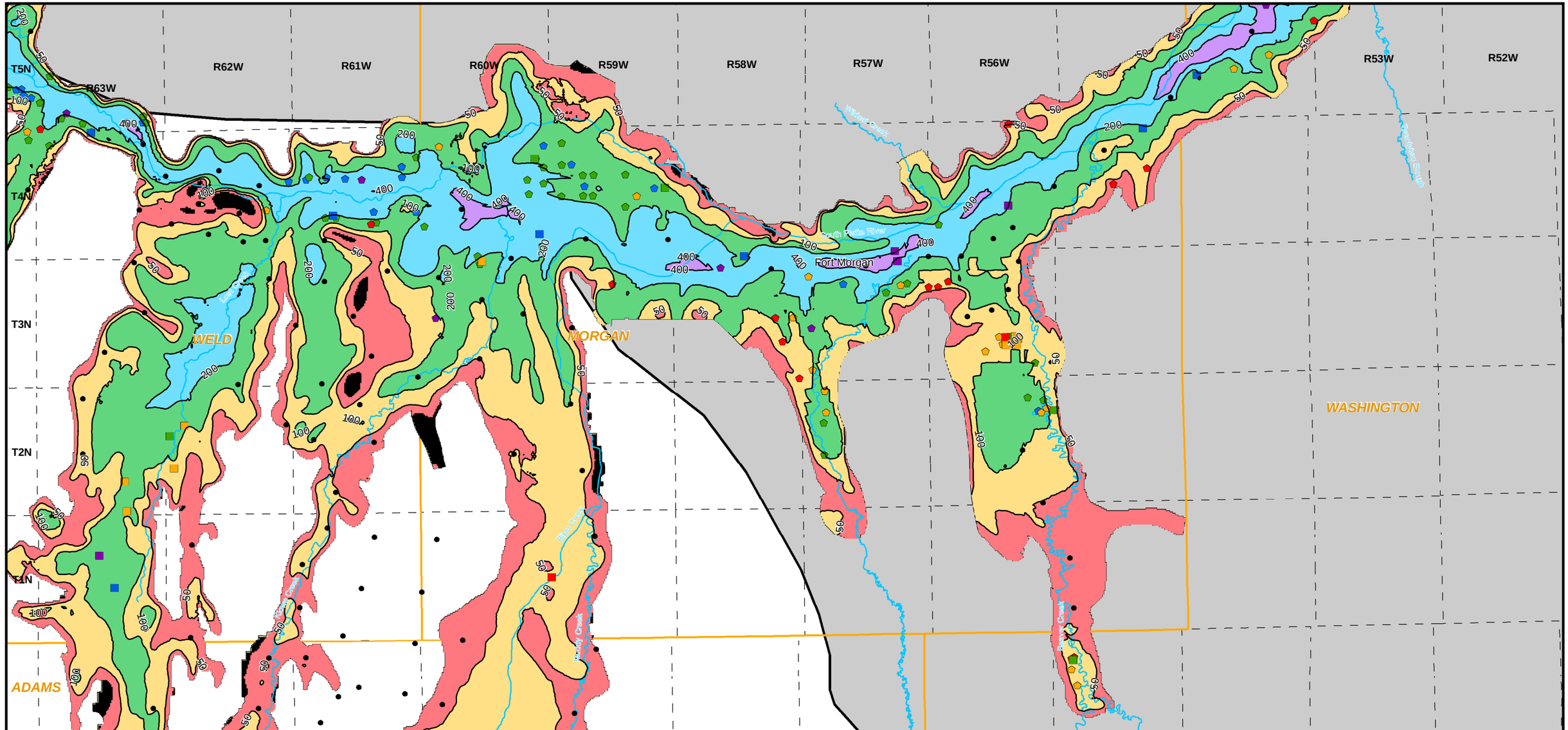
Figure 6d: Transmissivity (T) Distribution, Greeley to Beaver Creek



Scale
1:290,000

0 2.5 5 10 Miles

NAD 1983 UTM Zone 13N

- Highway
- Stream
- City
- County
- Township
- Denver Basin Extent
- Engineering Control Point
- Transmissivity Contour (1000's gpd/ft)

Transmissivity (1000's gpd/ft)	Pumping Test T (1000's gpd/ft)	Specific Capacity T (1000's gpd/ft)
Bedrock High	< 50	< 50
0 - 50	50 - 100	50 - 100
50 - 100	100 - 200	100 - 200
100 - 200	200 - 400	200 - 400
200 - 400	> 400	> 400
400 - 800		
> 800		

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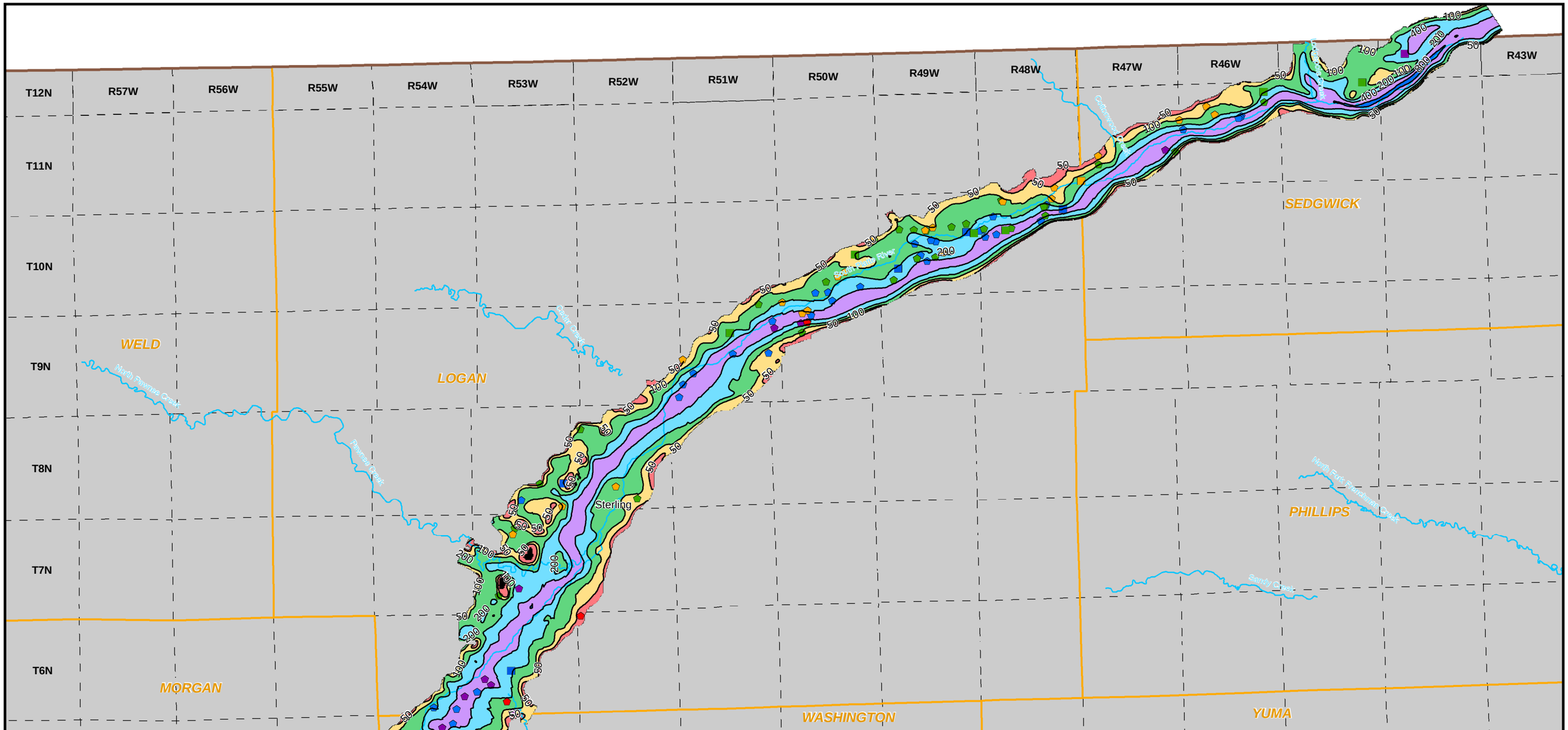
Figure 6e: Transmissivity (T) Distribution, Sterling to Julesburg



N
W E
S

Scale
1:370,000

0 3 6 12 Miles

NAD 1983 UTM Zone 13N

- Highway
- Stream
- City
- County
- Township
- Denver Basin Extent
- Engineering Control Point
- Transmissivity Contour (1000's gpd/ft)

Transmissivity (1000's gpd/ft)	Pumping Test T (1000's gpd/ft)	Specific Capacity T (1000's gpd/ft)
Bedrock High	< 50	< 50
0 - 50	50 - 100	50 - 100
50 - 100	100 - 200	100 - 200
100 - 200	200 - 400	200 - 400
200 - 400	> 400	> 400
400 - 800		
> 800		

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Figure 6f: Transmissivity (T) Distribution, Upper Kiowa-Bijou and Lost Creek Designated Basins and Boxelder Creek

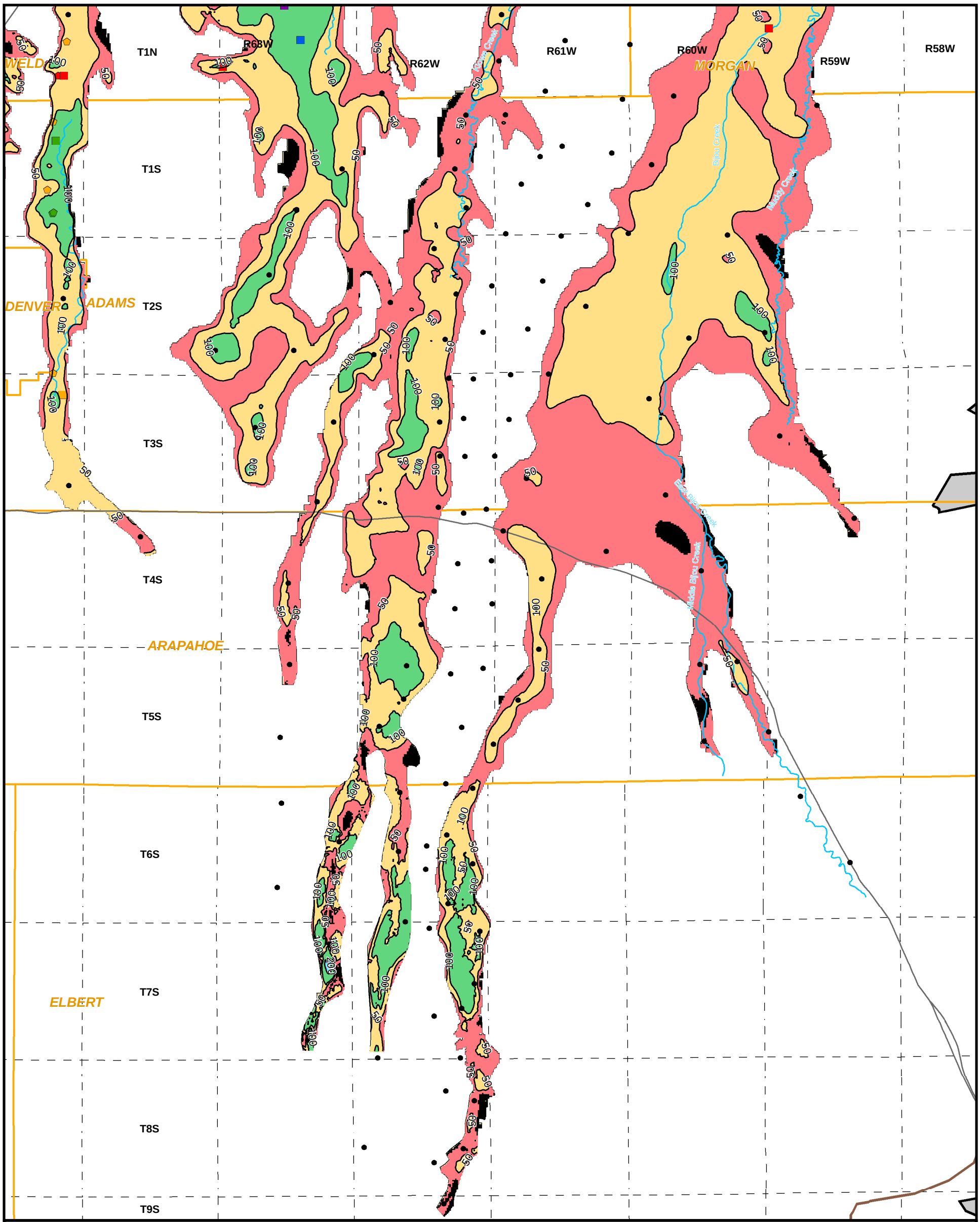

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Figure 7a: Comparison of SPDSS and Hurr and Schneider Transmissivity, Brighton to Lost Creek

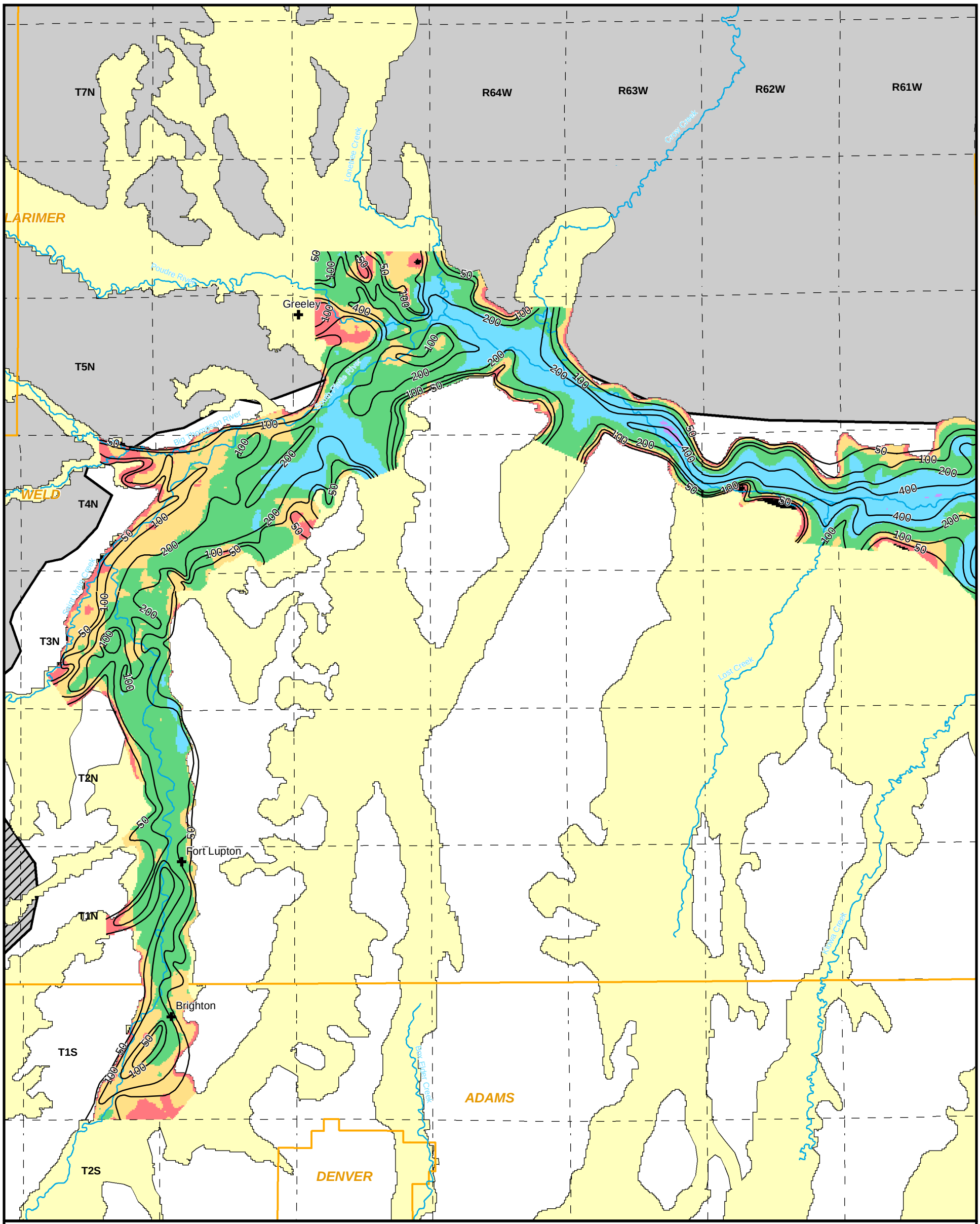

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Figure 7b: Comparison of SPDSS and Hurr and SchneiderTransmissivity, Lost Creek to Pawnee Creek

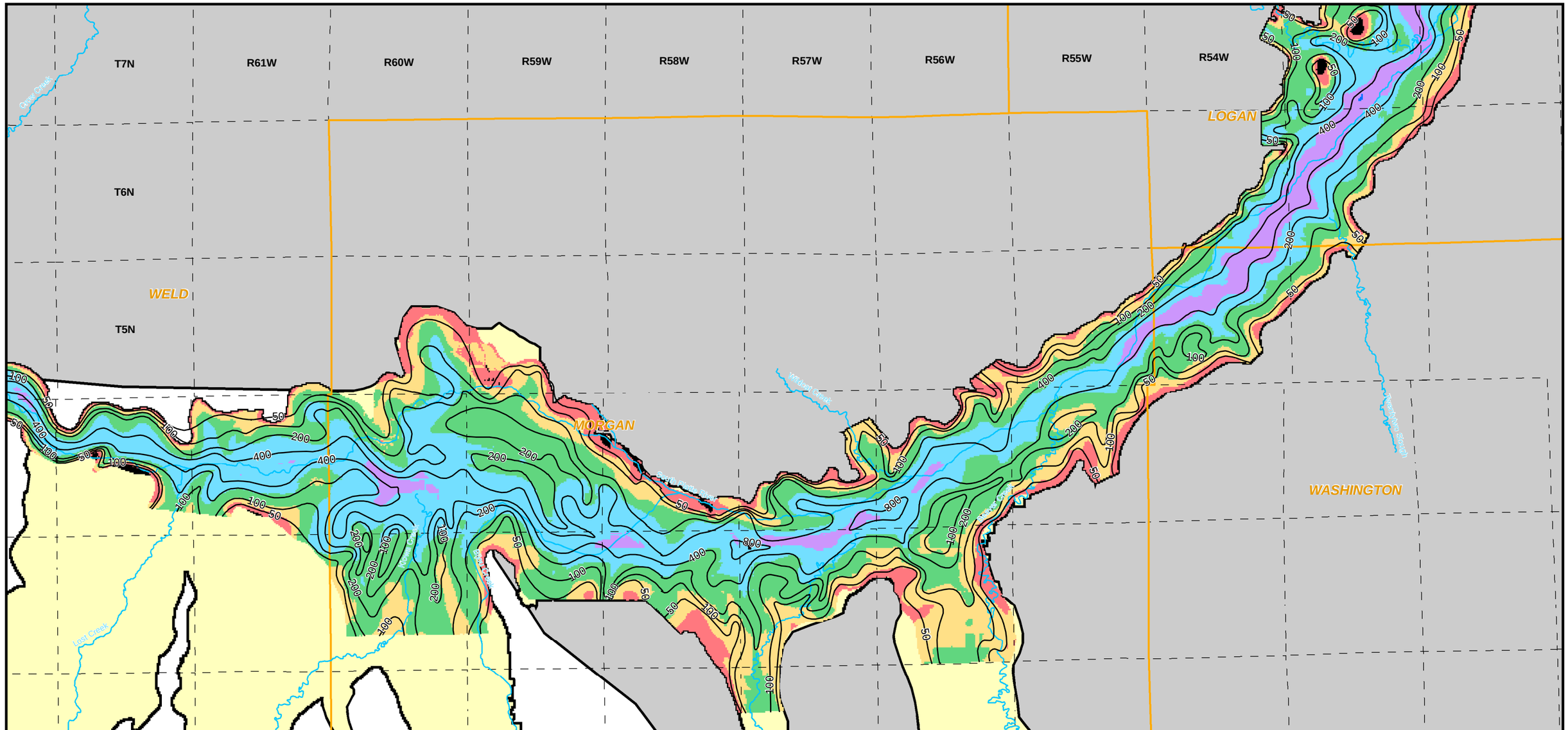

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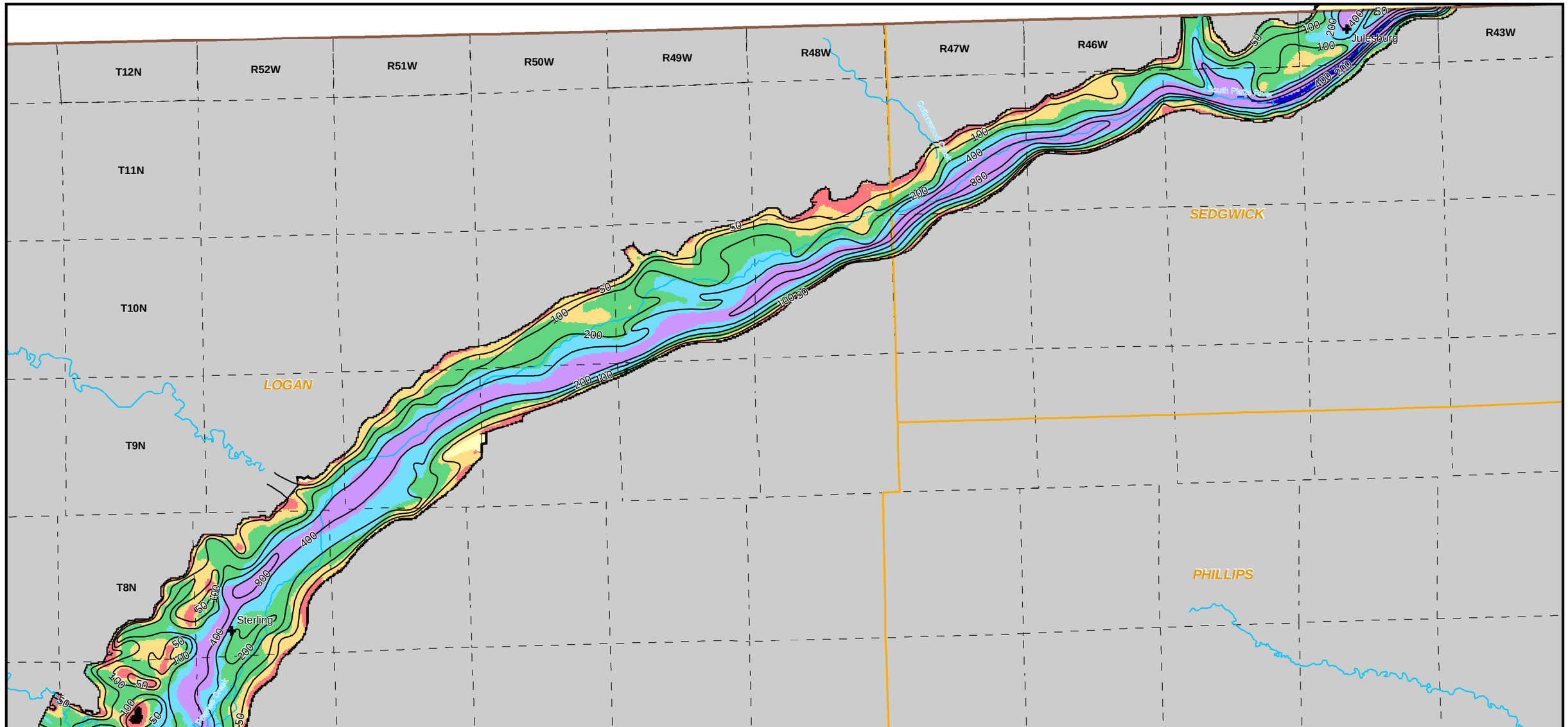
Figure 7c: Comparison of SPDSS and Hurr and Schneider Transmissivity, Pawnee Creek to Julesburg



N
W
E
S

Scale 1:270,000

0 2.5 5 10 Miles

NAD 1983 UTM Zone 13N

Stream
City
County
Township
Denver Basin Extent
Alluvial Model Extent
Hurr and Schneider T Contour (1000's gpd/ft)

SPDSS T (1000's gpd/ft)
Bedrock High
0 - 50
50 - 100
100 - 200
200 - 400
400 - 800
> 800

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Figure 8a: Storage Coeffecient (S) and Specific Yield (Sy) Distribution, Southern Area

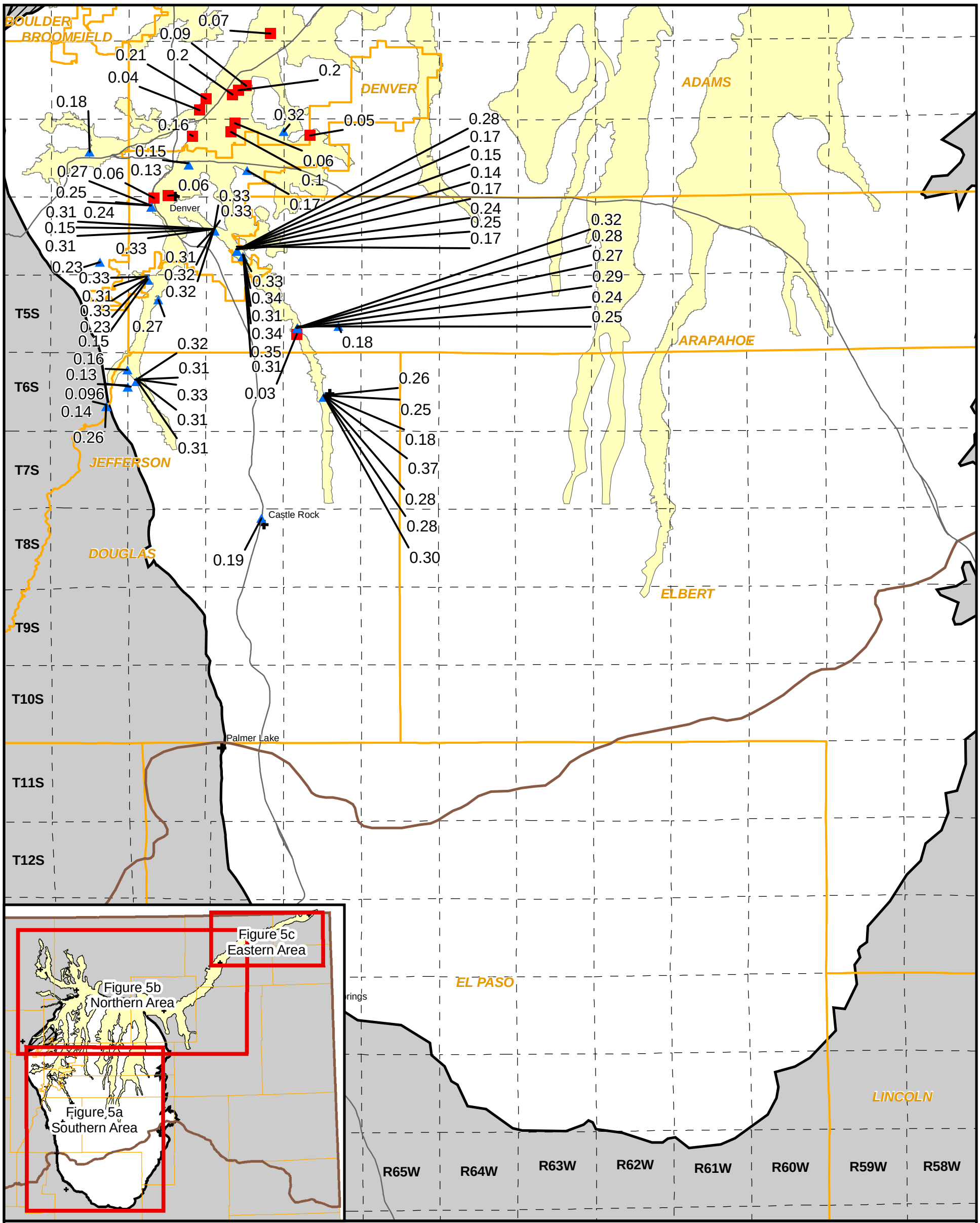

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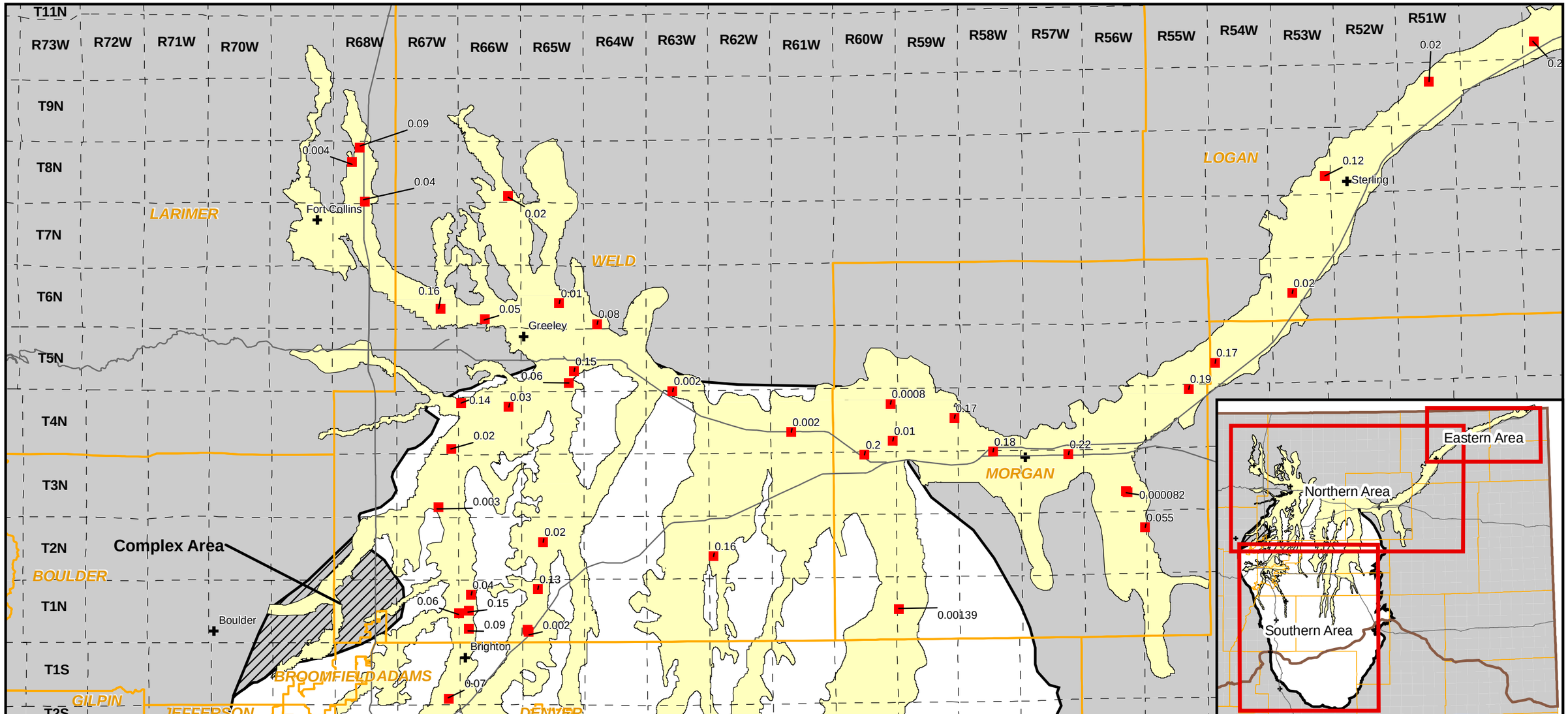
Figure 8b: Storage Coeffecient (S) and Specific Yield (Sy) Distribution, Northern Area



Scale
1:600,000

0 5 10 20 Miles

NAD 1983 UTM Zone 13N

City
Highway
County
Township
Denver Basin Extent

Storage Coeffecient and Specific Yield

Pumping Test
Lab
Alluvial Model Domain

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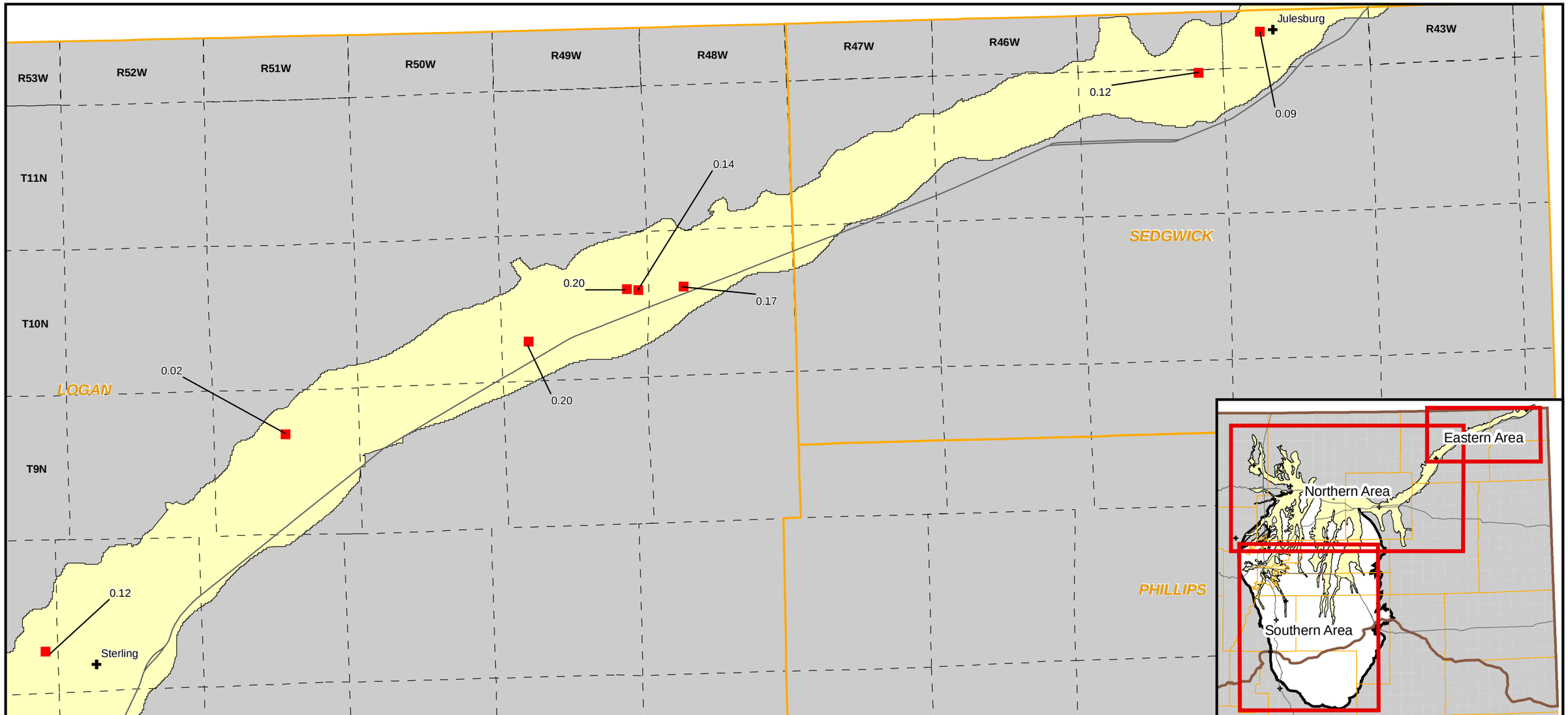
Figure 8c: Storage Coeffecient (S) and Specific Yield (Sy) Distribution, Eastern Area



Scale
1:260,000

0 5 10 20 Miles

NAD 1983 UTM Zone 13N

City
Highway
County
Township
Denver Basin Extent

Storage Coeffecient and Specific Yield

Pumping Test
Lab
Alluvial Model Domain

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Appendix A

Development of the Phase 3 Task 43.3, South Platte Alluvium Region Aquifer Property Dataset

Appendix A

Development of the Phase 3 Task 43.3 Aquifer Property Data Set

1.0 Purpose/Objective

To document the procedure used to query aquifer properties data from HydroBase, merge the data collected under Phase 3 with HydroBase data, and to process all the data for the Phase 3 Task 43.3 analysis.

Explanation of Formatting used below:

1. *Noun*: the name of a HydroBase table
2. "Noun": the name of a field in a table
3. 'Noun': the name of a value for a field

2.0 Procedure/Approach

A. Sources of Data

Five sources of data were merged into one full data set using the HydroBase format: HydroBase, Phase 2 Task 37, Phase 2 Task 35, Phase 1 Task 43 Lab data, and additional alluvial data.

1. In the August 2005 version of the HydroBase database transmitted to CDM by the DWR, *Wells* and *Pumping_test* tables were linked in a select query using the "well_id" field. Selected fields were chosen from the *Wells* table (well id, permit number, location information, etc.) and all fields were chosen from the *Pumping_test* table, which contains information pertinent to aquifer hydraulic properties testing results. Records where "aquifer1" = 'QAL' were selected, so that all bedrock aquifer tests would be excluded.
2. Solicited test data were obtained from the Phase 2 SPDSS Task 37 TM.
3. Phase 2 field test data were obtained from the Phase 2 SPDSS Task 35 TM.
4. Lab data from Phase 1 of Task 43 which were not included in HydroBase were also obtained. These data points were excluded from the data added to HydroBase, because HydroBase's current structure cannot accommodate multiple samples (collected from multiple depths) at one borehole.
5. Additional data was collected for alluvial areas identified for incorporation into an expanded study area (Cache la Poudre, Crow, Beaver and Badger Creeks)

B. Data Exclusions

Data were excluded from the Task 43 TM analysis for a variety of reasons, which are listed below. Table A-1 (at the end of this appensix) shows only HydroBase records that were excluded from analysis in Phase 2, but does not include any data collected under Phase 3 of the SPDSS project that were identified for exclusion.

1. **Multiple HydroBase specific capacity tests for the same well** were excluded. The tests were identified as being from the same well if they had matching permit number ("permitno") and suffix ("permitsuf"), unless the suffix differed because it was a replacement well. The most recent test was retained, including replacement well tests taken over original well tests (2 tests excluded).
2. **Duplicate Pumping Test.** Identical pumping tests reported in more than one source were excluded (4 tests excluded)
3. **HydroBase specific capacity tests were excluded where the duration of pumping for the test was less than 2 hours.** This was identified where "testtime" was less than 2**.** (23 tests excluded).
4. **HydroBase specific capacity tests were excluded where the calculated specific capacity was greater than 400 gpm/ft.** This was identified where "sp_cap" greater than 400. Specific capacities > 400 gpm/ft are considered highly unlikely (28 tests excluded).
5. **HydroBase specific capacity tests were excluded where the test drawdown was greater than the estimated saturated thickness at a location.** This was identified where "drawdown" was greater than "b" (67 tests excluded).
6. **HydroBase specific capacity tests were excluded where the final pumping water level was below the total depth of the well.** This was identified where "tfwl" was greater than "well_depth". Such a depth to water could not be measured in the well (1 test excluded).
7. **HydroBase specific capacity tests were excluded where the bottom of the perforated interval was reported below the total depth of the well.** This was identified where "bperf" was greater than "well_depth". Because of this discrepancy, an accurate estimate of the water column in the well could not be made (4 tests excluded).
8. **HydroBase pumping tests were excluded for being located outside of the study area** (3 tests excluded).

C. Data Processing:

1. **"b" (aquifer saturated thickness) values** were estimated for all HydroBase pumping tests and specific capacity tests and for all Task 37 pumping tests where "b" was null and "K" (hydraulic conductivity) was null. Saturated thickness (b) was calculated as the well total depth ("well_depth") or bottom of perforated interval ("bperf), if the well's total depth was not available, minus the static water level ("tswl"). If the data were not available to calculate b in such a manner, then the b value was extracted from the Phase 2 Task 42.3 saturated thickness grid. Some tests had insufficient data to calculate a b value using the total depth/bperf minus depth to water level or were located outside the extent of the saturated thickness grid. For such tests no b value was estimated.

2. For all wells where a new b was estimated, **"K" values were calculated** by "Trans" divided by 7.48 divided by "b" to obtain "K" in ft/d.
3. All values in the specific yield ("Sy") were moved to the storativity field ("storativity"). This was done so that all storativity values could be found in the storativity field and the user can determine if the value is reflective of the specific yield.

D. Final Data Set

After all exclusions were made and all data processed as indicated in items B and C, the final data set was used to complete the Phase 3 Task 43.3 TM data analysis. Some data from this final data set was not used in contouring K values. See section 1.2.4 and Appendix B for further details.

Table A-1
Excluded HydroBase Records

X- X Coordinate in NAD1983 UTM13N (meters)
Y- Y Coordinate in NAD1983 UTM13N (meters)

ID	X	Y	Exclusion Reason
11819	513440	4426637	Test Drawdown > Saturated Thickness
11829	509638	4411657	Test Drawdown > Saturated Thickness
11840	505346	4407111	Test Drawdown > Saturated Thickness
11841	505347	4407010	Test Drawdown > Saturated Thickness
11845	510840	4399589	Test Drawdown > Saturated Thickness
11849	502415	4402698	Specific Capacity > 400 gpm/ft
11850	499501	4400687	Test Drawdown > Saturated Thickness
11854	492474	4404326	Test Drawdown > Saturated Thickness
11857	493673	4402911	Test Drawdown > Saturated Thickness
11863	521454	4397170	Test Drawdown > Saturated Thickness
11869	508638	4393429	Test Drawdown > Saturated Thickness
11885	498385	4398286	Test Drawdown > Saturated Thickness
11886	498485	4398287	Test Drawdown > Saturated Thickness
11893	500429	4393934	Test Drawdown > Saturated Thickness
11894	500507	4392827	Test Drawdown > Saturated Thickness
11915	498174	4387500	Test Drawdown > Saturated Thickness
11919	498770	4386302	Test Drawdown > Saturated Thickness
11933	518217	4377229	Test Drawdown > Saturated Thickness
11973	511051	4417185	Test Drawdown > Saturated Thickness
11977	511154	4415377	Test Drawdown > Saturated Thickness
11997	487942	4405412	Test Drawdown > Saturated Thickness
12002	492973	4405221	Test Drawdown > Saturated Thickness
12004	492874	4404222	Test Drawdown > Saturated Thickness
12008	492171	4404729	Test Drawdown > Saturated Thickness
12010	487740	4404503	Test Drawdown > Saturated Thickness
12016	492075	4403727	Test Drawdown > Saturated Thickness
12033	483156	4401696	Test Drawdown > Saturated Thickness
12037	505330	4395735	Test Drawdown > Saturated Thickness
12044	510162	4391515	Test Drawdown > Saturated Thickness
12054	504637	4395130	Test Drawdown > Saturated Thickness
12057	500529	4393934	Test Drawdown > Saturated Thickness
12059	500198	4392125	Test Drawdown > Saturated Thickness

Table A-1
Excluded HydroBase Records

X- X Coordinate in NAD1983 UTM13N (meters)

Y- Y Coordinate in NAD1983 UTM13N (meters)

ID	X	Y	Exclusion Reason
12064	491864	4390724	Test Drawdown > Saturated Thickness
12065	491762	4390824	Test Drawdown > Saturated Thickness
12071	503509	4387618	Test Drawdown > Saturated Thickness
12525	664032	4509379	Specific Capacity > 400 gpm/ft
12526	591517	4457668	Specific Capacity > 400 gpm/ft
12527	591450	4462228	Specific Capacity > 400 gpm/ft
12528	601105	4455918	Specific Capacity > 400 gpm/ft
12529	633286	4473938	Specific Capacity > 400 gpm/ft
12530	664597	4507409	Specific Capacity > 400 gpm/ft
12531	650016	4489709	Specific Capacity > 400 gpm/ft
12532	585282	4460328	Specific Capacity > 400 gpm/ft
12533	605056	4454308	Specific Capacity > 400 gpm/ft
12534	649400	4489118	Specific Capacity > 400 gpm/ft
12535	591547	4462928	Specific Capacity > 400 gpm/ft
12536	648573	4497219	Specific Capacity > 400 gpm/ft
12537	610766	4458208	Specific Capacity > 400 gpm/ft
12538	648111	4499129	Specific Capacity > 400 gpm/ft
12545	650330	4501859	Test Duration < 2 Hours
12566	694929	4526910	Test Duration < 2 Hours
12636	644869	4481868	Test Duration < 2 Hours
12643	616955	4451538	Depth to Water > Well Depth
12648	611931	4459208	Test Duration < 2 Hours
12656	709533	4536840	Test Duration < 2 Hours
12658	616645	4458068	Test Duration < 2 Hours
12659	644070	4488458	Test Duration < 2 Hours
12660	669073	4517579	Test Duration < 2 Hours
12679	598535	4451128	Test Drawdown > Saturated Thickness
12681	622124	4468778	Test Duration < 2 Hours
12682	671428	4516259	Test Duration < 2 Hours
12687	603130	4449438	Test Duration < 2 Hours
12710	616524	4451308	Duplicate Test
12713	637534	4477858	Test Duration < 2 Hours
12717	640911	4491858	Test Duration < 2 Hours

Table A-1
Excluded HydroBase Records

X- X Coordinate in NAD1983 UTM13N (meters)

Y- Y Coordinate in NAD1983 UTM13N (meters)

ID	X	Y	Exclusion Reason
12722	643021	4481668	Test Duration < 2 Hours
12724	621966	4462678	Test Duration < 2 Hours
12727	645201	4489518	Test Duration < 2 Hours
12729	665717	4515839	Test Duration < 2 Hours
12731	621179	4461568	Test Duration < 2 Hours
12732	656343	4506999	Test Duration < 2 Hours
12740	618176	4456078	Test Drawdown > Saturated Thickness
12741	650418	4502479	Test Duration < 2 Hours
12747	646360	4495039	Test Duration < 2 Hours
12750	623968	4462268	Test Duration < 2 Hours
12752	639867	4493228	Test Drawdown > Saturated Thickness
12759	629623	4466778	Test Duration < 2 Hours
12760	607419	4452098	Test Drawdown > Saturated Thickness
12762	647530	4496179	Test Drawdown > Saturated Thickness
12765	513069	4421498	Test Drawdown > Saturated Thickness
12776	525732	4462708	Test Drawdown > Saturated Thickness
12786	531597	4464308	Test Drawdown > Saturated Thickness
12790	537116	4476769	Test Drawdown > Saturated Thickness
12816	516976	4435808	Test Drawdown > Saturated Thickness
12817	579555	4452458	Specific Capacity > 400 gpm/ft
12818	581096	4450748	Specific Capacity > 400 gpm/ft
12819	515446	4424798	Test Drawdown > Saturated Thickness
12820	581990	4452428	Specific Capacity > 400 gpm/ft
12821	581110	4452408	Specific Capacity > 400 gpm/ft
12822	580404	4455138	Specific Capacity > 400 gpm/ft
12823	519608	4466769	Test Drawdown > Saturated Thickness
12824	580344	4454088	Specific Capacity > 400 gpm/ft
12825	576510	4453758	Specific Capacity > 400 gpm/ft
12826	576104	4450818	Specific Capacity > 400 gpm/ft
12827	575800	4455588	Specific Capacity > 400 gpm/ft
12828	573703	4453348	Specific Capacity > 400 gpm/ft
12832	575479	4450778	Specific Capacity > 400 gpm/ft
12840	511422	4448708	Specific Capacity > 400 gpm/ft

Table A-1
Excluded HydroBase Records

X- X Coordinate in NAD1983 UTM13N (meters)
Y- Y Coordinate in NAD1983 UTM13N (meters)

ID	X	Y	Exclusion Reason
12841	516282	4435728	Test Drawdown > Saturated Thickness
12859	528864	4478249	Test Drawdown > Saturated Thickness
12867	513010	4448748	Screened Interval Below Bottom of Well
12872	507917	4450209	Test Drawdown > Saturated Thickness
12875	554334	4464588	Test Drawdown > Saturated Thickness
12898	547431	4466488	Duplicate Test
12909	540322	4473588	Screened Interval Below Bottom of Well
12912	545120	4466388	Screened Interval Below Bottom of Well
12914	515923	4442478	Test Drawdown > Saturated Thickness
12916	517141	4441688	Test Drawdown > Saturated Thickness
12917	516348	4437668	Test Drawdown > Saturated Thickness
12918	517142	4440488	Test Drawdown > Saturated Thickness
12919	513098	4444068	Test Drawdown > Saturated Thickness
12920	515515	4442878	Test Drawdown > Saturated Thickness
12921	513096	4443268	Test Drawdown > Saturated Thickness
12923	515326	4442378	Specific Capacity > 400 gpm/ft
12923	515326	4442378	Test Drawdown > Saturated Thickness
13112	530465	4293833	Outside SPDSS Study Area
13132	530465	4293833	Outside SPDSS Study Area
13148	629106	4396833	Outside SPDSS Study Area
3000012	531471	4467818	Duplicate Test
3000014	535820	4476852	Duplicate Test
3000019	530023	4480052	Duplicate Test
3000041	620339	4445555	Duplicate Test
3000043	544804	4480575	Test Duration Not Provided
3000044	546608	4481009	Test Duration Not Provided
3000045	544035	4479358	Test Duration Not Provided
5000083	601040	4447975	Test Drawdown > Saturated Thickness
5000132	626797	4421538	Test Drawdown > Saturated Thickness
5000134	626959	4421574	Test Drawdown > Saturated Thickness
5000139	621636	4426787	Test Drawdown > Saturated Thickness
5000158	622448	4425833	Test Drawdown > Saturated Thickness
5000164	618787	4440268	Test Drawdown > Saturated Thickness

Table A-1
Excluded HydroBase Records

X- X Coordinate in NAD1983 UTM13N (meters)

Y- Y Coordinate in NAD1983 UTM13N (meters)

ID	X	Y	Exclusion Reason
5000165	618608	4440611	Test Drawdown > Saturated Thickness
5000166	619424	4451993	Test Drawdown > Saturated Thickness
5000167	619137	4451472	Test Drawdown > Saturated Thickness
5000182	621159	4444377	Test Drawdown > Saturated Thickness

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Development of the Hydraulic Conductivity Data Set Used for Contouring

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Development of the Hydraulic Conductivity Data Set Used for Contouring

This appendix to the Phase 3, Task 43.3 Technical Memorandum (TM) addresses several details referenced in section 1.2.4 of the TM. This data includes a summary and listing of data that was not used to create the contouring data set, a summary and listing of the engineering control points used to constrain the gridding and contouring process, and the parameters used in kriging to develop the grid and contours.

Data Not Used in Contouring Data Set

As described in section 1.2.4 of the TM, a subset of specific capacity tests were excluded from the contouring data set. These specific capacity tests are from low capacity wells that were tested at 50gpm or less. Notably, all the specific capacity-based K values that are less than the lowest pumping test-based K value are from low capacity wells.

The low pumping rate of the low capacity wells suggests that the tests were performed on domestic wells. This type of well is likely to have less efficient communication with the aquifer than would a high capacity well. A less efficient well will have a higher drawdown for a given pumping rate which will lead to a smaller T value when calculated using the specific capacity-based methods. Figure 3 in the TM shows the discrepancy between specific capacity-based K values taken from low and high capacity wells. Since aquifer pumping test-derived data is considered the most reliable data source available, it was used as a baseline for the statistical characterization of the aquifer. Table B-1 summarizes the statistics of the excluded specific capacity-based K data relative to the aquifer pumping test-based K data.

Table B-1 Statistical Summary of Aquifer K Data Excluded from Contouring

Exclusion Reason	Number of points excluded	minimum	Q1	median	Q3	maximum
Pumping Test (Baseline Data)	0	18.0	298.5	489.0	735.3	1872.0
Laboratory Tests	73	0.0	17.4	92.3	388.0	3877.0
Specific Capacity Test with Q < 50gpm	166	0.5	7.2	27.3	74.9	986.6
K > 2000 ft/day	13	2005.0	2174.8	2558.0	3157.0	6016.9
Division 2 Tests	6	84.3	116.8	156.0	166.0	311.0
Total	258	--	--	--	--	--

Laboratory data were also excluded from the data set used to generate the K and T grids. As described in section 1.1, it is the least reliable source of data for determining bulk aquifer properties. While some lab results show values that are within the range of K derived from aquifer pumping tests, the local nature of laboratory core samples adds

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little to regional trend analysis. In addition, more than 25% of lab data have K less than the minimum K seen in aquifer pumping tests, suggesting some samples were taken from clay portions of the aquifer that do not represent the overall sandy makeup of the South Platte alluvium. A statistical summary of K data from laboratory tests is presented in Table B-1

Six pumping tests in Division 2 (Upper Black Squirrel and Big Sandy Designated Basins) were not included in the contouring data set. The alluvial model for which the contours are initial inputs does not include these areas.

A final set of data excluded from contouring is all data that shows a K greater than 2000 ft/day. This value is abnormally high, and, compared to surrounding data, appears unreasonable. In addition, this high of a K value is expected from coarse gravels, not from the sands of the South Platte alluvium.

Table B-4 towards the end of this appendix lists each data point excluded from the contouring data set.

Engineering Control Points

As described in section 1.2.4 of the TM, engineering control points were added to several areas to help constrain the contouring algorithms. Control points were added to areas with a lack of data and also along alluvial boundaries adjacent to neighboring tributary basins that had significantly different aquifer property characteristics. Values for the control points were determined by calculating the median value of K from available data for each specific basin, or from averages presented in published reports. Table B-2 summarizes the number and value of control points used. Table B-5 lists the X and Y coordinates along with the K value.

Table B-2 – Summary of Engineering Control Point Values

Area of Control	Count	Median K (ft/day)	Note
Beaver-Badger Creeks	8	147	
Bijou Creek	50	140	Avg. K value 140 ft/d (Duke and Longenbaugh, 1966)
Boxelder Creek	12	321	
Cherry and Plum Creeks	15	565	
Clear Creek	9	226	
East Metro Denver	10	348	
Inter Kiowa-Bijou	37	200, 250	Points placed between basins to force proper contouring within each basin

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Kiowa Creek	54	270	Avg. K value 270 ft/d (Duke and Longenbaugh, 1966)
Lost Creek	20	262	
Lower South Platte	25	425	
Upper South Platte	34	605	
Western Tributaries	46	200	Avg. K value 200 ft/day (McCurry, 2000)
Total	320	--	

Kriging Algorithm

As described in section 1.2.4, kriging was employed as the statistical method to interpolate the spatially distributed raw data onto a regular grid. Kriging uses a variogram to interpolate from known data to neighboring grid cells. A variogram displays the spatial correlation between pairs of data points that are within a given distance of each other, referred to as lag distance. This correlation is calculated at several lag distances to formulate the variogram based on the data, referred to as the experimental variogram. Once the experimental variogram is calculated, a model variogram is developed whereby a mathematical equation is fit to the variogram for use in the kriging algorithm to interpolate values onto a grid. Due to the highly variable nature of the data, a 'nugget' was used in kriging. The nugget allows the kriging algorithm to smooth data as it interpolates to each grid location. Figure B-1 shows the experimental and model variograms developed and used to generate K contours. The data is log-normally distributed, so in order to use linear interpolation methods the data needed to be converted to log space. Kriging of this data set was done using log-transformed values and then converted back to linear space. Table B-3 summarizes other parameters used in the kriging algorithm.

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Figure B-1 Experimental and Model Variograms

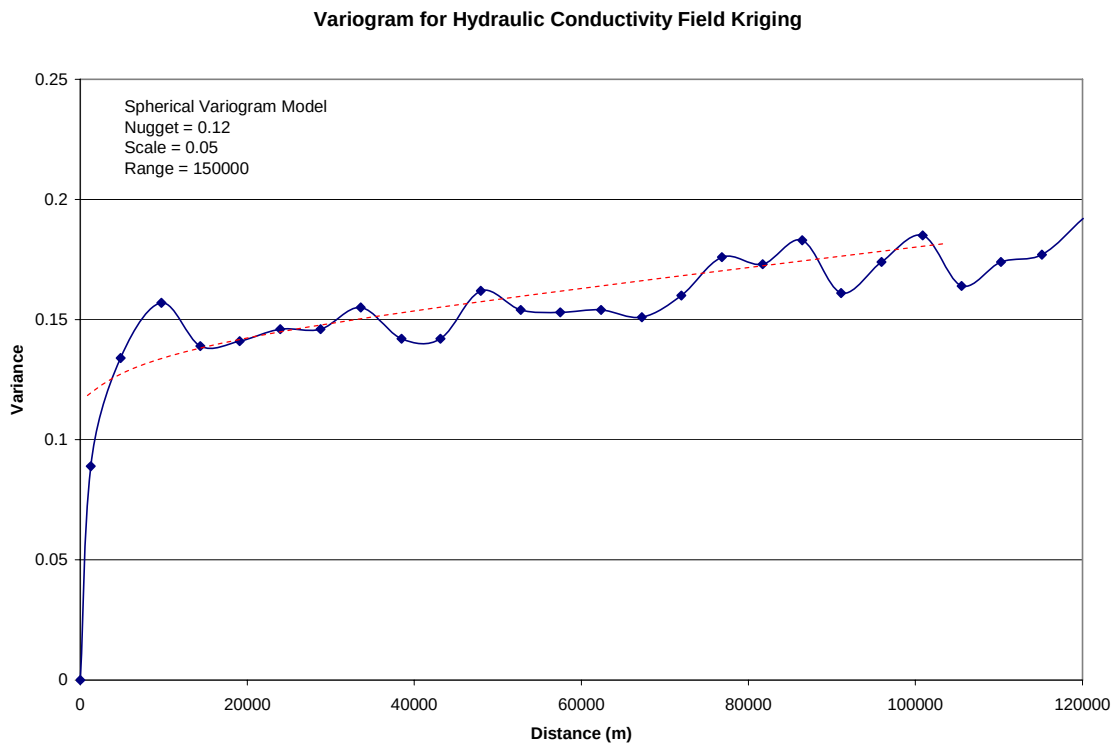

Table B-3 – Kriging Algorithm Parameters

	Parameter	Value
Model Variogram	Type	Spherical
	Length	15000m
	Scale	0.05
	Nugget	0.08
Kriging	Search Radius	30000m
	Grid Spacing	10000m

Table B-4 – List of Data Not Used in Contouring

well_id	utm_x[1]	utm_y[1]	K (ft/day)	Contouring Exclusion Reason
13108	596595	4341382	311.0	Division 2
13109	592371	4338346	167.0	Division 2
13110	559438	4325633	163.0	Division 2
13111	556499	4297162	106.0	Division 2
13130	552470	4311326	84.3	Division 2

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well_id	utm_x[1]	utm_y[1]	K (ft/day)	Contouring Exclusion Reason
13131	555655	4298943	149.0	Division 2
11918	499275	4386695	3758.3	K > 2000ft/d
11963	514257	4424754	2706.0	K > 2000ft/d
11996	502618	4405112	3157.0	K > 2000ft/d
12041	507928	4394034	2071.8	K > 2000ft/d
12506	516484	4428329	2959.7	K > 2000ft/d
12508	526510	4438439	2333.4	K > 2000ft/d
12540	642738	4490588	6016.9	K > 2000ft/d
12542	602686	4454878	2174.8	K > 2000ft/d
12913	573180	4463998	2367.8	K > 2000ft/d
12958	515620	4425406	2005.0	K > 2000ft/d
1002378	508295	4409313	2558.0	K > 2000ft/d
3000010	490667	4498697	2139.2	K > 2000ft/d
5000133	626959	4421573	3446.8	K > 2000ft/d
12100	512454	4413164	241.0	Lab data
12107	514155	4408030	0.4	Lab data
12108	513655	4408535	2.1	Lab data
12109	514656	4407019	13.4	Lab data
12111	490565	4404513	89.6	Lab data
12118	491863	4390824	134.0	Lab data
12130	521447	4382879	2.0	Lab data
12131	497785	4388716	0.4	Lab data
12132	497867	4386900	2941.0	Lab data
12133	499120	4386147	174.0	Lab data
12137	495274	4377459	21.4	Lab data
1003744	510084	4410844	1.2	Lab data
1003744	510084	4410844	13.4	Lab data
1003743	505636	4408870	414.0	Lab data
1003743	505636	4408870	254.0	Lab data
1003743	505636	4408870	201.0	Lab data
1003743	505636	4408870	227.0	Lab data
1003743	505636	4408870	348.0	Lab data
1003743	505636	4408870	187.0	Lab data
1003743	505636	4408870	588.0	Lab data
1003742	502865	4402893	12.4	Lab data
1003741	506070	4394726	949.0	Lab data
1003741	506070	4394726	548.0	Lab data
1003741	506070	4394726	561.0	Lab data
1003741	506070	4394726	775.0	Lab data
1003741	506070	4394726	388.0	Lab data

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well_id	utm_x[1]	utm_y[1]	K (ft/day)	Contouring Exclusion Reason
1003741	506070	4394726	147.0	Lab data
1003741	506070	4394726	802.0	Lab data
1003741	506070	4394726	80.2	Lab data
1003741	506070	4394726	30.8	Lab data
1003740	509603	4391507	227.0	Lab data
1003740	509603	4391507	78.9	Lab data
1003740	509603	4391507	2941.0	Lab data
1003740	509603	4391507	441.0	Lab data
1003740	509603	4391507	548.0	Lab data
1003740	509603	4391507	561.0	Lab data
1003739	508889	4392215	0.0	Lab data
1003739	508889	4392215	1.1	Lab data
1003739	508889	4392215	1.1	Lab data
1003739	508889	4392215	4.4	Lab data
1003739	508889	4392215	2.3	Lab data
1003739	508889	4392215	2.9	Lab data
1003739	508889	4392215	2.5	Lab data
1003739	508889	4392215	12.2	Lab data
1003739	508889	4392215	17.4	Lab data
1003738	498238	4397665	1203.0	Lab data
1003738	498238	4397665	267.0	Lab data
1003738	498238	4397665	72.2	Lab data
1003737	516344	4382653	112.0	Lab data
1003737	516344	4382653	73.5	Lab data
1003737	516344	4382653	126.0	Lab data
1003737	516344	4382653	414.0	Lab data
1003737	516344	4382653	73.5	Lab data
1003737	516344	4382653	52.1	Lab data
1003736	497833	4388609	92.3	Lab data
1003736	497833	4388609	1872.0	Lab data
1003736	497833	4388609	1872.0	Lab data
1003736	497833	4388609	120.0	Lab data
1003735	519656	4374101	22.7	Lab data
1003735	519656	4374101	3.7	Lab data
1003735	519656	4374101	174.0	Lab data
1003735	519656	4374101	82.9	Lab data
1003735	519656	4374101	53.5	Lab data
1003735	519656	4374101	77.5	Lab data
1003735	519656	4374101	85.6	Lab data
1003734	496394	4376044	147.0	Lab data

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well_id	utm_x[1]	utm_y[1]	K (ft/day)	Contouring Exclusion Reason
1003734	496394	4376044	58.8	Lab data
1003734	496394	4376044	615.0	Lab data
1003734	496394	4376044	3877.0	Lab data
1003734	496394	4376044	307.0	Lab data
1003733	495312	4375328	18.7	Lab data
1003733	495312	4375328	1.9	Lab data
1003732	492680	4372915	38.8	Lab data
11842	506518	4407223	47.8	testq <= 50gpm
11855	490561	4404113	30.1	testq <= 50gpm
11861	516533	4398485	102.3	testq <= 50gpm
11880	500407	4398367	191.3	testq <= 50gpm
11887	503435	4396537	90.2	testq <= 50gpm
11957	514866	4425459	7.2	testq <= 50gpm
11960	516366	4423539	4.7	testq <= 50gpm
11964	513149	4421535	252.6	testq <= 50gpm
11966	513951	4421431	131.5	testq <= 50gpm
11974	509340	4415170	143.5	testq <= 50gpm
11975	509341	4415069	287.0	testq <= 50gpm
11976	509845	4415068	17.5	testq <= 50gpm
11978	511957	4415178	986.6	testq <= 50gpm
11989	508210	4404925	177.6	testq <= 50gpm
11992	501032	4407422	67.7	testq <= 50gpm
11998	494887	4405421	239.2	testq <= 50gpm
11999	494684	4405018	38.2	testq <= 50gpm
12000	493777	4405013	182.1	testq <= 50gpm
12001	493074	4404620	631.4	testq <= 50gpm
12003	492873	4404522	131.5	testq <= 50gpm
12005	492374	4404327	210.5	testq <= 50gpm
12006	493474	4404416	175.4	testq <= 50gpm
12007	492069	4405328	36.1	testq <= 50gpm
12009	491972	4404327	80.9	testq <= 50gpm
12011	485997	4404685	145.7	testq <= 50gpm
12012	486276	4403177	131.5	testq <= 50gpm
12013	488346	4402995	21.3	testq <= 50gpm
12014	487944	4402488	124.6	testq <= 50gpm
12015	489955	4403609	34.8	testq <= 50gpm
12018	492573	4402415	225.5	testq <= 50gpm
12019	493774	4402409	242.8	testq <= 50gpm
12020	493976	4402007	18.8	testq <= 50gpm
12021	493775	4401704	42.9	testq <= 50gpm

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well_id	utm_x[1]	utm_y[1]	K (ft/day)	Contouring Exclusion Reason
12022	493172	4401200	32.5	testq <= 50gpm
12024	486082	4401366	16.3	testq <= 50gpm
12032	485692	4403676	70.2	testq <= 50gpm
12038	511843	4394151	25.1	testq <= 50gpm
12039	511344	4394247	4.3	testq <= 50gpm
12040	507827	4394134	19.7	testq <= 50gpm
12043	508231	4392725	8.7	testq <= 50gpm
12047	503439	4396034	48.7	testq <= 50gpm
12058	501112	4391920	171.6	testq <= 50gpm
12061	499104	4389323	20.2	testq <= 50gpm
12069	499584	4387594	40.5	testq <= 50gpm
12070	499478	4386993	52.6	testq <= 50gpm
12627	622813	4461038	203.7	testq <= 50gpm
12628	598727	4458478	360.8	testq <= 50gpm
12642	597570	4458938	378.8	testq <= 50gpm
12661	625853	4464738	64.9	testq <= 50gpm
12662	625534	4464718	74.0	testq <= 50gpm
12663	648534	4498509	91.1	testq <= 50gpm
12664	655734	4500839	83.1	testq <= 50gpm
12665	605092	4458788	74.0	testq <= 50gpm
12666	600951	4447678	92.9	testq <= 50gpm
12667	653829	4497159	143.5	testq <= 50gpm
12668	610797	4463268	96.6	testq <= 50gpm
12669	654258	4506749	135.3	testq <= 50gpm
12673	648775	4499939	136.8	testq <= 50gpm
12683	651139	4496629	40.5	testq <= 50gpm
12684	673431	4517099	42.7	testq <= 50gpm
12685	684300	4524680	64.4	testq <= 50gpm
12686	713748	4536410	87.7	testq <= 50gpm
12688	610709	4461118	71.0	testq <= 50gpm
12690	649159	4492749	30.4	testq <= 50gpm
12691	633298	4473938	31.6	testq <= 50gpm
12692	648919	4498469	33.8	testq <= 50gpm
12693	651947	4500219	34.8	testq <= 50gpm
12694	599662	4448688	38.8	testq <= 50gpm
12695	649698	4503519	59.2	testq <= 50gpm
12696	695986	4528740	221.0	testq <= 50gpm
12699	624022	4469798	32.2	testq <= 50gpm
12700	644067	4488348	21.9	testq <= 50gpm
12701	638913	4483468	46.4	testq <= 50gpm

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well_id	utm_x[1]	utm_y[1]	K (ft/day)	Contouring Exclusion Reason
12702	633237	4469428	21.3	testq <= 50gpm
12703	730044	4540400	39.5	testq <= 50gpm
12704	610566	4459578	27.5	testq <= 50gpm
12705	652521	4504989	33.8	testq <= 50gpm
12706	633506	4472548	9.5	testq <= 50gpm
12707	631655	4475918	22.0	testq <= 50gpm
12708	715423	4537630	27.1	testq <= 50gpm
12709	651789	4499179	19.7	testq <= 50gpm
12711	640361	4480808	8.8	testq <= 50gpm
12712	592468	4462768	43.8	testq <= 50gpm
12714	651985	4503479	9.9	testq <= 50gpm
12715	653796	4497109	12.3	testq <= 50gpm
12716	732178	4539730	31.6	testq <= 50gpm
12718	720285	4536920	10.5	testq <= 50gpm
12719	598125	4451938	7.8	testq <= 50gpm
12720	673355	4517559	7.1	testq <= 50gpm
12721	698018	4528810	11.3	testq <= 50gpm
12723	643433	4483188	4.4	testq <= 50gpm
12725	617907	4456908	9.1	testq <= 50gpm
12726	622095	4465688	16.9	testq <= 50gpm
12728	644089	4484178	4.5	testq <= 50gpm
12730	630143	4469488	2.9	testq <= 50gpm
12733	617981	4452998	4.2	testq <= 50gpm
12734	708986	4532440	3.7	testq <= 50gpm
12735	600700	4447778	7.2	testq <= 50gpm
12736	617795	4454588	4.0	testq <= 50gpm
12737	645602	4489538	2.5	testq <= 50gpm
12738	632729	4470958	1.5	testq <= 50gpm
12739	645519	4485838	2.1	testq <= 50gpm
12742	679745	4523780	3.4	testq <= 50gpm
12743	610607	4463108	3.2	testq <= 50gpm
12744	625100	4463338	2.9	testq <= 50gpm
12745	687981	4523950	2.2	testq <= 50gpm
12746	619136	4451468	4.7	testq <= 50gpm
12748	617119	4456228	2.5	testq <= 50gpm
12749	685231	4524290	3.6	testq <= 50gpm
12751	639621	4491888	2.1	testq <= 50gpm
12753	640878	4479238	1.5	testq <= 50gpm
12754	626522	4468988	1.6	testq <= 50gpm

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well_id	utm_x[1]	utm_y[1]	K (ft/day)	Contouring Exclusion Reason
12755	696468	4527470	1.3	testq <= 50gpm
12756	591705	4453058	1.6	testq <= 50gpm
12757	614151	4453498	1.0	testq <= 50gpm
12758	650490	4503339	2.4	testq <= 50gpm
12761	595686	4451928	0.5	testq <= 50gpm
12764	512661	4457389	13.7	testq <= 50gpm
12767	515361	4430428	4.5	testq <= 50gpm
12768	515945	4444198	4.5	testq <= 50gpm
12769	516108	4434388	6.2	testq <= 50gpm
12770	516044	4462599	14.6	testq <= 50gpm
12771	516360	4434848	4.6	testq <= 50gpm
12777	526272	4476969	1.6	testq <= 50gpm
12778	526564	4475309	30.4	testq <= 50gpm
12779	526609	4465708	6.7	testq <= 50gpm
12781	565968	4463758	15.6	testq <= 50gpm
12782	528921	4467818	17.5	testq <= 50gpm
12784	529448	4477699	13.7	testq <= 50gpm
12785	530617	4479319	25.6	testq <= 50gpm
12788	532275	4471398	7.5	testq <= 50gpm
12793	554013	4463818	2.2	testq <= 50gpm
12796	576645	4465578	3.8	testq <= 50gpm
12802	581133	4470038	8.2	testq <= 50gpm
12834	528987	4464508	4.1	testq <= 50gpm
12835	536897	4471898	6.4	testq <= 50gpm
12837	512906	4456239	61.9	testq <= 50gpm
12838	574052	4461908	75.2	testq <= 50gpm
12842	514511	4456149	15.6	testq <= 50gpm
12844	529775	4469618	26.3	testq <= 50gpm
12845	509745	4452729	105.2	testq <= 50gpm
12846	516072	4432848	19.3	testq <= 50gpm
12847	514685	4455709	152.8	testq <= 50gpm
12848	513463	4455159	116.9	testq <= 50gpm
12849	508324	4448819	12.3	testq <= 50gpm
12850	514522	4454299	21.2	testq <= 50gpm
12851	516088	4456749	30.4	testq <= 50gpm
12852	583559	4467328	157.9	testq <= 50gpm
12853	513011	4456589	84.6	testq <= 50gpm
12854	529944	4473529	11.3	testq <= 50gpm
12855	515782	4429418	45.5	testq <= 50gpm
12856	579881	4453988	6.2	testq <= 50gpm

Appendix B

Development of the Hydraulic Conductivity Data Set Used for Contouring

well_id	utm_x[1]	utm_y[1]	K (ft/day)	Contouring Exclusion Reason
12857	521460	4467019	2.6	testq <= 50gpm
12858	527963	4473769	41.2	testq <= 50gpm
12860	528915	4473019	13.1	testq <= 50gpm
12861	511643	4452729	17.2	testq <= 50gpm
12862	531352	4472139	47.8	testq <= 50gpm
12863	515380	4452048	118.4	testq <= 50gpm
12864	515550	4427838	14.1	testq <= 50gpm
12865	509786	4449199	87.7	testq <= 50gpm
12866	509966	4448819	43.8	testq <= 50gpm
12868	528056	4474959	3.0	testq <= 50gpm
12869	511432	4464499	33.0	testq <= 50gpm
12870	514912	4426878	23.9	testq <= 50gpm
12871	521137	4465819	47.4	testq <= 50gpm
12885	515524	4437258	4.5	testq <= 50gpm

Note 1: X and Y coordinates in UTM 13N NAD83 meters

Table B-5 List of Engineering Control Points

utm_x[1]	utm_y[1]	K (ft/day)	Basin
617624	4456814	147.0	Beaver-Badger Creeks
616847	4454678	147.0	Beaver-Badger Creeks
615585	4453125	147.0	Beaver-Badger Creeks
613741	4452639	147.0	Beaver-Badger Creeks
617915	4442543	147.0	Beaver-Badger Creeks
619468	4438563	147.0	Beaver-Badger Creeks
621507	4434389	147.0	Beaver-Badger Creeks
621798	4430603	147.0	Beaver-Badger Creeks
553552	4459629	262.0	Lost Creek
556367	4458853	262.0	Lost Creek
558988	4458270	262.0	Lost Creek
560953	4455487	262.0	Lost Creek
550737	4456717	262.0	Lost Creek
551513	4452931	262.0	Lost Creek
548504	4449921	262.0	Lost Creek
546853	4446426	262.0	Lost Creek
546853	4442252	262.0	Lost Creek
558600	4447494	262.0	Lost Creek
546465	4425846	262.0	Lost Creek
555105	4435359	262.0	Lost Creek

Appendix B

Development of the Hydraulic Conductivity Data Set Used for Contouring

utm_x[1]	utm_y[1]	K (ft/day)	Basin
555008	4428370	262.0	Lost Creek
552193	4423030	262.0	Lost Creek
548989	4420118	262.0	Lost Creek
547048	4415555	262.0	Lost Creek
543262	4410216	262.0	Lost Creek
548795	4410216	262.0	Lost Creek
546077	4404780	262.0	Lost Creek
551125	4460697	262.0	Lost Creek
573764	4455583	270.0	Kiowa Creek
562969	4451960	270.0	Kiowa Creek
567794	4445980	270.0	Kiowa Creek
564328	4443320	270.0	Kiowa Creek
568890	4443126	270.0	Kiowa Creek
572191	4448077	270.0	Kiowa Creek
568696	4449630	270.0	Kiowa Creek
565978	4439340	270.0	Kiowa Creek
563454	4433903	270.0	Kiowa Creek
560930	4426817	270.0	Kiowa Creek
566172	4423904	270.0	Kiowa Creek
560153	4423030	270.0	Kiowa Creek
558697	4417400	270.0	Kiowa Creek
555591	4413614	270.0	Kiowa Creek
554426	4409925	270.0	Kiowa Creek
551610	4405168	270.0	Kiowa Creek
550445	4399537	270.0	Kiowa Creek
548407	4393810	270.0	Kiowa Creek
548504	4388082	270.0	Kiowa Creek
559474	4410993	270.0	Kiowa Creek
559085	4405168	270.0	Kiowa Creek
558988	4399149	270.0	Kiowa Creek
558697	4393227	270.0	Kiowa Creek
556756	4387985	270.0	Kiowa Creek
547824	4382937	270.0	Kiowa Creek
547921	4378277	270.0	Kiowa Creek
547630	4372355	270.0	Kiowa Creek
554814	4383713	270.0	Kiowa Creek
556270	4379054	270.0	Kiowa Creek
556173	4374879	270.0	Kiowa Creek
556658	4369928	270.0	Kiowa Creek
555202	4365657	270.0	Kiowa Creek

Appendix B

Development of the Hydraulic Conductivity Data Set Used for Contouring

utm_x[1]	utm_y[1]	K (ft/day)	Basin
554717	4360317	270.0	Kiowa Creek
553746	4354007	270.0	Kiowa Creek
551125	4347697	270.0	Kiowa Creek
551999	4375559	270.0	Kiowa Creek
551319	4368375	270.0	Kiowa Creek
549766	4361580	270.0	Kiowa Creek
577045	4453902	140.0	Bijou Creek
580152	4452834	140.0	Bijou Creek
583841	4451766	140.0	Bijou Creek
576851	4449436	140.0	Bijou Creek
583743	4446038	140.0	Bijou Creek
584617	4440990	140.0	Bijou Creek
585588	4436039	140.0	Bijou Creek
585685	4427496	140.0	Bijou Creek
575589	4428176	140.0	Bijou Creek
579472	4442252	140.0	Bijou Creek
574036	4423322	140.0	Bijou Creek
584035	4422642	140.0	Bijou Creek
572385	4418468	140.0	Bijou Creek
569376	4413323	140.0	Bijou Creek
566755	4408566	140.0	Bijou Creek
565201	4401188	140.0	Bijou Creek
563551	4397499	140.0	Bijou Creek
566269	4394101	140.0	Bijou Creek
566075	4389150	140.0	Bijou Creek
564619	4385558	140.0	Bijou Creek
562872	4382451	140.0	Bijou Creek
579375	4418371	140.0	Bijou Creek
581996	4411478	140.0	Bijou Creek
583064	4404197	140.0	Bijou Creek
588306	4398372	140.0	Bijou Creek
576657	4411090	140.0	Bijou Creek
573841	4406818	140.0	Bijou Creek
575006	4400023	140.0	Bijou Creek
577530	4394683	140.0	Bijou Creek
580054	4388276	140.0	Bijou Creek
582287	4383325	140.0	Bijou Creek
577433	4388082	140.0	Bijou Creek
577725	4382646	140.0	Bijou Creek
584520	4378762	140.0	Bijou Creek

Appendix B

Development of the Hydraulic Conductivity Data Set Used for Contouring

utm_x[1]	utm_y[1]	K (ft/day)	Basin
588015	4374103	140.0	Bijou Creek
561415	4379345	140.0	Bijou Creek
559571	4376044	140.0	Bijou Creek
559668	4371190	140.0	Bijou Creek
559862	4367598	140.0	Bijou Creek
560639	4363812	140.0	Bijou Creek
560542	4360317	140.0	Bijou Creek
561512	4357308	140.0	Bijou Creek
560736	4353910	140.0	Bijou Creek
558697	4352939	140.0	Bijou Creek
559377	4350027	140.0	Bijou Creek
556464	4345659	140.0	Bijou Creek
561512	4365560	140.0	Bijou Creek
561901	4369249	140.0	Bijou Creek
561415	4374006	140.0	Bijou Creek
570832	4396043	140.0	Bijou Creek
565124	4455287	270.0	Kiowa Creek
567315	4452645	270.0	Kiowa Creek
564931	4447556	270.0	Kiowa Creek
562225	4444463	270.0	Kiowa Creek
569892	4456060	270.0	Kiowa Creek
565124	4458379	425.0	Lower South Platte
560679	4458379	425.0	Lower South Platte
558682	4460441	425.0	Lower South Platte
555589	4461149	425.0	Lower South Platte
579233	4457026	425.0	Lower South Platte
584903	4458508	425.0	Lower South Platte
542901	4474181	425.0	Lower South Platte
540486	4474785	425.0	Lower South Platte
540184	4464518	321.0	Boxelder Creek
542700	4462202	321.0	Boxelder Creek
537667	4454451	321.0	Boxelder Creek
533842	4448109	321.0	Boxelder Creek
531929	4439150	321.0	Boxelder Creek
532875	4433895	321.0	Boxelder Creek
532533	4413883	321.0	Boxelder Creek
532936	4400696	321.0	Boxelder Creek
537969	4397072	321.0	Boxelder Creek
526329	4451487	605.0	Upper South Platte
530994	4452540	605.0	Upper South Platte

Appendix B

Development of the Hydraulic Conductivity Data Set Used for Contouring

utm_x[1]	utm_y[1]	K (ft/day)	Basin
529489	4445618	605.0	Upper South Platte
526630	4426506	605.0	Upper South Platte
508191	4450229	605.0	Upper South Platte
508933	4448240	605.0	Upper South Platte
505320	4447675	200.0	Western Tributaries
508106	4443795	200.0	Western Tributaries
508053	4441279	200.0	Western Tributaries
504639	4446259	200.0	Western Tributaries
501231	4445211	200.0	Western Tributaries
498924	4441698	200.0	Western Tributaries
494730	4436718	200.0	Western Tributaries
490641	4433415	200.0	Western Tributaries
486552	4432838	200.0	Western Tributaries
495936	4432786	200.0	Western Tributaries
494626	4428487	200.0	Western Tributaries
487915	4424031	200.0	Western Tributaries
512031	4432629	200.0	Western Tributaries
512031	4432000	200.0	Western Tributaries
508885	4430951	200.0	Western Tributaries
506998	4429483	200.0	Western Tributaries
503066	4428068	200.0	Western Tributaries
503748	4424922	200.0	Western Tributaries
500707	4421514	200.0	Western Tributaries
495936	4417582	200.0	Western Tributaries
503066	4419679	200.0	Western Tributaries
506159	4419155	200.0	Western Tributaries
506002	4421410	200.0	Western Tributaries
506264	4424922	200.0	Western Tributaries
501179	4425341	200.0	Western Tributaries
500917	4431475	200.0	Western Tributaries
502804	4432367	200.0	Western Tributaries
507208	4434988	200.0	Western Tributaries
509462	4436351	200.0	Western Tributaries
511769	4437819	200.0	Western Tributaries
513152	4464961	200.0	Western Tributaries
511334	4465021	200.0	Western Tributaries
508993	4466950	200.0	Western Tributaries
506039	4469361	200.0	Western Tributaries
499228	4472375	200.0	Western Tributaries
491392	4471953	200.0	Western Tributaries

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Development of the Hydraulic Conductivity Data Set Used for Contouring

utm_x[1]	utm_y[1]	K (ft/day)	Basin
493441	4459596	200.0	Western Tributaries
499107	4460561	200.0	Western Tributaries
504050	4462128	200.0	Western Tributaries
508390	4464177	200.0	Western Tributaries
617176	4459368	425.0	Lower South Platte
615714	4458517	425.0	Lower South Platte
613280	4457210	425.0	Lower South Platte
610784	4457171	425.0	Lower South Platte
514393	4463462	605.0	Upper South Platte
512387	4438931	605.0	Upper South Platte
513027	4437268	605.0	Upper South Platte
512729	4433087	605.0	Upper South Platte
512899	4431721	605.0	Upper South Platte
509316	4417558	605.0	Upper South Platte
511790	4420843	605.0	Upper South Platte
513027	4423658	605.0	Upper South Platte
507524	4414443	605.0	Upper South Platte
501679	4403522	605.0	Upper South Platte
504367	4408727	605.0	Upper South Platte
502789	4401090	605.0	Upper South Platte
501167	4397223	605.0	Upper South Platte
500911	4391449	605.0	Upper South Platte
496176	4377498	605.0	Upper South Platte
496389	4376816	565.0	Cherry and Plum Creeks
497370	4375024	565.0	Cherry and Plum Creeks
497968	4373702	565.0	Cherry and Plum Creeks
498693	4371952	565.0	Cherry and Plum Creeks
500314	4369777	565.0	Cherry and Plum Creeks
501039	4367857	565.0	Cherry and Plum Creeks
520102	4361242	565.0	Cherry and Plum Creeks
520019	4364908	565.0	Cherry and Plum Creeks
520102	4368408	565.0	Cherry and Plum Creeks
520019	4372407	565.0	Cherry and Plum Creeks
518852	4376240	565.0	Cherry and Plum Creeks
513103	4387406	565.0	Cherry and Plum Creeks
513269	4393072	348.0	East Metro Denver
510353	4394488	348.0	East Metro Denver
508187	4395321	348.0	East Metro Denver
507437	4399238	348.0	East Metro Denver
506770	4402737	348.0	East Metro Denver

Appendix B

Development of the Hydraulic Conductivity Data Set Used for Contouring

utm_x[1]	utm_y[1]	K (ft/day)	Basin
508936	4404654	348.0	East Metro Denver
510853	4407237	348.0	East Metro Denver
513686	4413653	348.0	East Metro Denver
513519	4403904	348.0	East Metro Denver
515019	4398404	348.0	East Metro Denver
520435	4417236	605.0	Upper South Platte
516269	4417819	605.0	Upper South Platte
501214	4396351	605.0	Upper South Platte
502854	4400071	605.0	Upper South Platte
507285	4449011	200.0	Western Tributaries
508262	4446748	200.0	Western Tributaries
511039	4441811	605.0	Upper South Platte
485582	4407817	226.0	Clear Creek
488977	4403548	226.0	Clear Creek
486200	4402931	226.0	Clear Creek
502605	4408794	226.0	Clear Creek
496279	4408691	226.0	Clear Creek
492834	4404937	226.0	Clear Creek
635260	4474179	425.0	Lower South Platte
629109	4469214	425.0	Lower South Platte
624069	4465212	425.0	Lower South Platte
620290	4462470	425.0	Lower South Platte
598901	4456232	425.0	Lower South Platte
606066	4456454	425.0	Lower South Platte
591094	4458453	425.0	Lower South Platte
578845	4461496	425.0	Lower South Platte
575486	4460745	425.0	Lower South Platte
551423	4465645	425.0	Lower South Platte
553122	4463235	425.0	Lower South Platte
557152	4463669	425.0	Lower South Platte
560194	4462523	425.0	Lower South Platte
565340	4436647	270.0	Kiowa Creek
563257	4430628	270.0	Kiowa Creek
563720	4426846	270.0	Kiowa Creek
560941	4420287	270.0	Kiowa Creek
560247	4414190	270.0	Kiowa Creek
559707	4408247	270.0	Kiowa Creek
559089	4402768	270.0	Kiowa Creek
558472	4396355	270.0	Kiowa Creek
557777	4390876	270.0	Kiowa Creek

Appendix B

Development of the Hydraulic Conductivity Data Set Used for Contouring

utm_x[1]	utm_y[1]	K (ft/day)	Basin
556543	4385628	270.0	Kiowa Creek
557160	4381615	270.0	Kiowa Creek
530766	4442119	321.0	Boxelder Creek
535551	4451997	321.0	Boxelder Creek
532387	4436177	321.0	Boxelder Creek
527602	4440807	605.0	Upper South Platte
519808	4420433	605.0	Upper South Platte
520022	4452456	605.0	Upper South Platte
521300	4459620	605.0	Upper South Platte
530362	4463183	605.0	Upper South Platte
520100	4363347	565.0	Cherry and Plum Creeks
519945	4366600	565.0	Cherry and Plum Creeks
519983	4370433	565.0	Cherry and Plum Creeks
501894	4408376	226.0	Clear Creek
500986	4407728	226.0	Clear Creek
503682	4409257	226.0	Clear Creek
504770	4409698	605.0	Upper South Platte
510938	4431908	200.0	Western Tributaries
509591	4431156	200.0	Western Tributaries
510835	4437091	200.0	Western Tributaries
508684	4435899	200.0	Western Tributaries
512234	4447432	605.0	Upper South Platte
512390	4444141	605.0	Upper South Platte
568917	4435969	250.0	Inter Kiowa-Bijou
567922	4432089	250.0	Inter Kiowa-Bijou
566529	4428507	250.0	Inter Kiowa-Bijou
567723	4424627	250.0	Inter Kiowa-Bijou
564838	4421941	250.0	Inter Kiowa-Bijou
563743	4418458	250.0	Inter Kiowa-Bijou
562748	4414777	250.0	Inter Kiowa-Bijou
562151	4411494	250.0	Inter Kiowa-Bijou
561455	4408211	250.0	Inter Kiowa-Bijou
560758	4405425	250.0	Inter Kiowa-Bijou
560858	4402738	250.0	Inter Kiowa-Bijou
560758	4398759	250.0	Inter Kiowa-Bijou
560360	4395177	250.0	Inter Kiowa-Bijou
560161	4391993	250.0	Inter Kiowa-Bijou
559863	4387417	250.0	Inter Kiowa-Bijou
573615	4435783	200.0	Inter Kiowa-Bijou
572503	4431803	150.0	Inter Kiowa-Bijou

Appendix B

Development of the Hydraulic Conductivity Data Set Used for Contouring

utm_x[1]	utm_y[1]	K (ft/day)	Basin
571976	4427940	150.0	Inter Kiowa-Bijou
571215	4424135	150.0	Inter Kiowa-Bijou
569518	4420506	150.0	Inter Kiowa-Bijou
567645	4418282	150.0	Inter Kiowa-Bijou
566357	4415122	150.0	Inter Kiowa-Bijou
565304	4411727	150.0	Inter Kiowa-Bijou
564075	4408508	150.0	Inter Kiowa-Bijou
563958	4405347	150.0	Inter Kiowa-Bijou
562963	4402772	150.0	Inter Kiowa-Bijou
562377	4399026	150.0	Inter Kiowa-Bijou
562729	4395397	150.0	Inter Kiowa-Bijou
562787	4392354	150.0	Inter Kiowa-Bijou
562143	4387788	150.0	Inter Kiowa-Bijou
560622	4383633	150.0	Inter Kiowa-Bijou
559509	4379653	150.0	Inter Kiowa-Bijou
558163	4375263	150.0	Inter Kiowa-Bijou
558105	4373624	150.0	Inter Kiowa-Bijou
558339	4369469	150.0	Inter Kiowa-Bijou
558690	4363265	150.0	Inter Kiowa-Bijou
559509	4357997	150.0	Inter Kiowa-Bijou

Note 1: X and Y coordinates in UTM 13N NAD83 meters

Appendix C

Data Directory for Aquifer Property Data in HydroBase

Appendix C
Data Directory for Aquifer Properties Data in HydroBase

Table Name: *WELLS*	**Task:** Task 42, 43 and 44 of the SPDSS
Description: The core table in the database containing key information on wells including location, permit number, receipt, name, depth, aquifer tapped, and perforated interval.	
Field Name	**Field Description**
well_id	Well identifier.
well_name	Name of the well.
div	SEO Division number.
wd	SEO Water district.
receipt	Unique identifer. Generated by cash register.
permitno	Well permit number.
permitsuf	Well suffix code.
permitrpl	Well replacement code. Contains an 'A' for exempt, and 'R' for non-exempt.
locnum	USBR location identifier string.
Site_ID	USGS site identifier.
basin	Designated basin code.
md	Management district code.
cty	County code.
PM	Principle meridian.
ts	Township number
tsa	Half township indicator.
tdir	Township direction.
rng	Range number.
rnga	Half range indicator.
rdir	Range direction.
sec	Section number.
seca	Upper section indicator.
q160	160 acre quarter section indicator.
q40	40 acre quarter section indicator.
q10	10 acre quarter section indicator.
coordsns	Distance from north/south section line (feet).
coordsns_dir	Direction of measurement from north/south section line.
coordsew	Distance from east/west section line (feet).
coordsew_dir	Direction of measurement from east/west section line.
utm_x	The x (Easting) component of the Universal Transverse Mercator system. NAD83 Zone 13.
utm_y	The y (Northing) component of the Universal Transverse Mercator system. NAD83 Zone 13.
latdecdeg	Latitude (decimal degrees).
longdecdeg	Longitude (decimal degrees).
loc_accuracy	Horizontal location accuracy indicator.
gs_elev	Ground surface elevation.
elev_accuracy	Vertical location accuracy indicator.
well_depth	Completed depth of well (feet).
log_depth	Geophysical log measurement depth
log_type	Geophysical log measurement method.
log_SWL	Geophysical log measurement surface water level.
log_date	Geophysical log measurement date of measurement.

Appendix C
Data Directory for Aquifer Properties Data in HydroBase

Table Name: *WELLS*	**Task:** Task 42, 43 and 44 of the SPDSS
aquifer1	Aquifer in which well is located.
aquifer2	If well is located in two aquifers, name of second aquifer.
aquifer_comment	Any comments associated with the aquifer(s) that the well transverses.
tperf	Depth to top of first perforated casing. (FEET)
bperf	Depth to base of last perforated casing. (FEET)
yield	Actual pumping rate. (GPM)
bedrock_elev	Elevation of bedrock.
sat_1965	
remarks1	Generic remarks.
remarks2	Generic remarks.
owner	Owner's fullname.
address	Address of owner.
city	City.
st	State abbreviation.
zip	Zip code.
phone	Phone number.
cell_phone	Cell phone number.
email	E-mail address or internet address.
collection_order	Water level collection number. Used to indicate route to gather WL measurements.
data_source_id	A unique identifer of the data. Either the Site_ID or the locnum string.
data_source	Source of data.
publish?	Boolean indicating if well is part of DWR's water level publications.
geoplog?	Boolean indicating if well is part of DWR's geophysical log archive.
modified	Date the record was last modified.
user	User who last modified the record.
cdm_id	TEMPORARY - Identifer originally given to well by CDM in SPDSS project.
cmd_modified	TEMPORARY - Date the record was last modified by CDM.

Table Name: *PUMPING_TEST*	**Task:** Task 43 of the SPDSS
Description: Table containing aquifer hydraulic properties test results.	
Field Name	**Field Description**
pump_test_num	Unique pump test identifier.
well_id	Well identifier. Foreign key from [wells].
testdate	Date of the pump test.
toptestint	Top of tested interval (FT).
basetestint	Base of tested interval (FT).
tswl	Pre-test static water level measured in feet from ground level. Pressure head above ground level is given as a negative value.
tfwl	Post-test final water level measured in feet from ground level. Pressure head above ground level is given as a negative value.
drawdown	Change in feet between pretest water level and end of test water level. Pressure head above ground level is given as a negative number.

Appendix C
Data Directory for Aquifer Properties Data in HydroBase

Table Name: *PUMPING_TEST*	**Task:** Task 43 of the SPDSS
testq	Average testing discharge rate measured in gallons per minute.
testtime	Time in hours that the test was conducted.
trans	Estimated transmissivity in gallons per day per foot (gpd/ft).
k	Hydraulic conductivity measured in feet per day (ft/day).
storativity	Storativity (dimensionless- can only be calculated from confined aquifer tests with one or more monitoring wells.
leakance	Composite leakance between aquifer layers in units of 1/Day
ptsource	Entity reporting the pump test data. CDWR= Colorado Division of Water Resources, CBP = Closed Basin Project (subset of USBR), CWCB 11 = Colorado Water Conservation Board circular #11.
pttype	Pump test type. Either pumping, recovery, slug, flow, or other.
ptmon	Indicates observation point available for test.
ptobs	Check box indicating if the pump test included observation well data. Observation wells must be screened in the same aquifer as the pumping well.
ptobs_well	Check box indicating that test results are from observation well.
ptmultiple	Flag indicating the presence of multiple pump tests available for a well.
sp_cap	Specific capacity in Gpm/ft.
sp_yield	Specific Yield in decimal percent.
porosity	Porosity in decimal Percent.
B	Saturated thickness in feet
comments	Pump test comments.
cdm_modified	Date modified by CDM.

Table Name: *REF_ELEV_ACCURACY*	**Task:** Task 42, 43 and 44 of the SPDSS
Description: Table containing lookup values for elevation accuracy codes.	
elev_accuracy_num	**Description**
1	Original database
2	USGS 30-meter DEM
3	Surveyed

Table Name: *REF_ELEV_ACCURACY*	**Task:** Task 42, 43 and 44 of the SPDSS
Description: Table containing lookup values for location accuracy codes.	
loc_accuracy_num	**Description**
1	Spotted from PLSS quarters
2	Spotted from PLSS distances from section lines
3	Surveyed
4	Digitized
5	Original database
6	GPS

Task 44.3 South Platte Alluvium Region Water Level Technical Memorandum

SPDSS Phase 3 Task 44.3 South Platte Alluvium Region Water Level Technical Memorandum
FINAL

To: Ray Alvarado, CWCB
From: Camp Dresser and McKee Inc.
Mark McCluskey, Donavon Paschall, Jessica Poceta, and Gordon McCurry
Subject: SPDSS Groundwater Component Phase 3, Final Task 44.3
South Platte Alluvium Region Water Level Technical Memorandum
Date: November 29, 2006

Introduction

The groundwater component of the South Platte Decision Support System (SPDSS) focuses on compiling and evaluating available relevant data to support the Decision Support System (DSS) for the South Platte River watershed and to add the data to HydroBase, the State of Colorado's hydrological database. The SPDSS groundwater study area is presented in Figure 1. For the purposes of the SPDSS, the groundwater study area is divided into two hydrologic regions. The Denver Basin Region includes the bedrock aquifers of the Denver Basin. The South Platte Alluvium Region consists of the unconsolidated deposits of the South Platte River mainstem, extending downstream from just below Chatfield Reservoir to the Nebraska state line at Julesburg, and consists of the unconsolidated deposits of the tributaries to the South Platte River. The South Platte Alluvium Region also includes the alluvium overlying the Denver Basin bedrock aquifers in Water Divisions 1 and 2.

The unconsolidated alluvial aquifers in the SPDSS study area consist of the South Platte River and its tributaries, as well as tributaries to the Arkansas River where they overlie the Denver Basin Region. From a hydrogeologic perspective, key tributaries in the SPDSS study area include East Plum Creek, Cherry Creek, Sand Creek, Clear Creek, Big Dry, St. Vrain, Big Thompson, Beebe Draw, Cache la Poudre, Lonetree Creek, Crow Creek, Box Elder Creek, Lost Creek, Kiowa Creek, Bijou Creek, Badger Creek, Beaver Creek, Upper Black Squirrel Creek, and Upper Big Sandy Creek, the last two of which are located in Water Division 2 and drain into the Arkansas River. The eastern and southern portions of the Denver Basin have been divided into several Designated Basins for the purposes of water rights administration. The Designated Basins within the Denver Basin Region include the Lost Creek, Kiowa-Bijou, Upper Black Squirrel, and Upper Big Sandy Creek Designated Basins.

This work was undertaken for the Colorado Water Conservation Board (CWCB) and Division of Water Resources (DWR), under Tasks 35 and 44 of Phases 1, 2, and 3 of the SPDSS by Camp Dresser & McKee (CDM). Task 35 of the SPDSS identified, drilled, and instrumented monitoring wells in the South Platte Alluvium and Task 44 of the SPDSS include the collection, analysis, and mapping of existing water level data. The objectives of these tasks are as follows:

1. *Compile, analyze and map existing aquifer water level information and create HydroBase-compatible databases with data from the South Platte Alluvium Region*
2. *Identify additional data needs in the Region*
3. *Support the design of the groundwater field program*
4. *Enhance HydroBase with aquifer water level data collected during the field activities*
5. *Collect data that is appropriate to support future development and calibration of a groundwater model*

This Technical Memorandum (TM) summarizes the compilation, analysis and mapping of water level data of the South Platte Alluvial Aquifer.

Approach

The following table summarizes the sections contained in this TM and identifies which section pertains to the objectives outlined above.

Section	Description
1.0	Water Level Data Collection and Analysis
1.1	Sources of Data
1.2	Data Analysis and Processing
1.3	Database Queries
1.4	Grid Development and Contouring
1.5	Water Level Trend Analysis
2.0	Water Level Data Database
2.1	Database Structure
2.2	Database Quality Control
3.0	Results
3.1	Water Level Surfaces
3.2	Water Level Trends
3.3	Hydrographs
4.0	Summary and Conclusions
5.0	Recommendations
6.0	References

1.0 Water Level Data Collection and Analysis

Information on aquifer water levels are important in evaluating aquifer yield, stream-aquifer interactions, drawdown due to pumping, and the direction and rate of groundwater flow. This section describes the sources of existing water level data, summarizes the methods used to screen these data for reliability and usability, and discusses the analysis and processing of historic water level data for the South Platte Alluvium Region.

<u>Data Flow Process</u>
During this phase, water level data were obtained from HydroBase and added to a temporary HydroBase-compatible SPDSS database. New data obtained during Phase 3 were also added to

this SPDSS database. This SPDSS database was queried for water level data in selected time periods and analyzed. The data in this TM is presented in several forms to depict spatial and temporal water level tends. This process is very similar to the process that was undertaken in the Denver Basin Bedrock Region (Task 44.2) Water Level TM. The HydroBase-compatible SPDSS database will be submitted to the DWR at the end of this phase so that all new data can be incorporated into HydroBase by the DWR.

1.1 Sources of Data

Numerous sources were used to compile a water level database for this study, including water level data gathered from both public and private entities for the South Platte Alluvium Region. Sources of data collected during this study included the Colorado Division of Water Resources (DWR), U.S. Geological Survey (USGS), Central Colorado Water Conservancy District, CWCB Basic Data Report #8, Colorado Division of Wildlife, City of Thornton, Thornton Northern Project, Town of Julesburg, Metropolitan Wastewater Reclamation District, Morgan County Quality Water District, South Adams County Water and Sanitation District (WSD), Rocky Mountain Arsenal, and SPDSS Tasks 35 and 39, as summarized in Table 1.

In August 2006, CDM received from the State a portion of HydroBase that contained water level data collected by the SPDSS during Phase 1 & 2 for the South Platte Alluvium (including SPDSS Tasks 35 and 37), as well as other data compiled by the DWR. These data were appended to the SPDSS database containing data obtained during Phase 3 of Tasks 39 and 44. Table 1 summarizes the water level data in this database.

Table 1: Summary of Water Level Data for the South Platte Alluvium Region

Source		Total Number of Alluvial Wells	Total Number of Alluvial Water Level Measurements
1.	Central Colorado Water Conservancy District	190	4,056
2.	City of Thornton	46	380
3.	Colorado Division of Water Resources	185	5,494
4.	Colorado Division of Wildlife	39	582
5.	CWCB Basic Data Report #8	663	663
6.	Colorado State University	168	2,711
7.	Metropolitan Wastewater Reclamation District	23	118
8.	Morgan County Quality Water District	9	353
9.	Rocky Mountain Arsenal	11	746
10.	South Adams County WSD	20	708
11.	SPDSS Tasks 35 and 39[1]	38	24,894
12.	Thornton Northern Project	55	1,829
13.	Town of Julesburg	37	1,601
14	USGS General Database[2]	5,246	64,459
15.	USGS National Water Quality Assessment Program	24	246
Total		6,754	108,843

[1] Data collected on daily basis.
[2] Data set contains data for bedrock and alluvial aquifers.

During Phases 1, 2 and 3 of SPDSS, water level databases were identified and obtained from sources within the South Platte Alluvium Region. As part of this task, these databases are submitted to the DWR for inclusion in HydroBase. The following is a brief description of each of the source databases.

A database was obtained from the Central Colorado Water Conservancy District (CCWCD). The CCWCD database contains 191 alluvial wells distributed over much of the South Platte Alluvium study area, with 4,056 water level measurements. Data in the CCWCD database consists of water level measurements from 1930 to 2004.

A water level database containing alluvial aquifer well data was obtained from the DWR. The DWR collects water level data from the alluvial aquifers downstream of Denver, starting at the flow gaging site on the South Platte River at Henderson. This database includes 185 wells in the South Platte Alluvium Region and 5,494 measurements from 1930 to present.

The Colorado Division of Wildlife (CDOW) provided water level data associated with the Tamarack Project. The CDOW database consists of 39 alluvial wells that were measured 582 times periodically at different increments between 2000 and 2005.

Historic water level data were obtained from the CWCB Basic Data Report #8. This report consists of 663 alluvial wells measured between 1957 and 1961 in the Cache la Poudre Basin. These data were entered into an Excel spreadsheet from hard-copy format.

Another database developed and maintained at Colorado State University (CSU) was obtained. This data set includes 168 wells in the alluvial aquifer of the South Platte Alluvium Region. The CSU data were made available in hard copy format and entered into an Excel spreadsheet by DWR staff. The majority of the water levels in this database were measured through the 1970's. Approximately 120 wells in this network were also measured in the spring of 2003 as part of the SPDSS Task 44 effort to obtain recent water level data in the region.

A database was obtained from Metropolitan Wastewater Reclamation District. The Metropolitan Wastewater Reclamation District has 24 alluvial monitoring wells located in pairs along the mainstem of the South Platte from 64th Avenue to County Road 32.5. Data consists of 118 quarterly water level measurements from 2003 to 2005.

The Morgan County Quality Water District provided water levels from 9 alluvial wells located in Morgan County. Data consists of 353 monthly water level measurements from 2003 and 2006.

An alluvial water level database was obtained from the Rocky Mountain Arsenal. The data were acquired via a request sent to the Department of the Army for well information and water level data for 11 alluvial wells. These 11 wells provide a spatially distributed sample of their monitoring network in western Adams County. These wells are located in the South Platte Alluvium in western Adams County. The data set contains 746 water level measurements from 1983 to 2004.

The South Adams County WSD provided a water level database for 20 alluvial wells. Data consists of 708 quarterly water level measurements from 1986 and 2005.

Additional water level data were collected from the Task 35 and 39 field studies. The Task 35 and 39 water level data are from 38 alluvial monitoring wells installed during Phases 1 and 2 of the SPDSS. Water level data have been recorded on an hourly interval since November 2003 using pressure transducer and data logging equipment. The locations of the wells, discussion of water level measurement techniques and results, and hydrographs of the water level elevation data are reported in the Phase 3 Task 39 TM.

The City of Thornton provided alluvial water level data for wells located in the Cache la Poudre River and its tributaries. Thornton has 46 wells that are measured in the spring. Water level data has been collected from these wells once a year in the spring since 1998 and were also collected in November 2002. In addition to water level data from their current monitoring program, historical water level measurements were obtained from the Thornton Northern Project Groundwater Investigations Report (Rocky Mountain Consultants, 1990). During this study Rocky Mountain Consultants collected over 1,800 water level measurements for 55 wells, primarily located in the alluvial systems of the Cache la Poudre River and its tributaries. Data associated with the Thornton Northern Project was provided by Thornton via a series of Lotus spreadsheets.

The Town of Julesburg, located at the northeastern edge of the study area, provided a water level database. Julesburg has 37 alluvial wells in their monitoring network where water levels are collected monthly. Data consists of 1,601 water level measurements from 1992 to 2004.

A significant data set was obtained from the USGS by the DWR that consisted of the USGS general water level database for the entire State of Colorado. The database contains additional wells and water level measurements for both alluvial and bedrock aquifers. Water level data was provided by the DWR for Water Division 1 and was queried for alluvial wells located within the SPDSS study area for the current analysis. This query resulted in 5,246 wells and 64,459 water level measurements.

A database of water level measurements was obtained from the USGS's National Water Quality Assessment (NAWQA) program. The database contains 24 wells located in the South Platte Alluvium Region. Water levels at the NAWQA sites were recorded in July and August of 1994 and 2002.

1.2 Data Analysis and Processing

Several processing steps were required to convert the data into a format suitable for uploading into a HydroBase compatible database and for subsequent analysis and mapping. These steps are described below. In some of the discussion, there is reference to specific tables and fields contained in HydroBase; these are described in Section 2 of this TM.

Aquifer Assignment

All measurements were assigned to an aquifer, using the DWR aquifer definitions summarized in the Introduction section above. No attempt was made to verify the accuracy of aquifer designations for wells as provided by an outside entity.

Data obtained from the USGS general database contained a 7-character alphanumeric USGS aquifer code classification, such as '125DNVR'. This USGS aquifer code was correlated to the DWR Denver Basin and alluvial aquifer classifications using an aquifer formation and soil type key provided by the USGS.

Selection of Temporal Data

Water level data in the South Platte Alluvium Region was analyzed for up to six distinct time periods. The South Platte Alluvium Region water level database was evaluated to identify a series of time periods where a sufficient amount of data was available to allow mapping of the water table surface. This was determined by summing the number of measurements recorded for the alluvial aquifer for each year and for each month over the period represented by the database. Summaries of the results are shown in Figures 2 and 3.

Figure 2 shows the number of measurements collected by year. Water level measurements began in 1926 and increased to about 200 per year by the early 1950s. The number of measurements increased to about 2,800 per year by the mid 1970s, and decreased to 950 measurements in 1979. The number of measurements decreased between 1979 and 1984,

averaging about 900 per year, and then increased in the 1987-1991 time period to about 2,200 per year. It was during the 1987 to 1991 time period that the number of measurements collected by the USGS started to decrease, and the number of measurements collected by the DWR increased. The DWR has been collecting approximately 70 water level measurements per year in the South Platte Alluvial Region since 1988. The number of measurements in 2004 to 2006 shows a substantial increase due to the SPDSS alluvial water data collection efforts under Task 35 and Task 39. It should be noted that the spike in measurements from 2004 to 2006 represents a very high measurement frequency on a limited number of wells.

Figure 3 represents a tabulation of the total number of measurements collected in a given month. The majority of measurements are collected in either the spring or fall, prior to and immediately following the irrigation season. The largest number of measurements have been collected in the spring season. Water level measurements collected from the alluvial aquifer before the irrigation season begins are important because they are least likely to be impacted by localized irrigation pumping and thus reflect the long-term changes in the alluvial aquifer in the South Platte Basin.

An important consideration is that for most of the data it is unknown whether a given water level measurement was collected from or near a well that was pumping. HydroBase does not have a field describing the pumping status of the measured wells. For the time periods selected for detailed analysis and mapping for this TM, the pumping status was inferred through the evaluation and screening of outliers, as discussed in Sections 1.3 and 1.4.

The analysis of water level measurement dates described above, combined with analysis of the bedrock water level measurements from the Denver Basin Region, led the SPDSS team to choose spring pre-irrigation time periods in 1968, 1978, 1990, 2001, 2003, and 2005 as the years upon which contoured water table maps would be developed. These time periods were selected so that water level contour maps would exist for both SPDSS study area regions for the same time periods. These time periods represent, collectively, the periods with the most data that could be contoured and would correlate with data gathered by other SPDSS contractors. General water level trends can be determined using hydrographs and potentiometric or water table maps prepared for these years.

1.3 Database Queries

To develop water table surfaces for the selected time periods, several queries were made from the SPDSS database. The first step was to identify all wells in the database that are located in the SPDSS South Platte Alluvium Region. The August 2006 download from HydroBase includes wells from all of Division 1. All the wells were imported into ArcGIS, and a spatial query was used to select wells within the South Platte Alluvium Region.

In the SPDSS database, the WELLS and WELL_MEAS tables were linked using the *well_id* field allowing water levels for the alluvial aquifer to be queried. Once this linkage was established the first early spring (February to April) water level measurement for a given alluvial well within the South Platte Alluvium Region was queried for each of the time periods (1968, 1978, 1990, 2001, 2003 and 2005). This set of queries resulted in the data sets used for gridding the water table surfaces. Detailed instructions for querying the water level measurements for each time period can be found in Appendix A.

Control points representing the South Platte River bottom elevation were added to the water level data set before gridding. South Platte River bottom elevation data, provided by the CWCB Flood Control Group, were obtained every five miles along the river. These data help control the water level contours along the mainstem of the South Platte River in time periods where data are absent. All control points are noted in Appendix B.

1.4 Grid Development and Contouring

The water level measurements for the selected years were gridded and contoured using the kriging method in the software package Surfer® (Golden Software Inc; Version 8). The kriging method provides a smoothed representation of the water table surface. This method was chosen after an evaluation of several methods based on each method's ability to be consistent with the individual data and with regional trends in the data.

As part of the kriging process, a linear variogram was developed for each time period using the characteristics unique to that data set. The alluvial aquifer contours were generated using a circular search radius of 20,000 meters, using a maximum of 64 measurements to estimate a water level value at each grid node. This relatively small search radius limits the influence of a water level measurement in one tributary alluvial aquifer on the grid levels in neighboring tributary alluvial aquifers. This relatively small search radius is particularly important to accurately map the alluvium that overlies the Denver Basin. The contouring parameters used in Surfer® to create the water level contours are shown in Table 2 below. In addition, Table 2 summarizes the number of water level measurements available in the spring (February to April) time period for the years selected for contouring including fifty four South Platte River bottom elevation control points were used, as discussed in Section 1.3. The resulting water level contour maps and associated discussion are presented in Section 3.1.

After the initial gridding and contouring was performed, each grid was reviewed for measurements causing bull's-eye contours, or what appeared to be anomalous bends in the contours. Water levels that caused the bull's-eye or anomalous contour shapes were evaluated by comparing the water level at the given time period against the water level at that well at other times. Anomalous water level measurements for the period being contoured were excluded and are identified in Appendix C. If the water levels measurements identified for contouring were consistent with water level data from other time periods for that well, even if the water level differed from the levels in neighboring wells, it was maintained in the data set for the gridding. It was assumed such measurements represented wells near areas of persistent pumping, and removing such measurements would give a false representation of actual water levels.

Another step to check for outliers was to compare water level elevations against ground surface elevations, using a USGS 30-meter DEM of the land surface. All measurements with a water level more than 10 feet above the DEM ground surface were excluded. The 10 foot value was selected based on the range of error of the DEM ground surface contours. All excluded water level elevations are noted in Appendix C.

As a final check of the water level grids, each was compared to ground surface (USGS 30-meter NED). This check identified several small areas along mainstem of the South Platte River and

Cache la Poudre where the water level elevation grids extend above ground surface. In these areas the water level grids were adjusted to be consistent with ground surface. These areas represent approximately two percent of the alluvial grid area.

Contours were then smoothed by adding a nugget effect to the linear variogram model. This process smoothes contours in areas where significant variations in water level measurements exist within a small geographical area.

Table 2: Water Level Contour Parameters and Number of Water level Measurements for Each Time Period

Year	Slope	Nugget Effect	Number of Water Level Measurements	Number of Excluded Water Level Measurements	Number of Streambed Elevation Control Points	Number of Water Level Measurements Used to Contour
1968	0.2	225	1,343	7	54	1,390
1978	0.45	225	744	3	54	795
1990	1.1	225	327	4	54	377
2001	1.35	225	373	8	54	419
2003	1.5	225	546	10	54	590
2005	0.8	225	264	0	54	318

A 50-foot contour interval was chosen for each of the five sets of maps developed for this TM. This contour interval was appropriate for presentation purposes due to regional scale of the maps. For several of the historic time periods mapped, contours are not shown in the portions of each map where insufficient data exists. In general, contour lines extend out approximately five miles from the nearest data point. Contours were trimmed manually in remaining areas where water level trends were extrapolated without supporting data. The lack of contour lines on many of the maps indicates the lack of water level data available for parts of the alluvial aquifer.

1.5 Water Level Trend Analyses

Changes in groundwater levels in the alluvial aquifer were evaluated both spatially and temporally.

<u>Spatial Analysis</u>

Historical groundwater elevation data were utilized to evaluate groundwater trends in the South Platte Alluvial Region. First, individual well data sets were analyzed to determine the total number of measurements and the most recent water level measurement. Wells that had at least three spring (February to April) water level measurements in different years with at least one measurement since 2000 were selected to generate groundwater trends. Depending on the well being evaluated, the water level trends extend back in time to the 1930's.

For each well, a trend line was fit to the historic water level measurements to determine the average annual change in water level. Each chart was manually inspected to determine whether the trend line appeared appropriate for the data. The inspection evaluated if the trend line was biased by pumping season data, isolated data values, or by historic data over more recent (post-2000) data. Wells with water level data that appeared to be heavily influenced by

pumping or that contained too few water level measurements to determine a trend were omitted from the analysis. The goodness of fit of the regression line was assessed to identify those locations where the correlation was statistically significant. The correlation coefficient for this line was statistically tested using the Student's t test and only those regressions that had a significance level of ten percent or lower were retained, i.e., the probability of random variation accounting for the correlation was 10 percent or less.

After groundwater elevation trends were analyzed, the identified water level change per year for each well was posted on a map. The posted trends were used to generate color gradated symbols to display regional groundwater elevation changes per year in the alluvium. The resulting water level trend map and associated discussion are presented in Section 3.2.

Temporal Analysis

Hydrographs for selected wells located throughout the South Platte Alluvium Region were created. Hydrographs provide a detailed record of water level changes over time. Wells for which hydrographs were created were selected based upon the period of record available, existence of recent data, and the spatial distribution. Hydrographs were created for twenty wells.

To create a hydrograph, all historical water level measurements from a given well were queried from the SPDSS database. Using this historical record, the data set was filtered to only include the first late winter/early spring (February to April) water level measurement of a given year. These water level measurements were used to generate a hydrograph for a given well. Spring water level measurements were used to minimize water level fluctuations due to summer pumping. Spring water level data will most accurately represent long-term trends in water levels. Hydrographs for the 20 wells in the South Platte Alluvium Region are presented in Section 3.3. To aid in comparison, the vertical axis of each hydrograph is presented with a uniform 10-foot interval and a range of 50 feet.

2.0 Water Level Database

One of the objectives of Task 44 was to create a HydroBase-compatible database with water level data from the South Platte Alluvium Region. The remainder of this section describes the SPDSS database with HydroBase compatible tables that are used to store water level data.

2.1 Database Structure

HydroBase is the State of Colorado's database used to manage hydrological data. Appendix D provides a detailed listing of the database and fields from HydroBase that contain water level information.

Four data tables contain aquifer water level data. These named WELL, WELL_MEAS, REF_LOC_ACCURACY and REF_ELEV_ACCURACY.

The WELLS table contains the location, well elevation, permit number, well depth, and many other types of information about wells. The WELLS table is the core table that links well information data with water level, geophysical log, and aquifer test data.

The WELL_MEAS table contains the water level measurement data for wells. This table is linked to the WELLS table by the *well_id* field. The WELL_MEAS table contains the measurement date, measuring point height, and the depth to water for each measurement. The ground surface elevation in the WELLS table allows the water level elevation to be calculated.

The REF_LOC_ACCURACY table includes comments on the siting accuracy of the location (X,Y) data.

The REF_ELEV_ACCURACY table includes comments indicating the source and accuracy of the elevation value.

2.2 Database Quality Control

A series of quality control steps were undertaken once the data were compiled into a common electronic format. These steps were performed to check accuracy of the data before submitting it to the State for uploading into HydroBase.

Numerical data from each of the sources identified in Section 1.1 were initially entered into a Microsoft Excel® spreadsheet. The data were then checked for accuracy by comparing the entered data to the original hard copy data. New data received in electronic format were checked with the original database for data importation/data entry accuracy on a 10-percent quality control frequency. If errors in the data entry were found then 100 percent of the data from that data source was checked. The spreadsheet was then exported to the HydroBase-compatible SPDSS database. This procedure was used to assure quality for all data that was added to the SPDSS database.

After the SPDSS database was checked for quality control purposes, it contained 6,754 unique alluvial wells with over 108,843 alluvial aquifer water level measurements in the South Platte Alluvium Region. It should be noted that the time periods selected in this TM for data presentation represent a subset of these data.

3.0 Results

This section presents a summary of the water level data for the South Platte Alluvium Region. The data are presented in plan-view maps of the water level surface at specified time periods, in a trend map, and in hydrographs that depict water level trends over time at individual wells located throughout the region.

The water level contours, database water level measurements, and control points presented in this section will be provided in shapefile format to the DWR as part of this TM.

3.1 Water Level Surfaces

The six time periods selected for water level mapping and comparison were 1968, 1978, 1990, 2001, 2003, and 2005. The water level maps for the alluvial aquifer for these selected time periods are shown in Figures 4 to 9, respectively. The contours shown on these maps were generated using the data described in Section 1.4.

The well locations for which water level data was available in the selected year are posted on each figure. Some time periods have substantially more water level data than others.

As shown in Figure 4, in 1968 there were a relatively large number of water level measurement locations available for contouring in the South Platte Alluvium Region. This large data set is due to an extensive USGS monitoring program undertaken in 1968. For this year, 1,390 water level measurements were used for contouring (Table 2). This distribution provides for a clearly defined water level surface in the alluvial aquifer, including Cache la Poudre, Beaver and Badger Creeks. The water level elevations and trends developed in this study are consistent with the water levels and trends presented by Hurr and Schneider (1972a-1972f), except near Ft. Morgan and at the edges of the alluvium along the mainstem. The dataset used to develop the Hurr and Schneider (1972a-1972f) contours are not available, so it is concluded that the differences in water level surfaces represent a combination of different datasets and contouring methodologies. The shape of the groundwater surface contours indicate that groundwater flows toward and discharges at the river, but also has a strong component of flow down-valley. The water level elevation in the upstream (north of Denver) portion of the South Platte Alluvium Region is 5,100 feet, 15 feet below land surface and decreases to an elevation of 3,450, 20 feet below land surface near the Colorado-Nebraska state line. Water level elevations in the Cache la Poudre range from approximately 5,400 feet, 25 feet below land surface, north of Ft. Collins to approximately 4,600 feet, 25 feet below land surface at the confluence with the South Platte River.

As shown in Figure 5, water level measurements in 1978 were not as abundant along the mainstem as in 1968. A majority of the measurements (795; Table 2) were centered on Badger and Beaver Creeks in southern Morgan County. Other measurements are located at irregular intervals along the mainstem of the South Platte River extending to the state line. The overall water level gradients in the mainstem of the South Platte and its tributaries are consistent with the 1968 gradients with local rises in the water table along the mainstem in southwestern Logan County. A majority of the differences can be attributed to the density of data in a given area particularly in Beaver and Badger Creeks and along the mainstem of the South Platte downstream of Ft. Morgan. The water level elevations near Ft. Morgan are approximately 4,275 feet, 35 feet below land surface and decrease to the northeast at the state line with an elevation of 3,450 feet, 20 feet below land surface. The water level elevations in the Cache la Poudre in 1978 are similar to those in 1968.

A water level surface similar to the preceding time periods is seen in 1990 (Figure 6). Data for this time period was relatively sparse compared with previous periods, with 377 water level measurements available for contouring (Table 2). These measurements are distributed spatially throughout the region, although there are large areas with no measurements. Since there were few data points for this time period, the water level contours are based more heavily on the stream bed control points, discussed in Section 1.3. These control points were inserted on a regular 5-mile interval along the mainstem of the South Platte River from Ft. Lupton to Julesburg. These control points provide additional water level data in an alluvial system where the stream is hydraulically connected with the river. These control points may be slightly higher or lower than the water table depending on if the river appears to be gaining or losing flow to

the surrounding aquifer based on the shape of the water table contours, but help constrain water levels in areas where no data are available.

In 2001 (Figure 7), the available water level data used for contouring consisted of 419 measurements (Table 2). The data are distributed throughout the region except for the upper reaches of the Cache la Poudre where spring 2001 measurements were not available. In this time period additional water level data was available for Weld County south of Greeley and the Julesburg area. As in previous years, streambed control points were inserted along the mainstem of the South Platte from Ft. Lupton to Julesburg since there is an absence of water level data from Ft. Morgan to Julesburg. In this year, the DWR's South Platte alluvial water level program wells located in this reach were not measured until May and were not used for contouring. Water level elevations show similar contours as those created for preceding years.

In 2003, CSU provided water levels from approximately 170 additional wells in the South Platte Alluvium. This data collection effort provided a greater understanding of the alluvial water levels than in 2001, with a total of 590 water level measurements being available (Table 2; Figure 8). Again, streambed control points were inserted along the mainstem of the South Platte since there is an absence of alluvial water level data from Ft. Morgan to Julesburg. Water level data for the alluvium near Ft. Collins was not available in 2003. The data are distributed throughout the region. Water level elevations show similar contours as those created for preceding years.

In 2005, the databases from DWR, City of Thornton and Metro Wastewater Reclamation District comprise a majority of the alluvial water levels collected in the South Platte Alluvium Region (Figure 9). As in previous years, streambed control points were inserted along the mainstem of the South Platte from Ft. Lupton to Julesburg since there is an absence of water level data from Ft. Morgan to Julesburg. In this year, the DWR's South Platte alluvial water level program wells provided data that is spatially distributed about the South Platte Alluvial Region, allowing a regional water table to be developed for 2005 (Figure 9). Data was not sufficient for contouring in the upper Cache la Poudre and in Beaver and Badger Creeks in 2005. Water level elevations in the rest of the South Platte Alluvial Region show similar contours as those created for preceding years

Upon review of the alluvial water level elevation contours from 1968 to 2005, the regional water table has remained stable in the South Platte alluvium. This stability is likely the result of the aquifer's hydraulic communication with the South Platte River, its tributaries and diversion canals. Local variations from year to year could be a result of lower or higher than normal stream flows or local pumping. The hydraulic connection and relatively limited spatial extent of the alluvial aquifer allows for quick responses to aquifer stresses or recharge. This local sensitivity in alluvial water levels is identified in the following section which looks at historic water level trends in alluvial wells throughout the South Platte Alluvium Region.

3.2 Water Level Trends

The methodology described in Section 1.5 was used to analyze and evaluate historic spring season water trends in the South Platte alluvium over the past 20 to 30 years. Where data met specified criteria specified in Section 1.5, the water level trend in a well was calculated. A total of 289 wells had sufficient data to be able to calculate statistically significant trends (Figure 10).

The spatial variability of the water level trends in the South Platte alluvium does not allow for color-fill contouring of the water level trends so the trends have been posted by well.

Water level trends from spring (pre-irrigation season) measurements in the alluvium show what appear to be three general patterns in the South Platte Alluvium Region. The first is that, over most of the alluvial aquifer (including the mainstem of the South Platte River, and the alluvial aquifer in the Lost Creek and Kiowa-Bijou Designated Basins) there has been little to no change in water levels over time. This is suggested by the large number of monitoring locations that show less than a foot change in water levels (Figure 10). The second observed trend occurs in the Cache la Poudre River and Upper Black Squirrel Creek Designated Basin. In these locations there have been both increases and decreases in the water levels in wells located in close proximity to each other over the 20 to 30 year time period (Figure 10). The variability of water level trends in these areas are likely due to the localized effects of pumping and recharge. The third observed trend is where water levels have shown consistent declined based on the spring measurements. This includes wells located along the lower portion of Box Elder Creek and the downstream (northern) portion of Bijou Creek in the Kiowa-Bijou Designated Basin. The water level declines in these areas are likely a result localized pumping.

3.3 Hydrographs

Water level trends over time at individual wells were used to create hydrographs for 24 wells located throughout the South Platte Alluvium Region. Wells were selected based upon the period of record available, existence of recent data, and spatial distribution. The wells selected are spatially distributed throughout the South Platte Alluvium Region as shown in Figure 11. Hydrographs for the 24 wells in the South Platte Alluvial Region are shown in Figures 12 to 17.

Based on analysis of the individual well hydrographs, the water levels in the mainstem of the South Platte Alluvium Region generally appear to have remained stable over time, with water levels changing by less than 5 feet in 14 of the 20 wells shown in Figures 12 to 17. Water levels in most wells, however, do show the effects of localized pumping.

Two of the wells shown (designated as wells 1268 and 1238 and shown on Figures 13 and 17, respectively) do show approximately 25-foot declines in water levels over the period of record. These wells are located in eastern Weld and Morgan Counties, respectively, and are located near wells for which other hydrographs do not show long-term declining trends. It is possible that these water levels are influenced by pumping from nearby wells.

4.0 Summary and Conclusions

CDM has completed SPDSS Task 44.3: the collection, analysis, and mapping of water level data for the South Platte Alluvium Region. The purpose of this task was to examine the sources and types of data available in the region, perform the data processing to allow it to be internally consistent and HydroBase-compatible, and provide data useful in the support of upcoming groundwater modeling.

Below are conclusions from the completion of these tasks.

General Conclusions

- The water level data collected, analyzed, and presented in this TM represent an important addition to the knowledge and characterization of the groundwater system within the South Platte Alluvium Region. The information presented here depicts the water table configuration for six periods over the past 40 years, presents the trends in water levels at a basin-wide level and provides a more detailed perspective on water level changes over time from 44 individual hydrographs. This task of the SPDSS has compiled a database of water level measurements from 6,754 unique alluvial wells with over 108,843 water level measurements in the South Platte Alluvium Region.

- Many of these data are being presented in this Task 44 for the first time in a publicly accessible report and electronic database (HydroBase). The water level data and mapping are the most comprehensive currently available.

- Water levels in the alluvial aquifer within the study area have remained stable over the past 20 to 30 years in most locations based on spring measurements. Areas showing water level declines include Box Elder Creek and the lower portion of Bijou Creek within the Kiowa-Bijou Designated Basin.

- The water level surfaces presented in the TM are consistent with those presented in the earlier reports by Hurr and Schneider (1972). However, the source data from those reports is not available so the water table maps in this TM represent the best available data-supported mapping of the alluvial aquifer water table.

- The water level database as presented in this TM is sufficient for regional-scale water resources planning and for developing a groundwater model in the South Platte Alluvium Region.

Specific Conclusions

- Task 44 activities satisfy the objectives of collecting available published water level data, analyzing the data, enhancing HydroBase with these data, guiding the SPDSS field investigations, and helping characterize groundwater flow and water levels in the South Platte Alluvium Region.

- The Task 35 and 39 data have helped fill previous water level data gaps and helped characterize the alluvial water level surface trends in the South Platte Alluvium Region. In Phase 1, Task 35 wells were installed to provide water level data and fill aquifer property data gaps. In Phase 2, Task 35 wells were installed at tributary mouths and at stream gage locations to better understand groundwater fluxes at these locations, with water level data presented under Task 39.

- Based on spring season measurements, water levels in the South Platte Alluvium Region have generally remained relatively stable over time. Exceptions to this are in areas of Morgan and Weld Counties, where water levels have declined in excess of 20 feet in the past 75 and 18 years, respectively, and in the Kiowa and Lost Creek Designated Basins, where water levels also have declined in recent years. The saturated thicknesses in these areas were 100 feet and 175 feet respectively.

- Data collected in Task 39 using automated data loggers provides high-resolution water level data in 37 dedicated monitoring wells. This previously unavailable data is necessary for understanding water level fluctuations throughout the year that are caused by pumping, changes in stream stage, precipitation, irrigation and managed recharge sources.

- Water level measurements in the South Platte Alluvium Region were abundant in the late 1960s (approximately 3,000 measurements per year), but by the 1990s the number of measurements had declined to about one-third of that amount. Recent programs such as the enhanced 2003 spring water level measurement effort (denoted by "Colorado State University" in Table 1) represent a substantial improvement in the number and distribution of measurements in the South Platte Alluvium Region. The primary source of water level data in the South Platte Alluvium Region since 1986 has been the DWR.

5.0 Recommendations

The following additional data needs were identified based upon this analysis:

- The alluvial water level data presented in this TM and in HydroBase are the most comprehensive currently available and should be utilized by members of government agencies, water management groups and the public in water resources-related activities for the alluvial aquifer of the South Platte River downstream of Chatfield Reservoir and its tributaries.

- Continue alluvial aquifer water level data collection efforts in the spring and autumn from the existing DWR monitoring network and from the SPDSS monitoring wells with automated data loggers, as is planned for Task 39 in Phase 4.

- Collect spring alluvial water level measurements consistently in the month of April to minimize the year-to-year variability and reduce the influence of spring and early summer pumping on the water level data collected.

- Continue programs such as the enhanced 2003 spring water level measurement effort (denoted by "Colorado State University" in Table 1) on a periodic basis. This water level data represents a substantial improvement in the number and distribution of measurements in the South Plate Alluvium Region and helps reduce uncertainties in groundwater modeling by providing a good data set for model calibration purposes.

- Expand the current water level collection program to include additional alluvial wells in areas with data gaps. This includes areas in the Cache la Poudre River and in Box Elder, Beaver and Badger Creeks. A greater density of water level measurements will allow for a greater understanding of local water level trends from year to year.

- HydroBase should include a field in its water level measurement tables to indicate if the water level measurement was collected under pumping conditions. For data solicited

from outside entities, the State should evaluate the data to determine if the measurements represent pumping or non-pumping conditions. This could be accomplished by analysis of hydrographs from individual wells and by evaluating data eliminated from contouring in this TM.

- The water level data presented in this TM should be used to develop continuous water table maps of the alluvial aquifer for use as initial aquifer water levels and in model calibration of a South Platte Alluvium Region groundwater model, being developed under Task 48 of the SPDSS project.

6.0 References

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_____. 1972c. Hydrogeologic Characteristics of the Valley-Fill Aquifer in the Julesburg Reach of the South Platte River Valley, Colorado. USGS Open-File Report 73-125.

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_____. 1972e. Hydrogeologic Characteristics of the Valley-Fill Aquifer in the Weldona Reach of the South Platte River Valley, Colorado. USGS Open-File Report 73-127.

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Figure 1: SPDSS Study Area

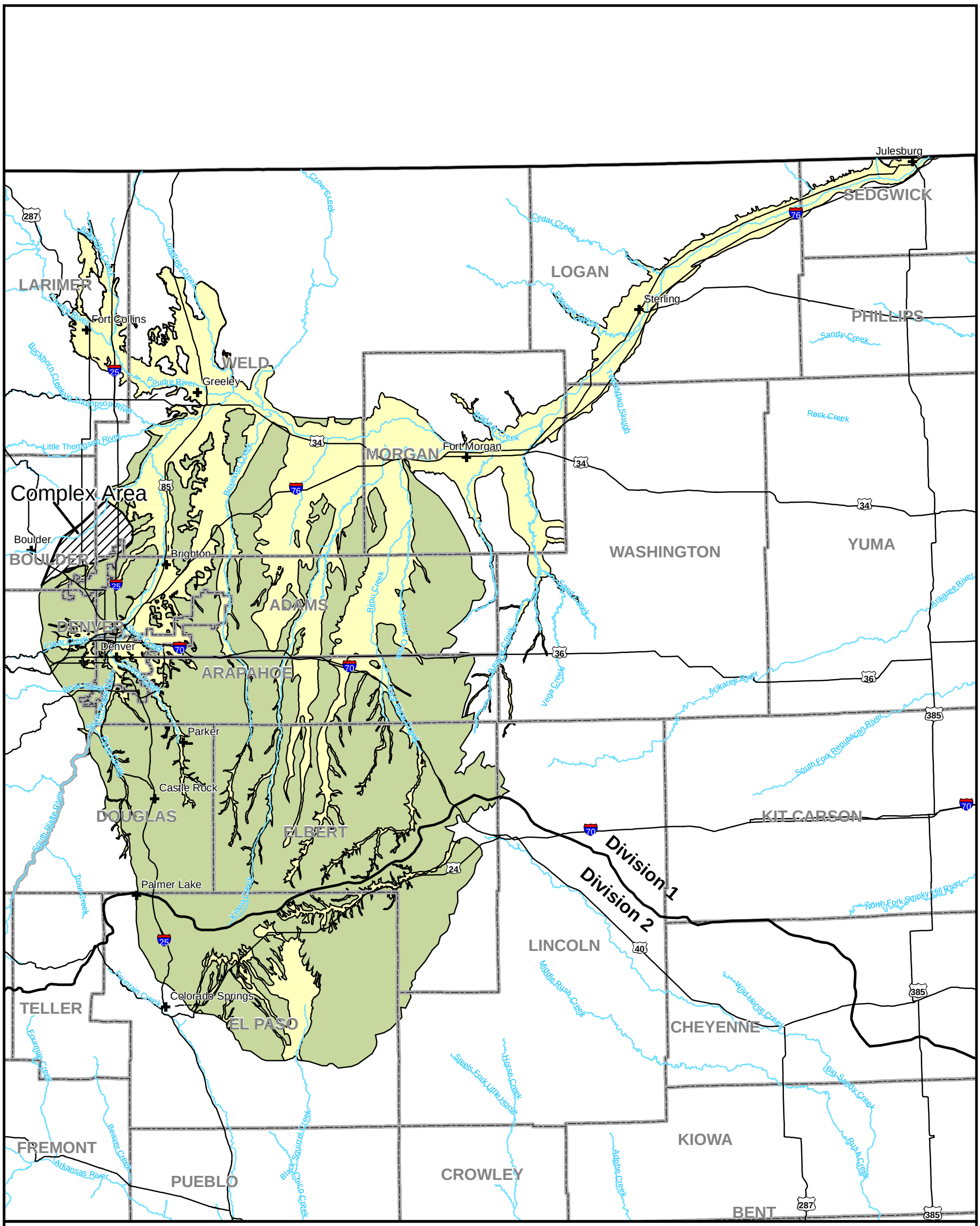

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Figure 2: Number of Water Level Measurements in a Given Year in the South Platte Alluvial Aquifer

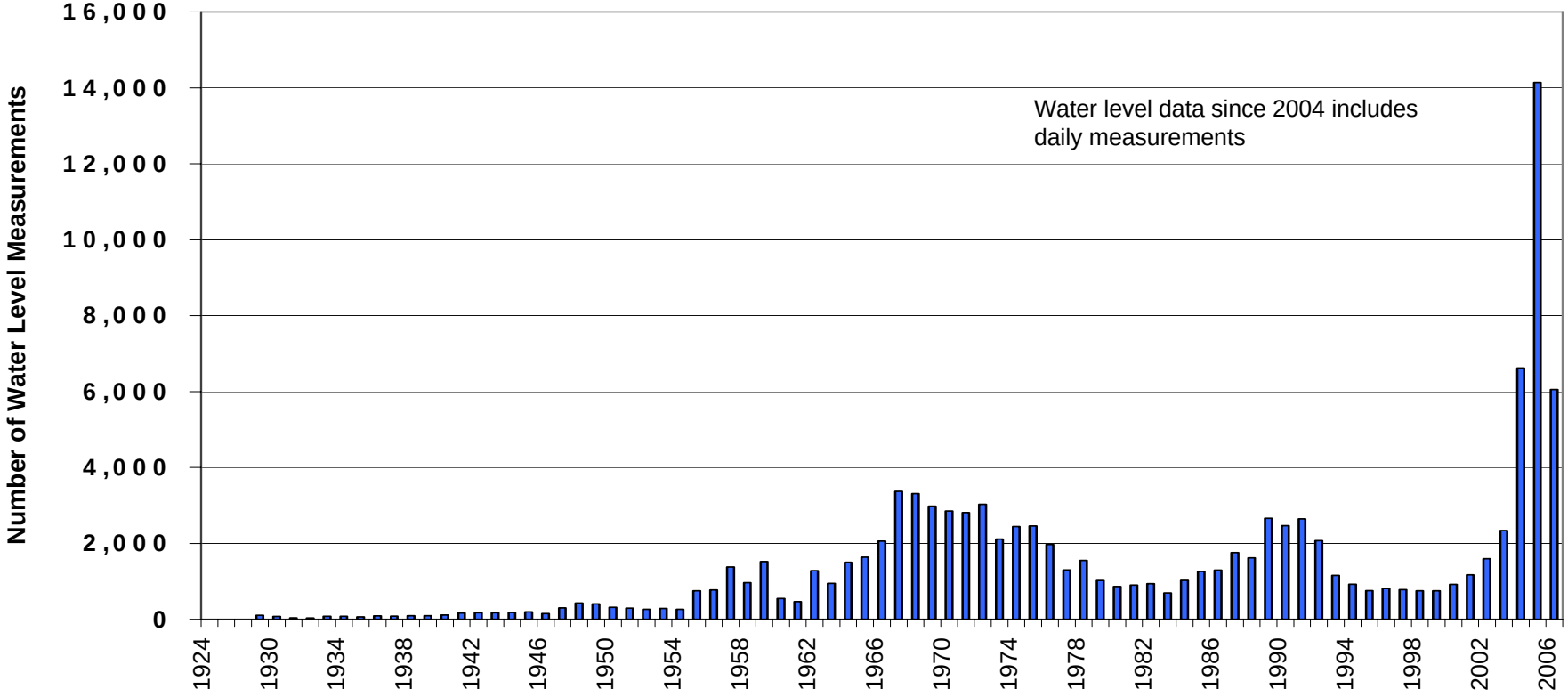

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Figure 3: Number of Water Level Measurements in a Given Month in the South Platte Alluvial Aquifer

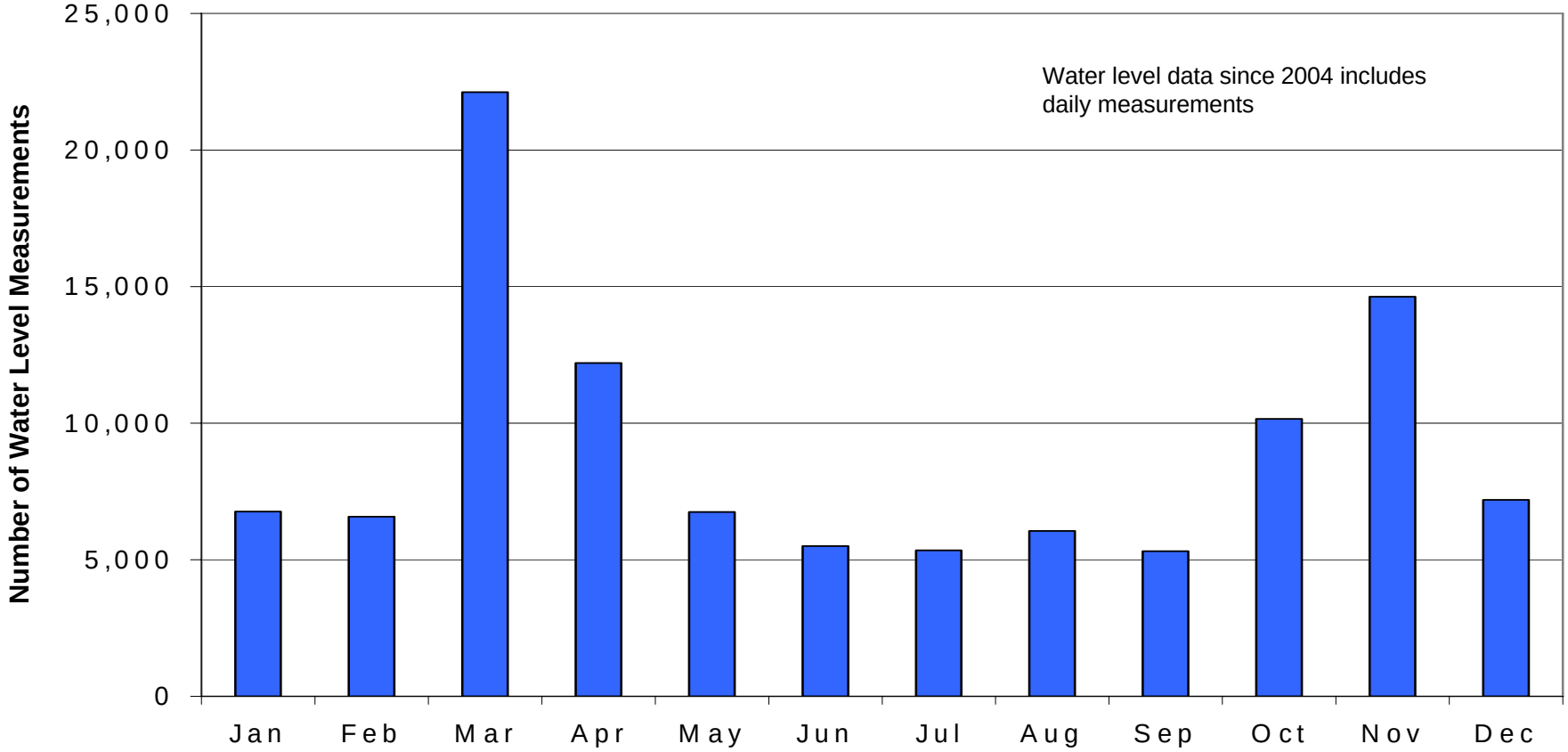

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Figure 4: Water Level Elevations in the Alluvial Aquifer 1968

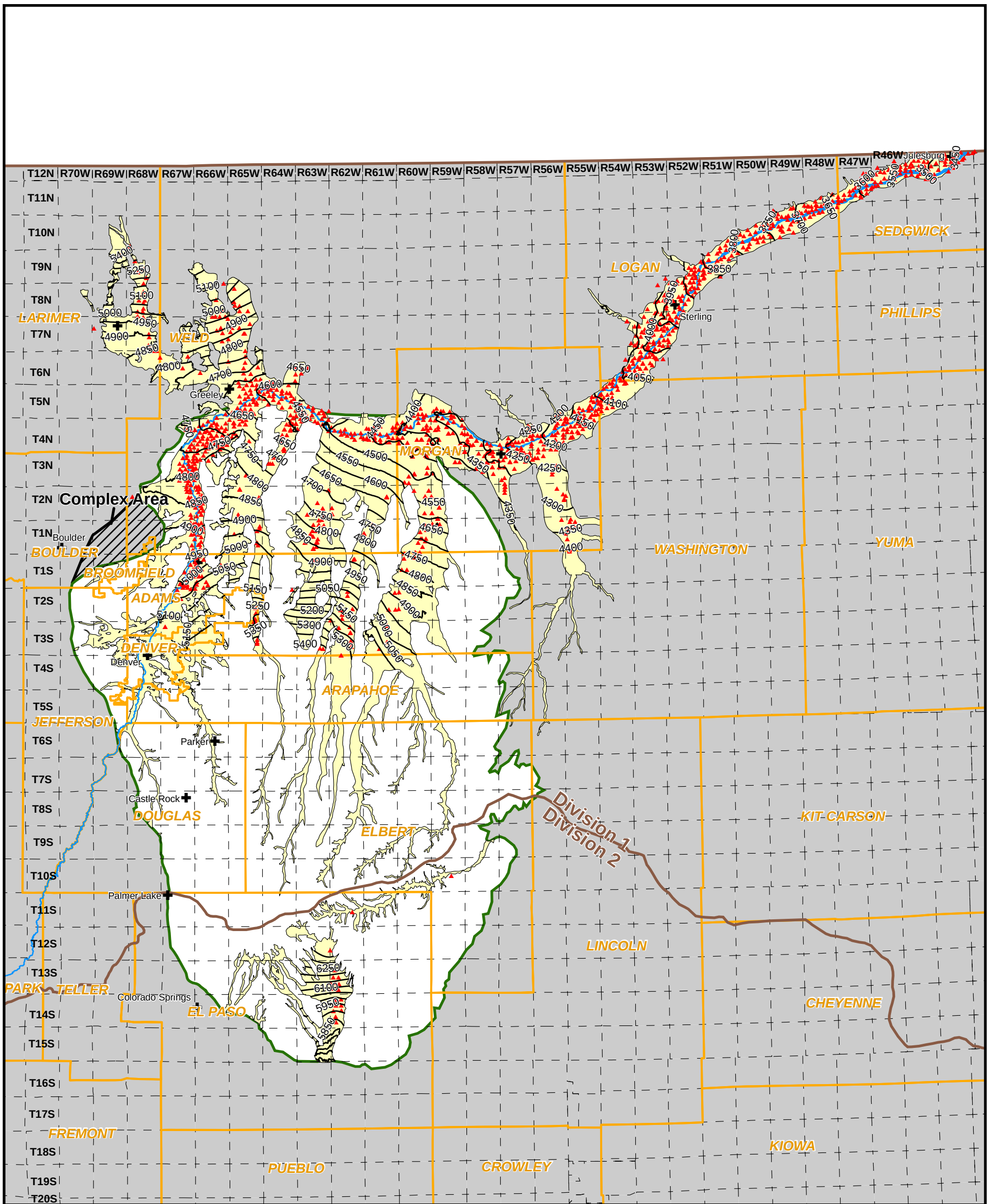

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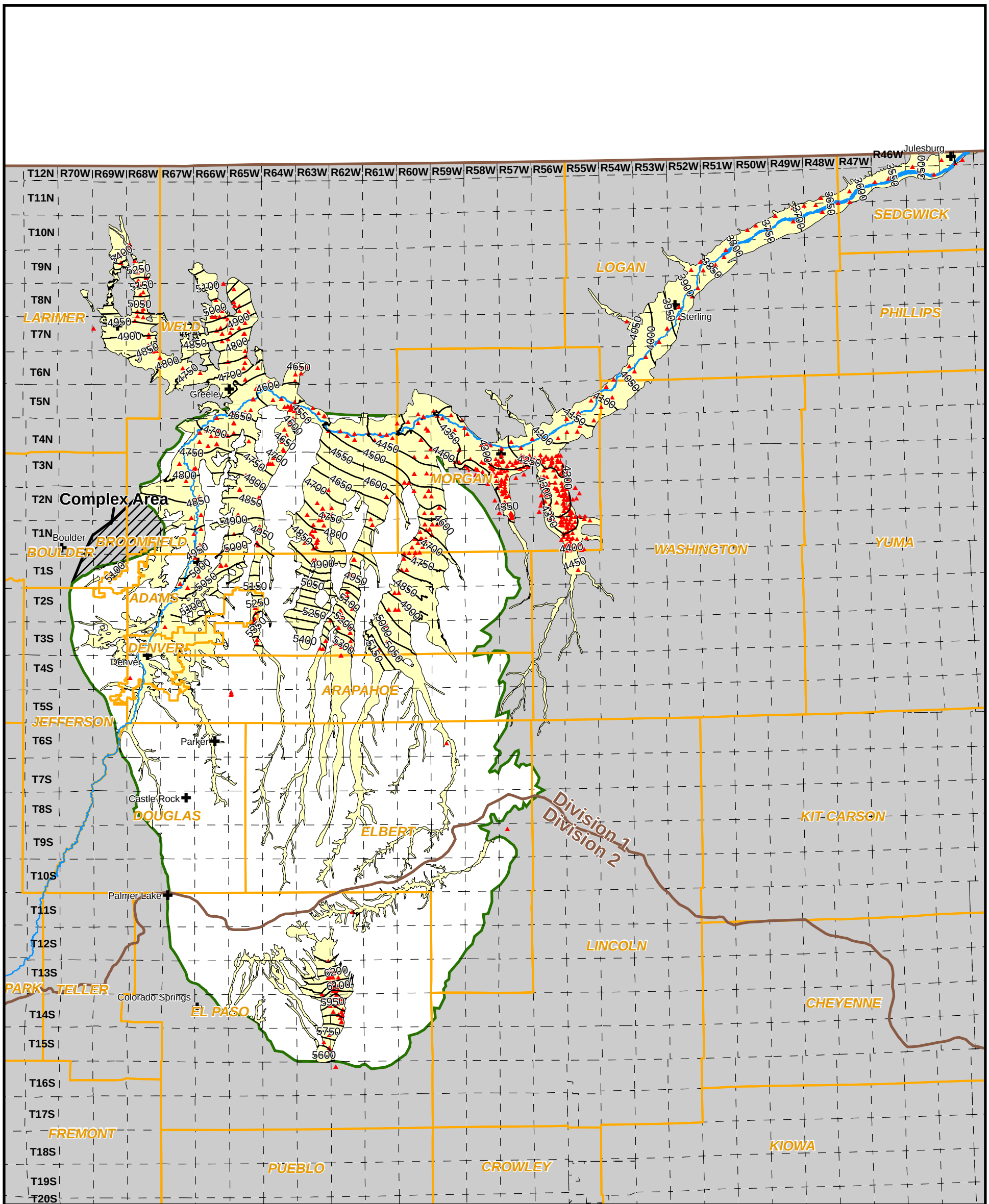
Figure 5: Water Level Elevations in the Alluvial Aquifer 1978



N
W
E
S

Scale
1:1,100,000

0 5 10 20
Miles

NAD 1983 UTM Zone 13N

South Platte River
City
County
Township
Alluvial Aquifer Extent
Denver Basin Extent

Water Level Elevation Contour
(50 ft interval)
Spring Water Level Measurement

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Figure 6: Water Level Elevations in the Alluvial Aquifer 1990

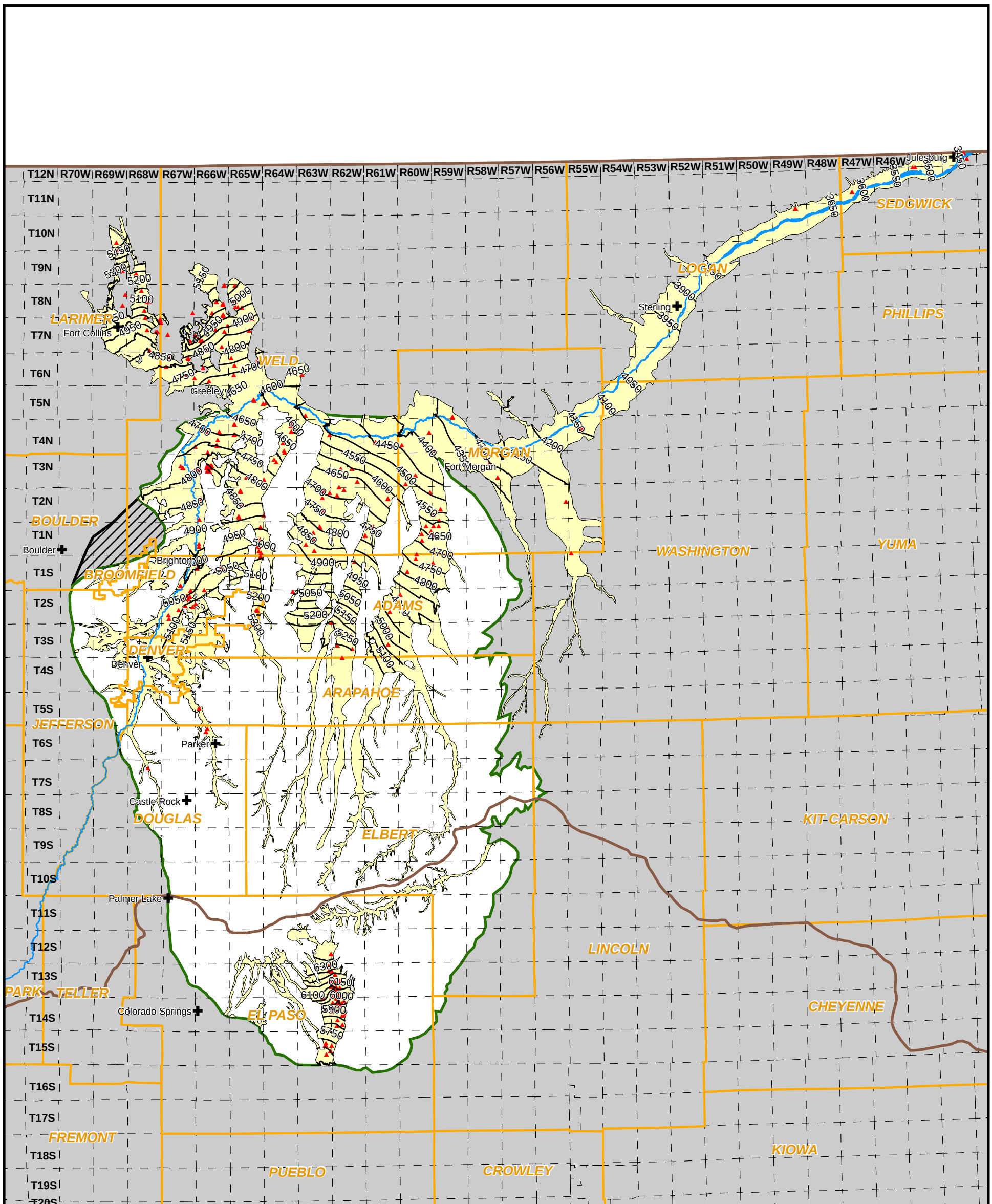

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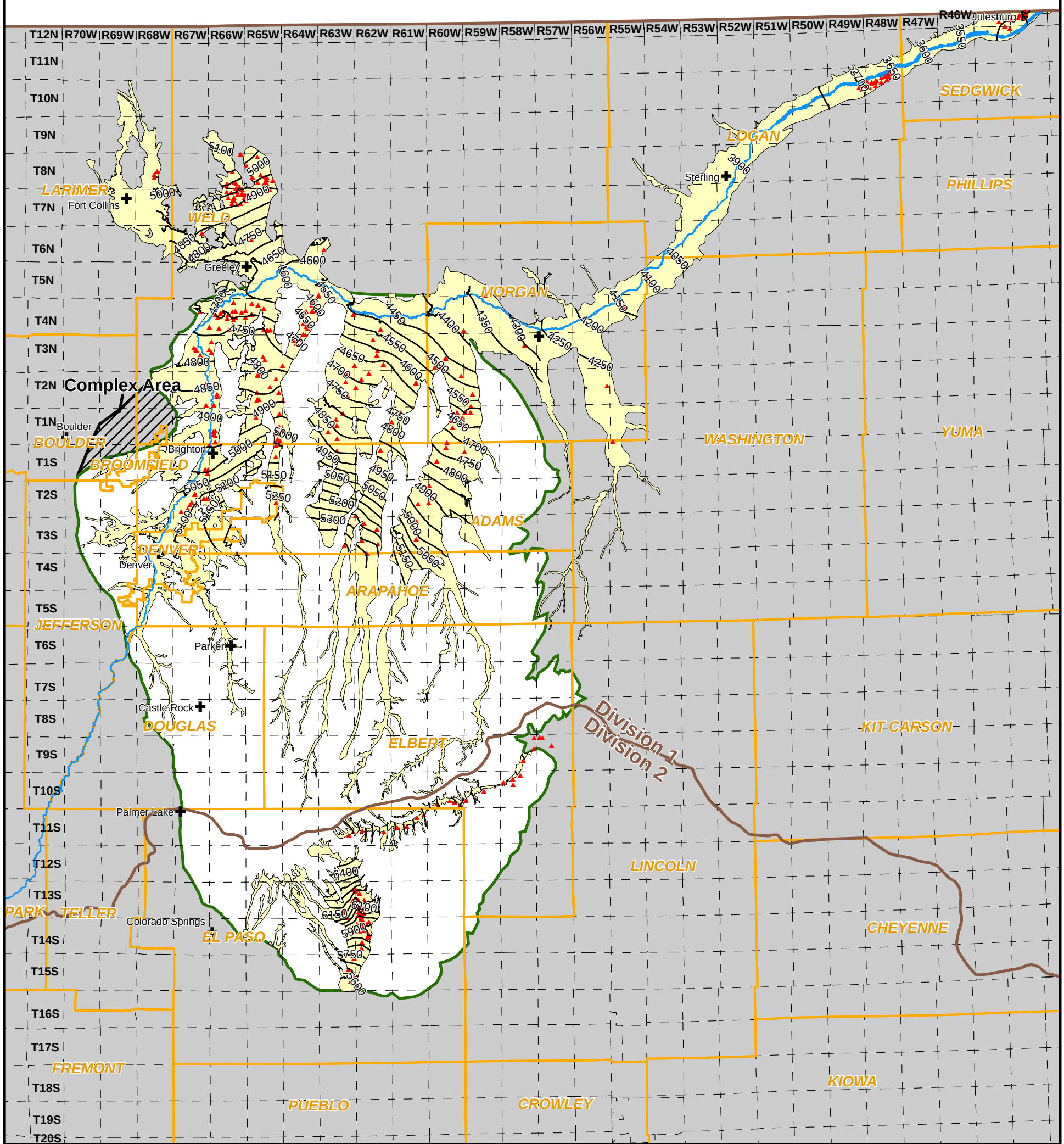
Figure 7: Water Level Elevations in the Alluvial Aquifer 2001



N
W E
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Scale
1:1,100,000

0 5 10 20
Miles

NAD 1983 UTM Zone 13N

- South Platte River
- City
- County
- Township
- Alluvial Aquifer Extent
- Denver Basin Extent

Water Level Elevation Contour
(50 ft interval)
Spring Water Level Measurement

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Figure 8: Water Level Elevations in the Alluvial Aquifer 2003

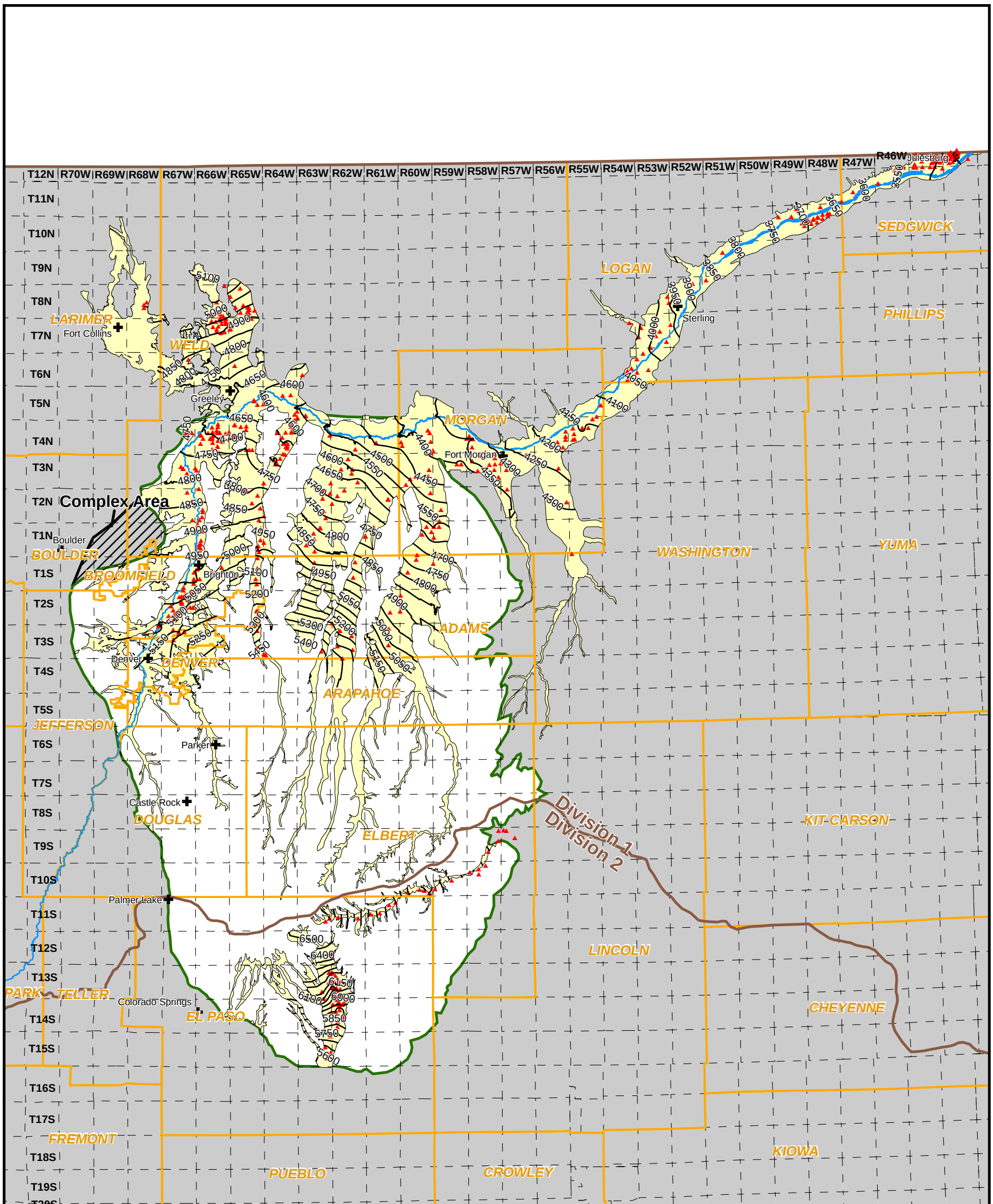

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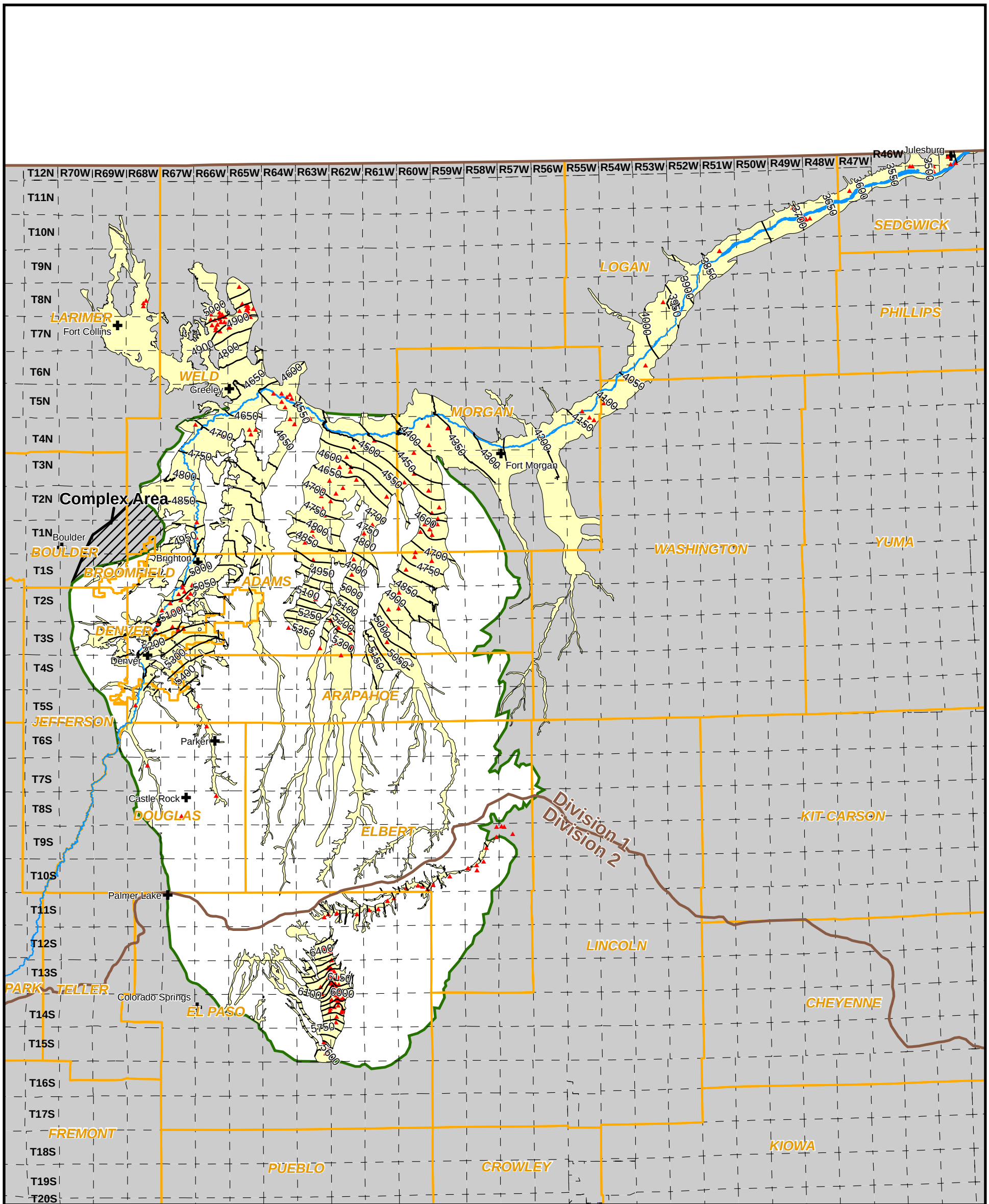
Figure 9: Water Level Elevation in the Alluvial Aquifer 2005



N
W
E
S

Scale
1:1,100,000

0 5 10 20
Miles

NAD 1983 UTM Zone 13N

South Platte River
City
County
Township
Alluvial Aquifer Extent
Denver Basin Extent

Water Level Elevation Contour
(50 ft interval)
Spring Water Level Measurement

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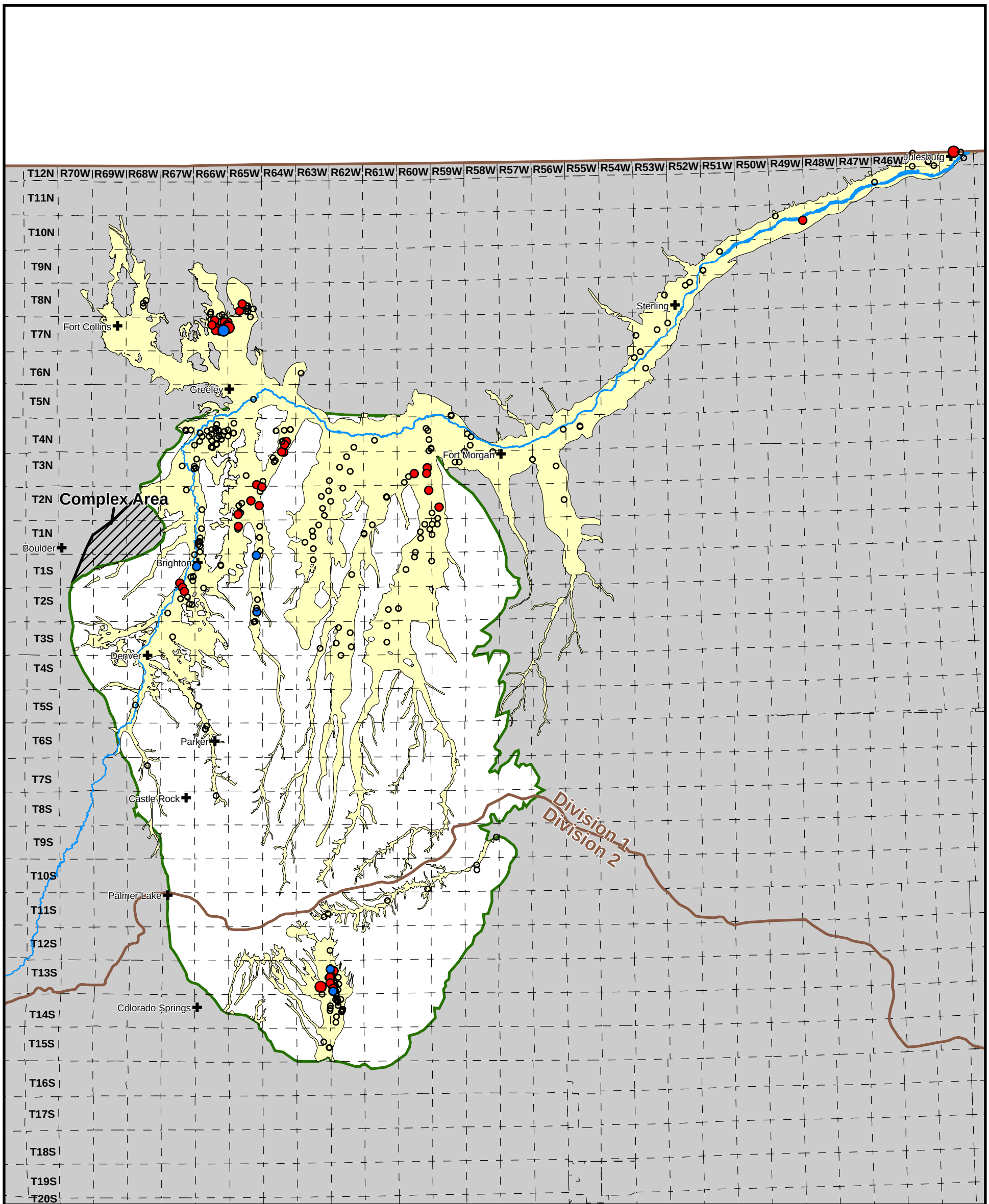
Figure 10: South Platte Alluvial Aquifer Water Level Trends



Scale 1:1,100,000

0 5 10 20 Miles

NAD 1983 UTM Zone 13N

	Positive trend (ft/yr)	Negative trend (ft/yr)
South Platte River	0 to 1	-1 to 0
City	1 to 3	-3 to -1
Township	>3	< -3
Alluvial Aquifer Extent		
Denver Basin Extent		

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Figure 11: Location of Hydrographs in the South Platte Alluvial Aquifer

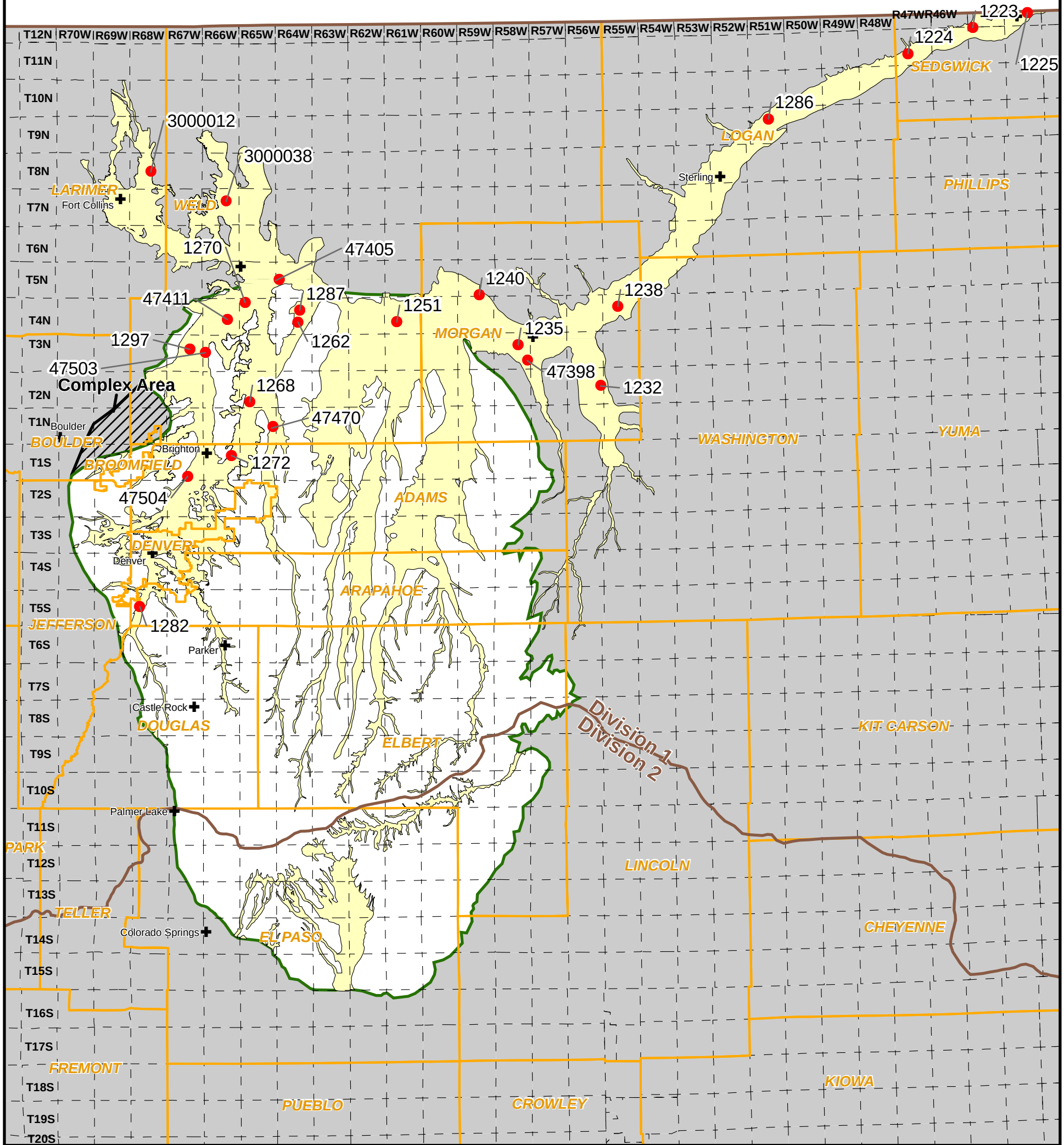

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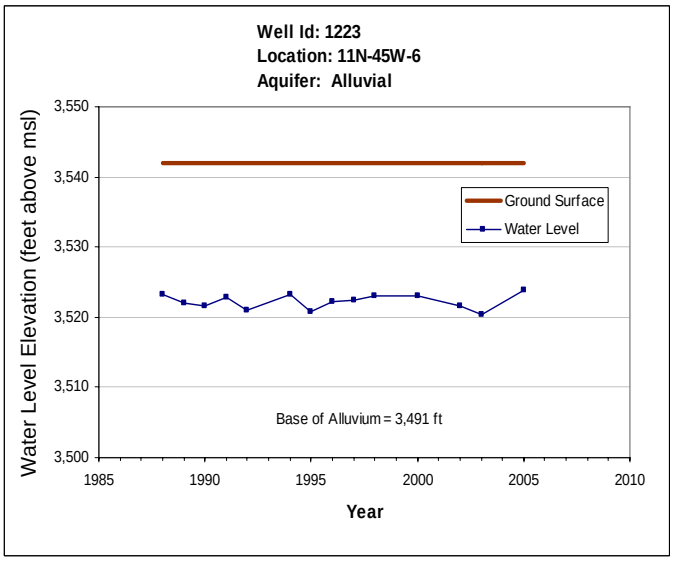
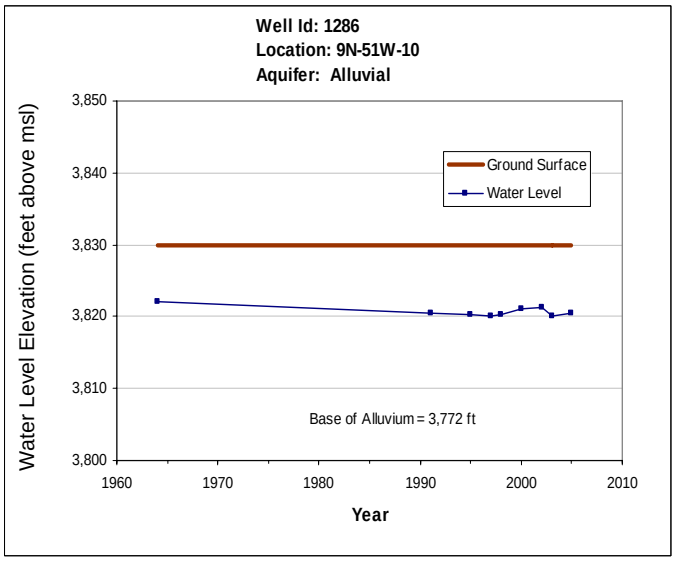
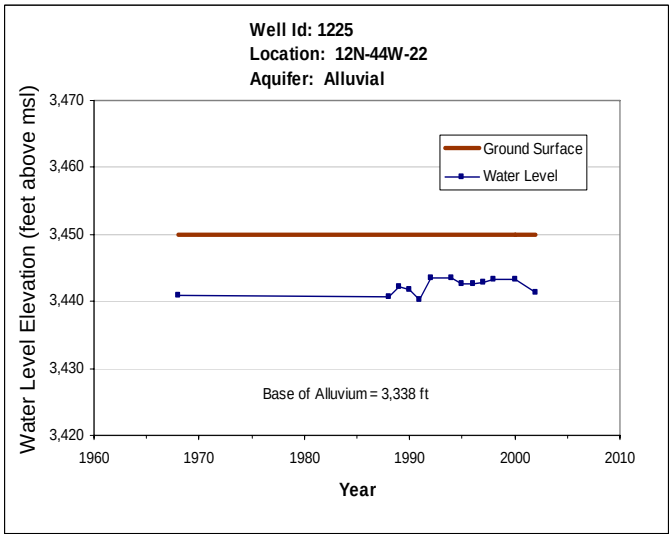
Figure 12: Hydrographs of Selected Wells in the South Platte Alluvial Aquifer







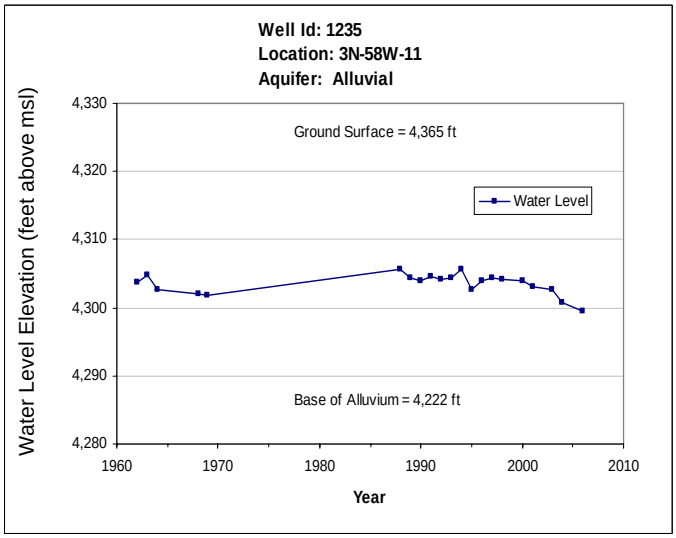


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Figure 13: Hydrographs of Selected Wells in the South Platte Alluvial Aquifer

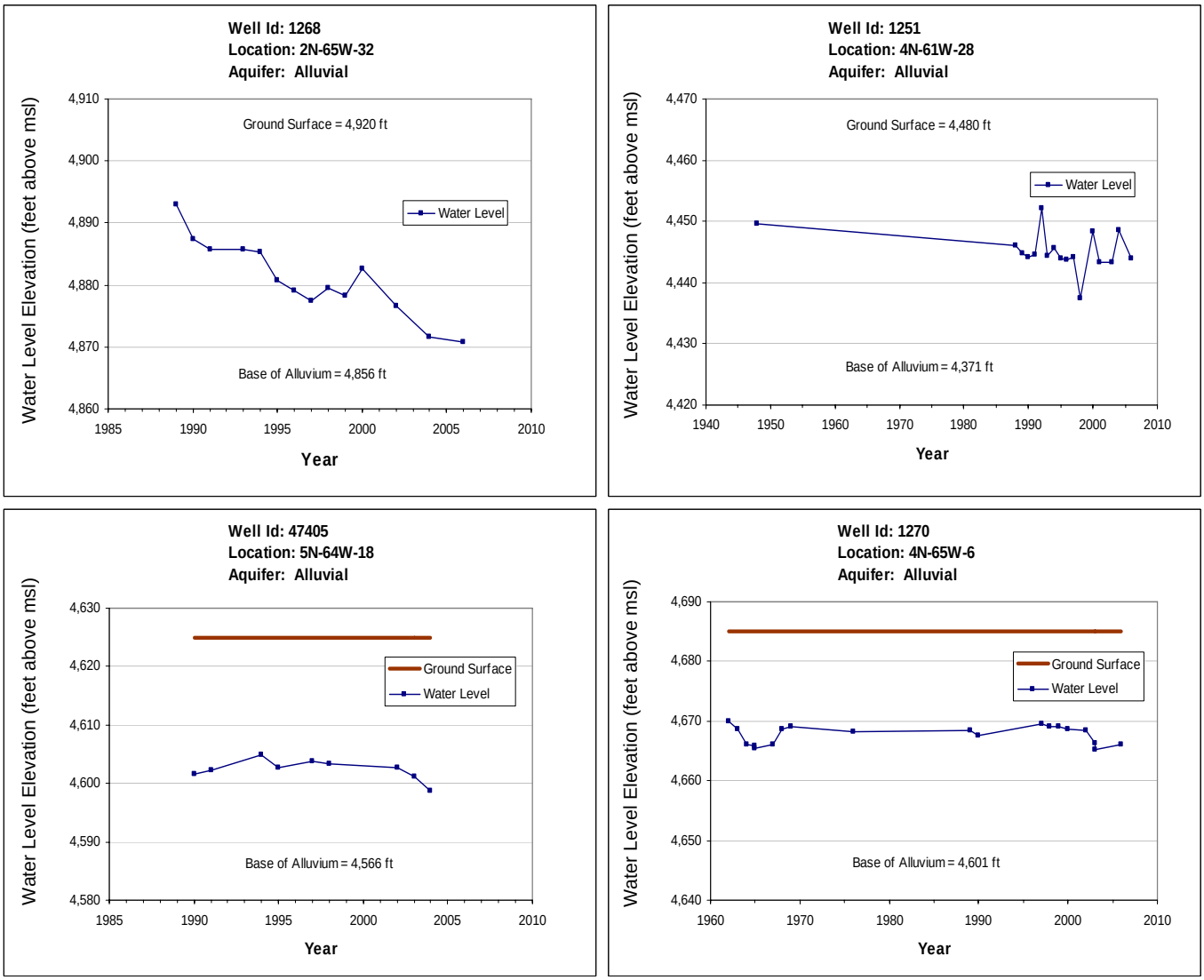

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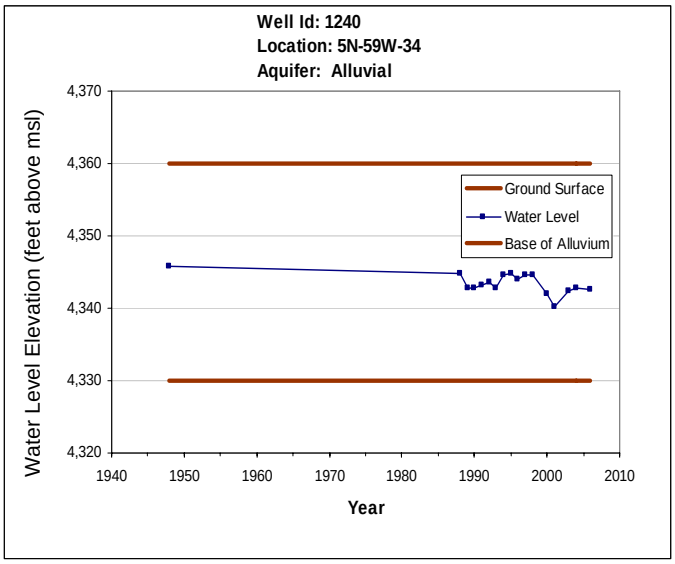
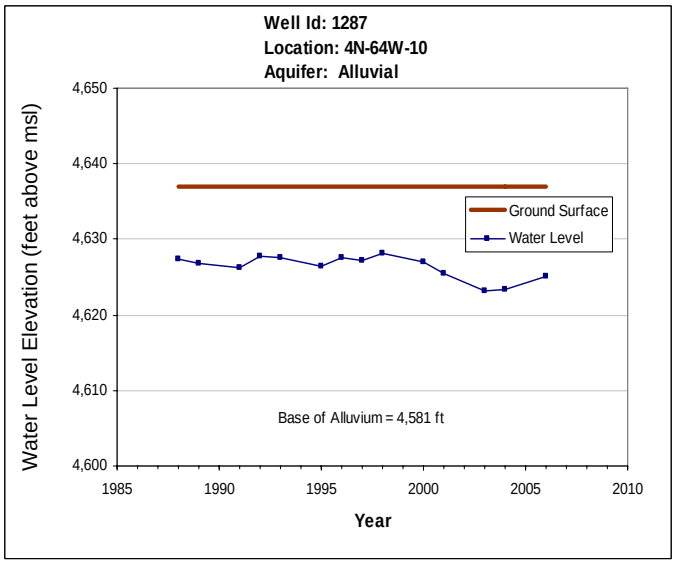
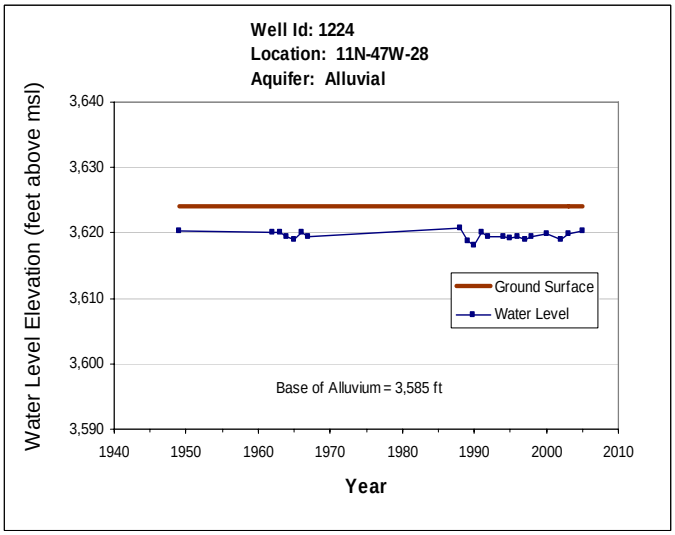
Figure 14: Hydrographs of Selected Wells in the South Platte Alluvial Aquifer







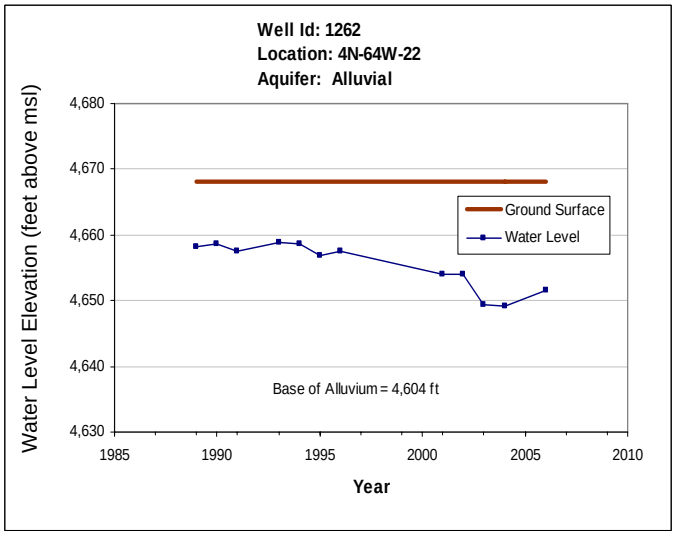


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Figure 15: Hydrographs of Selected Wells in the South Platte Alluvial Aquifer

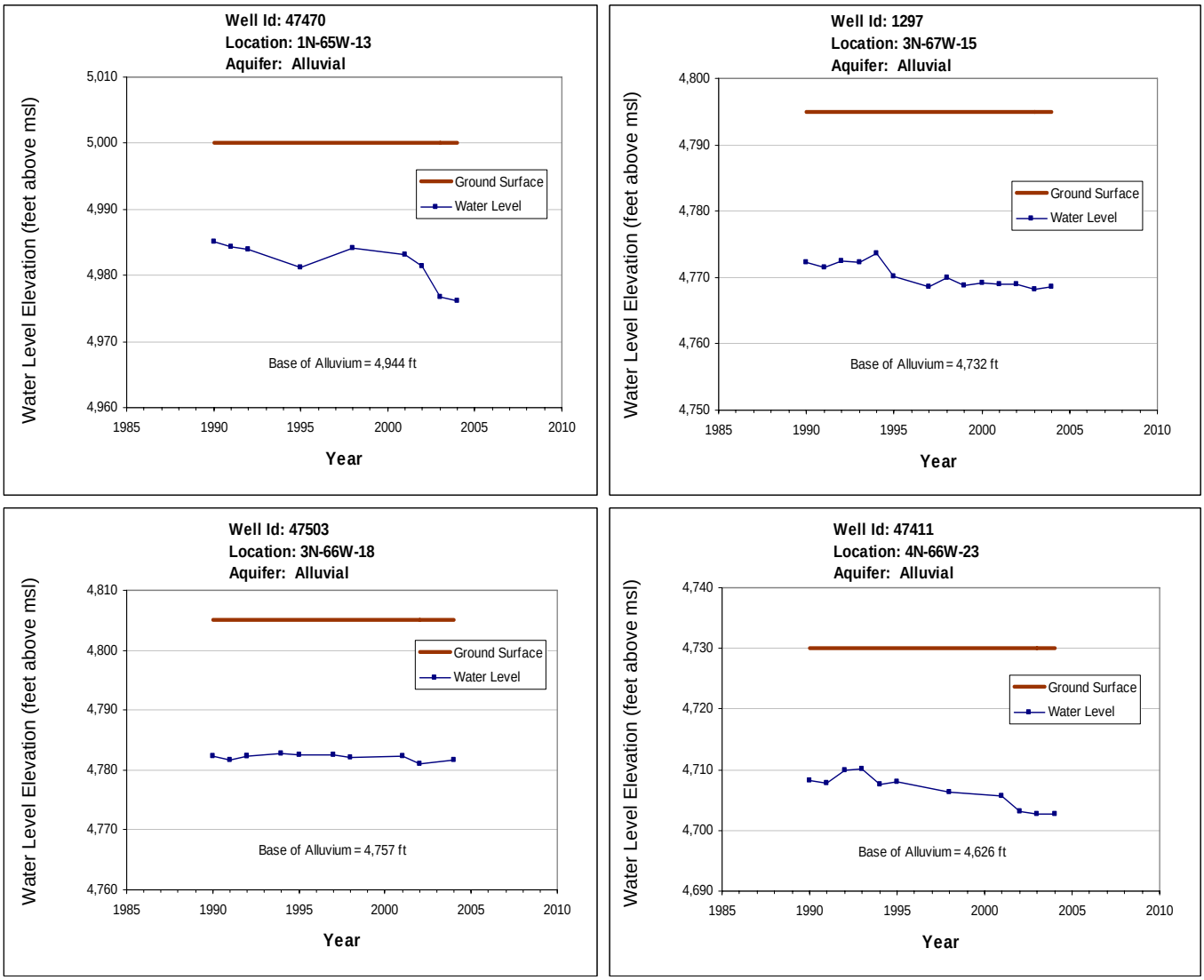

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Figure 16: Hydrographs of Selected Wells in the South Platte Alluvial Aquifer

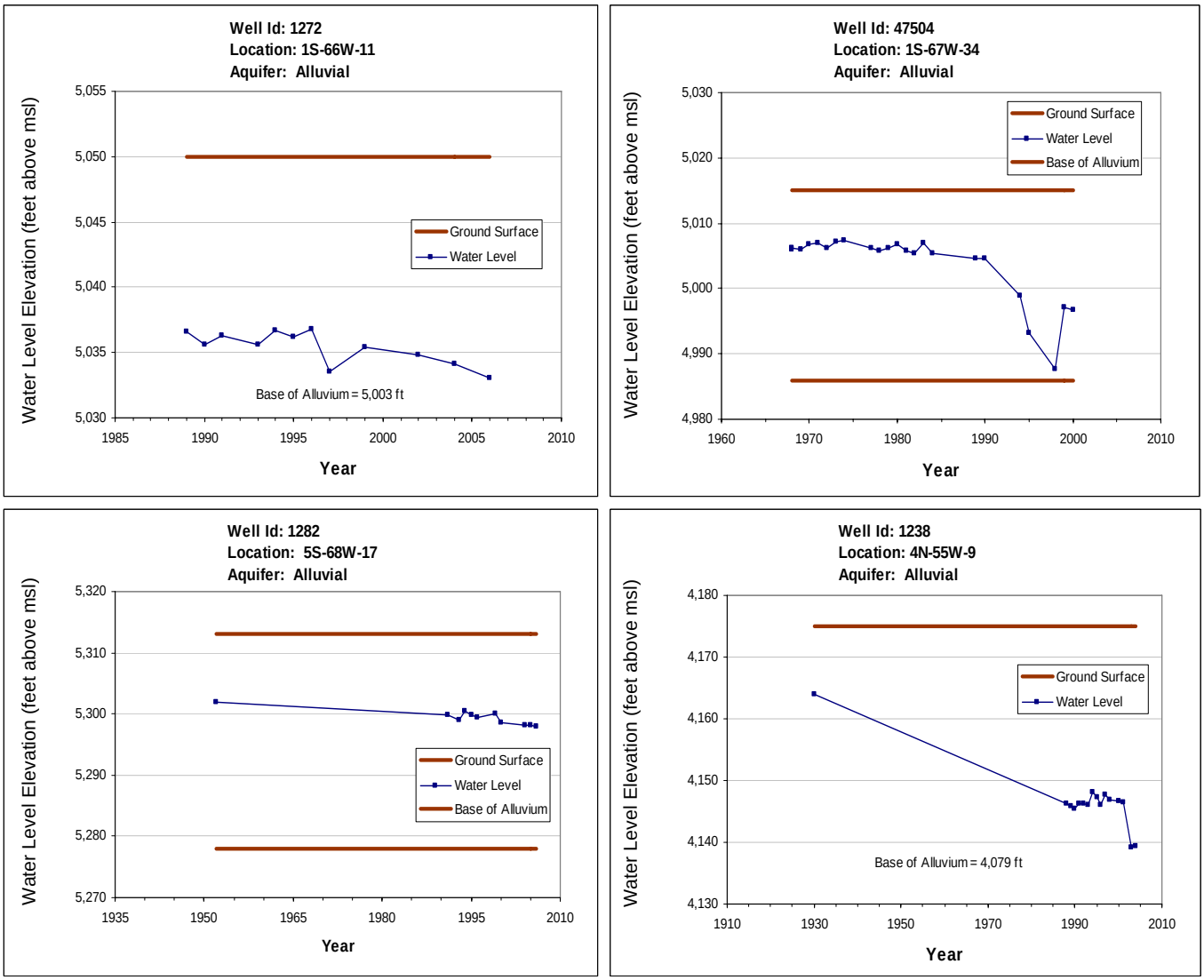

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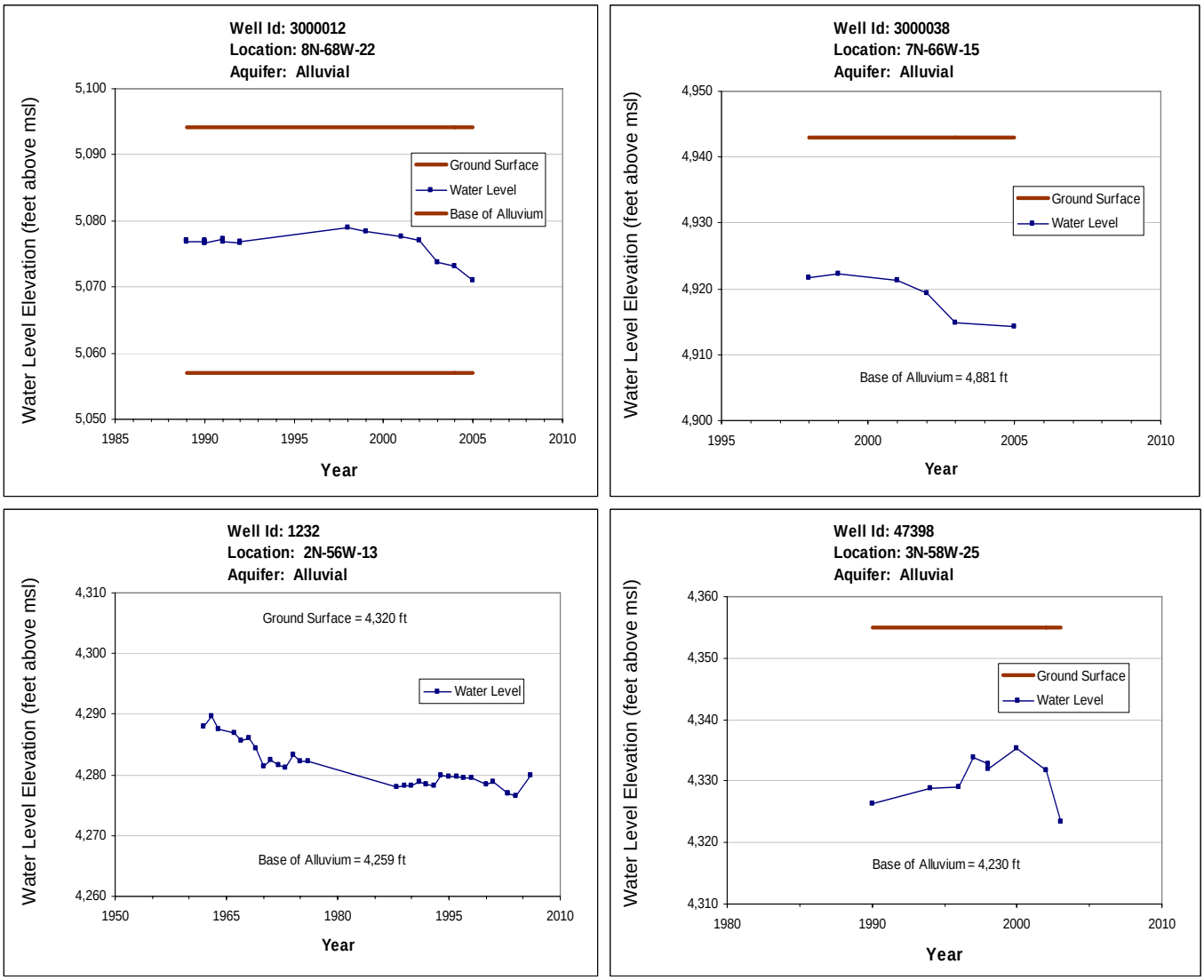
Figure 17: Hydrographs of Selected Wells in the South Platte Alluvial Aquifer



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Appendix A

Phase 3 Task 44.3, Instructions to Query Water Levels from HydroBase for Contouring the South Platte Alluvial Water Level Surfaces

Appendix A: Instructions to Query Water Levels from HydroBase for Contouring the South Platte Alluvial Aquifer Water Level Surfaces

1.0 Purpose/Objective

To document the procedure used to query the water level picks from HydroBase for contouring the Phase 2 South Platte Alluvium Region water surfaces.

2.0 Procedure/Approach

The following procedure was used to query spring alluvial water level data from HydroBase:

1) In Microsoft Access, a table containing the aquifer codes assigned to wells in the WELLS table during Phase 1, WELLS_DSS_AQUIFERS was imported into the database. This correlation table was supplied by the State. A select query was defined to create two new fields *DSSAquifer1* and *DSSAquifer2* by first using the values reported in *aquifer1* and *aquifer2* codes in WELLS_DSS_AQUIFERS and if those values are null, using the *aquifer1* and *aquifer2* codes in the WELLS table.

2) In ArcGIS a spatial query was performed to identify all wells located within the SPDSS South Platte Alluvium Region study area (div1_alluvial_extent_20051010.shp) using a 2-mile buffer. The results of this spatial query were used to populate a temporary lookup table, SPDSS_REGION. This table contains the *well_id* and a new field, *spdss_reg*, indicating the well is located in the SPDSS study area. The table is linked to the WELLS and WELL_MEAS table by the *well_id* field.

3) A query of the WELLS table was performed to identify any wells in the WELLS table with an *aquifer_comment* noting a USGS primary aquifer code that did not already have values for *DSSAquifer1* and/or *DSSAquifer2* fields and is located in the SPDSS study area. The USGS aquifer codes were correlated to SEO aquifer codes.

4) In Microsoft Access, the WELLS, WELL_MEAS and SPDSS_REGION tables were linked via *well_id* field. Selected fields were chosen from the WELLS table (location and aquifer information) and all fields were chosen from the WELL_MEAS table. A query using the *DSSAquifer1* and *DSSAquifer2* and *meas_date* fields was used to identify the spring water level measurements for a well in a given year. The query is depicted below.

<u>South Platte Alluvium Region</u>

a. DSSAquifer1 = "QAL" AND DSSAquifer2 = Is Null AND SPDSS_REG = "SPDSS" AND Year(meas_date) = 1968 and Month(meas_date) = 2 OR Month(meas_date) = 3 OR Month(meas_date) = 4

The query results were exported to Excel.

5) In Excel, the first spring water level measurement in a given year was identified and included in the dataset used for contouring.

6) Steps 4 and 5 were repeated for all time periods (1968, 1978, 1990, 2001, 2003, and 2005).

Appendix B

Phase 3 Task 44.3, List of Control Points Used in Contouring Water Levels in the South Platte Alluvium Region

Appendix B
South Platte River Streambed Elevation Data Used in Contouring

X- X Coordinate in NAD1983 UTM13N

Y- Y Coordinate in NAD1983 UTM13N

Elevation of Streambed in Feet

X	Y	Elevation
514954	4432129	4919
514822	4436068	4897
514935	4439351	4875
514704	4443067	4851
514577	4448646	4817
512775	4452183	4784
511480	4456270	4757
514651	4461103	4716
517098	4464485	4697
521584	4467474	4668
525849	4468340	4646
529523	4471443	4624
532404	4473367	4609
536316	4474341	4588
540519	4472105	4571
543774	4469976	4557
549708	4466647	4523
552489	4463532	4518
558884	4461757	4476
564190	4462057	4455
570284	4461988	4425
574991	4464039	4395
579719	4466444	4375
583532	4467510	4351
588149	4465162	4330
593299	4462560	4301
599167	4459114	4269
605282	4458472	4241
610779	4460063	4212
617566	4463395	4181
622757	4465790	4155
625015	4468446	4134
629109	4471031	4113
633841	4475252	4073
636602	4479283	4049
640586	4482350	4025
644696	4486457	4002
648286	4489936	3972
652161	4496338	3937
653860	4500292	3914
657726	4506668	3875
660483	4510906	3849
665374	4513550	3818
671998	4517408	3782

Appendix B
South Platte River Streambed Elevation Data Used in Contouring

X- X Coordinate in NAD1983 UTM13N

Y- Y Coordinate in NAD1983 UTM13N

Elevation of Streambed in Feet

X	Y	Elevation
675705	4519629	3761
682273	4523509	3722
688458	4524842	3689
694631	4527269	3653
700379	4529161	3626
706363	4533123	3588
711883	4534102	3558
718772	4536387	3525
724446	4536259	3496
730505	4539141	3458

Appendix C

Phase 3 Task 44.3, Outlier Water Level Elevations Identified when Contouring Water Levels in the South Platte Alluvium Region

Appendix C
Water Level Elevations Identified as Outliers, Bull's Eye or Greater Than 10 Feet Above Ground Surface

X- X Coordinate in NAD1983 UTM13N

Y- Y Coordinate in NAD1983 UTM13N

Elevation - Water Level Elevation in Feet

ID	X	Y	Elevation	Year
8004	516911	4458390	7685	1968
6570	514505	4444665	4855	1968
33286	548301	4439440	4845	1968
7881	549213	4466579	4518	1968
7885	549712	4466120	4517	1968
7901	551709	4463852	4506	1968
7799	573795	4461970	4417	1968
7795	575085	4462754	4405	1978
33286	548301	4439440	4851	1978
10095	553224	4286037	5655	1978
1364	559944	4458286	4537	1990
47575	534072	4448599	4907	1990
47574	533234	4445725	4906	1990
47499	515655	4438111	4943	1990
47499	515655	4438111	4943	2001
47578	532276	4447637	4906	2001
47577	532294	4447024	4908	2001
47574	533234	4445725	4903	2001
1290	533413	4445994	4678	2001
47576	533792	4447008	4904	2001
47575	534072	4448599	4898	2001
47476	540785	4459944	4669	2001
47575	534072	4448599	4899	2003
47578	532276	4447637	4903	2003
47577	532294	4447024	4905	2003
47576	533792	4447008	4900	2003
47574	533234	4445725	4897	2003
47499	515655	4438111	4944	2003
47370	515024	4432643	4970	2003
47369	515051	4432606	4955	2003
47353	511323	4419284	5027	2003
47462	532523	4414850	5283	2003

Appendix D

Phase 3 Task 44.3, Data Directory for Water Level Data in HydroBase

Appendix D
Data Directory for Water Level Data in HydroBase

Table Name: *WELLS*	**Task:** Task 42, 43 and 44 of the SPDSS
Description: The core table in the database containing key information on wells including location, permit number, receipt, name, depth, aquifer tapped, and perforated interval.	
Field Name	**Field Description**
well_id	Well identifier.
well_name	Name of the well.
div	SEO Division number.
wd	SEO Water district.
receipt	Unique identifier. Generated by cash register.
permitno	Well permit number.
permitsuf	Well suffix code.
permitrpl	Well replacement code. Contains an 'A' for exempt, and 'R' for non-exempt.
locnum	USBR location identifier string.
Site_ID	USGS site identifier.
basin	Designated basin code.
md	Management district code.
cty	County code.
PM	Principle meridian.
ts	Township number
tsa	Half township indicator.
tdir	Township direction.
rng	Range number.
rnga	Half range indicator.
rdir	Range direction.
sec	Section number.
seca	Upper section indicator.
q160	160 acre quarter section indicator.
q40	40 acre quarter section indicator.
q10	10 acre quarter section indicator.
coordsns	Distance from north/south section line (feet).
coordsns_dir	Direction of measurement from north/south section line.
coordsew	Distance from east/west section line (feet).
coordsew_dir	Direction of measurement from east/west section line.
utm_x	The x (Easting) component of the Universal Transverse Mercator system. NAD83 Zone 13.
utm_y	The y (Northing) component of the Universal Transverse Mercator system. NAD83 Zone 13.
latdecdeg	Latitude (decimal degrees).
longdecdeg	Longitude (decimal degrees).
loc_accuracy	Horizontal location accuracy indicator.
gs_elev	Ground surface elevation.
elev_accuracy	Vertical location accuracy indicator.
well_depth	Completed depth of well (feet).
log_depth	Geophysical log measurement depth
log_type	Geophysical log measurement method.
log_SWL	Geophysical log measurement surface water level.
log_date	Geophysical log measurement date of measurement.
aquifer1	Aquifer in which well is located.

Appendix D
Data Directory for Water Level Data in HydroBase

aquifer2	If well is located in two aquifers, name of second aquifer.
aquifer_comment	Any comments associated with the aquifer(s) that the well transverses.
tperf	Depth to top of first perforated casing. (FEET)
bperf	Depth to base of last perforated casing. (FEET)
yield	Actual pumping rate. (GPM)
bedrock_elev	Elevation of bedrock.
sat_1965	
remarks1	Generic remarks.
remarks2	Generic remarks.
owner	Owner's fullname.
address	Address of owner.
city	City.
st	State abbreviation.
zip	Zip code.
phone	Phone number.
cell_phone	Cell phone number.
email	E-mail address or internet address.
collection_order	Water level collection number. Used to indicate route to gather WL measurements.
data_source_id	A unique identifier of the data. Either the Site_ID or the locnum string.
data_source	Source of data.
publish?	Boolean indicating if well is part of DWR's water level publications.
geoplog?	Boolean indicating if well is part of DWR's geophysical log archive.
modified	Date the record was last modified.
user	User who last modified the record.
cdm_id	TEMPORARY - Identifier originally given to well by CDM in SPDSS project.
cmd_modified	TEMPORARY - Date the record was last modified by CDM.

Table Name: *WELL_MEAS*	**Task:** Task 44 of the SPDDS
Description: Table containing depth to water and water level elevation time series data	
Field Name	**Field Description**
well_id	Well identifier. Foreign key from [wells].
meas_date	Date of water level measurement.
wl_depth	Depth of water from measurement point. (FEET)
mp_height	Height of measurement point above ground. (FEET)
wl_depth_calc	Depth of water below ground surface. (FEET)
wl_elevation_calc	Elevation of water level. (Feet above sea level)
meas_by	Person who made the water level measurement.
modified	Date the record was last modified.
user	User who last modified the record.
cdm_modified	TEMPORARY - Date CDM last modified the record.

Appendix D
Data Directory for Water Level Data in HydroBase

Database Key Tables

REF_ELEV_ACCURACY

elev_accuracy_num	Description
1	Original database
2	USGS 30-meter DEM
3	Surveyed

REF_LOC_ACCURACY

loc_accuracy_num	Description
1	Spotted from PLSS quarters
2	Spotted from PLSS distances from section lines
3	Surveyed
4	Digitized
5	Original database
6	GPS