ELBERT COUNTY, CO

Rural Water Supply Study

June 2018

FORSGREN Associates Inc.

Submitted by:

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FORSGREN Associates Inc.

Project No. 04-16-0199

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EXECUTIVE SUMMARY

GENERAL

Elbert County is a sprawling rural county with a long history of farming and cattle ranching. The county is facing growth pressure from the Denver metropolitan area while trying to preserve the rural character that is so important to its residents. Elbert County's population is largely concentrated in the areas of Elizabeth and Kiowa in the west, and to the northwest, near Parker and Aurora; these are the areas expected to grow the most. In fact, the county is expected to grow from a 2015 population of approximately 24,700 to a population of over 68,000 by 2050.

Most of the county's residential demands are met by nonrenewable Denver Basin groundwater, concentrated in the western portion of the county. The majority of residents rely on domestic wells into the shallower bedrock aquifers (Upper and Lower Dawson), while those served by municipalities or special districts generally rely on deeper aquifers (Denver and Arapahoe). Elbert County's very limited surface water, and alluvial supplies such as the Kiowa-Bijou and Upper Big Sandy Designated Basins, are primarily used for agriculture.

ANALYSIS

The total recoverable volume of Denver Basin groundwater in Elbert County is estimated at 54 MAF, and this aquifer system can be expected to meet the county's growing demands well beyond 2050. Cumulative demands estimated now through 2050 would be expected to reduce the total recoverable volume by only 0.75 percent to 53.6 MAF, and the annual demand in 2050 would take only 0.03 percent of that remaining volume. Aquifer declines can be expected over time, however, increasing pumping costs and requiring the addition of more wells to maintain production. It could ultimately be more economical to serve the heavy demand areas of the county with imported renewable water.

Approximately half of Elbert County's total water demand of 17,900 AF in 2017 was met by Denver Basin groundwater. As total annual demand in the county is projected to approach 23,000 AF by 2050, approximately 15,700 AF of that future demand must be met by Denver Basin groundwater (or alternative supplies); nearly 70 percent of the total. Meeting that share of the projected 2050 demand with only Denver Basin groundwater would represent an 80 percent increase over its 2017 use.

FUTURE SUPPLY ALTERNATIVES

While this Study presents a countywide analysis, there is greater focus on areas where the most growth is anticipated. The Elizabeth-Kiowa and Northwest planning areas are projected to have a total population of over 59,000 in 2050, comprising 87 percent of the county's population. The projected water demand for those areas will then total nearly 9,000 AF. This demand could be met through water reuse, agricultural transfers, and one of three water supply alternatives as described:

Water Reuse – 810 AF (9 percent of planned demand)

1. New reuse treatment facility starting operation in the Elizabeth-Kiowa area in 2027

2. New reuse treatment facility starting operation in the Northwest area in 2032

Agricultural Transfers – 300 AF (3 percent of planned demand)
Water supplies to be converted from agricultural to municipal use as development occurs

Alternatives for Main Supply - 7,860 AF (88 percent of planned demand)

1. No renewable water imported from outside the county; demand met fully by Denver Basin groundwater

2. 10 Percent renewable water imported from outside the county starting in 2035, reducing the Denver Basin share to 90 percent

3. 25 Percent renewable water imported from outside the county starting in 2035, reducing the Denver Basin share to 75 percent

A present-worth cost analysis, including capital, operation, and maintenance costs to be incurred through 2050 for a combination of reuse, agricultural transfers, and each of the three supply alternatives is shown in Table E-1.

Table E-1

Alternative	Groundwater Pumping	Renewable Water & Reuse	Total Cost
Scenario 1 (No Import)	$429M	$49M	$478M
Scenario 2 (10% Import)	$389M	$85M	$474M
Scenario 3 (25% Import)	$324M	$134M	$458M

CONCLUSIONS

In total, the Denver Basin supply is plentiful and can meet Elbert County demands well into the future if managed carefully. There are many variables that can affect well production, however. With heavy dependence on Denver Basin groundwater throughout the region, aquifer pressures are expected to continue declining. That results in less driving force pushing water into the wells, and production at each well will likely decline over time. Also, the aquifers are not homogeneous, and more significant localized declines, or even lost production could occur in certain areas, and at the fringes of the aquifers.

Considering the total present-worth costs of water production through 2050 for both water providers and domestic well owners, meeting 25 percent of the main supply needs for the Elizabeth-Kiowa and Northwest planning areas with renewable water imported from outside the county by 2035 (Scenario 3) could save as much as $20M. This is less than a five percent savings compared to Scenarios 1 (no import) and 2 (10 percent import), but could offer a more substantial savings beyond 2050. Having such a system in place would also hedge against the possibility of an increasing rate of decline in the Denver Basin aquifers over the long term.

RECOMMENDATIONS

As Elbert County continues to grow, water supply planning and management will become increasingly important. Forsgren recommends the following actions:

1. Although the total volume of Denver Basin groundwater can sustain Elbert County well beyond 2050, the aquifers are expected to continue to decline. Some areas may experience more rapid declines than others, depending on the aquifer. The USGS recently completed a three-year well monitoring program that provides data on pressure levels in the aquifers from over 30 Denver Basin wells. The County is extending the monitoring program, but should make this a permanent function and continue to monitor these aquifers indefinitely. More wells could be added to the program in particular areas of interest, such as areas where higher drawdowns are occurring, or along the northern and western county lines. In addition, the County should update this Rural Water Supply Study every five to ten years to reassess its position with respect to water supplies as conditions change.

2. Denver Basin groundwater should be preserved as much as practicable through water conservation and efficiency, extending the economically useful life of the aquifers. Front Range water providers have found that tiered water rates in which higher usages are charged at escalating unit costs, are the most effective means of promoting conservation. The County should incentivize central water systems to develop such rate structures.

3. Denver Basin water can be preserved further if a portion of future demands is met by water reuse. Reuse requires sanitary sewer systems to collect wastewater for centralized treatment. The water can then either be distributed to irrigation sites (possibly even individual residences, depending on the level of treatment) or returned to blend with a potable water supply (normally, after first passing through an environmental buffer such as a lake, river, or aquifer). This also points to the need for a service provider to collect wastewater for treatment and reuse.

4. Centralized water service, and possibly sewer service followed by reuse, are only economically practicable for denser developments due to the costs of constructing and maintaining those piping networks. The County should consider incentivizing denser developments that use centralized water and sewer systems.

5. The majority of domestic water wells are completed in the Upper and Lower Dawson formations, although the deeper Denver and Arapahoe aquifers generally offer higher production. It would be beneficial to incentivize central water systems for new developments that use the Denver and Arapahoe aquifers, rather than the Dawson, thus leaving the shallower aquifers for the more dispersed domestic well users.

6. The County's 300-year rule for new development using Denver Basin groundwater promotes dispersed development on 5- and 10-acre ranchettes vs. subdivisions served by a

water distribution system. It will be cost-prohibitive to extend water mains to dispersed development, so those acreages will likely need to continue on Denver Basin groundwater. Denser development served by water mains from a central well system will be easier to convert to renewable water if needed. Such development also allows for cost-effective wastewater collection, allowing reuse to offset a portion of future water supply needs. The County should consider allowing variances to the 300-year rule as an incentive for developers that commit to "best practices" which may include: (1) producing water only from the deeper aquifers for centralized distribution; (2) promoting conservation and efficiency through a tiered rate structure; (3) collecting wastewater for treatment and reuse to offset a portion of demand; and (4) adopting water efficient landscaping standards.

7. The cost analysis shows the economy of meeting a portion of future demand with imported renewable supplies to offset 25 percent of projected Denver Basin use in the key planning areas. However, financing, constructing, and then operating a water import system will require many years of planning and collaboration by Elbert County water providers, possibly with facilitation by the County. It will also require working with water providers and regional water partnerships outside of Elbert County. The County and/or its water providers should start engaging in regional water planning as soon as practicable. (The WISE project took more than 15 years to reach the point of water deliveries in Fall 2017.)

8. The County should evaluate storage options further; surface storage as well as recharge for storage in bedrock and alluvial aquifers. Storage will become more important as reuse and renewable water options are implemented.

9. The County could also make provisions for future renewable water delivery by identifying and securing transmission pipeline corridors and treatment plant sites. This could be part of the County's broader framework of water, wastewater, and reuse systems in the planned growth areas to guide future development. The County should develop a "water and wastewater master plan" to serve as a reference during the land-use planning process so that the County can fit each development into a coordinated system from a countywide perspective.

10. Localized zones of low well productivity, or along fringes of the aquifers may not be conducive to dense development, or it may be necessary to have water piped from satellite well fields located in more productive areas. Mapping of these low production zones by aquifer should be considered for referral in the land-use planning process.

CHAPTER 1
INTRODUCTION

1.1 PROJECT OVERVIEW

Elbert County is a rural, sprawling county with a long history of farming and cattle ranching. The county is feeling growth pressure from the expanding Denver metropolitan area while trying to preserve the rural character that is so important to its residents. At 1,849 square miles, the 2010 population was 23,086 making it the 24th most populous county in the state; in 2015 the population was estimated at 24,694 with a projected population of 68,375 in 2050. Elbert County is situated south and east of Denver and is included in the Denver-Aurora Metropolitan Statistical Area; bounded on the north by Arapahoe County, on the east by Lincoln County, on the southwest by El Paso County, and the west by Douglas County (see Map 1-1: Elbert County and Planning Areas at the end of this chapter) Elbert County's population is largely concentrated on the west near the towns of Elizabeth and Kiowa and the northwest county lines where the fast growing Denver Metropolitan area is quickly expanding.

Elbert County's renewable surface water and alluvial groundwater supplies are fully subscribed, and provide for nearly half of current water demands in the county; primarily agricultural demands. The rest of the demands are met by Denver Basin groundwater, and this is essentially the only supply available to provide for future growth. The majority of Elbert County's residents rely on their own domestic Denver Basin wells for drinking water, irrigation and other household needs, and do not fall within a water or sewer service provider area. The water and sewer providers in the county, whether they are municipalities or special districts, also rely on Denver Basin groundwater through municipal supply wells.

Denver Basin groundwater is considered a nonrenewable water supply. Recharge rates for the Denver Basin aquifers are very slow, and rates of withdrawal far exceed them. Therefore, the county is growing its dependence on a diminishing water supply. This issue has become more apparent as the state continues to experience a rapid increase in population. In 2016, U.S. Census Bureau estimates show that from 2010-2016, the population of Colorado increased by 511,221, the majority of which are born in, or moving to the Denver Metropolitan Area. This growth is reflected in northwest Elbert County.

Observed water level declines in the Denver Basin along with the expected increases in population leads to the need for a better understanding of the water availability in these aquifers for Elbert County residents. This Rural Water Supply Study was developed for Elbert County to examine the reliability of current and future water supplies and under varying projected growth scenarios. The goal is to take a comprehensive view of water supply and infrastructure systems, develop policy options, and identify time-critical thresholds to ensure adequate water supply to meet Elbert County's future needs.

1.2 ELBERT COUNTY HYDROLOGY AND HYDROGEOLOGY

This section will overview the surface water supplies available in the county as well as overview the Denver Basin groundwater supplies.

1.2.1 Surface Water

Surface water supplies are very limited in Elbert County, despite the 44 named streams that exist. These streams are all small ephemeral tributaries to either the South Platte River or the Arkansas River, and are fed by brief rain events. However, some streams are fed by alluvial groundwater and are able to provide adequate water supplies via alluvial wells (see Section 1.2.2). The county is split between Water Divisions 1 and 2 by the Palmer Divide that spans from the southwest to the northeast through the county. See Map 1-2: “Elbert County Hydrology and Irrigation” at the end of this chapter.

1.2.2 Alluvial Aquifers

Alluvial sand, gravel, and clay deposits overlie the bedrock formations along major stream channels, and these materials form an unconfined alluvial aquifer where saturated with groundwater. In Elbert County, the more significant alluvial aquifers simulated in recent modeling by the Colorado Water Conservation Board (CWCB) as part of the South Platte Decision Support System (SPDSS) study (CDM, 2013) include Wolf, Comanche, and West Bijou Creeks (tributaries to the South Platte River), and the Nussbaum alluvial aquifer in the southeastern portion of the county. The Nussbaum aquifer is in contact with the Big Sandy Creek alluvium on its northern edge, which is a tributary to the Arkansas River.

Two designated basins have a significant portion of their areas within Elbert County. They are the Kiowa Bijou Designated Basin and the Upper Big Sandy Designated Basin.

1.2.3 The Denver Basin

Much of Elbert County overlies the Denver Basin aquifer system. From oldest to youngest, or deepest to shallowest, the four main units of the Denver Basin are: the Laramie-Fox Hills aquifer, the Arapahoe aquifer, the Denver aquifer, and the Dawson aquifer (Paschke et. al., 2011) – See Figure 1-1. The Dawson is commonly divided into two units, the Upper Dawson, and the Lower Dawson. See map 1-3: Denver Basin Aquifer Extents in Elbert County at the end of this chapter.

Figure 1-1
Generalized Geologic Cross Section of the Denver Basin Aquifer System
(Everett, 2014, modified from Robson, 1987)

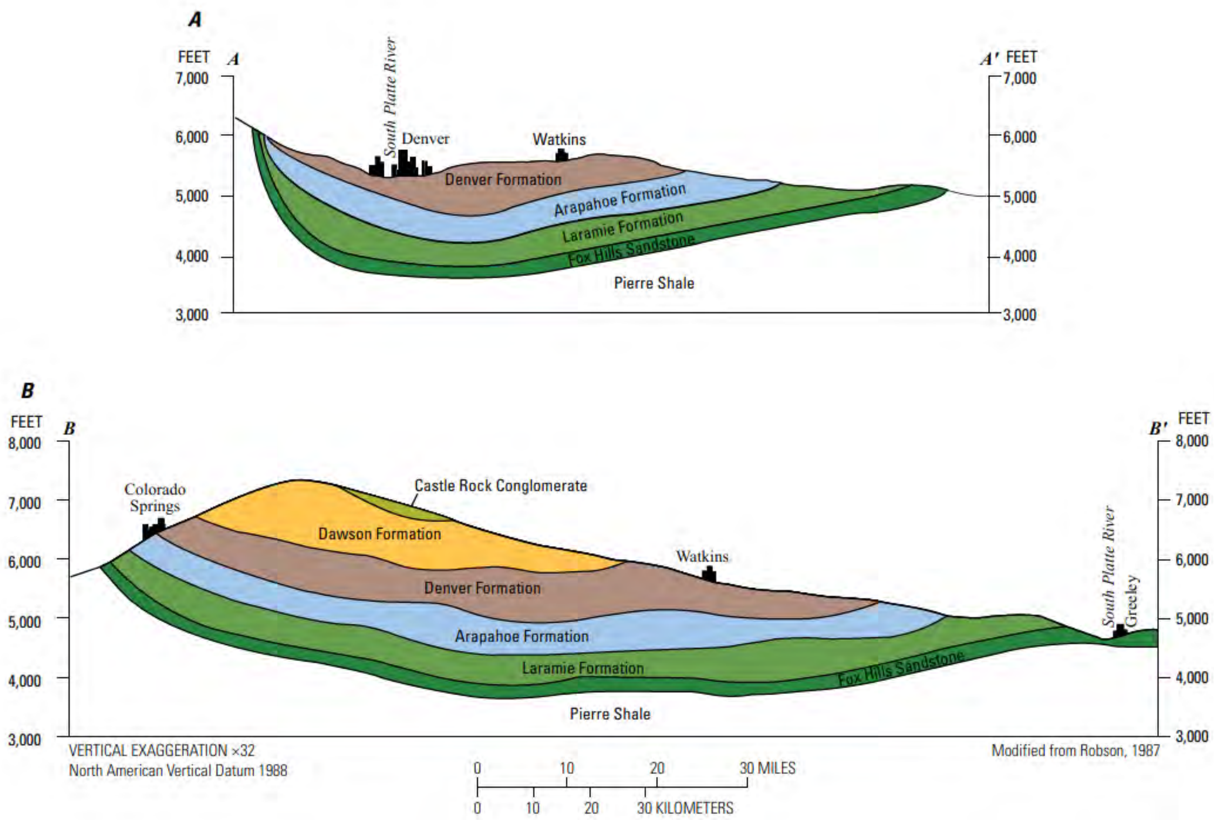


Figure 1-2 Conceptual Diagram of the Denver Basin Aquifer System
(from Paschke et. al., USGS, 2011)

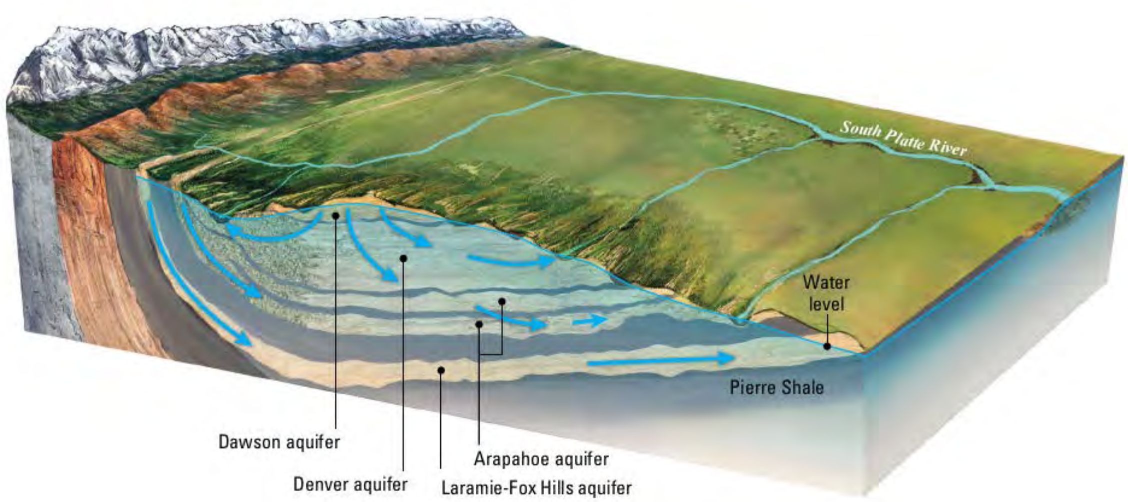


Figure 1-2 is a block diagram for the southern portion of Denver Basin illustrating the shape of the geologic units located beneath Elbert County. In layman's terms, the Denver Basin is shaped like a giant bowl. As the center of the basin slowly sank over geologic millennia, the bowl was filled with a sequence of sand, silt, and clay deposits that were compressed to form sedimentary rock. The west side of the bowl slopes steeply up against the uplifted Front Range, and the east side of the bowl slopes gently towards Nebraska and Kansas.

For more detailed information on the Denver Basin aquifers, including depth, water levels, well yields, thicknesses, and water quality, see memorandum by McGrane Water Engineering titled "Tasks 1 and 2 – Elbert County Groundwater Supply and USGS Modeling" dated September 12, 2017 in Appendix A.

In summary:

- The Laramie-Fox Hills aquifer, as seen in figures 1-1, and 1-2 above, is the deepest and most extensive of the aquifers and its base is approximately 2,200 to 2,300 feet below land surface at the structural center of the basin, and it ranges from 100 to 500 ft in thickness.
- The Arapahoe aquifer ranges from 400 to 600 ft in thickness and its base is approximately 1,700 ft below land surface at the structural center of the basin.
- The Denver aquifer ranges from 600 to 1,200 ft in thickness.
- The Lower Dawson in Elbert County typically ranges from 600 to over 800 feet deep.
- The Upper Dawson in Elbert County typically ranges from 200-500 feet deep in Elbert County.

1.3 STUDY OBJECTIVES

The goal of this study is to take a comprehensive view of water supply and infrastructure systems, and to develop policy options and identify time-critical thresholds to ensure adequate water supply to meet Elbert County's future needs.

The main scope of effort relies upon six main Study Objectives:

1. Identify supplies and quantify long-term projected water demand for Elbert County through the 2050 planning horizon under varying growth scenarios (Chapters 2, 3).
2. Review recent Denver Basin groundwater studies and water level data for Elbert County (Appendices A and B)
3. Assess the sustainability of current future use of Denver Basin groundwater by Elbert County's rural residents, water districts, and municipalities (Chapter 3).

4. Identify water resource options, and opportunities to optimize existing and future water supply infrastructure including renewable water, reuse and water efficiency alternatives (Chapter 4).

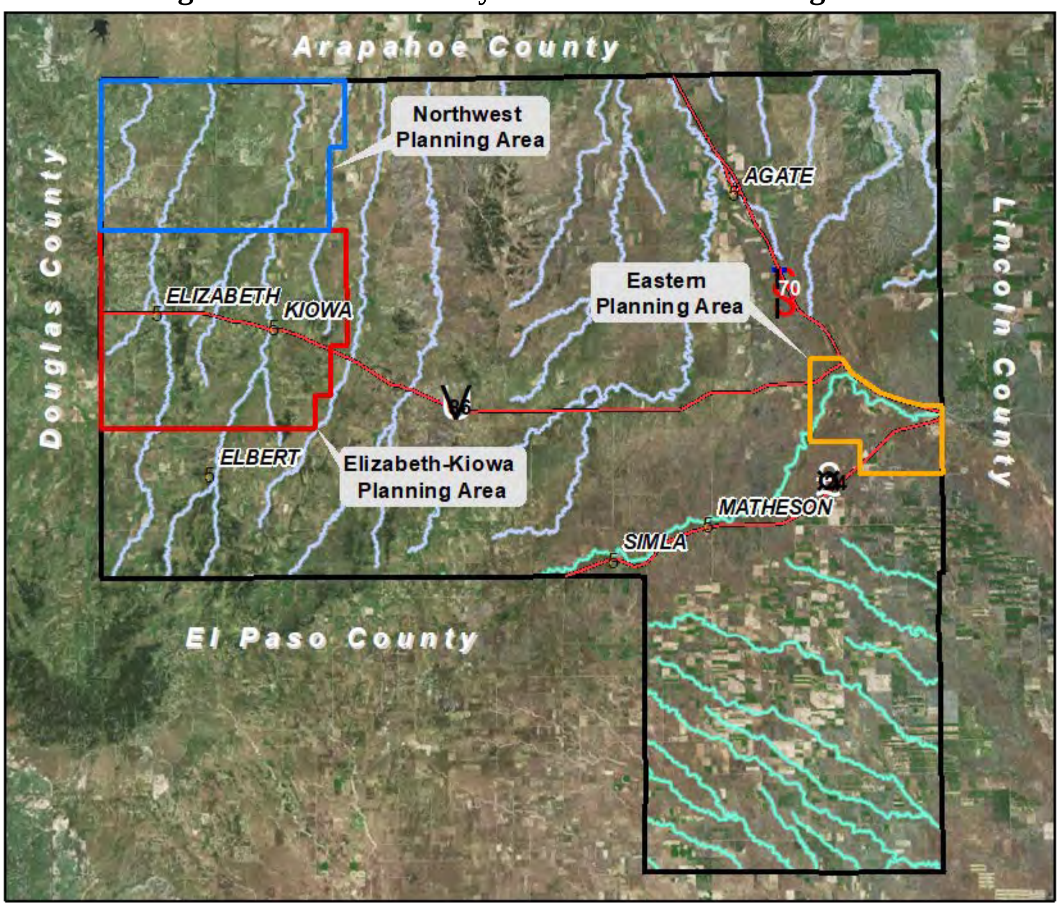
5. Provide comparative cost-benefit analysis for water resource alternatives and identify potential funding scenarios (Chapter 5).

6. Identify goals, opportunities, challenges and measurable outcomes for decision makers' policy development, and time-critical thresholds for preserving options for existing and new water supply (Chapter 6).

1.3.1 Planning Areas

Although this study presents a countywide analysis, there is a focus on three specific planning areas. These planning areas were chosen at the direction of the Board of County Commissioners (BOCC) due to the high population density and expected growth. These three study areas are: the Northwest Planning Area, the Elizabeth-Kiowa Planning Area, and the Eastern Planning Area (see Figure 1-3).

Figure 1-3 Elbert County and the Three Planning Areas



1.4 BACKGROUND INFORMATION

In completing this report, several previous studies/reports were referenced:

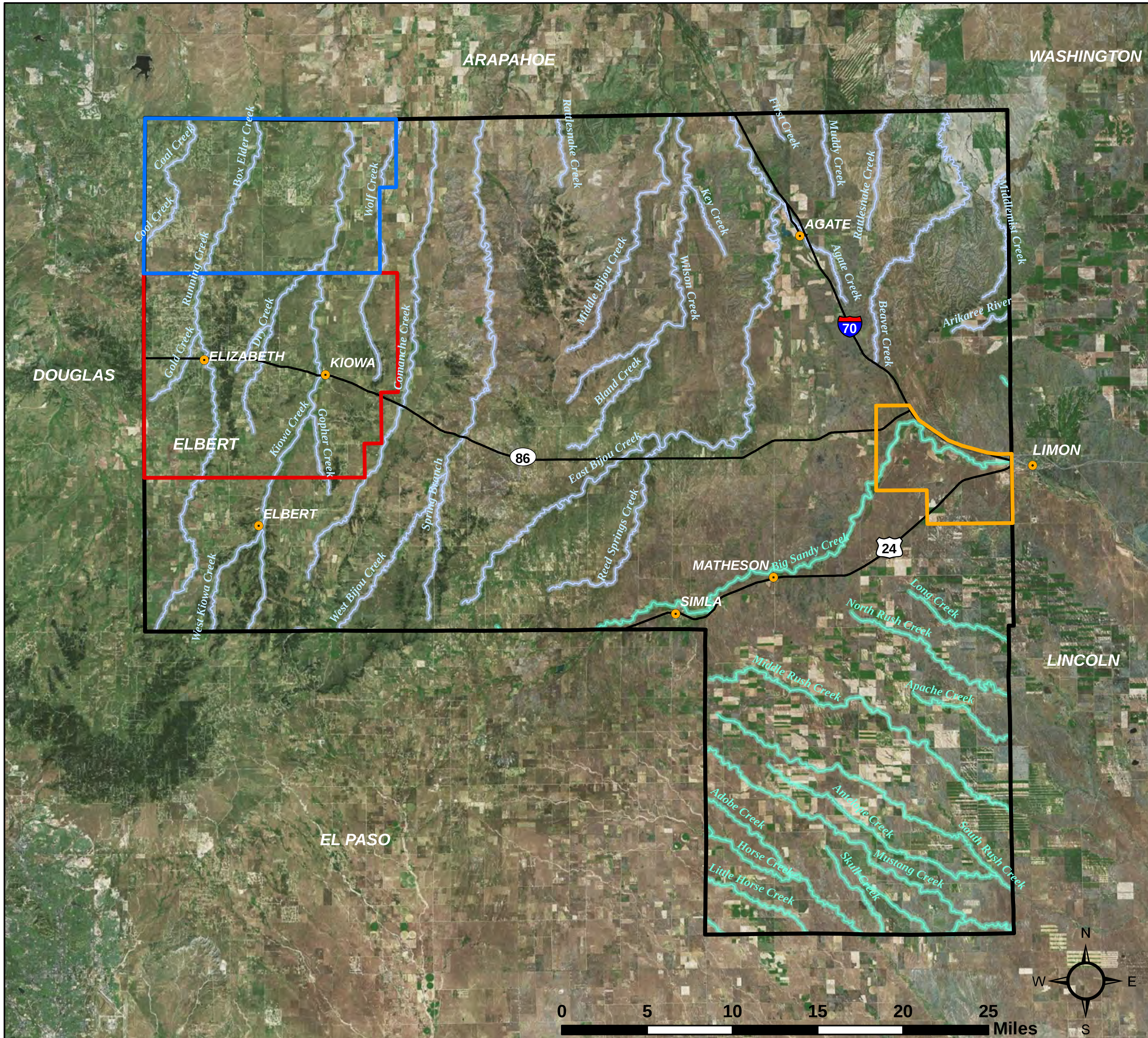
- The Denver Basin Groundwater Model developed by Paschke et. al. and described in the USGS Professional Paper 1770 titled Groundwater Availability of the Denver Basin Aquifer System, 2011. This model was used in determining groundwater storage under Elbert County, future drawdown, and to help determine future pumping costs.
- USGS Report 2014-5172, Groundwater Levels in the Denver Basin Bedrock Aquifers of Douglas County, Colorado 2011-2013 by Rhett R. Everett.
- The Douglas County Rural Water Supply System Feasibility Study, URS Corporation in association with Harvey Economics, 2013

1.5 ABBREVIATIONS

This section presents common abbreviations used in this report.

AF:	acre-feet
AFD:	acre-feet per day
AFY:	acre-feet per year
AFY:	acre-feet per year
BOCC:	Board of County Commissioners
CCF:	hundred cubic feet
CDPHE:	Colorado Department of Public Health and Environment
CIP:	Capital improvement plan
CWCB:	Colorado Water Conservation Board
DOLA:	Department of Local Affairs
DWR:	Division of Water Resources (Office of State Engineer)
FT:	feet
FT-MSL:	feet, mean sea level
GAL:	gallons
GPCD:	gallons per capita per day
GPD:	gallons per day
GPM:	gallons per minute
HP:	horsepower
IPR:	indirect potable reuse
LIRF:	lawn irrigation return flows
KGAL:	one thousand gallons
MAF:	million acre-feet
MCL:	maximum contaminant level
MGAL:	one million gallons
MGD:	million gallons per day

SDO:	State Demography Office
SDS:	Southern Delivery System
SEO:	State Engineer's Office (Office of the State Engineer)
SFE:	single family equivalent
SMWSA:	South Metro Water Supply Authority
SWSI:	Statewide Water Supply Initiative
WCP:	Water Conservation Plan
WHMD:	Woodmen Hills Metro District
WISE:	Water Infrastructure and Supply Efficiency Partnership
WRF:	Water Reclamation Facility
WSMP:	Water Supply Master Plan
WTP:	Water Treatment Plant

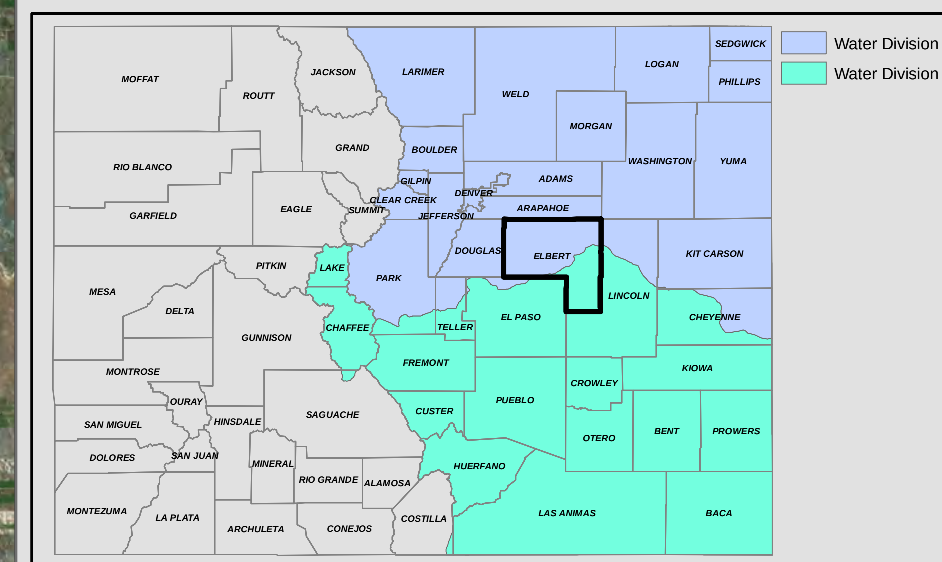


MAP LEGEND

City/Town
Highways
Elbert County Boundary
Streams in Water Division 1
Streams in Water Division 2

Planning Areas

Eastern Planning Area
Elizabeth-Kiowa Planning Area
NW Planning Area



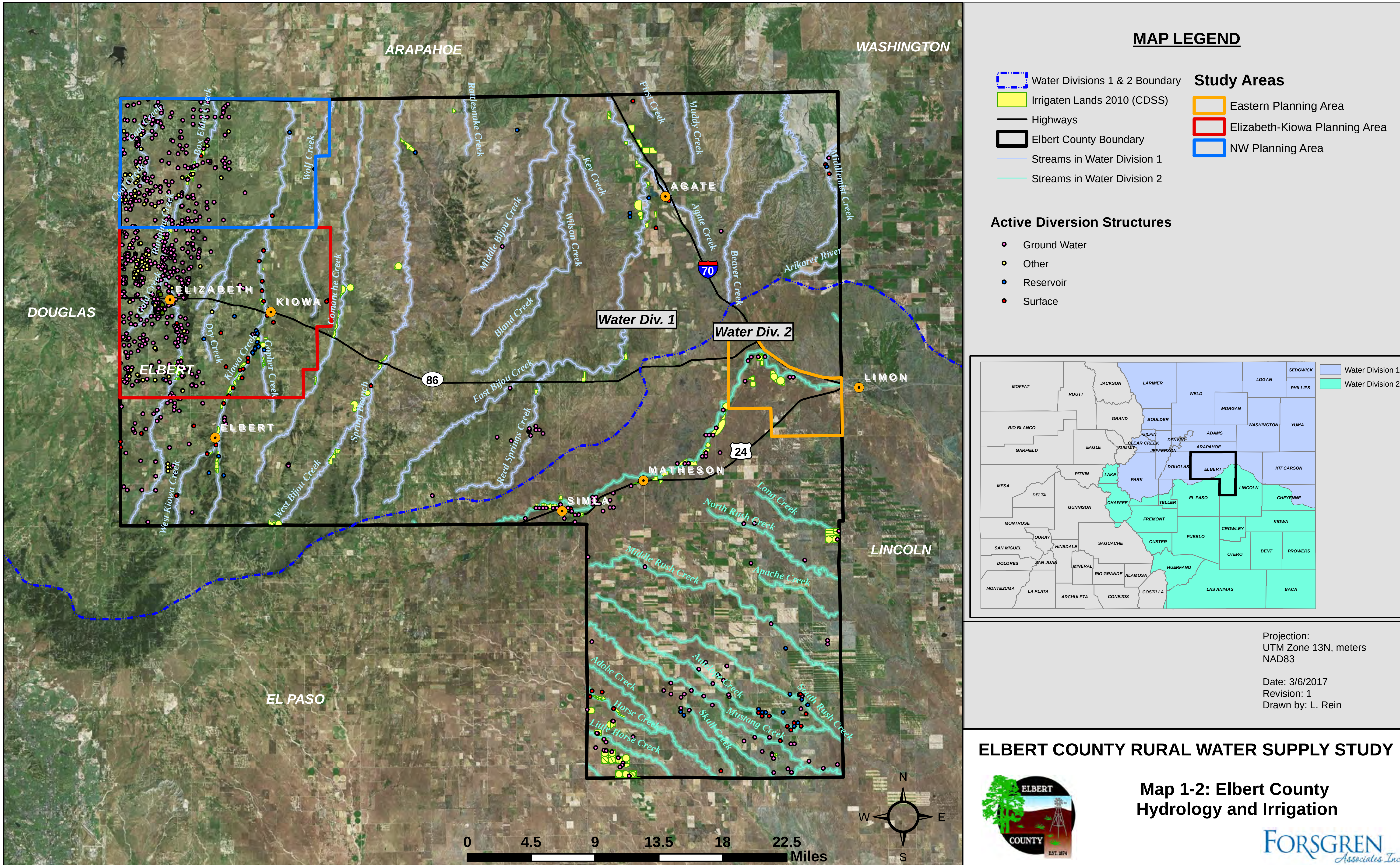
Projection:
UTM Zone 13N, meters
NAD83

Drawn by: L. Rein
Date: 12/5/2017

ELBERT COUNTY RURAL WATER SUPPLY STUDY

Map 1-1: Elbert County and Planning Areas

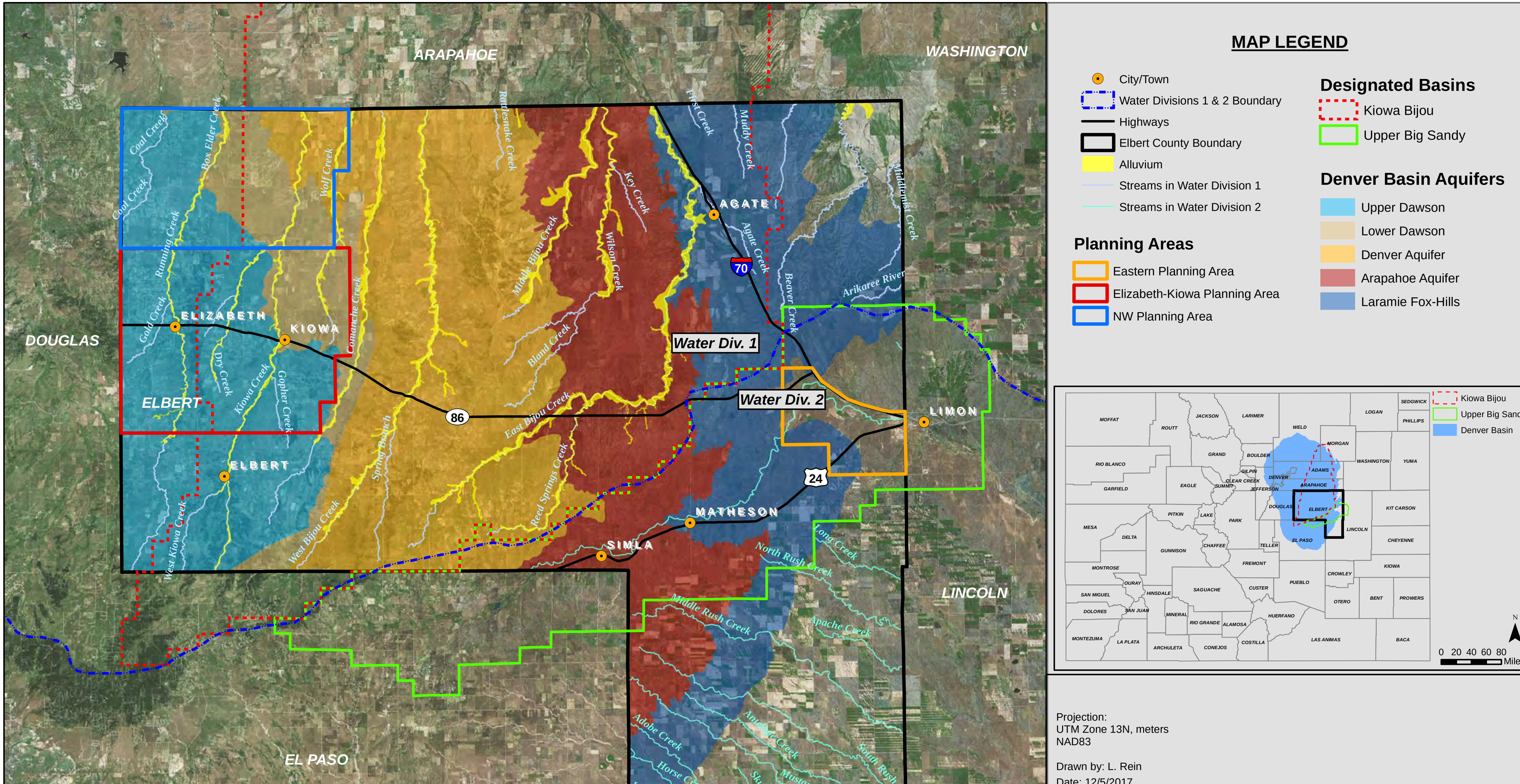
FORSGREN Associates Inc.



ELBERT COUNTY RURAL WATER SUPPLY STUDY

Map 1-2: Elbert County Hydrology and Irrigation

FORSGREN Associates Inc.



ELBERT COUNTY RURAL WATER SUPPLY STUDY

Map 1-3: Denver Basin Aquifer Extents in Elbert County

FORSGREN Associates Inc.

CHAPTER 2
EXISTING WATER SUPPLY AND SYSTEMS

2.1 GENERAL

Elbert County is in an area where surface water supplies are fairly limited. The USGS reported for the year 2010 that Elbert County residential water demand was 100% reliant on groundwater (USGS Circular 1405, Maupin, et. al., 2014).

Table 2-1 shows data from the DWR on diversion structures in Elbert County. These are structures with adjudicated surface water rights tied to them, and do not reflect the total number of groundwater wells, including Denver Basin wells, in the county. They do however, reflect the dependence on groundwater. There are 1,516 permitted groundwater “diversion” structures or wells, as compared to 62 permitted and adjudicated surface water diversion structures. It is likely that most, if not all, of the surface water and reservoir diversion structures are used for agricultural irrigation purposes, and the groundwater structures are predominantly used for domestic and municipal water supply. See Map 1-2: Elbert County Hydrology and Irrigation at the end of Chapter 1.

Table 2-1
Active Diversion Structures in Elbert County (source: Colorado DWR)

Active Diversion Structures	
Surface	62
Ground Water	1,516
Reservoir	42
Other	170
Total	1,790

Note: Active Diversion Structures are considered surface water diversions by DWR. These include groundwater wells that are considered to have a quantifiable impact to surface waters. These largely exclude Denver Basin wells.

The total number of groundwater wells by type are tabulated in Table 2-2. Most of these wells do not require water court adjudication and simply need permits through the State Engineer’s Office (SEO). If the well would be within the boundaries of a designated groundwater basin, the management district for that designated basin provides permitting oversight. These wells are not classified as diversion structures; therefore the count of all wells in the county is much higher.

Table 2-2
Primary Types of Groundwater Wells in Elbert County

Use	Number of Wells
Domestic	7,748
Stock	1,597
Commercial	1,442
Household Use Only	319
Irrigation	307
Other	191
Municipal	75
Industrial	18
Total	**11,697**

2.2 MUNICIPALITIES

There are three incorporated municipalities in Elbert County: the Towns of Elizabeth, Kiowa, and Simla. Elizabeth and Kiowa each have their own municipal water and wastewater systems that serve the town and some of the surrounding community. While Elizabeth and Kiowa both have dedicated water supply systems for their residents, they both rely almost entirely on Denver Basin wells for their water supply – with the exception of one well for Kiowa stated to be drilled into the Quaternary Alluvium. Everywhere else in the county is either served by private wells or covered under a metropolitan district providing water services. The majority of residents rely on domestic wells.

Records from the DWR show that the Town of Kiowa has two supply wells that are drilled within the Kiowa-Bijou Designated Groundwater Basin; one into the Dawson Aquifer and one into Quaternary Alluvium, an aquifer surrounding a surface water stream. These were the best records readily available for Kiowa's wells, as this information was not obtained from the town. Kiowa may have supply wells that were missed in the compilation of this information. See Table 2-3 for the list of water supply wells used by Kiowa.

The Town of Elizabeth has five municipal wells as listed in Table 2-4. This list of wells was provided by the town through its pumping and billing records.

Table 2-3
Town of Kiowa Water Supply Wells

Permit #	Aquifer	Date Constructed	Depth (ft)	Annual Allowed Withdrawal (AF)
2875-F-R	DAWSON	2/8/1993	392	15
2794-F-R	QUATERNARY ALLUVIUM	2/10/2006	66	575

Table 2-4
Town of Elizabeth Water Supply Wells

Permit #	Aquifer	Date Constructed	Depth (ft)	Annual Allowed Withdrawal (AF)
44454-F	ARAPAHOE	10/6/1995	2149	132
52511-F	DENVER	2/20/1995	1010	39.7
52512-F	LOWER DAWSON	2/20/1995	648	21
15617-F-R	LOWER DAWSON	8/24/2009	540	50
16210-F-R	LOWER DAWSON	11/13/2012	1600	150

Note: Well 16210-F-R is permitted for, and draws from the Upper Dawson and Denver aquifers in addition to the Lower Dawson.

Tables 2-5 and 2-6 list the population, production, and consumption of water for the towns of Kiowa and Elizabeth, respectively. Production values show how much water was pumped from their municipal wells, which are listed in Tables 2-3 and 2-4; the consumption values indicate how much water was actually billed to the customers through meters. Consumption values are less than production due to system losses.

Table 2-5
Water Supply Production and Consumption in Kiowa with Population
(Source: Town of Kiowa)

Year	Kiowa Population	Kiowa Water Supply Production (AF)	Kiowa Water Consumption (AF)
2012	726	148	136
2013	731	109	94
2014	739	102	87
2015	744	108	99
2016	-	100	91
Average	**735**	**113**	**101**

Table 2-6
Water Supply Production and Consumption (water sales) in Elizabeth with Population (Source: Town of Elizabeth)

Year	Elizabeth Population	Elizabeth Water Supply Production (AF)	Elizabeth Water Consumption (AF)
2012	1,364	215	196
2013	1,376	199	183
2014	1,395	200	186
2015	1,412	188	172
2016	-	175	161
Average	**1,387**	**195**	**179**

2.3 SPECIAL DISTRICTS

There are 21 Special Districts in Elbert County, 12 of which provide water service to customers. They are organized for the purposes of providing services to communities in an efficient and area-specific manner as needed. The formation of a special district requires the approval of a "Service Plan" by the Board of County Commissioners and the governing body of each municipality that the district may overlap. Each special district in Elbert County, therefore has submitted a service plan to the County outlining specifics such as: the need for a special district; the type of special district, what services will be provided (this is typically the case for metropolitan districts that provide multiple services), preliminary details on finances and the issuance of bonds; projected infrastructure needs and associated costs. If the special district provides water services, it will often provide details on water supply and infrastructure needs, such as wells, storage tanks, water treatment, and water rights within the service plan.

Service plans for all 21 special districts were provided by Elbert County staff (see Table 2-6). Special districts in Elbert County are concentrated in the northwest portion of the county, and all but one - Elbert Water and Sanitation District - fall within the Elizabeth-Kiowa and the NW Planning Areas (see map 2-1: Metropolitan and Water & Sanitation Districts at the end of this chapter).

Table 2-6
The 21 Identified Special Districts in Elbert County

Special District	Service Plan Available?	Service Plan Date	Developed?	Provides Water?*
Britanie Ridge Metropolitan District	Yes	2005	Yes	Yes
Clearwater Metropolitan District (provides water services to North Pines Metro.)	Yes	Jul-01	Yes	Yes
Deer Creek Water District	Yes	Apr-08	Yes	Yes
Diamond Ridge Metropolitan District	Yes	Jan-06	No	No
Diamond Ridge Water & Sanitation District	Yes	Jan-06	No	Yes
Elbert and Highway 86 Commercial Metropolitan District	Yes	Aug-08	Yes	Yes
Elbert and Highway 86 Metropolitan District	Yes	Oct-02	Yes	No
Elkhorn Ranch Metropolitan District No. 1	Yes	2002	Yes	Yes
Gold Creek Commons Metropolitan District	No		No	No
Miller Ranch Metropolitan District	Yes	Oct-07	No	No
Miller Ranch Water & Sanitation District	Yes	Oct-07	No	Yes
North Pines Metropolitan District (Serves with Clearwater)	Yes	May-97	Yes	No
Ritoro Metropolitan District	Yes	Sep-16	No	Yes
Spring Valley Metropolitan District Nos. 1	Yes	Mar-04	Yes	Yes
Spring Valley Metropolitan District Nos. 2	Yes	Mar-04	Yes	No
Spring Valley Metropolitan District Nos. 3	Yes	Mar-04	Yes	No
Spring Valley Metropolitan District Nos. 4	Yes	Mar-04	Yes	No
Sterling Crossing Commercial Metropolitan District	Yes	Sep-04	No	Yes
Sterling Crossing Residential Metropolitan District	Yes	Sep-04	No	Yes
Summit Park Metropolitan District	Yes	Oct-03	Yes	Yes
United Water & Sanitation District	Yes	Oct-02	Yes	No**

*Those that don't provide water services are typically overlapped by another special district that does (e.g., North Pines Metro. Dist. gets its water services from Clearwater Metro. Distr.)
** Does not provide any water in Elbert County

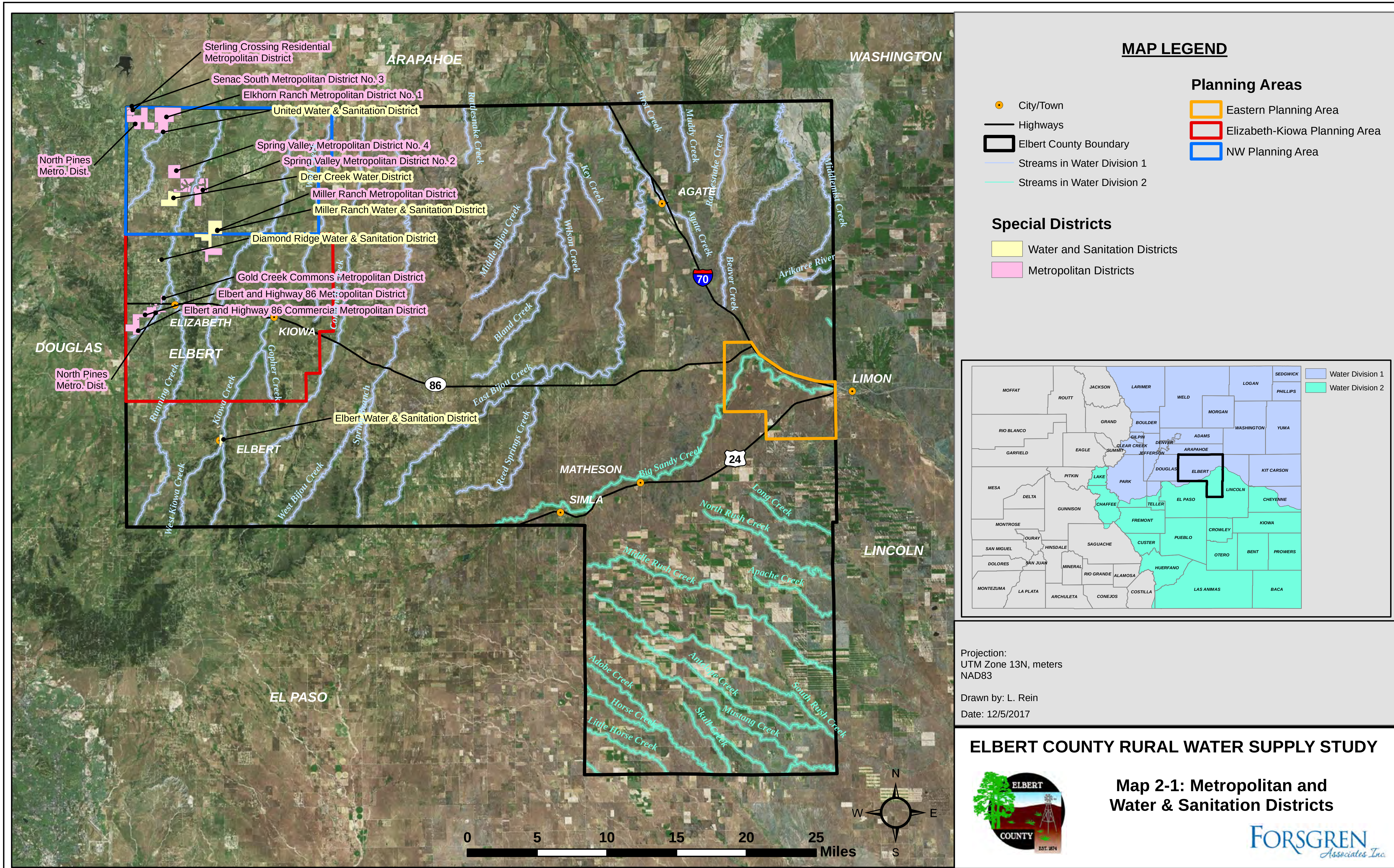
These service plans were reviewed for water supply information such as:

- Number of single family homes anticipated within the district
- Secured water rights and water resources (in acre-feet)
- Projected total population of the district
- Service area size (acres)
- Details on groundwater supply wells (if any)
- Water storage (tanks, volumes, decreed storage rights, etc.)
- Water transmission systems
    - Pumping systems

  - Transmission lines (linear feet)
- Wastewater treatment
  - Reuse (if any)

Availability of this information per service plan varied and was not consistently presented. Largely, this is due to the lack of specificity required by law as to how much detail must be provided by a special district service plan. They are primarily required to present such things as district boundaries and financials, including debt obligations, projected revenues, general infrastructure, and operations and maintenance cost estimates. As long as this information is presented, the special district can decide what degree of detail they would like to go into regarding development plans.

Due to the very nature of a service plan being an initial plan, with best estimates as to costs and infrastructure referring to full buildout and development, it is not clear how much in the plans was fully developed as intended. A special district could have been anticipating a certain number of housing developments upon completion of their service plan, and then - perhaps due to economic factors - half of those developments were never completed. More research would be needed to determine to what extent these service plans reflect reality. But these service plans provide readily available estimates as to water infrastructure for areas outside of incorporated municipalities that provide their own water services – Table C-1 in Appendix C summarizes the information obtained from the service plans.



ELBERT COUNTY RURAL WATER SUPPLY STUDY
Map 2-1: Metropolitan and Water & Sanitation Districts
MAP LEGEND
City/Town
Highways
Elbert County Boundary
Streams in Water Division 1
Streams in Water Division 2
Planning Areas
Eastern Planning Area
Elizabeth-Kiowa Planning Area
NW Planning Area
Special Districts
Water and Sanitation Districts
Metropolitan Districts
Water Division 1
Water Division 2
Projection:
UTM Zone 13N, meters
NAD83
Drawn by: L. Rein
Date: 12/5/2017
Sterling Crossing Residential Metropolitan District
Senac South Metropolitan District No. 3
Elkhorn Ranch Metropolitan District No. 1
United Water & Sanitation District
North Pines Metro. Dist.
Spring Valley Metropolitan District No. 4
Spring Valley Metropolitan District No. 2
Deer Creek Water District
Miller Ranch Metropolitan District
Miller Ranch Water & Sanitation District
Diamond Ridge Water & Sanitation District
Gold Creek Commons Metropolitan District
Elbert and Highway 86 Metropolitan District
Elbert and Highway 86 Commercial Metropolitan District
North Pines Metro. Dist.
Elbert Water & Sanitation District
ARAPAHOE
WASHINGTON
DOUGLAS
ELBERT
LINCOLN
EL PASO
ELIZABETH
KIOWA
ELBERT
AGATE
MATHESON
SIMLA
LIMON
70
86
24
0 5 10 15 20 25 Miles
N S E W
ELBERT COUNTY EST. 1874
FORSGREN Associates Inc.

CHAPTER 3
FUTURE WATER SUPPLIES

3.1 GENERAL

There are four main categories of demand that are projected to years 2035 and 2050 in this Study:

1. Residential and Commercial

2. Agricultural Irrigation

3. Livestock

4. Oil and Gas

This chapter provides an overview of current and future water demands for Elbert County. These demands are compared with Denver Basin storage volume estimates prepared by McGrane Water Engineers to understand the future water supply outlook of the county.

Of the four categories of water demands being quantified, the second largest after agricultural demand is residential and commercial, which is dependent on the population. Therefore, reasonable current and future population estimates of the county and the planning areas are necessary.

3.2 CURRENT AND FUTURE POPULATION

Elbert County had a population of 23,107 as of the 2010 Census, and recent estimates from Elbert County show a population of 24,694 as of the year 2015. The three areas of particular interest in this study – the Northwest Planning Area, Elizabeth-Kiowa Planning Area, and Eastern Planning Area – will be the focus for future population growth along with the county as a whole.

The State Demography Office (SDO) manages and regularly publishes Colorado population data available to the public on statewide, regional, county, and select municipal levels. They also publish population projections. The SDO forecasting model is largely economically based, while taking into account birth and death rates among other demographic factors. The economic basis of the model is the link to net migration into the state, which is very closely correlated to job growth.

The SDO model is considered the best available model for Colorado, and it was similarly used in the 2010 Statewide Water Supply Initiative for forecasting statewide populations and water demands. For these reasons, the SDO projections are also used for the Elbert County Rural Water Supply Study.

3.2.1 Current and Future Populations for Elbert County

Current Population
Data from the SDO for populations of counties and census designated places can be accessed from their website (https://demography.dola.colorado.gov/population/). The SDO will estimate populations for inter-census years along with its decennial census e.g., 2000 or 2010. The most recent estimates developed by the SDO at the time of this writing were for 2015 and were published in October 2016. The SDO updates these forecasts annually in October.

For Elbert County, the SDO provides estimates for the county as a whole, the three census designated places (CDP) in the county, and the unincorporated portion of Elbert County. Unincorporated Elbert County comprises the majority of Elbert County's population. Elbert County historical populations are shown in Table 3-1.

Table 3-1
Population of Elbert County; the Towns of Elizabeth, Kiowa, and Simla; and Unincorporated Elbert County (Source: SDO)

Year	Population				
	Elbert County	Elizabeth	Kiowa	Simla	Unincorporated Elbert County
1985	8,560	967	287	527	6,779
1990	9,646	818	275	481	8,072
1995	14,328	903	366	484	12,575
2000	20,104	1,464	600	664	17,376
2005	22,259	1,440	655	668	19,496
2010	23,107	1,358	723	618	20,408
2015	24,694	1,412	744	638	21,900

Future Population
The Colorado SDO projects the population of Elbert County to be 53,654 in the year 2035 and 68,375 in the year 2050. These estimates were obtained from the most recent projections prepared by the SDO in October 2015 as shown in Table 3-2.

Table 3-2
Elbert County Population Estimates through 2050 (Source: Colorado Department of Local Affairs, State Demographers Office, Oct. 2015)

Year	Elbert County Population
2010	23,107
2015	24,694
2020	32,968
2025	41,349
2030	48,026
2035	53,654
2040	58,856
2045	63,745
2050	68,375

3.2.2 Current and Future Populations for Planning Areas

Current Population – Planning Areas

The planning areas do not have population estimates available for them as they are arbitrarily drawn with regard to where the census makes estimates. Therefore, a GIS analysis was performed using census block data from the 2010 Census. The 2010 Census is the most recent, and therefore, the only data available for making population estimates for the planning areas. Estimates of the 2010 planning area populations are shown in Table 3-3.

Table 3-3
Planning Area Population Estimates

Planning Area	2010 Population	Fraction of Entire County (2010)
NW Area	7,315	32%
Elizabeth Kiowa Area	11,123	48%
Eastern Area	61	0.3%
All Planning Areas	18,499	80%
Elbert County	23,107	-

Future Population – Planning Areas

To estimate planning area populations into the future, compound annual average growth rates were determined from the Elbert County population projections put together by the SDO, and were similarly applied to the initial population estimates for the planning areas determined in Section 3.2.2. However, the growth rate in the countywide SDO projection is likely to be lower than in the Northwest and Elizabeth-Kiowa Planning areas due to the proximity of these areas to the expanding Denver Metro Area. Therefore, the growth rates for these planning areas were assumed to be between 0.4-1.2% higher than the countywide rates.

Table 3-4
Planning Area Population Projections

Planning Area	2010 Population	Fraction of Entire County (2010)	2017 Estimate	2035 Estimate	2050 Estimate
NW Area	7,315	32%	8,398	17,485	23,532
Elizabeth-Kiowa Area	11,123	48%	12,770	26,586	35,782
Eastern Area	61	0.3%	70	153	238
All Planning Areas	18,499	80%	21,239	44,224	59,552
Elbert County	23,107	-	27,674	53,654	68,375

3.3 CURRENT AND FUTURE DEMANDS

Demands were estimated for the four main categories: Residential and Commercial, Agricultural Irrigation, Livestock, and Oil and Gas development in Elbert County for years 2035 and 2050. This section briefly overviews the assumptions necessary for each, and reports the total estimated demands.

3.3.1 Residential and Commercial

It is assumed that 100% of residential and commercial demand is to be met by Denver Basin groundwater. In estimating total residential water demand, 135 gallons per capita day per day (gpcd) was used and applied to the current and projected population (see Section 3.2 for population projections). This value is also used in the Douglas County Rural Water Supply System Feasibility Study. Douglas County is similarly heavily dependent on Denver Basin groundwater. The Town of Castle Rock, also heavily dependent on the Denver Basin has seen similar per capita demands (Town of Castle Rock Water Efficiency Master Plan, 2015). Therefore, this is considered a reasonable and conservative per capita consumption figure to use for Elbert County planning. Commercial demands are assumed to be 10% of the residential demands.

3.3.2 Irrigation

The USGS most recently compiled water use estimates for Elbert County in 2010. USGS Circular 1405 – Estimated Use of Water in The United States (Maupin et. al., 2014) estimates nationwide water use down to the state and county level. Using their agriculture irrigation water demand estimates for 2010 and the 2010 irrigated acres layer retrieved from the DWR for Elbert County, an average 1.4 AFY/Acre was calculated to apply to future irrigated acreage estimates.

Data on irrigated acreage is also available from the USDA Census of Agriculture for the years 2007 and 2012. To project irrigation demands using future irrigated acreage estimates, DWR data on irrigated acreage in 2010 for Elbert County was used as the starting point. The year 2010 is chosen due to that fact that this is also the starting point for population estimates.

The DWR data estimates that 9,226 acres were irrigated for agriculture in Elbert County in 2010; data from the United States Department of Agriculture (USDA) Census of Agriculture reported 13,368 acres in 2007 and 8,435 acres in 2012 (see Table 3-5). Refer to Map 1-2 at the end of Chapter 1.

Table 3-5
Irrigated Acres in Elbert County (Source: USDA, DWR)

	Year		
Description	**2007***	**2010****	**2012***
Irrigated Land (acres)	13,368	9,226	8,435

*USDA Census of Agriculture
**DWR

This data shows that irrigated acreage has been lost since 2007, most severely between 2007 and 2010. Colorado's Water Plan also identifies this trend, which is prevalent through Colorado. Loss of irrigated agriculture cannot be entirely halted however, Colorado's Water Plan places a high priority on the value of agriculture, and prompts steps to minimize the loss of productive farmland.

This downward trend in irrigated acreage has been incorporated into the demand model for projections to the year 2050. The 2010 Colorado Statewide Water Supply Initiative estimated a maximum statewide loss of irrigated acreage of 20% by 2050. Irrigated acreage estimates for Elbert County will assume this same overall loss by the year 2050. For the years between 2010 and 2050, estimates will be made by assuming a constant linear loss each year, starting in 2010 and ending in 2050. See Table 3-6 for irrigated acreage estimates out to 2050.

Using data from the USGS Denver Basin Groundwater Model (Paschke, 2011), it is assumed that approximately 30% of agricultural irrigation demand comes from Denver Basin groundwater in Elbert County; the other 70% is sourced from alluvial groundwater or surface water supplies – this is also reflected in Table 3-6.

Table 3-6
Irrigation Demand for Elbert County
Based on 1.4 AFY/Acre and Irrigated Acreage Estimates

ELBERT COUNTY	Year			
	2010	2017	2035	2050
Irrigated Farmland (Acres)	9,226	8,873	8,025	7,381
Total Irrigation Demand (AF)	12,916	12,422	11,235	10,333
Irrigation Demand from Surface Water or Alluvial (AF)	9,041	8,695	7,864	7,233
Irrigation Demand from Denver Basin (AF)	3,875	3,727	3,370	3,100

3.3.3 Livestock

The USGS reports that approximately 77% of livestock water demand is sourced from groundwater (Maupin, et. al., 2014). This Study uses a simplifying assumption that 100% of livestock water demands are sourced from the Denver Basin. To assess current demands for livestock, the number (or head) of cattle in the county and the average demand per head of cattle is needed. The USDA reports on head of cattle on a county-level through its National Agriculture Statistics Survey (NASS) annual report.

These reports were queried for the years 2010-2016 with 2016 being the most recent available data. Table 3-7 shows the results of this query with 39,000 head of cattle in Elbert County in 2016 – this number is lower than the 43,000 head of cattle reported in 2010 with numbers ranging up and down in between. Due to this variation, it is difficult to predict whether cattle numbers are trending up or down, and the future is largely determined by market conditions. To be somewhat conservative in estimating future water demands for livestock, a growth rate of 1% per year was applied starting with the 2016 value through 2050.

Table 3-7
Head of Cattle in Elbert County from 2010-2016 (Source: USDA, NASS)

Year	Head of Cattle
2010	43,000
2011	44,000
2012	45,500
2013	38,000
2014	37,000
2015	37,000
2016	39,000

Cattle water demands can range between 13-20 gallons per head per day, for this report 20 gallons per head per day will be assumed. Table 3-8 shows the cattle demands for 2017, 2035, and 2050.

Table 3-8
Projected Head of Cattle and Cattle Demand for 2017, 2035, and 2050

Year	Head of Cattle	Cattle Demand (AF)
2017	39,390	882
2035	47,116	1,056
2050	54,701	1,225

3.3.4 Oil and Gas

Although there has been some exploratory work in Elbert County, water demands for the oil and gas industry are expected to be relatively insignificant for the near term. Starting in 2035, however, the demand model incorporates 38 AF of demand associated with oil and gas development. Unless there are large advances in oilfield drilling technology or a new oilfield discovery within Elbert County, there is no evidence to suggest a large increase in water demand for this activity. As with all other demand projections, however, this assumption needs to be checked as this report is regularly updated.

Water demands for future oil and gas activity are expected to be fairly minor for several reasons: 1) Elbert County is on the very edge and largely just outside of the Denver-Julesburg Basin, and oil and gas yields for new wells in the DJ Basin in this area are unlikely to be economical; 2) according to the Colorado Oil and Gas Conservation Commission, only six oil and gas wells have been drilled in Elbert County since the year 2000 (See Table 3-9), compared to over 16,000 new oil and gas wells drilled in Weld County over the same time period. Weld County is a top producer of oil in Colorado and sits right over the core area of the DJ Basin.

Oil and Gas Water Demands

The DWR reported in 2010 that hydraulic fracturing alone represented roughly 0.08% of overall water use in the state at roughly 13,900 AFY. At the same time agricultural water use was at 13.9 million acre-feet which represented 85.5% of the state's water use.

It has been shown that median water use for drilling vertical wells (not hydraulically fractured) is around 360,000 gallons and median values for hydraulically fractured horizontal wells can range from roughly 2.8-5.6 million gallons, depending primarily on the horizontal length of the well (Goodwin et. al., 2013). And while this is a large volume of water, specifically for horizontally drilled and hydraulically fractured wells (roughly 8.5 to 17 acre-feet) it is small percentage of the state's water use. It is important to note that this is a one-time use of water for each new well.

Thirty-eight acre-feet of future oil and gas water demand was estimated by taking the median of the range of water demand (8.5 AF + 17 AF) of 12.75 AF and assuming that 3 wells per year could be drilled in the future.

Table 3-9
Number of new oil and gas wells drilled in Elbert and Weld Counties, and the state of Colorado since the year 2000 as of January 2017 (Source: COGCC)

Year	Elbert County	Weld County	Colorado
2000	2	259	1,084
2001	-	450	1,735
2002	-	456	1,441
2003	-	571	1,878
2004	-	671	2,325
2005	-	719	2,985
2006	1	930	3,510
2007	-	1,215	3,996
2008	-	1,304	4,353
2009	-	871	2,017
2010	-	1,185	2,719
2011	-	1,626	3,108
2012	-	1,404	2,202
2013	-	1,256	1,871
2014	-	1,507	2,139
2015	3	1,091	1,430
2016	-	734	944
2017	-	81	111
Grand Total	**6**	**16,330**	**39,848**

There is much uncertainty in regards to oil and gas development. It is a volatile industry with many complicated driving factors, including global stability, natural disasters, foreign competition, advancing technologies, and more. If Elbert County were to experience a boom in the oil and gas industry, the above values could be used to roughly estimate expected demands based off new well information. However, as technologies continue to advance and as oil and gas operators continue to invest in efficient technologies, the water demands for each well will continue to decrease.

3.3.5 Total Countywide Projected Demand

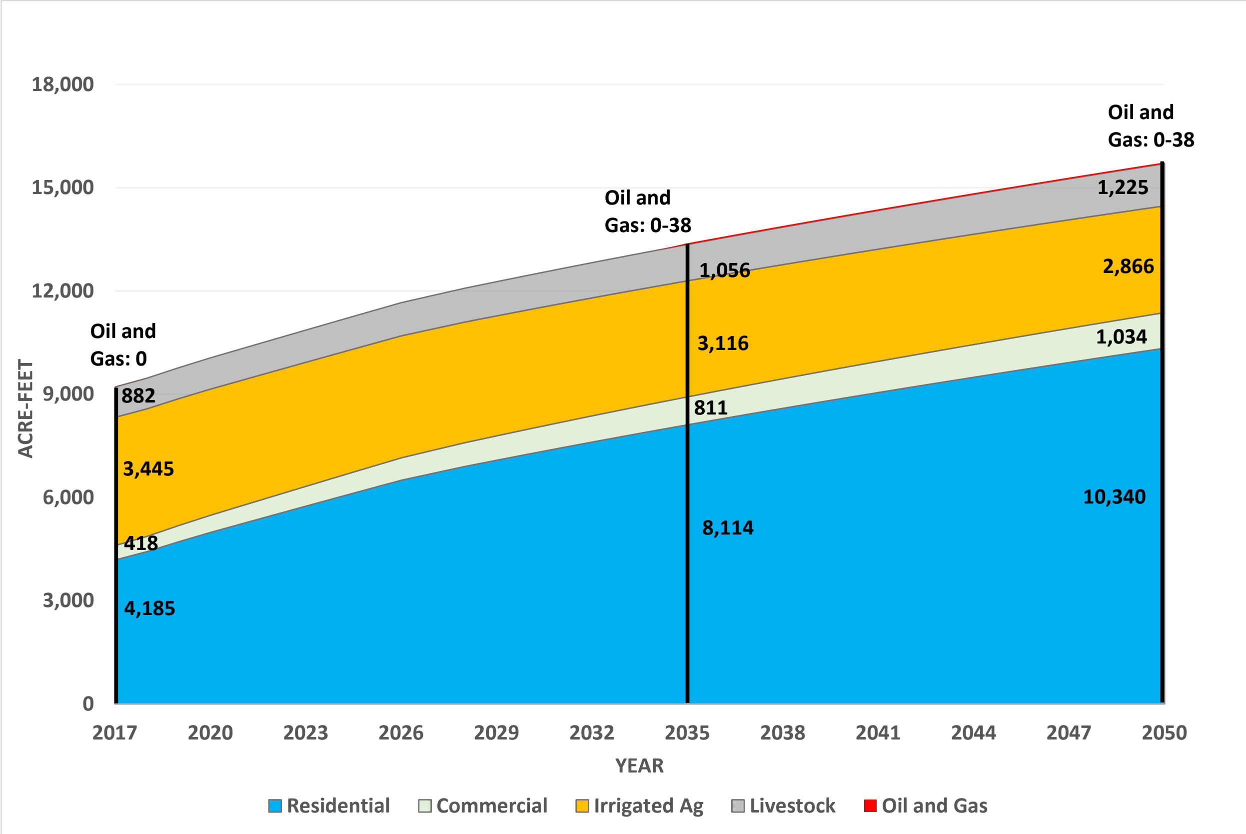
The combined countywide demands for the four categories above are shown below in Table 3-10. It is assumed that all demand is supplied by Denver Basin groundwater except for 70% of the agricultural irrigation demands which is assumed to come from alluvial and surface water supplies. A graph of Denver Basin only demand is shown in Figure 3-1.

Totals for all countywide demands as well as Denver Basin groundwater only are shown. Total demand is expected to be 22,970 AF in the year 2050 for all water and 15,737 AF for Denver Basin water only – approximately 80 percent higher than the Denver Basin demands estimated for 2017.

Table 3-10
Total Water Demands for Elbert County including Total Demand for Denver Basin Groundwater Only

ELBERT COUNTY	Year 2010	2017	2035	2050
Population	23,107	27,674	53,654	68,375
User	**Demand in Acre-Feet**			
Residential (Countywide)	3,494	4,185	8,114	10,340
Commercial	349	418	811	1,034
Irrigated Agriculture	12,916	12,422	11,235	10,333
Irrig. Ag. From Surface Water or Alluvial	9,041	8,695	7,864	7,233
Irrig. Ag. From Denver Basin	3,875	3,727	3,370	3,100
Livestock	963	882	1,056	1,225
Oil and Gas Development	0	0	38	38
Total Demand	**17,723**	**17,908**	**21,253**	**22,970**
Total Demand from Denver Basin Only	**8,682**	**9,212**	**13,389**	**15,737**

Figure 3-1
Graph of Estimated Denver Basin Groundwater Demand for Elbert County Years 2017-2050



3.3.6 Total Projected Demand by Planning Area

For each planning area, total demands were only estimated for the residential sector. Residential demands are the demands expected to have substantial increases through the year 2050 and for which new infrastructure and water resource alternatives will be the most necessary. Estimated demands for each planning area are shown in Table 3-11.

Table 3-11
Projected Residential Water Demand Estimates for each Planning Area Through 2050

Demand in Acre-feet			
Year	Elizabeth-Kiowa Study Area	NW Study Area	Eastern Study Area
2010	1,682	1,106	9
2017	1,931	1,270	11
2035	4,020	2,644	23
2050	5,411	3,559	36

3.4 DENVER BASIN STORAGE VOLUME ESTIMATES

To gain an understanding of Elbert County's water supply future, it is necessary to have an understanding of the county's available supply. Estimates for the volume of Denver Basin groundwater underlying Elbert County and the Planning Areas as were defined in this report.

3.4.1 Current Storage

Due to the nature of the USGS Groundwater Model and the time steps it operates on, 2018 must be the starting point for storage estimates. It is assumed that differences between 2018 and 2017 are negligible. Table 3-12 shows that the amount of unconfined storage in 2018 is approximately 71.6 million acre-feet (MAF). Unconfined storage, in this case, is being defined as water that is not under a coefficient of compressibility within the aquifer; when this water is removed from the aquifer it actively lowers the water table and drains the aquifer – it does not necessarily mean that confining units do not exist above and below the aquifer.

The estimated 71.6 MAF of unconfined storage is consistent with 467 MAF of total storage and 269 MAF of recoverable storage in all Denver Basin aquifers previously estimated by the USGS (MWE, Robson, 1987, p. 18). It is then assumed that only 75% of unconfined storage is physically recoverable, resulting in a total of approximately 54 MAF of recoverable storage underlying Elbert County in the Denver Basin aquifers.

The same process was repeated for the Northwest and Elizabeth-Kiowa Planning Areas. These calculations resulted in approximately 5.1 MAF of recoverable storage underlying the Northwest Planning Area and 10.9 MAF of recoverable storage underlying the Elizabeth-Kiowa Planning Area.

For further details on the storage analysis see Memorandum titled “Tasks 1 and 2 – Elbert County Groundwater Supply and USGS Modeling” from McGrane Water Engineers in Appendix A.

Table 3-12
Estimates of Recoverable Storage of Denver Basin Groundwater Underlying Elbert County and two of the Planning Areas

Recoverable Storage Estimates in Acre-Feet			
Year	County Wide	Northwest Planning Area	Elizabeth-Kiowa Planning Area
Confined	300,842	43,417	87,705
Unconfined	71,648,530	7,163,878	14,406,871
Total	71,949,373	7,207,295	14,494,576
Total Recoverable (75% of Unconfined)	54,037,240	5,416,326	10,892,858

3.4.2 Future Remaining Storage

Using the storage values shown in Table 3-12, a simple analysis to estimate the future remaining storage was performed in order to gain an understanding of the future available supply remaining to Elbert County residents.

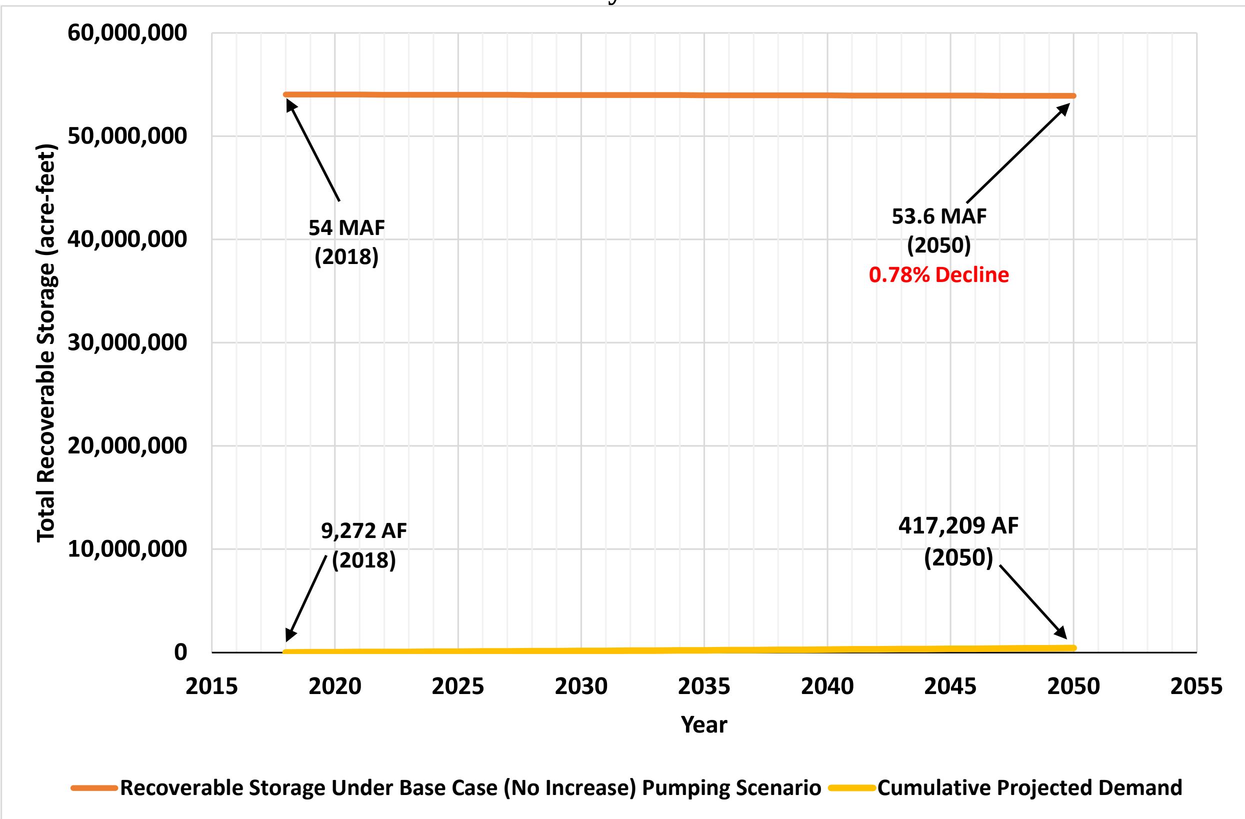
Remaining storage estimates for the years 2035 and 2050 were made by subtracting annual cumulative demand from the recoverable storage estimates for 2018 year-by-year out to the year 2050 (see Figure 3-2). By then, Elbert County will see a reduction of available Denver Basin groundwater from 54 MAF to approximately 53.6 MAF; a loss of only 0.78 percent (see Table 3-13).

Based purely on this volume analysis, Denver Basin groundwater should provide an adequate supply for Elbert County well beyond 2050. However, this analysis does not account for the effects of pumping from neighboring counties or communities, nor does it account for inter-aquifer flow or recharge. Continued heavy pumping of Denver Basin groundwater throughout the region will continue to lower the pressure head in the aquifers, ultimately affecting the economic productivity of Denver Basin wells to some degree. The timing and extent to which particular wells will no longer be economically usable is difficult to predict.

Table 3-13
Remaining Recoverable Denver Basin Storage Volumes through 2050

Year	Elbert County Total Demand (AF)	Elbert County Cumulative Annual Demand (AF)	Elbert County Total Recoverable Water Volume (AF)
2018	9,466	9,466	54,036,000
2035	13,389	208,996	53,836,508
2050	15,737	429,090	53,616,984
		Total Change	**-0.78%**

Figure 3-2
Estimated Recoverable Storage for Elbert County Plotted with Cumulative Demand for Elbert County for 2018-2050



CHAPTER 4
WATER RESOURCE OPTIONS

4.1 GENERAL

Chapter 4 outlines the options for Elbert County to consider in water resource planning through the year 2050. The options point to making efficient use of current supplies and possibly, supplementing Denver Basin groundwater with renewable water. These options include: importing renewable water from outside the county, reusing water, and transferring water use from agriculture.

The above options were discussed in workshops with the BOCC. The alternatives evaluation (Section 4.3) reviews three scenarios that incorporate the water resource supply options selected for evaluation. While these options are considered on a countywide basis, they will be evaluated in more detail for the planning areas. The majority of the population and therefore, water demand, exists and is projected to increase the most in the Northwest and Elizabeth-Kiowa Planning Areas.

This chapter also addresses options to help maximize the efficient use of the county's water supplies. These options were not quantified as a part of the alternatives evaluation, but should be considered. They are:

1. Storage
    a. Aquifer Storage and Recovery (ASR), either in the Denver Basin or alluvial aquifers
    b. Surface Storage (Reservoirs)
2. Reuse Water Systems
3. Conservation/Efficiency Practices

4.2 WATER SUPPLY OPTIONS

4.2.1 Renewable Water Import

Water could be imported from renewable supplies sourced from the South Platte or Arkansas River basins via participation in regional partnerships, collaboration with water providers outside of Elbert County, and/or water rights purchases and transfers. This option requires extensive infrastructure and funding.

4.2.2 Reuse

Reuse can involve everything from reusing water for augmentation supplies, irrigation, storage, indirect, or even direct reuse. Reuse broadly refers to using water after its first use and after it has been treated in a wastewater treatment facility. Utilizing this water involves the construction of sanitary sewer systems, typically in more densely populated areas for which such systems are economically feasible. Reuse systems operate by reclaiming treated wastewater flows, often from a point downstream of treatment plant discharges. This process has the natural effect of improving water quality through river bank and alluvial filtration. After the water is reclaimed within a flowing stream it undergoes further treatment to the point where it can be blended with the potable supply, or used for irrigation. Water could also be left in the river to meet augmentation requirements for alluvial groundwater wells.

4.2.3 Agricultural Transfer

As development and growth in Elbert County progresses, water that was used for farming and irrigation prior to development can then be used for municipal supply. This, however, is water that would continue to be sourced from the Denver Basin and alluvial aquifers within the county.

4.3 ALTERNATIVES EVALUATION

This section presents the alternatives that were screened for closer evaluation. These alternatives focus on how the demand structure could be changed for **residential and commercial demand** in the planning areas by increasing water reuse, accounting for agricultural transfer, and considering varying degrees of import of renewable water. Again, only the Northwest and Elizabeth-Kiowa planning areas will be the focus for renewable water – the Eastern Planning area is of low projected demand and would be served much more cost effectively from local supplies.

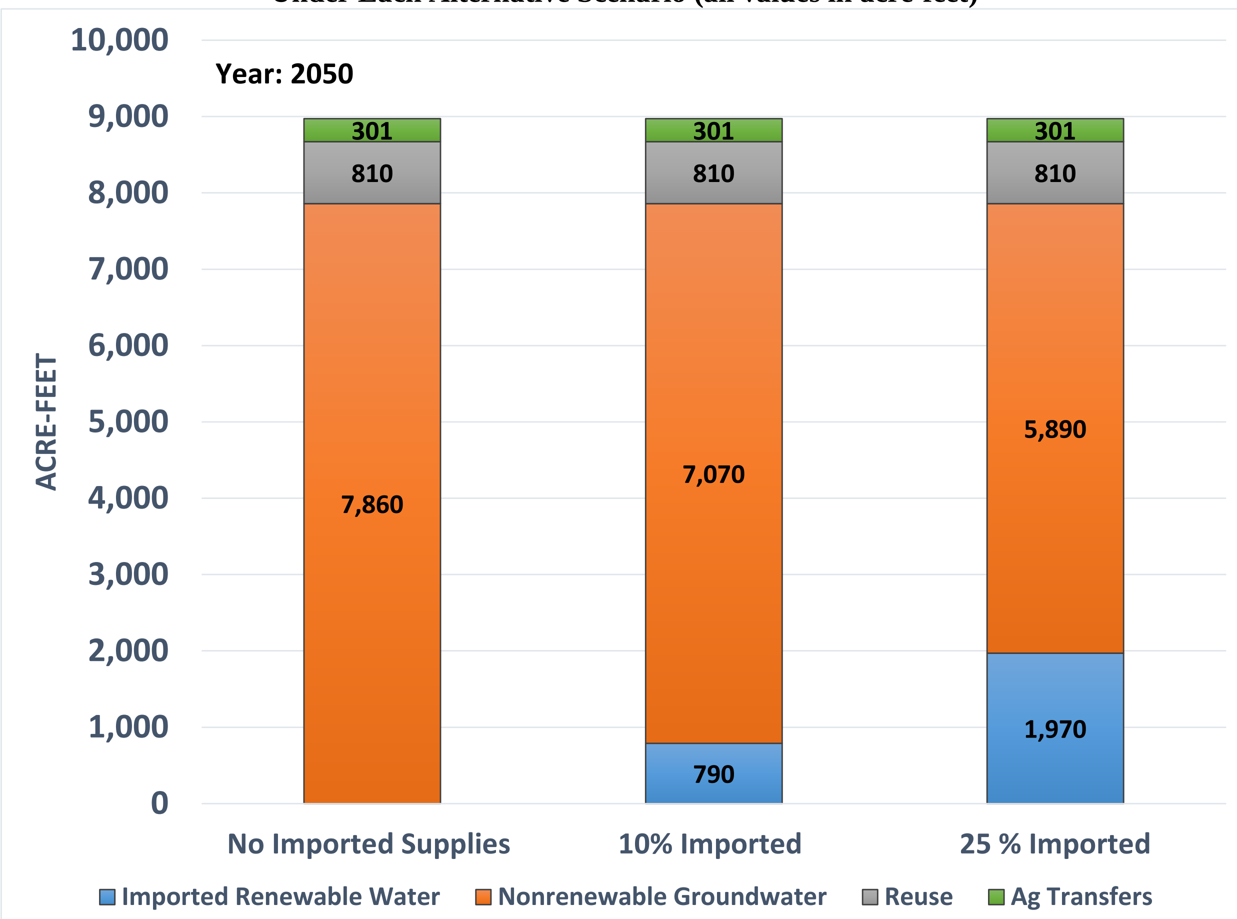
The overall average **residential and commercial** water demand for the three planning areas in the year 2050 is estimated to be 9,005 AF; the Northwest and Elizabeth-Kiowa Planning Areas total 8,971 AF. Each scenario outlines how this demand can be met. From this information, flow rates are estimated on an average basis for Import, Reuse, and Agricultural Transfer. These values will allow the sizing of the infrastructure necessary to convey water under each alternative scenario. This includes sizing components such as: water treatment plants, raw water piping, reuse water piping, pump stations, and staging reservoirs (see Chapter 5 for details). The demands and flow rates for each water supply option under each scenario in the year 2050 are discussed and presented below (see Figure 4-1). The alternatives are:

1. **No Renewable Water Import**: Continued use of groundwater, with increased reuse and accounting for a portion of agricultural transfer meeting some water demand.

2. **10% Renewable Water Import**: 10% of the groundwater demand is replaced by renewable water import from outside the county, with the same level of reuse and agricultural transfer.

3. **25% Renewable Water Import**: 25% of the groundwater demand is now replaced by renewable water import from outside the county, with the same level of reuse and agricultural transfer.

Figure 4-1
Graph of Total Residential and Commercial Demands for the EK and NW Planning Areas in 2050 Under Each Alternative Scenario (all values in acre-feet)



4.3.1 Scenario 1: No Renewable Water Import

The "No Import" scenario does not include any imported renewable water supplies. Reuse and potential agricultural transfers will be the only inputs to the water supply alternatives under this scenario. Otherwise, all residential water demand will continue to be met with Denver Basin groundwater (see Table 4-1).

Table 4-1 - Values for Scenario 1 "No Import" By Planning Area

Water Supply Alternatives: 0% Import	Elizabeth-Kiowa			Northwest			Eastern		
	AFY	GPM	MGD	AFY	GPM	MGD	AFY	GPM	MGD
Imported Renewable Water	0	0	0.00	0	0	0.00	-	-	-
Nonrenewable Groundwater	4,715	2,923	4.21	3,150	1,953	2.81	36	22	0.03
Reuse	487	302	0.43	320	199	0.29	3	2	0.003
Ag Transfers	209	130	0.19	92	57	0.08	-	-	-
Total	**5,411**	**3,355**	**4.83**	**3,562**	**2,208**	**3.18**	**-**	**-**	**-**

Note: Totals may differ slightly from Figure 4-1 due to rounding.

4.3.2 Scenario 2: 10% Renewable Water Import

The 10% Import scenario (Scenario 2) incorporates renewable water into the water supply alternatives. This fraction of import water represents 10% of the residential water demand not met by reuse and agricultural transfer water, not 10% of the total residential demand (see Table 4-2).

Table 4-2 - Values for 10% Import by Planning Area

Water Supply Alternatives: 10% Import	Elizabeth-Kiowa			Northwest			Eastern		
	AFY	GPM	MGD	AFY	GPM	MGD	AFY	GPM	MGD
Imported Renewable Water	470	291	0.42	310	192	0.28	-	-	-
Nonrenewable Groundwater	4,245	2,632	3.79	2,840	1,761	2.54	36	22	0.03
Reuse	487	302	0.43	320	199	0.29	3	2	0.003
Ag Transfers	209	130	0.19	92	57	0.08	-	-	-
Total	**5,411**	**3,355**	**4.83**	**3,562**	**2,208**	**3.18**	**-**	**-**	**-**

Note: Totals may differ slightly from Figure 4-1 due to rounding.

4.3.3 Scenario 3: 25% Renewable Water Import

The 25% Import scenario (Scenario 3) is similar to Scenario 2, only the renewable water import volume is 25% of the residential and commercial demand not met by reuse and agricultural transfer (see Table 4-3).

Table 4-3 - Values for 25% Import by Planning Area

Water SupplyAlternatives 25%	Elizabeth-Kiowa			Northwest			Eastern		
	AFY	GPM	MGD	AFY	GPM	MGD	AFY	GPM	MGD
Imported Renewable Water	1,180	732	1.05	790	490	0.71	-	-	-
Nonrenewable Groundwater	3,535	2,192	3.16	2,360	1,463	2.11	36	22	0.03
Reuse	487	302	0.43	320	199	0.29	3	2	0.003
Ag Transfers	209	130	0.19	92	57	0.08	-	-	-
Total	**5,411**	**3,355**	**4.83**	**3,562**	**2,208**	**3.18**	**-**	**-**	**-**

Note: Totals may differ slightly from Figure 4-1 due to rounding.

4.4 OTHER MANAGEMENT PRACTICES

There are other initiatives that the County can encourage or pursue to extend the life of its Denver Basin supplies. These options were not quantified, but nonetheless are valuable options in managing water supplies wisely and efficiently. These include:

1. Storage
    a. Aquifer Storage and Recovery (ASR)
    b. Surface Water Storage
2. Reuse Water Systems
3. Conservation and Efficiency Practices

4.4.1 Storage

(a) Aquifer Storage and Recovery

ASR involves the underground storage of water in aquifers for later use. This practice is a trend that is gaining popularity, particularly in semi-arid states like Colorado. ASR is regarded as a more effective method of water storage due to the elimination of losses from evaporation and seepage. For this option, renewable or reclaimed water could be recharged to an alluvial aquifer, or pumped into bedrock aquifers to extend their life, storing the water as needed.

ASR in Colorado is more commonly used for storage in nontributary confined aquifers, and this has been successfully accomplished in Highlands Ranch for many years. It can also be used for alluvial aquifers and, in that case, it may be advisable to confine the storage volume with underground slurry walls to prevent the migration of stored water back to surface waters.

The rules for ASR in Colorado are still being refined. However, the long-standing practice of ASR in Denver Basin aquifers is well established, and requires injected water to meet drinking water standards. Recharge occurring to alluvial groundwater typically requires compliance with groundwater standards. As the State Engineers Office continues to expand their rulemaking, allowing for ASR to take place in certain areas, this practice will hopefully become easier to accomplish from an administrative standpoint.

ASR is a promising water management strategy that should be evaluated further as the county continues to plan for its water future.

(b) Surface Water Storage

Surface water storage is an important management strategy as well. It allows for seasonal capture of renewable water, year-round storage for reuse water, and helps to provide a buffer in times of drought.

New storage facilities were not explored for this Study. Given the relatively low water demands of Elbert County, the proximity to regional water supply reservoirs, and the extreme cost and complexity of permitting and constructing reservoirs, the construction of new surface storage does not currently appear to be the most practical investment.

Rather, if water providers in Elbert County were to consider participation in regional projects, such as the South Metro Water Supply Authority's Water Infrastructure and Supply Efficiency (WISE) partnership, storage in a regional reservoir could be considered at that point.

Such participation would go hand-in-hand with the import option stated in section 4.2.1. For the purposes of this Study, it will be assumed that Elbert County would join a regional project such as WISE for its renewable water supply alternatives. This option could conceptually include storage in Reuter-Hess reservoir – that will be assumed for strictly for purposes of developing conceptual infrastructure costs, but is just one of several possibilities.

4.4.2 Reuse Water Systems

Water reuse is an effective method of increasing the efficiency and conservation of a water supply. By utilizing nonpotable reuse water to irrigate or serve industrial needs that otherwise would have been served by potable water, water providers and municipalities can stretch their supplies further. Reuse can also be integrated into potable supplies, typically after higher-level treatment and an environmental buffer such as a lake, river, or aquifer. Reuse of treated wastewater is included as part of the future water supply scenarios, but is also an efficient practice to extend the life of existing supplies.

Nonpotable systems that effectively recycle treated wastewater effluent should be considered as new development continues in the county. Nonpotable water systems can potentially be constructed in combination with indirect potable reuse systems as described in Section 4.2.2.

4.4.3 Conservation Practices

There are multiple conservation practices that can lead to substantial water savings and should be a priority for all districts and municipalities. Things such as:

- Xeric landscaping and proper soil preparation

- Efficient fixtures such as showerheads and toilets
- Smart irrigation practices
- Increasing block rates for water sales
- Distribution system leak repair
- Water audits and surveys
- Public information and education on water use

Although each of these practices can provide some benefit, many Front Range water providers have implemented increasing block rates since the 2002-2003 drought, and found this to be a very effective means of promoting water conservation.

CHAPTER 5
COST BENEFIT ANALYSIS

5.1 GENERAL

Costs to implement the alternatives presented in Chapter 4 have been estimated to determine what will be most cost effective. Costs were estimated for each category of water supply using the volumes and rates estimated for each alternative (Scenarios 1-3). These volumes and rates, combined with the locations of sources and demands, were used to estimate water rights costs, conceptually size the infrastructure needed to convey the water, and project pumping costs associated with continued use of Denver Basin groundwater. See Table 5-1 on the next page, and Map 5-1 at the end of this chapter for conceptual infrastructure sizing and plans for the Northwest and Elizabeth-Kiowa Planning Areas.

5.2 COST COMPONENTS

The components that comprise the cost estimates associated with the supply alternatives include: infrastructure capital costs, operations and maintenance (O&M) of the facilities, and the purchase of water rights and/or agricultural transfer water.

5.2.1 Infrastructure

To conceptually size the infrastructure for each alternative, the estimated flows as calculated for the 0, 10%, and 25% Import Alternatives under 2050 demands were used (See Section 4.3). Generally, the highest expected flows are used for a design basis. The demands for each type of water supply alternative require different infrastructure as described below:

- **Import:** Requires diversion structures and water transmission pipelines that would utilize pump stations to convey raw water to demand areas in either the Northwest or Elizabeth-Kiowa Planning areas. Portions of this pipe would need to be sized at the combined demand of both the planning areas. Reuse volumes are taken into account for sizing where reuse water would also be conveyed by these lines. Renewable water would most likely be conveyed from a large reservoir in the region, pursuant to participation in a regional partnership with a water provider(s) outside of Elbert County. Both Aurora and Rueter-Hess Reservoirs are located within 10 miles of Elbert County. The costs for renewable water import are based on conveyance from Rueter-Hess Reservoir, strictly for the purpose of conceptually estimating the cost of renewable water import; there are no plans to store water for Elbert County there, or in any other reservoir.

- **Reuse:** Requires waterlines sized at the estimated reuse flow rates that convey recaptured water to treatment facilities.

Financing, designing, and constructing such infrastructure should be expected to take an extended length of time. For the purposes of this report, it is assumed that the Elizabeth-Kiowa Planning Area reuse will not come online until 2027 and Northwest Planning Area reuse will not come online until 2032. This is also a function of the fact that there needs to be enough water use/demand in order for there to be a reliable supply of available reuse water – therefore it is a function of current and expected growth. Due to the complexity associated with importing renewable water from sources outside the county and the infrastructure required to convey it to demand centers within the county, it is assumed that renewable water import does not come online until the year 2035.

Table 5-1
Minimum Necessary Infrastructure for the Alternatives

Item / Description	Unit	Quantity	0% Import Scenario Sizes	10% Import Scenario Sizes	25% Import Scenario Sizes
Raw Water Pump Station 1 - Import	LS	1	0 MGD	0.7 MGD	1.76 MGD
Raw Water Pump Station 2 - Import	LS	1	0 MGD	0.42 MGD	1.05 MGD
Northwest Planning Area					
Reuse Pipe - NW Area	LF	43,400	6"	6"	6"
WTP 1 - NW Area	LS	1	0.29	0.57 MGD	1.0 MGD
Import Pipe 1A	LF	62,800	N/A	10"	10"
Import Pipe 1B	LF	8,600	N/A	6"	8"
Operational Storage Reservoir 1	LS	1	N/A	2 MG	2 MG
Reuse Pump Station No. 1	LS	1	0.29 MGD	0.29 MGD	0.29 MGD
Elizabeth-Kiowa Planning Area					
Reuse Pipe - Elizabeth	LF	9,500	8"	8"	8"
Reuse Pump Station #2	LS	1	0.43 MGD	0.43 MGD	0.43 MGD
WTP 2 - Elizabeth	LS	1	0.43 MGD	0.85 MGD	1.48 MGD
Import Pipe 2	LF	26,300	N/A	6"	8"
Operational Storage Reservoir 2	LS	1	N/A	3 MG	4.5 MG

5.2.2 Operations and Maintenance (O&M) Costs

Infrastructure for each alternative requires consideration of operations and maintenance costs, particularly for pump stations and water treatment plants. These costs are estimated using average values of similar facilities; these values are:

- O&M Costs for Water Treatment Plants: $1.00 per kgal per year
- O&M Costs for Pump Stations: $0.35 per kgal per year

These costs would begin the year that these facilities are completed and expected to come online. Therefore pump stations for the renewable water import will not incur costs until 2035. Similarly, for reuse facilities in each planning area; the Northwest Planning Area begins O&M costs in 2027 and the Elizabeth-Kiowa Planning Area begins O&M costs for reuse in 2032.

5.2.3 Water Rights

It is assumed that any renewable water supplies obtained through the purchase of water rights in the South Platte or Arkansas River basins would cost approximately $15,000/AF plus some engineering and legal fees**.**

5.2.4 Agricultural Transfer

For Elbert County, agricultural transfer water would be in the form of Designated Basin alluvial groundwater or Denver Basin groundwater, not surface water supplies. Based on transactions reviewed in Upper Black Squirrel Designated Basin this water is assumed to cost $7,000/AF plus some engineering and legal fees**.**

5.2.5 Groundwater Pumping Costs

Groundwater pumping costs are the costs associated with the continued use of Denver Basin groundwater. This will change with each scenario, based on the volume of renewable import water and reuse water replacing groundwater pumping needs, using a prototypical well analysis.

Prototypical Well Analysis

The prototypical well analysis uses average aquifer well depths, water demand and aquifer parameters in a cost model developed for each of the planning areas. The demand is driven by population growth which drives the number of wells. New wells were distributed to the various aquifers according to the current ratio of people per well per aquifer obtained from the State's well database. The number of wells drives the direct capital costs (wells and pumps). The number of pumps drives the operations costs which include pump replacement costs and electrical power. The total cost for each alternative is the sum of capital and operations costs for each prototypical well multiplied by the number of future wells, which vary in depth by aquifer.

Average physical aquifer characteristics were extracted from the USGS (2011) groundwater model including:

- Ground elevation;
- Aquifer bottom (assumed to represent new well depths);
- 2018 and 2053 water level elevation (used to estimate regional water level decline rates); and
- Aquifer characteristics: sand thickness, transmissivity - measure of permeability multiplied by the sand thickness - and confined and unconfined storage properties.

Costs for well drilling and completion, pumping systems (including wellhead appurtenances), and power costs are based on interviews with domestic and municipal drillers and pump installers (Heir Drilling in Castle Rock, and Layne-Christensen in Aurora). The comparative economic analysis calculates the Net Present Value (NPV) of totaled annual direct costs from 2018 to 2050 (32 years) assuming annual inflation rates and a discount rates of 2 percent.

The results of the prototypical well analysis are shown for each scenario in Tables 5-2 through 5-4 in section 5.4. As expected, well costs decreased with less reliance on Denver Basin groundwater primarily via an increase in imported renewable water. An extensive memorandum explaining the prototypical well analysis and cost model is found in Appendix B titled “Task 3 – Prototypical Well Analysis Detail” by McGrane Water Engineers.

5.3 ALTERNATIVES COST SUMMARY

The sum of all the costs under each scenario are presented here. For detailed cost tables, see Appendix D. The dollars are reported in Net Present Value (NPV). For NPV an inflation and discount rate of 2% was used.

5.3.1 Scenario 1 (No Renewable Water Import)

Scenario 1 has no renewable water import, but does contain reuse and agricultural transfer water as new sources. Total costs are summarized in Table 5-2.

Table 5-2
Scenario 1 Total Cost Through the Year 2050

Item / Description	Total Cost (2017 $)
Agricultural Water Rights Transfer	$6,000,000
Indirect Potable Reuse Systems	
Project Costs	$32,000,000
O&M Costs	$ 11,000,000
Renewable Water Import	
Project Costs	$ -
O&M Costs	$ -
Groundwater Pumping Cost (2017-2050)	$429,000,000
Total Cost	**$478,000,000**

5.3.2 Scenario 2 (10% Renewable Water Import)

Scenario 2 differs from Scenario 1 in that 10% of the groundwater pumping is replaced with renewable water supplies. Scenario 2 costs are summarized in Table 5-3.

Table 5-3
Scenario 2 Total Cost Through the Year 2050

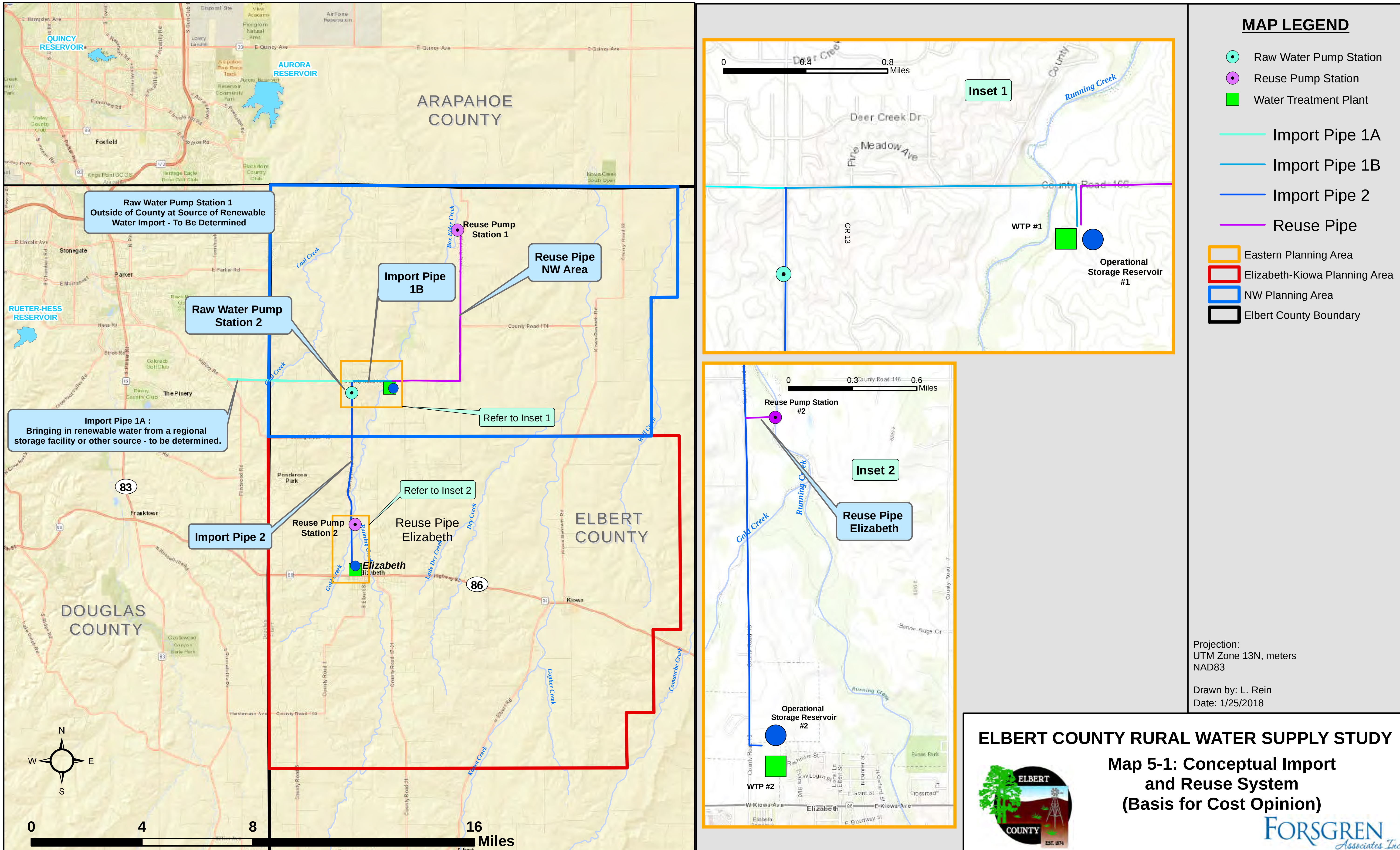
Item / Description	Total Cost (2017 $)
Agricultural Water Rights Transfer	$ 6,000,000
Indirect Potable Reuse Systems	
Project Costs	$ 32,000,000
O&M Costs	$ 11,000,000
Renewable Water Import (Q = 0.7 MGD)	
Project Costs	$ 34,000,000
O&M Costs	$ 2,000,000
Groundwater Pumping Cost (2017-2050)	$389,000,000
Total Cost	**$474,000,000**

5.3.3 Scenario 3 (25% Renewable Water Supply)

Scenario 3, is similar to Scenario 2, only differing from Scenario 1 in that 25% of groundwater demand is replaced by renewable water. Note that while the costs for indirect potable reuse systems increased in Scenario 3, the volumes of reuse water did not. The increase in cost is due to upsizing the treatment plants to treat raw renewable water. Therefore, an increase in renewable water import results in an increase in water treatment plant size, and operations and maintenance cost per thousand gallons of water. Scenario 3 costs are summarized in Table 5-4.

Table 5-4
Scenario 3 Total Cost Through the Year 2050

Item / Description	Total Cost (2017 $)
Agricultural Water Rights Transfer	$ 6,000,000
Indirect Potable Reuse Systems	
Project Costs	$ 44,000,000
O&M Costs	$ 17,000,000
Renewable Water Import (Q = 1.76 MGD)	
Project Costs	$62,000,000
O&M Costs	$ 5,000,000
Groundwater Pumping Cost (2017-2050)	$324,000,000
Total Cost	**$458,000,000**



Projection:
UTM Zone 13N, meters
NAD83

Drawn by: L. Rein
Date: 1/25/2018

ELBERT COUNTY RURAL WATER SUPPLY STUDY

Map 5-1: Conceptual Import and Reuse System (Basis for Cost Opinion)

FORSGREN Associates Inc.

CHAPTER 6
SUMMARY AND RECOMMENDATIONS

6.1 GENERAL

From the analysis provided in this report, Elbert County has adequate Denver Basin groundwater supplies to last well beyond 2050, considering the county as a whole. It is important, however, to continue monitoring well levels, plan for the possible need to import renewable water at some point, and to promote conservation and increased efficiency. This is particularly true as local geological variations in the Denver Basin aquifers could limit economical well production in some areas of the county sooner than others.

6.2 SUMMARY AND CONCLUSIONS

While the modeling performed for this report shows that there is more than adequate overall supply in volume of water available in the Denver Basin underlying the county, there are several important factors to consider:

- Future Denver Basin pumping from neighboring counties and population centers is difficult to project, and may lead to more significant drawdowns than estimated

- While there is adequate supply in all of the aquifers through the year 2050, local variations in geology and aquifer depth mean that some wells could experience significant water level declines before others

- The prototypical well analysis, while accounting for water level changes, does not show at what point groundwater pumping becomes uneconomical for specific users

The state's goals as outlined in Colorado's Water Plan point to increasing efficiencies, conservation, and pursuing smart storage projects. As a county within a semi-arid state with water supplies that are stretched thin, Elbert County is an integral component in a larger statewide effort in smart water planning.

Elbert County has implemented rules in the past with the goal of lengthening the life of the aquifers. DWR rules allow for development of Denver Basin groundwater based on an assumed 100-year life. The estimated total volume of groundwater by aquifer beneath a property is divided by 100 to establish the annual pumping volume allowed from each aquifer. Neighboring Douglas and Arapahoe Counties use this DWR rule for new development. Like El Paso County however, Elbert County has implemented a more onerous 300-year rule, meaning that a particular property can only support one-third the density that would be allowed under the 100-year rule.

Although the 300-year rule may have been intended to reduce the draw on Denver Basin groundwater and promote development of renewable supplies, it has had the effect of promoting more dispersed development in unincorporated Elbert County. While such a development pattern appears to be compatible with the county's rural character, it is not conducive to the centralized water services or possibly, wastewater collection for reuse that would make for more efficient use of water resources over the long term. If production from domestic wells is lost due to localized aquifer declines, retrofitting dispersed development areas with centralized water service will either be very costly or not economically feasible. Property values could be affected, particularly if homeowners must resort to hauling water and using cisterns. Dispersed development, in general, makes for more costly infrastructure and maintenance on a per home basis.

6.3 QUALITATIVE BENEFITS

The qualitative benefits to be achieved by pursuing increased efficiencies, conservation, and smart water storage for renewable water, thereby lessening dependence on the Denver Basin include:

- Saves Denver Basin Water for dry years and extended droughts

- Renewable water supply and infrastructure systems, as shown in this report, become the more cost-effective option for the long term.

6.4 COST BENEFITS

According to the cost benefit analysis, Scenarios 1 (No Import) and 2 (10% Import) are essentially the same cost within the margin of error at this level of conceptual analysis. Scenario 3 (25% Import) is slightly more cost effective, saving less than 5 percent compared to Scenarios 1 and 2 on a net present value basis over the long-term planning period (see Table 6-1). Despite the high cost of renewable water infrastructure and development, these costs could ultimately offset the increasing costs of groundwater pumping. Costs can be expected to increase with continued groundwater pumping, as more Denver Basin wells will be required over time even to maintain production as aquifers decline.

Table 6-1 - Summary of Alternatives Costs

Alternative	Groundwater Pumping	Renewable Water & Reuse	Total Cost
Scenario 1 (No Import)	$429M	$49M	$478M
Scenario 2 (10% Import)	$389M	$85M	$474M
Scenario 3 (25% Import)	$324M	$134M	$458M

6.5 MANAGEMENT AND OVERSIGHT

Renewable water import will require extensive collaboration and financing to develop. The municipalities and special districts would need to share the vision and commitment to develop a single system. This presents a significant political and institutional hurdle. They may also be able to join in on a larger regional scale to partner on projects such as the

WISE (Water Infrastructure and Supply Efficiency) Partnership with the South Metro Water Supply Authority (SMWSA).

6.5.1 Regional System

The WISE partnership consists of 10 of SMWSA's 13 members that have formed the South Metro WISE Authority. They include: Centennial Water and Sanitation District, Cottonwood Water and Sanitation District, Dominion Water and Sanitation District, Inverness Water and Sanitation District, Meridian Metropolitan District, Parker Water and Sanitation District, Pinery Water and Wastewater District, Rangeview Metropolitan District, Stonegate Village Metropolitan District, and the Town of Castle Rock.

Many of the WISE members are similar to Elbert County water users in that they have a heavy reliance on Denver Basin groundwater. The WISE project seeks to deliver more renewable South Platte Basin water supplies to these water providers in an effort to create a more sustainable long-term water supply future.

It is projects such as this that Elbert County water providers should seek to contribute to and partner with. Elbert County itself could help facilitate such participation, or work towards developing similar plans for water supply projects apart from SMWSA.

6.5.2 Formation of Management Districts

Special districts already exist in Elbert County, although their numbers are limited. As the population increases and demand centers begin to develop, more special districts will likely be formed. These districts create an efficient means of funding infrastructure for water supply and wastewater treatment. But, they should be developed around a common plan for long-term water supply.

As the water needs of the county become larger and more difficult to manage with time, these districts could potentially form a water authority, similar to SMWSA or the Pikes Peak Regional Water Authority (PPRWA) in the Colorado Springs area. Such an authority would work to coordinate the efforts of the districts in order to help efficiently work together in reaching common, regional, water supply goals.

6.5.3 Funding

Funding for projects that include renewable water supply in the county and increased reuse systems would have to largely come from municipal and special district financing. However, the Colorado Water Conservation Board (CWCB) has sources of funding through multiple grants and loans specifically for water related projects. Below is a list of some of the grants offered through the CWCB that would have relevance to the water supply alternatives for Elbert County.

A. Colorado's Water Plan Grants

- Provides financial assistance to make progress on the CWP's Measurable Objectives or critical actions. Current funding levels are shown, but will vary year to year.
  - Supply and Demand Gap Projects ($2 M available)
  - Water Storage Projects ($3 M available)
  - Conservation, Land Use Planning ($1 M available)
  - Engagement and Innovation Activities ($1 M available)
  - Agricultural Projects ($1 M available)
  - Environmental and Recreational Projects ($1 M available)

B. Water Efficiency Grants

- Provides financial assistance to communities, water providers and eligible agencies for water conservation-related activities and projects.
  - Water Conservation Planning Grants
  - Water Conservation Implementation Grants
  - Drought Mitigation Planning Grants
  - Water Resource Conservation Public Education and Outreach Grants

C. Water Supply Reserve Account

- Provides grants and loans to assist Colorado water users in addressing their critical water supply issues and interests. The funds help eligible entities complete water activities, which may include competitive grants for (requests for these funds must be approved by at least one of Colorado's nine basin roundtables):
  - Technical assistance regarding permitting, feasibility studies and environmental compliance;
  - Studies or analysis of structural, nonstructural, consumptive and nonconsumptive water needs, projects or activities; and
  - Structural and nonstructural water projects or activities.

D. Severance Tax Trust Fund Operational Account Grants

- Provides grants for regional water resource planning studies and associated demonstration projects.

- The funds from the Account can be used for a study or demonstration project that will benefit a wide range of people and organizations, and/or a large geographic area within Colorado. Approved grants must be able to begin the project 6 months after the application date and complete the project within 12 months.

6.6 RECOMMENDATIONS

1. Although the total volume of Denver Basin groundwater can sustain Elbert County well beyond 2050, the aquifers are expected to continue to decline. Some areas may experience more rapid declines than others, depending on the aquifer. The USGS recently completed a three-year well monitoring program that provides data on pressure levels in the aquifers from over 30 Denver Basin wells. The County is extending the monitoring program, but should make this a permanent function and continue to monitor these aquifers indefinitely. More wells could be added to the program in particular areas of interest, such as areas where higher drawdowns are occurring, or along the northern and western county lines. In addition, the County should update this Rural Water Supply Study every five to ten years to reassess its position with respect to water supplies as conditions change.

2. Denver Basin groundwater should be preserved as much as practicable through water conservation and efficiency, extending the economically useful life of the aquifers. Front Range water providers have found that tiered water rates in which higher usages are charged at escalating unit costs, are the most effective means of promoting conservation. The County should incentivize central water systems to develop such rate structures.

3. Denver Basin water can be preserved further if a portion of future demands is met by water reuse. Reuse requires sanitary sewer systems to collect wastewater for centralized treatment. The water can then either be distributed to irrigation sites (possibly even individual residences, depending on the level of treatment) or returned to blend with a potable water supply (normally, after first passing through an environmental buffer such as a lake, river, or aquifer). This also points to the need for a service provider to collect wastewater for treatment and reuse.

4. Centralized water service, and possibly sewer service followed by reuse, are only economically practicable for denser developments due to the costs of constructing and maintaining those piping networks. The County should consider incentivizing denser developments that use centralized water and sewer systems.

5. The majority of domestic water wells are completed in the Upper and Lower Dawson formations, although the deeper Denver and Arapahoe aquifers generally offer higher production. It would be beneficial to incentivize central water systems for new

developments that use the Denver and Arapahoe aquifers, rather than the Dawson, thus leaving the shallower aquifers for the more dispersed domestic well users.

6. The County's 300-year rule for new development using Denver Basin groundwater promotes dispersed development on 5- and 10-acre ranchettes vs. subdivisions served by a water distribution system. It will be cost-prohibitive to extend water mains to dispersed development, so those acreages will likely need to continue on Denver Basin groundwater. Denser development served by water mains from a central well system will be easier to convert to renewable water if needed. Such development also allows for cost-effective wastewater collection, allowing reuse to offset a portion of future water supply needs. The County should consider allowing variances to the 300-year rule as an incentive for developers that commit to "best practices" which may include: (1) producing water only from the deeper aquifers for centralized distribution; (2) promoting conservation and efficiency through a tiered rate structure; (3) collecting wastewater for treatment and reuse to offset a portion of demand; and (4) adopting water efficient landscaping standards.

7. The cost analysis shows the economy of meeting a portion of future demand with imported renewable supplies to offset 25 percent of projected Denver Basin use in the key planning areas. However, financing, constructing, and then operating a water import system will require many years of planning and collaboration by Elbert County water providers, possibly with facilitation by the County. It will also require working with water providers and regional water partnerships outside of Elbert County. The County and/or its water providers should start engaging in regional water planning as soon as practicable. (The WISE project took more than 15 years to reach the point of water deliveries in Fall 2017.)

8. The County should evaluate storage options further; surface storage as well as recharge for storage in bedrock and alluvial aquifers. Storage will become more important as reuse and renewable water options are implemented.

9. The County could also make provisions for future renewable water delivery by identifying and securing transmission pipeline corridors and treatment plant sites. This could be part of the County's broader framework of water, wastewater, and reuse systems in the planned growth areas to guide future development. The County should develop a "water and wastewater master plan" to serve as a reference during the land-use planning process so that the County can fit each development into a coordinated system from a countywide perspective.

10. Localized zones of low well productivity, or along fringes of the aquifers may not be conducive to dense development, or it may be necessary to have water piped from satellite well fields located in more productive areas. Mapping of these low production zones by aquifer should be considered for referral in the land-use planning process.

Appendix A

MEMORANDUM

To: Will Koger, P.E. – Forsgren Associates
From: Dennis McGrane, P.E., C.P.G. - McGrane Water Engineering, llc.
Date: June 6, 2018
Project: Elbert County Rural Water Supply Study
Subject: Tasks 1 and 2 – Elbert County Groundwater Supply and USGS Modeling

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BACKGROUND

Forsgren and Associates (FA) was retained by Elbert County (County) to conduct a "Rural Water Supply Study." McGrane Water Engineeering, llc (MWE) was retained by FA to evaluate the groundwater source options and conduct the prototypical well economic analysis. This memo focuses on the County's Groundwater Supply and USGS Modeling. Topics include:

- Denver Basin aquifer hydrogeology;
- Aquifer well development;
- Water Quality;
- US Geological Survey modeling (Paschke, 2011) including predictions from predevelopment time (approximately 1885) to 2018 drawdown, and from 2018 to 2053;
- Aquifer Storage; and
- Sustainability

This memorandum provides input into our "Prototypical Well Analysis (MWE memorandum to FA dated June 6, 2018) which includes a cost comparison of three future groundwater demand alternatives for the Northwestern (NW) and Elizabeth-Kiowa (EK) study areas between 2018 and 2050. Most figures and appendices are provided at the end of the memo.

Study Areas

Our evaluation focuses on two planning areas within the County that were designated by FA. Figure 1 shows the location of all registered and completed wells within the county and the designated study areas. The Northwestern (NW) Study Area includes the northwest portion of the county in close proximity to the Town of Parker (Douglas County) an established groundwater pumper. The Elizabeth-Kiowa (EK) study area includes the west-central portion of the county that includes the towns of Elizabeth and Kiowa. Water levels in the EK study area are heavily influenced by groundwater pumping from the Town of Castle Rock; and the Eastern Study area includes a smaller area located west of Limon. We did not provide tabulated aquifer and water level data for the Eastern Study area because it does not contain any bedrock wells and the Laramie-Fox Hills (LFH) aquifer only viable bedrock aquifer and it only exists in the western portion of the eastern study area.

Previous Studies

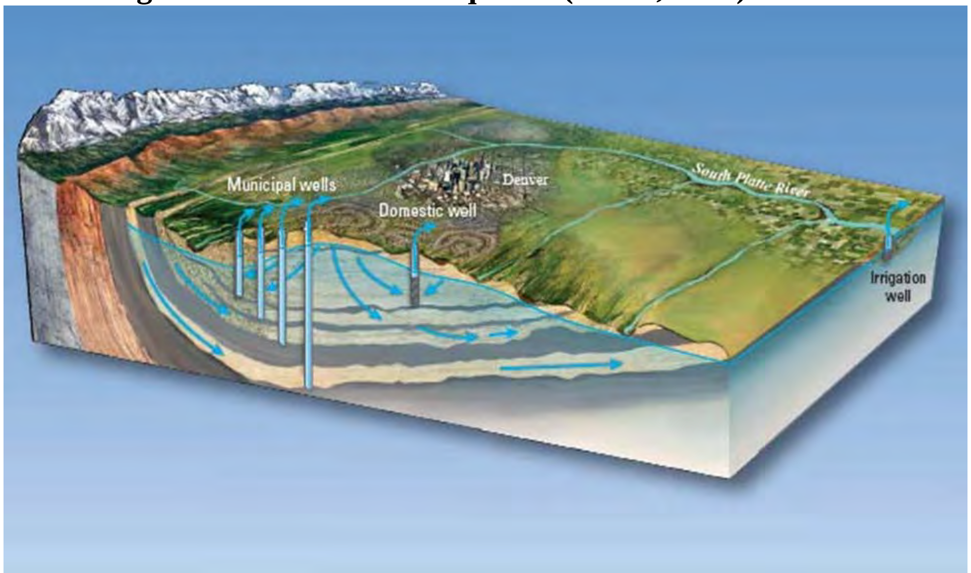
The Douglas County (DC) Rural Water Supply Study (CDM, 2013) was used as a general template for this study. Similar to the DC study, we also focused on evaluating designated "study areas." Unlike the DC study, we did not compare the USGS model results with observed water level monitoring by the Colorado Department of Water Resources (CDWR) because there is not a long record of monitoring within the county. We believe that short "snap-shots" of only a few wells often reflect local pumping conditions and do not represent regional trends. We relied extensively on the USGS, 2011 modeling of the entire Denver Basin which is centered around Elbert County. We feel the use of USGS model drawdown predictions for Elbert County provide a more moderate and realistic predictions of future hydrologic conditions.

HYDROGEOLOGY

Stratigraphy and Structure

Figure 2 is a block diagram for the southern portion of Denver Basin illustrating the shape of the geologic units located beneath Elbert County. In layman's terms, the Denver Basin is shaped like a giant bowl. As the center of the basin slowly sank over geologic millennia, the bowl was filled with a sequence of sand, silt, clay deposits that were compressed to form sedimentary rock. The west side of the bowl slopes steeply up against the uplifted Front Range, and the east side of the bowl slopes gently towards Nebraska and Kansas.

Figure 2 - Block Diagram of Denver Basin aquifers (USGS, 2011)



The uppermost sedimentary rock formations of the Denver Basin comprise the Denver Basin aquifers that include from top (youngest) to bottom (oldest) the following aquifers:

- Upper Dawson;
- Lower Dawson;
- Denver;

- Lower Arapahoe; and
- Laramie-Fox Hills (LFH).

Between the major sandstone units are lower permeability shale "aquitards" that limits vertical flow on a short time-scale but do allow quantifiable flow (using the USGS, 2011 model) over longer periods (decade scale), and on a regional basis. The Pierre Shale is a thick, low permeability unit below the LFH aquifer and it defines the lower limit of groundwater development within the Denver Basin. Figure 1 shows the outcrop locations of the aquifers based on geologic mapping and does not match precisely with the "administrative" top of aquifer used by the CDWR, but it is sufficiently accurate for the scale of this investigation.

Alluvial Aquifer

Alluvial sand, gravel, and clay deposits overlie the bedrock formations along major stream channels and these materials form an unconfined alluvial aquifer where saturated. In Elbert County, the more significant alluvial aquifers simulated in recent modeling by the Colorado Water Conservation Board (CWCB) as part of the South Platte Decision Support System (SPDSS) study (CDM, 2013) include alluvium (sand and gravel) beneath Wolf, Comanche, and West Bijou Creeks (tributaries to the South Platte River), and the Nussbaum alluvial aquifer in the southeastern portion of the county. The Nussbaum aquifer is in contact with the Big Sandy Creek alluvium on its northern border which is a tributary to the Arkansas River.

Aquifer Depth

Figures 3 – 9 show the contoured depth to the bottom of the various Denver Basin aquifer units within Elbert County. The aquifer depths were calculated by subtracting the bottom of aquifer altitude from the land surface elevation which is based on a 30-meter resolution digital elevation model [DEM], (U.S Geological Survey, 1999). The bottom of aquifer altitudes were originally derived from approximately 4,000 geophysical logs from the State's geophysical log database. Aquifer depths were used to estimate the costs of new well development in this study on a footage basis. Figure 3 shows the simulated alluvial depths in Wolf, Commanche, and West Bijou Creeks) are approximately 40, 100, and 140 feet deep respectively. The depth to the bottom of the Nussbaum aquifer is typically between 60 and 240 feet thick southeast of Simla. The alluvial aquifer beneath Big Sandy creek is approximately 60 to 80 feet deep in most areas. The alluvial Nussbaum and Big Sandy creek aquifers are the primary aquifers in the Eastern study area.

All five bedrock aquifer units are present in the western portion of the county. Figure 4 shows that the Upper Dawson outcrops at the surface in the western portion of the county and varies in depth from less than 100 feet near Kiowa to over 500 feet along the western county boundary. The Upper Dawson is not present in the eastern half of the NW study area or in the northeast portion of the EK study area. Large clusters of 200 to 500 deep Upper Dawson aquifer residential (domestic and household use) wells exist wherever the depth to the bottom is greater than 200 feet.

Figure 5 shows that the Lower Dawson outcrops in the eastern portion of the NW and EK study area (wells under 200 feet) and is deepest, beneath the Upper Dawson, in the western portion of the county. The Lower Dawson is not present in the northeastern half of the NW study area, but is present throughout the EK study area. It is over 800 feet deep in the southwestern portions of both the NW and EK study areas. Large clusters of 600 to 960 deep Lower Dawson aquifer residential wells exist around developments along the western and northwestern county lines, and near Elizabeth. In the EK study area, the Lower Dawson is nearly twice as deep near Elizabeth (600 to 700 feet deep) as it is near Kiowa (300 to 400 feet deep).

Figure 6 shows that the Denver aquifer is approximately 600 to 800 feet deep in the eastern portions of the NW and EK study areas and is 1,400 to over 1,600 feet deep along the western county line. Large clusters of 500 to 750 deep Denver aquifer residential wells exist near Elizabeth and around existing developments. Very few Denver aquifer wells exist east of the NW and EK study areas. In the EK study area, the Lower Dawson is nearly twice as deep near Elizabeth (600 to 700 feet deep) as it is near Kiowa (300 to 400 feet deep). The Lower Dawson is not present in the northeastern half of the NW study area, but is present throughout the EK study area.

Figure 7 shows that the Arapahoe aquifer is approximately 1,200 to 1,400 feet deep in the eastern portions of the NW and EK study areas, and 1,800 to over 2,200 feet deep along the western county line. Less than 10 domestic Arapahoe aquifer wells have been drilled and completed in the two western study areas because other shallower aquifers exist that more cost-effective for homeowners. Most of the Arapahoe aquifer residential wells are located in the center of the county, east of West Bijou Creek, where the aquifer is less than 1,000 feet deep. The Arapahoe s been eroded away in the Eastern study area.

Figure 8 shows that the LFH aquifer is approximately 1,800 to 2,200 feet deep in the eastern portions of the NW and EK study areas, and 2,600 to over 3,000 feet deep along the western county line. Only one LFH aquifer well has been drilled in the NW study area due to its excessive depth for residential use. Most of the LFH aquifer wells are less than 800 feet deep on a line extending north of Simla and shallow further east. No LFH aquifer wells exist in the Eastern study area because alluvial aquifers are available for residential uses and the water has higher salinity. Therefore, the USGS does not predict any future drawdown in the Eastern study area through 2053.

Water Levels and Well Yields

Figures 9 – 14 show the contoured water table elevations from USGS (2011) model output for 2018 and reported well yields of wells completed in the various aquifers from the State's well permit database. Figure 9 shows the simulated water tables in the Wolf, Commanche, and West Bijou Creek alluvial aquifers, and the Nussbaum aquifer. Groundwater within the Nussbaum aquifer flows northeast from the recharge area near Simla toward Limon.

Well yields generally exceed 200 gpm for irrigation wells located in close proximity to Big Sandy creek, whereas most alluvial wells along Wolf, Comanche, and West Bijou Creeks and produce less than 20 gpm.

Figures 10-14 show the simulated water tables in the Denver Basin Bedrock aquifers. Groundwater flow is generally from south to north toward tributary alluvium in the South Platte River. A few localized cones of depression exist around Arapahoe and LFH wells near Elizabeth and Elbert. Based on the request of the county commissioners, we looked in more detail at the cone of depression near Elbert. We determined that existing well pumping from multiple aquifers contributes to the cone of depression which suggest that inter-aquifer flow is occurring. The existence of significant inter-aquifer flow between bedrock aquifers was confirmed with the USGS (USGS, Personal communication, 2017). Figure 14 shows LFH aquifer flow beneath, and tributary to, the Nussbaum aquifer which have similar water levels.

The reported well yields on Figures 10-14 are generally less than 20 gpm because most wells are small diameter (4-in) residential (household and domestic) wells. However properly designed large diameter (8 to 12 inches) wells can produce hundreds of gallons per minute. There are several 100 to 200 gpm bedrock wells located in the Upper and Lower Dawson and Denver aquifers (Figures 10-12) that reportedly pump over 200 gpm. These wells are likely alluvial wells that are dually completed in the underlying bedrock aquifers. Figure 13 shows that well yields in excess of 300 gpm exist in the Arapahoe aquifer in the western portions of the NW and EK study areas. Figure 14 shows that there has been nearly no development of the LFH aquifer in the western study areas, but that numerous low producing domestic LFH wells exist in the eastern portion of the county. Although Figure 14 shows the existence of greater than 200 gpm LFH wells along Big Sandy Creek, we believe they are actually alluvial but their depths are too shallow to effectively discriminate from LFH wells due to the sandy nature of both aquifers.

Predevelopment to 2018 Regional Drawdown

Figures 15-20 show the locations of existing wells in the State's well database and changes in water levels from predevelopment time (approximately 1880) to 2018 extracted from the USGS groundwater model. The 2018 water levels were extracted from the future scenario (Predictive Stress Period 3, Time Step 5). The model grids were then subtracted and contoured using GIS techniques to obtain the drawdown maps. The calculated drawdown was not confirmed with actual water level measurements. The USGS model was meant to be a regional planning tool and little effort went into focusing on accurately modeling the drawdown around individual wells. This is especially true of localized cones of depression around isolated wells in the NW and EK study areas and south of Elbert (see "Model Accuracy" section below). We therefore do not focus on localized cones of depression in our regional drawdown discussion.

Figure 15 shows less than 10 feet of drawdown is predicted in the alluvial aquifers. In bedrock aquifers, the USGS modeled less than 20 feet of drawdown in all aquifers in the eastern portions of the NW and EK study areas which is also insignificant. Modeled historical drawdown is significant along the western county line. In the Upper Dawson aquifer, the simulated historical drawdown is between 100 to 200 feet along the Douglas county line (Figure 16). In the Lower Dawson aquifer, between 100 and 200 feet of historical drawdown is simulated. Historical regional drawdown in the Denver, Arapahoe aquifers also exceeds 200 feet along the Douglas county line (Figures 18 and 19), but only approximately 100 feet in the LFH aquifer (Figure 20). The large amount of drawdown is likely caused by historical pumping in Douglas County which is creating an expanding cone of depression eastward into Elbert County.

Predicted 2018 -2053 Regional Drawdown

Figures 21-25 show the locations of existing wells in the State's well database and changes in water levels from 2018 to 2053 extracted from the USGS groundwater model for their "Status Quo" run using 2003 pumping rates. The 2053 water levels were extracted and subtracted from the 2018 levels and contoured.

Based on a comparison of USGS model pumping, and groundwater demand estimates provided by FA (Section "USGS Model Verses FA County Pumping Comparison" below), we believe the USGS model underestimates 2018 to 2053 drawdown by up to 50 percent. As a result, Figures 21 to 25 better reflect the minimum drawdown expected to occur between 2018 and 2053.

For the alluvial aquifers, the USGS predicts 0.5 to 2 feet of recovery occurring (Figure 21) as recharge likely exceeds pumping. For the Upper and Lower Dawson bedrock aquifers (Figures 21 and 22), the

USGS predicts only 25 to 40 feet of additional drawdown along the Douglas county line with 0 to 5 feet of drawdown in the eastern NW and EK study areas. For the Denver and Arapahoe aquifers (Figures 23 and 24), the USGS predicts 20 to 80 feet of additional drawdown along the Douglas county line and less than 20 feet along the eastern study areas. For the LFH aquifer, the USGS predicts 80 to 120 feet of additional drawdown along the Douglas county line and less than 20 feet in the eastern study areas. The localized drawdown cones around existing pumping centers (near Elizabeth and south of Elbert) cannot be confirmed with existing available data discussed below.

USGS Model Accuracy

Since the USGS model does not simulate increased pumping between 2003 and 2053, its predicted drawdown needs to be confirmed with actual monitoring well data. Appendix A contains a table of monitoring wells within the county for the various aquifers. The monitoring wells are listed on each drawdown map Figures 15 – 25 and can be cross referenced to USGS and State monitoring wells. Appendix B contains URL links to the USGS online data. The existing monitoring data is inadequate to confirm whether the regional drawdown or localized cones of depression around existing wells is accurate. For example, monitoring well UD2 (actually USGS monitoring well UDAW 11) located on the Douglas county line (in the NW study area) is within an area showing 200 feet of historical drawdown (Figure 16). Unfortunately, the data from UDAW_11 has only been monitored for the past 2 years and does not shown any recognizable water level decline trends. Recent efforts by the USGS (Everett, 2016) to establish more monitoring well sites and collect more long-term data is ongoing and could take five to ten years to clearly identify drawdown trends that can be used to improve the existing model and its predictions. **Despite the lack of existing monitoring well data to confirm modeled water levels in Elbert County, we still believe the USGS model is the best tool for evaluating existing and future conditions.**

WATER QUALITY

The USGS has compiled and publish water quality data for the past 25 years. According to the USGS (Bauch et al., 2014), the quality of the groundwater for drinking water in the Denver Basin aquifers is generally very good. The water quality is effected mostly by the geochemistry of the bedrock aquifers and the travel time in the subsurface. As recharge water percolates to depth additional minerals are dissolved from the surrounding rock. Water quality generally degrades from west to east as travel time increases. The cornerstone of the USGS water quality database are maps of the Total Dissolved Solids (TDS), a measure of total mineral content. The TDS maps (Figures 27-30) were reproduced for this study.

Upper and Lower Dawson Aquifers

The water quality of the Dawson Aquifers is generally excellent (Robson, et al, 1981a). Figure 27 shows the TDS concentration of the combined Dawson aquifers ranging from less than 150 to over 500 ppm from south to north. Sulfate concentrations are also typically less than 25 ppm. Some areas of hard water (60 to 180 ppm hardness as calcium carbonate) exist in the northwestern part of the county.

Denver Aquifer

Figure 28 shows the TDS concentration in the Denver aquifer (Robson, et al, 1981b). TDS concentrations increase to over 1,000 ppm as the water moves from the south (recharge location) toward the north, east and south margins of the aquifer. Sulfate concentrations in the range of 25 to 250 ppm exist in the eastern portion of the County. The USEPA (1977) recommends that dissolved sulfate concentrations not exceed 250 ppm.

Arapahoe Aquifer

Figure 29 shows the TDS concentration in the Arapahoe aquifer (Robson, et al, 1981c). TDS concentrations increase to over 1,000 ppm as the water moves from south to north. Sulfate concentrations in the range of 25 to 250 ppm exist in the eastern portion of the County.

Laramie-Fox Hills Aquifer

Figure 30 shows the TDS concentrations in the Laramie-Fox Hills aquifer (Robson, et al, 1981d). TDS concentrations increase from under 300 to over 1,000 ppm as the water moves from west to east. Dissolved sulfate concentrations in excess of 250 ppm occur in the northeastern part of the county.

Other Water Quality Data Sources

In 2012, S.S. Papadopulos and Associates contracted with the Colorado Oil and Gas Conservation Commission (COGCC) to provide a broad assessment of Elbert County groundwater quality. SSPA evaluated 25 groundwater samples collected by the COGCC, and 209 groundwater and spring samples obtained through the USGS NWIS database. Nine of the samples were from alluvial aquifers. The results indicate that the groundwater has a low TDS. The bedrock samples indicate an overall evolution from Ca-HCO3 water towards a Na-SO4 end member as flow paths increase and naturally soluble sodium and sulfate leach into the water from the bedrock. Exceedances of TDS, sulfate, manganese, and/or iron were reported in 89 locations (SSPA, 2012, p. 16).

Appendix B includes a link to 170 water quality results in the USGS NWIS database for Elbert County. Reviewing the data was beyond the scope of this study.

WELL DEVELOPMENT

Figure 31 shows queried wells in Elbert County in 2017 from the Colorado Division of Water Resources well database based on use. Well development grew in response to population growth outside existing residential areas in the late 1960's when the number of domestic wells first exceeded alluvial mostly agricultural wells. Table 1 shows that by 2017, the total number of registered and completed wells is approximately 7,058, of which 88 percent (6,269) are domestic use wells. Only 663 wells are for agricultural use (9.4 %), and only 33 are designated municipal.

Table 1 – 2017 Permitted and Completed Wells in Elbert County

Type	Total	Percent
Domestic	6229	88.3%
Municipal	33	0.5%
Ag	663	9.4%
Commercial and Industrial	99	1.4%
Other	34	0.5%
Total (rounded)	7058	100%

Source: CDWR well database (http//:water.state.us/)

Figure 32 shows wells queried by aquifer completion. The number of alluvial aquifer wells exceeded bedrock aquifers during the 1930s through the 1950s. Alluvial wells are located along the primary drainages above alluvial aquifers. The primary northward flowing tributaries to the South Platte River with significant alluvial aquifers modeled by the USGS (2011) include Wolf Creek, Comanche Creek and West Bijou Creek. In the southern portion of the County, alluvial aquifer development occurred mostly in the Big Sandy Designated Groundwater basin which exists south of Big Sandy Creek, a tributary to the Arkansas River basin. The rate of alluvial well installation decreased and stabilized after 1969 in response to imposed regulation. After 1960, the number of bedrock wells surpassed the number of alluvial wells and then increased dramatically in the 1970's, 1980's, and 1990's. Since 2000, the rate of new wells has slowed, but has not stabilized due to continued reliance on groundwater.

Since 1970, most bedrock wells are completed in the Dawson aquifer (3,270 wells or 46 percent), followed by the Denver aquifer (1,443wells or 20 percent), the Lower Dawson (1,235 wells or 17 percent), the Arapahoe aquifer (619 wells or 9 percent), and the Laramie–Fox Hills aquifer (338 wells or 5 percent). Figure 2 shows that bedrock residential wells are generally located in the bedrock aquifer closest to the surface. Municipal bedrock wells exist near the larger towns of Elizabeth and Elbert. Water pumped from various depths to meet demand commonly are blended to meet water-quality standards. Municipal water is used for lawn and garden irrigation in some Elbert County developments, and water use peaks during the summer months to meet outside uses.

US GEOLOGICAL SURVEY DENVER BASIN MODEL

The USGS groundwater flow model for the Denver Basin aquifers (Paschke, 2011) is the third generation of Denver Basin numerical models which evolution is worth mentioning because of the drawdown results discussed above. The first model was a four-layer model by the USGS (Robson, 1987) which served as the basis of all groundwater resource evaluations conducted by the USGS and Colorado Department of Water Resources (CDWR) until 1996. The four-layer model was superseded by a six layer model constructed by the CDWR in response to Colorado Senate Bill 96-74 (CDWR, 1998) which simulated all the bedrock aquifers but simulated aquitards between model layers using a constant conductance term calculated based on an assumed constant vertical permeability and the layer thicknesses. The third generation model results used for this analysis was a more comprehensive effort conducted by the US Geological Survey (2011) which resulted in a 12 layer model that included the surficial alluvial aquifers and modeled the aquitard layers between aquifers as individual layers. In the USGS (Paschke, 2011) report, they include a section describing "Comparisons between Current and Previous Models."

The USGS, 2011 model extends beneath the full extent of the Denver Basin aquifers which consists of 84 columns and 124 rows, or 10,416 square miles. The model simulates the geologic and hydrologic conditions within the Denver Basin, and includes pumping by domestic, household, municipal, commercial and industrial, and stock and their respective pumping rates completed in each aquifer.

The model input and output files were obtained from the USGS website, but was not run as part of this project; however the model pumping was compared to our own research. About 52,000 permitted pumping wells with sufficient well-location and completion data were included in the USGS analysis. About 8,000 wells (15 percent) were completed in the alluvial aquifer and about 44,000 wells (85 percent) were completed in bedrock aquifers by 2003. This includes over 7,000 wells in Elbert County. Table 2 lists the model layers that simulate the various aquifers.

Table 2 - USGS Model Layers and Simulated Aquifers

Model Layer	Aquifer Simulated
Layer 1	Stream Alluvium
Layer 2	Upper Dawson
Layer 4	Lower Dawson
Layer 6	Denver
Layer 8	Upper Arapahoe
Layer 10	Lower Arapahoe
Layer 12	Laramie-Fox Hills
Source: Paschke, 2011	

Lower permeability aquitard layers are simulated between the modeled bedrock aquifer layers. Therefore, a total of twelve model layers were simulated.

Model Scenarios

The USGS (2011) model was developed and calibrated to simulate groundwater development from 1880 through 2003 utilizing 16 stress periods, corresponding to sequential growth of the metropolitan, suburban, and rural greater Denver area (USGS 2011). The number of water wells simulated in the model generally increased with each successive stress period. The final stress period (number 16), represents the time period from 1999 through 2003. The model input parameters for this final stress period (including climatic conditions (evapotranspiration rates and recharge from precipitation), locations of irrigated areas and irrigation rates, and pumping rates) were used to simulate two predictive model scenarios for 50 years into the future (years 2003 to 2053). Predictive scenario 1 ("Status Quo" Scenario) utilized the input for stress period 16 for the next 50 years, while predictive scenario 2 used lower pumping rates for Arapahoe aquifer municipal wells to evaluate less future municipal pumping in the future (assuming that could occur in response to trends in conservation and conversion to renewable supplies). The USGS report concluded that results from predictive scenario 1, which maintained the same number of pumping wells and pumping rates simulated in 2003 for the next 50 years, indicated continued water level declines in confined aquifers, an increase in unconfined areas of each aquifer, and continued storage loss in all model aquifer layers. It is important to note that the USGS model did not evaluate a scenario with increased pumping. An important assumption in this analysis is that the status quo scenario is reasonably accurate for future conditions within the county, and especially along the western county boundaries near significant pumping centers (Castle Rock and Parker for instance). Therefore, the results represent a "best case" modeling scenario. Due to the fact that the volume of pumping in Elbert County is considerably small and trends in Douglas county are to reduce their dependence on groundwater, we believe that the USGS (2011) model makes reasonable future predictions for Elbert County and is the best tool for this type of evaluation.

USGS (2011) Model Pumping

Pumping rates were assigned to individual wells on the basis of aquifer of completion and water use consistent with previous methodology (Colorado Division of Water Resources, 1998). The previous methodology developed average annual pumping factors on the basis of actual pumping rates reported by municipal providers for 1996. Average annual pumping rates of 72, 104, 158, and 64 acre-ft per well were indicated for1996 for municipal wells completed in the Dawson, Denver, Arapahoe, and Laramie–Fox Hills aquifers, respectively (Colorado Division of Water Resources, 1998). Weighting factors for each aquifer (Table 3) were calculated as the ratio of the average pumping rate for the aquifer divided by the overall average annual pumping rate for all wells (120 acre-ft/yr.; Colorado Division of Water Resources, 1998). Categorized by water use, the following average pumping rates were assigned to each well for all time periods: 0.6 acre-ft/yr for domestic and livestock wells, 0.3 acre-ft/yr for household-use only wells (a subset of domestic wells with no outdoor water use), and 9.0 acre-ft/yr for commercial and industrial wells (Colorado Division of Water Resources, 1998). Assigned pumping rates for domestic and livestock wells assume 50-percent consumptive use and 50-percent return flow assigned pumping rates for household-use only, commercial, and industrial wells assume 10-percent consumptive use and 90-percent return flow (Colorado Division of Water Resources, 1998). The assigned pumping rate for irrigation wells (41 acre-ft/yr for all time periods) assumes 90-percent consumptive use and 10-percent return flow, and the rate is multiplied by the appropriate aquifer weighting factor to compute a per-well pumping rate depending on the aquifer of completion (table B1). The assigned pumping rate for municipal wells (32 acre-ft/yr in 1979) assumes 50-percent consumptive use, and the rate is multiplied by the appropriate aquifer weighting factor to compute a per-well pumping rate depending on the aquifer of completion (Table 3). In addition, the assigned municipal pumping rate for this study was increased linearly from 32 acre-ft/yr in 1979 to 45 acre-ft/yr in 1996 consistent with methods used by the Colorado Division of Water Resources (1998). The assigned municipal pumping rate for this study was held constant at 45 acre-ft/yr from 1997 to 2003.

Table 3. Modeled Pumping Rates in the Denver Basin Model

Aquifer Completion	Aquifer Weighting Factor	Assigned Pumping Rate						
		Municipal			Irrigation	Commercial/ Industrial	Domestic and Livestock	Household Only
		1880-1978	1979-1996	1997-1996				
Alluvial aquifer	1	32	Linear increase to 45.0	45	41	9	0.6	0.3
Upper and lower Dawson aquifer	0.6	19.2	Linear increase to 27.0	27	24.6	9	0.6	0.3
Denver aquifer	0.87	27.8	Linear increase to 39.1	39.1	35.7	9	0.6	0.3
Upper and lower Arapahoe aquifer	1.32	42.2	Linear increase to 59.4	59.4	54.1	9	0.6	0.3
Laramie–Fox Hills aquifer	0.53	17	Linear increase to 23.8	23.8	21.7	9	0.6	0.3

Source: USGS, 2011 Table B2

Table 4 shows the 2003 to 2053 sector pumping for the County extracted from the model input files based on the above assumptions.

Table 4 – USGS Model Pumping (2003-2053) for Elbert County (af/yr)

Model Layer	Aquifer	Type	Acre-Feet/year
1	**Alluvial**	Commerical/Industrial	27
		Municipal	180
		Irrigation	1864
		Dom., Stock and houshld	120
	Subtotal		**2191**
2	**Upper Dawson**	Commerical/Industrial	267
		Municipal	162
		Irrigation	221
		Dom., Stock and houshld	1742
	Subtotal		**2393**
4	**Lower Dawson**	Commerical/Industrial	168
		Municipal	378
		Irrigation	92
		Dom., Stock and houshld	568
	Subtotal		**1206**
6	**Denver**	Commerical/Industrial	141
		Municipal	372
		Irrigation	160
		Dom., Stock and houshld	756
	Subtotal		**1430**
10	**Arapahoe**	Commerical/Industrial	85
		Municipal	267
		Irrigation	203
		Dom., Stock and houshld	360
	Subtotal		**915**
12	**Laramie-Fox Hills**	Commerical/Industrial	67
		Municipal	6
		Irrigation	130
		Dom., Stock and houshld	184
	Subtotal		**387**
Grand Total			**8522**

Source: USGS, 2011 model input files

The total amount of annual pumping simulated for the 2003 to 2053 model run was 8,522 af/yr. If we subtract alluvial groundwater pumping (2,191 af/yr) the total pumping of Denver Basin bedrock aquifers is approximately 6,331 af/yr (8,522-2,191).

USGS Model Verses FA County Pumping Comparison

We did not prepare a comprehensive comparison of USGS modeled verses recent sector pumping forecasts. It is difficult because the USGS based their pumping estimate on the number of wells and average use estimates for the entire model area, whereas FA prepared estimates specific to Elbert County. For sector pumping, FA grouped municipal, domestic, and household uses into a "Residential" Category and calculated demand based on per capita consumption (135 gpdc). For this analysis, we focused on the total pumping amounts. Table 5 provides sector pumping estimates from the FA report (Table 3-10), and the 2003 and 2017 values are interpolated from the reported values.

Table 5 –Elbert County Sector Pumping (Source: FA Report, Table 3-10)

Year	2003	2017	2035	2050
Population	21,933	27,674	53,654	68,375
Well Use	**Pumping (af/yr)**			
Residential (1)	3,317	4,185	8,114	10,340
Commercial (2)	332	418	811	1,034
Agriculture (3)	5,741	3,727	3,370	3,100
Livestock (4)	907	882	1,056	1,225
Oil and Gas (5)	-	-	38	38
Total	**10,296**	**9,212**	**13,389**	**15,737**

Notes:

1. Countywide residential/domestic demand based on DOLA population projection and 135 gpd/person assumption
2. Year 2010 and 2017 used estimated values based on commercial taps provided by Kiowa and Elizabeth. In 2035 and 2050 assuming that commercial is represented by 5 and 10% of the county wide demand respectively
3. Used 2010 irrigated acres (CDSS) X 1.4 AFY/acre
4. Using 20 gpd/head and annual average growth rate of 1% based on discussions with the Cattlemans Association estimate
5. Forsgren Assumed

FA estimates that 2017 groundwater use is approximately 9,212 acre-feet, but it does not discriminate between pumping from alluvial and bedrock aquifers. If we assume that all agricultural pumping comes from alluvial aquifers, then the total Denver Basin bedrock aquifer pumping would be 5,485 af/yr (9,212-3,727) which is approximately 846 af/yr less (6,331-5,485) than what the USGS simulated in their future "Status Quo" scenario. We would therefore expect the USGS simulated drawdown in 2018 would slightly under predict actual drawdown. Using the same assumption that all agricultural pumping occurs from Alluvial aquifers, then FA's estimate of future bedrock pumping in 2050 would be approximately 12,637 af/yr (15,737 - 3,100), which is approximately twice that of USGS bedrock pumping 2050. **As a result, we would expect the USGS's future drawdown results (Figures 21 – 25) are less than what will likely occur.** We considered this in our "Prototypical Well Analysis Assumptions" below.

Model Extractions for Study Areas

Model input and output data extractions were made to conduct the prototypical well analyses for the NW and EK Study areas (See MWE memo to FA dated June 6, 2018).

Tables 6 and 7 provide a comparison of average model cell (1mi^2) input and output data within the eastern and western portions of the NW and EK study areas. The dividing line is the middle of Range 64 W. We calculated average values for the east and west sides to decide which to use in the prototypical well analysis.

Table 6 – USGS Groundwater Model Data Extraction – Northwest Study Area

	U. Dawson		L. Dawson		Denver		Arapahoe		LFH	
	West	East	West	East	West	East	West	East	West	East
Cell Ground Elev. (ftmsl)	6292	6128	6292	6128	6292	6128	6292	6128	6292	6128
Predevelopment Water Level Elev. (ftmsl)	6210	6194	6056	6126	5938	5993	5888	5946	5885	5944
2018 Water Level Elev. (ftmsl)	6066	6150	5883	6091	5743	5933	5686	5881	5772	5909
2053 Water Level Elev. (ftmsl)	6059	6144	5866	6084	5712	5916	5648	5861	5680	5873
Predevelopment - 2018 Drawdown (ft)	144	44	174	35	195	61	202	65	112	35
2018 to 2053 Drawdown (ft)	7	6	17	7	31	17	38	21	92	36
Aquifer Top Elev. (ftmsl)	6059	6083	5849	6061	5681	5890	4827	5108	4032	4292
Aquifer Bottom Elev. (ftmsl)	5904	6029	5725	5940	4864	5153	4317	4575	3696	4036
2018 Layer Thickness (ft)	155.09	53.77	123.98	121.44	817.14	737.85	509.93	532.45	335.93	256.56
2053 Layer Thickness (ft)	155.03	53.77	123.98	121.44	817.14	737.85	509.93	532.45	335.93	256.56
Avg. Sand Thickness	37	22	57	58	293	224	254	244	191	159
Sand + Silt Fraction	0.24	0.41	0.46	0.48	0.36	0.30	0.50	0.46	0.57	0.62
Hydraulic Conductivity (ft/day)	4.7	4.7	0.3	0.3	1.0	1.0	1.8	1.9	1.0	1.0
Transmissivity (ft^2/day)	175.5	103.0	15.3	15.8	293.5	224.2	462.7	458.9	192.1	159.6
Specific Storage	5.20E-07	5.20E-07	5.20E-07	5.2E-07	5.2E-07	5.2E-07	5.2E-07	5.2E-07	5.2E-07	5.2E-07
Confined Storage Coefficient	0.00008	0.00003	0.00006	0.00006	0.00042	0.00038	0.00027	0.00028	0.00017	0.00013
Specific yield of layer	0.152	0.152	0.152	0.152	0.133	0.133	0.178	0.178	0.186	0.186
Effective Specific Yield of Sand+Silt	0.04	0.06	0.07	0.07	0.05	0.04	0.09	0.08	0.11	0.12

Table 7 – USGS Groundwater Model Data Extraction – Elizabeth-Kiowa Study Area

	U. Dawson		L. Dawson		Denver		Arapahoe		LFH	
	West	East	West	East	West	East	West	East	West	East
Cell Ground Elev. (ftmsl)	6648	6488	6648	6488	6648	6488	6648	6488	6648	6488
Predevelopment Water Level Elev. (ftmsl)	6528	6483	6503	6405	6476	6374	6466	6361	6464	6361
2018 Water Level Elev. (ftmsl)	6493	6473	6369	6378	6340	6341	6333	6332	6383	6347
2053 Water Level Elev. (ftmsl)	6477	6468	6341	6371	6288	6324	6272	6312	6291	6322
Predevelopment - 2018 Drawdown (ft)	34	9	134	26	136	34	133	30	81	14
2018 to 2053 Drawdown (ft)	16	5	28	8	52	17	61	20	93	25
Aquifer Top Elev. (ftmsl)	6559	6497	6133	6296	5879	5997	5016	5322	4263	4519
Aquifer Bottom Elev. (ftmsl)	6208	6349	5936	6071	5066	5370	4551	4783	3941	4171
2018 Layer Thickness (ft)	286	124	197	224	814	627	464	539	322	348
2053 Layer Thickness (ft)	269	119	405	299	1222	954	1720	1528	2349	2151
Avg. Sand Thickness	89	45	93	101	258	195	196	254	204	207
Sand + Silt Fraction	0.31	0.36	0.47	0.45	0.32	0.31	0.42	0.47	0.63	0.60
Hydraulic Conductivity (ft/day)	4.7	4.7	0.3	0.3	1.0	1.0	1.2	1.3	1.0	1.0
Transmissivity (ft^2/day)	417.6	211.6	25.1	27.1	258.4	194.8	241.0	323.0	204.4	207.7
Specific Storage	5.20E-07	5.20E-07	5.20E-07	5.20E-07	5.20E-07	5.20E-07	5.20E-07	5.20E-07	5.20E-07	5.20E-07
Confined Storage Coefficient	0.00015	0.00006	0.00010	0.00012	0.00042	0.00033	0.00024	0.00028	0.00017	0.00018
Specific yield of layer	0.152	0.152	0.152	0.152	0.133	0.133	0.178	0.178	0.186	0.186
Effective Specific Yield of Sand+Silt	0.05	0.05	0.07	0.07	0.04	0.04	0.08	0.08	0.12	0.11

The average model cell data was extracted and averaged using GIS techniques. The extracted data was used to calculate other variables used in the prototypical well analysis as described below:

- Ground elevations were extracted from the top model layer 1 model input file and used to calculate aquifer top and bottom elevations;
- Predevelopment water level elevations were extracted from the steady state model run model output files and subtracted from the 2018 modeled water level to calculate the predevelopment to 2018 drawdown (Figures 15 to 20);
- 2053 water levels were extracted from the model output file and subtracted from the 2018 water levels to calculate the 2018 to 2053 drawdown (Figures 21 to 25);

- Aquifer bottom elevations were extracted from the model input files and averaged to represent prototypical well depths;
- Aquifer bottom elevations were extracted from model input files for the various model layers, and subtracted from the Aquifer top elevation to calculate the model layer thicknesses for 2018 and 2053;
- If the aquifer water levels were below the top of aquifer, then the model layer thicknesses were determined by subtracting the model bottom elevations from the water levels;
- The average sand thicknesses were determined by multiplying the percent silt plus sand array by the model layer thickness;
- The sand + silt fractions were determined by dividing the average sand thickness by the 2018 layer thickness;
- The hydraulic conductivities (k) were either taken directly from the model input files (Upper and Lower Dawson) or calculated by taking the inverse log of the model K input arrays (Denver, Arapahoe and LFH aquifers);
- The transmissivities were calculated by multiplying the hydraulic conductivity by the average sand thickness, and used to evaluate seasonal pumping drawdown to estimate power costs in the prototypical well analysis.
- The specific storages were derived from the USGS modeling report, and used to calculate the confined storage coefficient;
- The confined storage coefficients were determined by multiplying the specific storage values by the 2018 layer thicknesses, and used to evaluate seasonal pumping drawdown (confined conditions) to estimate power costs in the prototypical well analysis; and
- The specific yield values were derived from the USGS modeling report, and used to calculate the effective specific yield; and
- The effective specific yield was calculated by multiplying the sand + silt fraction by the specific yield, and used to evaluate seasonal pumping drawdown (unconfined conditions) to estimate power costs in the prototypical well analysis.

We compared the data from the east and west sides of the study areas and determined:

- The ground elevations are higher in the western portions of the study area then the eastern;
- The predevelopment water levels are within 100 feet;
- The aquifer tops and bottoms are over 200 feet deeper in the west for the Denver, Arapahoe, and LFH aquifers due to a deepening of the aquifer structure;
- The 2018 and 2053 aquifer water levels are up to 200 feet deeper in the west;
- Predevelopment to 2018 drawdowns are generally 100 feet more in the west than the east due to pumping west of the Elbert county line;
- 2018 to 2053 predicted drawdowns are generally less than 40 feet, and about the same on the east and west, except for the LFH aquifer which will likely be much higher in the west (likely over 100 ft) than the in the east;
- Typical aquifer sand thicknesses and transmissivities are generally higher in the west than east;
- Aquifer storage properties including specific storage, confined storage coefficient and specific yield do not vary significantly across the study areas.

The USGS future drawdown predictions in bedrock aquifers (Figures 21 – 26) are likely less than will actually occur due to pumping rates exceeding the 2003 estimate rate discussed above. However, we decided to not account for this in our prototypical well analysis because the future cost of electricity is not a very sensitive variable in determining overall groundwater development costs because the additional future pumping depths (and electricity costs) are small compared to overall pumping depth, and it is possible that other sensitive assumptions in our cost model may contribute more to error in our economic analysis results.

Model Limitations and Uncertainty

The USG's Denver Basin groundwater flow model "simulates a reasonable conceptual understanding of regional Hydrogeologic conditions to calculate temporal changes in groundwater availability since predevelopment (USGS, 2011, p. 267)." The model is "well suited for evaluating changing regional groundwater flow directions and water budgets (including changes in storage) over time (USGS, 2011, p. 272)."

Along the western Elbert County line, the USGS states that "future modeling efforts should consider additional data collection or refinement of model parameters in areas where the model did not achieve a good fit between transient simulated and observed hydraulic heads. For example, large simulated drawdown in the upper Dawson east of Parker was not observed in the CDWR water-level data, and the model appears to underestimate drawdown in the lower Arapahoe aquifer compared to CDWR water-level data. (USGS, 2011,p. 268)." In the future, the USGS recommend refining pumping estimates from measured discharge and installing additional monitoring to refine the model calibration. The current well monitoring and data collection effort by the USGS (Everett, 2016) is an ongoing effort to collect additional data to improve the model for potential future modeling efforts.

Denver Basin Aquifer Storage

The total storage in the Denver Basin aquifers is the combined amount of water under pressure head conditions plus the amount of physical storage within the pore space of each aquifer. To determine this, we used GIS techniques to first identify USGS model cells within the county that were either confined or unconfined in 2018. We then calculated the amount of available confined aquifer storage in each modeled aquifer layer by multiplying the potentiometric head (water table – top of aquifer) by the aquifer storage coefficient (model layer thickness * the specific storage). Table 8 shows that the amount of confined storage in 2018 is approximately 0.3 Million acre-feet (MAF).

Table 8 – Denver Basin Aquifer Storage (Million Acre-feet)

	2018				2053					Change in Total Recoverable GW (2018-2053)	
	Confined	Unconfined			Confined	Unconfined					
Aquifer	2018 Storage Volume (MAF)	2018 Storage Volume (1000 MAF)	Recoverable (75%)	Total Recoverable (MAF)	2053 Storage Volume (MAF)	2053 Storage Volume (MAF)	Decrease in Recoverable Volume (MAF)	Recoverable (MAF)	(Total Recoverable (MAF)	Decrease (MAF)	% Decrease from 2018 to 2053
Upper Dawson	NA	1.9	1.5	1.5	NA	1.9	0.068	1.4	1.4	0.07	4.7%
Lower Dawson	0.01	3.6	2.7	2.7	0.005	3.6	0.010	2.7	2.7	0.01	0.4%
Denver	0.04	11.7	8.8	8.8	0.04	11.7	0.034	8.8	8.8	0.04	0.4%
Arapahoe	0.11	24.0	18.0	18.1	0.11	24.0	0.010	18.0	18.1	0.01	0.07%
Laramie-Fox Hills	0.15	30.4	22.8	23.0	0.14	30.4	0.001	22.8	22.9	0.003	0.015%
Total (af) rounded	**0.30**	**71.6**	**53.7**	**54.0**	**0.29**	**71.5**	**0.12**	**53.6**	**53.9**	**0.13**	**0.24%**

Source: USGS, 2011 Model Output files

We then calculated the amount of unconfined aquifer storage in each modeled aquifer layer in 2018 by multiplying the model layer thickness (aquifer top – bottom) by the effective specific yield (aquifer specific yield * sand + silt fraction). The aquifer specific yields were those reported by the CDWR (Paschke, 2011, page viii) listed below:

- Upper and Lower Dawson = 15.2%
- Denver = 13.3%
- Arapahoe = 17.8%
- Laramie-Fox = 18.6%

The net sand + silt fraction was provided in multiplier arrays for input files into the USGS (Paschke, 2011) model. Table 8 shows that the amount of unconfined storage in 2018 is approximately 71.6 million acre-feet (MAF). This estimate is consistent with 467 MAF of total storage and 269 MAF of recoverable storage in all Denver Basin aquifers previously estimated by the USGS (Robson, 1987, p. 18).

Recoverable Aquifer Storage

We estimate that approximately 75% of the total storage is recoverable by wells. Therefore, the amount of recoverable storage in the Denver basin aquifers beneath Elbert County is approximately 54 MAF.

Change in Aquifer Storage (2018 to 2050)

To evaluate the change in aquifer storage between 2018 and 2050, we totaled the amount of confined (0.29 MAF) and recoverable unconfined water (53.6 MAF) in 2053, and subtracted the total (53.9 MAF) from the 2018 storage. The result is a 0.130 MAF change in storage or decrease in recoverable storage by 0.24 percent. The average change in storage rate over the 35 years is approximately 3,717 af/yr. This is approximately 59% of the estimated pumping rate. This means that approximately 41% of the pumping that occurred between 2018 and 2053 was either recharged back into the aquifer and not consumed, came out of storage from outside the county due to the expanding cone of depression, or was the result of reduced evapotranspiration or depleted from Alluvial aquifers. We believe it is a reasonable assumption because over 50% of the 2018 water demand is for residential uses (FA report Table 3-10), which would allow for a large amount of return flow.

Aquifer Sustainability

The sustainability of the aquifer depends on the overall water balance which consists of inflows, outflows and changes in storage using Equation 3:

Equation 3 – Aquifer Water Balance

Inflows = Outflows + Change in storage, where

Inflows = Recharge (net precipitation + return flows), and

Outflows = Pumping + Evapotranspiration + the net discharge to the alluvial aquifer system.

The 0.130 MAF decline in storage between 2018 and 2053 equals the sum of all Inflows – Outflows. On average it equals approximately 3,717 af/yr over 35 years. The ratio of the annual change in storage (3,717 af/yr) divided by the total model pumping (8,522 af/yr) = 59% which is net effect of the change in other inflow and outflow variables. We can therefore estimate aquifer life by dividing the retrievable storage by the storage/pumping ratio and then divide by the average future annual pumping volume.

Table 9 shows that if we assume the future pumping rate for the next several thousand years is the same as the 2050 pumping rate (approximately 15,244 af/yr) than the aquifer life is approximately 6,000 years. If we make a gross assumption that the average future pumping is 20,000 af/yr, then the aquifer life decreases to 5,000 years. If we assume that future pumping is 40,000 af/yr, then the aquifer life declines to approximately 2,000 years. If we make a more conservative assumption that the storage/pumping ratio averages 90 percent in the future and pumping is high (40,000 af/yr) then the aquifer life declines to approximately 1,500 years.

Table 9 – Denver Basin Aquifer Life (USGS, 2011)

Denver Basin Storage			Total (MAF)
Total Storage (MAF) =			72
Retrievable Storage =		75%	54
Future pumping (af/yr)		**Aquifer Life (yrs) rounded**	
Storage/Pumping Ratio =		59%	90%
2050 Rate* =	15244	6000	3900
Future (low) =	20000	5000	3000
Future (high) =	40000	2000	1500
Notes: * Total Pumping by FA			

Therefore, we conclude that the life of the Denver Basin aquifers within Elbert County is at least 1,500 years. This is considerably higher estimate than the aquifer life of less than 100 years for Douglas County (URS, 2013, p. 5-5) which we feel is overly pessimistic.

Uncertainty

Our analysis is based on numerous assumptions of various sensitivities that affect costs and our conclusions of available aquifer life. This includes uncertainty in:

- Future population growth and demand;
- Aquifer parameters;
- Aquifer Water level declines;
- The prototypical well analysis methodology and cost assumptions (ie. inflation and discount rates);
- The actual hydrology of the Denver Basin Aquifers;
- The effect of future pumping outside the county on water levels and storage;
- The accuracy of USGS Denver Basin Aquifer modeling; and
- Other regulatory and economic uncertainties.

Therefore, the results and conclusions are conceptual in nature and regional in extent, and therefore should only be used for general planning purposes.

Prototypical Well Analysis Assumptions

Based on the data extracted from the USGS model across the NW and EK study areas and a comparison of the total USGS model pumping verses FA's future use estimate, the assumption could be made that if we double the USGS's future predicted drawdown from 2018 to 2053, the predicted water levels would be more realistic. We decided not to make that prediction for the following reasons:

We decided to utilize the average data from the west side of the study area for our prototypical well analysis because the depth to water and depth of wells are greater which would result in conservative (higher) well development and future pumping water level costs, and because future growth is likely to occur more in that area. We did not make any correction to future 2018 to 2053 predicted water levels due to under pumping because we believe the under-estimate is less than 100 feet for the LFH and less than 50 feet for all other aquifers (double the predicted drawdown) which would not significantly affect future pumping costs. By using both assumptions, we believe the results of the prototypical well evaluation will be realistic and conservative (more expensive).

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Figures

List of Figures		
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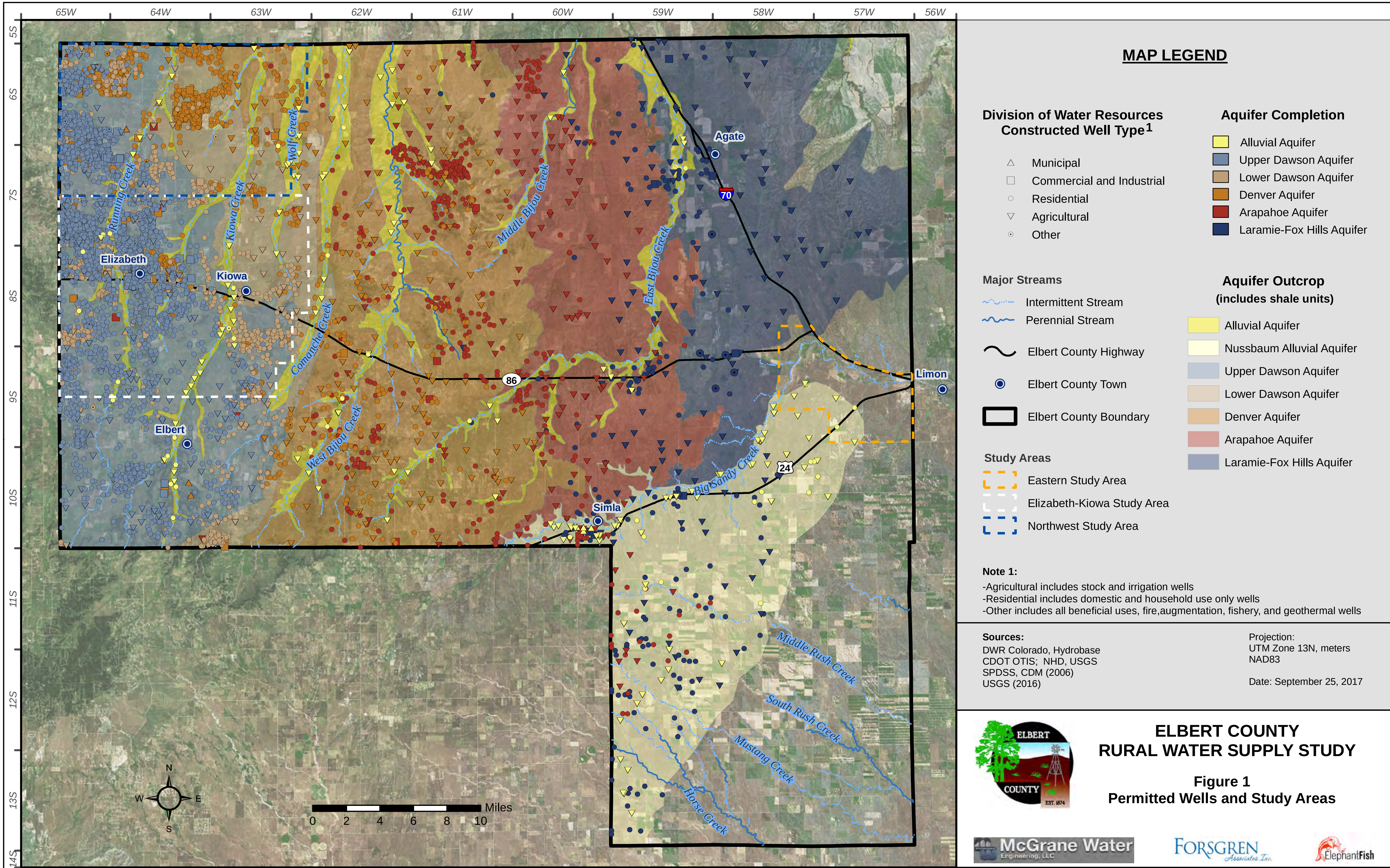
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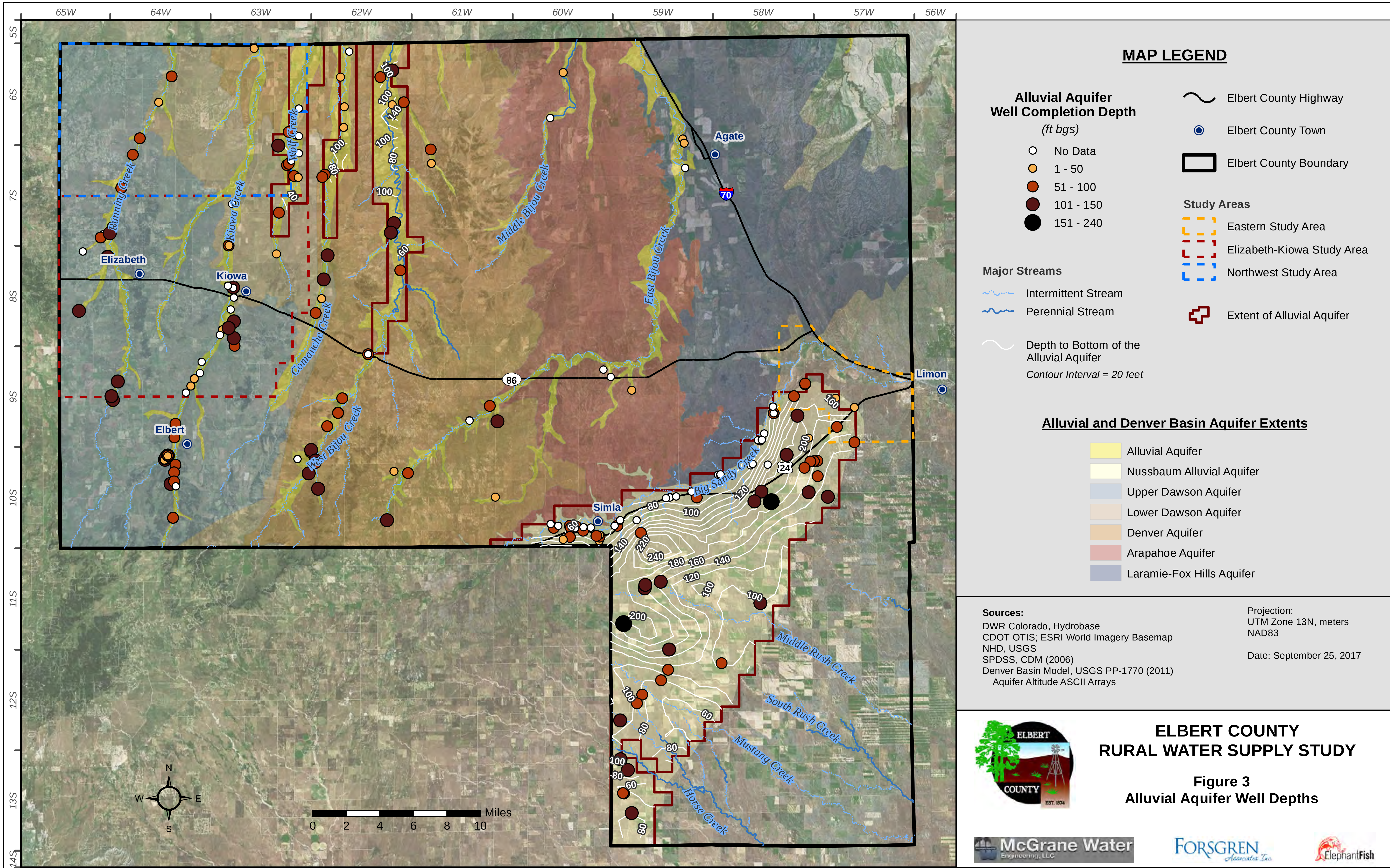
64W
63W
62W
61W
60W
59W
58W
57W
56W
5S
6S
7S
8S
9S
10S
11S
12S
13S
14S
Running Creek
Wolf Creek
Kiowa Creek
Comanche Creek
Middle Bijou Creek
East Bijou Creek
West Bijou Creek
Big Sandy Creek
Middle Rush Creek
South Rush Creek
Mustang Creek
Horse Creek
Elizabeth
Kiowa
Elbert
Agate
Simla
Limon
86
70
24
N
W
E
S
Miles
0 2 4 6 8 10
MAP LEGEND
Division of Water Resources Constructed Well Type[1]
Municipal
Commercial and Industrial
Residential
Agricultural
Other
Aquifer Completion
Alluvial Aquifer
Upper Dawson Aquifer
Lower Dawson Aquifer
Denver Aquifer
Arapahoe Aquifer
Laramie-Fox Hills Aquifer
Major Streams
Intermittent Stream
Perennial Stream
Elbert County Highway
Elbert County Town
Elbert County Boundary
Aquifer Outcrop (includes shale units)
Alluvial Aquifer
Nussbaum Alluvial Aquifer
Upper Dawson Aquifer
Lower Dawson Aquifer
Denver Aquifer
Arapahoe Aquifer
Laramie-Fox Hills Aquifer
Study Areas
Eastern Study Area
Elizabeth-Kiowa Study Area
Northwest Study Area
Note 1:
-Agricultural includes stock and irrigation wells
-Residential includes domestic and household use only wells
-Other includes all beneficial uses, fire,augmentation, fishery, and geothermal wells
Sources:
DWR Colorado, Hydrobase
CDOT OTIS; NHD, USGS
SPDSS, CDM (2006)
USGS (2016)
Projection:
UTM Zone 13N, meters
NAD83
Date: September 25, 2017
ELBERT COUNTY
RURAL WATER SUPPLY STUDY
Figure 1
Permitted Wells and Study Areas
ELBERT
COUNTY
EST. 1874
McGrane Water
Engineering, LLC
FORSGREN
Associates Inc.
ElephantFish


MAP LEGEND
Alluvial Aquifer Well Completion Depth
(ft bgs)
No Data
1 - 50
51 - 100
101 - 150
151 - 240
Elbert County Highway
Elbert County Town
Elbert County Boundary
Study Areas
Eastern Study Area
Elizabeth-Kiowa Study Area
Northwest Study Area
Extent of Alluvial Aquifer
Major Streams
Intermittent Stream
Perennial Stream
Depth to Bottom of the Alluvial Aquifer
Contour Interval = 20 feet
Alluvial and Denver Basin Aquifer Extents
Alluvial Aquifer
Nussbaum Alluvial Aquifer
Upper Dawson Aquifer
Lower Dawson Aquifer
Denver Aquifer
Arapahoe Aquifer
Laramie-Fox Hills Aquifer
Sources:
DWR Colorado, Hydrobase
CDOT OTIS; ESRI World Imagery Basemap
NHD, USGS
SPDSS, CDM (2006)
Denver Basin Model, USGS PP-1770 (2011)
Aquifer Altitude ASCII Arrays
Projection:
UTM Zone 13N, meters
NAD83
Date: September 25, 2017
ELBERT COUNTY
RURAL WATER SUPPLY STUDY
Figure 3
Alluvial Aquifer Well Depths
McGrane Water
FORSGREN
ElephantFish
Elizabeth
Kiowa
Elbert
Agate
Simla
Limon
Running Creek
Kiowa Creek
Wolf Creek
Comanche Creek
West Bijou Creek
Middle Bijou Creek
East Bijou Creek
Big Sandy Creek
Middle Rush Creek
South Rush Creek
Mustang Creek
Horse Creek
65W
64W
63W
62W
61W
60W
59W
58W
57W
56W
5S
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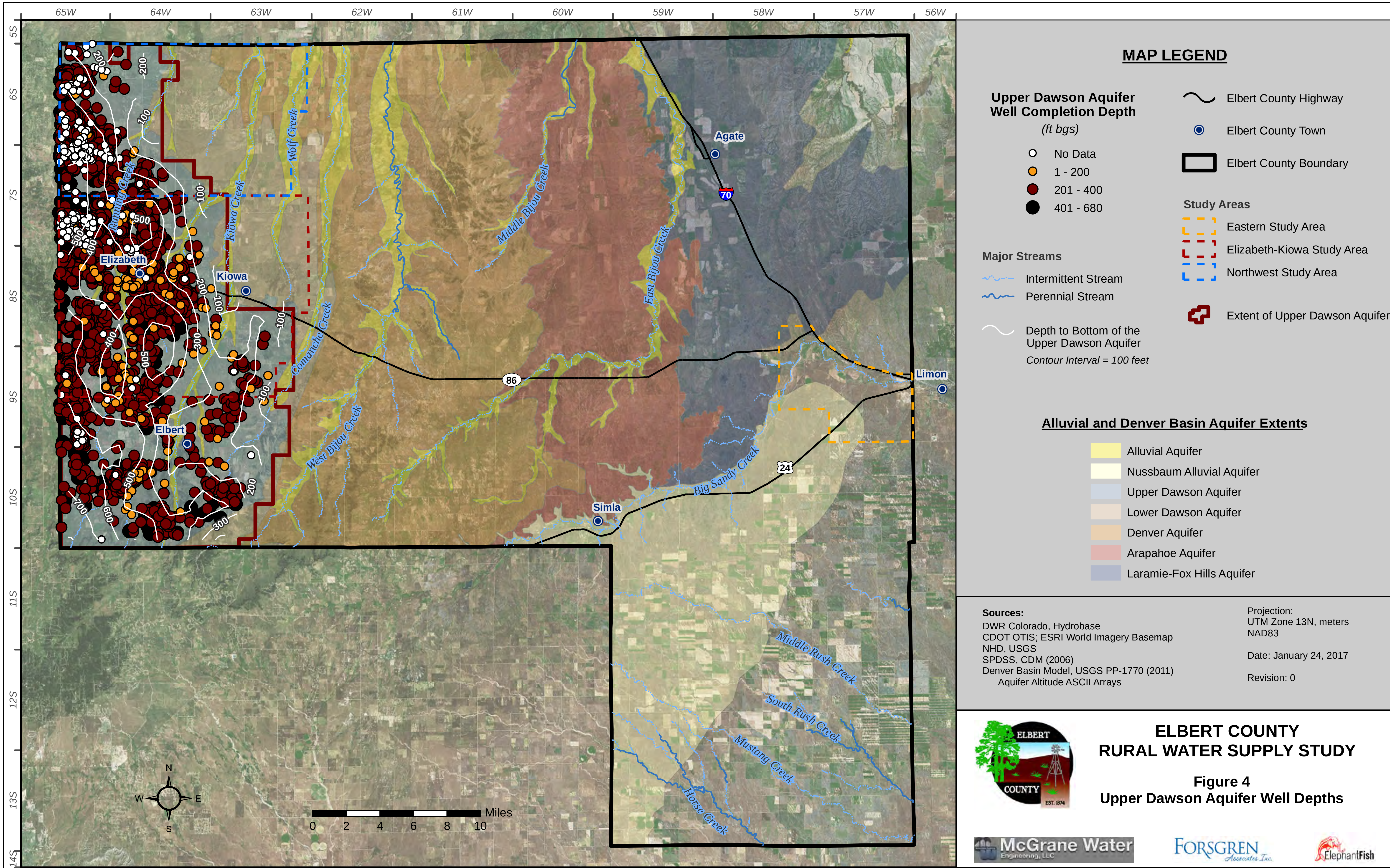

MAP LEGEND
Upper Dawson Aquifer Well Completion Depth
(ft bgs)
No Data
1 - 200
201 - 400
401 - 680
Elbert County Highway
Elbert County Town
Elbert County Boundary
Study Areas
Eastern Study Area
Elizabeth-Kiowa Study Area
Northwest Study Area
Extent of Upper Dawson Aquifer
Major Streams
Intermittent Stream
Perennial Stream
Depth to Bottom of the Upper Dawson Aquifer
Contour Interval = 100 feet
Alluvial and Denver Basin Aquifer Extents
Alluvial Aquifer
Nussbaum Alluvial Aquifer
Upper Dawson Aquifer
Lower Dawson Aquifer
Denver Aquifer
Arapahoe Aquifer
Laramie-Fox Hills Aquifer
Sources:
DWR Colorado, Hydrobase
CDOT OTIS; ESRI World Imagery Basemap
NHD, USGS
SPDSS, CDM (2006)
Denver Basin Model, USGS PP-1770 (2011)
Aquifer Altitude ASCII Arrays
Projection:
UTM Zone 13N, meters
NAD83
Date: January 24, 2017
Revision: 0
ELBERT COUNTY
RURAL WATER SUPPLY STUDY
Figure 4
Upper Dawson Aquifer Well Depths
McGrane Water
FORSGREN
ElephantFish
Elizabeth
Kiowa
Elbert
Agate
Simla
Limon
Running Creek
Kiowa Creek
Wolf Creek
Comanche Creek
West Bijou Creek
Middle Bijou Creek
East Bijou Creek
Big Sandy Creek
Middle Rush Creek
South Rush Creek
Mustang Creek
Horse Creek
65W
64W
63W
62W
61W
60W
59W
58W
57W
56W
5S
6S
7S
8S
9S
10S
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N
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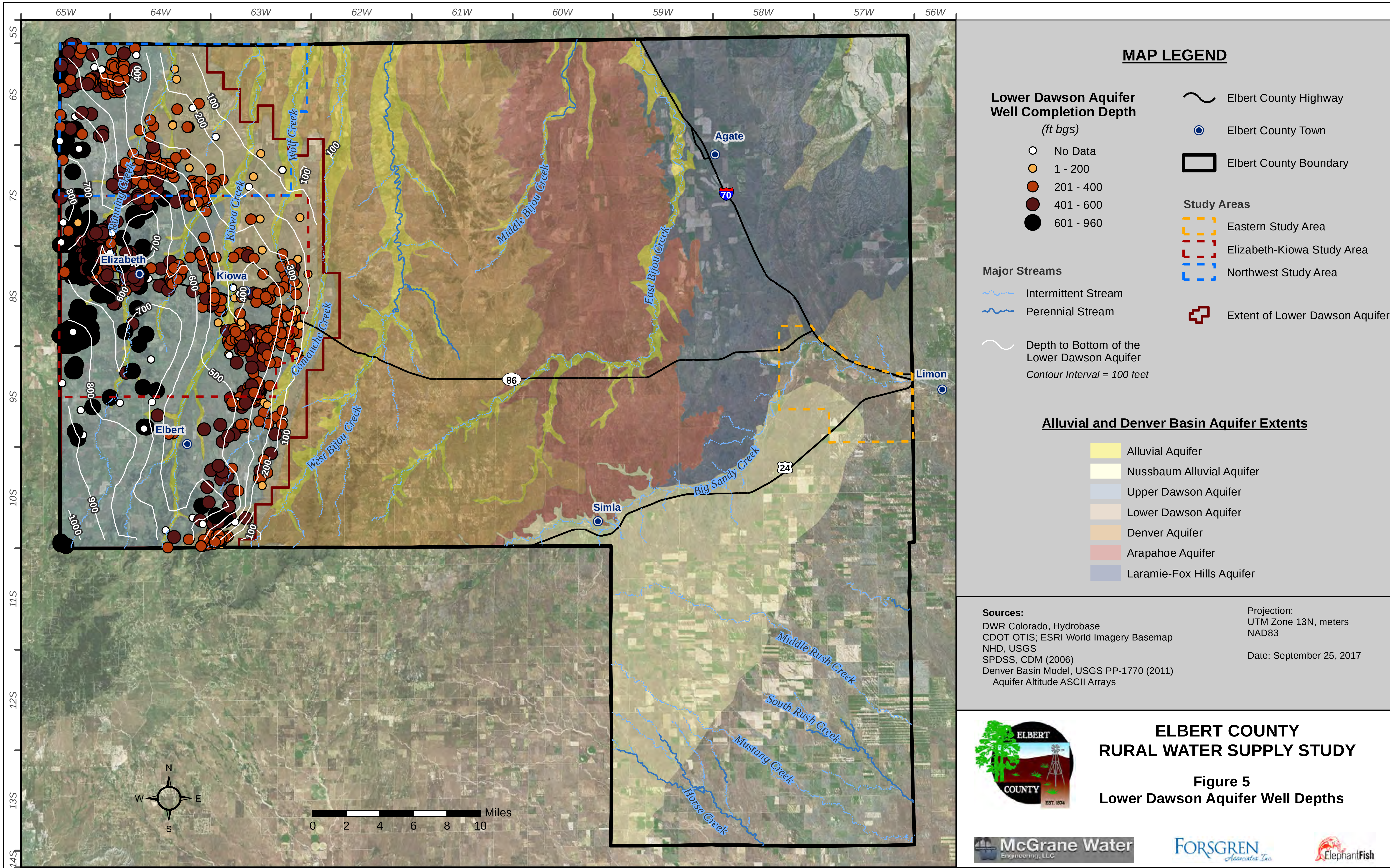
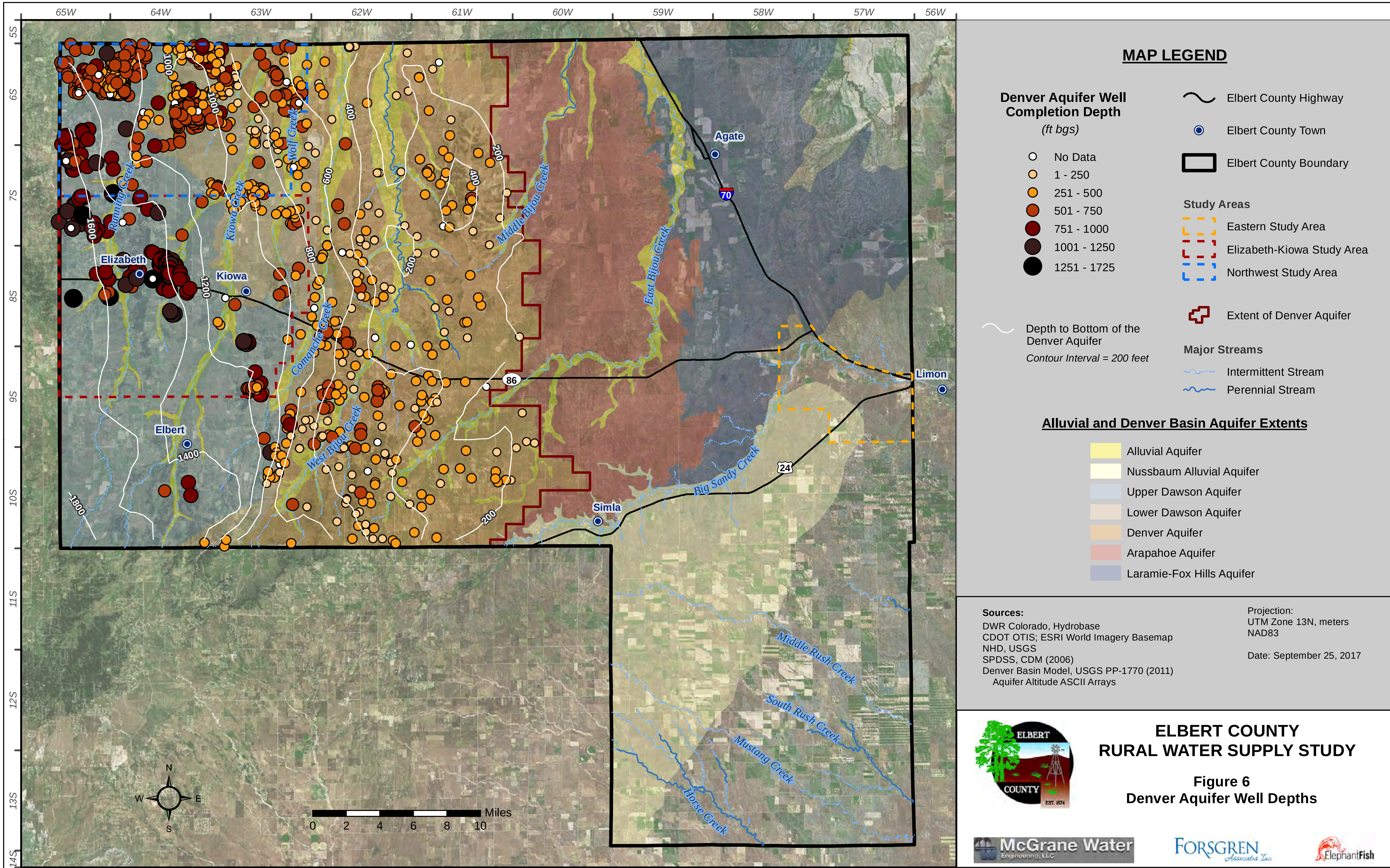
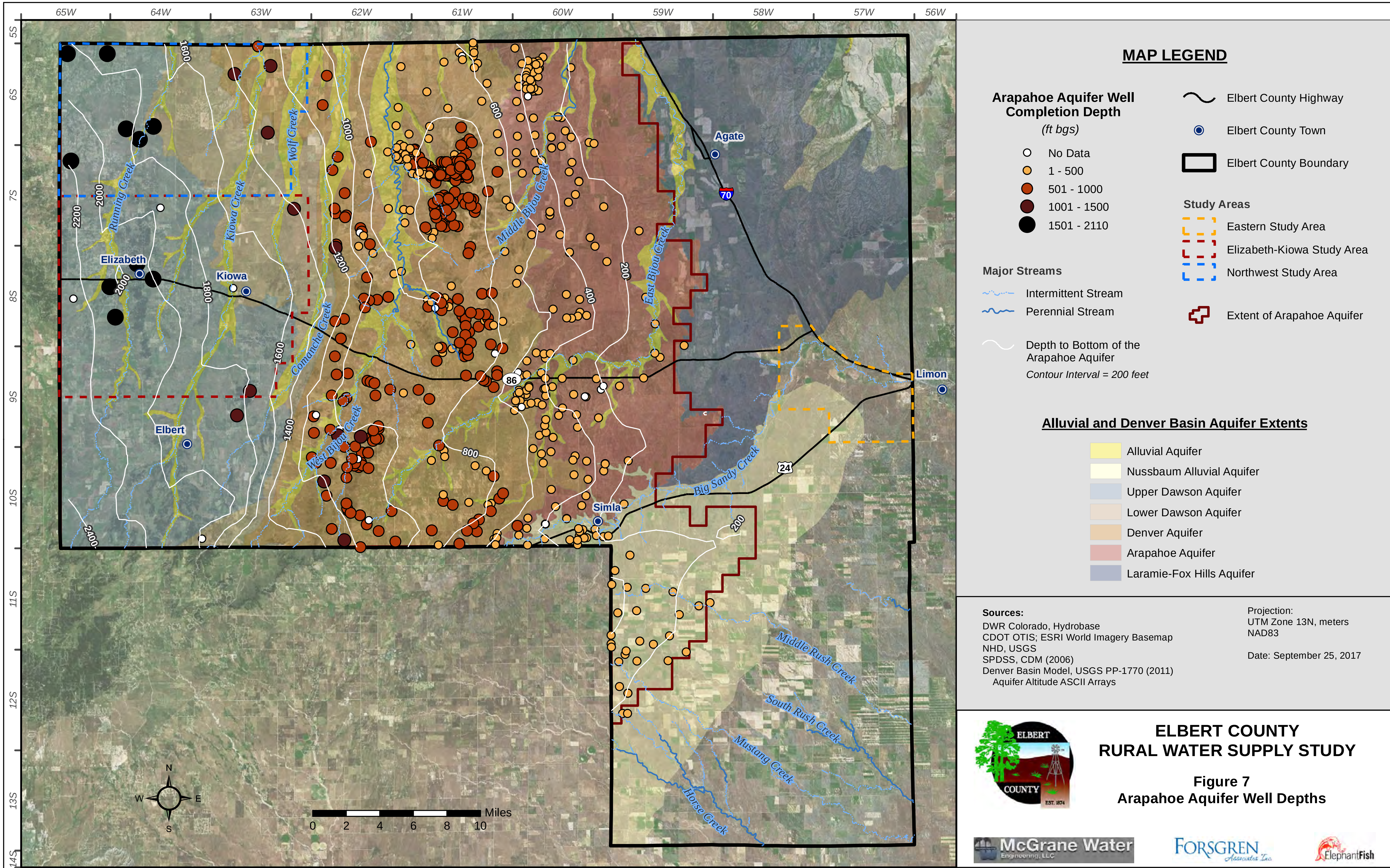
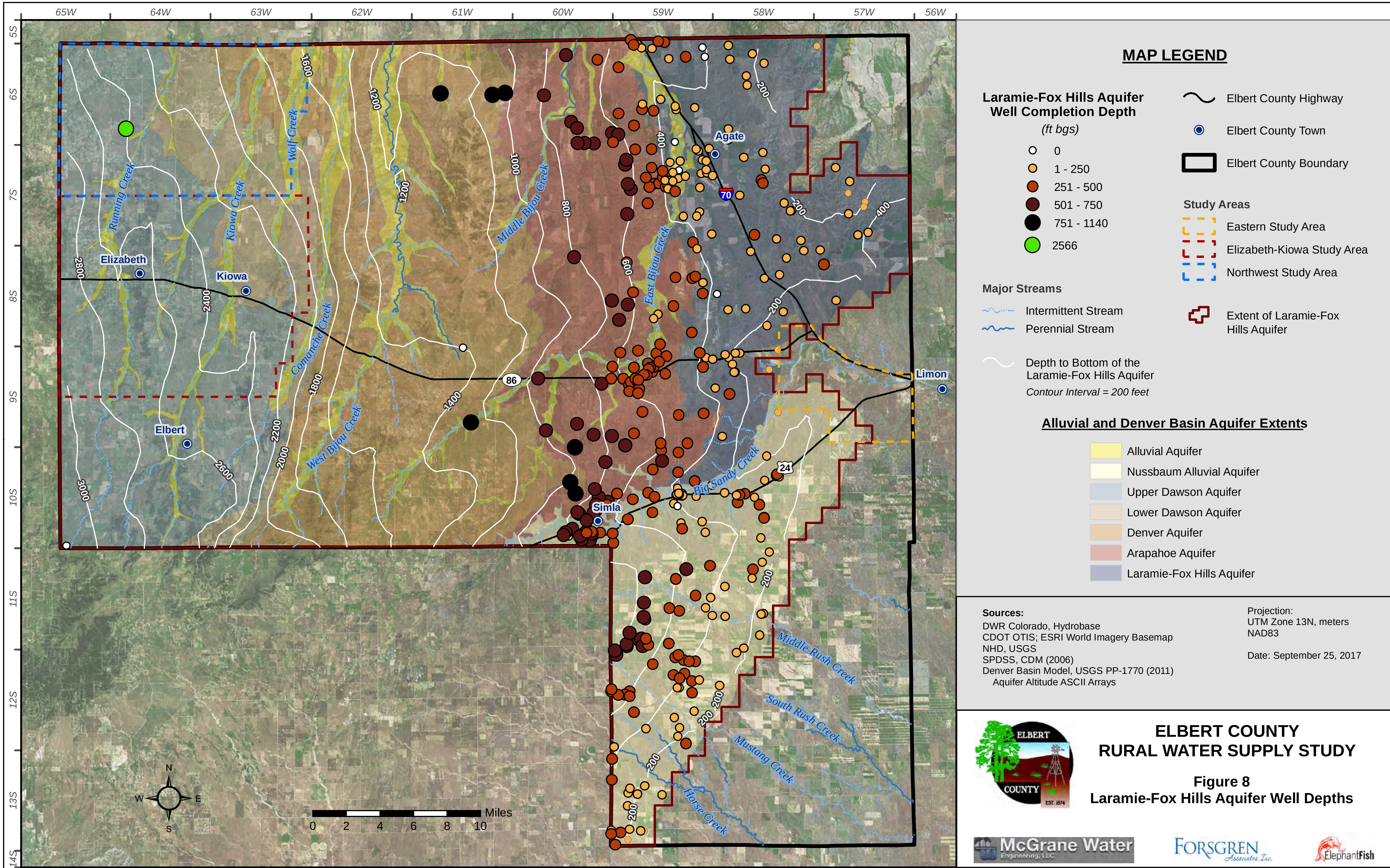


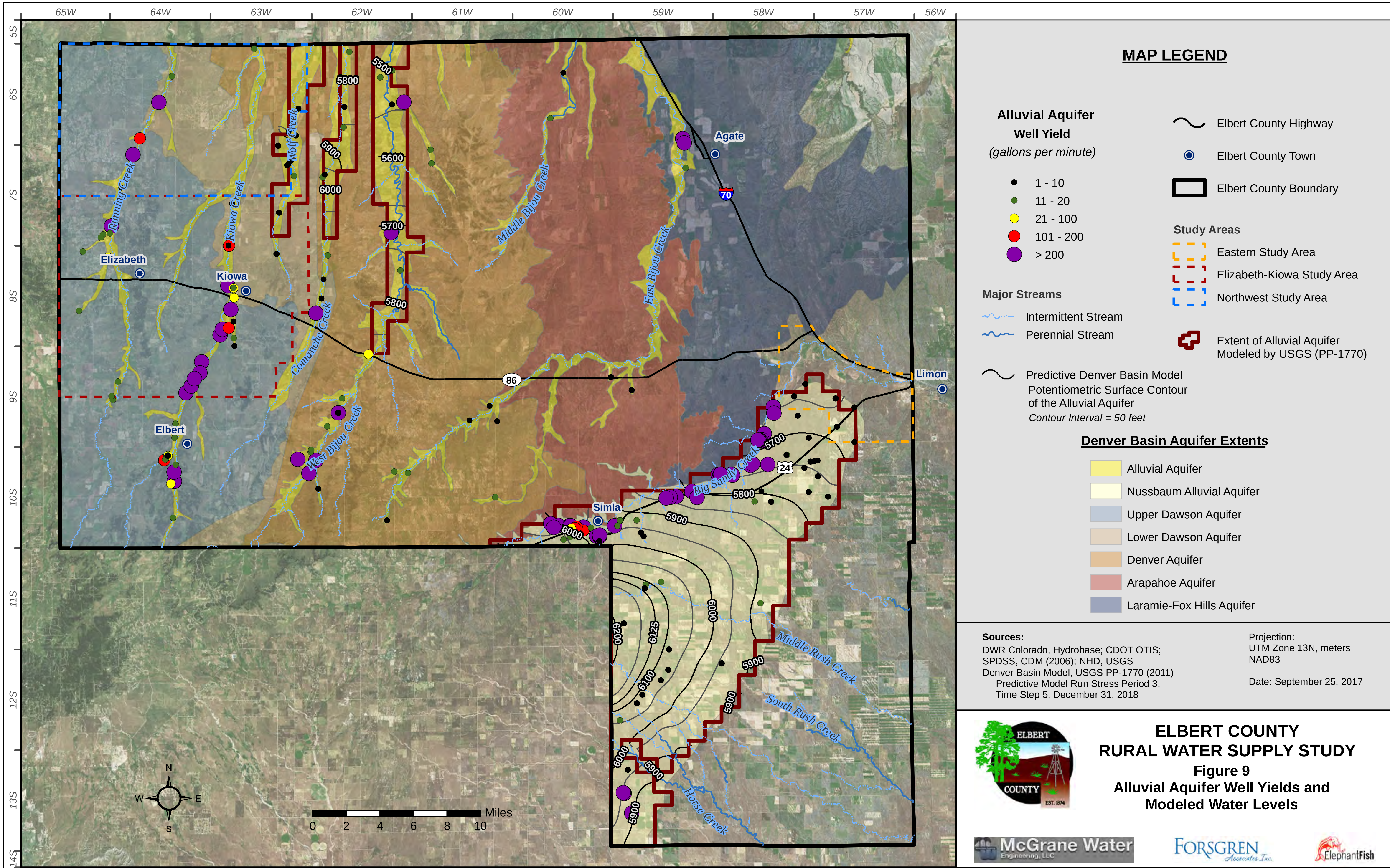
MAP LEGEND
Lower Dawson Aquifer Well Completion Depth
(ft bgs)
No Data
1 - 200
201 - 400
401 - 600
601 - 960
Elbert County Highway
Elbert County Town
Elbert County Boundary
Study Areas
Eastern Study Area
Elizabeth-Kiowa Study Area
Northwest Study Area
Extent of Lower Dawson Aquifer
Major Streams
Intermittent Stream
Perennial Stream
Depth to Bottom of the Lower Dawson Aquifer
Contour Interval = 100 feet
Alluvial and Denver Basin Aquifer Extents
Alluvial Aquifer
Nussbaum Alluvial Aquifer
Upper Dawson Aquifer
Lower Dawson Aquifer
Denver Aquifer
Arapahoe Aquifer
Laramie-Fox Hills Aquifer
Sources:
DWR Colorado, Hydrobase
CDOT OTIS; ESRI World Imagery Basemap
NHD, USGS
SPDSS, CDM (2006)
Denver Basin Model, USGS PP-1770 (2011)
Aquifer Altitude ASCII Arrays
Projection:
UTM Zone 13N, meters
NAD83
Date: September 25, 2017
ELBERT COUNTY
RURAL WATER SUPPLY STUDY
Figure 5
Lower Dawson Aquifer Well Depths
McGrane Water Engineering, LLC
FORSGREN Associates Inc.
ElephantFish
Agate
Elizabeth
Kiowa
Elbert
Simla
Limon
Running Creek
Kiowa Creek
Wolf Creek
Comanche Creek
West Bijou Creek
Middle Bijou Creek
East Bijou Creek
Big Sandy Creek
Middle Rush Creek
South Rush Creek
Mustang Creek
Horse Creek
86
70
24
65W
64W
63W
62W
61W
60W
59W
58W
57W
56W
5S
6S
7S
8S
9S
10S
11S
12S
13S
14S
Miles
0
2
4
6
8
10
N
E
S
W


MAP LEGEND
Denver Aquifer Well Completion Depth
(ft bgs)
No Data
1 - 250
251 - 500
501 - 750
751 - 1000
1001 - 1250
1251 - 1725
Depth to Bottom of the Denver Aquifer
Contour Interval = 200 feet
Elbert County Highway
Elbert County Town
Elbert County Boundary
Study Areas
Eastern Study Area
Elizabeth-Kiowa Study Area
Northwest Study Area
Extent of Denver Aquifer
Major Streams
Intermittent Stream
Perennial Stream
Alluvial and Denver Basin Aquifer Extents
Alluvial Aquifer
Nussbaum Alluvial Aquifer
Upper Dawson Aquifer
Lower Dawson Aquifer
Denver Aquifer
Arapahoe Aquifer
Laramie-Fox Hills Aquifer
Sources:
DWR Colorado, Hydrobase
CDOT OTIS; ESRI World Imagery Basemap
NHD, USGS
SPDSS, CDM (2006)
Denver Basin Model, USGS PP-1770 (2011)
Aquifer Altitude ASCII Arrays
Projection:
UTM Zone 13N, meters
NAD83
Date: September 25, 2017
ELBERT COUNTY
RURAL WATER SUPPLY STUDY
Figure 6
Denver Aquifer Well Depths
McGrane Water Engineering, LLC
FORSGREN Associates Inc.
ElephantFish
65W 64W 63W 62W 61W 60W 59W 58W 57W 56W
5S 6S 7S 8S 9S 10S 11S 12S 13S 14S
Agate
Elizabeth
Kiowa
Elbert
Simla
Limon
Running Creek
Kiowa Creek
Wolf Creek
Comanche Creek
West Bijou Creek
Middle Bijou Creek
East Bijou Creek
Big Sandy Creek
Middle Rush Creek
South Rush Creek
Mustang Creek
Horse Creek
70
86
24
Miles
0 2 4 6 8 10
N
S
E
W

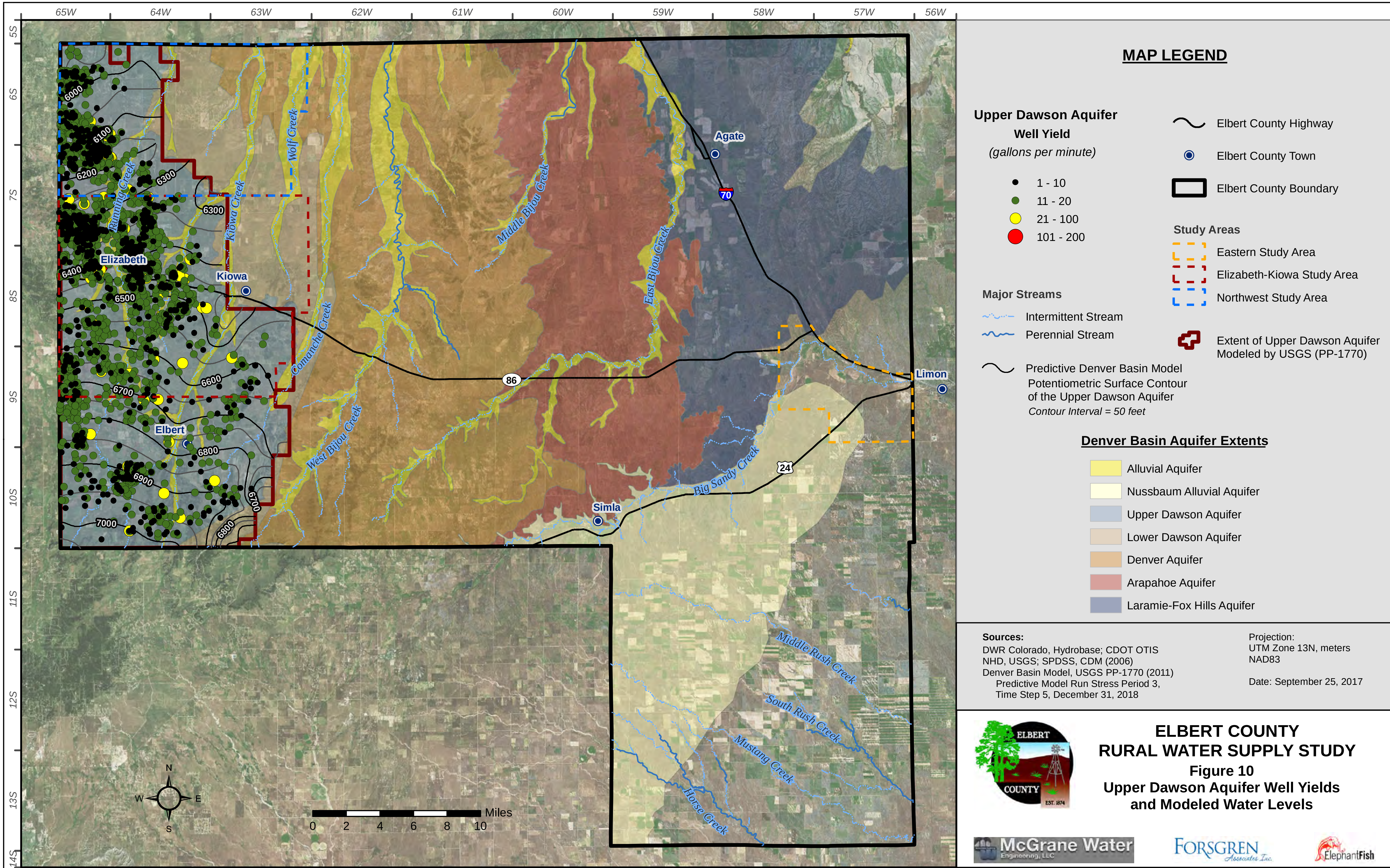


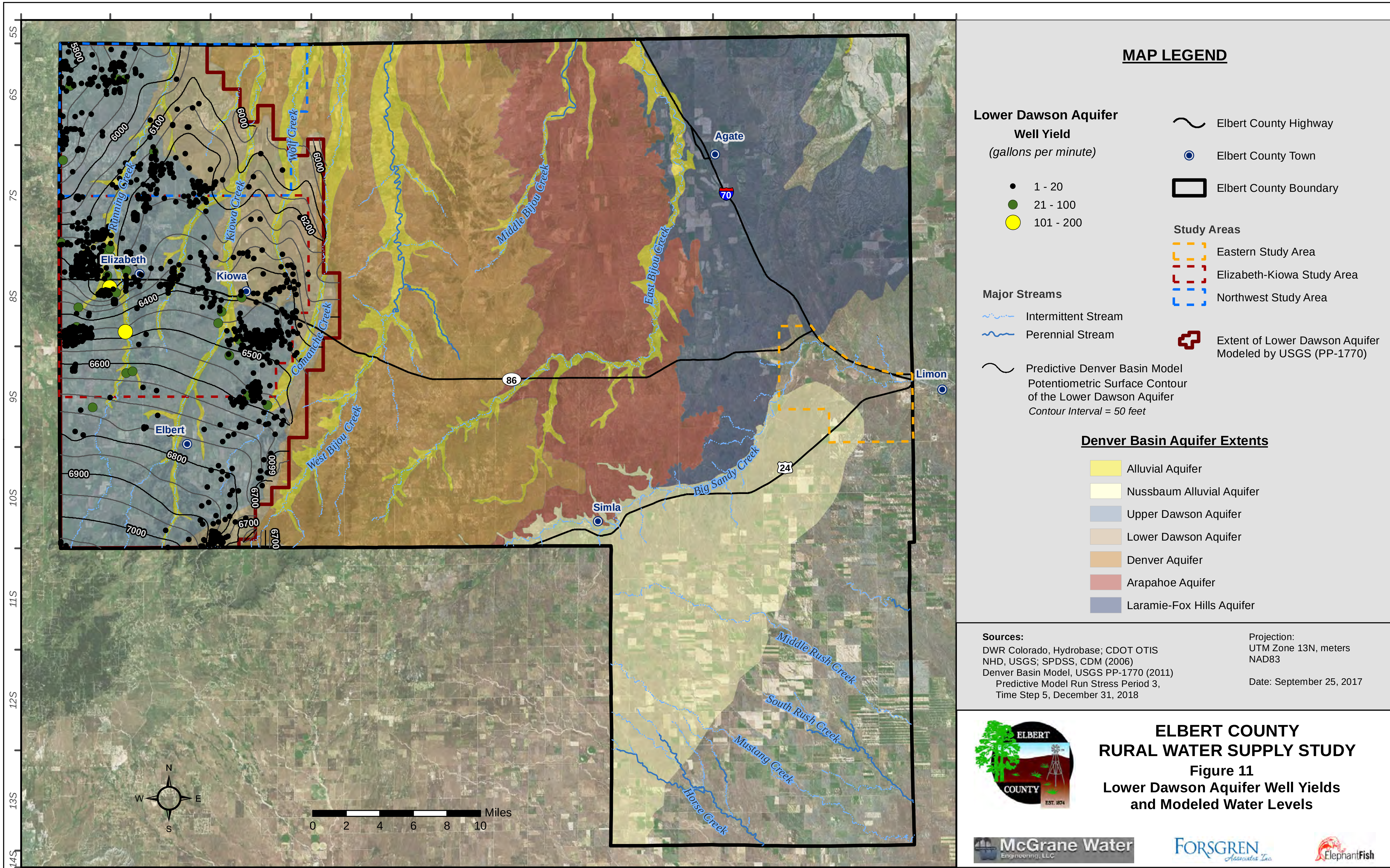
65W
64W
63W
62W
61W
60W
59W
58W
57W
56W
5S
6S
7S
8S
9S
10S
11S
12S
13S
14S
MAP LEGEND
Arapahoe Aquifer Well Completion Depth
(ft bgs)
No Data
1 - 500
501 - 1000
1001 - 1500
1501 - 2110
Elbert County Highway
Elbert County Town
Elbert County Boundary
Study Areas
Eastern Study Area
Elizabeth-Kiowa Study Area
Northwest Study Area
Extent of Arapahoe Aquifer
Major Streams
Intermittent Stream
Perennial Stream
Depth to Bottom of the Arapahoe Aquifer
Contour Interval = 200 feet
Alluvial and Denver Basin Aquifer Extents
Alluvial Aquifer
Nussbaum Alluvial Aquifer
Upper Dawson Aquifer
Lower Dawson Aquifer
Denver Aquifer
Arapahoe Aquifer
Laramie-Fox Hills Aquifer
Sources:
DWR Colorado, Hydrobase
CDOT OTIS; ESRI World Imagery Basemap
NHD, USGS
SPDSS, CDM (2006)
Denver Basin Model, USGS PP-1770 (2011)
Aquifer Altitude ASCII Arrays
Projection:
UTM Zone 13N, meters
NAD83
Date: September 25, 2017
ELBERT COUNTY
RURAL WATER SUPPLY STUDY
Figure 7
Arapahoe Aquifer Well Depths
ELBERT COUNTY EST. 1874
McGrane Water Engineering, LLC
FORSGREN Associates Inc.
ElephantFish
Agate
Elizabeth
Kiowa
Elbert
Simla
Limon
Running Creek
Kiowa Creek
Wolf Creek
Comanche Creek
West Bijou Creek
Middle Bijou Creek
East Bijou Creek
Big Sandy Creek
Middle Rush Creek
South Rush Creek
Mustang Creek
Horse Creek
70
86
24
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
2400
N
W
E
S
Miles
0
2
4
6
8
10


MAP LEGEND
Laramie-Fox Hills Aquifer Well Completion Depth
(ft bgs)
0
1 - 250
251 - 500
501 - 750
751 - 1140
2566
Elbert County Highway
Elbert County Town
Elbert County Boundary
Study Areas
Eastern Study Area
Elizabeth-Kiowa Study Area
Northwest Study Area
Extent of Laramie-Fox Hills Aquifer
Major Streams
Intermittent Stream
Perennial Stream
Depth to Bottom of the Laramie-Fox Hills Aquifer
Contour Interval = 200 feet
Alluvial and Denver Basin Aquifer Extents
Alluvial Aquifer
Nussbaum Alluvial Aquifer
Upper Dawson Aquifer
Lower Dawson Aquifer
Denver Aquifer
Arapahoe Aquifer
Laramie-Fox Hills Aquifer
Sources:
DWR Colorado, Hydrobase
CDOT OTIS; ESRI World Imagery Basemap
NHD, USGS
SPDSS, CDM (2006)
Denver Basin Model, USGS PP-1770 (2011)
Aquifer Altitude ASCII Arrays
Projection:
UTM Zone 13N, meters
NAD83
Date: September 25, 2017
ELBERT COUNTY
RURAL WATER SUPPLY STUDY
Figure 8
Laramie-Fox Hills Aquifer Well Depths
McGrane Water Engineering, LLC
FORSGREN Associates Inc.
ElephantFish
Elizabeth
Kiowa
Elbert
Agate
Simla
Limon
Running Creek
Kiowa Creek
Wolf Creek
Comanche Creek
West Bijou Creek
Middle Bijou Creek
East Bijou Creek
Big Sandy Creek
Middle Rush Creek
South Rush Creek
Mustang Creek
Horse Creek
65W
64W
63W
62W
61W
60W
59W
58W
57W
56W
5S
6S
7S
8S
9S
10S
11S
12S
13S
14S
Miles
0 2 4 6 8 10

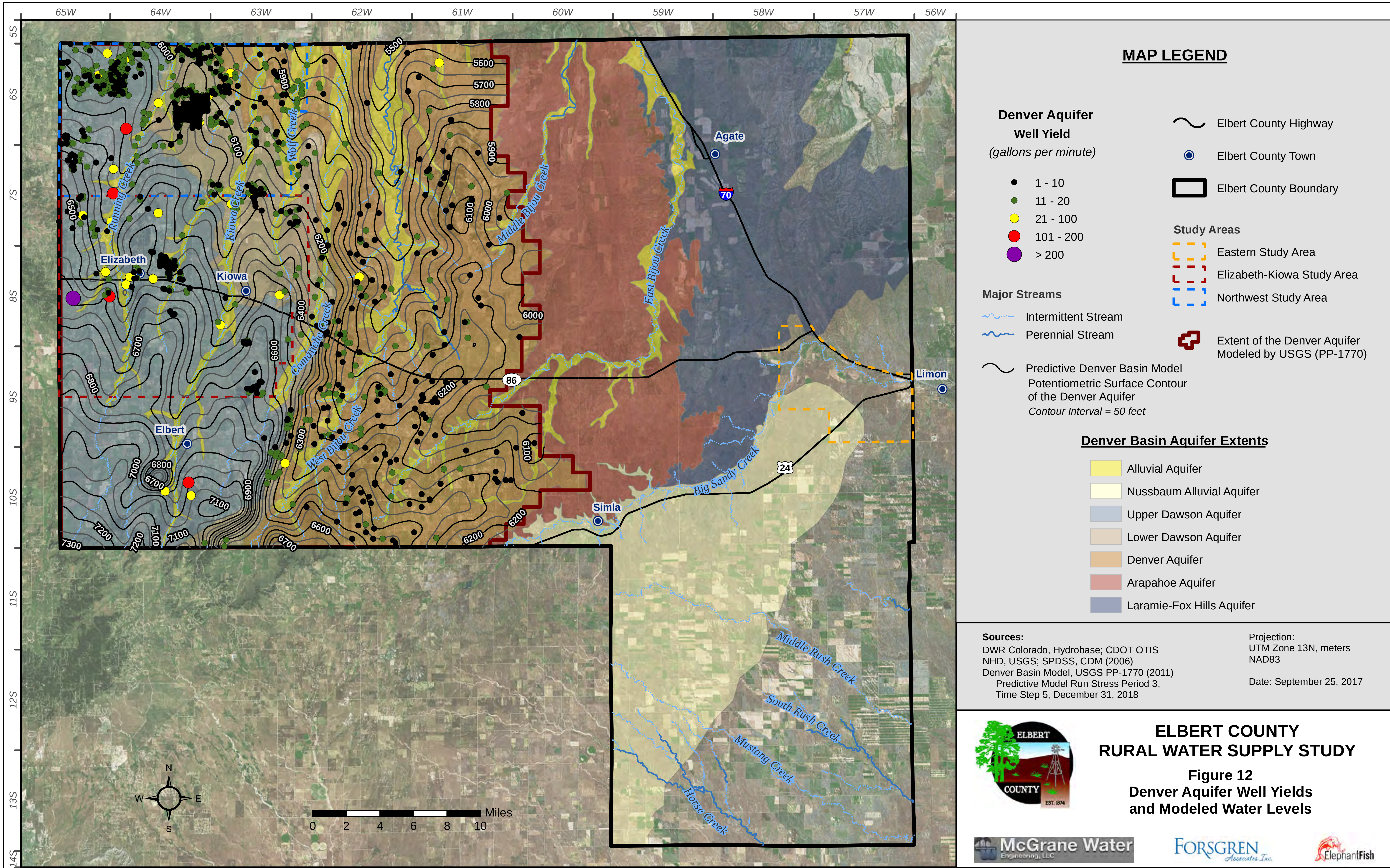


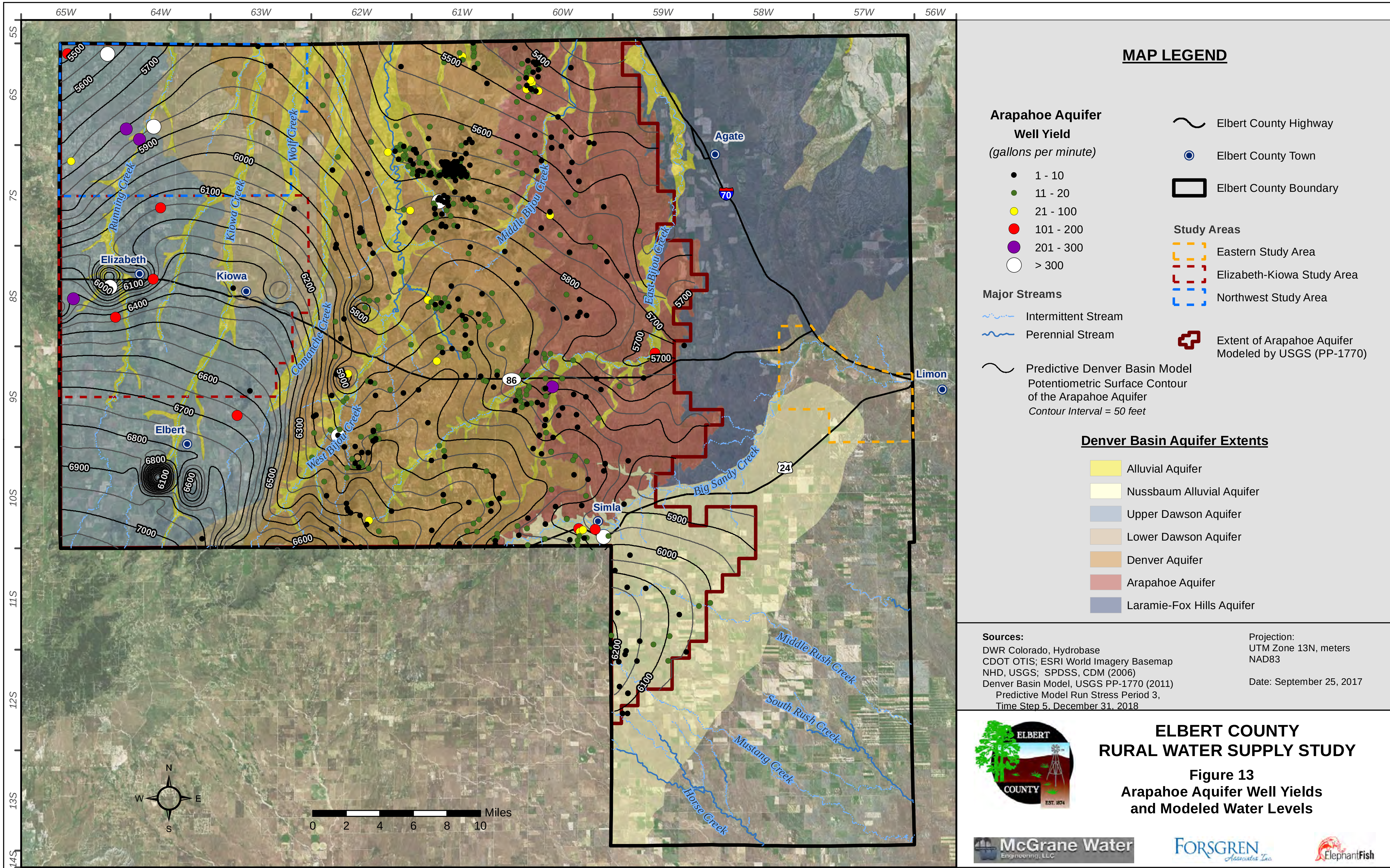
ELBERT COUNTY
RURAL WATER SUPPLY STUDY
Figure 9
Alluvial Aquifer Well Yields and Modeled Water Levels

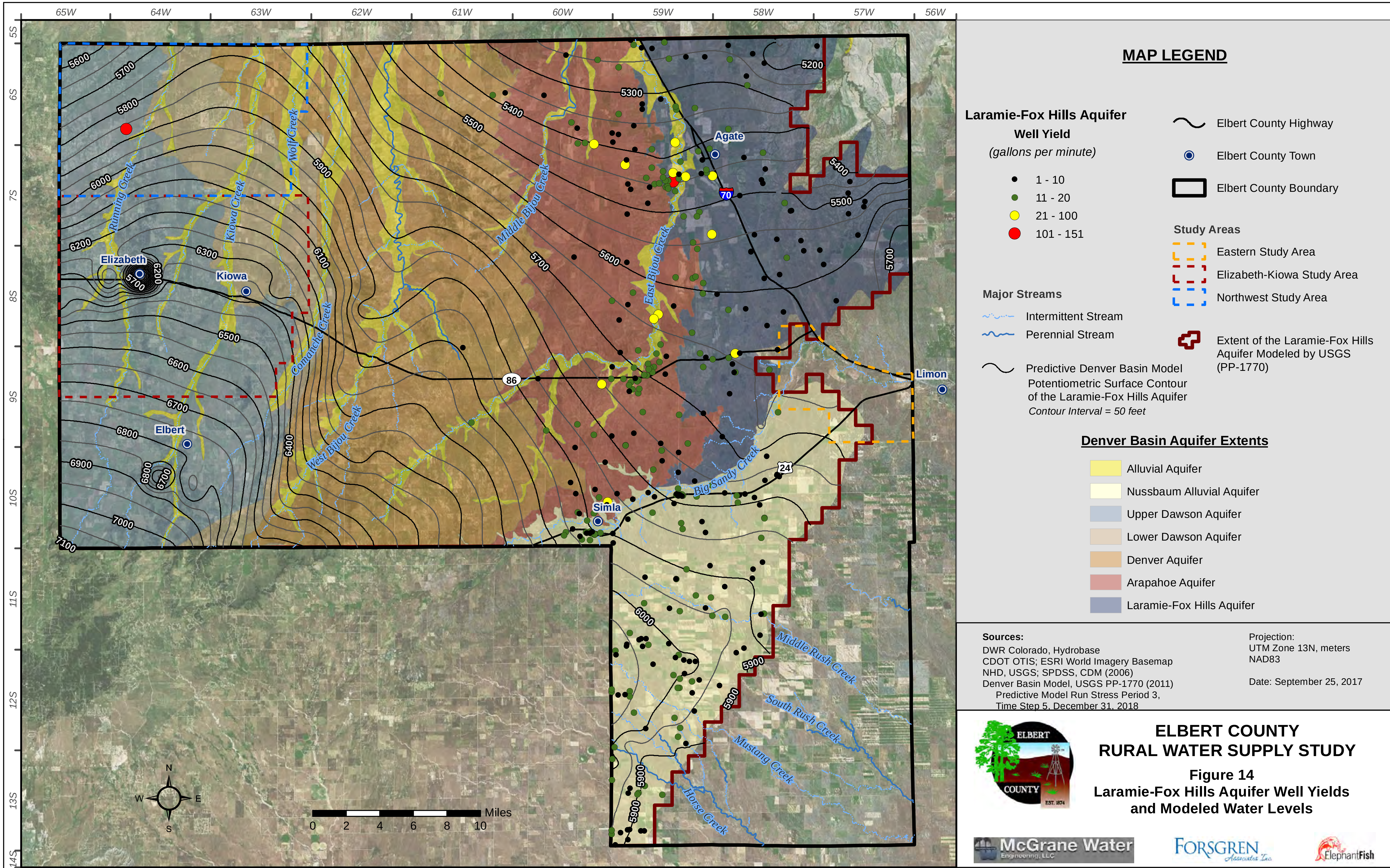

MAP LEGEND
Upper Dawson Aquifer
Well Yield
(gallons per minute)
1 - 10
11 - 20
21 - 100
101 - 200
Elbert County Highway
Elbert County Town
Elbert County Boundary
Study Areas
Eastern Study Area
Elizabeth-Kiowa Study Area
Northwest Study Area
Extent of Upper Dawson Aquifer Modeled by USGS (PP-1770)
Major Streams
Intermittent Stream
Perennial Stream
Predictive Denver Basin Model Potentiometric Surface Contour of the Upper Dawson Aquifer
Contour Interval = 50 feet
Denver Basin Aquifer Extents
Alluvial Aquifer
Nussbaum Alluvial Aquifer
Upper Dawson Aquifer
Lower Dawson Aquifer
Denver Aquifer
Arapahoe Aquifer
Laramie-Fox Hills Aquifer
Sources:
DWR Colorado, Hydrobase; CDOT OTIS
NHD, USGS; SPDSS, CDM (2006)
Denver Basin Model, USGS PP-1770 (2011)
Predictive Model Run Stress Period 3,
Time Step 5, December 31, 2018
Projection:
UTM Zone 13N, meters
NAD83
Date: September 25, 2017
ELBERT COUNTY
RURAL WATER SUPPLY STUDY
Figure 10
Upper Dawson Aquifer Well Yields
and Modeled Water Levels
McGrane Water
FORSGREN
ElephantFish
65W
64W
63W
62W
61W
60W
59W
58W
57W
56W
5S
6S
7S
8S
9S
10S
11S
12S
13S
14S
Agate
Elizabeth
Kiowa
Elbert
Simla
Limon
Running Creek
Kiowa Creek
Wolf Creek
Comanche Creek
West Bijou Creek
Middle Bijou Creek
East Bijou Creek
Big Sandy Creek
Middle Rush Creek
South Rush Creek
Mustang Creek
Horse Creek
70
86
24
6000
6100
6200
6300
6400
6500
6600
6700
6800
6900
7000
Miles
0
2
4
6
8
10
N
S
E
W

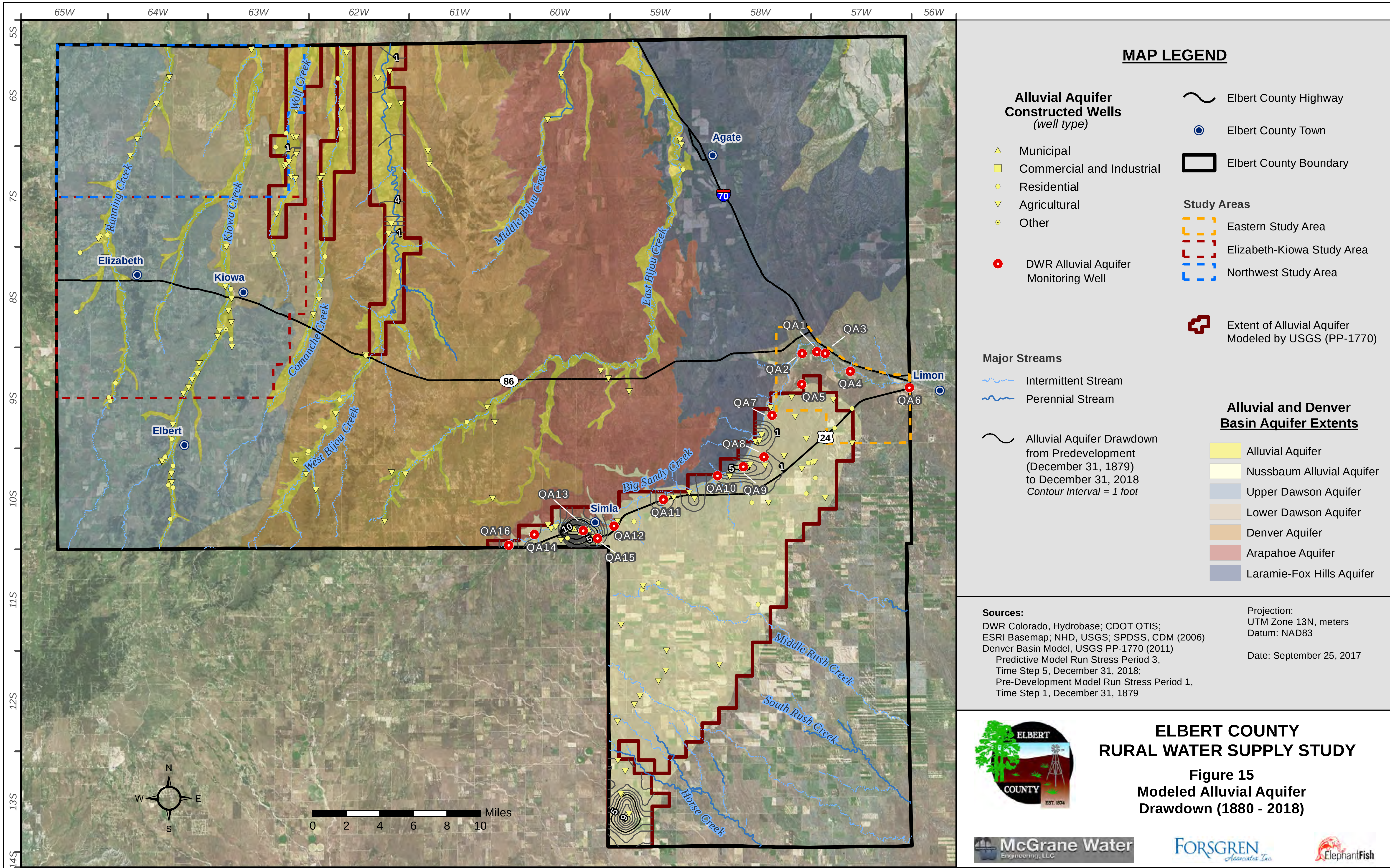


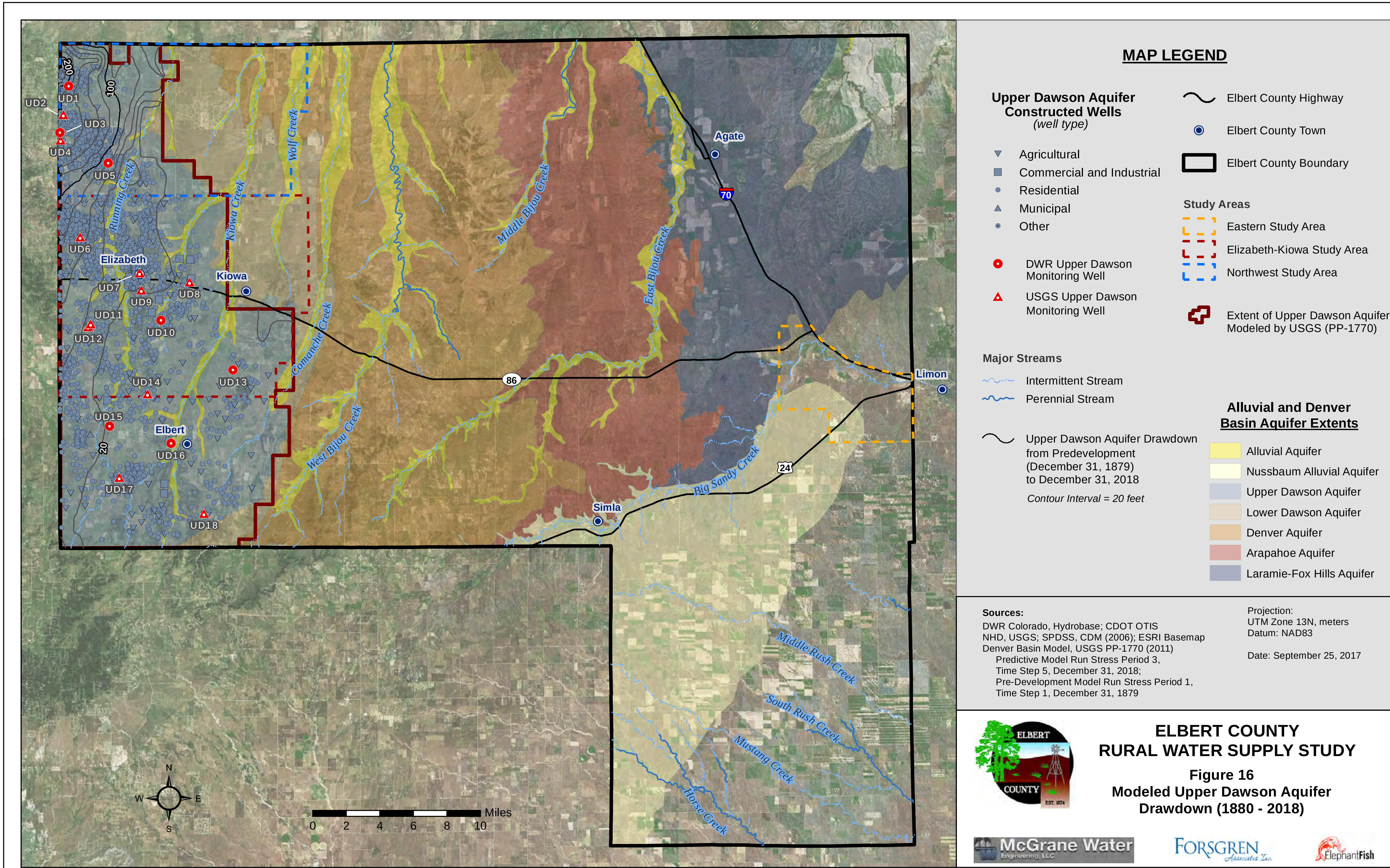
MAP LEGEND
Lower Dawson Aquifer
Well Yield
(gallons per minute)
1 - 20
21 - 100
101 - 200
Elbert County Highway
Elbert County Town
Elbert County Boundary
Study Areas
Eastern Study Area
Elizabeth-Kiowa Study Area
Northwest Study Area
Extent of Lower Dawson Aquifer Modeled by USGS (PP-1770)
Major Streams
Intermittent Stream
Perennial Stream
Predictive Denver Basin Model Potentiometric Surface Contour of the Lower Dawson Aquifer
Contour Interval = 50 feet
Denver Basin Aquifer Extents
Alluvial Aquifer
Nussbaum Alluvial Aquifer
Upper Dawson Aquifer
Lower Dawson Aquifer
Denver Aquifer
Arapahoe Aquifer
Laramie-Fox Hills Aquifer
Sources:
DWR Colorado, Hydrobase; CDOT OTIS
NHD, USGS; SPDSS, CDM (2006)
Denver Basin Model, USGS PP-1770 (2011)
Predictive Model Run Stress Period 3,
Time Step 5, December 31, 2018
Projection:
UTM Zone 13N, meters
NAD83
Date: September 25, 2017
ELBERT COUNTY
RURAL WATER SUPPLY STUDY
Figure 11
Lower Dawson Aquifer Well Yields
and Modeled Water Levels
McGrane Water
FORSGREN
ElephantFish
Agate
Elizabeth
Kiowa
Elbert
Simla
Limon
Running Creek
Kiowa Creek
Wolf Creek
Comanche Creek
West Bijou Creek
Middle Bijou Creek
East Bijou Creek
Big Sandy Creek
Middle Rush Creek
South Rush Creek
Mustang Creek
Horse Creek
70
86
24
5800
6000
6100
6200
6400
6500
6600
6700
6800
6900
7000
5S
6S
7S
8S
9S
10S
11S
12S
13S
14S
N
E
S
W
Miles
0
2
4
6
8
10

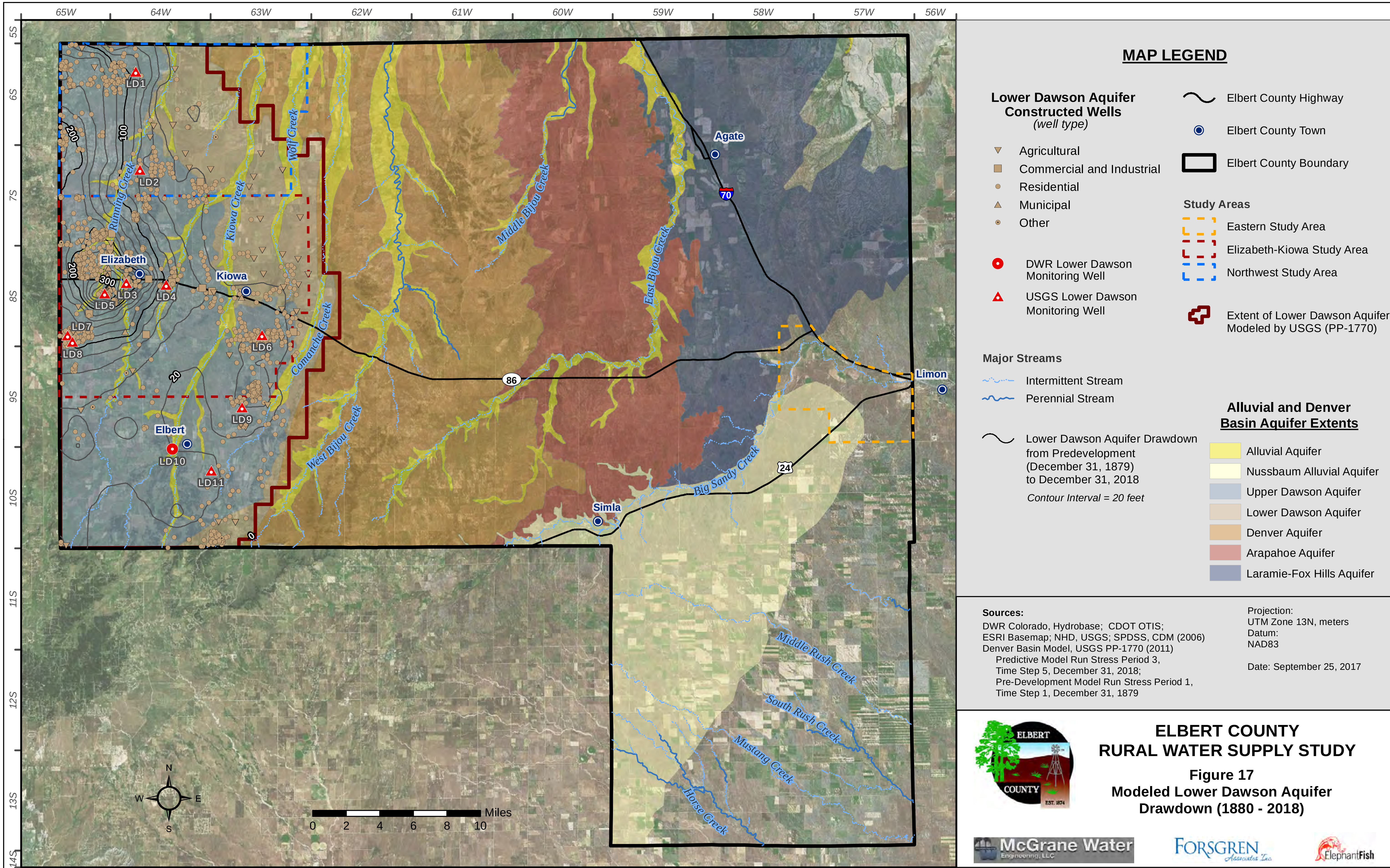

65W
64W
63W
62W
61W
60W
59W
58W
57W
56W
5S
6S
7S
8S
9S
10S
11S
12S
13S
14S
MAP LEGEND
Denver Aquifer
Well Yield
(gallons per minute)
1 - 10
11 - 20
21 - 100
101 - 200
> 200
Elbert County Highway
Elbert County Town
Elbert County Boundary
Study Areas
Eastern Study Area
Elizabeth-Kiowa Study Area
Northwest Study Area
Major Streams
Intermittent Stream
Perennial Stream
Extent of the Denver Aquifer Modeled by USGS (PP-1770)
Predictive Denver Basin Model Potentiometric Surface Contour of the Denver Aquifer
Contour Interval = 50 feet
Denver Basin Aquifer Extents
Alluvial Aquifer
Nussbaum Alluvial Aquifer
Upper Dawson Aquifer
Lower Dawson Aquifer
Denver Aquifer
Arapahoe Aquifer
Laramie-Fox Hills Aquifer
Sources:
DWR Colorado, Hydrobase; CDOT OTIS
NHD, USGS; SPDSS, CDM (2006)
Denver Basin Model, USGS PP-1770 (2011)
Predictive Model Run Stress Period 3,
Time Step 5, December 31, 2018
Projection:
UTM Zone 13N, meters
NAD83
Date: September 25, 2017
ELBERT COUNTY
RURAL WATER SUPPLY STUDY
Figure 12
Denver Aquifer Well Yields
and Modeled Water Levels
ELBERT COUNTY EST. 1874
McGrane Water Engineering, LLC
FORSGREN Associates Inc.
ElephantFish
Agate
Elizabeth
Kiowa
Elbert
Simla
Limon
Running Creek
Kiowa Creek
Wolf Creek
Comanche Creek
West Bijou Creek
Middle Bijou Creek
East Bijou Creek
Big Sandy Creek
Middle Rush Creek
South Rush Creek
Mustang Creek
Horse Creek
70
86
24
N
S
E
W
Miles
0
2
4
6
8
10


MAP LEGEND
Arapahoe Aquifer
Well Yield
(gallons per minute)
1 - 10
11 - 20
21 - 100
101 - 200
201 - 300
> 300
Major Streams
Intermittent Stream
Perennial Stream
Predictive Denver Basin Model
Potentiometric Surface Contour
of the Arapahoe Aquifer
Contour Interval = 50 feet
Elbert County Highway
Elbert County Town
Elbert County Boundary
Study Areas
Eastern Study Area
Elizabeth-Kiowa Study Area
Northwest Study Area
Extent of Arapahoe Aquifer
Modeled by USGS (PP-1770)
Denver Basin Aquifer Extents
Alluvial Aquifer
Nussbaum Alluvial Aquifer
Upper Dawson Aquifer
Lower Dawson Aquifer
Denver Aquifer
Arapahoe Aquifer
Laramie-Fox Hills Aquifer
Sources:
DWR Colorado, Hydrobase
CDOT OTIS; ESRI World Imagery Basemap
NHD, USGS; SPDSS, CDM (2006)
Denver Basin Model, USGS PP-1770 (2011)
Predictive Model Run Stress Period 3,
Time Step 5, December 31, 2018
Projection:
UTM Zone 13N, meters
NAD83
Date: September 25, 2017
ELBERT COUNTY
RURAL WATER SUPPLY STUDY
Figure 13
Arapahoe Aquifer Well Yields
and Modeled Water Levels
Elizabeth
Kiowa
Elbert
Agate
Simla
Limon
Running Creek
Kiowa Creek
Wolf Creek
Comanche Creek
West Bijou Creek
Middle Bijou Creek
East Bijou Creek
Big Sandy Creek
Middle Rush Creek
South Rush Creek
Mustang Creek
Horse Creek
Miles
0 2 4 6 8 10

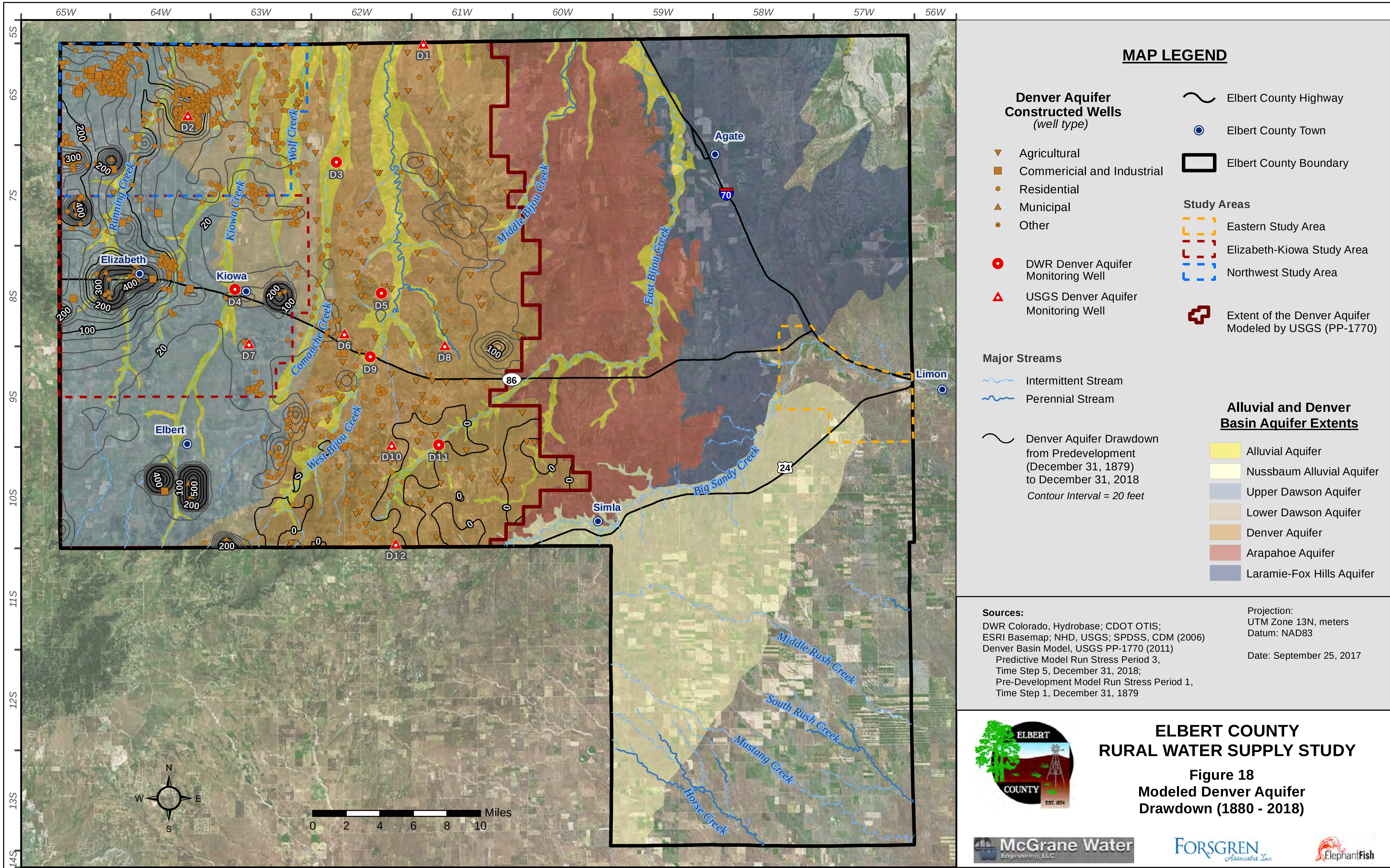

MAP LEGEND
Laramie-Fox Hills Aquifer
Well Yield
(gallons per minute)
1 - 10
11 - 20
21 - 100
101 - 151
Elbert County Highway
Elbert County Town
Elbert County Boundary
Study Areas
Eastern Study Area
Elizabeth-Kiowa Study Area
Northwest Study Area
Extent of the Laramie-Fox Hills Aquifer Modeled by USGS (PP-1770)
Major Streams
Intermittent Stream
Perennial Stream
Predictive Denver Basin Model Potentiometric Surface Contour of the Laramie-Fox Hills Aquifer
Contour Interval = 50 feet
Denver Basin Aquifer Extents
Alluvial Aquifer
Nussbaum Alluvial Aquifer
Upper Dawson Aquifer
Lower Dawson Aquifer
Denver Aquifer
Arapahoe Aquifer
Laramie-Fox Hills Aquifer
Sources:
DWR Colorado, Hydrobase
CDOT OTIS; ESRI World Imagery Basemap
NHD, USGS; SPDSS, CDM (2006)
Denver Basin Model, USGS PP-1770 (2011)
Predictive Model Run Stress Period 3,
Time Step 5, December 31, 2018
Projection:
UTM Zone 13N, meters
NAD83
Date: September 25, 2017
ELBERT COUNTY
RURAL WATER SUPPLY STUDY
Figure 14
Laramie-Fox Hills Aquifer Well Yields and Modeled Water Levels
McGrane Water
FORSGREN
ElephantFish
Elizabeth
Kiowa
Elbert
Agate
Simla
Limon
Running Creek
Kiowa Creek
Wolf Creek
Comanche Creek
West Bijou Creek
Middle Bijou Creek
East Bijou Creek
Big Sandy Creek
Middle Rush Creek
South Rush Creek
Mustang Creek
Horse Creek
86
70
24
Miles
0 2 4 6 8 10
65W 64W 63W 62W 61W 60W 59W 58W 57W 56W
5S 6S 7S 8S 9S 10S 11S 12S 13S 14S

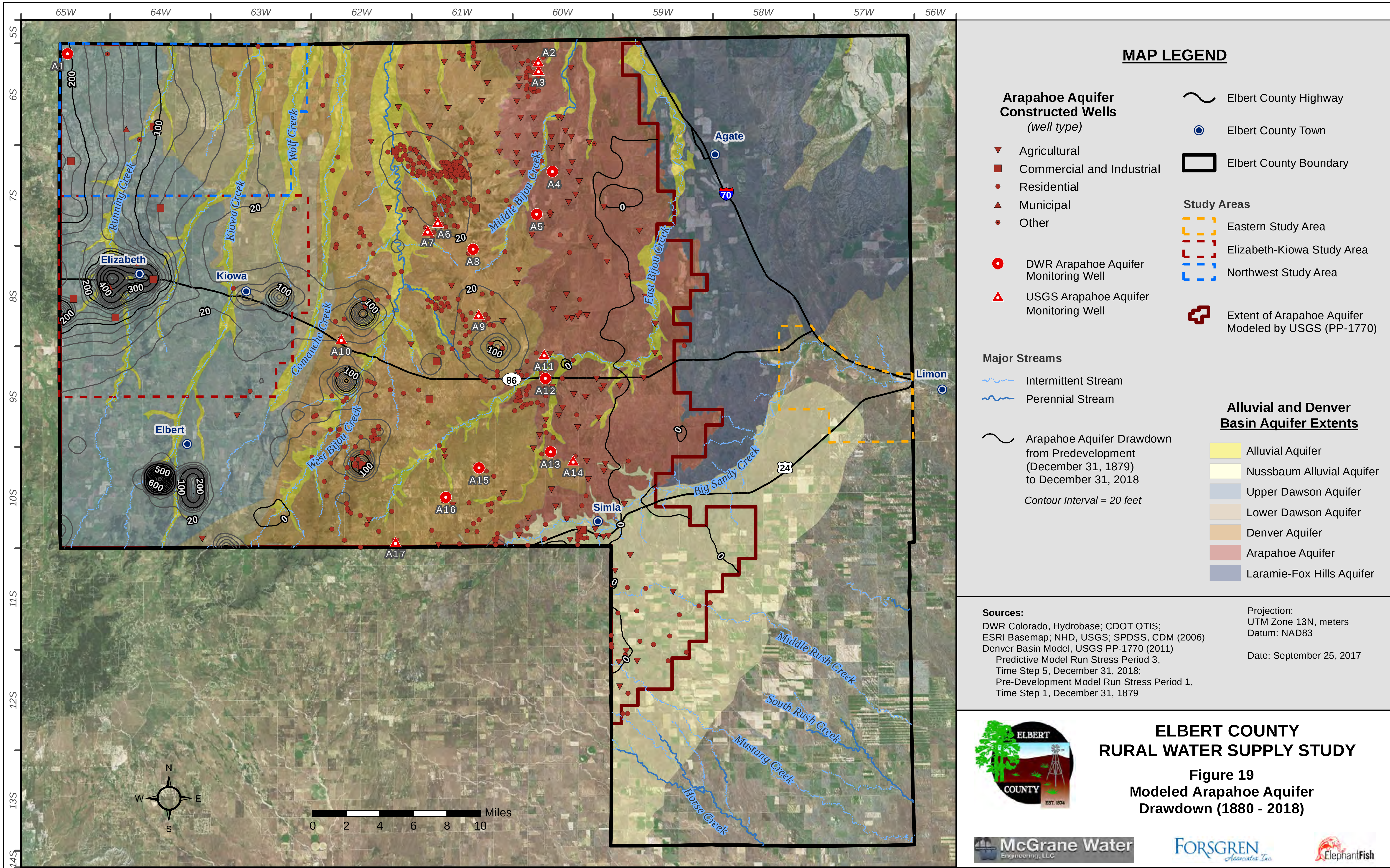

65W
64W
63W
62W
61W
60W
59W
58W
57W
56W
5S
6S
7S
8S
9S
10S
11S
12S
13S
14S
Elizabeth
Kiowa
Elbert
Agate
Simla
Limon
Running Creek
Kiowa Creek
Wolf Creek
Comanche Creek
West Bijou Creek
Middle Bijou Creek
East Bijou Creek
Big Sandy Creek
Middle Rush Creek
South Rush Creek
Horse Creek
70
86
24
QA1
QA2
QA3
QA4
QA5
QA6
QA7
QA8
QA9
QA10
QA11
QA12
QA13
QA14
QA15
QA16
N
S
E
W
0
2
4
6
8
10
Miles
MAP LEGEND
Alluvial Aquifer Constructed Wells
(well type)
Municipal
Commercial and Industrial
Residential
Agricultural
Other
DWR Alluvial Aquifer Monitoring Well
Major Streams
Intermittent Stream
Perennial Stream
Alluvial Aquifer Drawdown from Predevelopment (December 31, 1879) to December 31, 2018
Contour Interval = 1 foot
Elbert County Highway
Elbert County Town
Elbert County Boundary
Study Areas
Eastern Study Area
Elizabeth-Kiowa Study Area
Northwest Study Area
Extent of Alluvial Aquifer Modeled by USGS (PP-1770)
Alluvial and Denver Basin Aquifer Extents
Alluvial Aquifer
Nussbaum Alluvial Aquifer
Upper Dawson Aquifer
Lower Dawson Aquifer
Denver Aquifer
Arapahoe Aquifer
Laramie-Fox Hills Aquifer
Sources:
DWR Colorado, Hydrobase; CDOT OTIS;
ESRI Basemap; NHD, USGS; SPDSS, CDM (2006)
Denver Basin Model, USGS PP-1770 (2011)
Predictive Model Run Stress Period 3, Time Step 5, December 31, 2018;
Pre-Development Model Run Stress Period 1, Time Step 1, December 31, 1879
Projection:
UTM Zone 13N, meters
Datum: NAD83
Date: September 25, 2017
ELBERT COUNTY
EST. 1874
ELBERT COUNTY
RURAL WATER SUPPLY STUDY
Figure 15
Modeled Alluvial Aquifer
Drawdown (1880 - 2018)
McGrane Water Engineering, LLC
FORSGREN Associates Inc.
ElephantFish

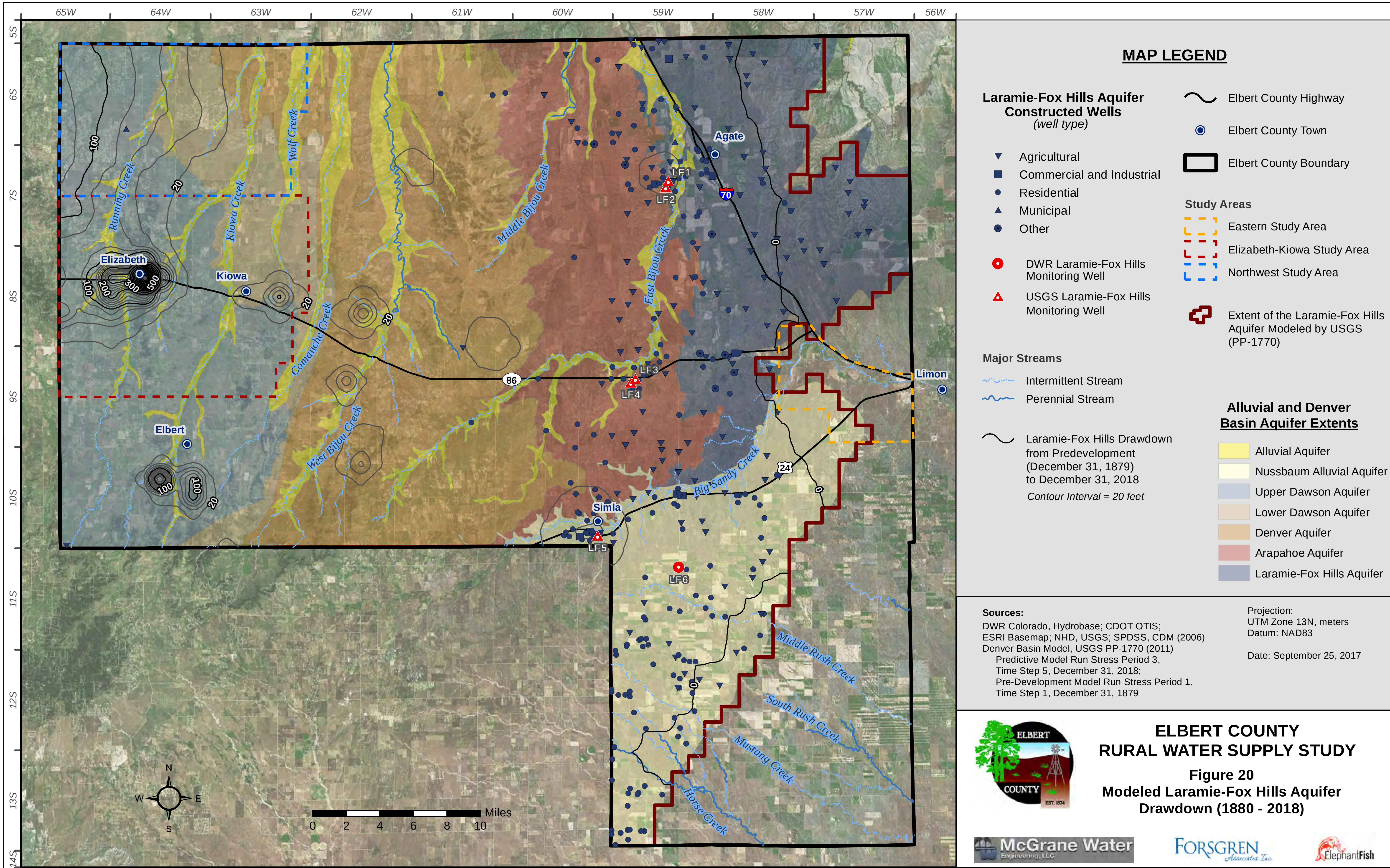

MAP LEGEND
Upper Dawson Aquifer Constructed Wells
(well type)
Agricultural
Commercial and Industrial
Residential
Municipal
Other
DWR Upper Dawson Monitoring Well
USGS Upper Dawson Monitoring Well
Elbert County Highway
Elbert County Town
Elbert County Boundary
Study Areas
Eastern Study Area
Elizabeth-Kiowa Study Area
Northwest Study Area
Extent of Upper Dawson Aquifer Modeled by USGS (PP-1770)
Major Streams
Intermittent Stream
Perennial Stream
Upper Dawson Aquifer Drawdown from Predevelopment (December 31, 1879) to December 31, 2018
Contour Interval = 20 feet
Alluvial and Denver Basin Aquifer Extents
Alluvial Aquifer
Nussbaum Alluvial Aquifer
Upper Dawson Aquifer
Lower Dawson Aquifer
Denver Aquifer
Arapahoe Aquifer
Laramie-Fox Hills Aquifer
Sources:
DWR Colorado, Hydrobase; CDOT OTIS
NHD, USGS; SPDSS, CDM (2006); ESRI Basemap
Denver Basin Model, USGS PP-1770 (2011)
Predictive Model Run Stress Period 3, Time Step 5, December 31, 2018;
Pre-Development Model Run Stress Period 1, Time Step 1, December 31, 1879
Projection:
UTM Zone 13N, meters
Datum: NAD83
Date: September 25, 2017
ELBERT COUNTY
RURAL WATER SUPPLY STUDY
Figure 16
Modeled Upper Dawson Aquifer Drawdown (1880 - 2018)
McGrane Water Engineering, LLC
FORSGREN Associates Inc.
ElephantFish
Agate
Kiowa
Elizabeth
Elbert
Simla
Limon
Wolf Creek
Kiowa Creek
Running Creek
Comanche Creek
West Bijou Creek
Middle Bijou Creek
East Bijou Creek
Big Sandy Creek
Middle Rush Creek
South Rush Creek
Mustang Creek
Horse Creek
UD1
UD2
UD3
UD4
UD5
UD6
UD7
UD8
UD9
UD10
UD11
UD12
UD13
UD14
UD15
UD16
UD17
UD18
200
100
20
70
86
24
Miles
0 2 4 6 8 10
N
E
S
W



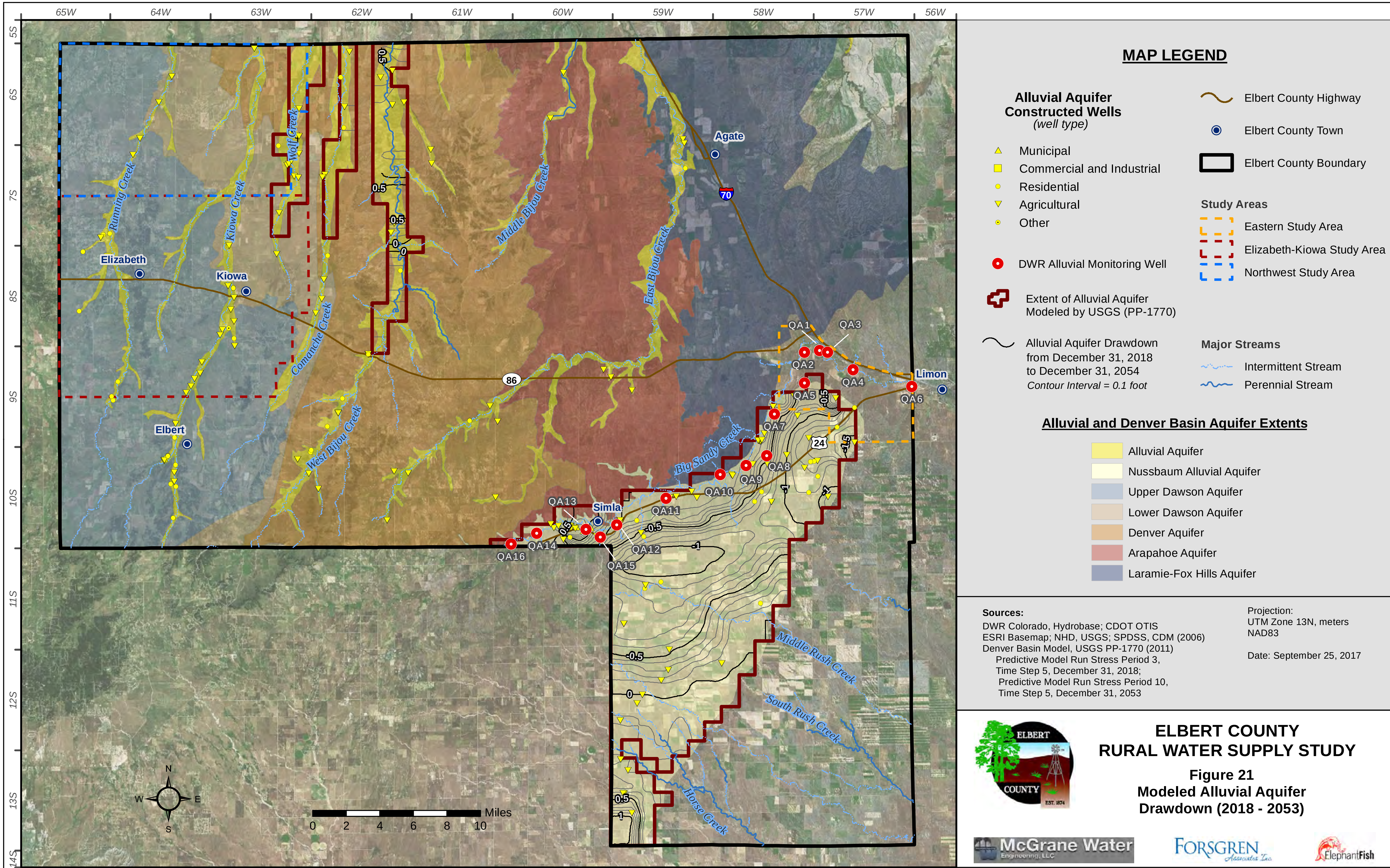
65W
64W
63W
62W
61W
60W
59W
58W
57W
56W
5S
6S
7S
8S
9S
10S
11S
12S
13S
14S
LD1
LD2
LD3
LD4
LD5
LD6
LD7
LD8
LD9
LD10
LD11
Elizabeth
Kiowa
Elbert
Agate
Simla
Limon
Running Creek
Kiowa Creek
Wolf Creek
Comanche Creek
West Bijou Creek
Middle Bijou Creek
East Bijou Creek
Big Sandy Creek
Middle Rush Creek
South Rush Creek
Mustang Creek
Horse Creek
200
100
300
20
0
86
70
24
N
S
E
W
0 2 4 6 8 10 Miles
MAP LEGEND
Lower Dawson Aquifer Constructed Wells
(well type)
Agricultural
Commercial and Industrial
Residential
Municipal
Other
DWR Lower Dawson Monitoring Well
USGS Lower Dawson Monitoring Well
Major Streams
Intermittent Stream
Perennial Stream
Lower Dawson Aquifer Drawdown from Predevelopment (December 31, 1879) to December 31, 2018
Contour Interval = 20 feet
Elbert County Highway
Elbert County Town
Elbert County Boundary
Study Areas
Eastern Study Area
Elizabeth-Kiowa Study Area
Northwest Study Area
Extent of Lower Dawson Aquifer Modeled by USGS (PP-1770)
Alluvial and Denver Basin Aquifer Extents
Alluvial Aquifer
Nussbaum Alluvial Aquifer
Upper Dawson Aquifer
Lower Dawson Aquifer
Denver Aquifer
Arapahoe Aquifer
Laramie-Fox Hills Aquifer
Sources:
DWR Colorado, Hydrobase; CDOT OTIS;
ESRI Basemap; NHD, USGS; SPDSS, CDM (2006)
Denver Basin Model, USGS PP-1770 (2011)
Predictive Model Run Stress Period 3,
Time Step 5, December 31, 2018;
Pre-Development Model Run Stress Period 1,
Time Step 1, December 31, 1879
Projection:
UTM Zone 13N, meters
Datum:
NAD83
Date: September 25, 2017
ELBERT COUNTY
RURAL WATER SUPPLY STUDY
Figure 17
Modeled Lower Dawson Aquifer
Drawdown (1880 - 2018)
ELBERT
COUNTY
EST. 1874
McGrane Water
Engineering, LLC
FORSGREN
Associates Inc.
ElephantFish

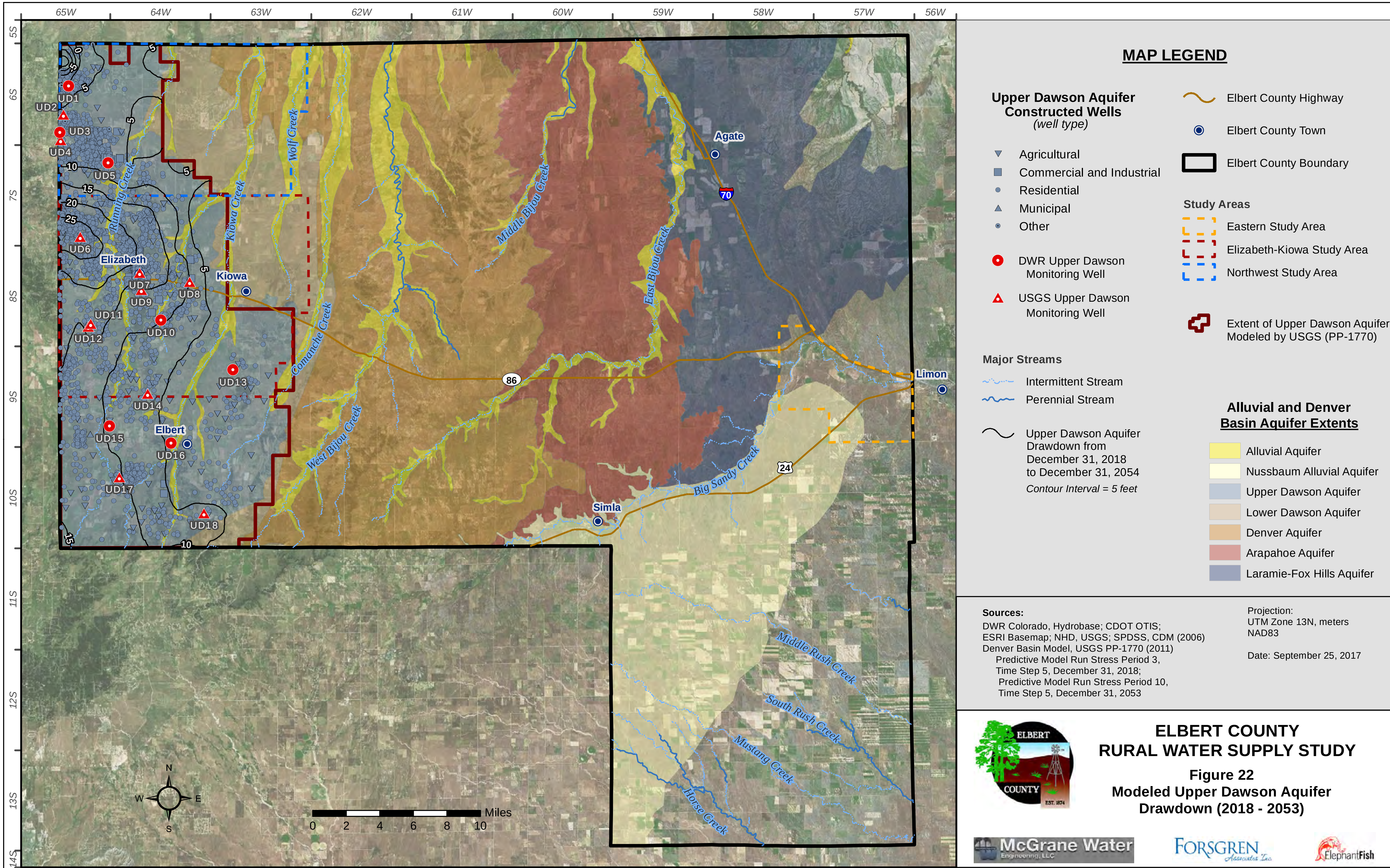

65W
64W
63W
62W
61W
60W
59W
58W
57W
56W
5S
6S
7S
8S
9S
10S
11S
12S
13S
14S
Agate
Elizabeth
Kiowa
Elbert
Simla
Limon
D1
D2
D3
D4
D5
D6
D7
D8
D9
D10
D11
D12
Running Creek
Kiowa Creek
Wolf Creek
Comanche Creek
West Bijou Creek
Middle Bijou Creek
East Bijou Creek
Big Sandy Creek
Middle Rush Creek
South Rush Creek
Mustang Creek
Horse Creek
70
86
24
N
E
S
W
0 2 4 6 8 10 Miles
MAP LEGEND
Denver Aquifer Constructed Wells
(well type)
Agricultural
Commericial and Industrial
Residential
Municipal
Other
DWR Denver Aquifer Monitoring Well
USGS Denver Aquifer Monitoring Well
Major Streams
Intermittent Stream
Perennial Stream
Denver Aquifer Drawdown from Predevelopment (December 31, 1879) to December 31, 2018
Contour Interval = 20 feet
Elbert County Highway
Elbert County Town
Elbert County Boundary
Study Areas
Eastern Study Area
Elizabeth-Kiowa Study Area
Northwest Study Area
Extent of the Denver Aquifer Modeled by USGS (PP-1770)
Alluvial and Denver Basin Aquifer Extents
Alluvial Aquifer
Nussbaum Alluvial Aquifer
Upper Dawson Aquifer
Lower Dawson Aquifer
Denver Aquifer
Arapahoe Aquifer
Laramie-Fox Hills Aquifer
Sources:
DWR Colorado, Hydrobase; CDOT OTIS;
ESRI Basemap; NHD, USGS; SPDSS, CDM (2006)
Denver Basin Model, USGS PP-1770 (2011)
Predictive Model Run Stress Period 3, Time Step 5, December 31, 2018;
Pre-Development Model Run Stress Period 1, Time Step 1, December 31, 1879
Projection:
UTM Zone 13N, meters
Datum: NAD83
Date: September 25, 2017
ELBERT COUNTY
EST. 1874
ELBERT COUNTY RURAL WATER SUPPLY STUDY
Figure 18
Modeled Denver Aquifer Drawdown (1880 - 2018)
McGrane Water Engineering, LLC
FORSGREN Associates Inc.
ElephantFish


MAP LEGEND
Arapahoe Aquifer Constructed Wells
(well type)
Agricultural
Commercial and Industrial
Residential
Municipal
Other
DWR Arapahoe Aquifer Monitoring Well
USGS Arapahoe Aquifer Monitoring Well
Major Streams
Intermittent Stream
Perennial Stream
Arapahoe Aquifer Drawdown from Predevelopment (December 31, 1879) to December 31, 2018
Contour Interval = 20 feet
Elbert County Highway
Elbert County Town
Elbert County Boundary
Study Areas
Eastern Study Area
Elizabeth-Kiowa Study Area
Northwest Study Area
Extent of Arapahoe Aquifer Modeled by USGS (PP-1770)
Alluvial and Denver Basin Aquifer Extents
Alluvial Aquifer
Nussbaum Alluvial Aquifer
Upper Dawson Aquifer
Lower Dawson Aquifer
Denver Aquifer
Arapahoe Aquifer
Laramie-Fox Hills Aquifer
Sources:
DWR Colorado, Hydrobase; CDOT OTIS;
ESRI Basemap; NHD, USGS; SPDSS, CDM (2006)
Denver Basin Model, USGS PP-1770 (2011)
Predictive Model Run Stress Period 3, Time Step 5, December 31, 2018;
Pre-Development Model Run Stress Period 1, Time Step 1, December 31, 1879
Projection:
UTM Zone 13N, meters
Datum: NAD83
Date: September 25, 2017
ELBERT COUNTY
RURAL WATER SUPPLY STUDY
Figure 19
Modeled Arapahoe Aquifer Drawdown (1880 - 2018)
McGrane Water Engineering, LLC
FORSGREN Associates Inc.
ElephantFish
Elizabeth
Kiowa
Elbert
Agate
Simla
Limon
Running Creek
Kiowa Creek
Wolf Creek
Comanche Creek
West Bijou Creek
Middle Bijou Creek
East Bijou Creek
Big Sandy Creek
Middle Rush Creek
South Rush Creek
Mustang Creek
Horse Creek
65W
64W
63W
62W
61W
60W
59W
58W
57W
56W
5S
6S
7S
8S
9S
10S
11S
12S
13S
14S
Miles
0
2
4
6
8
10
N
S
E
W

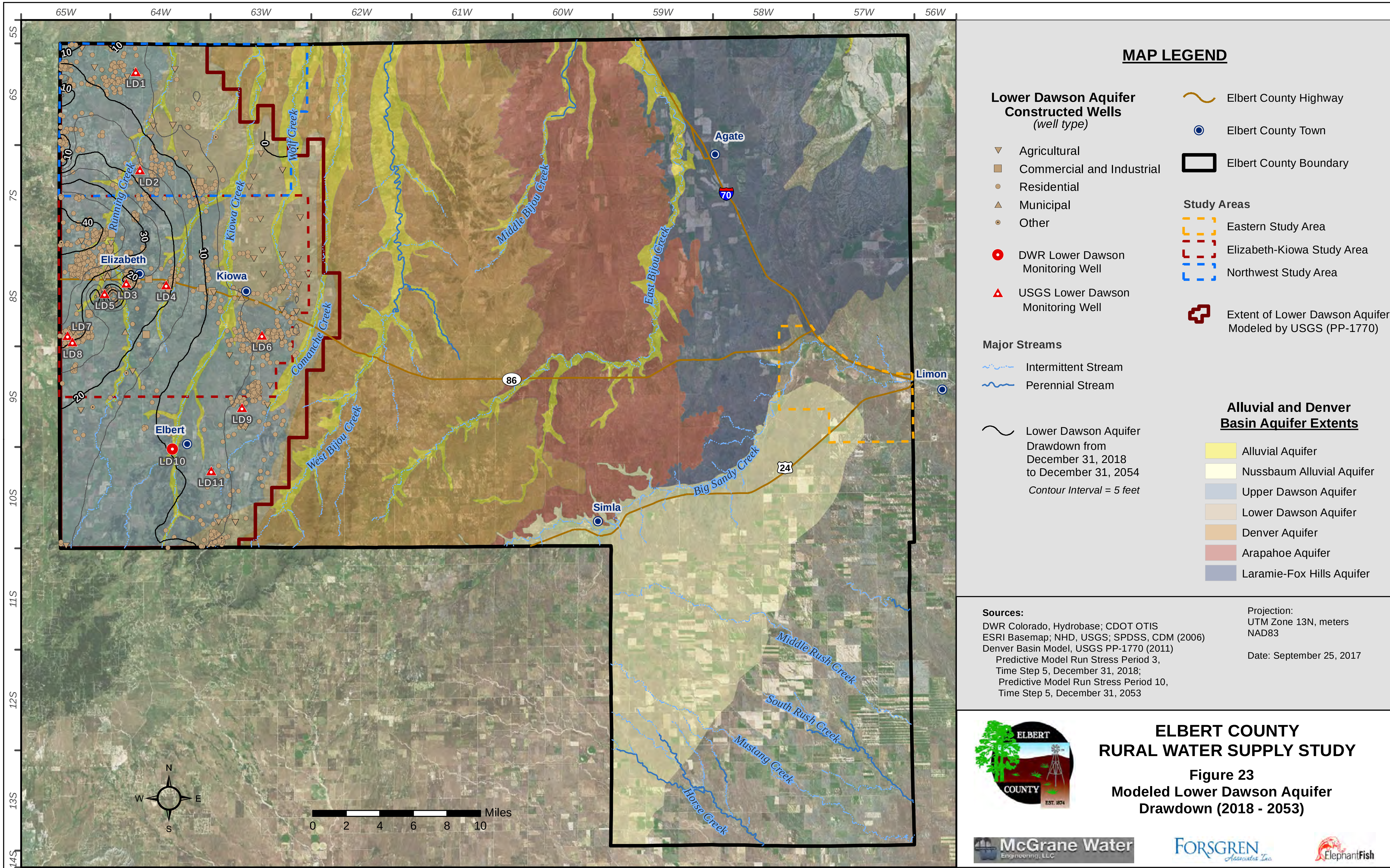


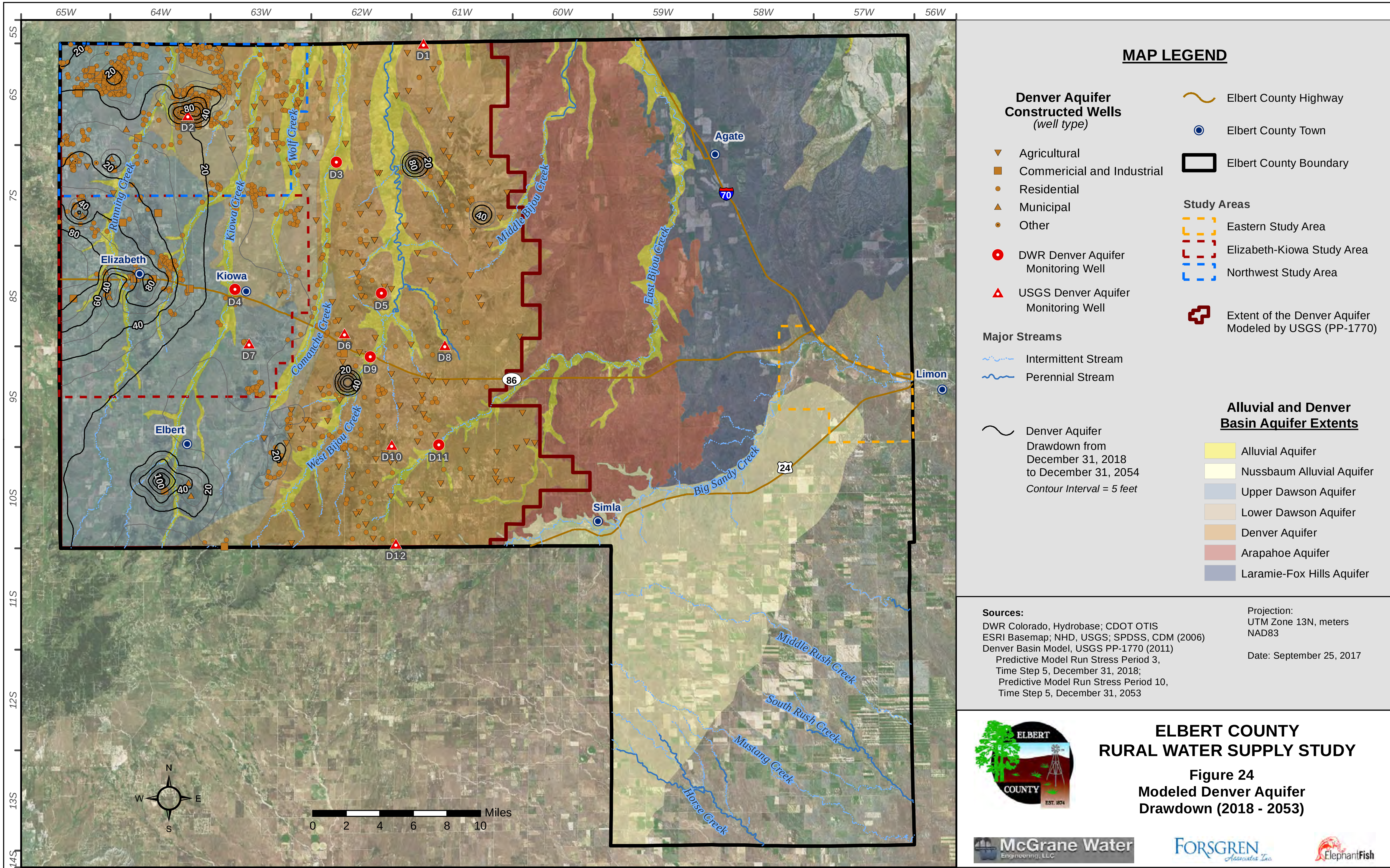
MAP LEGEND
Laramie-Fox Hills Aquifer Constructed Wells
(well type)
Agricultural
Commercial and Industrial
Residential
Municipal
Other
DWR Laramie-Fox Hills Monitoring Well
USGS Laramie-Fox Hills Monitoring Well
Major Streams
Intermittent Stream
Perennial Stream
Laramie-Fox Hills Drawdown from Predevelopment (December 31, 1879) to December 31, 2018
Contour Interval = 20 feet
Elbert County Highway
Elbert County Town
Elbert County Boundary
Study Areas
Eastern Study Area
Elizabeth-Kiowa Study Area
Northwest Study Area
Extent of the Laramie-Fox Hills Aquifer Modeled by USGS (PP-1770)
Alluvial and Denver Basin Aquifer Extents
Alluvial Aquifer
Nussbaum Alluvial Aquifer
Upper Dawson Aquifer
Lower Dawson Aquifer
Denver Aquifer
Arapahoe Aquifer
Laramie-Fox Hills Aquifer
Sources:
DWR Colorado, Hydrobase; CDOT OTIS;
ESRI Basemap; NHD, USGS; SPDSS, CDM (2006)
Denver Basin Model, USGS PP-1770 (2011)
Predictive Model Run Stress Period 3, Time Step 5, December 31, 2018;
Pre-Development Model Run Stress Period 1, Time Step 1, December 31, 1879
Projection:
UTM Zone 13N, meters
Datum: NAD83
Date: September 25, 2017
ELBERT COUNTY
RURAL WATER SUPPLY STUDY
Figure 20
Modeled Laramie-Fox Hills Aquifer Drawdown (1880 - 2018)
McGrane Water Engineering, LLC
FORSGREN Associates Inc.
ElephantFish
ELBERT COUNTY EST. 1874
65W
64W
63W
62W
61W
60W
59W
58W
57W
56W
5S
6S
7S
8S
9S
10S
11S
12S
13S
14S
Elizabeth
Kiowa
Elbert
Agate
Simla
Limon
LF1
LF2
LF3
LF4
LF5
LF6
Running Creek
Kiowa Creek
Wolf Creek
Comanche Creek
West Bijou Creek
Middle Bijou Creek
East Bijou Creek
Big Sandy Creek
Middle Rush Creek
South Rush Creek
Mustang Creek
Horse Creek
86
70
24
100
200
300
500
20
0
N
E
S
W
Miles
0
2
4
6
8
10


MAP LEGEND
Alluvial Aquifer Constructed Wells (well type)
Municipal
Commercial and Industrial
Residential
Agricultural
Other
DWR Alluvial Monitoring Well
Extent of Alluvial Aquifer Modeled by USGS (PP-1770)
Alluvial Aquifer Drawdown from December 31, 2018 to December 31, 2054
Contour Interval = 0.1 foot
Elbert County Highway
Elbert County Town
Elbert County Boundary
Study Areas
Eastern Study Area
Elizabeth-Kiowa Study Area
Northwest Study Area
Major Streams
Intermittent Stream
Perennial Stream
Alluvial and Denver Basin Aquifer Extents
Alluvial Aquifer
Nussbaum Alluvial Aquifer
Upper Dawson Aquifer
Lower Dawson Aquifer
Denver Aquifer
Arapahoe Aquifer
Laramie-Fox Hills Aquifer
Sources:
DWR Colorado, Hydrobase; CDOT OTIS
ESRI Basemap; NHD, USGS; SPDSS, CDM (2006)
Denver Basin Model, USGS PP-1770 (2011)
Predictive Model Run Stress Period 3, Time Step 5, December 31, 2018;
Predictive Model Run Stress Period 10, Time Step 5, December 31, 2053
Projection: UTM Zone 13N, meters NAD83
Date: September 25, 2017
ELBERT COUNTY
RURAL WATER SUPPLY STUDY
Figure 21
Modeled Alluvial Aquifer Drawdown (2018 - 2053)
McGrane Water Engineering, LLC
FORSGREN Associates Inc.
ElephantFish
65W
64W
63W
62W
61W
60W
59W
58W
57W
56W
5S
6S
7S
8S
9S
10S
11S
12S
13S
14S
Elizabeth
Kiowa
Elbert
Agate
Simla
Limon
Running Creek
Kiowa Creek
Wolf Creek
Comanche Creek
West Bijou Creek
Middle Bijou Creek
East Bijou Creek
Big Sandy Creek
Middle Rush Creek
South Rush Creek
Horse Creek
QA1
QA2
QA3
QA4
QA5
QA6
QA7
QA8
QA9
QA10
QA11
QA12
QA13
QA14
QA15
QA16
86
70
24
Miles
0
2
4
6
8
10
N
S
E
W

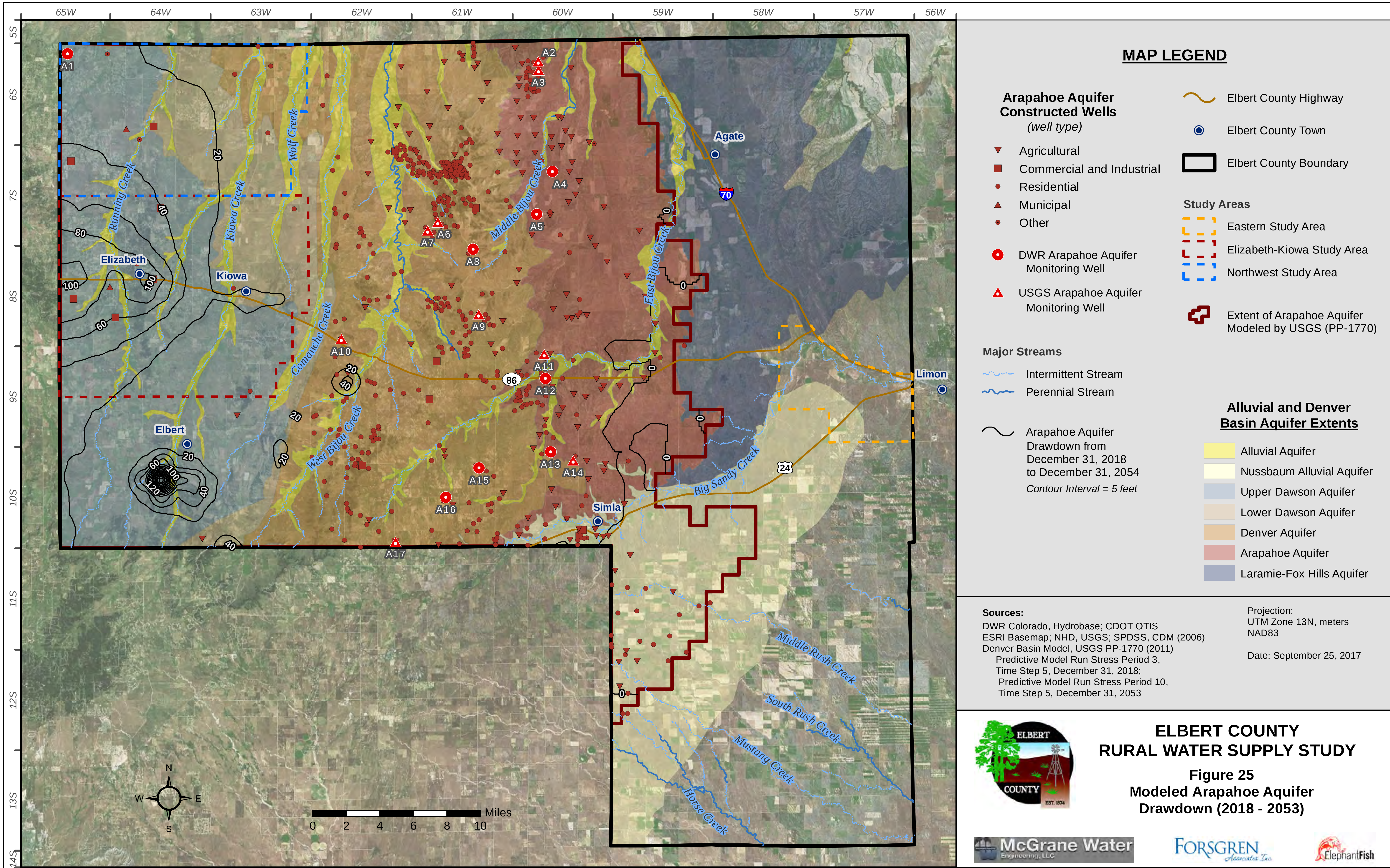


65W
64W
63W
62W
61W
60W
59W
58W
57W
56W
5S
6S
7S
8S
9S
10S
11S
12S
13S
14S
UD1
UD2
UD3
UD4
UD5
UD6
UD7
UD8
UD9
UD10
UD11
UD12
UD13
UD14
UD15
UD16
UD17
UD18
Elizabeth
Kiowa
Elbert
Agate
Limon
Simla
Running Creek
Kiowa Creek
Wolf Creek
Comanche Creek
West Bijou Creek
Middle Bijou Creek
East Bijou Creek
Big Sandy Creek
Middle Rush Creek
South Rush Creek
Mustang Creek
Horse Creek
70
86
24
Miles
0 2 4 6 8 10
N
E
S
W
MAP LEGEND
Upper Dawson Aquifer Constructed Wells
(well type)
Agricultural
Commercial and Industrial
Residential
Municipal
Other
DWR Upper Dawson Monitoring Well
USGS Upper Dawson Monitoring Well
Major Streams
Intermittent Stream
Perennial Stream
Upper Dawson Aquifer Drawdown from December 31, 2018 to December 31, 2054
Contour Interval = 5 feet
Elbert County Highway
Elbert County Town
Elbert County Boundary
Study Areas
Eastern Study Area
Elizabeth-Kiowa Study Area
Northwest Study Area
Extent of Upper Dawson Aquifer Modeled by USGS (PP-1770)
Alluvial and Denver Basin Aquifer Extents
Alluvial Aquifer
Nussbaum Alluvial Aquifer
Upper Dawson Aquifer
Lower Dawson Aquifer
Denver Aquifer
Arapahoe Aquifer
Laramie-Fox Hills Aquifer
Sources:
DWR Colorado, Hydrobase; CDOT OTIS;
ESRI Basemap; NHD, USGS; SPDSS, CDM (2006)
Denver Basin Model, USGS PP-1770 (2011)
Predictive Model Run Stress Period 3,
Time Step 5, December 31, 2018;
Predictive Model Run Stress Period 10,
Time Step 5, December 31, 2053
Projection:
UTM Zone 13N, meters
NAD83
Date: September 25, 2017
ELBERT COUNTY
RURAL WATER SUPPLY STUDY
Figure 22
Modeled Upper Dawson Aquifer
Drawdown (2018 - 2053)
McGrane Water
FORSGREN
ElephantFish

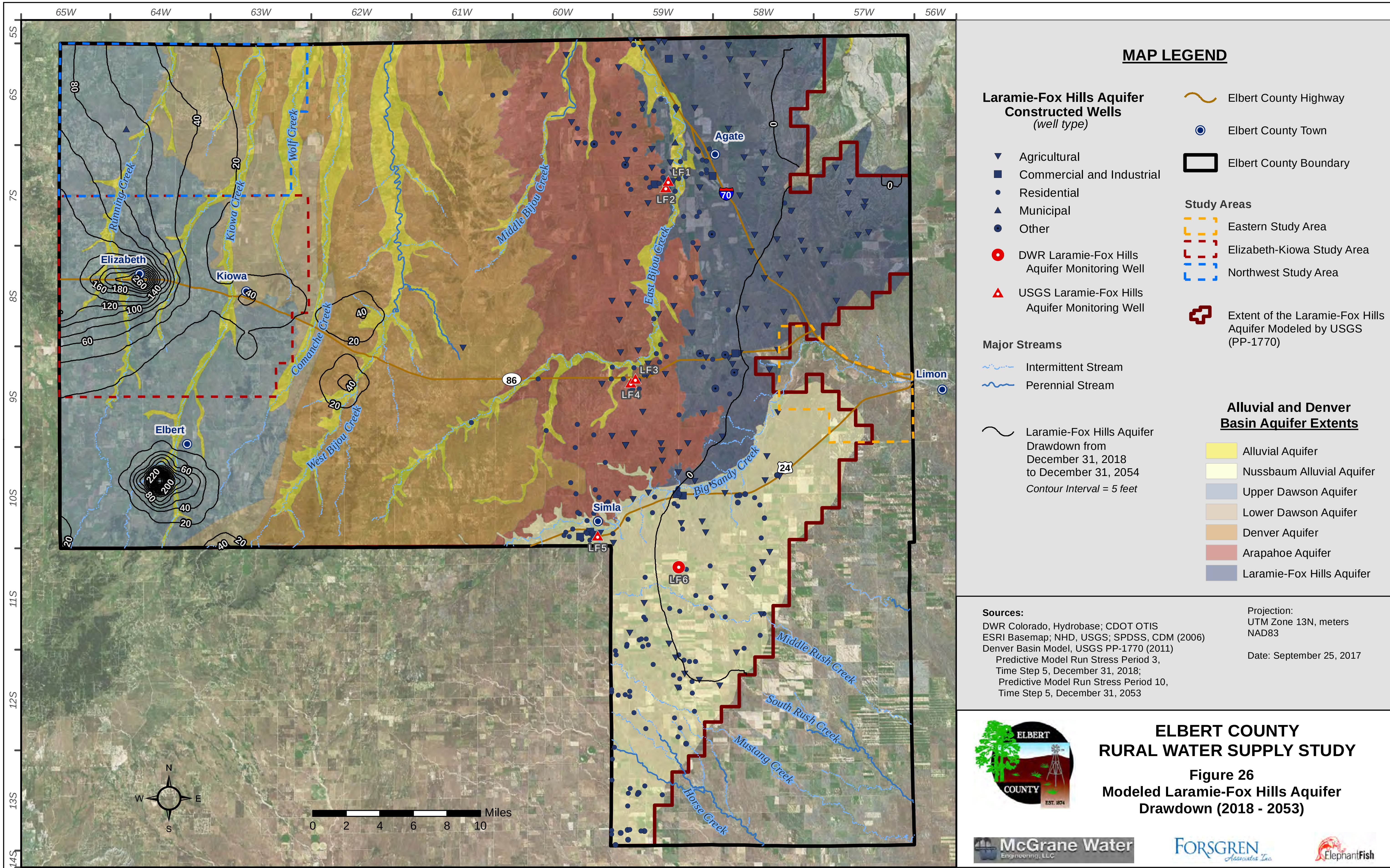

MAP LEGEND
Lower Dawson Aquifer Constructed Wells
(well type)
Agricultural
Commercial and Industrial
Residential
Municipal
Other
DWR Lower Dawson Monitoring Well
USGS Lower Dawson Monitoring Well
Major Streams
Intermittent Stream
Perennial Stream
Lower Dawson Aquifer Drawdown from December 31, 2018 to December 31, 2054
Contour Interval = 5 feet
Elbert County Highway
Elbert County Town
Elbert County Boundary
Study Areas
Eastern Study Area
Elizabeth-Kiowa Study Area
Northwest Study Area
Extent of Lower Dawson Aquifer Modeled by USGS (PP-1770)
Alluvial and Denver Basin Aquifer Extents
Alluvial Aquifer
Nussbaum Alluvial Aquifer
Upper Dawson Aquifer
Lower Dawson Aquifer
Denver Aquifer
Arapahoe Aquifer
Laramie-Fox Hills Aquifer
Sources:
DWR Colorado, Hydrobase; CDOT OTIS
ESRI Basemap; NHD, USGS; SPDSS, CDM (2006)
Denver Basin Model, USGS PP-1770 (2011)
Predictive Model Run Stress Period 3,
Time Step 5, December 31, 2018;
Predictive Model Run Stress Period 10,
Time Step 5, December 31, 2053
Projection:
UTM Zone 13N, meters
NAD83
Date: September 25, 2017
ELBERT COUNTY
RURAL WATER SUPPLY STUDY
Figure 23
Modeled Lower Dawson Aquifer
Drawdown (2018 - 2053)
McGrane Water
FORSGREN
ElephantFish
65W
64W
63W
62W
61W
60W
59W
58W
57W
56W
5S
6S
7S
8S
9S
10S
11S
12S
13S
14S
LD1
LD2
LD3
LD4
LD5
LD6
LD7
LD8
LD9
LD10
LD11
Elizabeth
Kiowa
Elbert
Agate
Simla
Limon
Running Creek
Kiowa Creek
Wolf Creek
Comanche Creek
West Bijou Creek
Middle Bijou Creek
East Bijou Creek
Big Sandy Creek
Middle Rush Creek
South Rush Creek
Mustang Creek
Horse Creek
70
86
24
N
E
S
W
Miles
0 2 4 6 8 10

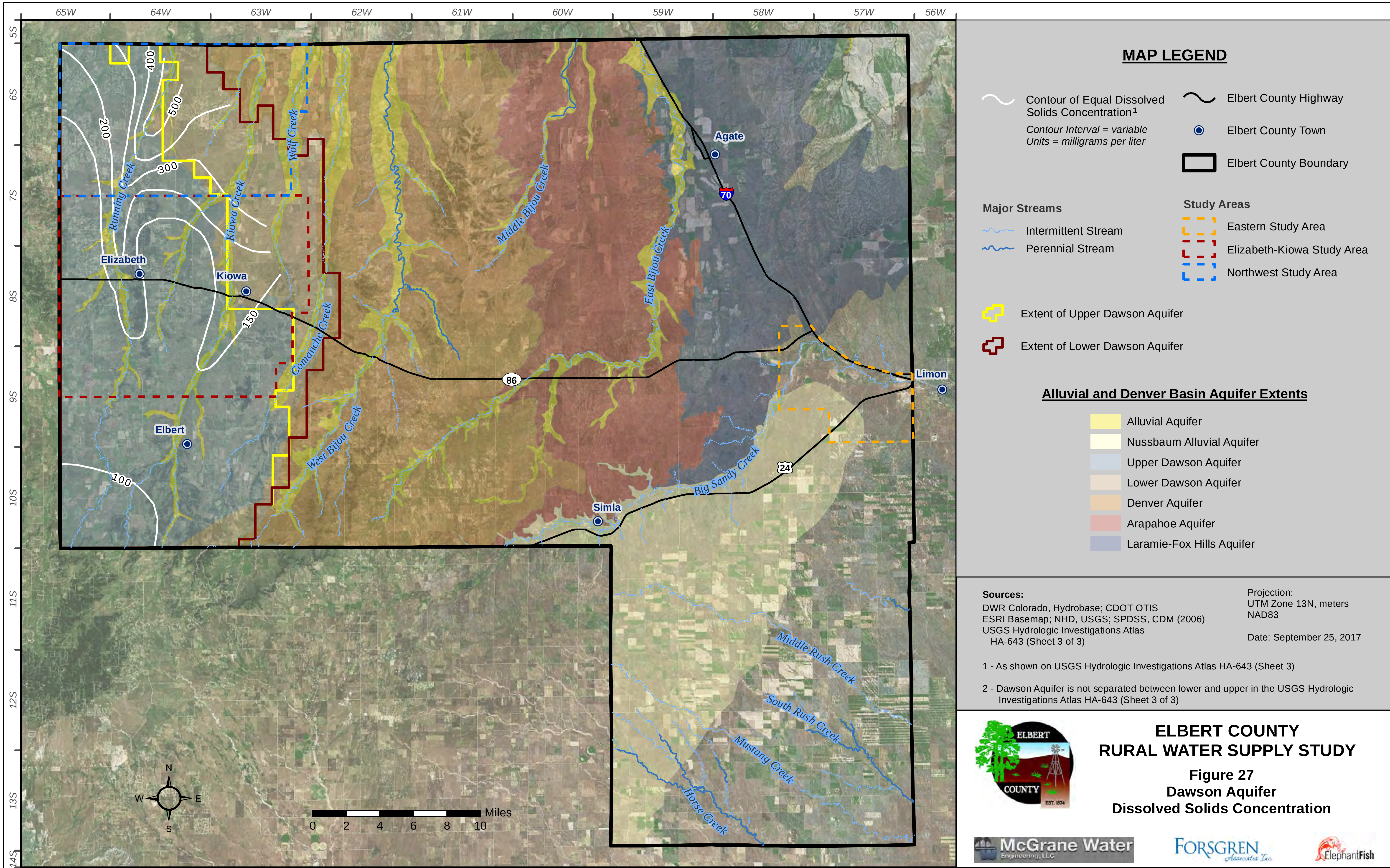


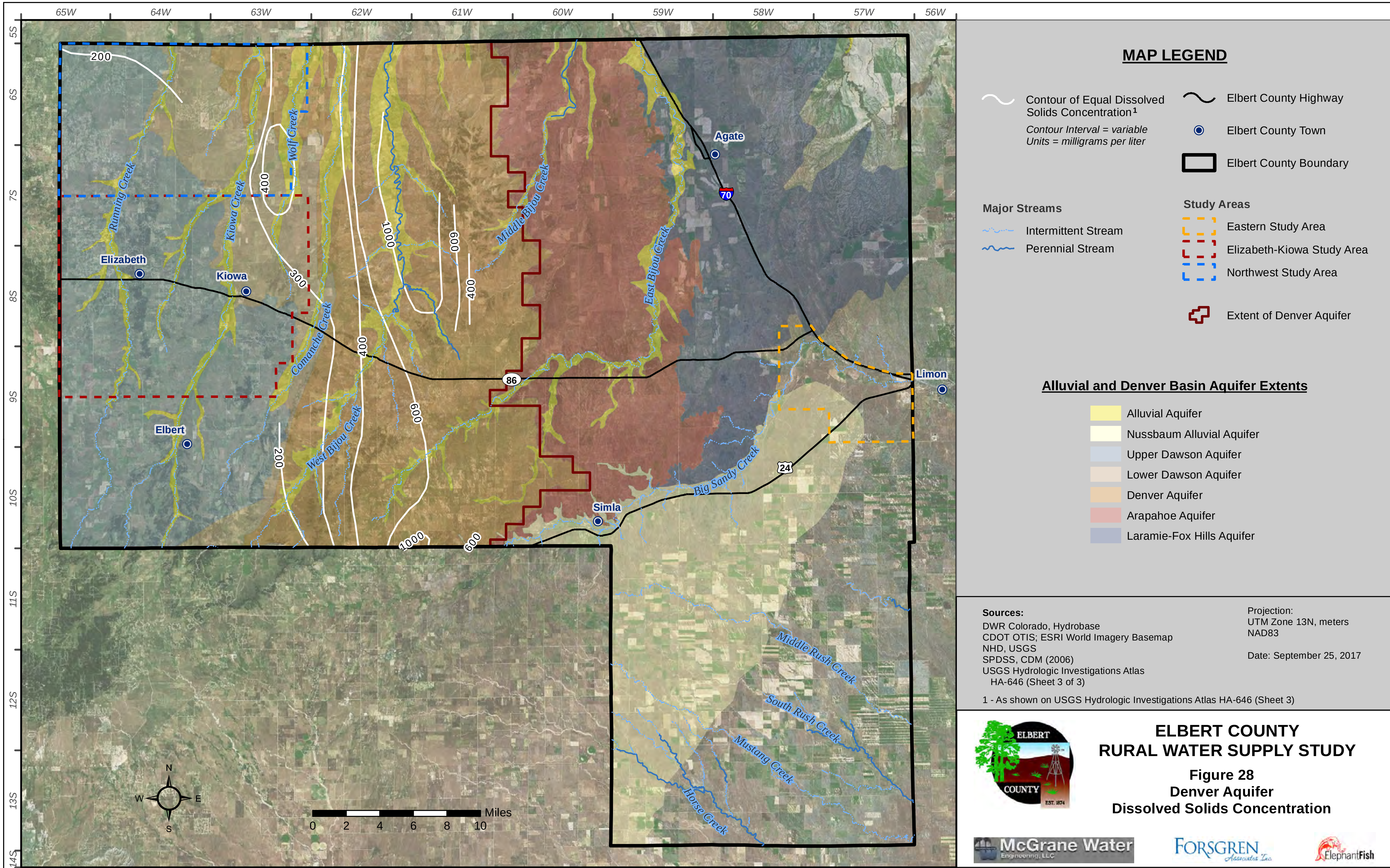
MAP LEGEND
Denver Aquifer Constructed Wells (well type)
Agricultural
Commericial and Industrial
Residential
Municipal
Other
DWR Denver Aquifer Monitoring Well
USGS Denver Aquifer Monitoring Well
Major Streams
Intermittent Stream
Perennial Stream
Denver Aquifer Drawdown from December 31, 2018 to December 31, 2054
Contour Interval = 5 feet
Elbert County Highway
Elbert County Town
Elbert County Boundary
Study Areas
Eastern Study Area
Elizabeth-Kiowa Study Area
Northwest Study Area
Extent of the Denver Aquifer Modeled by USGS (PP-1770)
Alluvial and Denver Basin Aquifer Extents
Alluvial Aquifer
Nussbaum Alluvial Aquifer
Upper Dawson Aquifer
Lower Dawson Aquifer
Denver Aquifer
Arapahoe Aquifer
Laramie-Fox Hills Aquifer
Sources:
DWR Colorado, Hydrobase; CDOT OTIS
ESRI Basemap; NHD, USGS; SPDSS, CDM (2006)
Denver Basin Model, USGS PP-1770 (2011)
Predictive Model Run Stress Period 3, Time Step 5, December 31, 2018;
Predictive Model Run Stress Period 10, Time Step 5, December 31, 2053
Projection: UTM Zone 13N, meters NAD83
Date: September 25, 2017
ELBERT COUNTY RURAL WATER SUPPLY STUDY
Figure 24
Modeled Denver Aquifer Drawdown (2018 - 2053)
McGrane Water Engineering, LLC
FORSGREN Associates Inc.
ElephantFish
Agate
Elizabeth
Kiowa
Elbert
Simla
Limon
Running Creek
Kiowa Creek
Wolf Creek
Comanche Creek
West Bijou Creek
Middle Bijou Creek
East Bijou Creek
Big Sandy Creek
Middle Rush Creek
South Rush Creek
Mustang Creek
Horse Creek
Miles
0 2 4 6 8 10



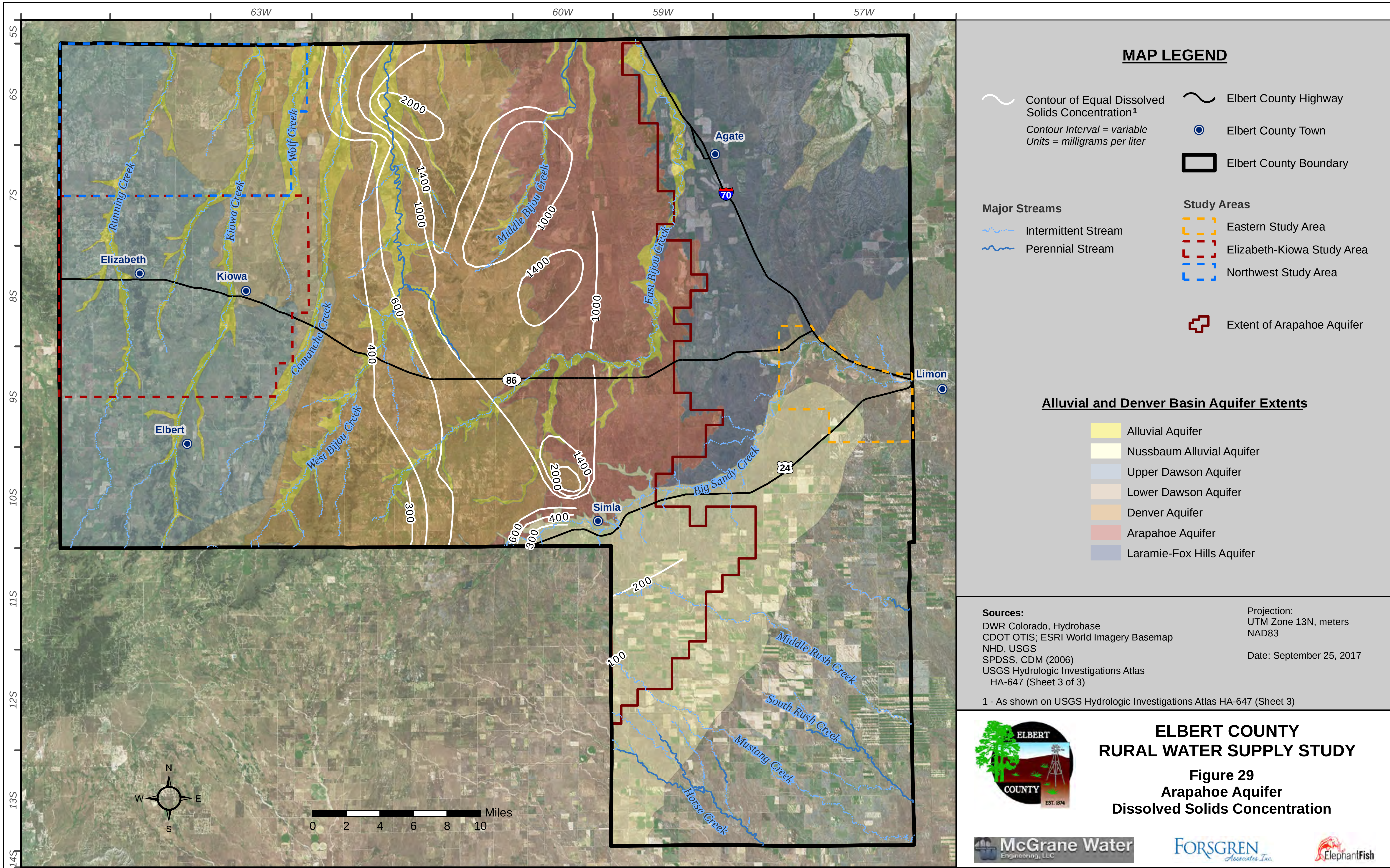
MAP LEGEND
Arapahoe Aquifer Constructed Wells
(well type)
Agricultural
Commercial and Industrial
Residential
Municipal
Other
DWR Arapahoe Aquifer Monitoring Well
USGS Arapahoe Aquifer Monitoring Well
Major Streams
Intermittent Stream
Perennial Stream
Arapahoe Aquifer Drawdown from December 31, 2018 to December 31, 2054
Contour Interval = 5 feet
Elbert County Highway
Elbert County Town
Elbert County Boundary
Study Areas
Eastern Study Area
Elizabeth-Kiowa Study Area
Northwest Study Area
Extent of Arapahoe Aquifer Modeled by USGS (PP-1770)
Alluvial and Denver Basin Aquifer Extents
Alluvial Aquifer
Nussbaum Alluvial Aquifer
Upper Dawson Aquifer
Lower Dawson Aquifer
Denver Aquifer
Arapahoe Aquifer
Laramie-Fox Hills Aquifer
Sources:
DWR Colorado, Hydrobase; CDOT OTIS
ESRI Basemap; NHD, USGS; SPDSS, CDM (2006)
Denver Basin Model, USGS PP-1770 (2011)
Predictive Model Run Stress Period 3, Time Step 5, December 31, 2018;
Predictive Model Run Stress Period 10, Time Step 5, December 31, 2053
Projection:
UTM Zone 13N, meters
NAD83
Date: September 25, 2017
ELBERT COUNTY
RURAL WATER SUPPLY STUDY
Figure 25
Modeled Arapahoe Aquifer Drawdown (2018 - 2053)
McGrane Water Engineering, LLC
FORSGREN Associates Inc.
ElephantFish
65W
64W
63W
62W
61W
60W
59W
58W
57W
56W
5S
6S
7S
8S
9S
10S
11S
12S
13S
14S
Elizabeth
Kiowa
Elbert
Agate
Simla
Limon
Running Creek
Kiowa Creek
Wolf Creek
Comanche Creek
West Bijou Creek
Middle Bijou Creek
East Bijou Creek
Big Sandy Creek
Middle Rush Creek
South Rush Creek
Mustang Creek
Horse Creek
A1
A2
A3
A4
A5
A6
A7
A8
A9
A10
A11
A12
A13
A14
A15
A16
A17
70
86
24
Miles
0 2 4 6 8 10
N
S
E
W


ELBERT COUNTY
RURAL WATER SUPPLY STUDY
Figure 26
Modeled Laramie-Fox Hills Aquifer
Drawdown (2018 - 2053)
MAP LEGEND
Laramie-Fox Hills Aquifer Constructed Wells
(well type)
Agricultural
Commercial and Industrial
Residential
Municipal
Other
DWR Laramie-Fox Hills Aquifer Monitoring Well
USGS Laramie-Fox Hills Aquifer Monitoring Well
Major Streams
Intermittent Stream
Perennial Stream
Laramie-Fox Hills Aquifer Drawdown from December 31, 2018 to December 31, 2054
Contour Interval = 5 feet
Elbert County Highway
Elbert County Town
Elbert County Boundary
Study Areas
Eastern Study Area
Elizabeth-Kiowa Study Area
Northwest Study Area
Extent of the Laramie-Fox Hills Aquifer Modeled by USGS (PP-1770)
Alluvial and Denver Basin Aquifer Extents
Alluvial Aquifer
Nussbaum Alluvial Aquifer
Upper Dawson Aquifer
Lower Dawson Aquifer
Denver Aquifer
Arapahoe Aquifer
Laramie-Fox Hills Aquifer
Sources:
DWR Colorado, Hydrobase; CDOT OTIS
ESRI Basemap; NHD, USGS; SPDSS, CDM (2006)
Denver Basin Model, USGS PP-1770 (2011)
Predictive Model Run Stress Period 3,
Time Step 5, December 31, 2018;
Predictive Model Run Stress Period 10,
Time Step 5, December 31, 2053
Projection:
UTM Zone 13N, meters
NAD83
Date: September 25, 2017
ELBERT COUNTY EST. 1874
McGrane Water Engineering, LLC
FORSGREN Associates Inc.
ElephantFish
65W
64W
63W
62W
61W
60W
59W
58W
57W
56W
5S
6S
7S
8S
9S
10S
11S
12S
13S
14S
Elizabeth
Kiowa
Elbert
Agate
Simla
Limon
LF1
LF2
LF3
LF4
LF5
LF6
Running Creek
Kiowa Creek
Wolf Creek
Comanche Creek
West Bijou Creek
Middle Bijou Creek
East Bijou Creek
Big Sandy Creek
Middle Rush Creek
South Rush Creek
Mustang Creek
Horse Creek
86
70
24
Miles
0
2
4
6
8
10
N
S
E
W

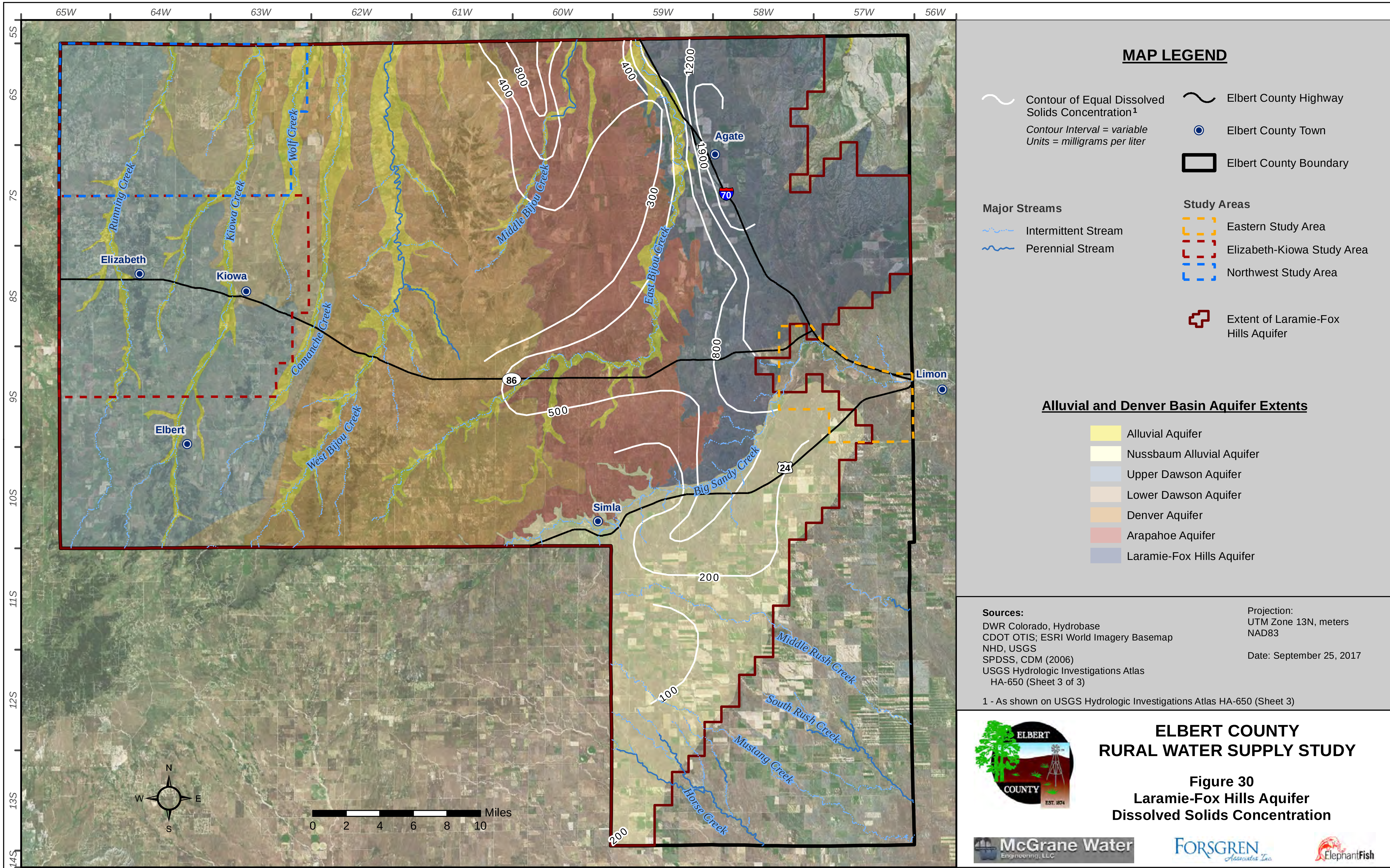

65W
64W
63W
62W
61W
60W
59W
58W
57W
56W
5S
6S
7S
8S
9S
10S
11S
12S
13S
14S
400
500
200
300
150
100
Running Creek
Kiowa Creek
Wolf Creek
Comanche Creek
West Bijou Creek
Middle Bijou Creek
East Bijou Creek
Big Sandy Creek
Middle Rush Creek
South Rush Creek
Mustang Creek
Horse Creek
Elizabeth
Kiowa
Elbert
Agate
Simla
Limon
70
86
24
N
W
E
S
Miles
0 2 4 6 8 10
MAP LEGEND
Contour of Equal Dissolved Solids Concentration¹
Contour Interval = variable
Units = milligrams per liter
Elbert County Highway
Elbert County Town
Elbert County Boundary
Major Streams
Intermittent Stream
Perennial Stream
Study Areas
Eastern Study Area
Elizabeth-Kiowa Study Area
Northwest Study Area
Extent of Upper Dawson Aquifer
Extent of Lower Dawson Aquifer
Alluvial and Denver Basin Aquifer Extents
Alluvial Aquifer
Nussbaum Alluvial Aquifer
Upper Dawson Aquifer
Lower Dawson Aquifer
Denver Aquifer
Arapahoe Aquifer
Laramie-Fox Hills Aquifer
Sources:
DWR Colorado, Hydrobase; CDOT OTIS
ESRI Basemap; NHD, USGS; SPDSS, CDM (2006)
USGS Hydrologic Investigations Atlas
HA-643 (Sheet 3 of 3)
Projection:
UTM Zone 13N, meters
NAD83
Date: September 25, 2017
1 - As shown on USGS Hydrologic Investigations Atlas HA-643 (Sheet 3)
2 - Dawson Aquifer is not separated between lower and upper in the USGS Hydrologic Investigations Atlas HA-643 (Sheet 3 of 3)
ELBERT COUNTY
EST. 1874
ELBERT COUNTY
RURAL WATER SUPPLY STUDY
Figure 27
Dawson Aquifer
Dissolved Solids Concentration
McGrane Water Engineering, LLC
FORSGREN Associates Inc.
ElephantFish

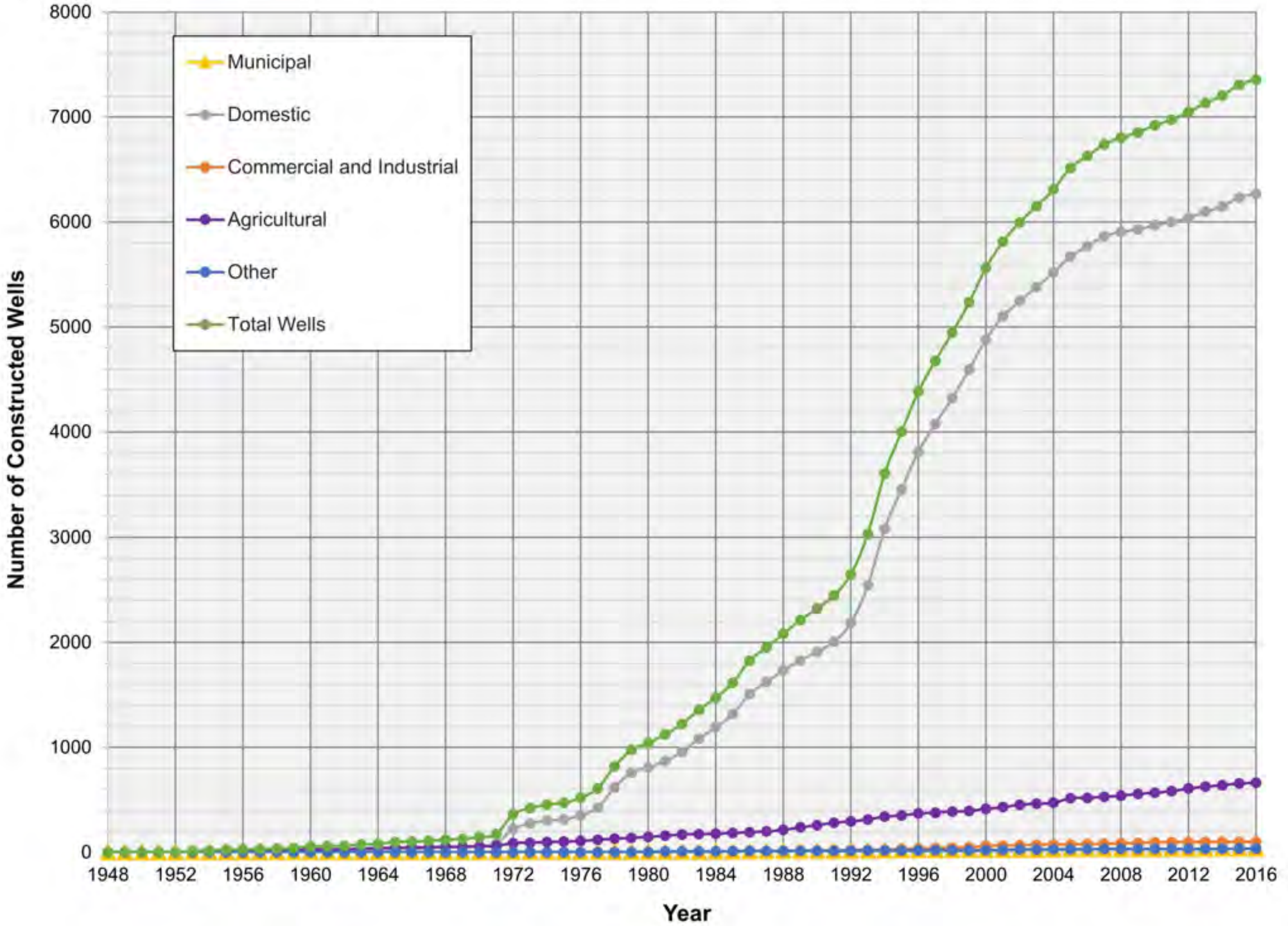


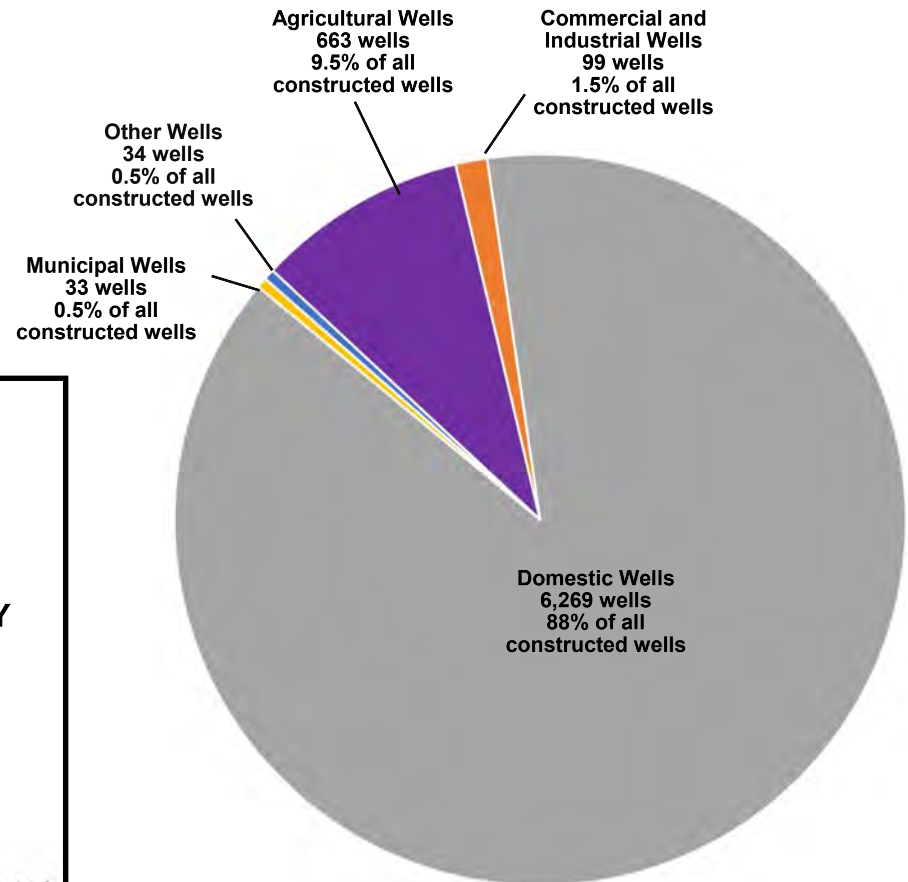
65W
64W
63W
62W
61W
60W
59W
58W
57W
56W
5S
6S
7S
8S
9S
10S
11S
12S
13S
14S
Running Creek
Kiowa Creek
Wolf Creek
Comanche Creek
West Bijou Creek
Middle Bijou Creek
East Bijou Creek
Big Sandy Creek
Middle Rush Creek
South Rush Creek
Mustang Creek
Horse Creek
Elizabeth
Kiowa
Elbert
Agate
Simla
Limon
200
300
400
600
1000
86
70
24
Miles
0 2 4 6 8 10
MAP LEGEND
Contour of Equal Dissolved Solids Concentration[1]
Contour Interval = variable
Units = milligrams per liter
Elbert County Highway
Elbert County Town
Elbert County Boundary
Major Streams
Intermittent Stream
Perennial Stream
Study Areas
Eastern Study Area
Elizabeth-Kiowa Study Area
Northwest Study Area
Extent of Denver Aquifer
Alluvial and Denver Basin Aquifer Extents
Alluvial Aquifer
Nussbaum Alluvial Aquifer
Upper Dawson Aquifer
Lower Dawson Aquifer
Denver Aquifer
Arapahoe Aquifer
Laramie-Fox Hills Aquifer
Sources:
DWR Colorado, Hydrobase
CDOT OTIS; ESRI World Imagery Basemap
NHD, USGS
SPDSS, CDM (2006)
USGS Hydrologic Investigations Atlas HA-646 (Sheet 3 of 3)
Projection:
UTM Zone 13N, meters
NAD83
Date: September 25, 2017
1 - As shown on USGS Hydrologic Investigations Atlas HA-646 (Sheet 3)
ELBERT COUNTY RURAL WATER SUPPLY STUDY
Figure 28
Denver Aquifer
Dissolved Solids Concentration
McGrane Water Engineering, LLC
FORSGREN Associates Inc.
ElephantFish



MAP LEGEND
Contour of Equal Dissolved Solids Concentration¹
Contour Interval = variable
Units = milligrams per liter
Elbert County Highway
Elbert County Town
Elbert County Boundary
Major Streams
Intermittent Stream
Perennial Stream
Study Areas
Eastern Study Area
Elizabeth-Kiowa Study Area
Northwest Study Area
Extent of Arapahoe Aquifer
Alluvial and Denver Basin Aquifer Extents
Alluvial Aquifer
Nussbaum Alluvial Aquifer
Upper Dawson Aquifer
Lower Dawson Aquifer
Denver Aquifer
Arapahoe Aquifer
Laramie-Fox Hills Aquifer
Sources:
DWR Colorado, Hydrobase
CDOT OTIS; ESRI World Imagery Basemap
NHD, USGS
SPDSS, CDM (2006)
USGS Hydrologic Investigations Atlas
HA-647 (Sheet 3 of 3)
1 - As shown on USGS Hydrologic Investigations Atlas HA-647 (Sheet 3)
Projection:
UTM Zone 13N, meters
NAD83
Date: September 25, 2017
ELBERT COUNTY
RURAL WATER SUPPLY STUDY
Figure 29
Arapahoe Aquifer
Dissolved Solids Concentration
McGrane Water Engineering, LLC
FORSGREN Associates Inc.
ElephantFish
63W
60W
59W
57W
5S
6S
7S
8S
9S
10S
11S
12S
13S
14S
Elizabeth
Kiowa
Elbert
Agate
Simla
Limon
Running Creek
Kiowa Creek
Wolf Creek
Comanche Creek
West Bijou Creek
Middle Bijou Creek
East Bijou Creek
Big Sandy Creek
Middle Rush Creek
South Rush Creek
Mustang Creek
Horse Creek
70
86
24
2000
1400
1000
600
400
300
200
100
N
S
E
W
Miles
0
2
4
6
8
10


65W
64W
63W
62W
61W
60W
59W
58W
57W
56W
5S
6S
7S
8S
9S
10S
11S
12S
13S
14S
Running Creek
Kiowa Creek
Wolf Creek
Comanche Creek
West Bijou Creek
Middle Bijou Creek
East Bijou Creek
Big Sandy Creek
Middle Rush Creek
South Rush Creek
Mustang Creek
Horse Creek
Elizabeth
Kiowa
Elbert
Simla
Agate
Limon
86
24
70
400
800
1200
1900
300
800
500
200
100
200
Miles
0 2 4 6 8 10
N
S
E
W
MAP LEGEND
Contour of Equal Dissolved Solids Concentration¹
Contour Interval = variable
Units = milligrams per liter
Elbert County Highway
Elbert County Town
Elbert County Boundary
Major Streams
Intermittent Stream
Perennial Stream
Study Areas
Eastern Study Area
Elizabeth-Kiowa Study Area
Northwest Study Area
Extent of Laramie-Fox Hills Aquifer
Alluvial and Denver Basin Aquifer Extents
Alluvial Aquifer
Nussbaum Alluvial Aquifer
Upper Dawson Aquifer
Lower Dawson Aquifer
Denver Aquifer
Arapahoe Aquifer
Laramie-Fox Hills Aquifer
Sources:
DWR Colorado, Hydrobase
CDOT OTIS; ESRI World Imagery Basemap
NHD, USGS
SPDSS, CDM (2006)
USGS Hydrologic Investigations Atlas HA-650 (Sheet 3 of 3)
1 - As shown on USGS Hydrologic Investigations Atlas HA-650 (Sheet 3)
Projection:
UTM Zone 13N, meters
NAD83
Date: September 25, 2017
ELBERT COUNTY
RURAL WATER SUPPLY STUDY
Figure 30
Laramie-Fox Hills Aquifer
Dissolved Solids Concentration
McGrane Water Engineering, LLC
FORSGREN Associates Inc.
ElephantFish





ELBERT COUNTY

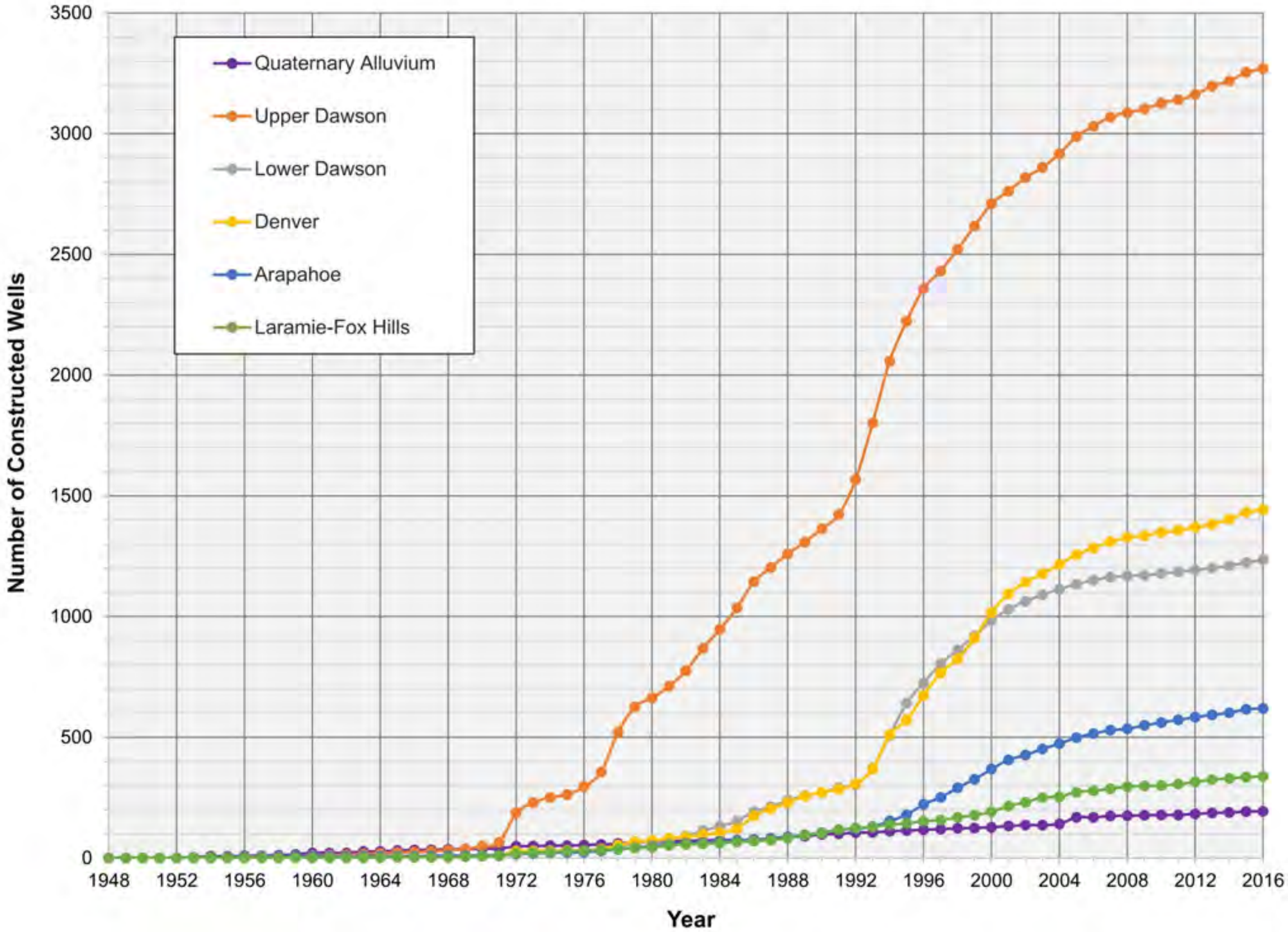
RURAL WATER SUPPLY STUDY

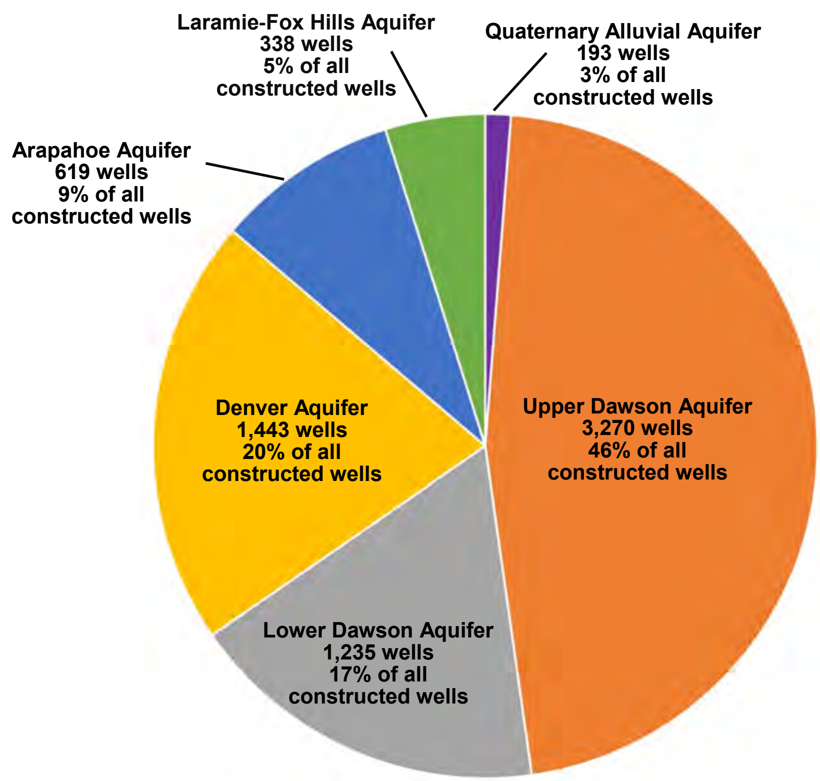
Figure 31
SEO Well Permits
Queried by Use

FORSGREN Associates Inc.

McGrane Water Engineering, LLC

ElephantFish





ELBERT COUNTY

RURAL WATER SUPPLY STUDY

Figure 32
SEO Well Permits
Queried by Aquifer Completion

Appendix A - Elbert County Monitoring Wells

Well_Name	Data Source	Map ID	Aquifer	Permit No	LOCNUM	Twn	Rng	Q160	Q40	Q10	UTM_x	UTM_y	Well Depth	Top Screen	Bot Screen
DB-122 CLEARWATER WELL #1	DWR	A1	ARAPAHOE	50337	SC00606503CA	6	65	SW	NE		529863.6	4378629	1829	1430	1809
	USGS	A2	ARAPAHOE	222117	SC00606008AA ARAP 3	6	60	NE	NE		574990.1	4377927	360	280	360
	USGS	A3	ARAPAHOE	189245	SC00606008DA ARAP 4	6	60	SE	NE		575027.9	4377104	287	240	287
DB-051 NAGEL, DAVID	DWR	A4	ARAPAHOE	6501	SC00706009DBC	7	60	SE	NW	SW	576351	4367318	160	130	160
DB-053 DEWINDT, JOHN	DWR	A5	ARAPAHOE	4840	SC00706029ABC	7	60	NE	NW	SW	574854	4363228	486	460	486
	USGS	A6	ARAPAHOE	117760	SC00706129DB ARAP 5	7	61	SE	NW		565355.5	4362514	0	344	425
	USGS	A7	ARAPAHOE	192790		7	61	NW	NW		564375.1	4361701	434	354	434
DB-061 BURNS, LEONARD	DWR	A8	ARAPAHOE	61822	SC00806103ADB	8	61	NE	SE	NW	568743	4359884	715	601	715
	USGS	A9	ARAPAHOE	243628	SC00806126BB ARAP 6	8	61	NW	NW		569287.9	4353658	580	380	580
	USGS	A10	ARAPAHOE	214304		8	62	SE	NE		556084.5	4351291	832	742	832
	USGS	A11	ARAPAHOE	254389		9	60	SE	NE		575560.8	4349833	130	85	105
DB-073 HASENBOLG, LEROY	DWR	A12	ARAPAHOE	85063	SC00906016BBB	9	60	NW	NW	NW	575697	4347495	186	146	186
DB-081 LEMLEY, DONALD	DWR	A13	ARAPAHOE	4712	SC01006004BDD	10	60	NW	SE	SE	576185	4340432	240	180	240
	USGS	A14	ARAPAHOE	262471	SC01006003DC ARAP 7	10	60	SE	SW		578345.1	4339632	320	200	320
DB-082 BEN LOMOND GUN CLUB	DWR	A15	ARAPAHOE	44490	SC01006111BCB	10	61	NW	SW	NW	569337	4338894	484	383	484
DB-083 HERTNEKY,GEO.& KEN.	DWR	A16	ARAPAHOE	48587	SC01006121BBB	10	61	NW	NW	NW	566124	4336099	510	390	510
	USGS	A17	ARAPAHOE	289859	SC01006236CB ARAP 8	10	62	SW	NW		561316	4331815	730	564	730
	USGS	D1	DENVER	273284	SC00606106AA DENV 12	6	61	NE	NE		564000.8	4379637	161	104	161
	USGS	D2	DENVER	255474	SC00606426AA DENV 13	6	64	NE	NE		541379.7	4372763	543	414	534
DB-054 WHITEHEAD,C.B.	DWR	D3	DENVER	10687	SC00706208AAB	7	62	NE	NE	NW	555639	4368237	685	531	616
DB-063 DENVER BASIN COREHOLE	DWR	D4	DENVER	216708	SC00806317DB	8	63	SE	NW		545929	4356023	2256	517	712
DB-062 KLUTH, RALPH	DWR	D5	DENVER	14310	SC00806214CDC	8	62	SW	SE	SW	559959	4355653	400	320	375
	USGS	D6	DENVER	182075		8	62	NW	NW		556401.2	4351850	545	460	545
	USGS	D7	DENVER	272705	SC00806333CD DENV 14	8	63	SW	SE		547265.1	4350878	923	683	863
	USGS	D8	DENVER	205274	SC00806133DC DENV 15	8	61	SW	SW		566020.8	4350713	280	140	280
DB-075 KELLY, DON	DWR	D9	DENVER	28853	SC00906203DBD	9	62	SE	NW	SE	558907	4349556	302	250	302
	USGS	D10	DENVER	8632		9	62	SE	SE		560930.5	4341154	140	104	131
DB-074 STOLL,R.	DWR	D11	DENVER	65657	SC00906132DCD	9	61	SE	SW	SE	565467	4341107	567	467	567
	USGS	D12	DENVER	220015	SC01006236DC DENV 17	10	62	SW	SW		561334.5	4331675	480	280	480
	USGS	LF1	LFH	236568	SC00705915BA LARA 4	7	59	NW	NE		587467.7	4366453	221	161	221
	USGS	LF2	LFH	269459	SC00705915CA LARA 3	7	59	SW	NE		587229	4365871	340	190	340
	USGS	LF3	LFH	221719	SC00905917BA LARA 5	9	59	NW	NE		584323.2	4347473	400	300	400
	USGS	LF4	LFH	232023	SC00905917BC LARA 6	9	59	NW	SW		583864.9	4347118	360	303	340
	USGS	LF5	LFH	25992		10	60	NW	SW		580703	4332441	438	333	373
DB-086 MOORE, C.D.	DWR	LF6	LFH	43448	SC01105911BCB	11	59	NW	SW	NW	588449	4329381	505	375	505
	USGS	LD1	L. DAWSON	174858		6	64	SE	NW		536380.6	4376948	320	200	320
	USGS	LD2	L. DAWSON	207237	SC00706408AD LDAW 13	7	64	NE	SE		536795.2	4367517	440	360	440
	USGS	LD3	L. DAWSON	172937		8	64	NW	NW		535494.6	4356674	435	395	435
	USGS	LD4	L. DAWSON	182995	SC00806415BD LDAW 14	8	64	NW	SE		539309.8	4356502	415	315	415
LD-9	USGS	LD5	L. DAWSON	41042	SC00806513DC LDAW 12	8	65	SE	SW		533395	4355653	540	460	540
	USGS	LD6	L. DAWSON	88874		8	63	NW	SW		548500.2	4351688	388	267	388
	USGS	LD7	L. DAWSON	197821		8	65	NE	SW		529857.9	4351637	720	558	720
	USGS	LD8	L. DAWSON	186352	SC00806534DA LDAW 15	8	65	SE	NE		530334.3	4351023	743	613	743
	USGS	LD9	L. DAWSON	241370	SC00906320DA LDAW 16	9	63	SE	NE		546591	4344726	441	321	441
DB-084 ELBERT CHRISTIAN CHURCI	DWR	LD10	L. DAWSON	32074	SC01006403AAB	10	64	NE	NE	NW	539913	4340702	130	90	130
	USGS	LD11	L. DAWSON	232970		10	63	NW	SW		543646.7	4338672	475	375	475
BSD-01	DWR	QA1	ALLUVIUM	37086	SC00905706DBB	9	57	SE	NW	NW	601972.4	4350178	65	21	65
BSD-02	DWR	QA2	ALLUVIUM	37088	SC00905801DBB	9	58	SE	NW	NW	600544.4	4350016	90	70	90
FRASIER FARMS	DWR	QA3	ALLUVIUM	21896	SC00905706DA	9	57	SE	NE		602758.4	4350015	58	38	58
BSD-04A	DWR	QA4	ALLUVIUM	10474	SC00905709CAD	9	57	SW	NE	SE	605198	4348311	53	33	53
BSD-13	DWR	QA5	ALLUVIUM	2653	SC00905813ACC	9	58	NE	SW	SW	600533.4	4347046	110	60	100
WESTFALL MH	DWR	QA6	ALLUVIUM	159373	SC00905713DAD	9	57	SE	NE	SE	610842.4	4346728	38	18	38
BSD-14	DWR	QA7	ALLUVIUM	15956	SC00905827ACA	9	58	NE	SW	NE	597659.4	4344060	56	30	55
BSD-39	DWR	QA8	ALLUVIUM	57234	SC01005803BC	10	58	NW	SW		596902.4	4340080	87	67	87
BSD-38	DWR	QA9	ALLUVIUM	0	SC01005809BC	10	58	NW	SW		594923.4	4339131	46	0	0
BSD-36	DWR	QA10	ALLUVIUM	16983	SC01005807CD	10	58	SW	SE		592443.5	4338277	60	0	0
BSD-33	DWR	QA11	ALLUVIUM	3997	SC01005922BA	10	59	NW	NE		587251.5	4335980	53	24	53
BSD-31	DWR	QA12	ALLUVIUM	0	SC01005930CA	10	59	SW	NE		582518.5	4333445	0	0	0
BSD-16A	DWR	QA13	ALLUVIUM	37087	SC01006035BAA	10	60	NW	NE	NE	579581.5	4333001	62	32	62
BSD-26	DWR	QA14	ALLUVIUM	0	SC01006032AC	10	60	NE	SW		574863.5	4332626	0	0	0
BSD-30	DWR	QA15	ALLUVIUM	4339	SC01006036BC	10	60	NW	SW		580949.5	4332270	50	20	50
BSD-40	DWR	QA16	ALLUVIUM	239238	SC01006136DD	10	61	SE	SE		572412	4331606	43	18	38
DB-044 ASCHOFF,J.	DWR	UD1	U. DAWSON	61880	SC00606515CAA	6	65	SW	NE	NE	529955	4375558	380	280	380
SEE 145836	USGS	UD2	U. DAWSON	152997	SC00606527BB UDAW 11	6	65	NW	NW		529455.3	4372815	220	200	340
DB-045 WALLDEN,G. WELL "B"	DWR	UD3	U. DAWSON	0	SC00606534BC	6	65	NW	SW		529136	4371075	0	0	0
	USGS	UD4	U. DAWSON	49413	SC00606534CB UDAW 13	6	65	SW	NW		529176.4	4370373	300	200	300
DB-056 THAI QUOC TRAN	DWR	UD5	U. DAWSON	48339	SC00706512AAA	7	65	NE	NE	NE	533755	4368156	295	204	285
	USGS	UD6	U. DAWSON	173020		7	65	NW	SE		531071.4	4361101	290	210	290
	USGS	UD7	U. DAWSON	119108	SC00806408DA UDAW 16	8	64	SE	NE		536773.8	4357655	312	252	312
	USGS	UD8	U. DAWSON	40470	SC00806414AA UDAW 12	8	64	NE	NE		541572.3	4356761	220	195	225
#1	USGS	UD9	U. DAWSON	75490		8	64	SE	NE		536917.8	4356015	270	230	270
DB-064 SMITH	DWR	UD10	U. DAWSON	254276	SC00806427BC	8	64	NW	SW		538802	4353094	378	220	360
	USGS	UD11	U. DAWSON	119305	SC00806526DA UDAW 14	8	65	SE	NE		532057.2	4352737	300	200	300
	USGS	UD12	U. DAWSON	139086	SC00806526DB UDAW 18	8	65	SE	NW		531838.2	4352468	340	260	340
DB-076 MILLER, RICK	DWR	UD13	U. DAWSON	67886	SC00906308BBD	9	63	NW	NW	SE	545701	4348326	0	110	210
	USGS	UD14	U. DAWSON	190922		9	64	SW	SE		537523.1	4346035	360	240	360
DB-078 OBRECT, WALTER	DWR	UD15	U. DAWSON	25802	SC00906525DBB	9	65	SE	NW	NW	533887	4342927	333	150	320
DB-077 BISSET,D.	DWR	UD16	U. DAWSON	42439	SC00906434DBA	9	64	SE	NW	NE	539770	4341295	287	120	287
	USGS	UD17	U. DAWSON	62351	SC01006407DC UDAW 19	10	64	SE	SW		534835	4338022	401	321	401
	USGS	UD18	U. DAWSON	172560		10	64	SE	SW		542949.9	4334565	500	369	492

Appendix B - Elbert County Monitoring Wells Links

Well Name	Data Source	Map ID	LOC NUM	Aquifer	Links to Water Level Data
DB-122 CLEARWATER WELL #1	DWR	A1	SC00606503CA	ARAPAHOE	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=0430022
	USGS	A10		ARAPAHOE	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=0438048
	USGS	A11		ARAPAHOE	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=0518256
DB-073 HASENBOLG, LEROY	DWR	A12	SC00906016BBB	ARAPAHOE	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=9022121
DB-081 LEMLEY, DONALD	DWR	A13	SC01006004BDD	ARAPAHOE	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=9020749
	USGS	A14	SC01006003DC ARAP 7	ARAPAHOE	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=0536059
DB-082 BEN LOMOND GUN CLUB	DWR	A15	SC01006111BCB	ARAPAHOE	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=9021446
DB-083 HERTNEKY,GEO.& KEN.	DWR	A16	SC01006121BBB	ARAPAHOE	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=9021530
	USGS	A17	SC01006236CB ARAP 8	ARAPAHOE	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=3657844
	USGS	A2	SC00606008AA ARAP 3	ARAPAHOE	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=0452672
	USGS	A3	SC00606008DA ARAP 4	ARAPAHOE	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=0388446
DB-051 NAGEL, DAVID	DWR	A4	SC00706009DBC	ARAPAHOE	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=9020787
DB-053 DEWINDT, JOHN	DWR	A5	SC00706029ABC	ARAPAHOE	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=9020757
	USGS	A6	SC00706129DB ARAP 5	ARAPAHOE	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=9022629
	USGS	A7		ARAPAHOE	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=0395586
DB-061 BURNS, LEONARD	DWR	A8	SC00806103ADB	ARAPAHOE	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=9021711
	USGS	A9	SC00806126BB ARAP 6	ARAPAHOE	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=0497201
	USGS	D1	SC00606106AA DENV 12	DENVER	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=3615181
	USGS	D10		DENVER	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=9020833
DB-074 STOLL,R.	DWR	D11	SC00906132DCD	DENVER	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=9021784
	USGS	D12	SC01006236DC DENV 17	DENVER	https://nwis.waterdata.usgs.gov/nwis/inventory/?site_no=390755104172501&agency_cd=USGS&
	USGS	D2	SC00606426AA DENV 13	DENVER	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=0520827
DB-054 WHITEHEAD,C.B.	DWR	D3	SC00706208AAB	DENVER	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=9020882
DB-063 DENVER BASIN COREHOLE	DWR	D4	SC00806317DB	DENVER	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=0442170
DB-062 KLUTH, RALPH	DWR	D5	SC00806214CDC	DENVER	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=9020961
	USGS	D6		DENVER	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=0373430
	USGS	D7	SC00806333CD DENV 14	DENVER	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=3612739
	USGS	D8	SC00806133DC DENV 15	DENVER	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=0417546
DB-075 KELLY, DON	DWR	D9	SC00906203DBD	DENVER	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=9021209
	USGS	LD1		L. DAWSON	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=0358951
DB-084 ELBERT CHRISTIAN CHURCH	DWR	LD10	SC01006403AAB	L. DAWSON	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=9021254
	USGS	LD11		L. DAWSON	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=0475229
	USGS	LD2	SC00706408AD LDAW 13	L. DAWSON	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=0423781
	USGS	LD3		L. DAWSON	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=0354814
	USGS	LD4	SC00806415BD LDAW 14	L. DAWSON	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=0375832
LD-9	USGS	LD5	SC00806513DC LDAW 12	L. DAWSON	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=0335946A
	USGS	LD6		L. DAWSON	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=0078523
	USGS	LD7		L. DAWSON	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=0402174
	USGS	LD8	SC00806534DA LDAW 15	L. DAWSON	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=0383258
	USGS	LD9	SC00906320DA LDAW 16	L. DAWSON	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=0492026

	USGS	LF1	SC00705915BA LARA 4	LFH	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=0481955
	USGS	LF2	SC00705915CA LARA 3	LFH	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=3605382
	USGS	LF3	SC00905917BA LARA 5	LFH	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=0451904
	USGS	LF4	SC00905917BC LARA 6	LFH	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=0472681
	USGS	LF5		LFH	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=9077931
DB-086 MOORE, C.D.	DWR	LF6	SC01105911BC B	LFH	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=9078031
BSD-01	DWR	QA1	SC00905706DB B	ALLUVIUM	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=0016229 D
BSD-36	DWR	QA10	SC01005807CD	ALLUVIUM	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=9077851
BSD-33	DWR	QA11	SC01005922BA	ALLUVIUM	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=9077711
BSD-31	DWR	QA12	SC01005930CA	ALLUVIUM	NA
BSD-16A	DWR	QA13	SC01006035BA A	ALLUVIUM	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=0016229 C
BSD-26	DWR	QA14	SC01006032AC	ALLUVIUM	NA
BSD-30	DWR	QA15	SC01006036BC	ALLUVIUM	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=9077720
BSD-40	DWR	QA16	SC01006136DD	ALLUVIUM	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=0487902 A
BSD-02	DWR	QA2	SC00905801DB B	ALLUVIUM	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=0016229 B
FRASIER FARMS	DWR	QA3	SC00905706DA	ALLUVIUM	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=9077896
BSD-04A	DWR	QA4	SC00905709CA D	ALLUVIUM	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=0407767
BSD-13	DWR	QA5	SC00905813AC C	ALLUVIUM	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=0429583
WESTFALL MH	DWR	QA6	SC00905713DA D	ALLUVIUM	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=0017140 B
BSD-14	DWR	QA7	SC00905827AC A	ALLUVIUM	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=9077836
BSD-39	DWR	QA8	SC01005803BC	ALLUVIUM	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=9078078
BSD-38	DWR	QA9	SC01005809BC	ALLUVIUM	NA
DB-044 ASCHOFF,J.	DWR	UD1	SC00606515CA A	U. DAWSON	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=9021715
DB-064 SMITH	DWR	UD10	SC00806427BC	U. DAWSON	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=0518067
	USGS	UD11	SC00806526DA UDAW 14	U. DAWSON	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=0209296
	USGS	UD12	SC00806526DB UDAW 18	U. DAWSON	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=0252774
DB-076 MILLER, RICK	DWR	UD13	SC00906308BB D	U. DAWSON	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=9021836
	USGS	UD14		U. DAWSON	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=0389811
DB-078 OBRECT, WALTER	DWR	UD15	SC00906525DB B	U. DAWSON	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=9021161
DB-077 BISSET,D.	DWR	UD16	SC00906434DB A	U. DAWSON	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=9021406
	USGS	UD17	SC01006407DC UDAW 19	U. DAWSON	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=0535061
	USGS	UD18		U. DAWSON	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=0357519
SEE 145836	USGS	UD2	SC00606527BB UDAW 11	U. DAWSON	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=0294283
DB-045 WALLDEN,G. WELL "B"	DWR	UD3	SC00606534BC	U. DAWSON	NA
	USGS	UD4	SC00606534CB UDAW 13	U. DAWSON	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=0422645 B
DB-056 THAI QUOC TRAN	DWR	UD5	SC00706512AA A	U. DAWSON	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=9021523
	USGS	UD6	SC00706535BD UDAW 15	U. DAWSON	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=0359937
	USGS	UD7	SC00806408DA UDAW 16	U. DAWSON	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=9022639
	USGS	UD8	SC00806414AA UDAW 12	U. DAWSON	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=9021367
#1	USGS	UD9		U. DAWSON	http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=9021971

USGS NWIS Website Link to All Wells			
Data for individual sites can be obtained by selecting the site number below			
Forsgren Map ID	**Agency**	**Site Number**	**Site Name**
A2	USGS	393251104073701	SC00606008AA ARAP 3
A3	USGS	393225104073601	SC00606008DA ARAP 4
A6	USGS	392434104142701	SC00706129DB ARAP 5
A7	USGS	392400104150601	SC00706132BBC ARAPMAS28
A9	USGS	391946104114501	SC00806126BB ARAP 6
A10	USGS	391834104205601	SC00806232DAA ARAPMAS22
A11	USGS	391740104072401	SC00906005DAA ARAPMAS27
A14	USGS	391208104053301	SC01006003DC ARAP 7
A17	USGS	390800104172601	SC01006236CB ARAP 8
D1	USGS	393350104151701	SC00606106AA DENV 12
D2	USGS	393012104310701	SC00606408DBB DAWMAS19
D6	USGS	391851104204501	SC00806233BBC DENMAS05
D7	USGS	391821104270601	SC00806333CD DENV 14
D8	USGS	391811104140301	SC00806133DC DENV 15
D10	USGS	391257104173601	SC00906235DDD (DENV 16)
D12	USGS	390755104172501	SC01006236DC DENV 17
LD1	USGS	393227104343401	SC00606408DBB DAWMAS19
LD2	USGS	392724104341901	SC00706408AD LDAW 13
LD3	USGS	392131104351701	SC00806417BBC DAWMAS21
LD4	USGS	392125104323701	SC00806415BD LDAW 14
LD5	USGS	392058104364401	SC00806513DC LDAW 12
LD6	USGS	391848104261401	SC00806334BCA DAWMAS28
LD7	USGS	391852104391301	SC00806534ACB DAWMAS16
LD8	USGS	391829104385301	SC00806534DA LDAW 15
LD9	USGS	391502104273601	SC00906320DA LDAW 16
LD11	USGS	391148104294101	SC01006307BCC DAWMAS27
LF1	USGS	392635103590001	SC00705915BA LARA 4
LF2	USGS	392616103591001	SC00705915CA LARA 3
LF3	USGS	391621104012001	SC00905917BA LARA 5
LF4	USGS	391609104014001	SC00905917BC LARA 6
LF5	USGS	390817104040301	SC01006036BCC1 (LARA 7)
UD2	USGS	393016104392601	SC00606527BB UDAW 11
UD4	USGS	392856104393801	SC00606534CB UDAW 13
UD6	USGS	392355104382001	SC00706535BD UDAW 15
UD7	USGS	392203104342301	SC00806408DA UDAW 16
UD8	USGS	392133104310201	SC00806414AA UDAW 12
UD9	USGS	392130104341401	SC00806417AAD1 (UDAW 17)
UD11	USGS	391924104374101	SC00806526DA UDAW 14
UD12	USGS	391915104375001	SC00806526DB UDAW 18
UD14	USGS	391545104335401	SC00906416CDB DAWMAS22
UD17	USGS	391126104354701	SC01006407DC UDAW 19
UD18	USGS	390935104301001	SC01006424DCD DAWMAS26

Appendix B

MEMORANDUM

To: Will Koger, P.E. – Forsgren and Associates

From: Dennis McGrane, P.E., C.P.G. – McGrane Water Engineering, llc.

Date: June 6, 2018

Project: Elbert County Rural Water Supply Study

Subject: Task 3 - Prototypical Well Analysis Details

PROTOTYPICIAL WELL ANALYSIS

Forsgren and Associates (FA) was retained by Elbert County (County) to conduct a "Rural Water Supply Study." McGrane Water Engineering, llc (MWE) was retained by FA to evaluate the groundwater source options. This memo includes the results of Task 3 of our scope of work that includes a cost comparison of the three future groundwater demand alternatives for the Northwestern (NW) and Elizabeth-Kiowa (EK) study areas between 2018 and 2050. The "No-Action" Alternative No. l assumes the continued sole use of groundwater. Action Alternative No. 2 assumes that the County substitutes groundwater with 10% "renewable" options in 2035. Action Alternative No. 3 assumes a 25% percent increase in "renewable" options in 2035.

The prototypical well analysis uses average aquifer well depths, water demand and aquifer parameters in a cost model developed for each study area. The demand is driven by population growth which drives the number of wells. We distribute new wells to the various aquifers according to the current ratio of people per well per aquifer obtained from the State's well database. The number of wells drives the direct capital costs (wells and pumps). The number of pumps drives the operations costs which include pump replacement costs and electrical power. The total cost for each alternative is the sum of capital and operations costs for each prototypical well multiplied by the number of future wells which vary in depth by aquifer.

Background and additional data and assumptions related to this analysis are included in MWE memo to FA dated June 6, 2018 titled, "Task 1 and 2 - Elbert County Groundwater Supply and USGS Modeling."

Cost Estimation Method

Average physical aquifer characteristics were extracted from the USGS (2011) groundwater model including:

- Ground elevation;
- Aquifer bottom (represents well depth);
- 2018 and 2053 water level elevations (used to estimate regional water level decline rates); and
- Aquifer characteristics (sand thickness, transmissivity (a measure of permeability multiplied by the sand thickness), and confined and unconfined storage properties).

A detailed description of the model extraction process and assumptions is included in MWE memorandum to FA dated September 12, 2017 which is not included in this memo, but is available on request.

Costs for well drilling and completion, pumping systems (including wellhead appurtenances), and power costs are based on interviews with domestic and municipal drillers and pump installers (Heir Drilling, Castle Rock, Co., and Layne Christensen, Aurora, Co.). The comparative economic analysis calculates the Net Present Value (NPV) of totaled annual direct costs from 2018 to 2050 (32 years) assuming annual inflation rates and a discount rate of 2 percent which were provided by FA.

Well Distribution

The number of residential and municipal wells and their aquifer distribution is based on the current distribution of permitted wells determined by querying the State's well permit database. Table 1 shows that 2031 wells exist in the NW study area and 2911 wells exist in the EK study area. Most residential and municipal wells are located in the Upper Dawson, Lower Dawson and Denver aquifers and only a few Arapahoe and LFH wells currently exist.

Table 1 - Total Permitted Wells by Aquifer

		Aquifer					
		Upper Dawson	Lower Dawson	Denver	Arapahoe	Laramie Fox Hills	Total
Well Type	Northwest Study Area						
Residential	Number	894	230	903	4	0	2031
	Percentage	44.0%	11.3%	44.5%	0.2%	0.0%	100.0%
Municipal	Number	0	0	5	2	1	8
	Percentage	0.0%	0.0%	62.5%	25.0%	12.5%	100.0%
	Elbert-Kiowa Study Area						
Residential	Number	1952	796	159	4	0	2911
	Percentage	67.1%	27.3%	5.5%	0.1%	0.0%	100.0%
Municipal	Number	1	12	4	1	0	18
	Percentage	5.6%	66.7%	22.2%	5.6%	0.0%	100.0%
	Limon Study Area						
Residential	Number	na	na	na	na	0	0
	Percentage	na	na	na	na	0	0
Municipal	Number	na	na	na	na	0	0
	Percentage	na	na	na	na	0	0

Source: Colorado Division of Water Resources, Colorado's Well Permit Search, 2017.

A major assumption in our economic model is that the ratio of the number of wells per person in each aquifer in 2017 is constant in the future. Table 2 shows the number of wells per capita in various bedrock aquifers for residential and municipal uses for 2017.

Table 2 – 2017 Permitted Residential and Municipal Wells Per Capita*

Well Use	Location	Upper Dawson	Lower Dawson	Denver	Arapahoe	Laramie Fox Hills	Total
Residential	Northwest Study Area	0.11	0.03	0.11	0.0005	0	0.24
	Elizabeth-Kiowa Study Area	0.15	0.06	0.01	0.0003	0	0.23
	Eastern Study Area	na	na	na	na	na	na
Municipal	Northwest Study Area	0	0	0.00060	0.00024	0.00012	0.00095
	Elizabeth-Kiowa Study Area	0.00008	0.00094	0.00031	0.00008	0	0.0014
	Limon Study Area	na	na	na	na	na	na

Notes: * Based on 2017 population divided by permitted wells queried by permit type.

Table 2 used to calculate future residential and municipal use for each aquifer in each study (Tables not provided in this summary report). As a result, the number of future Arapahoe and LFH wells will also remain extremely low. We believe this assumption is reasonable until past 2050, when continued drawdown around towns and cities will drives municipal suppliers to drill deeper Arapahoe Aquifer wells.

In the NW and EK study areas, we averaged model elevations and aquifer parameters from the western half of Range 64W to the western county line due to the significantly greater depth, depth to water (due to existing aquifer drawdown) and greater expected future development. For the Eastern study area, only the LFH aquifer exists in the western portion. Since no bedrock (LFH) wells exist in the Eastern Study area, we did not include the Eastern Study area in our prototypical well analysis.

Elevation

Table 3 shows the average elevation of the ground surface in the NW and EK study areas.

Table 3 - Average Study Area Elevation

Study Area	Elevation (fmsl)
Northwest (NW)	6292
Elizabeth-Kiowa (EK)	6648

Source: USGS, 2011

The average elevation of the western portion of the EK study area is significantly higher than the NW study area.

Top of Aquifers

The average depth to the top of aquifer ranges from zero for the Upper Dawson to over 2,200 feet for the LFH aquifer in the western portions of both the NW and EK study areas as shown in Table 4.

Table 4 - Average Depth (ft.) to Top of Aquifer

Study Area	Upper Dawson	Lower Dawson	Denver	Arapahoe	Laramie Fox Hills
Northwest (NW)	0	444	611	1466	2260
Elizabeth-Kiowa (EK)	0	516	769	1633	2385

Source: USGS, 2011

Since the Upper Dawson aquifer outcrops at the ground surface, we expect the aquifer to behave like an unconfined aquifer where only the specific yield was used to calculate drawdown and available storage. Based on the USGS model results, all other aquifer behave confined throughout the study period.

Aquifer Bottom/Well Depth

Since the aquifer tops and bottoms were determined from well data, it is reasonable to assume that the modeled depth to the bottom of each aquifer is a proxy for the average depths of prototypical wells. The average aquifer bottom/well depths range from 388 feet for the Upper Dawson aquifer in the NW study area to over 2,700 for the LFH aquifer in the EK study area as shown in Table 5.

Table 5 - Average Aquifer Bottom/Well Depth (ft.)

Study Area	Upper Dawson	Lower Dawson	Denver	Arapahoe	Laramie Fox Hills
Northwest (NW)	388	568	1428	1976	2596
Elizabeth-Kiowa (EK)	440	712	1583	2097	2707

Source: USGS, 2011

Depth to Groundwater

The depths to groundwater in 2018 and 2053 were used to estimate average water level declines for prototypical wells. The average depth to groundwater in the western portion of the NW and EK study for 2018 areas ranges from 155 ft. in the Upper Dawson to 606 ft. in the Arapahoe aquifer as shown in Table 6.

Table 6 - Average Depth (ft.) to Groundwater in Study Areas

Study Area	Upper Dawson	Lower Dawson	Denver	Arapahoe	Laramie Fox Hills
Northwest (NW)	226	409	549	606	520
Elizabeth-Kiowa (EK)	155	279	308	316	265

Source: USGS, 2011

The significantly deeper depth to groundwater in the NW compared to the EK study area is because there is significantly more drawdown currently occurring in the NW study area compared to the EK study area.

Aquifer Transmissivity

The aquifer transmissivity was used to estimate seasonal drawdown for prototypical wells. Average aquifer transmissivities within study areas were determined by multiplying average aquifer hydraulic conductivity (K) values by the average layer thickness and the average percent sand-silt multiplier arrays for model cells. The K values were determined during model calibration. The average transmissivities range from 15 ft^2/day in the Lower Dawson (NW study area) to 463 ft^2/day in the Arapahoe aquifer (NW study area) as shown in Table 7.

Table 7 - Average Aquifer Transmissivity (ft^2/day)

Study Area	Upper Dawson	Lower Dawson	Denver	Arapahoe	Laramie Fox Hills
Northwest (NW)	175	15	293	463	192
Elizabeth-Kiowa (EK)	418	25	258	241	204

Source: USGS, 2011

Confined Aquifer Storativity

The confined aquifer storativity or storage coefficient was used to estimate seasonal drawdown amounts for prototypical wells. The average confined aquifer storativity for the western portions of the NW and EK study areas are fairly consistent ranging from 0.0001 to 0.0004 as shown in Table 8.

Table 8 - Average Confined Storativity

Study Area	Upper Dawson	Lower Dawson	Denver	Arapahoe	Laramie Fox Hills
Northwest (NW)	na	0.0001	0.0004	0.0003	0.0002
Elizabeth-Kiowa (EK)	na	0.0001	0.0004	0.0002	0.0002

Source: USGS, 2011

Net Specific Yield

Aquifer net specific yield values were used to calculate total storage and aquifer life. The net specific yield was determined by multiplying reported aquifer specific yield values (Upper and Lower Dawson aquifers = 0.152; Denver aquifer = 0.133; Arapahoe aquifer = 0.178; and LFH aquifer = 0.186) by the USGS' net sand/silt percentage arrays extracted from their model. This was necessary because the model determines changes in storage by multiplying the layer thickness by the layer specific yield. The resulting net specific yield values range from 0.04 for the Upper Dawson aquifer to 0.09 in the Arapahoe aquifer as shown in Table 9.

Table 9 - Average Aquifer Layer Specific Yield

Study Area	Upper Dawson	Lower Dawson	Denver	Arapahoe	Laramie Fox Hills
Northwest (NW)	0.04	0.07	0.05	0.09	0.11
Elizabeth-Kiowa (EK)	0.05	0.07	0.04	0.08	0.12

Source: USGS, 2011

We multiplied these values by the layer thickness to obtain model layer storage and change in storage over time.

Study Area Drawdown and Decline Rates

We extracted the average 2018 to 2053 (35 year) water level decline (drawdown) from the USGS model to calculate the average aquifer decline rates. The modeled drawdown over this period is between 7 feet in the Upper Dawson (NW study area) to over 90 feet in the LFH model for both study areas as shown in Table 10.

Table 10 – Average Aquifer Water Level Declines (ft.) between 2018 and 2053

	Upper Dawson	Lower Dawson	Denver	Arapahoe	Laramie Fox Hills
Northwest (NW)	7	17	31	38	92
Elizabeth-Kiowa (EK)	16	28	52	61	93

Source: USGS, 2011

The decline rates were determined by dividing the total decline by 35 years which range from 0.2 ft/yr to 2.6 ft/yr as shown in Table 11.

Table 11 – Average Aquifer Water Level Future Decline Rates (ft/yr)

	Upper Dawson	Lower Dawson	Denver	Arapahoe	Laramie Fox Hills
Northwest (NW)	0.2	0.5	0.9	1.1	2.6
Elizabeth-Kiowa (EK)	0.5	0.8	1.5	1.7	2.6

Source: USGS, 2011

The estimated future water level decline rates were used to estimate future pumping costs; the number of wells in various aquifers; and to calculate available storage and therefore aquifer life.

In a similar study conducted for Douglas County (DC) by URS Corp (2013), the authors presented costs based on USGS modeled water level declines which they compared to observed drawdown in some CDWR monitoring wells. The authors concluded that if water level declines in the future are consistent with that observed in some CDWR wells, that: 1) the costs for future pumping and infrastructure will be significantly higher; and 2) that the amount of storage and estimated life of the Denver Basin aquifer will be significantly shorter.

We believe that using average well declines determined by the model is inappropriate for this level of study for the following reasons:

1. The declines observed used in the DC analysis are not representative of the entire County;
2. High decline rates within major pumping centers typically reflect confined drawdown conditions which are 3 to four times more than unconfined conditions where gravity drainage occurs; and
3. In Elbert County, there is less of a need to be overly conservative considering a small percentage of water has already been withdrawn.

Cost Assumptions

We made the following additional assumptions related to capital costs and operating characteristics for residential and municipal wells.

Well Pump Motor Size

Pump motor sizing is measured in horsepower. For all wells and aquifers, the annual static water level is based on modeled future depths and decline rates; a power cost of $0.12 per kilowatt-hour (KWH); a well efficiency of 80 percent; and a pump and motor efficiency of 70 percent. For domestic and household wells, we calculate drawdown using the Cooper-Jacob (1947) method using average daily pumping rates of 5 gpm for 3 hours per day totaling 900 gallons per day (1 af/yr). The calculated horsepower for domestic and household wells is based on Equation 1.

Equation 1:

Horsepower (HP) = (TDH (ft.) x Rate (gpm)/ (3960 * Efficiency), whereas

- TDH = water level depth (ft.) + drawdown (ft.) + head losses and system pressure (assume 20 psi);
- Rate = 5 gpm; and
- Efficiency = pump efficiency (assumed 70 percent)

The resulting horsepower is less than 1 hp per well for all aquifers. Domestic pumps are often over-sized (typically 3 to 5 horsepower) to allow higher pumping rates for shorter periods of time to meet peak demands, but the total power cost is the same.

Well Cost

The cost of drilling and equipping a well is also a function of depth and diameter. We obtained well costs with local drillers who specialize in drilling residential (4-in diameter) and municipal (>8-in. diameter) wells. According to Heir Drilling (Castle Rock, Co.), the average footage cost to drill and install a typical 4-in. diameter residential well, less than 700 feet deep, with basic controls, pressure tank, and hookup is approximately $16 per foot. The average footage cost to drill a residential well over 700 feet deep is approximately $26 per foot as shown in Table 12.

Table 12 – Average Residential Well Cost

Depth	Cost/ft
< 700 ft	$16
> 700 ft	$26

Source: Heir Drilling, 2017

Most municipal wells are completed with larger diameter (8 to 12-in.) steel casing and stainless steel screens. Extensive well development and testing are required which also increases unit costs. Layne Christensen (Aurora, Co.) provided footage costs ranging from $300 to $360 per foot for 400 to 2,600 foot wells completed in various aquifers as shown in Table 13. The table also includes the cost of a basic well house, controls and engineering based on our professional experience which range from $200,000 to $400,000 per municipal well.

Table 13 – Average Municipal Well Cost

Aquifer	Unit Well Costs				Basic Well House, Controls and Engineering	Total $
	Total Depth (TD) (ft)	Diam. (in)	Cost/ft	Well $		
U Dawson	400	8	$360	$144,000	$200,000	$344,000
L. Dawson	600	8	$360	$216,000	$250,000	$466,000
Denver	1500	10	$300	$450,000	$300,000	$750,000
Arapahoe	2000	12	$350	$700,000	$350,000	$1,050,000
LFH	2600	12	$350	$910,000	$400,000	$1,310,000

Sources: Unit Well Costs - Layne Christensen, 2017; Well House, Controls and Engineering – MWE, 2017

The total cost of the well, basic well house, controls, and engineering ranges from $344,000 to $1,310,000.

The expected life of a properly constructed municipal well is 30 to 50 years. Therefore, we did not include any costs to replace existing wells in our cost model. This assumption is reasonable because there are so few municipal wells in the county (MWE Task 1 and 2 memorandum to FA, June 6, 2017 - Figure 31), and they are likely less than 20 years old.

Pump Cost

Heir Drilling (Castle Rock, Co.) provided cost estimates for 4-in. diameter residential wells. Heir Drilling estimates that less than 3 hp systems installed in wells less than 700 feet deep with basic controls, pressure tank, and pipeline hookup would cost approximately $12,000. The cost for a residential pumping system in wells over 700 feet deep is approximately $20,000 as shown in Table 14.

Table 14 – Average Residential Pump Cost

Depth	Cost
< 700 ft	$ 12,000
> 700 ft	$ 20,000

Source: Heir Drilling, 2017

The cost of a municipal pumping system is also a function of setting depth and horsepower. Layne Christensen (Aurora, Co.) provided cost estimates to provide and install complete pumping systems that can pump 200 gpm from a setting depth of two thirds the well depth. Their price includes all down-hole equipment (pump, motor, drop pipe, submersible cable, transducer, PVC sounding tube) and surface equipment (pitless adapter, variable speed drives, and basic controls). The pumping system costs in Table 15 range from $150,000 for an Upper Dawson well to $350,000 for a LFH well respectively.

Table 15 – Average Municipal Pumping System Cost

Municipal Pumping System Costs			
Aquifer	Setting Depth (.66*TD)	Horse power*	Pump, Cable, Pipe $
U Dawson	264	26	$150,000
L. Dawson	396	36	$160,000
Denver	990	79	$250,000
Arapahoe	1320	102	$300,000
LFH	1716	131	$350,000
***Assumptions:** 200 gpm from a TDH of setting depth + 100 ft and eff of 70%			

Source: Layne Christensen, 2017

Well pumps are replaced every 15 years on average in both residential and municipal wells. Therefore, half of all existing and new pumps were replaced every 8 years in the cost model. We assumed the cost of a residential replacement pump is the same as the initial pump since the surface controls are relatively inexpensive compared to downhole components. We assume the cost of replacing municipal pumps is half that listed in Table 15 because the above ground controls and pump houses are approximately half of the total costs.

Power Cost

We calculated the cost of pumping for residential wells based on Equation 2.

Equation 2:

Annual Power Cost ($/yr) = 0.746* HP * $/kwh * Pumping Time (hrs/yr), whereas

- HP = horsepower
- $/kwh = $0.12 (URS, 2013)
- Pumping Time = (3 hrs/day * 365.25 days/year = 1 acre foot per well)

The resulting 2017 power costs range from $37 to $117 per year per well.

For municipal wells, we assume that pumping costs are linearly proportional to the pumped volume. If we assume that an average municipal well produces 200 af/yr, then the annual power cost is approximately 200 times more than a domestic well that pumps 1 af/yr. Therefore, the resulting 2017 power costs are $7,400 to $23,400 year per well. Operating (electrical) costs increase over time due to the increasing lift (based on water decline rates) while well efficiency was held constant. Operating costs appear to be relatively minor compared to the pump replacement and drilling costs. We did not assume any demand charges for municipal. To avoid demand charges, municipalities tend to leave their wells on for extended periods of time during peak demand periods and use variable speed drives to avoid turning the wells on and off repeatedly.

Net Present Value

To perform this comparative cost analysis, it is important to translate the units of comparison into a common measure, in this case net present value (NPV). The NPV allows future costs to be expressed in present day dollar values by accounting (or discounting) for inflation and the fact that a dollar available today is worth more than a dollar received in the future (URS, 2013). The costs are inflated by 2.0 percent, and then discounted by 2.0 percent (determined by FA).

Prototypical Well Cost Example

The prototypical well cost model methodology is further explained through the use of the following example of a prototypical well in the Lower Dawson aquifer (EK study area). URS (2013) provided a similar hypothetical example in their report for comparison purposes. This analysis represents just one of the 796 existing Upper Dawson wells in 2017 (Table 1) that we assume operates under "average" conditions in the future. By 2050, FA estimates that the population will be 35,782 (FA report Figure 3-4) in the EK study area. By multiplying by the per capita aquifer well distribution (0.06 well/person) for the Lower Dawson Aquifer (Table 2), we estimate that 2,230 (23,532 * 0.06) Lower Dawson wells will exists in 2050. That represents a 281 percent increase (2,230/796*100).

The starting conditions of the Lower Dawson aquifer are as follows. The average depth to the bottom of the Lower Dawson aquifer from ground level is 516 feet with a depth to water of 279 feet and average decline rate of approximately 1 foot per year based on the USGS modeling. From 2018 to 2050, the depth to water is above the top of aquifer (assuming the well pumps 5 gpm for 3 hours per day (1 acre-feet per year)), the power cost is $67 per year using a power cost of $0.12 per kilowatt hour. The well is assumed to be halfway through their useful life (8 out of 15 years).

Using this information, the following is a step by step of the methodology used in determining the prototypical well cost:

1. During the first 8 years of the model (2018 -2025), regional water levels decline from a depth of 279 to 286 feet and seasonal pumping levels decline from 327 to 334 feet;
2. Due to inflation and increased pumping levels, annual power costs increase from $67 to $80;
3. In year nine, the pump has reached the end of its useful life and is replaced at a cost of $14,060. This is the first sizeable cost of ownership in the cost model.
4. For the next 16 years (2025-2041) annual electricity charges increase from $80 to $113;
5. In 2041, the pump has reached the end of its useful life and is replaced at a cost of $19,301.
6. For the remainder of the study period (2042 to 2050), only annual electricity charges increase from $113 to $137 per year.

Over the planning period, the prototypical Lower Dawson well in the EK study area required two new pumps totaling $33,361 and approximately $3,331 in electricity charges for a total cost of ownership of $36,692. This compares to $33,000 reported for a Lower Dawson well in a similar study conducted for Douglas County (URS, 2013, p.5-8).

The model calculates the NPV costs for prototypical residential or municipal wells in each aquifer for each service area. Each prototypical well has individual starting conditions, aquifer parameters, and water level decline rates. The spreadsheet to do this is large and therefore it is impractical to provide a printout of each table.

The methodology described does not reflect the wide variation in individual circumstances for individual wells throughout each service area. The aquifer elevations, depth to water and depths of wells all vary on a site-specific basis. Each well owner would need to apply her/his individual well characteristics to understand their individual cost. However, on average, throughout the region for the NW and EK service areas, these weighted average prototypical well costs would apply.

Alternative Cost Comparison

The alternative cost comparison provides the capital and O&M costs for the "No Action" and two "Action" Alternatives for each study area from 2018 to 2050. Tables 16 and 17 provide the number of wells necessary to satisfy demand under the three scenarios in the two study areas. In the NW study area, 2,031 residential and 8 municipal wells exist in 2018, totaling 2,039 wells. The number of wells is expected to be approximately 5,713 for the No Action Alternative No. 1; 5,142 wells for the Action Alternative No. 2 and approximately 4,285 for Action Alternative No. 3.

Table 16 – Number of Wells for Various Alternatives – Northwest (NW) Study Area

	No of Wells in 2018 =	Residential	Muni	Total
		2031	8	2039
No of Wells in 2050 =				
Alternative	**Description**	**Residential**	**Muni**	**Total**
No Action - Alt. No. 1	All Groundwater	5690	23	5713
Action - Alt. No. 2	10% Renewable Imports in 2035	5121	21	5142
Action - Alt. No. 3	25% Renewable Imports in 2035	4268	17	4285

In the EK study area, 2,911 residential and 18 municipal wells exist in 2018, totaling 2,929 wells. The number of wells is expected to be approximately 8,207 for the No Action Alternative No. 1; 7,387 wells for the Action Alternative No. 2 and approximately 6,154 for Action Alternative No. 3.wells

Table 17 – Number of Wells for Various Alternatives – Elizabeth-Kiowa Study Area

	No of Wells in 2018 =	Residential	Muni	Total
		2911	18	**2929**
No of Wells in 2050 =				
Alternative	**Description**	**Residential**	**Muni**	**Total**
No Action - Alt. No. 1	All Groundwater	8156	51	8207
Action - Alt. No. 2	10% Renewable Imports in 2035	7341	46	7387
Action - Alt. No. 3	25% Renewable Imports in 2035	6117	37	6154

The tables below provide the capital and O&M costs of the "No Action" and "Action" Alternatives for each study area and a combined summary through 2050. For the "No Action" Alternative, capital expenditures are highest for new wells ($64M), followed by replacement pumps in existing wells ($51M); followed by new pumps in future wells ($44M), then replacement pumps in future wells ($29M), and lastly power ($12M). The cost of residential wells far exceeds municipal wells due to the rural nature of the County. The comparison provides stakeholders and public agencies the ability to further assess the comparative capital and OMR costs of maintaining the status quo, seeking renewable options, or evaluating other action alternative on the future.

Northwest (NW) Study Area

No Action Alternative 1

The total cost for all capital and operating costs for the No Action Alternative 1 in the NW study area are presented in Table 18.

Table 18 - No Action Alternative 1 Cost (NW Study Area)

Costs	Items	Domestic	Municipal	Total
Capital Costs	New Wells	$54,257,957	$9,944,032	$64,201,990
	New Pumps for Future Wells	$41,480,098	$3,086,845	$44,566,943
O&M	Replacement Pumps in Existing Wells	$49,669,257	$868,442	$50,537,700
	Replacement Pumps Future Wells	$28,860,038	$459,540	$29,319,578
	Power	$3,538,869	$8,113,834	$11,652,703
Total NPV		**$177,806,219**	**$22,472,695**	**$200,278,913**

The total cost for the No Action Alternative is approximately $200 million (M) which consists of approximately $178M in residential costs and $22M in municipal well costs.

Action Alternative No. 2

Action Alternative No. 2 consists of offsetting demand with 10 percent renewables in 2035. Additional wells after 2035 are not necessary until new growth increases the demand another 10 percent around 2040. The total cost for all capital and operating costs for Action Alternative No. 2 in the NW study area are presented in Table 19.

Table 19 - Action Alternative 2 Cost (NW Study Area)

Costs	Items	Domestic	Municipal	Total
Capital Costs	New Wells	$45,407,302	$8,606,999	$54,014,301
	New Pumps for Future Wells	$34,711,510	$2,670,242	$37,381,752
O&M	Replacement Pumps in Existing Wells	$49,669,257	$868,442	$50,537,700
	Replacement Pumps Future Wells	$27,568,038	$459,540	$28,027,578
	Power	$3,328,367	$7,546,307	$10,874,674
Total NPV		**$160,684,474**	**$20,151,530**	**$180,836,004**

The total cost is approximately $181M which consists of approximately $161M in residential costs and $20M in municipal costs.

Action Alternative No. 3

Action Alternative No. 3 consists of offsetting demand with 25 percent renewables in 2035. Additional wells after 2035 are not necessary until new growth increases the demand another 25 percent around 2049. The total cost for all capital and operating costs for Action Alternative 3 in the NW study area are presented in Table 20.

Table 20 - Action Alternative 3 Cost (NW Study Area)

Costs	Items	Domestic	Municipal	Total
Capital Costs	New Wells	$30,063,672	$5,072,594	$35,136,266
	New Pumps for Future Wells	$22,991,615	$1,608,372	$24,599,988
O&M	Replacement Pumps in Existing Wells	$49,669,257	$868,442	$50,537,700
	Replacement Pumps Future Wells	$27,568,038	$459,540	$28,027,578
	Power	$3,012,361	$6,769,779	$9,782,140
Total NPV		**$133,304,943**	**$14,778,729**	**$148,083,672**

The total cost is approximately $148M which consists of approximately $133M in residential costs and $15M in municipal costs.

Elizabeth-Kiowa (EK) Study Area

No Action Alternative 1

The total cost for all capital and operating costs for the No Action Alternative 1 in the EK study area are presented in Table 21.

Table 21 - No Action Alternative 1 Cost (EK Study Area)

Costs	Items	Domestic	Municipal	Total
Capital Costs	New Wells	$46,238,585	$3,086,845	$49,325,431
	New Pumps for Future Wells	$55,883,237	$4,517,731	$60,400,967
O&M	Replacement Pumps Existing Wells	$66,906,192	$1,327,005	$68,233,197
	Replacement Pumps Future Wells	$38,874,174	$739,862	$39,614,036
	Power	$7,634,961	$3,290,562	$10,925,522
Total NPV		**$215,537,148**	**$12,962,006**	**$228,499,154**

The total cost for the No Action Alternative is approximately $228 million (M) which consists of approximately $215M in residential costs and $13M in municipal costs.

Action Alternative 2

The total cost for all capital and operating costs for Action Alternative 2 in the EK study area are presented in Table 22.

Table 22 - Action Alternative 2 Cost (EK Study Area)

Costs	Items	Domestic	Municipal	Total
Capital Costs	New Wells	$38,717,298	$2,670,242	$41,387,540
	New Pumps for Future Wells	$46,780,488	$3,838,167	$50,618,655
O&M	Replacement Pumps Existing Wells	$66,906,192	$1,327,005	$68,233,197
	Replacement Pumps Future Wells	$37,154,174	$699,862	$37,854,036
	Power	$7,119,346	$3,058,797	$10,178,143
Total NPV		**$196,677,498**	**$11,594,074**	**$208,271,571**

The total cost is approximately $208M (rounded) which consists of approximately $197M in residential costs and $11M in municipal costs.

Action Alternative 3

The total cost for all capital and operating costs for Action Alternative 3 in the EK study area are presented in Table 23.

Table 23 - Action Alternative 3 Cost (EK Study Area)

Costs	Items	Domestic	Municipal	Total
Capital Costs	New Wells	$25,697,815	$1,608,372	$27,306,187
	New Pumps for Future Wells	$31,001,706	$2,390,738	$33,392,444
O&M	Replacement Pumps Existing Wells	$66,906,192	$1,327,005	$68,233,197
	Replacement Pumps Future Wells	$37,154,174	$699,862	$37,854,036
	Power	$6,346,508	$2,744,863	$9,091,371
Total NPV		**$167,106,395**	**$8,770,840**	**$175,877,235**

The total cost is approximately $176M which consists of approximately $167M in residential costs and $9M in municipal costs.

Combined Study Area Cost Alternative Summary

The cost of the No Action Alternative in 2017 dollars is $429M for both study areas. The cost of Action Alternative No. 1 (10% renewables) is $389M which is a savings of $40M (9 percent) compared to the No Action Alternative. The cost of Action Alternative No. 2 (25% renewables) is $324M which is a savings of $105M (24 percent) compared to the No Action Alternative. Table 24 summarizes the total cost and savings between alternatives.

Table 24 – Total Alternative Cost Comparison Summary ($ x 1 million)

	No Action Alternative 1	Action Alternative 2 (10% Renewables)			Action Alternative 3 (25% renewables)		
Study Area	NPV Cost $	NPV Cost $	Cost Diff. (Alt 2 - Alt 1)	% Cost Diff.	NPV Cost $	Cost Diff. (Alt 3- Alt 1)	% Cost Diff.
Northwest	$200	$181	-19	-10%	$148	-$52	-26%
Elizabeth-Kiowa	$228	$208	-20	-9%	$176	-$53	-23%
Total $	**$429**	**$389**	**-40**	**-9%**	**$324**	**-$105**	**-24%**

The comparison provides stakeholders and public agencies the ability to further assess the comparative capital and OMR costs of maintaining the status quo, seeking renewable options, or evaluating other action alternatives by the County or other entities in the future.

Uncertainty

Our analysis is based on numerous assumptions of various sensitivity that affect the final costs and apparent conclusion. This includes uncertainty in:

- Future population growth and demand;

- Aquifer parameters;
- Aquifer Water level declines;
- The prototypical well analysis methodology and cost assumptions (ie. inflation and discount rates);
- The actual hydrology of the Denver Basin Aquifers;
- The effect of future pumping outside the county on water levels and storage;
- The accuracy of USGS Denver Basin Aquifer modeling; and
- Other regulatory and economic uncertainties.

Therefore, our results should only be used in a conceptual nature for general planning purposes.

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Appendix C

ELBERT COUNTY RURAL WATER SUPPLY STUDY
SPECIAL DISTRICT WATER SYSTEM INVENTORY

	WATER RIGHTS / DEMANDS				POPULATION		AREA
SPECIAL DISTRICT	Single Family Homes (anticipated)	Total Water Supply (AFY)*	Total Water Demand**	Demand Notes	Most Recent	Projected Total	Anticipated Service Area (Acres)
Britanie Ridge Metropolitan District	86	53.9					522.92
Clearwater Metropolitan District (serves with North Pines)					762	762	1034
Deer Creek Water District	284				682	682	723
Diamond Ridge Metropolitan District	27				79	79	51.2
Diamond Ridge Water & Sanitation District		14.85					0.75
Elbert and Highway 86 Commercial Metropolitan District		418					1,131
Elbert and Highway 86 Metropolitan District					646	646	1,068
Elkhorn Ranch Metropolitan District No. 1	245				750	750	1,555
Gold Creek Commons Metropolitan District							
Miller Ranch Metropolitan District	193				463	463	970
Miller Ranch Water & Sanitation District		156.2					970
North Pines Metropolitan District (Serves with Clearwater)							459
Ritoro Metropolitan District	340				1190	1190	113
Spring Valley Metropolitan District Nos. 1, 2, 3, 4	1186				3375	3375	1,811
Sterling Crossing Commercial Metropolitan District					400	400	25.95
Sterling Crossing Residential Metropolitan District	113				329	329	167.67
Summit Park Metropolitan District					336	336	47.94
United Water & Sanitation District	0						1

*The total volume of water in acre-feet the district owns through water rights, leases, exchanges, or otherwise has availabe for use in its own water system.

**The total volume of water demand of the districts customers on an annual basis in acre-feet

***Does the district reuse in any capacity its effluent water from water treatment facilitites?

ELBERT COUNTY RURAL WATER SUPPLY STUDY
SPECIAL DISTRICT WATER SYSTEM INVENTORY

	WATER SYSTEM													
	WATER SUPPLY WELLS / OTHER SOURCES				WATER STORAGE		PUMP SYSTEMS		TRANSMISSION / DISTRIBUTION		Sewer		Reuse***	
SPECIAL DISTRICT	No. Wells	Well Permit Number and decree if available	Surface water rights? (yes/no)	Description of surface water rights (priorities, decrees, etc.)	Volume (MG)	Description of tanks or any storage rights	Pumping System	Description	Length (LF)	Description (transmission 8" or greater)	Has treatment facility?	Description	Yes or no?	Description
Britanie Ridge Metropolitan District	2				0.13	Storage Tank	Yes		20,090	8" PVC		no mention of one		
Clearwater Metropolitan District (serves with North Pines)	3	1 Arapahoe Aquifer + 2 in 2001			0.48	Potable Storage Tank (1997) + 2001 Improvements	Yes	Booster Pump Station (3)	36,900	4 and 6 inch waterline and appurtenances (18200) + 18700 in 2001 improvements	Yes	Eagleview Ranch/Clearwater Improvements (2001)		
Deer Creek Water District	17	1 Denver; 16 Dawson			0.293	3 tanks 275K, 10K, 8K gallons	Yes	(3) 10HP, (10) 5 HP	60,141	8", 6", 4", and 2"	Yes	Only minor chlorination added		
Diamond Ridge Metropolitan District														
Diamond Ridge Water & Sanitation District		Yes, volumes not specified				Yes, volumes not specified	Yes	vague details	10,049	8" WW PVC; 12", 8", and 6" water lines	Yes			
Elbert and Highway 86 Commercial Metropolitan District	2	Denver well, arapahoe well				Yes (2) volumes not specified	Yes	vague details	12,725	8" sewer main (12375') + 8" PVC from wells to tanks	Yes	vague details - "purification"		
Elbert and Highway 86 Metropolitan District									49,500					
Elkhorn Ranch Metropolitan District No. 1		none mentioned				Yes (1), no details though	Yes	No details						
Gold Creek Commons Metropolitan District														
Miller Ranch Metropolitan District														
Miller Ranch Water & Sanitation District	1	no details			0.235				45,540	8" (40090 ft) and 12" (5450 ft)				
North Pines Metropolitan District (Serves with Clearwater)														
Ritoro Metropolitan District		no information				no information		no information		no information		no information		
Spring Valley Metropolitan District Nos. 1, 2, 3, 4		no information				no information		no information		no information		no information		
Sterling Crossing Commercial Metropolitan District										Has transmission, details limited		Has sewer, details limited		
Sterling Crossing Residential Metropolitan District														
Summit Park Metropolitan District	1	950 feet			0.23		yes		2,384			not mentioned		
United Water & Sanitation District														

*The total volume of water in acre-feet the district owns through water rights, leases, exchanges, or otherwise has availabe for use in its own water system.
**The total volume of water demand of the districts customers on an annual basis in acre-feet
***Does the district reuse in any capacity its effluent water from water treatment facilitites?

ELBERT COUNTY RURAL WATER SUPPLY STUDY
SPECIAL DISTRICT WATER SYSTEM INVENTORY

	WATER SYSTEM													
	WATER SUPPLY WELLS / OTHER SOURCES				WATER STORAGE		PUMP SYSTEMS		TRANSMISSION / DISTRIBUTION		Sewer		Reuse***	
SPECIAL DISTRICT	No. Wells	Well Permit Number and decree if available	Surface water rights? (yes/no)	Description of surface water rights (priorities, decrees, etc.)	Volume (MG)	Description of tanks or any storage rights	Pumping System	Description	Length (LF)	Description (transmission 8" or greater)	Has treatment facility?	Description	Yes or no?	Description
Britanie Ridge Metropolitan District	2				0.13	Storage Tank	Yes		20,090	8" PVC		no mention of one		
Clearwater Metropolitan District (serves with North Pines)	3	1 Arapahoe Aquifer + 2 in 2001			0.48	Potable Storage Tank (1997) + 2001 Improvements	Yes	Booster Pump Station (3)	36,900	4 and 6 inch waterline and appurtenances (18200) + 18700 in 2001 improvements	Yes	Eagleview Ranch/Clearwater Improvements (2001)		
Deer Creek Water District	17	1 Denver; 16 Dawson			0.293	3 tanks 275K, 10K, 8K gallons	Yes	(3) 10HP, (10) 5 HP	60,141	8", 6", 4", and 2"	Yes	Only minor chlorination added		
Diamond Ridge Metropolitan District														
Diamond Ridge Water & Sanitation District		Yes, volumes not specified				Yes, volumes not specified	Yes	vague details	10,049	8" WW PVC; 12", 8", and 6" water lines	Yes			
Elbert and Highway 86 Commercial Metropolitan District	2	Denver well, arapahoe well				Yes (2) volumes not specified	Yes	vague details	12,725	8" sewer main (12375') + 8" PVC from wells to tanks	Yes	vague details - "purification"		
Elbert and Highway 86 Metropolitan District									49,500					
Elkhorn Ranch Metropolitan District No. 1		none mentioned				Yes (1), no details though	Yes	No details						
Gold Creek Commons Metropolitan District														
Miller Ranch Metropolitan District														
Miller Ranch Water & Sanitation District	1	no details			0.235				45,540	8" (40090 ft) and 12" (5450 ft)				
North Pines Metropolitan District (Serves with Clearwater)														
Ritoro Metropolitan District		no information				no information		no information		no information		no information		
Spring Valley Metropolitan District Nos. 1, 2, 3, 4		no information				no information		no information		no information		no information		
Sterling Crossing Commercial Metropolitan District										Has transmission, details limited		Has sewer, details limited		
Sterling Crossing Residential Metropolitan District														
Summit Park Metropolitan District	1	950 feet			0.23		yes		2,384			not mentioned		
United Water & Sanitation District														

*The total volume of water in acre-feet the district owns through water rights, leases, exchanges, or otherwise has availabe for use in its own water system.
**The total volume of water demand of the districts customers on an annual basis in acre-feet
***Does the district reuse in any capacity its effluent water from water treatment facilitites?

Appendix D

Elbert County Rural Water Study
Engineer's Opinion of Probable Construction Costs
Case 2 (Project Alternatives Including 10% Imported Water) - Year 2050

Agricultural Water Rights Transfer

Item / Description	Unit	Quantity	Unit Cost	Total Cost
Water Rights Acquisition	AF	373	$7,000	$2,611,000
Sub-Total Capital Costs				**$2,611,000**
Purchase Contingency			25%	$653,000
Engineering/Professional Services			20%	$522,000
Legal Services (Water Court)			50%	$1,306,000
Total Costs				**$5,092,000**

Indirect Potable Reuse Systems

Item / Description	Unit	Quantity	Unit Cost	Total Cost
Northwest Study Area				
Reuse Pump Station 1 (NW Area)	LS	1	$296,000	$296,000
Reuse Pipe - NW Area - 6" PVC C900 (Material)	LF	43,402	$15	$651,000
Reuse Pipe - NW Area - 6" PVC C900 (Labor)	LF	43,402	$40	$1,736,000
Reuse WTP 1 - NW Area (0.57 MGD Combined)	LS	1	$7,423,000	$7,423,000
Elizabeth-Kiowa Study Area				
Reuse Pump Station 2 (Elizabeth)	LS	1	$241,000	$241,000
Reuse Pipe - Elizabeth - 8" PVC C900 (Material)	LF	9,504	$20	$190,000
Reuse Pipe - Elizabeth - 8" PVC C900 (Labor)	LF	9,504	$45	$428,000
Reuse WTP 2 - Elizabeth (0.85 MGD Combined)	LS	1	$10,176,000	$10,176,000
Sub-Total Capital Costs				**$20,845,000**
Construction Contingency			30%	$6,254,000
Design/Professional Services			20%	$4,169,000
Total Costs				**$31,268,000**

Renewable Water Import (Q = 0.7 MGD)

Item / Description	Unit	Quantity	Unit Cost	Total Cost
Senior Water Rights Purchase	AF	780	$15,000	$11,700,000
Reservoir Inlet Structure	LS	1	$50,000	$50,000
Corridor 1 - Northwest Study Area				
Raw Water Pump Station 1 (0.7 MGD)	LS	1	$727,000	$727,000
Pipe 1A - 10" PVC C900 (Material)	LF	62,832	$32	$1,994,000
Pipe 1A - 10" PVC C900 (Labor)	LF	62,832	$45	$2,827,000
Pipe 1B - 6" PVC C900 (Material)	LF	8,606	$15	$129,000
Pipe 1B - 6" PVC C900 (Labor)	LF	8,606	$40	$344,000
Reservoir 1 - 2MG	LS	1	$1,189,000	$1,189,000
Corridor 2 - Elizabeth-Kiowa Study Area				
Pipe 2 - 6" PVC C900 (Material)	LF	26,241	$15	$394,000
Pipe 2 - 6" PVC C900 (Labor)	LF	26,241	$40	$1,050,000
Raw Water Pump Station 2 (0.42 MGD)	LS	1	$314,300	$314,000
Reservoir 2 - 3MG	LS	1	$1,497,500	$1,498,000
Sub-Total Capital Costs				**$22,216,000**
Construction Contingency			30%	$6,665,000
Design/Professional Services			20%	$4,443,000
Total Costs				**$33,324,000**

Elbert County Rural Water Study
Engineer's Opinion of Probable Construction Costs
Case 3 (Project Alternatives Including 25% Imported Water) - Year 2050

Agricultural Water Rights Transfer

Item / Description	Unit	Quantity	Unit Cost	Total Cost
Water Rights Acquisition	AF	373	$7,000	$2,611,000
Sub-Total Capital Costs				**$2,611,000**
Purchase Contingency			25%	$653,000
Engineering/Professional Services			20%	$522,000
Legal Services (Water Court)			50%	$1,306,000
Total Costs				**$5,092,000**

Indirect Potable Reuse Systems

Item / Description	Unit	Quantity	Unit Cost	Total Cost
Northwest Study Area				
Reuse Pump Station 1 (NW Area)	LS	1	$296,000	$296,000
Reuse Pipe - NW Area - 6" PVC C900 (Material)	LF	43,402	$15	$651,000
Reuse Pipe - NW Area - 6" PVC C900 (Labor)	LF	43,402	$40	$1,736,000
Reuse WTP 1 - NW Area (0.99 MGD Combined)	LS	1	$10,176,000	$10,176,000
Elizabeth-Kiowa Study Area				
Reuse Pump Station 2 (Elizabeth)	LS	1	$241,000	$241,000
Reuse Pipe - Elizabeth - 8" PVC C900 (Material)	LF	9,504	$20	$190,000
Reuse Pipe - Elizabeth - 8" PVC C900 (Labor)	LF	9,504	$45	$428,000
Reuse WTP 2 - Elizabeth (1.48 MGD Combined)	LS	1	$15,402,000	$15,402,000
Sub-Total Capital Costs				**$28,824,000**
Construction Contingency			30%	$8,647,000
Design/Professional Services			20%	$5,765,000
Total Costs				**$43,236,000**

Renewable Water Import (Q = 1.76 MGD)

Item / Description	Unit	Quantity	Unit Cost	Total Cost
Senior Water Rights Purchase	AF	1950	$15,000	$29,250,000
Reservoir Inlet Structure	LS	1	$50,000	$50,000
Corridor 1 - Northwest Study Area				
Raw Water Pump Station 1 (1.76 MGD)	LS	1	$1,732,000	$1,732,000
Pipe 1A - 10" PVC C900 (Material)	LF	62,832	$32	$1,994,000
Pipe 1A - 10" PVC C900 (Labor)	LF	62,832	$45	$2,827,000
Pipe 1B - 8" PVC C900 (Material)	LF	8,606	$20	$172,000
Pipe 1B - 8" PVC C900 (Labor)	LF	8,606	$45	$387,000
Reservoir 1 (2 MG)	LS	1	$891,500	$892,000
Corridor 2 - Elizabeth-Kiowa Study Area				
Pipe 2 - 8" PVC C900 (Material)	LF	26,241	$20	$525,000
Pipe 2 - 8" PVC C900 (Labor)	LF	26,241	$45	$1,181,000
Raw Water Pump Station 2	LS	1	$419,500	$420,000
Reservoir 2 (4.5 MG)	LS	1	$1,755,300	$1,755,000
Sub-Total Capital Costs				**$41,185,000**
Construction Contingency			30%	$12,356,000
Design/Professional Services			20%	$8,237,000
Total Costs				**$61,778,000**

Facility Capital Estimates

Case 2 (Project Alternatives Including 10% Imported Water) - Year 2050

Reuse Water Treatment Plants

Reuse WTP 1 - NW Area (0.57 MGD Combined)

Item / Description	Unit	Quantity	Unit Cost	Total Cost
Land / Easements / Access	AC	0.5	$50,000	$25,000
Building (60'x75')	SF	4,500	$300	$1,350,000
Clarification Equip. (Coagulation/Chem Feed/Mixing)	LS	1	$150,000	$150,000
Settling Tanks / Flocculation	LS	1	$200,000	$200,000
Membrane (UF) Filtration Equipment	LS	1	$500,000	$500,000
Disinfection Equipment - AOP (UV+peroxide)	LS	1	$300,000	$300,000
OSHG Equipment	LS	1	$150,000	$150,000
Equipment Installation	LS	1	40%	$520,000
Process Piping Work	LS	1	$800,000	$800,000
Electrical	LS	1	20%	$794,000
Sub-Total				**$4,789,000**
Construction Contingency			30%	$1,437,000
Engineering Services			20%	$958,000
Legal / Regulatory Services			5%	$239,000
Total Cost				**$7,423,000**

Reuse WTP 2 - Elizabeth (0.85 MGD Combined)

Item / Description	Unit	Quantity	Unit Cost	Total Cost
Land / Easements / Access	AC	0.5	$50,000	$25,000
Building (60'x100')	SF	6,000	$300	$1,800,000
Clarification Equip. (Coagulation/Chem Feed/Mixing)	LS	1	$200,000	$200,000
Settling Tanks / Flocculation	LS	1	$250,000	$250,000
Membrane (UF) Filtration Equipment	LS	1	$700,000	$700,000
Disinfection Equipment - AOP (UV+peroxide)	LS	1	$450,000	$450,000
OSHG Equipment	LS	1	$150,000	$150,000
Equipment Installation	LS	1	40%	$700,000
Process Piping Work	LS	1	$1,200,000	$1,200,000
Electrical	LS	1	20%	$1,090,000
Sub-Total				**$6,565,000**
Construction Contingency			30%	$1,970,000
Engineering Services			20%	$1,313,000
Legal / Regulatory Services			5%	$328,000
Total Cost				**$10,176,000**

Facility Capital Estimates

Case 3 (Project Alternatives Including 25% Imported Water) - Year 2050

Reuse Water Treatment Plants

Reuse WTP 1 - NW Area (0.99 MGD Combined)

Item / Description	Unit	Quantity	Unit Cost	Total Cost
Land / Easements / Access	AC	0.5	$50,000	$25,000
Building (60'x100')	SF	6,000	$300	$1,800,000
Clarification Equip. (Coagulation/Chem Feed/Mixing)	LS	1	$200,000	$200,000
Settling Tanks / Flocculation	LS	1	$250,000	$250,000
Membrane (UF) Filtration Equipment	LS	1	$700,000	$700,000
Disinfection Equipment - AOP (UV+peroxide)	LS	1	$450,000	$450,000
OSHG Equipment	LS	1	$150,000	$150,000
Equipment Installation	LS	1	40%	$700,000
Process Piping Work	LS	1	$1,200,000	$1,200,000
Electrical	LS	1	20%	$1,090,000
Sub-Total				**$6,565,000**
Construction Contingency			30%	$1,970,000
Engineering Services			20%	$1,313,000
Legal / Regulatory Services			5%	$328,000
Total Cost				**$10,176,000**

Reuse WTP 2 - Elizabeth (1.48 MGD Combined)

Item / Description	Unit	Quantity	Unit Cost	Total Cost
Land / Easements / Access	AC	0.5	$50,000	$25,000
Building (60'x175')	SF	10,500	$300	$3,150,000
Clarification Equip. (Coagulation/Chem Feed/Mixing)	LS	1	$400,000	$400,000
Settling Tanks / Flocculation	LS	1	$400,000	$400,000
Membrane (UF) Filtration Equipment	LS	1	$1,200,000	$1,200,000
Disinfection Equipment - AOP (UV+peroxide)	LS	1	$500,000	$500,000
OSHG Equipment	LS	1	$150,000	$150,000
Equipment Installation	LS	1	40%	$1,060,000
Process Piping Work	LS	1	$1,400,000	$1,400,000
Electrical	LS	1	20%	$1,652,000
Sub-Total				**$9,937,000**
Construction Contingency			30%	$2,981,000
Engineering Services			20%	$1,987,000
Legal / Regulatory Services			5%	$497,000
Total Cost				**$15,402,000**

Facility Capital Estimates (cont.)

Case 2 (Project Alternatives Including 10% Imported Water) - Year 2050

Pump Stations

Reuse Pump Station 1 (NW Area)

Item / Description	Unit	Quantity	Unit Cost	Total Cost
Land / Easements / Access	AC	0.25	$50,000	$12,500
Structural	LS	1	$50,000	$50,000
Pumps	HP	40	$2,000	$80,000
Equipment Installation	LS	1	$12,000	$12,000
Piping Work	LS	1	$12,000	$12,000
Electrical	LS	1	20%	$30,800
Sub-Total				**$197,300**
Construction Contingency			30%	$59,000
Engineering Services			15%	$30,000
Legal Services / Land Agent			5%	$10,000
Total Cost				**$296,300**

Reuse Pump Station 2 (Elizabeth)

Item / Description	Unit	Quantity	Unit Cost	Total Cost
Land / Easements / Access	AC	0.25	$50,000	$12,500
Structural	LS	1	$50,000	$50,000
Pumps	HP	25	$2,000	$50,000
Equipment Installation	LS	1	$12,000	$12,000
Piping Work	LS	1	$12,000	$12,000
Electrical	LS	1	20%	$24,800
Sub-Total				**$161,300**
Construction Contingency			30%	$48,000
Engineering Services			15%	$24,000
Legal Services / Land Agent			5%	$8,000
Total Cost				**$241,300**

Facility Capital Estimates (cont.)

Case 3 (Project Alternatives Including 25% Imported Water) - Year 2050

Pump Stations

Reuse Pump Station 1 (NW Area)

Item / Description	Unit	Quantity	Unit Cost	Total Cost
Land / Easements / Access	AC	0.25	$50,000	$12,500
Structural	LS	1	$50,000	$50,000
Pumps	HP	40	$2,000	$80,000
Equipment Installation	LS	1	$12,000	$12,000
Piping Work	LS	1	$12,000	$12,000
Electrical	LS	1	20%	$30,800
Sub-Total				**$197,300**
Construction Contingency			30%	$59,000
Engineering Services			15%	$30,000
Legal Services / Land Agent			5%	$10,000
Total Cost				**$296,300**

Reuse Pump Station 2 (Elizabeth)

Item / Description	Unit	Quantity	Unit Cost	Total Cost
Land / Easements / Access	AC	0.25	$50,000	$12,500
Structural	LS	1	$50,000	$50,000
Pumps	HP	25	$2,000	$50,000
Equipment Installation	LS	1	$12,000	$12,000
Piping Work	LS	1	$12,000	$12,000
Electrical	LS	1	20%	$24,800
Sub-Total				**$161,300**
Construction Contingency			30%	$48,000
Engineering Services			15%	$24,000
Legal Services / Land Agent			5%	$8,000
Total Cost				**$241,300**

Facility Capital Estimates (cont.)

Case 2 (Project Alternatives Including 10% Imported Water) - Year 2050

Raw Water Pump Station 1

Item / Description	Unit	Quantity	Unit Cost	Total Cost
Land / Easements / Access	AC	0.5	$50,000	$25,000
Structural	LS	1	$150,000	$150,000
Pumps	HP	80	$2,000	$160,000
Equipment Installation	LS	1	$30,000	$30,000
Piping Work	LS	1	$30,000	$30,000
Electrical	LS	1	20%	$74,000
Sub-Total				**$469,000**
Construction Contingency			30%	$141,000
Engineering Services			15%	$70,000
Legal / Regulatory Services			10%	$47,000
Total Cost				**$727,000**

Raw Water Pump Station 2

Item / Description	Unit	Quantity	Unit Cost	Total Cost
Land / Easements / Access	AC	0.25	$50,000	$12,500
Structural	LS	1	$75,000	$75,000
Pumps	HP	30	$2,000	$60,000
Equipment Installation	LS	1	$12,000	$12,000
Piping Work	LS	1	$12,000	$12,000
Electrical	LS	1	20%	$31,800
Sub-Total				**$203,300**
Construction Contingency			30%	$61,000
Engineering Services			15%	$30,000
Legal / Regulatory Services			10%	$20,000
Total Cost				**$314,300**

Facility Capital Estimates (cont.)

Case 3 (Project Alternatives Including 25% Imported Water) - Year 2050

Raw Water Pump Station 1

Item / Description	Unit	Quantity	Unit Cost	Total Cost
Land / Easements / Access	AC	0.5	$50,000	$25,000
Structural	LS	1	$150,000	$150,000
Pumps	HP	280	$2,000	$560,000
Equipment Installation	LS	1	$100,000	$100,000
Piping Work	LS	1	$100,000	$100,000
Electrical	LS	1	20%	$182,000
Sub-Total				**$1,117,000**
Construction Contingency			30%	$335,000
Engineering Services			15%	$168,000
Legal / Regulatory Services			10%	$112,000
Total Cost				**$1,732,000**

Raw Water Pump Station 2

Item / Description	Unit	Quantity	Unit Cost	Total Cost
Land / Easements / Access	AC	0.25	$50,000	$12,500
Structural	LS	1	$75,000	$75,000
Pumps	HP	50	$2,000	$100,000
Equipment Installation	LS	1	$20,000	$20,000
Piping Work	LS	1	$20,000	$20,000
Electrical	LS	1	20%	$43,000
Sub-Total				**$270,500**
Construction Contingency			30%	$81,000
Engineering Services			15%	$41,000
Legal / Regulatory Services			10%	$27,000
Total Cost				**$419,500**

Facility Capital Estimates (cont.)

Case 2 (Project Alternatives Including 10% Imported Water) - Year 2050

Reservoirs

Reservoir 1 - 2MG

Item / Description	Unit	Quantity	Unit Cost	Total Cost
Land / Easements / Access	AC	1.0	$50,000	$50,000
Reservoir Construction (Grading and Liner)	GAL	2MG	$0.35	$700,000
Intake/Discharge Structures	LS	1	$50,000	$50,000
Piping Work	LS	1	$20,000	$20,000
Sub-Total				**$820,000**
Construction Contingency			30%	$246,000
Engineering Services			15%	$123,000
Total Cost				**$1,189,000**

Reservoir 2 - 3MG

Item / Description	Unit	Quantity	Unit Cost	Total Cost
Land / Easements / Access	AC	1.3	$50,000	$62,500
Reservoir Construction (Grading and Liner)	GAL	3MG	$0.30	$900,000
Intake/Discharge Structures	LS	1	$50,000	$50,000
Piping Work	LS	1	$20,000	$20,000
Sub-Total				**$1,032,500**
Construction Contingency			30%	$310,000
Engineering Services			15%	$155,000
Total Cost				**$1,497,500**

Facility Capital Estimates (cont.)

Case 3 (Project Alternatives Including 25% Imported Water) - Year 2050

Reservoirs

Reservoir 1 - 3MG

Item / Description	Unit	Quantity	Unit Cost	Total Cost
Land / Easements / Access	AC	1.3	$50,000	$62,500
Reservoir Construction (Grading and Liner)	GAL	3MG	$0.30	$900,000
Intake/Discharge Structures	LS	1	$50,000	$50,000
Piping Work	LS	1	$20,000	$20,000
Sub-Total				**$1,032,500**
Construction Contingency			30%	$310,000
Engineering Services			15%	$155,000
Total Cost				**$1,497,500**

Reservoir 2 - 4.5MG

Item / Description	Unit	Quantity	Unit Cost	Total Cost
Land / Easements / Access	AC	2.0	$50,000	$100,000
Reservoir Construction (Grading and Liner)	GAL	4.5MG	$0.25	$1,125,000
Intake/Discharge Structures	LS	1	$50,000	$50,000
Piping Work	LS	1	$20,000	$20,000
Sub-Total				**$1,295,000**
Construction Contingency			30%	$389,000
Engineering Services			15%	$194,000
Total Cost				**$1,878,000**