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

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	South Platte Alluvium Region Aquifer Property Technical Memorandum
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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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Figure 1: SPDSS Study Area

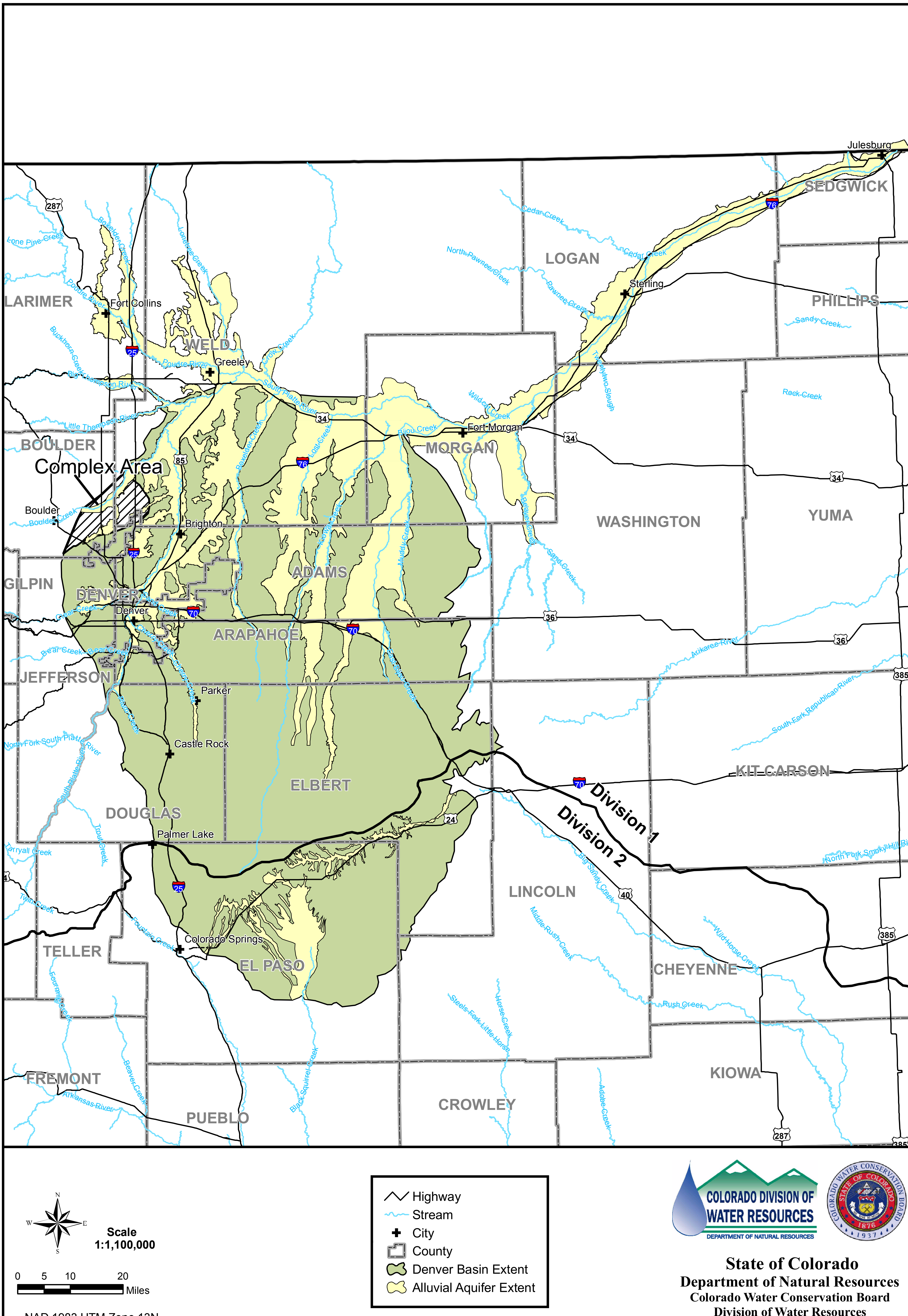

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Figure 2: Comparison of Alluvial Aquifer Tests Transmissivity and Specific Capacity Data in the SPDSS Study Area

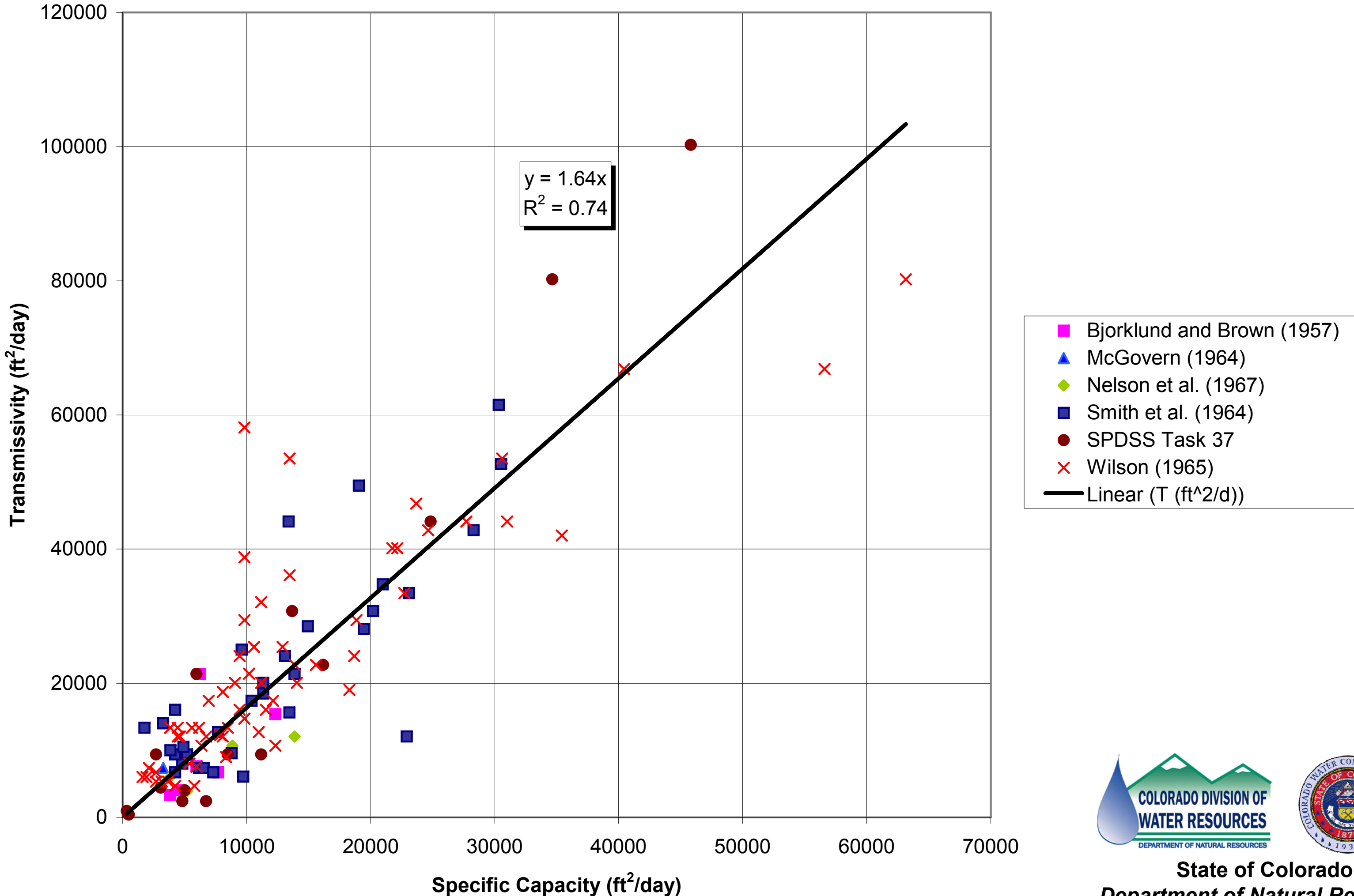

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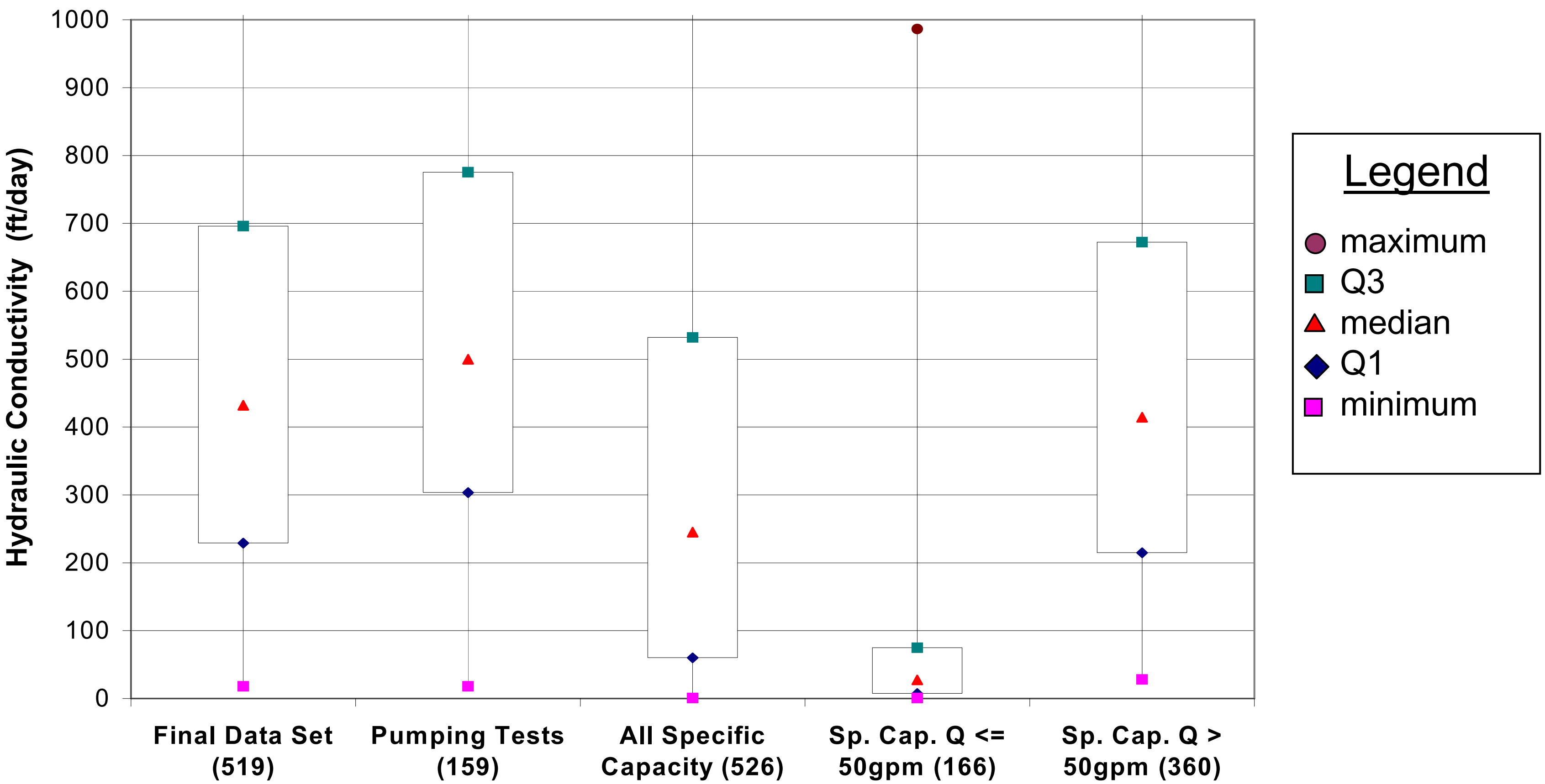
Figure 3: Specific Capacity Analysis by Test Flow Rate



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

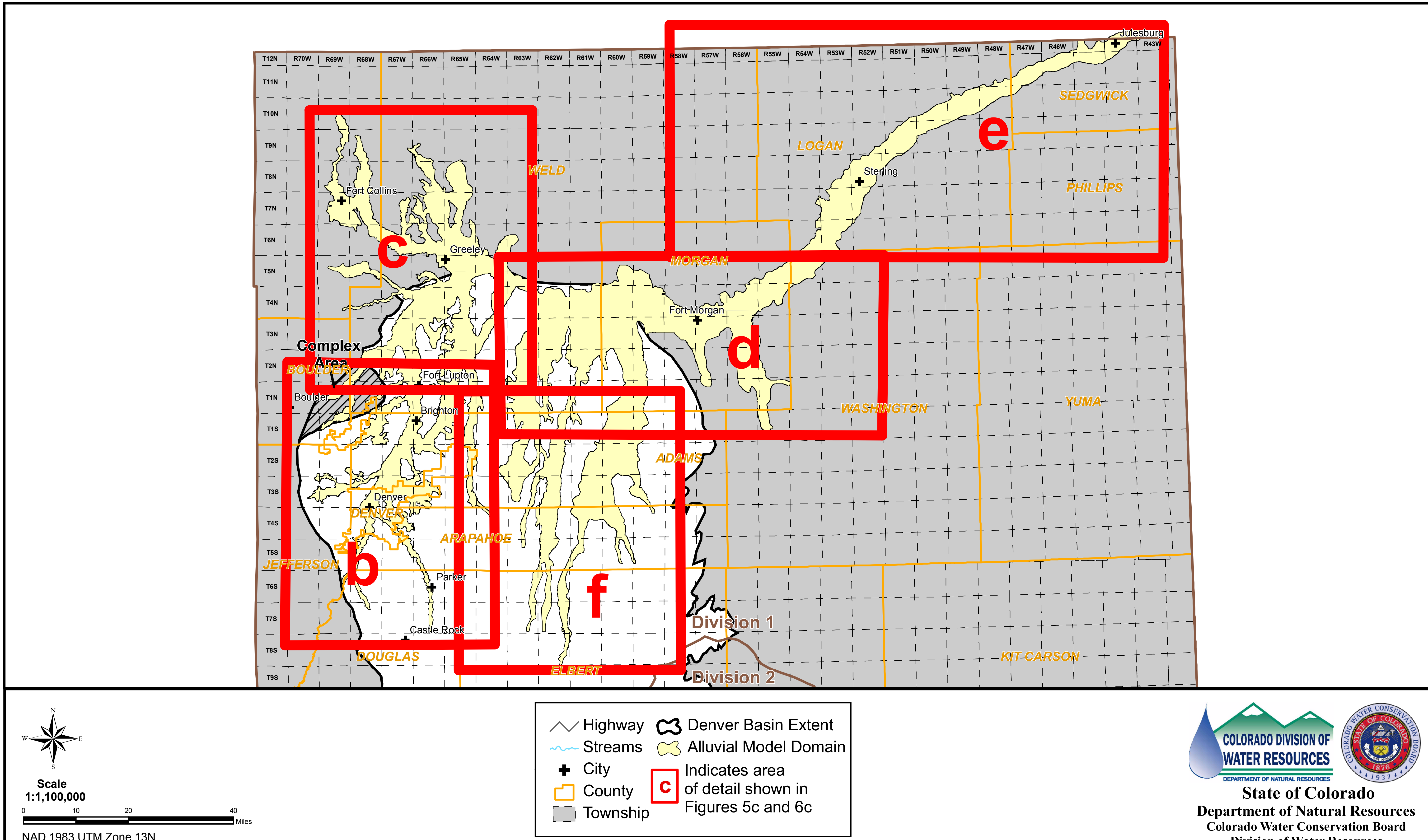

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Figure 5a: Hydraulic Conductivity (K) Distribution, SPDSS Alluvial Groundwater Model Extent

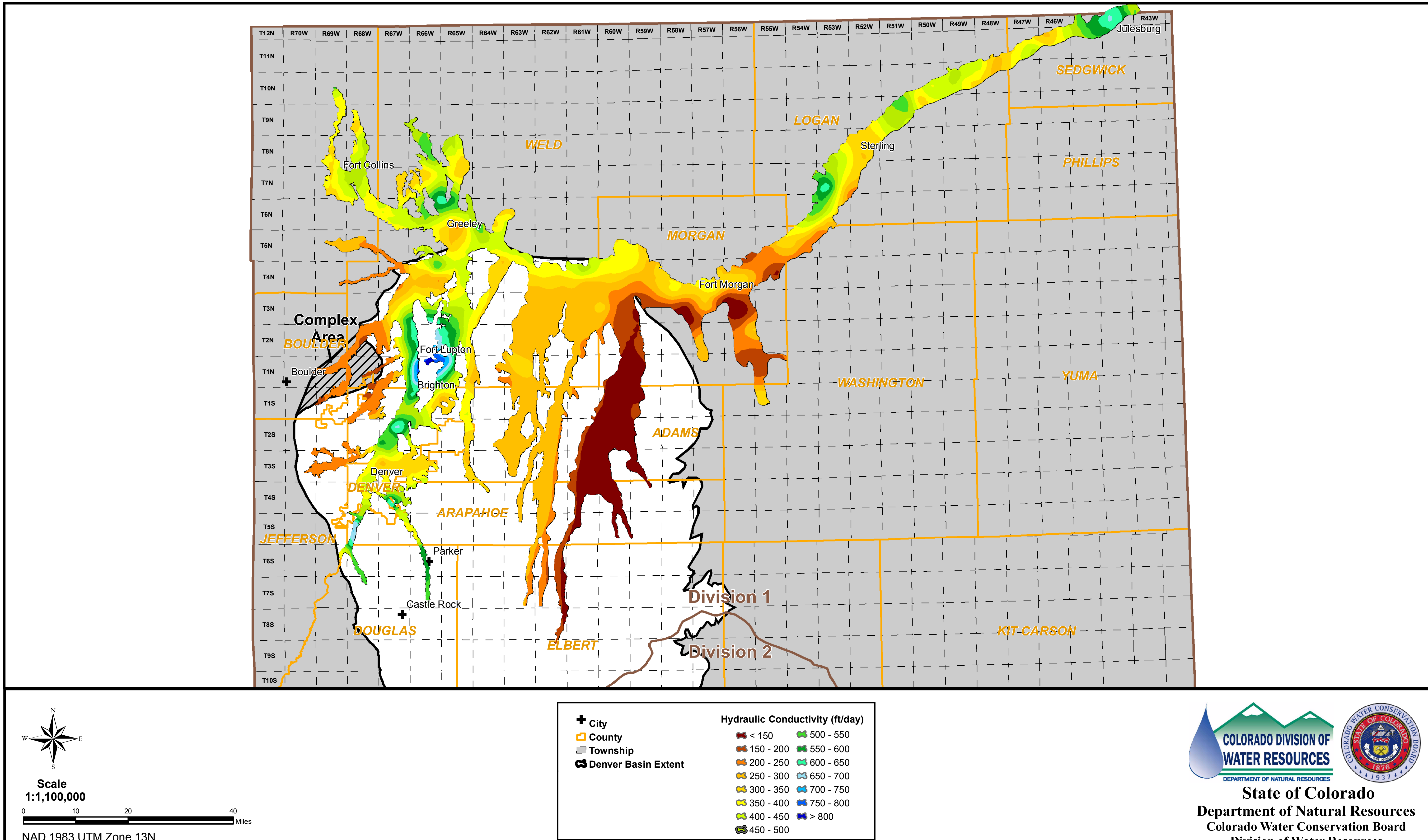

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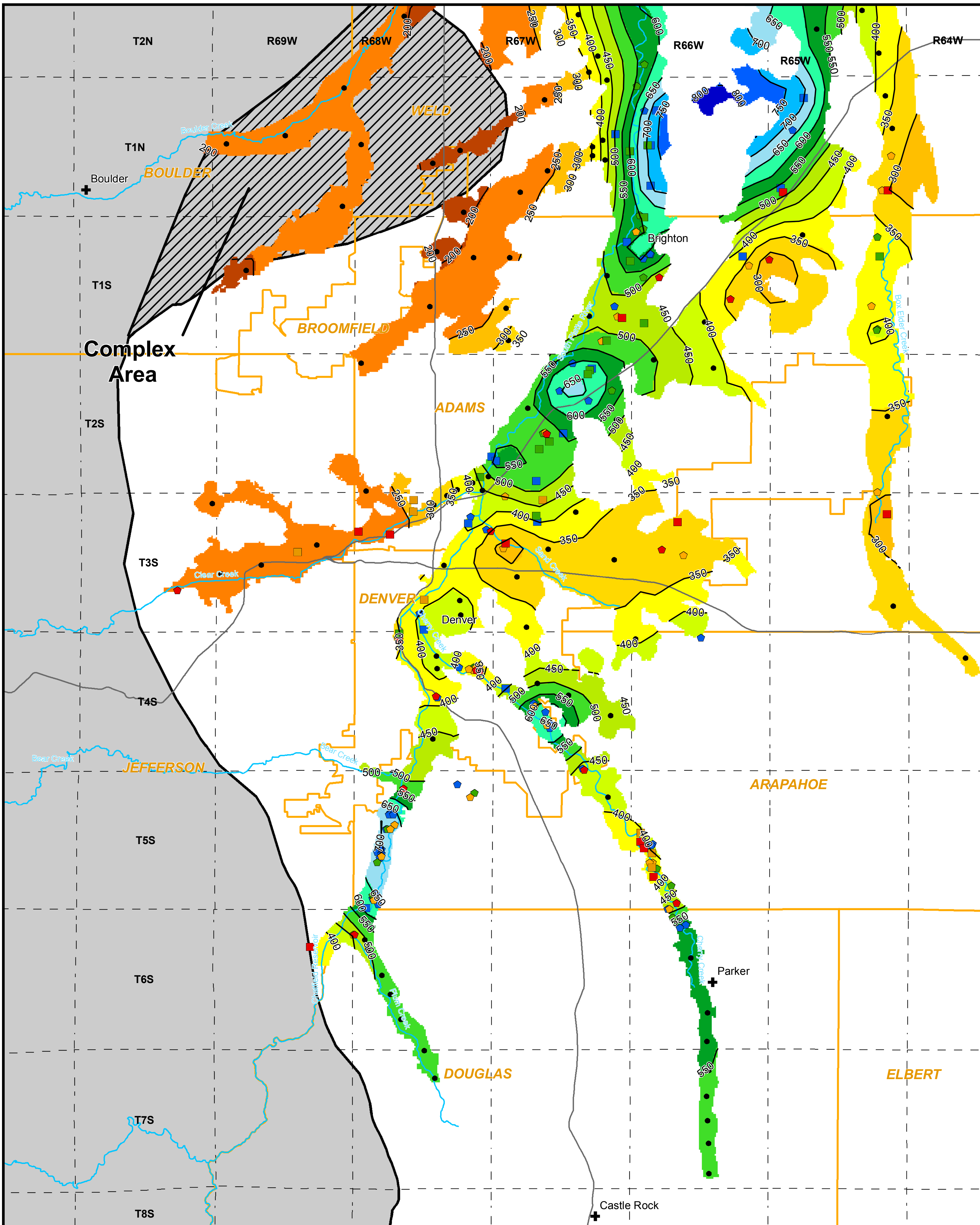
Figure 5b: Hydraulic Conductivity (K) Distribution, Denver to Ft. Lupton



Legend

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

Hydraulic Conductivity (ft/day)		Pumping Test K (ft/day)	Specific Capacity K (ft/day)
< 150	500 - 550	< 220	< 220
150 - 200	550 - 600	220 - 425	220 - 425
200 - 250	600 - 650	425 - 680	425 - 680
250 - 300	650 - 700	> 680	> 680
300 - 350	700 - 750		
350 - 400	750 - 800		
400 - 450	> 800		
450 - 500			

Scale
1:270,000

0 2.5 5 10 Miles

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

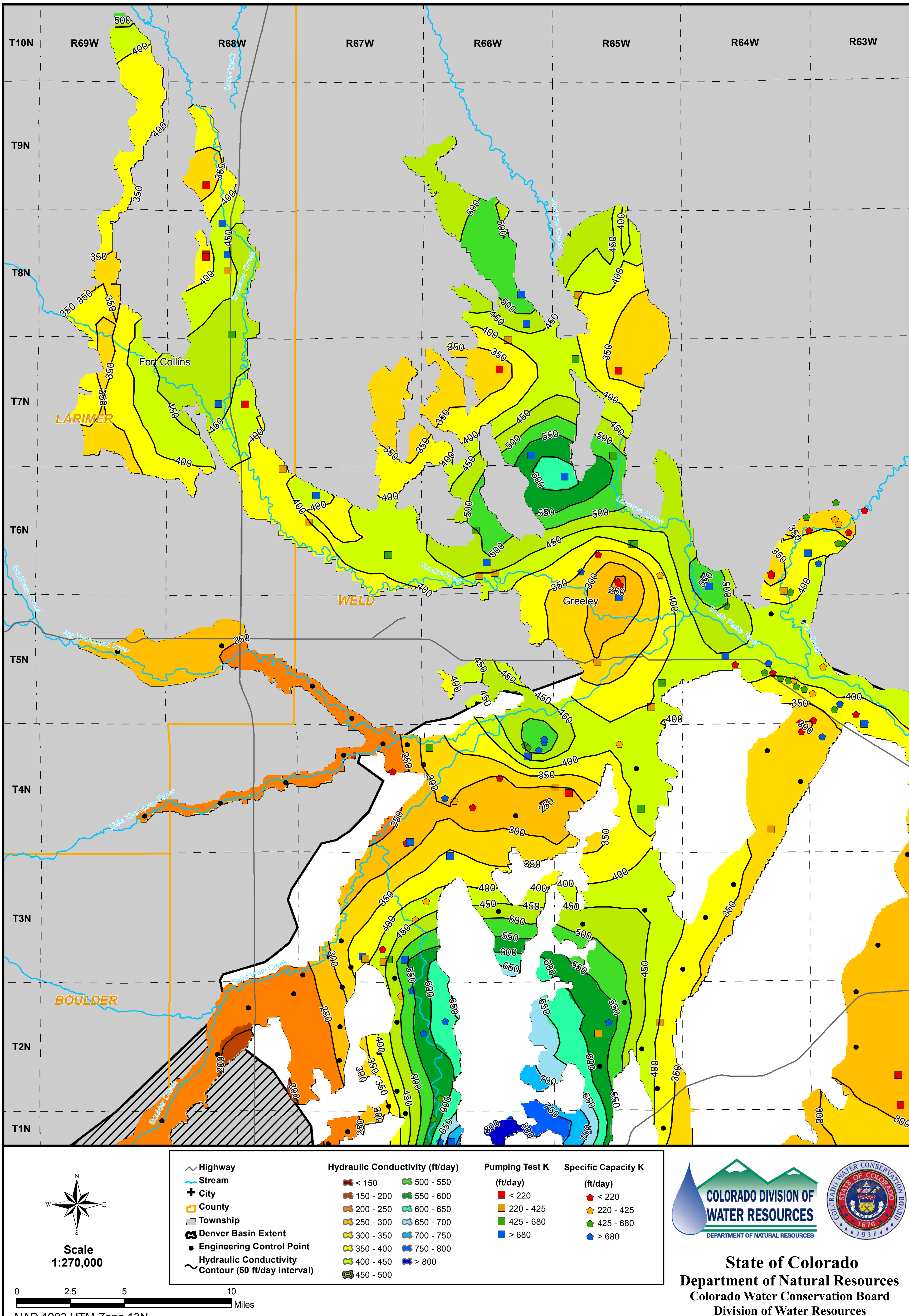

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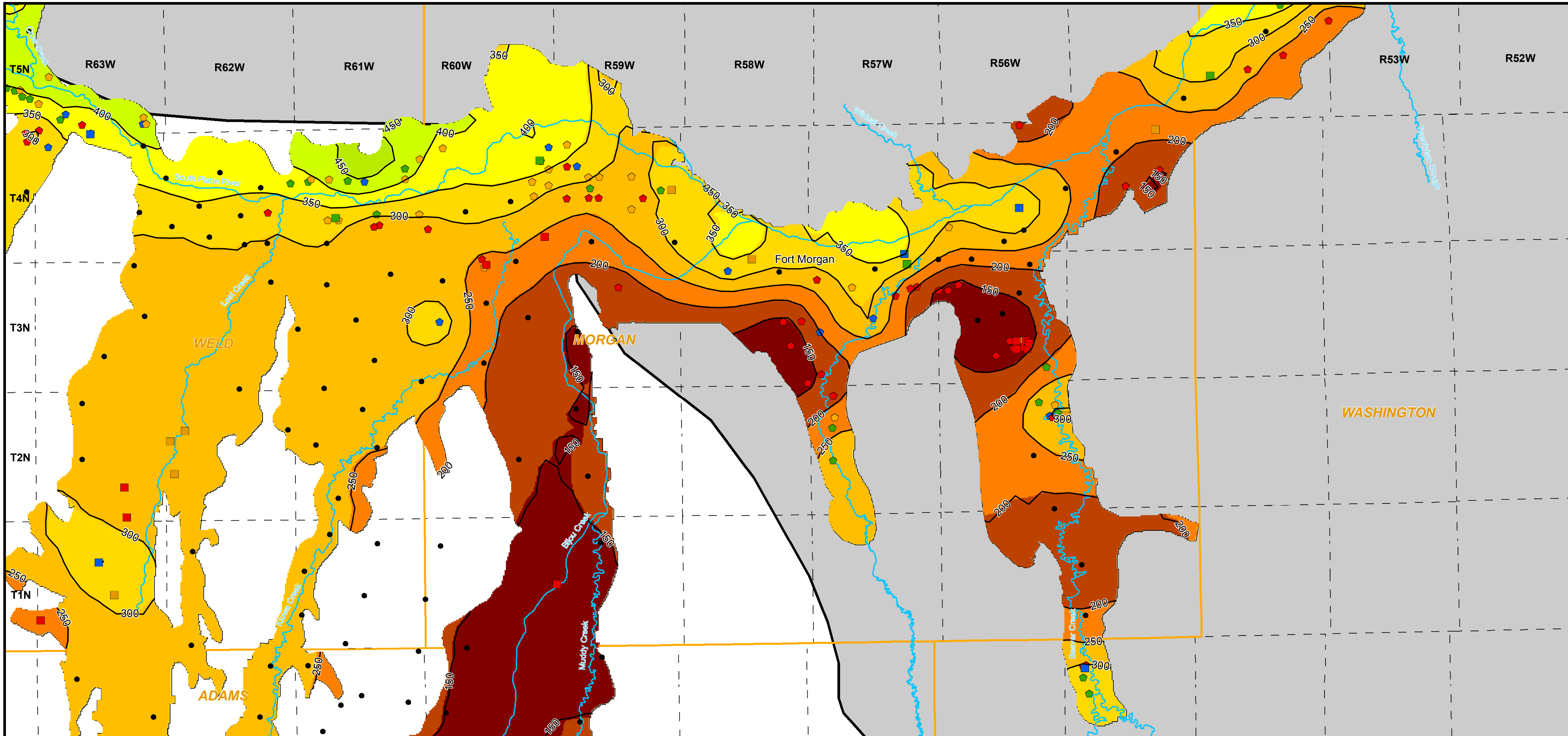
Figure 5d: Hydraulic Conductivity (K) Distribution, Greeley to Beaver Creek



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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STATE OF COLORADO
COLORADO WATER CONSERVATION BOARD
1876
1937

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

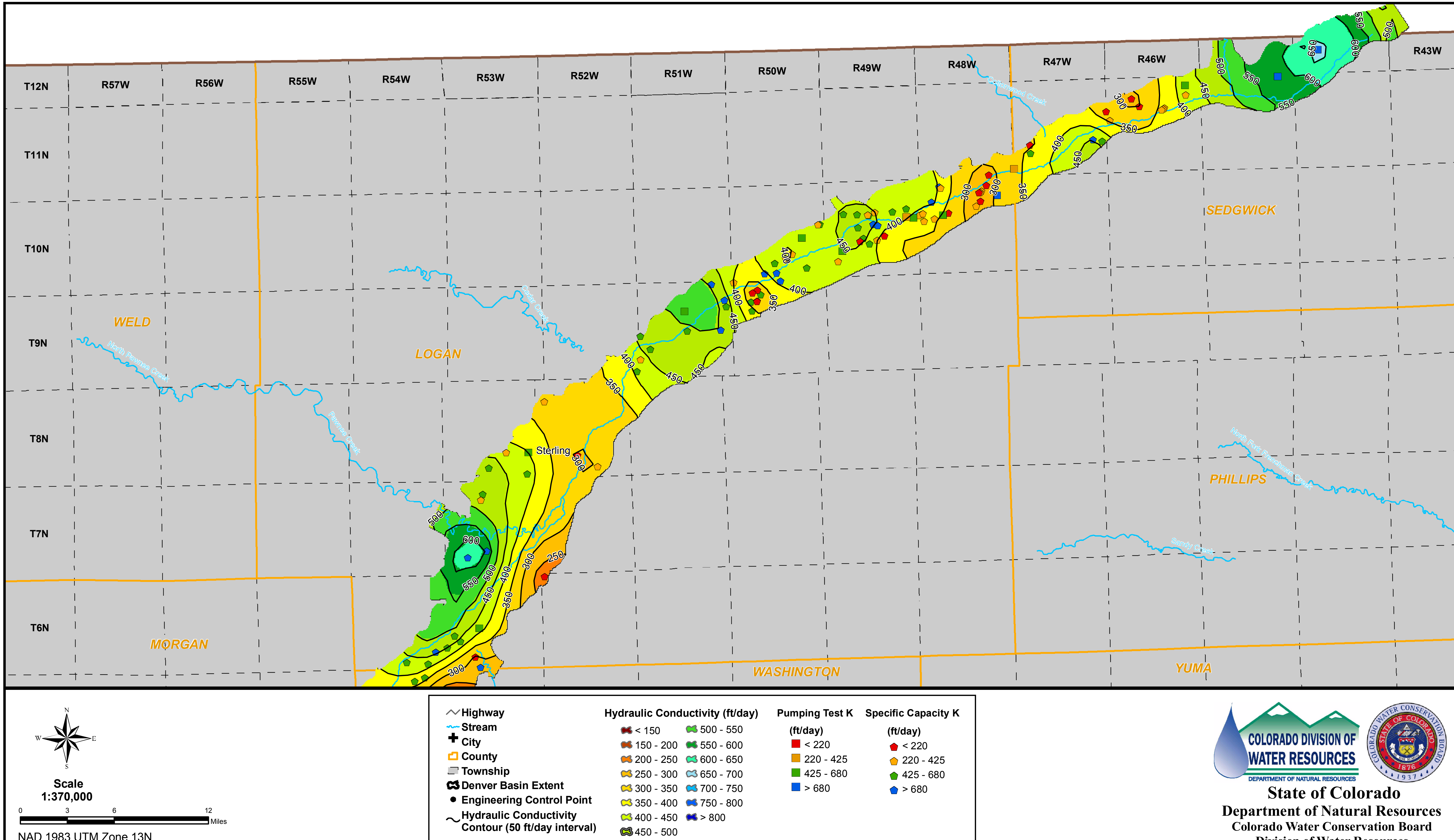

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Figure 5f: Hydraulic Conductivity (K) Distribution, Upper Kiowa-Bijou and Lost Creek Designated Basins and Boxelder Creek

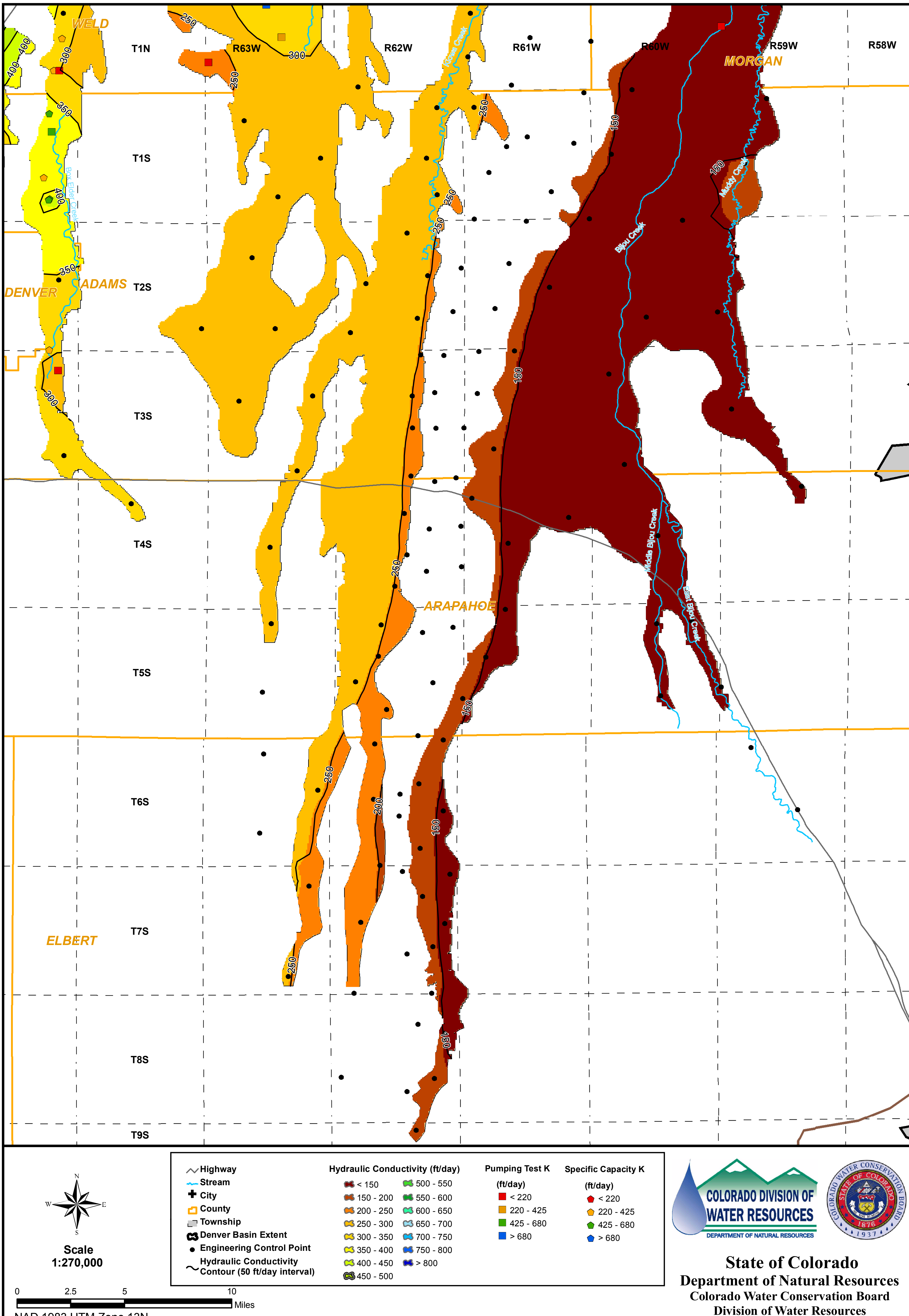

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Figure 6a: Transmissivity (T) Distribution, SPDSS Alluvial Groundwater Model Extent

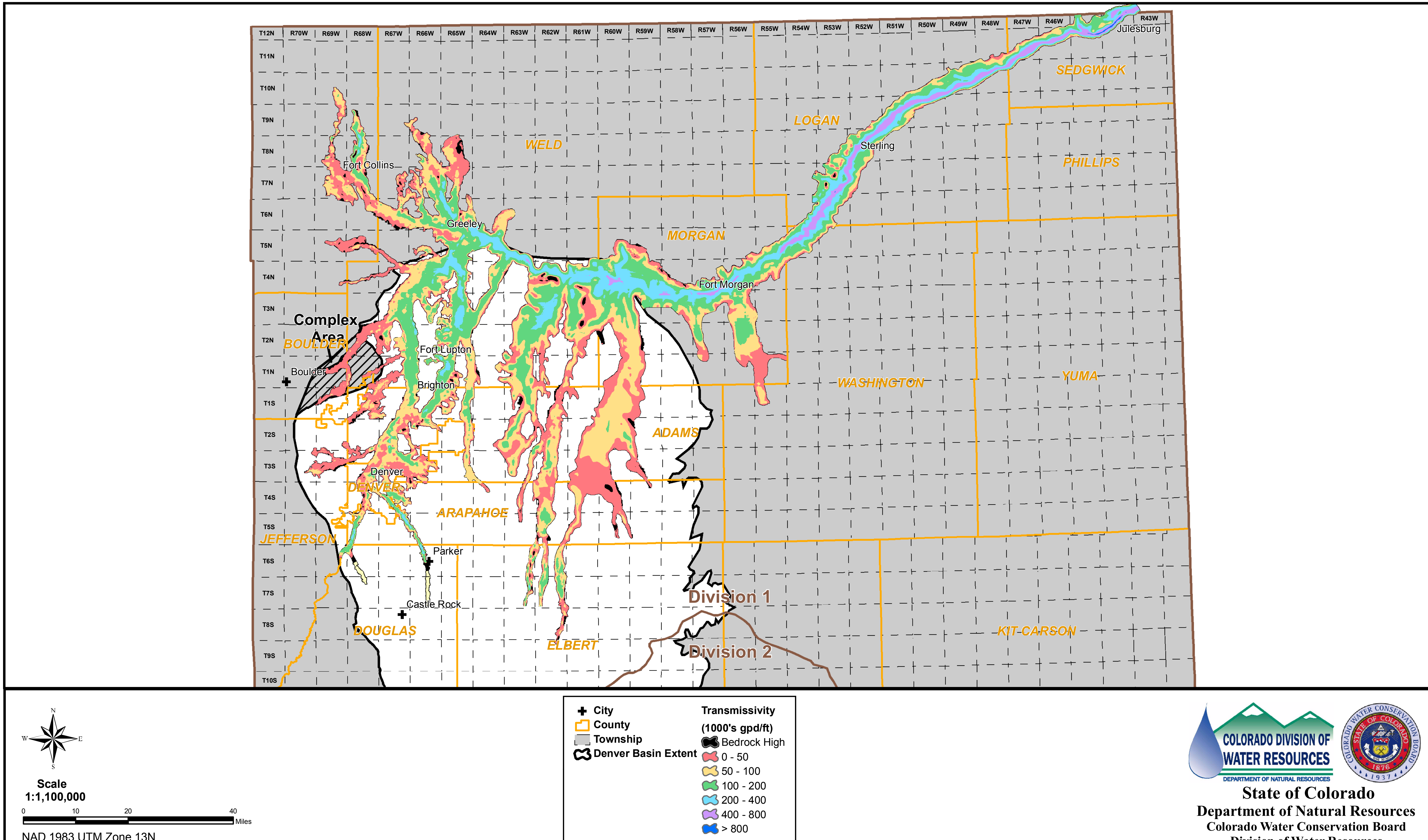

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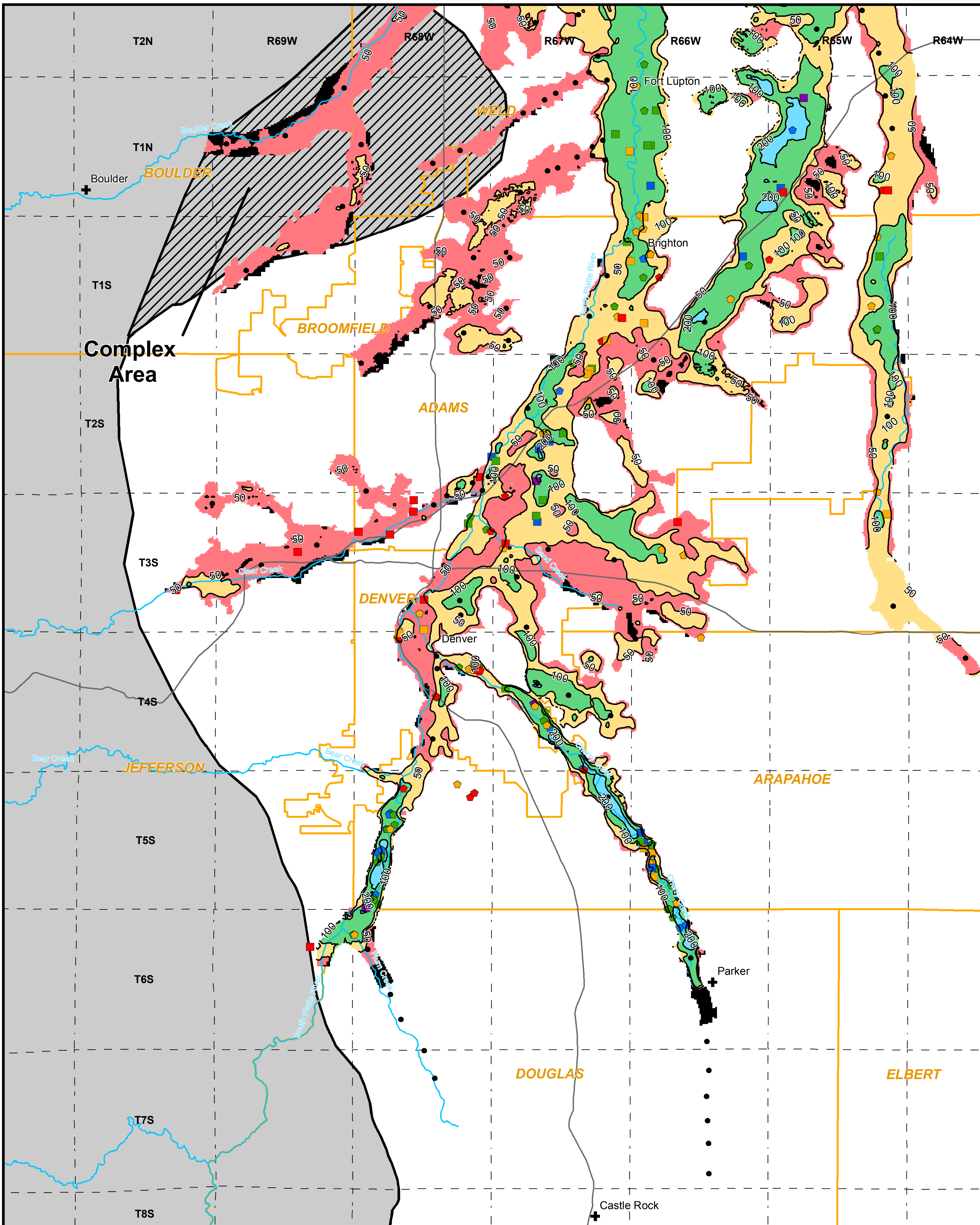
Figure 6b: Transmissivity (T) Distribution, Denver to Ft. Lupton



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		

Scale 1:270,000

0 2.5 5 10 Miles

NAD 1983 UTM Zone 13N

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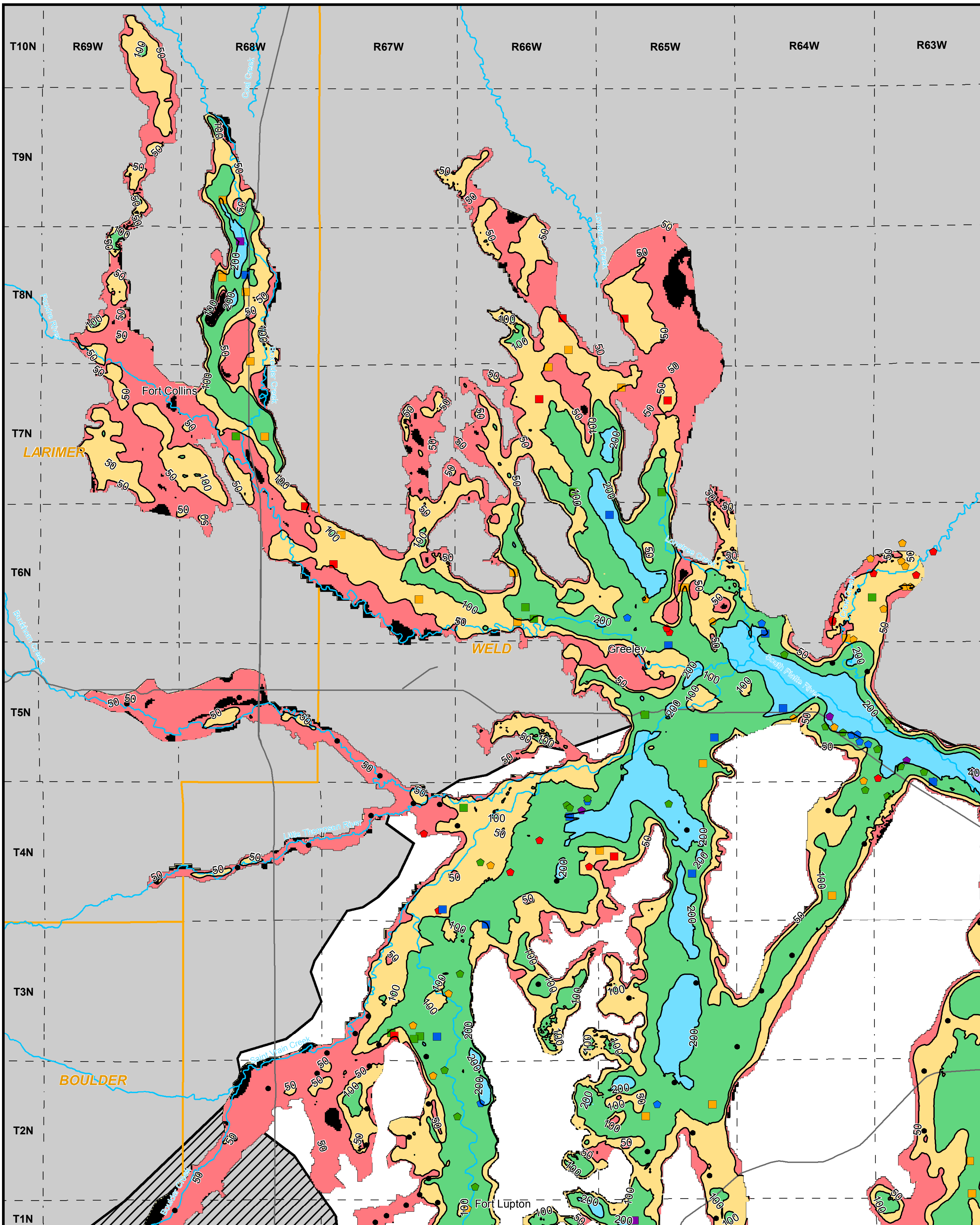
Figure 6c: Transmissivity (T) Distribution, Ft. Lupton to Greeley and Poudre River



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

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

Pumping Test T (1000's gpd/ft)
- < 50
- 50 - 100
- 100 - 200
- 200 - 400
- > 400

Specific Capacity T (1000's gpd/ft)
- < 50
- 50 - 100
- 100 - 200
- 200 - 400
- > 400

Scale 1:270,000

0 2.5 5 10 Miles

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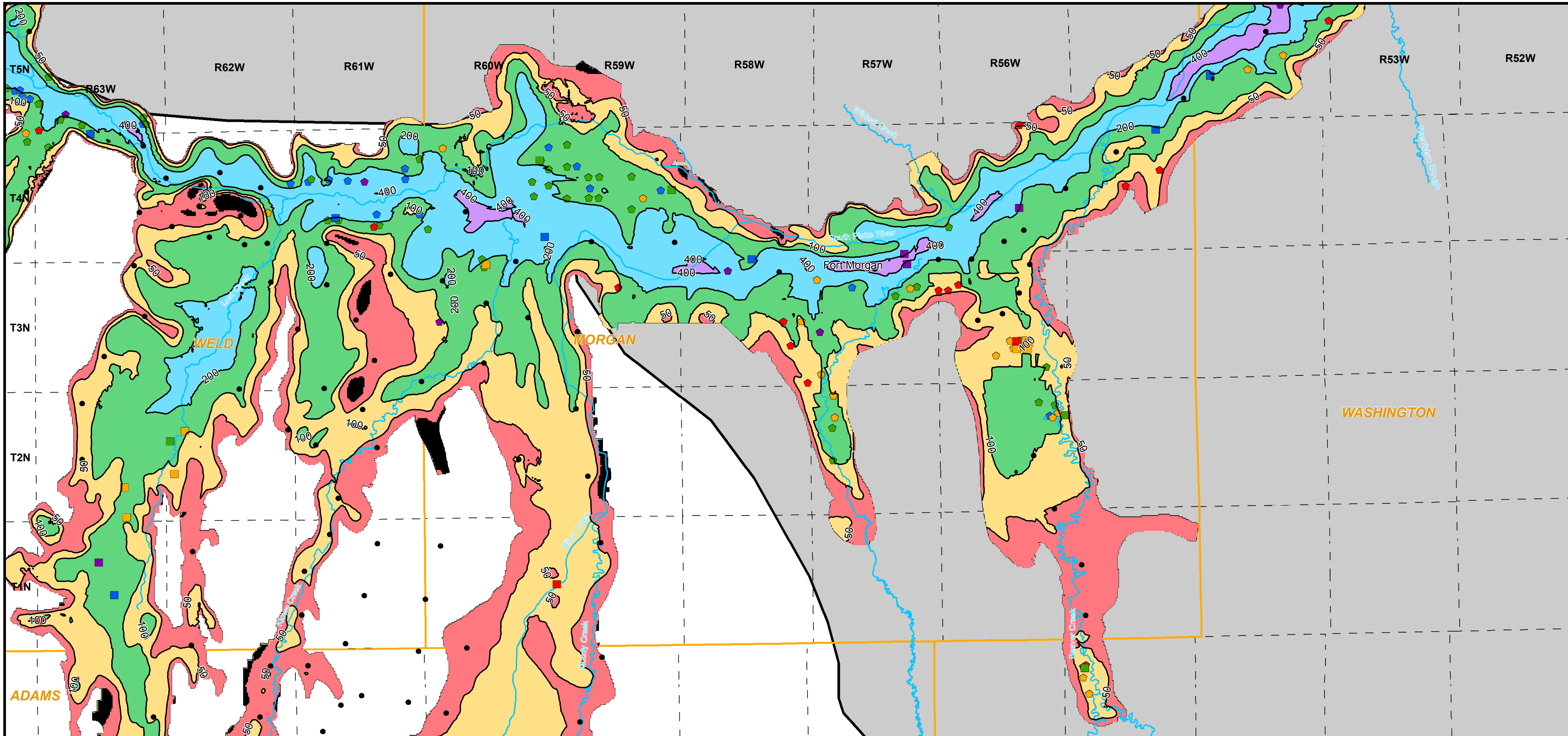
Figure 6d: Transmissivity (T) Distribution, Greeley to Beaver Creek



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)
Bedrock High
0 - 50
50 - 100
100 - 200
200 - 400
400 - 800
> 800

Pumping Test T (1000's gpd/ft)
< 50
50 - 100
100 - 200
200 - 400
> 400

Specific Capacity T (1000's gpd/ft)
< 50
50 - 100
100 - 200
200 - 400
> 400

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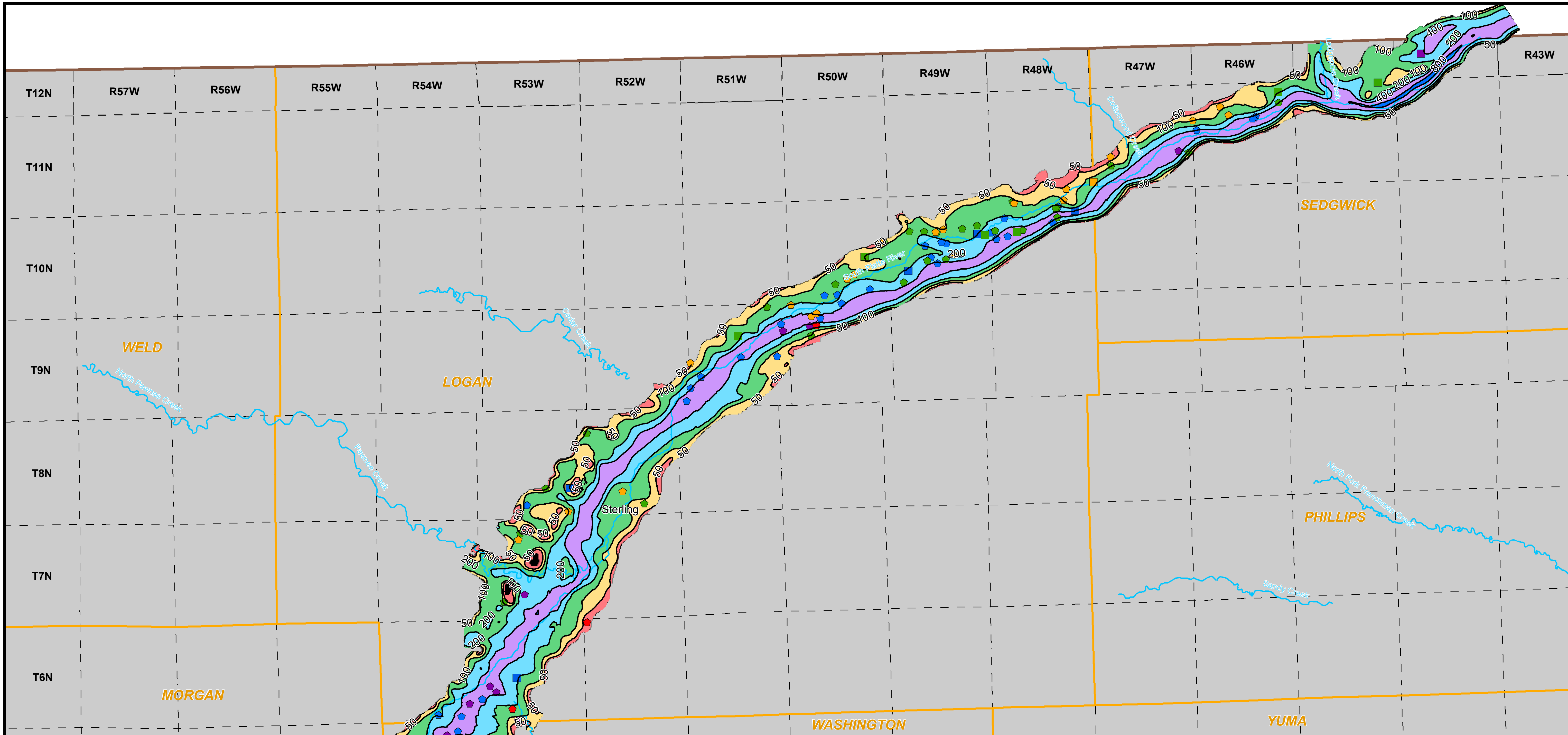
Figure 6e: Transmissivity (T) Distribution, Sterling to Julesburg



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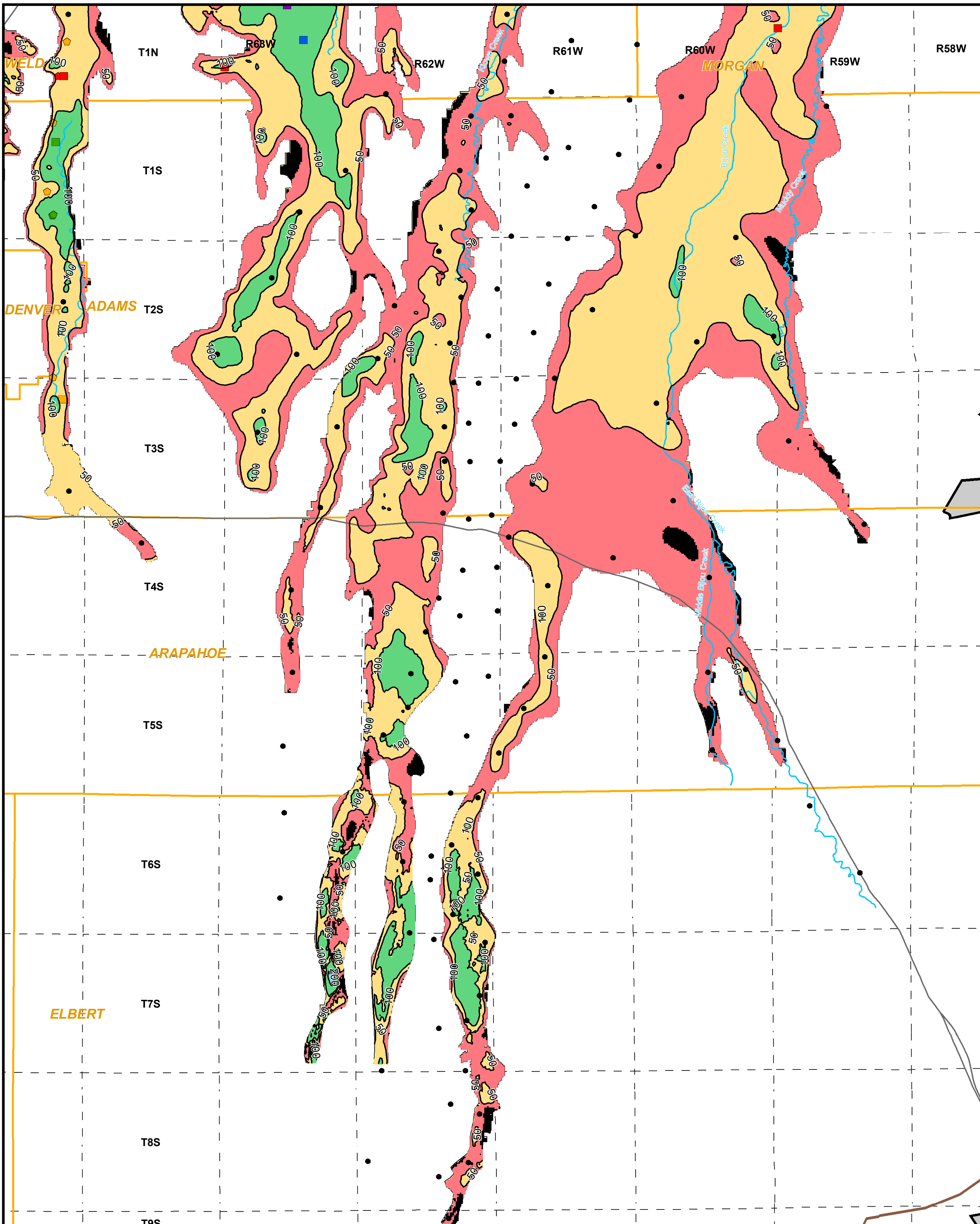
Figure 6f: Transmissivity (T) Distribution, Upper Kiowa-Bijou and Lost Creek Designated Basins and Boxelder Creek



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)
Bedrock High
0 - 50
50 - 100
100 - 200
200 - 400
400 - 800
> 800

Pumping Test T (1000's gpd/ft)
< 50
50 - 100
100 - 200
200 - 400
> 400

Specific Capacity T (1000's gpd/ft)
< 50
50 - 100
100 - 200
200 - 400
> 400

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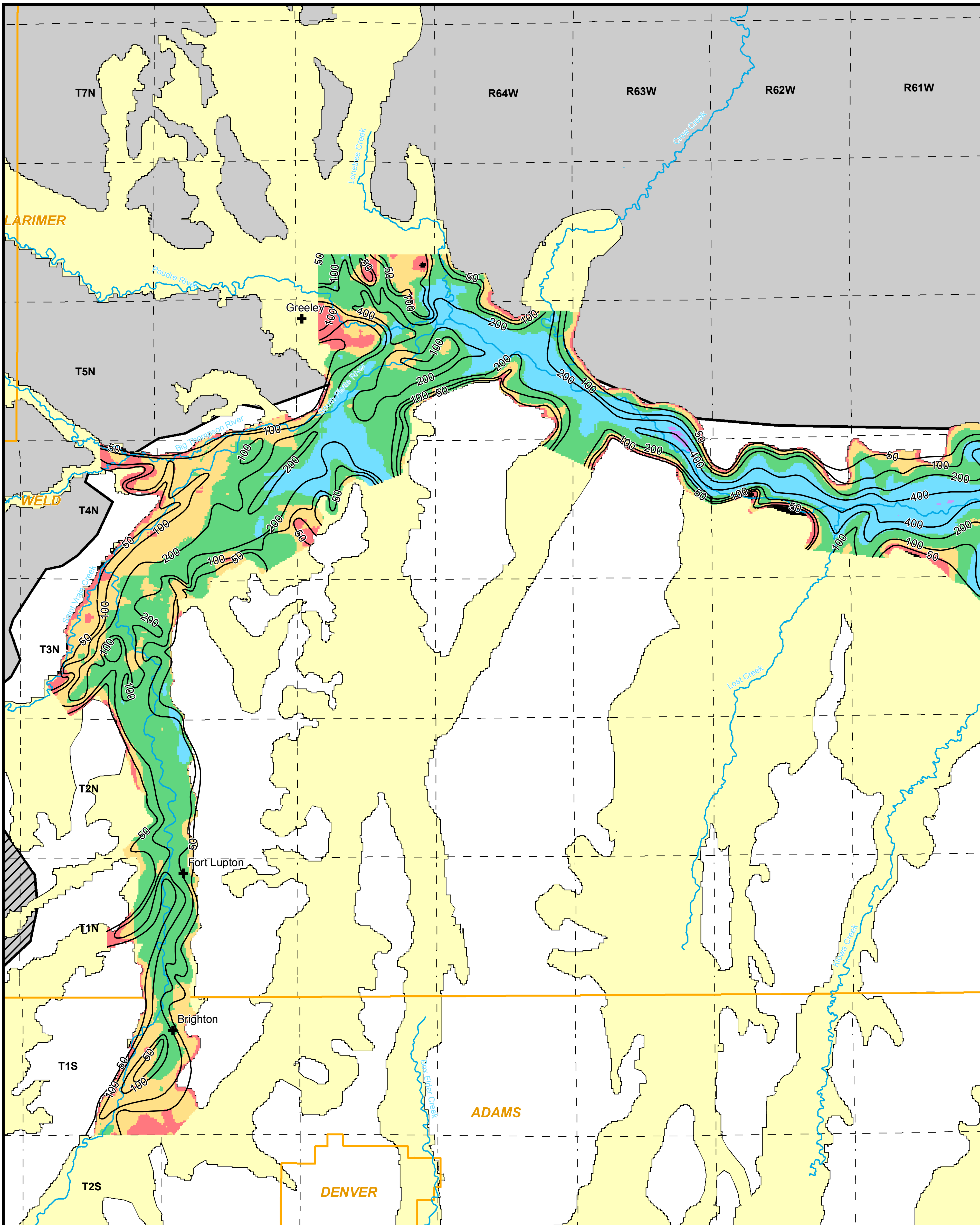
Figure 7a: Comparison of SPDSS and Hurr and Schneider Transmissivity, Brighton to Lost Creek



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

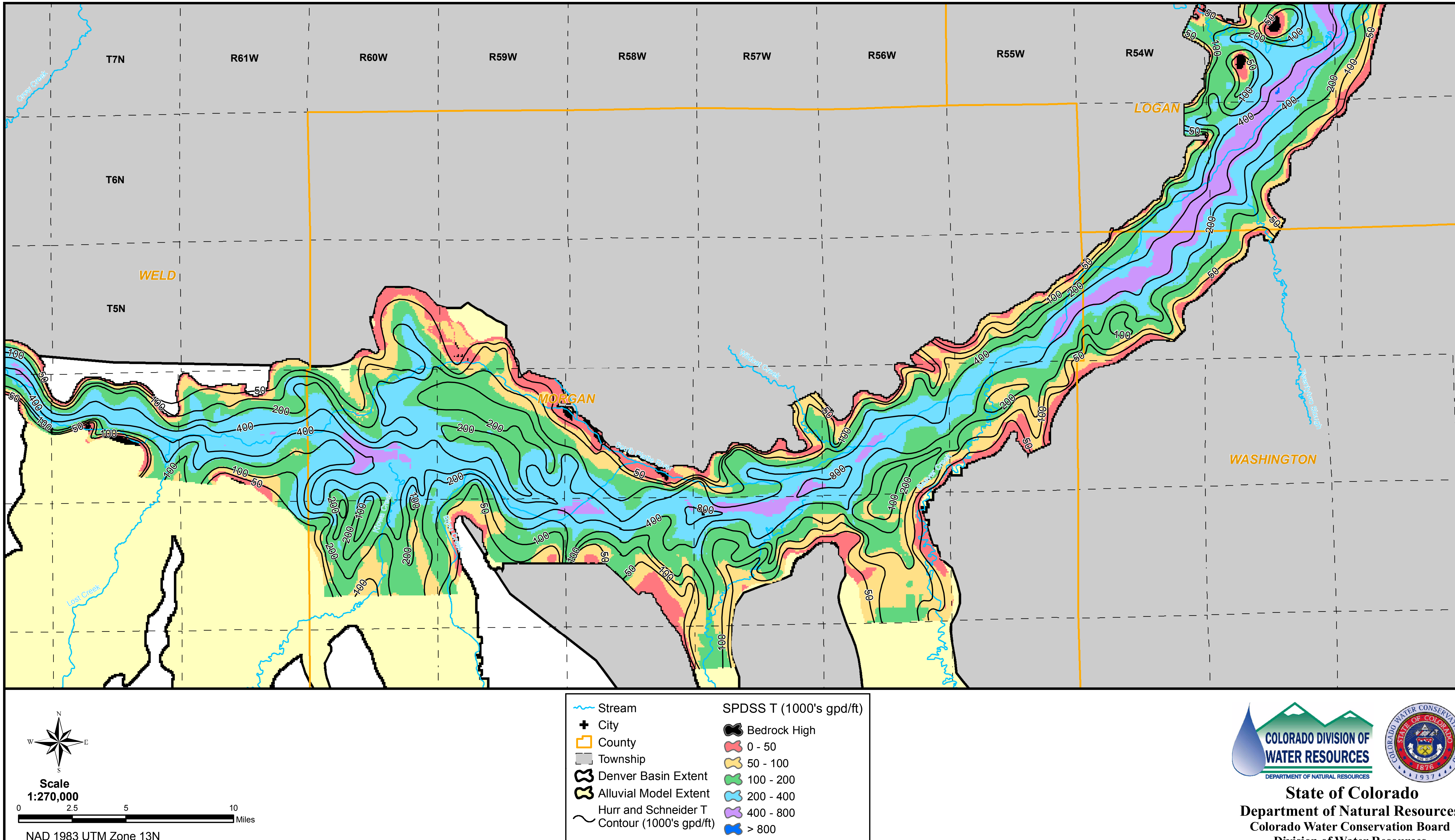

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Figure 7c: Comparison of SPDSS and Hurr and Schneider Transmissivity, Pawnee Creek to Julesburg

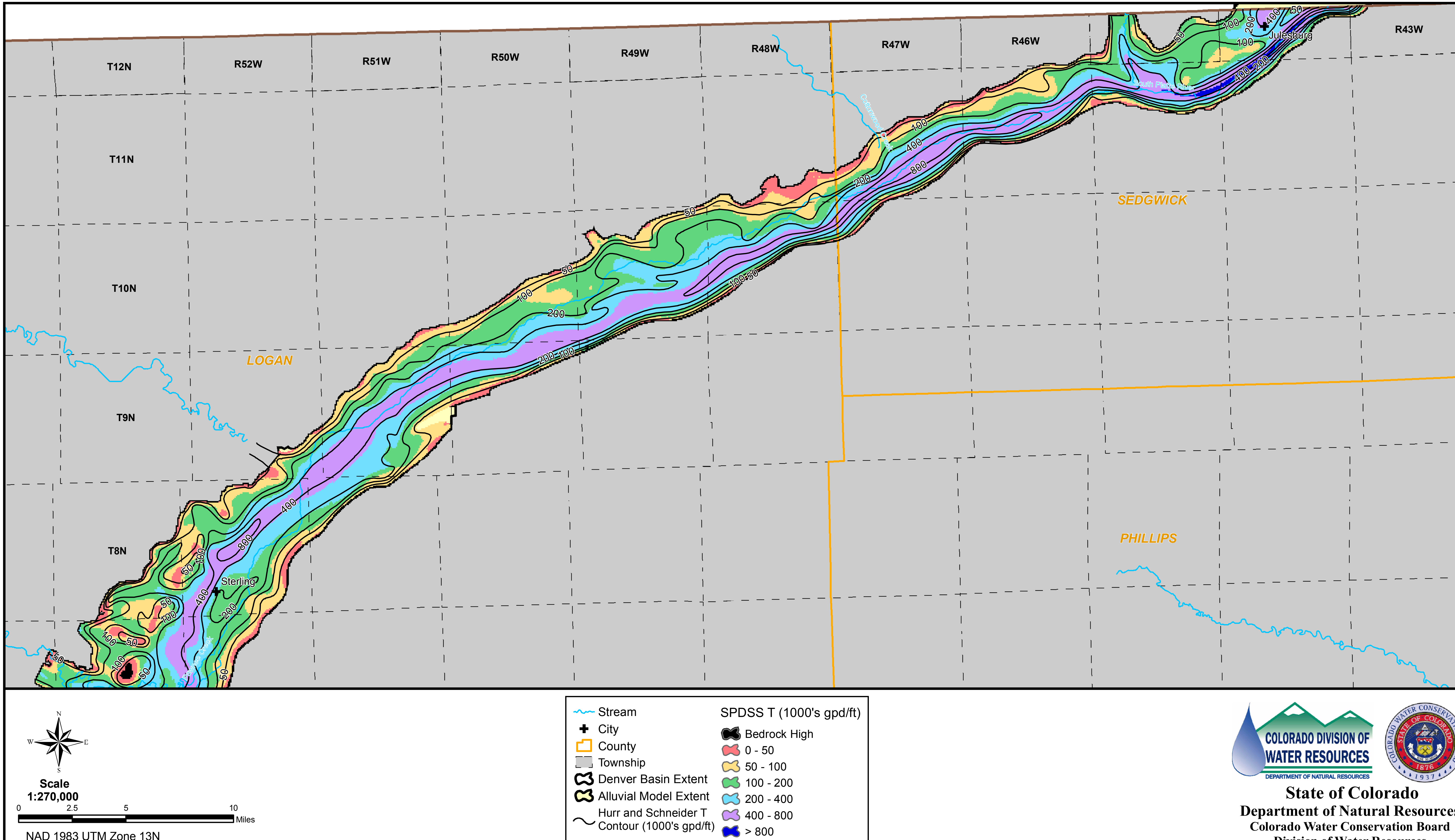

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Figure 8a: Storage Coeffecient (S) and Specific Yield (Sy) Distribution, Southern Area

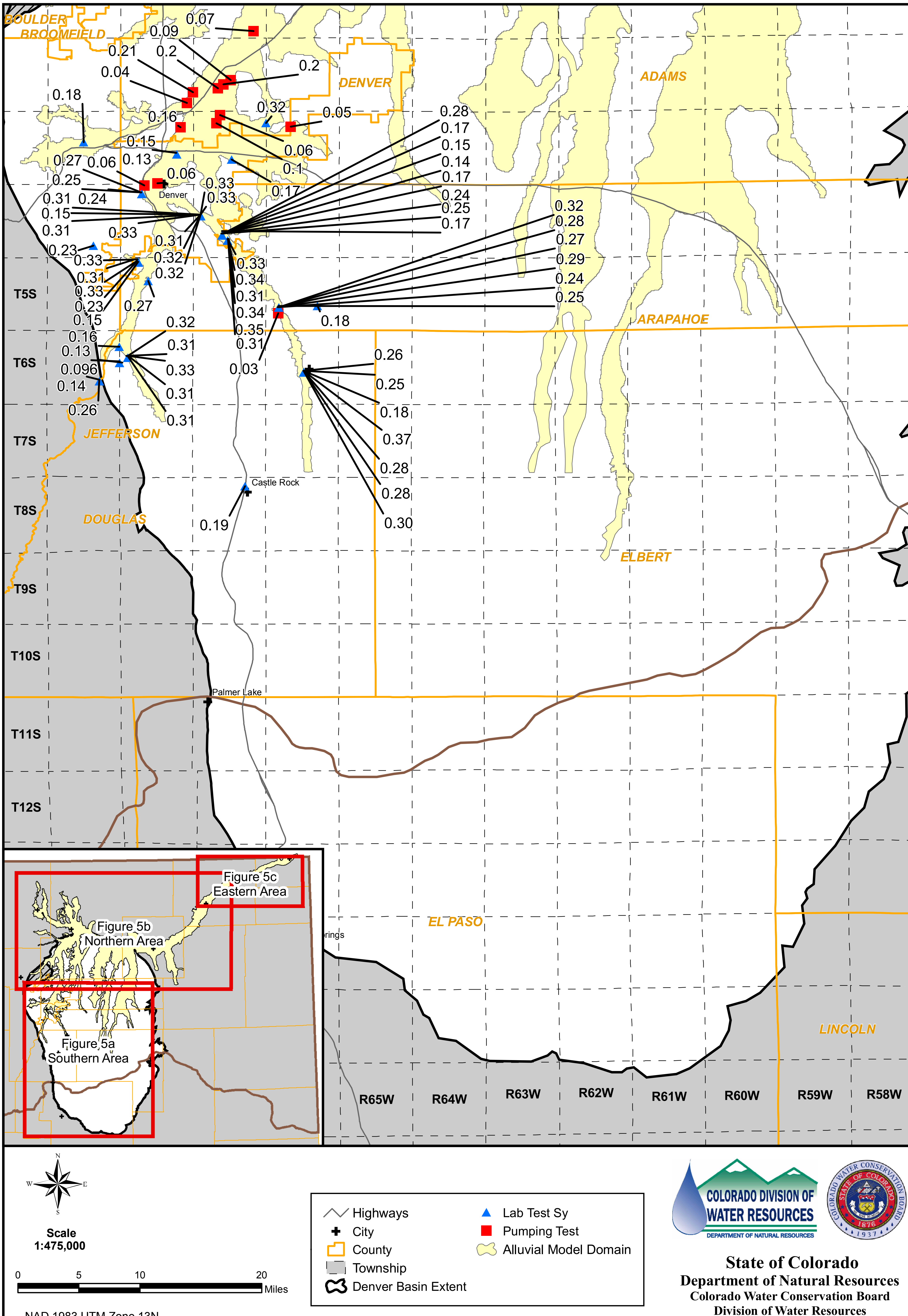

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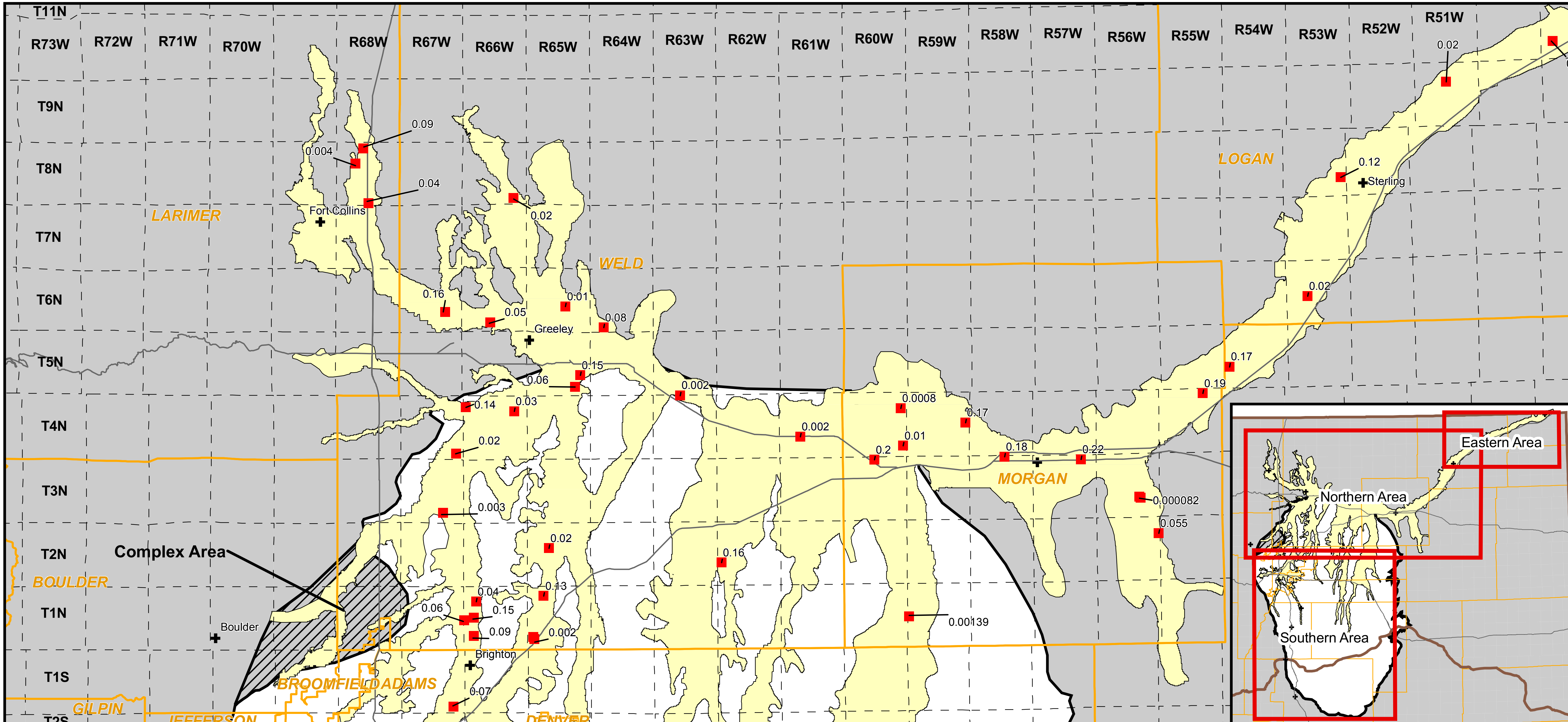
Figure 8b: Storage Coeffecient (S) and Specific Yield (Sy) Distribution, Northern Area



Scale 1:600,000

0 5 10 20 Miles

NAD 1983 UTM Zone 13N

City	**Storage Coeffecient and Specific Yield**
Highway	Pumping Test
County	Lab
Township	Alluvial Model Domain
Denver Basin Extent	

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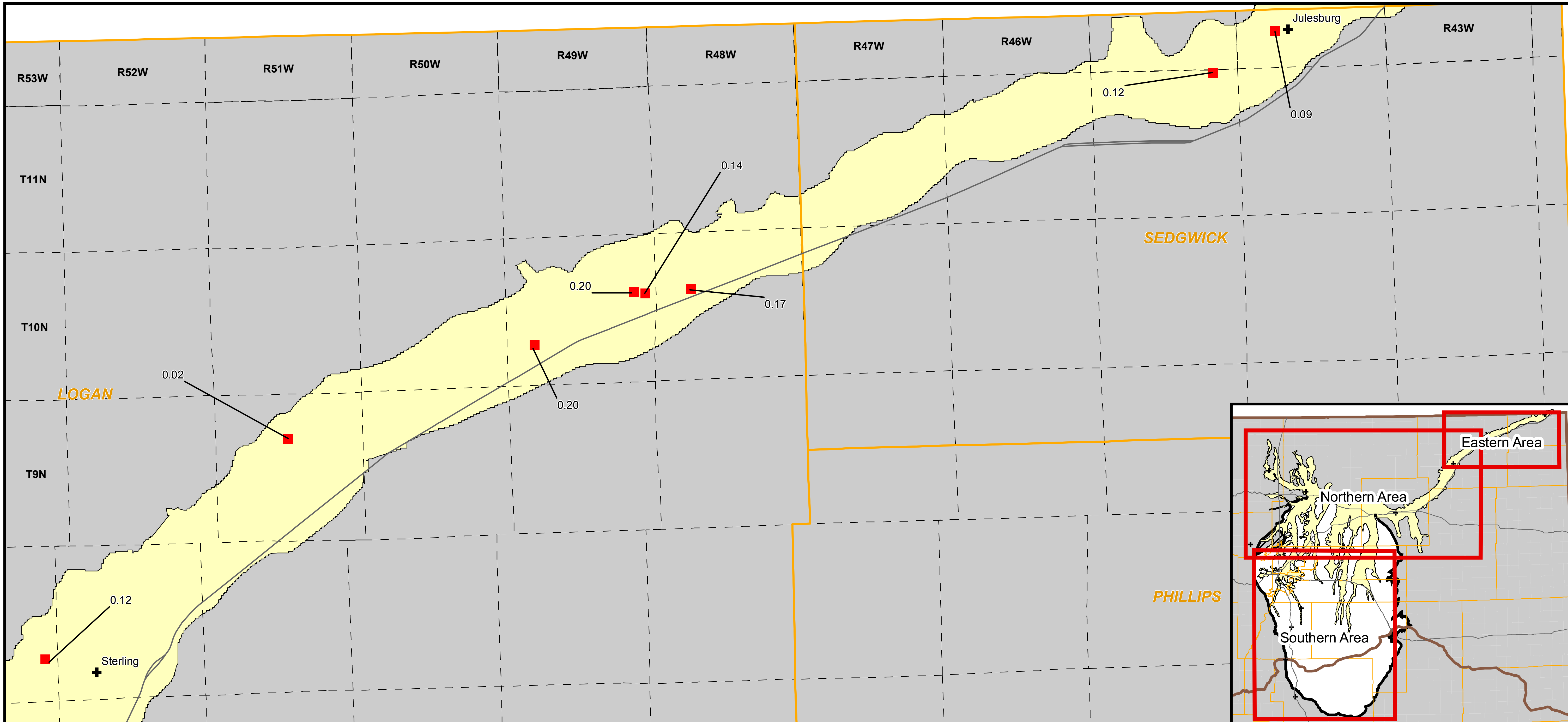
Figure 8c: Storage Coeffecient (S) and Specific Yield (Sy) Distribution, Eastern Area



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

Appendix B

Development of the Hydraulic Conductivity Data Set Used for Contouring

Appendix B

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

Appendix B

Development of the Hydraulic Conductivity Data Set Used for Contouring

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

Appendix B

Development of the Hydraulic Conductivity Data Set Used for Contouring

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

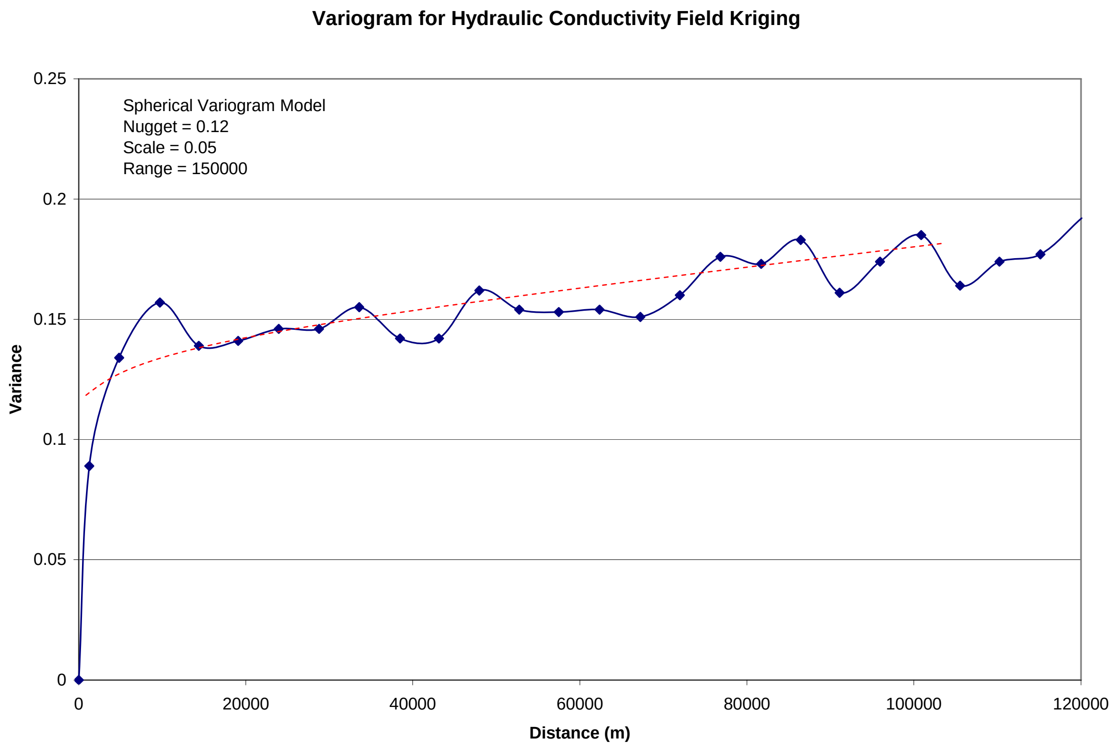

Table B-3 – Kriging Algorithm Parameters

	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

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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

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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

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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

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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

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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

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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

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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

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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.

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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