U.S. Department of the Interior - Bureau of Land Management (Colorado State Office) San Luis Valley Field Office - Reasonably Foreseeable Development (RFD) Scenario for Oil, Gas, and Geothermal Resources

RFD REPORT

Prepared for: U.S. Department of the Interior, Bureau of Land Management, Colorado State Office

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Table of Contents

1. Summary 1
2. Introduction 2
2.1 Information Sources 2
Geological Publications and Data 2
Oil & Gas Production Data and Reports 3
Geothermal Information and Data 3
Infrastructure 3
GIS Data 3
Guidance Documents 3
2.2 Physiogeographic Setting 4
2.3 Land Types within SLVFO RFD Study Area 4
2.4 Sedimentary Basins Actively Producing Oil & Gas in Proximity to SLVFO 4
2.4 Changes in U.S. Oil and Natural Gas Production and Drilling Practices 4
2.4 Determination of Oil & Gas Resource Potential 5
2.5 Relationship of Potential for Oil & Gas Resource Occurrence to Potential for Activity 5
2.6 Geothermal Energy Resources 5
2.7 Projected Geothermal Exploration and Development Activity 5
3. Description of Geology 6
3.1 Subsurface Stratigraphy and Structure 6
San Luis Basin 7
San Juan Sag Basin 8
3.2 Reservoirs, Traps, Source Rocks, Seals, and Hydrocarbon Generation and Migration 11
3.3 Summary of USGS or Other Play Descriptions 12
4. Past and Present Oil and Gas Exploration Activity 13
4.1 Geophysical Surveys 13
Gravity and Magnetic Surveys 13
Seismic Reflection Surveys 14
4.2 SLVFO Drilling Activity 17
Alamosa Horst 18
Rio Grande County: Del Norte Area 18
5. Past and Present Oil and Gas Development Activity 18

5.1 Well Spacing and Unit Spacing of Target Formations 19
5.2 Drilling and Completion Statistics by Basin 19
SLVFO 19
5.3 Hydraulic Fracturing and Water Needs 19
5.4 Reservoir Fluid Characteristics 19
Oil and Gas 19
Water Quality Characteristics 20
5.5 U.S. Oil and Gas Demand 20
5.6 Type Curves / Well Life of Target Formations 21
5.7 Oil and Gas Transmission Infrastructure 21
Refineries 21
Oil Transmission Lines 21
Gas Transmission Lines 21
5.8 Roads, Highways, and Railways 21
Roads 22
Highways 22
Railroads 22
5.9 Electrical Transmission Lines 22
Oil and Gas Electrical Needs 22
Geothermal Electrical Needs 23
6. Oil and Gas Occurrence Potential 23
6.1 RFDs Adjacent to SLVFO 23
6.2 Oil & Gas Production by Basin 23
Raton Basin 23
Denver Basin, CO 24
San Juan Basin, CO 24
San Juan Basin, NM 25
Paradox Basin, CO 25
Piceance Basin, CO 25
7. Oil and Gas Development Potential 26
7.1 Adjacent Area RFDs and Potential Border Conflicts 26
7.2 Development Potential Map 26
High Potential - Niobrara Formation Unconventional Play (San Juan Sag basin) 26

Medium Potential – Dakota and Other Sands Conventional Development Play (San Juan Sag basin) 27
Low Potential – Baca Graben Conventional Development Play (San Luis basin) 27
Very Low Potential – Alamosa Formation Biogenic Gas Development Play (San Luis basin) 28
8. RFD Baseline Scenario Assumptions and Discussion 28
8.1 Surface Disturbance Due to Oil and Gas Activity on All Lands 28
8.2 Well Pad Size Estimates 28
8.3 Access Road Size Estimates 29
8.4 Facility Piping Footprint Estimates 29
8.5 New Electrical Line Impact 29
8.6 New Oil & Gas Pipelines 29
8.7 Realistic Estimate of Wells and Land Impacts for 20 Years 30
SLVFO Drilling History and Average Wells Drilled Per Year 30
Well Density and Seismic Data 30
Oil & Gas Well Type and Well Pad Size 30
High Oil & Gas Potential Area 31
Medium Oil & Gas Potential Area 31
Low and Very Low Oil & Gas Potential Areas 31
9. Geothermal Energy Potential 32
9.1 Geothermal and Potential Electricity Production 32
Electricity Consumption Projections 33
Power Production from Geothermal Energy 33
Limits to Drilling 34
Low Temperature Geothermal Heat 34
Enhanced Geothermal Systems and Closed Loop Geothermal Systems 34
9.2 Thermal Springs, Geothermal Water, and Uses 34
Thermal Springs 34
Geothermal Water from Wells 35
9.3 Thermal Gradient, Heat Flow, and Depth to Temperature Maps 35
Geothermal Gradient 35
Temperature and Depth 35
9.4 Geothermal Supply Curve Estimates 36
9.5 Economic, Permitting, and Other Incentives 36

9.6 Geothermal Reasonable Foreseeable Development Scenario and Land Impacts..... 37
Geothermal Energy Potential 37
Development and Land Impact 37
References 37

List of Tables

Table 1, Land Types within SLVFO Area

Table 2, Well Spacing in Selected Formations in Neighboring Basins

Table 3, Hydraulic Fracturing Treatment Average Water Volume for Selected Formations in Neighboring Basins

Table 4, API Oil Gravity of Selected Formations in Neighboring Basins

Table 5, Produced Water TDS of Selected Formations in Neighboring Basins. USGS Produced Water Database (2021)

Table 6, Niobrara Formation Well, Denver Basin Hyperbolic Decline Characteristics

Table 7, Refinery Distance to SLVFO Centroid

Table 8, Raton Basin, CO Production Summary 2005 - 2024

Table 9, Denver Basin, CO Production, 2005 - 2024

Table 10, San Juan Basin, CO Production Summary 2005 - 2024

Table 11, Paradox Basin, CO Production Summary 2005 – 2024

Table 12, Piceance Basin, CO Production Summary 2005 – 2024

Table 13, Well Pad Size Estimates

Table 14, Estimated Number of Wells and Land Disturbance Impacts: High and Medium Oil and Gas Potential Areas

Table 15, Geothermal Energy Development Potential and Land Impacts

List of Figures

Figure 1, SLVFO Area

Figure 2, Land Types within SLVFO Area

Figure 3, Sedimentary Basins Producing Oil & Gas in Proximity to SLVFO Area

Figure 4, U.S. Dry Natural Gas and Oil Production vs. Time

Figure 5, San Luis Valley and San Juan Sag Basins Map as Defined by MS-33 (2002)

Figure 6, San Luis Valley and San Juan Sag Basins: Source Rock Outcroppings Map

Figure 7, Oil & Gas Source Rock and Reservoir Rock Outcroppings and Volcanic Calderas

Figure 8, Map of San Luis Basin and San Juan Sag with Structural Axes

Figure 9, San Luis Valley Stratigraphic Column

Figure 10, Isochore Map, Top Mancos Formation to Dakota Sandstone

Figure 11, Structure Contour Map, Top Mancos Formation

Figure 12, Isochore Map, Niobrara Formation

Figure 13, Depth to Niobrara Formation Map

Figure 14, Gravimetric Map of the SLVFO Area with Bouguer Anomalies and Oil & Gas Wells

Figure 15, 2D and 3D Seismic Survey Locations in SLVFO Area

Figure 16, Alamosa Horst Seismic Survey Locations

Figure 17, Synthetic Seismogram from Tennessee Gas Transmission 1 State B Well

Figure 18, Composed Seismic Lines 1A, 2A, 3A, 4A, 5A from Stoughton (1977)

Figure 19, Detailed Seismic Survey Map near Del Norte

Figure 20, Seismic Section between the San Luis Valley and Del Norte High (Tandon et al. 1999)

Figure 21, Seismic Survey Map for Baca High Area

Figure 22, SLVFO Area Wells Drilled & WTI Crude Oil Price vs. Time

Figure 23, U.S. Energy Consumption by Fuel Type 2025 to 2050. Adapted from the EIA (EIA, 2026)

Figure 24, Niobrara Formation Well, Denver Basin Hyperbolic Decline

Figure 25, Oil & Gas Transmission Infrastructure Map

Figure 26, Roads, Highways, and Railways Infrastructure Map

Figure 27, Electrical Transmission Infrastructure Map

Figure 28, Oil and Gas Development Potential Map within SLVFO & Slope

Figure 29, U.S. Total Electricity Consumption and Commercial Data Center Server Electricity Consumption, 2025 to 2050 (EIA, 2026).

Figure 30, Geothermal Power Plant Types (Morgan, 2024)

Figure 31, Geothermal Gradient Map of the SLVFO Study Area

Figure 32, Depth to 212 °F Map of the SLVFO Study Area

Figure 33, Depth to 302 °F and Geothermal Energy Potential at 5 km Depth

Figure 34, Geothermal Energy Potential of the SLVFO Study Area

List of Plates

Plate 1, Simplified E-W Geologic Cross-Section Through SLVFO Study Area

Plate 2, Regional Stratigraphic Cross-Section

Plate 3, Type Log for San Juan Sag Basin

Plate 4, Detailed Type Log Over the Niobrara Formation

List of Appendices

Appendix 1, Locations and Names of Seismic Surveys

Appendix 2, List of Wells Drilled within SLVFO

Appendix 3, ECMC Production Reports Revised to Sedimentary Basins Adjacent to SLVFO

Appendix 4, Geothermal Wells and Springs within SLVFO

List of Acronyms and Agency Names

BLM - Bureau of Land Management

BBL – Barrel

BCF – Billion Cubic Feet

BLS – Bureau of Labor Statistics

BTU – British Thermal Unit

CGS - Colorado Geological Survey

DOE – U.S. Department of Energy

ECMC - Energy & Carbon Management Commission

EIA – U.S. Energy Information Administration

FGDC - Federal Geographic Data Committee

GIS - Geographic Information System

MCF – Thousand Cubic Feet

MD – Measured Depth

NLR – National Laboratory of the Rockies

NREL – National Renewable Energy Laboratory of the Rockies

NMOCD – New Mexico Oil Conservation Division

QA/QC - Quality Assurance / Quality Control

RFD - Reasonably Foreseeable Development

SLVFO - San Luis Valley Field Office

TCF – Trillion Cubic Feet

TVD – True Vertical Depth

USGS – United States Geological Survey

Key Personnel Executive Summary

Jimmy Schloss, PE**,** PG / Program Manager; Lead Subsurface Technical Expert

Role on Contract: Program Manager; Contract Manager; Lead Subsurface Technical Expert

Jimmy served as the Program Manager and designated Contract Manager, held full authority for day-to-day performance, technical direction within scope, and coordination with the COR and Contracting Officer. He was responsible for developing and maintaining the Project Management Plan, including the detailed critical path schedule, work breakdown structure, staffing plan, risk management plan, quality control plan, data management plan, and project record plan required under the PWS.

Acting as Lead Subsurface Technical Expert, Jimmy oversaw all petroleum engineering and subsurface components of the 20-year RFD scenario, including development of assumptions for vertical and horizontal drilling, production profiles, and surface disturbance and reclamation projections. He ensured the RFD was scientifically and technically defensible, supported the RMP/NEPA process, and was fully compliant with quality standards, peer review expectations, and Section 508 requirements for the final Word and PDF deliverables.

Richard Rodríguez, Senior Geophysicist / Technical Oil & Gas Specialist

Role on Contract: Senior Geophysicist / Technical Oil & Gas Specialist

Richard served as the Senior Geophysicist responsible for geophysical interpretation across the planning area. He analyzed seismic and related geophysical datasets to define subsurface structure, trap configurations, and reservoir distribution that underpin the RFD's oil and gas occurrence and development potential mapping.

His work supported key RFD content including the description of subsurface stratigraphy and structure, play and reservoir summaries, and quantitative characterization of areas with high, medium, low, very low, or no known potential. By integrating geophysical, geological, and historical activity data, Richard provided the technical basis for spatial and volumetric estimates used in future activity forecasts and surface disturbance calculations, ensuring the RFD reflects realistic, data-supported scenarios.

Brian Hirst, PG, Petroleum Geologist / Technical Oil & Gas Specialist / Advisor

Role on Contract: Petroleum Geologist / Technical Oil & Gas Specialist

Brian served as the Petroleum Geologist responsible for assembling the geologic and historical exploration and development record for the SLVFO. He evaluated stratigraphy, reservoir characteristics, hydrocarbon systems, and drilling and production history using federal, state, and industry sources consistent with the PWS guidance on information inputs to the RFD. Brian also served as a project advisor who offered key advice and guidance on numerous aspects of the study.

Brian's work supported sections on past and present exploration and development activity, including drilling density and success rates, spacing practices, production trends, and field-level behavior. These analyses help define type curves and life-cycle expectations for wells, inform projections of future drilling and production, and provide the geologic and historical foundation for the baseline RFD scenario and its supporting documentation in the project record.

Ignacio Gatti, Ph.D. GIS Analyst & Data Management Lead

Role on Contract: GIS Analyst & Data Management Lead

Ignacio served as the GIS Analyst and Data Management Lead, responsible for all geospatial products and data standards compliance. He integrated BLM-provided GIS data (e.g., boundaries, federal mineral estate, leases) with contractor-supplied geospatial datasets to produce the required maps and GIS shapefiles of oil and gas potential areas that accompany the final RFD report.

He managed geospatial data in accordance with the PWS data management requirements, including use of acceptable GIS formats, adherence to BLM naming conventions, and creation of FGDC-compliant metadata compatible with ArcGIS. Ignacio supported the Project Record by organizing and cataloging GIS layers, maps, and associated documentation in an electronic, searchable structure, ensuring that spatial data are auditable, traceable, and suitable for long-term use in subsequent NEPA analyses.

Antonella Galetto, Ph.D. Independent Peer Reviewer (Petroleum Technical Expert)

Role on Contract: Independent Peer Reviewer (Petroleum Technical Expert)

Antonella served as the independent scientific and technical peer reviewer, satisfying the PWS requirement that the RFD be reviewed by a qualified geologist or petroleum engineer with experience forecasting reserves, resources, and exploration/production activity, who is not involved in its original preparation.

She evaluated the draft and updated RFD reports for completeness, technical accuracy, and reasonableness of assumptions and projections, including well forecasts, production profiles, surface disturbance and reclamation estimates, and integration of geology, geophysics, and engineering. Antonella documented her review in a Peer Review Memorandum, including comments, recommendations, and resolution tracking, which is incorporated into the Project Record. Her independent review was a critical quality gate prior to finalization and 508-compliant publication of the RFD.

1. Summary

This Reasonable Foreseeable Development (RFD) report has been prepared for the San Luis Valley Field Office (SLVFO) to aid and support land use planning in light of probable future oil, gas, and geothermal activity. It summarizes the geologic setting, major plays, historical and current oil, gas and geothermal activity and resource potential of the SLVFO study area. The SLVFO study area is defined by the drainage basin of the Rio Grande River within Colorado and covers approximately 4,832,891 acres (Figure 1). This document is intended to support regulatory land-use planning and potential disturbances related to development within the RFD Area.

With respect to oil and gas production, the SLVFO has never had a commercial oil and gas discovery, although the Colorado Energy and Carbon Management Commission (ECMC) has designated one noneconomic well an oil and gas field (Del Norte Field) near the town of Del Norte. As such, there is no existing potential for increased activity as a result of development of existing proved reserves. Any RFD activity for oil and gas must be based first on exploration and then on the probability of a successful effort that leads to development drilling activities. This study has identified four plays within the SLVFO administrative area with the potential for oil and gas exploration and development activities. By far, the San Juan Sag basin (west half of SLV) holds the greatest promise for such activity. This basin has the necessary source and reservoir rocks of the Late Cretaceous age (Mancos Formation) and these are buried at appropriate depths to generate oil (Gries et al., 1997). In addition, a 300 ft thick Niobrara Formation is present and buried at depths corresponding to that oil generating window over approximately 465 square miles. The Niobrara is a significant unconventional reservoir (i.e. Wattenberg Field, Denver-Julesburg Oil Field) and if the rock properties in the San Juan Sag basin are within the appropriate range for development, this basin could contain hundreds of millions of barrels of economically recoverable oil and associated gas. This fact alone makes it highly probable that an independent or major oil company will inevitably drill a test well (or wells) to evaluate this potential within the next 15 to 20 years. The potential for significant oil and gas development activity would then depend on the outcome of this testing well along with the prevailing regulatory demands, infrastructure needs, and oil and gas price forecasts. A successful test of the Niobrara Formation would also usher in the acquisition of one or more 3D seismic surveys. These seismic surveys would be large (± 100 square miles).

Successful tests of the Niobrara unconventional play and resulting large 3D seismic surveys could potentially then usher in conventional oil and gas prospecting in the San Juan Sag basin. There are roughly 1,293 square miles to explore for conventional structural oil and gas traps in the famous Dakota Sandstone as well as other Late Cretaceous reservoirs productive in nearby basins. The author's review of 2D and 3D seismic data in the San Juan Sag basin shows that data quality in the basin (outside of volcanic calderas) is potentially suitable for defining structure, guiding horizontal completions, rock physics mapping (porosity fairways) and gas detection. The San Juan Sag basin underwent compressional tectonism from the end of the Cretaceous to beginning of the Eocene and this structural fabric has been overprinted by tensional tectonism from the Oligocene to Present. Therefore, there is good reason to believe the basin has many structures capable of trapping oil and gas. The closest example of such a conventional oil and gas trap within this tectonic fabric is the Price Gramps Oil Field located 13 miles from the southern end of the SLVFO. This field has

estimated ultimate recovery of 7.2 million barrels of oil from the Dakota sandstone at a depth of 1,100 feet in a faulted anticlinal structure.

The eastern portion of the SLVFO includes the San Luis basin as defined by the ECMC. This basin includes two plays; oil and gas in the Baca graben and biogenic gas in the Tertiary non-marine Alamosa Formation. The Baca graben play assumes oil and gas source rocks are buried at the depths of this graben due to oil and gas shows encountered in two wells on the east side of the graben. However, no well has drilled the depths of graben nor found evidence of a thick section of Paleozoic and/or Cretaceous source rocks. The biogenic gas play in sands of the Alamosa Formation has good indications that biogenic gas is being generated, and the Alamosa Formation has suitable sand reservoirs. However, 24 wells have penetrated the Alamosa Formation and no well has run casing to attempt a completion for this gas. This is a shallow gas play so it would take a reservoir with a large vertical and lateral size to trap significant quantities of gas to be economic. In addition, this gas may be of poor quality, low BTU gas.

The classification of RFD potential for these plays is as follows:

Basin	Play	Development Potential
San Juan Sag	Niobrara, Unconventional	High
San Juan Sag	Conventional Reservoirs	Medium
San Luis	Baca Graben, Conventional Reservoirs	Low
San Luis	Alamosa Formation, Biogenic Gas, Conventional	Very Low

The SLVFO is seen to have relatively high geothermal gradients present. These geothermal gradients have historically led to the utilization of a very small and limited number of hot springs within the San Luis Valley area. The areas of the highest geothermal gradients and heat flux potentially offer geothermal energy development such as with the usage enhanced geothermal systems (EGS). Private companies and research institutions in the United States are now taking more interest in EGS and slowly starting to develop a few of these locations in the western United States.

2. Introduction

2.1 Information Sources

Geological Publications and Data

This RFD report relies exclusively on public data sources and publications. Geological reports, studies, and maps have been acquired from the United States Geological Survey (USGS), Colorado Geological Survey (CGS), and many professional papers and papers from petroleum geologists practicing in the oil & gas industry along with academic institutions. Well files, well reports, and well logs (as PDFs) were acquired from the Colorado Energy & Carbon Management Commission (ECMC) but digital well files in raster and vector formats were also acquired from the private data library MJ Logs and were used for our own geological interpretations, maps, and cross-section.

Oil & Gas Production Data and Reports

Oil and gas production data from the Colorado Energy & Carbon Management Commission (ECMC) was used exclusively in the evaluation of oil, gas, and water production in the sedimentary basins producing oil & gas nearest to the SLVFO area including the Raton Basin, San Juan Basin, Paradox Basin, and Denver Basin. Production data for the San Juan Basin in New Mexico was taken from San Juan Basin RFD reports made for the BLM Farmington, NM field office (Engler et al., 2014; Engler, 2025). Leasing and spacing rules were taken from the ECMC and the New Mexico Oil Conservation Division (NMOCD).

Long-term energy demand forecasts, historical crude oil prices, and other relevant information was referenced from the U.S. Energy Information Administration (EIA) and the U.S. Bureau of Labor Statistics (BLS) for the consumer price index.

Geothermal Information and Data

Geothermal energy and other geothermal data sources include numerous reports, studies, and tools from the CGS and National Renewable Energy Laboratory (NREL), now called the National Laboratory of the Rockies (NLR) under the U.S. Department of Energy (DOE).

Infrastructure

Infrastructure informational sources on highways & roads, railways, oil & gas infrastructure, and electrical infrastructure come from GIS data sources as described below.

GIS Data

GIS data sources are described below. The BLM GIS data server was used for numerous types of land classification and boundaries including county boundaries and the Public Land Survey System (PLSS).

Infrastructure aspects come from a wide variety of sources as follows. Roadway information included the Colorado Department of Transportation (CDOT), the BLM, and sources commonly used by ArcGIS, Esri including TomTom, Garmin, and Open Street Maps contributors. Railway information was used by the Energy Information Administration (EIA) and the Federal Railroad Administration (FRA). Oil & gas infrastructure such as well pad information, surface well locations, directional paths, and downhole well locations were used exclusively from the ECMC. Other oil & gas and energy infrastructure elements such as pipelines, refineries, and electrical transmission were from the EIA via ArcGIS online sources.

Guidance Documents

RFD-specific documents were as guidance documents in the preparation of this report. The BLM reference guidance document “Policy for Reasonably Foreseeable Development (RFD) for Oil and Gas (IM 2004-089) was used to serve as the structure and outline for this RFD report. RFDs published for sedimentary basins producing oil & gas nearest to the SLVFO area including the Raton Basin, San Juan Basin, Paradox Basin, and Denver Basin were also considered for the report content, structure, and other information.

2.2 Physiographic Setting

The San Luis Valley Field Office (SLVFO) is bounded by the Rio Grande River watershed from its origin in San Juan and Sangre de Cristo Mountains to the Colorado / New Mexico border and corresponds to the BLM's SLVFO administrative area (See Figure 1). The periphery of the SLVFO area is approximately bounded by (clockwise from the northwest corner of the Area): the Sangre de Cristo Range, including Great Sand Dunes National Park and Preserve; Culebra Range; the New Mexico state line; Archuleta Anticlinorium (arch) (border with San Juan Basin); the San Juan Sag. The RFD area includes Alamosa, Costilla, Conejos, Rio Grande, and Saguache counties in their entirety. Portions of Archuleta, Mineral, Hinsdale, and San Juan counties are also included in the SLVFO RFD study area.

2.3 Land Types within SLVFO RFD Study Area

There are numerous federal land types and private land within the SLVFO RFD study area and are shown in Figure 2. This RFD focuses on the federal lands in which the BLM has both subsurface and surface mineral development and leasing authority which corresponds to the designated BLM lands. It also focuses on the land types in which the BLM has subsurface mineral and oil & gas development and leasing authority which applies to the designated National Forest lands such as the Rio Grande National Forest, U.S. Fish & Wildlife lands, and national parks, where applicable.

A detailed breakdown of the specific acreage for each land type is presented in Table 1. Both Figure 2 and Table 1 include land designated as wilderness lands which are prohibited to any mineral and oil and gas leasing and development. Federal lands including BLM, US Forest Service, National Parks and US Fish & Wildlife cover 53.5% of the SLVFO area, followed by privately owned land at 42.6%, and state lands account for the remaining 3.8%. Practically speaking, the eastern San Juan Mountains in the entire western portion of the SLVFO is National Forest (Rio Grande National Forest) where BLM has subsurface mineral and oil and gas development and leasing authority whereas the eastern half of the SLVFO is privately owned land. The eastern portion also includes the Sangre de Cristo Mountains which also includes Wilderness.

2.4 Sedimentary Basins Actively Producing Oil & Gas in Proximity to SLVFO

Figure 3 illustrates these major sedimentary basins actively producing oil and natural gas in relation to the SLVFO. The San Juan Basin, Paradox Basin, and Denver Basin that surround the SLVFO have been actively producing oil & natural gas for over a century. The Raton Basin to the east has been producing natural gas for decades. These basins are referred to throughout this report and share some of the same geological formations or their stratigraphic equivalent as discussed in Section 3 to 7 in this report.

2.4 Changes in U.S. Oil and Natural Gas Production and Drilling Practices

Oil and natural gas production in the U.S. has undergone significant changes in terms of the total volume of production and reservoir types in the past 20 years. Both oil and natural gas production has increased significantly in the U.S. over the past 20 years and is due to a shift away from conventional reservoir types which exhibit higher permeability formations such as sandstones to expanded production in shale gas and what is referred to as "tight" oil production which are shales and other low permeability formations or unconventional reservoir types. For example, in 2008 shale gas only accounted for 16% of total U.S. gas production and tight oil accounted for 12% of

U.S. total crude oil production (EIA, 2019). By 2018, shale gas and tight plays (unconventional reservoirs) accounted for 70% of total U.S. dry gas production and 60% of total U.S. oil production (EIA, 2019). Figure 4 illustrates this expanded production and changes in sources from 2004 through 2019.

U.S. oil and natural gas production has increased from unconventional reservoir types due to changes in drilling methods and completions from vertical wells with standard perforations to horizontal wells and hydraulic fracturing treatments. According to the EIA, 94% of oil production and 92% of natural gas production in the lower 48 states came from horizontal wells (EIA, 2024).

2.4 Determination of Oil & Gas Resource Potential

This RFD does not assume commercial success for oil & gas production or geothermal energy development. Rather, it uses well documented evidence of the presence of oil & gas along with subsurface temperatures and heat flow data to estimate a realistic scenario of development activity that is expected to reasonably occur over the next 20 years given geological characteristics and conditions and technical constraints.

2.5 Relationship of Potential for Oil & Gas Resource Occurrence to Potential for Activity

Although localized hydrocarbon accumulations may exist, the low probability of discovery, combined with depth, structural complexity, limited infrastructure, water rights, etc. substantially constrains foreseeable exploration and development activity. As a result, potential activity is significantly lower than theoretical resource occurrence.

2.6 Geothermal Energy Resources

Geothermal resource potential of the SLVFO area is discussed in Section 9 and describes regions of existing and potential geothermal resources in the RFD area. The main existing geothermal resources are hydrothermal fluids in the form of hot springs. Potential geothermal resources are those that could provide direct energy such as enhanced geothermal systems.

Geothermal resource potential is assessed using:

- Measured geothermal gradients and heat-flow data
- Distribution of thermal springs and warm wells
- Structural controls on fluid circulation
- Depth–temperature relationships.

The focus is on technically accessible and sustainable geothermal resources. Section 9 also summarizes previous studies, and available data.

2.7 Projected Geothermal Exploration and Development Activity

Geothermal activity is expected to progress incrementally through surface studies, exploratory drilling, pilot projects, and limited expansion. Direct-use applications are the most foreseeable, while power generation is conditional and site-specific.

The scenario for future geothermal exploration and development activity is covered in Section 9 of this report. Economics and technology, access to an area of interest, and the availability of processing facilities and infrastructure also play a role in exploration and development. Some of these factors, such as economics and technology, are difficult to predict due to their complexity, interactive nature, and variability in time.

3. Description of Geology

3.1 Subsurface Stratigraphy and Structure

The BLM San Luis Valley Field Office (SLVFO) oversees the drainage basin of Rio Grande River located in south-central Colorado. This includes the intermountain San Luis Valley bounded by the Sangre de Cristo Mountains on the east and the San Juan Mountains on the west. The San Luis valley is a north-south feature approximately 100 miles long and 50 miles wide. The valley floor is nearly flat with an average elevation of 7,700 feet, while the mountain ranges on either side rise to a height of 5,000 to 6,000 feet above it (Figure 5). Publication MS-33 (2002) of the Colorado Energy and Carbon Management Commission (ECMC) defines the limits of the San Juan Sag and San Luis sedimentary basins which are largely contained within the SLVFO study area (Figures 5 and 6). Characterization of the geology and hydrocarbon potential of these two basins is the focus of the RFD for oil and gas activities.

Both the San Juan Mountains and the Sangre de Cristo Mountains have outcroppings of marine sediments (mainly of Pennsylvanian thru Upper Cretaceous age) known to have the potential for sourcing hydrocarbons and acting as reservoirs for oil and gas (Figure 6). In addition, these mountains have extensive outcroppings of Cenozoic volcanic rocks, intrusive igneous rocks including stocks, dikes and sills, and Precambrian sedimentary, metamorphic and igneous rocks (basement).

The subsurface stratigraphy with respect to oil and gas generation is restricted to Upper Cretaceous through Mississippian sediments which are mainly of marine origin and contain shales with total organic carbon values consistent with hydrocarbon source rocks. They were deposited in cratonic seas that covered large portions of North America and are well known in surrounding oil and gas productive basins. As shown in Figure 6, these sediments crop out in the Sangre de Cristo Mountains (eastern edge of SLVFO) and in the San Juan Mountains (western side of SLVFO). A total of 38 wells were drilled within the SLVFO since 1910. Twenty-four of these were drilled in San Luis basin and fourteen were drilled in the San Juan Sag basin. The subsurface stratigraphy has been interpreted using these wells supplemented by a few wells adjacent to the southwest corner of the SLVFO. The closest economic oil field is Price Gramps located adjacent to the southwest corner of the SLVFO (see Figure 6). This oil field is part of the San Juan Basin and produces from the Dakota Sandstone with an ultimate estimated recovery of 7.2 million barrels of 31.4°API oil (Donovan, 1978).

Following the deposition of Paleozoic through Cretaceous cratonic marine sediments, a period of compressional tectonic folding and faulting ensued at the end of the Late Cretaceous and continued to the Eocene. In the SLVFO the Paleozoic through Mesozoic sediments were uplifted and eroded in part. Tensional tectonism ensued accompanied by volcanism in many portions of the SLVFO

from the Oligocene to Recent. In the SLVFO this tensional tectonism resulted in a subsidence of the Upper Cretaceous through Mississippian sediments and burial beneath a thick blanket of volcanic rocks and non-marine sediments. Volcanic calderas and stocks are scattered throughout much of the SLVFO, but the largest of these is the La Garita caldera located in the San Juan Mountains 63 miles northwest of the town of Del Norte (Figure 7).

The present-day San Luis basin is a result of the post-Oligocene displacements (tectonism) of the Rio Grande Rift (McCalpin, 1996). The valley itself can be described as an east-tilted half graben (McCalpin, 1996) that is bounded by normal faulting to the east at the Sangre de Cristo Mountains and a hinge toward the western portion of the valley. Geological and geophysical exploration within the valley documents a buried, intrarift horst (Alamosa Horst) that has no surface expression surfacing south as the San Luis Hills ((McCalpin, 1996). The Alamosa Horst splits the San Luis Valley basin into two sub-basins: an east-tilted western basin defined by the Monte Vista Graben to the west and the Baca Graben to the east (McCalpin, 1996) as is shown in Figure 8. The Monte Vista Graben is filled with approximately 3,027 m (9,929 feet) of post-Eocene aged sediments whereas the Baca Graben is both deeper and narrower filled with roughly 5,000 m (16,400 feet) of these sediments (McCalpin, 1996).

Plate 1 is an east-west geologic section from the San Juan Sag basin to the San Luis basin showing the generalized geology and structure. The section clearly shows the Upper Cretaceous sediments of the San Juan Sag basin (western third of the cross section), and the horst and graben (highs and lows) filled with Tertiary sediments characteristic of the San Luis basin (eastern two thirds of the cross section). The Upper Cretaceous sediments in the San Juan Sag basin have been well studied and have produced small quantities of oil and gas. The San Luis basin has seen 63% of the drilling activity in the SLVFO and yet none of these wells have documented a significant section of Mississippian through Upper Cretaceous rocks. The best potential for these source and reservoir rocks to be discovered in San Luis basin is within the depths of the Baca graben adjacent to the Sangre de Cristo Mountains (Figure 8).

San Luis Basin

The San Luis basin is characterized by Oligocene to Recent tensional tectonics creating deep grabens filled with non-marine sediments and volcanic rocks. The non-marine sediments in these grabens are believed to contain sufficient organic matter to allow the biogenic generation of methane (Rice and Claypool, 1981). Buried horst and graben features within the San Luis basin are shown in Figure 8. The Monte Vista and Baca grabens have the greatest potential for biogenic gas source rocks. Based on well control, the Baca graben along the western margin of the Sangre de Cristo Mountains has the greatest potential for the preservation of Upper Cretaceous, Permian and Pennsylvanian sediments in its depths where thermal maturation of oil and gas could potentially take place. These rocks crop out in the Sangre de Cristo Mountains and wells were drilled on the eastern margin of Baca graben with reported oil and gas shows.

Well Blanca Trinchera 1 (API: 02305001) drilled in 1952 reported numerous oil and gas shows below 3180 feet and DD Vaughn #1 (API: 02340000) drilled in 1962 reported showings of heavy black oil on the mud pit with gas bubbles from 4080 to 4095 feet (see Figure 7). However, neither well was able to run open hole electric logs and no paleontological reports are available to confirm

the age of the rocks these oil and gas shows occur in. In addition, no well to date has been drilled into the deepest portion of the Baca graben to determine what (if any) oil and gas source rocks are present and determine their stage of maturation. Well State Land Board #1-32 (API: 00306001) made the deepest penetration into the Baca graben. It penetrated granitic rocks at 8490 feet and stayed in them to a total depth of 9,480 feet. This well was in Tertiary age lacustrine sands and clay sediments above the granite. A published 2D seismic line (Greis, 1985a) indicates the bottom of the graben six miles east of well State Land Board #1-32 could be as much as 3,500 feet deeper (250ms two-way travel time at 14,000 ft/sec). This would indicate the Baca graben is at least 13,000 feet deep in this area. The regional stratigraphy presented by Molenaar et al., 2002, (Plate 2) suggests the Upper Cretaceous section is eroded in the San Luis basin. If this is correct, only the Permian to Pennsylvanian rocks would be potential candidates for sourcing the oil and gas shows seen in wells Blanca Trinchera 1 and DD Vaughn 1. Significantly, the Baca graben was not included in the USGS assessment as a thermal oil and gas play (Molenaar, 1988 and 2001). However, given that two wells in the Baca Graben reported shows of oil and gas, there is the potential for an oil and gas play in this basin even if the source and reservoir rocks are as yet poorly defined.

Ground water in the San Luis basin often comes to the surface via artesian wells or springs. As described by Molenaar, 1988, biogenic gas within groundwater was used by farmers since the 1880's for heating purposes. Map MI-21 by the ECMC outlines an area of approximately 324 square miles in which gas is believed present in ground water wells (see Figure 6). Rice and Claypool (1981) analyzed a sample of gas from the Alamosa Formation at a depth of 300 meters (984 feet) in a well in the San Luis basin. This gas sample was determined to be of biogenic origin based on carbon isotope ratios. Figure 9 is a stratigraphic column that describes the Alamosa Formation as "Interbedded, discontinuous blue, gray and green clays and dark sands; sands are dominantly fine-grained; uppermost clay divides valley into upper unconfined aquifer and lower confined aquifer." The clays are believed to contain organic matter and microbes that produce the methane (and minor ethane) gas. The discontinuous sands are believed to be potential reservoirs. The USGS assessment classifies this biogenic gas as a play (Molenaar, 1988 and 2002).

However, all wells drilled in the San Luis basin have penetrated the Alamosa Formation and none to date have had encountered gas sands of sufficient size and potential to cause the operator to attempt a completion. Due to the limited depth and pore pressure of the Alamosa Formation, an economic gas reservoir would require a thick gas sand or series of gas sands covering hundreds of acres to be an economic discovery. In addition, biogenic gas is composed of only methane for all practical purposes and methane has a Btu (British thermal units) value of 1,000 Btu/ft^3. If the biogenic gas reservoirs include any inert gases such as nitrogen or carbon dioxide, the Btu value of the gas will be adversely affected. Commercial gas pipelines require a minimum gas quality which is at least 1,000 Btu. If the gas contained significant inert gases, the discovered gas would either need these inert gases removed or the gas use would be restricted local domestic or industrial uses.

San Juan Sag Basin

The San Juan Sag basin contains well documented Upper Cretaceous sediments including Mancos Formation and Dakota sandstone. The Mancos Formation is a proven oil and gas source rock in other basins and isochores of the Mancos Formation to the top of the Dakota sandstone reach 3,850 feet in thickness in the San Juan Sag basin (Figure 10). Within this thick section of Upper

Cretaceous rocks is the chalk rich Niobrara Formation which is an important unconventional resource zone in the San Juan basin to the southwest and the Denver-Julesburg basin to the northeast of the SLVFO. Thirteen wells have been drilled into the Upper Cretaceous section in the San Juan Sag basin and have proven that oil and gas are being generated and there is active migration of these hydrocarbons. Well Jynnifer 1 (API: 10506003) was completed in tight sands or igneous sill in the upper portion of the Mancos Formation and reportedly produced 1,855 bbl of oil and undisclosed quantities of associated gas (ECMC well report).

Greis 1997, has documented that the Upper Cretaceous sediments in the San Juan Sag basin possess hydrocarbon source rocks and that the geothermal gradient and burial depth of these rocks are conducive to oil generation. The well Basin 1 (API: 10506019) was selected as the Type Log for the San Juan Sag basin in this study (see Plate 2). This well has a good quality mud log with ditch gas chromatography and porosity logs. It is also located in close proximity to well Jynnifer 1 (API: 10506003) which was designated by ECMC as the Del Norte Oil Field.

Figure 11 shows the structure on the top of the Mancos Formation for the San Juan Sag basin. This map was constructed using well control as well as the elevation of the top Mancos Formation in outcrop. It is a simplified map (no faults interpreted) showing the extent and gross structure of the San Juan Sag basin. The Type Log (Plate 3) clearly shows that hydrocarbons are present and based on production in the Jynnifer 1 (API: 10506003) it can be concluded that hydrocarbons are migrating in the basin. To date, no economic well completion has been successful due to a failure to locate an oil and gas trap with adequate reservoir porosity and permeability.

All drilling in the San Juan Sag basin has targeted conventional oil and gas reservoirs. Conventional oil and gas exploration and development focuses on locating reservoir rocks with adequate porosity and permeability to allow a vertical well completion (or directional or horizontal) to produce oil and gas at economic rates. These reservoir rocks must form a trap to hold the oil and gas by way of structure and/or stratigraphy. Conventional oil and gas plays can be very profitable based on drilling and completion costs compared to production rates. However, the current size of new domestic onshore conventional oil and gas pools are a few tens of millions of barrels of oil or much less. Unconventional oil plays target formations that have sufficient porosity to accumulate large quantities of oil but have very low permeability so that a conventional vertical well (or directional or horizontal) cannot produce the oil and gas at economic rates even if the zone is hydraulically fractured. Due to the low permeability of these unconventional reservoirs, oil and gas are naturally trapped in the formation and the areal size of the oil and gas reservoir can be very large. Once the unconventional reservoir is identified it is developed by drilling long horizontal completions into it and if needed hydraulically fracturing the reservoir along the entire completion zone. These wells are very expensive compared to wells for conventional plays, but they produce at economic rates. In addition, the average reserves for these wells is predictable and the reservoirs can cover hundreds or even thousands of square miles. Unconventional oil and gas plays are responsible for making the US energy independent and have changed the focus of the oil and gas industry. There is tremendous pressure in the oil industry to locate more unconventional reservoirs because such a discovery can assure the future of an oil and gas company for decades.

Molenaar et al., 2002 (Plate 2) recognized the presence of the Niobrara Formation in the San Juan Sag basin. The Niobrara Formation interfingers with the Mancos Formation and is readily identifiable in well logs. The Niobrara Formation is an important unconventional reservoir in the Wattenberg Field northeast of Denver, Colorado (Denver-Julesburg basin). Figure 12 is a an isochore map of the Niobrara Formation in the San Juan Sag basin. Plate 4 is a detail of the Type Log over the Niobrara zone with the cuttings descriptions (right side) and zone temperature (left side) annotated. The wellsite geologist described the cuttings as "chalky" which is consistent with Niobrara lithology. There is increased ditch gas over the interval and weak oil shows were logged. Cuttings samples had faint oil cuts but no free oil was reported. The oil shows are consistent with a source rock just entering oil maturating temperatures. The zone temperature is calculated at 188°F to 194°F. The inferred oil maturation stage is in line with source rock and oil maturity studies conducted by Gries et al., 1997. They conclude the oil maturation window for upper Cretaceous rocks in the San Juan Sag basin is from 180°F to 250°F and based on the geothermal gradient, the oil generation window extends to depths of 9,000 feet to 10,000 feet. Figure 13 is a map of the depth to the top of the Niobrara. Color-filled contours in this map are color coded to represent hydrocarbon maturation phases as demonstrated by Gries et al., 1997. Depths between 8,000 feet and 10,700 feet, representing the prime oil maturation window, are considered to have good unconventional resource potential. These depths are outlined with a green dashed polygon and cover 465 square miles.

The oil and gas potential for a Niobrara unconventional reservoir covering 465 square miles is large. In the Wattenberg Field, recoveries range from 30 to 50 net equivalent barrels of oil and gas per foot. A net equivalent barrel (NEB) equals the barrels of oil plus each 6,000 cubic feet of associated gas is considered equivalent to one barrel of oil. Horizontal well completions are typically 10,000 feet long but can be up to 25,000 feet long in the Wattenberg Field. Assuming a well completion spacing of 1,320 feet and a recovery factor of 30 NEB per foot of completion, 600,000 NEB's can be recovered per square mile (5,000 ft of completion × 4 wells × 30 NEB/ ft). Therefore, the 465 square miles of Niobrara Formation within the oil generation window in the San Juan Sag basin could potentially yield 279 million NEB's of recoverable hydrocarbons (600,000 NEB/mi × 465 sq mi). These estimates assume the entire 465 square miles is productive, which is unlikely. However, the recovery factors used (recovery per foot of completion and completion spacing) are conservative and may be more favorable. The purpose of these estimates is to simply show the magnitude of oil and gas resources possible in the San Juan Sag basin.

The potential for the unconventional Niobrara development is significant but is hypothetical until a test well is drilled and the Niobrara is characterized by means of logging, coring and production testing to prove it has the proper reservoir properties and oil saturations. A test well would also identify the best zone or zones in the Niobrara Formation to be targeted for a horizontal completion test. Fortunately, such a horizontal test well could be designed and drilled within the extents of the existing San Juan Sag 3D seismic survey. If this test well proved to be economic, it can safely be assumed a large 3D seismic survey would be proposed and shot so that an optimal field development drilling plan could be designed and the location of drilling pads be determined.

The probability that a large independent or major oil company will drill a test well to investigate the Niobrara Formation in the San Juan Sag basin within the next 20 years is considered to be high.

There is significant pressure in the oil industry to have a large backlog of drillable unconventional well locations. Acquiring acreage in active resource plays is highly competitive and acreage costs are very high. Therefore, locating new undeveloped acreage is a good way to add oil and gas to a company's reserve base and guarantee company's growth for decades.

The potential for oil and gas activity in the San Juan Sag basin is high, but the area has no existing oil and gas infrastructure. Some existing infrastructure can be readily improved to accommodate development. The area is hilly to mountainous and yet there are numerous existing paved and unpaved roads throughout. These can be improved as needed to provide access to within a few miles or less for drilling pads thereby keeping the need for new roads to a minimum. This road network can also act as rights of way for production pipelines thereby limiting these disturbances. Rail transport of oil is a viable means to transport the oil. There is abundant groundwater available for hydraulic fracturing of well completions. Electrical needs would probably exceed capacity soon, but the abundant gas being produced would make local generation using gas turbines a viable option. The main infrastructure issue will be gas transport. Normally this is handled by pipelines but there is unlikely adequate capacity for the gas that would be produced. In the short term, the gas could be liquified and transported by rail if permission can be obtained. The long-term solution is a pipeline, but the permitting time is significant as is the construction cost for pipelines. Certainly, the gas could supply all local needs for sites within the SLVFO, but the produced volume would greatly exceed these needs.

3.2 Reservoirs, Traps, Source Rocks, Seals, and Hydrocarbon Generation and Migration

The nature and existence of hydrocarbon source rocks, seals and traps in the San Luis basin is purely speculative. Until a test well is drilled into the deep central portion of the Baca graben there is no way to ascertain the potential for oil and gas development in this basin. If Paleozoic and/or Cretaceous rocks are present in the depths of the Baca graben compressional structures formed between the latest Cretaceous and Eocene time may still be present and represent structural traps modified by tensional subsidence and rotation. Sandstones would be the most common reservoirs and oil and gas production from structures would be limited porosity and permeability fairways.

Shallow biogenic gas in the San Luis basin is considered a play by the USGS in their assessment but the quality and volumes of gas expected are not well understood. A review of wells in the San Luis basin with porosity and/or sonic logs indicates the Alamosa Formation is sand rich with relatively thin clay layers. This suggests stratigraphic traps would be thin localized accumulations and faults would not make good seals. Therefore, folding would have the best trapping properties. However, the Alamosa Formation is in a tensional structural setting where folds would only exist as second order features associated with normal faults. Therefore, a viable trapping mechanism for large biogenic gas pools is not readily apparent.

The stratigraphy of the San Juan Sag basin is well documented in the subsurface by 14 wells scattered from the north to south end along the eastern margin of the basin (Figure 10). The presence of viable source rocks and hydrocarbon generation is well documented by Greis et al., 1997. This includes the Entrada Sandstone and Junction Creek sandstones of Jurassic age as well as the Dakota Sandstone of Cretaceous age and fracture igneous sills (Molenaar, 1988). The thick Dakota

Sandstone is the most important conventional reservoir found throughout the basin. This widespread formation produces oil and gas in the San Juan, Denver, Powder River and Chama basins within Colorado, New Mexico, Nebraska, Montana and Wyoming. Other lesser sand bodies distributed within the Mancos Formation are also viable reservoirs. Plate 3 is the type log used for this study, shows a series of sands above the Mancos Formation that have oil shows. The age of these sands is in question, but they may be Mesa Verde age. Regardless of their age, they comprise a sand shale sequence with oil shows. This indicates they have a viable vertical seal and only lack a lateral trapping mechanism to form a conventional oil play. Generally, reservoirs in the Mancos Formation are encased in shale and have adequate vertical seals. Molenaar et al., 2002 (Plate 2) documents the Bridge Creek limestone member of the Mancos Formation (below the Niobrara Formation) is present in the San Juan Sag basin. This limestone is productive in the Denver basin and has potential as an unconventional resource.

Traps for conventional reservoirs will consist of structures formed by some combination of folds, faults and permeability barriers. Permeability and porosity variations will modify the lateral productivity within these reservoirs. Fault traps associated with the La Garita caldera and other calderas (Figure 7) may also provide structural trapping possibilities. Kroeger et al., 2022, investigated oil and gas generation and trapping associated with stratovolcanoes offshore New Zealand and show that these volcanic structures produce conditions suitable for conventional hydrocarbon traps. It is anticipated that large 3D seismic surveys will be acquired for unconventional development of the Niobrara Formation. The authors of this study believe that the 3D data should be able to identify suitable structures in the Dakota Sandstone and other sandstone reservoirs. Based upon the author's review of the 3D data previewed, it is believed that 3D seismic data is of sufficient quality will be sufficient to perform rock physics studies to determine porosity fairways and gas detection. This would allow a mixed development of unconventional and conventional play types.

Most importantly, over 300 feet of the Niobrara Formation is present (Plates 1, 2, 3, 4 and Figures 13, 14). This chalky marlstone is both a source and reservoir rock and an important unconventional resource plays in nearby basins. The high porosity and low permeability of the Niobrara give it the unique source rock, reservoir, and trap qualities of an unconventional resource play. Over the last two decades, unconventional reservoirs have become the focus of the domestic oil industry. Conventional oil and gas plays cannot compete with the size or economic impact of unconventional plays. Therefore, the Niobrara is considered the main draw for exploration and development dollars in the San Juan Sag basin. If conventional traps are encountered or located in 3D seismic associated with potential Niobrara development these may be developed as secondary targets. Complex structuring can be a problem when developing resource plays. As mentioned above, seismic quality is good in the San Juan Sag basin allowing structurally complex areas to be avoided when drilling horizontal completions. A review of the 48 square mile San Juan Sag 3D seismic volume indicated that structurally complex areas were localized and relatively small features within a regional homoclinal west dip.

3.3 Summary of USGS or Other Play Descriptions

The USGS (Molenaar, 1988) includes the Upper Cretaceous of the San Juan Sag basin and biogenic gas in the San Luis basin as oil and gas plays in the assessment of Province 23.

Molenaar describes the San Juan Sag play as Cretaceous rocks beneath volcanic rocks in the foothills of the San Juan Mountains. The eastern boundary of the play is defined by the "eastern extent of Cretaceous rocks preserved under the Eocene unconformity." The western boundary is "arbitrarily placed where the terrain becomes more mountainous and the volcanic cover is thicker." Molenaar concedes this western boundary could extend much further west "if the pre-Tertiary could be delineated under that area." We agree with Molenaar's assessment that the western extent of the play is arbitrary and there is reason to believe local areas further west of the current boundary could be defined by seismic. Our review of existing 2D and 3D seismic offered by Seismic Exchange, Inc. in the San Juan Sag basin showed that good data quality down to Precambrian rocks is the normal case. The only loss of data quality occurred when a 2D line approached the massive La Garita Caldera. This loss of data quality could be due to changes in the volcanic rocks associated with the caldera limiting acoustic penetration or the inability of 2D seismic to image the complex structure of the caldera. However, west of the La Garita caldera there are large areas without obvious calderas that are surrounded by outcroppings of Cretaceous rocks. The potential for the basin to be much larger exists but at present is speculative due to the absence of test wells and seismic data.

The biogenic gas play in the San Luis basin is primarily based on paper by Greis, 1985, Rice and Claypool 1981and documented gas in shallow groundwater wells MI-21. Greis attributes the source of the biogenic gas to the Alamosa Formation. Rice and Claypool, 1981 sampled gas from a well in the San Luis basin at 300 meters (984 feet) completed in the Alamosa Formation and lists this as a field.

4. Past and Present Oil and Gas Exploration Activity

4.1 Geophysical Surveys

Gravity and Magnetic Surveys

One of the earliest geophysical surveys of the San Luis Valley was a regional gravity survey of Colorado (Holmer, 1954). A regional gravity survey was conducted during the summer of 1961 and 1963, covering about 6,000 square miles of the San Luis Valley. The survey was aimed to outline the gravity field of the area and to determine the internal structure of the valley. It was not until 1969 that Gaca reduced the data and made the interpretation of the results.

Gaca identified major gravity highs in the central and western parts of the valley which he interpreted to indicate a horst of Precambrian rock buried and surrounded by basin fill. Along the eastern edge of the valley, near Sangre de Cristo Mountains, a major gravity low was interpreted to indicate a deep filled graben. On the basis of the gravity minimum in this valley, Gaca and Karig (1965) calculated a basement depth of as much as 30,000 feet (9.1 km).

Jordan (1974) conducted geothermal studies in the San Luis Valley near Mineral Hot Springs. From thermal infrared imagery flown over the valley view and Mineral Hot Springs areas, only the hot springs produced thermally anomalous features on the imagery.

Arestad (1977) conducted resistivity studies in the upper Arkansas Valley and the northern San Luis Valley. From the interpretation of the results he deduced the presence of two separate deep

subsurface basins, one northeast of Villa Grove and the other east of Mineral Hot Springs. Forty Schlumberger soundings conducted by the author and interpreted by Keller (1977) (for the Colorado Division of Water Resources), did not detect resistivity in the basement northeast of Villa Grove and east of Mineral Hot Springs.

In 1980 Ndala conducted a magnetotelluric survey in the north of the valley, with 25 stations. The interpretation of their results stated that temperatures were not high enough for commercial production of electricity. He recommended performing studios between Buena Vista and Alamosa.

Mackelprang (1983) performed a detailed gravimetric survey in San Luis Valley, 200 miles around the city of Alamosa for geothermal purposes. This survey has a long profile since the Del Norte high into Alamosa city. This profile indicates the western edge of the Alamosa horst as a steep local gradient which is superimposed on a strong regional gravimetric gradient. The regional trend continues westward into the San Juan Volcanic Field. The gravity profile across the horst indicates that the city of Alamosa sits on top of a gravity low. This survey obtained three gravity highs, separate and distinct from each other, that were delineated within the limits of this survey. These occur to the northwest, northeast and south of town and border the local gravity low at Alamosa. These gravity and magnetic data have been used to define basin geometry, fault systems, and basement structure beneath volcanic cover.

Figure 14 presents a gravimetric map from the SLVFO aera. This map was made for the complete state of Colorado by (Abrams,1993; Oshetski and Kucks, 2000). The map shows the San Juan Volcanic Field has great influence over the results and it has a very negative anomaly (higher density contrast) while those values are more moderate to the east, at the north of Raton Basin. These anomalies also highlight the structure of Alamosa Horst, with Baca and Monte Grande grabens.

Seismic Reflection Surveys

Seismic exploration in the SLVFO area has been performed in focused areas across decades with specific survey line locations in Figure 15. These surveys have been made on the San Luis Valley (Baca Graben-Alamosa Horst-Monte Vista Graben) looking for a continuity of the structural high with poor results. Seismic surveys have also been acquired in the San Juan Sag (where the topography has allowed) in the Del Norte High. The seismic data coverage is limited due to volcanic rocks and complex near-surface conditions. Where available, seismic data provides only partial imaging of deeper structures. Additionally, it should be noted that:

- High, rugged terrain makes seismic surveying very difficult and expensive.

- The quality of the seismic data is poor. As the thickness of volcanic rocks increases in the San Juan Mountains, the seismic quality decreases. The only way to face this challenge is to design surveys with longer offsets (distance among source and receivers) which has a high impact on the survey budget.

- The many igneous sills in the area are difficult to impossible to detect on seismic. The last Amoco well, Beaver Mountain Unit No. 1 (API: 10506008) encountered a 600-ft-thick sill that was intruded into the Dakota Sandstone. It had about the same seismic velocity as the Dakota. The

igneous activity has locally super-heated and metamorphosed adjacent shales into hornfels. Maturation of the source rocks ranges from the oil-generating range to super mature.

• A 3D seismic survey was performed near Del Norte (San Juan Sag 3D) in 2002. Another 3D seismic survey was performed in the Baca Graben area in 2007.

Alamosa Horst

2D seismic surveys were performed in the Alamos Horst locality between 1977 and 1985. This area has only 2D seismic. Other geophysical data, such as gravimetric and magnetic, are available. Figure 16 shows these survey locations in detail.

One regional 2D seismic line, which was used by Gries (1985) and Brister and Gries (1997), was used to describe the main structural framework from west to east. Such a line is too close to certain wells as Colorado State-1 (Amerada). The most important feature of this line is the clear division between Monte Vista Graben, Baca Graben and Alamosa Horst. This last one is clearly defined by gravimetric data and by the available seismic (Gries 1985). There is no clear date for this survey. Most 2D surveys were shot between 1973 and 1985.

The Tennessee Gas 1-B State well is used for Seismic-well tie (Brister and Gries 1997), with synthetic seismogram (Figure 17). This well has all the stratigraphic units in the San Luis basin. The strongest reflection marks the base of Santa Fe Group and is a regional seismic marker. Because the top of the tuffs is the transition among pre-rift and syn-rift deposits, any faults that offset these reflections are a result of the rifting events. In contrast, faults that offset units below the reflections (but not the reflections themselves) are a pre-rift in origin.

Another strong reflection is found at about 1.25 seconds, and it is a local reflection associated at a 75 m (246 feet) lava flow within Conejos Formation. A weak double reflection exists at about 1.95 seconds which is associated with the Precambrian top.

A regional interpreted seismic line across the Alamosa basin illustrates the seismic features of the stratigraphy. The late Oligocene tuffs are associated with a strong reflection which is faulted and tilted down with high depth in Baca Graben and it's not visibly faulted in Monte Vista graben. Well control helps to distinguish this reflection from internal seismic events of Santa Fe Group in Baca Graben.

Below strong tuff reflections, Conejos and Blanco Basin Formations contain reflections that vary from strong and continuous to weak and discontinuous. Sometimes a weak reflection exists at the contact between the two formations, although there is need of well control to correctly identify the contact. Conejos-Blanco Basin package of reflections thins eastward to zero over the central high of Alamosa basin.

Above the strong stuff reflections is a complex series of reflections of Santa Fe Group. Alamosa Formation has low-amplitude, weak reflections. The transition to Lower Santa Fe Group has higher amplitudes, and more continuous reflections. Lower Santa Fe Group has two seismic packages: the upper one is relatively flat lying and un-faulted and the lowest one dips moderately to the east, is

highly faulted and appears to be confined to Baca Graben. A summary of the existing seismic surveys in the Alamosa area are provided in the appendix.

Additional seismic lines in the public domain beyond in Brister and Gries (1997) which has been employed as the reference section for most of the geological cross-sections come from academic studies. In 1977, Stoughton made a study in his PhD Thesis, where he acquired, processed and interpreted lines which crossed the Alamosa horst and part of the Baca Graben. Such lines are of acceptable quality and can be reprocessed with modern algorithms until obtain an optimum image quality. Figure 18 shows two composite lines which are very close to drilled wells as reference.

Rio Grande County: Del Norte Area

A 3D seismic volume was acquired in November 2000, in the San Juan Sag (San Juan Sag 3D by Veritas DGC Land, Inc.). This survey has a bin size of 110 feet x 110 feet, with a record length of 8 seconds, maximum offset 19,070 feet, a surface of 48.51 square miles and a fold of 90. The energy source was a vibroseis. This 3D survey was processed by Tricon, and it has 2 enhanced migrated stacks and an enhanced 1-pass migration. It was also re-processed in 2002.

In 2002, 3D seismic data was reprocessed to better define structures distal to the faults that served as migration pathways for igneous sills. This effort aimed to identify potential traps within productive formations. While the 3D data improved the mapping of fault-bounded anticlines, basement highs, and shallow closures, imaging and depth conversion remain challenging due to thick volcanic cover and complex velocity anomalies associated with igneous intrusions.

Recent advancements, including broadband/Reverse Time Migration (RTM) processing and rigorous integration with well ties, have significantly improved interpretation success. These ongoing 3D seismic efforts and their underlying rationales are well-documented in regional reports and industry communications (Gries et al., 1997).

For the present study, access was granted to proprietary seismic data (not reproducible herein). Key observations include:

- Precambrian Horizon: Distinct reflections are observed at approximately 2,000 ms.
- Structural Regime: The data exhibits high reflectivity and confirms a reverse faulting regime, characterized by an east-west trending structural high to the north.
- Signal Quality: Seismic resolution is excellent in the west but weakens progressively toward the east.

Stratigraphy: The Tertiary Unconformity is a prominent, clearly defined seismic marker.

The existing 2D seismic inventory was acquired between 1983 and 1986, with the majority reprocessed in 1989. The regional coverage is relatively sparse due to two primary factors: 1) rugged topography: the difficult terrain severely restricted seismic operations to accessible zones and 2) volcanic rock interference: the presence of the San Juan Volcanic Field further complicated data acquisition and signal penetration. Figure 18 illustrates the location of the 2D and 3D seismic survey lines. A summary of the 2D seismic data along with the observed proprietary data in this area is provided in the appendix.

In 1999, Tandon et al. published an analysis of a reprocessed seismic line originally acquired by Chevron. This profile transects the entire San Luis Valley, spanning the Monte Vista Graben and extending into the Del Norte High.

The study highlights a significant degradation in seismic image quality toward the west. As the line enters the San Juan Volcanic Field (near VP 1640), the following observations were noted:

- Loss of Continuity: Coherent reflection patterns become difficult to discern.
- Vertical Variability: While some intermittent reflections are visible at greater depths, the shallow section is largely devoid of interpretable seismic character.

Figure 20 illustrates this seismic profile, specifically highlighting the transition zone between the San Luis Valley and the Del Norte High.

Saguache County: Baca Area

In order to define the exploration target, Lexam (2006) performed a 3D seismic exploration program on these lands, after receiving a permit from the ECMC to conduct the program. The 3D seismic survey area is shown on Figure 21.

New information resulting from the 3D seismic program led to defining better targets for the planned drilling program and changes to the proposed drill locations. These new targets are identified as Baca amended #6 (forthwith referred to as Baca #6) and Baca #7 drill locations. The amended Baca #6 was close enough to the original and did not require a new permit. Drilling will occur on Baca #5 and on either Baca 6 or Baca 7 locations; a total of two wells will be drilled. Drilling was executed to occur during 2008.

This area has a more complete 2D seismic coverage, which allowed a definition for the structure and the 3D was delimited by it. The 2D was acquired in several campaigns: 1973, 1984 and 2004 while the 3D was shot in 2007. (CO71-Baca NWR, 2008). Figure 21 shows a detailed map for the 2D and 3D seismic in Baca High. A summary of the seismic surveys for this area is included in the appendix.

4.2 SLVFO Drilling Activity

Very few oil & gas wells have been drilled in the SLVFO study area in comparison to the neighboring San Juan, Paradox, Raton, and Denver basins. A total of 38 wells have been drilled between 1910 and 2013 according to all available records from the ECMC. An additional 10 notices of intent to drill were filed with the ECMC between 1951 to 2014 but these wells were never drilled. Figure 22 shows a plot of the number of wells drilled in a single year vs. time. This plot also shows the price of West Texas Intermediate (WTI) crude oil adjusted to the consumer price index (CPI) for 2025 whose pricing records could only be found dating back to 1946. Six wells were drilled in 1985 and represents the greatest number of wells drilled in a single year. The last well was drilled in 2013 in the Del Norte Field. Greater drilling activity has occurred following appreciable increases in the crude oil price vs. time. The economic drilling success rate in the SLVFO area is 0%.

A brief summary of the wells drilled in the SLVFO area by geographic region follows. A summary table of all wells drilled and all notices of intent to drill wells within the SLVFO is provided in the appendix.

Alamosa Horst

Colorado State F-1 / Amerada F-1 (API: 00305000) is the main well described in the seismic line by Gries (Its objective was to reach Precambrian rocks at approximately10,000 feet. This well was drilled in the highest point of the Alamosa horst. There were no oil or gas shows.

The lithology of the well is described as follows. Shales are dominant in the upper intervals (between 0 and 4,018 ft) interbedded with sands and volcanic rocks. Below 4,018 feet, the main lithology is volcanic rocks until 4,717 feet. Below this, the lithology is sandstone through 6,070 ft (total depth). 30 sidewall cores were taken from 3825 to 6046 ft. Several of the cores were not recovered. The well was plugged and abandoned in 1959.

Holbrook – 1 (API: 00305001) was drilled in 1910, followed by Layne-1 (API: 00360001) in 1915. Additional drilling campaigns continued in the 1950's and 1970's. Although no oil or gas shows are evident in these wells, the data from them are useful for geothermal exploration.

Rio Grande County: Del Norte Area

Of the 38 wells drilled, only one well, Jynnifer 1, (API: 10506003) was completed and produced uneconomic quantities of oil and gas. Initial production rates are reported between 30 bbl/day and higher. The well only produced an uneconomic volume of oil, reportedly as 1,855 bbl of oil. Basin 1 (API: 10506019) is the only well drilled within a 3D seismic survey area and this well was an offset to the Jynnifer 1 on the edge of the 3D survey and represents the latest well drilled in the SVLFO in 2013. A hydraulic fracturing treatment was applied in this well and it is unclear if oil was ever produced. Regardless, these two wells proved the San Juan Sag basin is generating hydrocarbons and these hydrocarbons are migrating in the basin.

Other exploratory tests were done in wells in this area including Needham-Medford-1 (API: 10906001), AMF-1 (API: 10506001), LGM-1 (API: 10506002), Mosley 1-9 (API: 10506004), Horseshoe Mtn 1-10 (API: 10506010) & 1-14 (API: 10506013), and Federal 24A-1 (API: 10906002). These broader dataset of tests across the San Juan Sag and flanking high shows frequent hydrocarbon shows in Dakota, Niobrara/analog intervals, Lewis Shale, Jurassic sandstones, and Tertiary volcanics. Many wells encountered igneous sills; several recorded oil/gas shows but did not develop into sustained well production or commercial fields. The culmination of this data supports an active petroleum system with heterogeneous reservoir preservation.

5. Past and Present Oil and Gas Development Activity

No economic oil or natural gas has been produced within the SLVFO area. This section focuses on oil and gas production history, well spacing requirements, drilling practices, reservoir characteristics, oil & gas facilities, and other information from neighboring basins RFDs including the San Juan and Paradox Basin in Colorado, San Juan Basin in New Mexico, and the Raton and Denver Basins in Colorado. Each of these aspects are summarized as follows.

5.1 Well Spacing and Unit Spacing of Target Formations

Well spacing requirements are established by oil & gas regulatory agencies such as the ECMC and NMOCD and can differ by individual oil fields and unit agreements. Average well spacing and unit spacing for the Niobrara formation is summarized as follows and is intended to represent hypothetical well and unit spacing requirements that would occur in the SLVFO. Table 2 summarizes well spacing requirements for the Niobrara Formation and other formations in the neighboring RFDs.

Wells completed in the Niobrara Formation are horizontally drilled and hydraulically fractured. Wells in conventional reservoir types have mostly been drilled vertically but can also use hydraulic fracturing.

The unit size for wells completed in the Niobrara Formation and its associated members varies widely from 640-acre units with 1 horizontal wells (640 acres / well) to 640-acre units with 24 horizontal wells (27 acres / well) as shown in Table 2 (ECMC, 2026). The average is 263 acres per well. Horizontal wells are typically required to be 600 feet from boundaries and other horizontal wellbores (ECMC, 2026). There is not enough oil or gas production from the Niobrara Formation in the Raton Basin that has set spacing requirements.

5.2 Drilling and Completion Statistics by Basin

SLVFO

All but two wells have been drilled as vertical wells. Two wells in the Great Sand Dunes National Park and Preserve are slightly deviated. No horizontal wells have ever been drilled in the SLVFO area. Hydraulic fracturing in vertical wells has performed in these wells at least once as is documented in Basin 1 (API: 10506019).

5.3 Hydraulic Fracturing and Water Needs

The Niobrara Formation is a shale and unconventional reservoir. Hydraulic fracturing is needed in order to produce the oil and gas in the unit. Hydraulic fracturing is also commonly applied to unconventional and conventional reservoir types in the neighboring RFDs. Table 3 summarizes the average volume of water used in Niobrara hydraulic fracturing treatments along with the volume of water used in other conventional and unconventional reservoirs in the neighboring basins (Frac Focus, 2026).

The water needed for hydraulic fracturing is generally freshwater to brackish water and the water supply within the SLVFO appears to be available given the prevalence of aquifers within the SLVFO area as discussed in Section 3. Other factors such as water rights, water plans / basin implementation plans, and political issues are beyond the scope of this this study.

5.4 Reservoir Fluid Characteristics

Oil and Gas

As previously noted, an extremely limited amount of oil has been produced in the SLVFO except for Jynnifer 1(API: 10506003) within the Del Norte Field. This oil that has been produced or noted in mud logs and oil shows has not been characterized by standard laboratory methods. Therefore, the oil characteristics of the target formations are characterized from characteristics in the

production reports from the ECMC. The crude oil classification for the Niobrara Formation and other formations that could be produced will more than likely fall into the light crude oil category because this is the common oil classification range in the neighboring basins. The average API gravity of the Niobrara Formation in CO portion of the Denver Basin is 32. A summary of the crude oil gravity from neighboring basins is provided below in Table 4.

Water Quality Characteristics

Produced water refers to the formation water that is produced from oil & gas reservoirs. One of the most basic water quality characteristics used to classify produced water is total dissolved solids (TDS), which is a bulk measure of the minerals dissolved in water. Usually, this water is not freshwater (< 3,000 mg/L TDS), but rather water that would not be considered an underground source of drinking water (USDW) and has a TDS content of > 10,000 mg/L (saline water).

The TDS of the Niobrara Formation and other formations that could produce oil and gas within the SLVFO are not known due to a lack of water samples and testing from the 38 oil & gas wells. The TDS of these formations have been evaluated from the USGS Produced Water Database (USGS, 2021) for the San Juan and Denver Basins as discussed as follows.

Although the TDS of the target formation water is not specifically known, they are likely to be classified as saline in nature due to their depth. Due to the expected salinity of this formation water, any produced water would need to be disposed of such as through the usage of water disposal injection wells into a formation that is both a non-USDW or exempted aquifer which has suitable permeability for injection. Non-freshwater aquifers and non-USDWs exist within the SLVO (both in the San Juan Sag and San Luis Valley) and are expected to be at far greater depths than the deepest freshwater aquifers in the vicinity. Water disposal wells and associated facilities such as storage tanks and separation vessels would likely be placed on the same well pads the oil & gas wells are located on.

The Niobrara Formation TDS content was evaluated from wells in the Denver Basin of CO. The average TDS content of the Niobrara Formation is 20,856 mg/L. A summary of the formation water TDS by basin is provided in Table 5.

5.5 U.S. Oil and Gas Demand

Oil and natural gas demand within the U.S. is expected to remain similar to today's demand levels. The U.S. Energy Information Administration (EIA) projects that natural gas, petroleum, and other energy sources will remain as the sources of energy still most consumed in 2050 and that natural gas consumption is likely to increase while petroleum and other liquids may slightly decrease from today's consumption levels (EIA, 2026). Figure 23 illustrates the EIA's projections of fuel consumption by energy source type. While energy sources from nuclear energy, wind, solar, hydro power are expected to grow, their percentage of total energy consumption remains relatively small overall and natural gas and petroleum, and other liquids will still represent the overwhelming majority of sources of energy consumption.

5.6 Type Curves / Well Life of Target Formations

A representative average of well life, initial production rates, and ultimate estimated recovery were evaluated for wells within the Denver Basin of Colorado. The average Niobrara well produces for about 20 years. Average initial oil production rates and gas production rates are 760 bbl/day and 1,757 MCF/day (EIA, 2022). The average estimated ultimate recovery for a Niobrara well in the Denver Basin is 221,000 bbl (221 Mbbl) and 537,250 MCF (537.25 MMCF) per well (EIA, 2022).

Average hyperbolic decline parameters were evaluated from available Niobrara well data within counties in the Denver Basin (EIA, 2022). Table 6 summarizes the production rates of Niobrara wells and Figure 24 illustrates a representative average type curve for a Niobrara well using this average data for the EUR described above.

5.7 Oil and Gas Transmission Infrastructure

Practically speaking, no oil & gas infrastructure of any type exists within the SLVFO study area. Extensive oil & gas infrastructure does exist in the neighboring San Juan and Paradox basins immediately to the west and Raton, and Denver basins to the east and the northeast of the SLVFO study area. These elements are discussed briefly. Figure 25 illustrates the oil & gas infrastructure surrounding the SLVFO study area.

Refineries

The nearest oil refineries that could handle any potentially produced oil within the SLVFO are each located over 100 miles from the study area. The three nearest oil refineries in terms of the straight-line distance to the centroid are located in Commerce City, Colorado, Gallup, New Mexico, and Sunray, Texas. Table 7 summarizes the nearest refinery distance and location.

Oil Transmission Lines

There are no interstate or intrastate oil pipelines within the SLVFO study area but pipelines do exist in the neighboring San Juan, Piceance, and Denver Basins. The nearest oil pipeline is located to the southwest within the San Juan Basin in Farmington, New Mexico. The next nearest oil pipelines are located in the Denver Basin north of Denver, Colorado and east near Cheyenne Wells, Colorado.

Gas Transmission Lines

There are no gas interstate or intrastate gas pipelines within the SLVFO study area but pipelines do exist in the neighboring San Juan, Paradox, Raton, and Denver Basins.

5.8 Roads, Highways, and Railways

Thousands of miles of unpaved roadways, paved roads, and highways exist with the SLVFO study area and are summarized as follows. In addition, there is an active railroad within the study area which accommodates commercial transport. Please refer to Figure 26.

Transportation aspects have been considered from a general perspective and were evaluated as the most likely highway and railway routes to the nearest refineries. Truck and train traffic changes that could occur as potential environmental impacts, safety, etc. are beyond the scope of this study.

Roads

An extensive network of unpaved and paved roads exists within the Rio Grande National Forest and BLM lands across the SLVFO study area (BLM, 2026; USFS, 2026). This existing network would serve to reduce the total amount of land disturbance for any potential oil & gas development or geothermal development. This network of roads flow into the numerous towns and major state highways discussed in the next section.

Highways

Highway 160 spans southern Colorado from the east in Walsenburg, Colorado all the way west to the four corners of Arizona, Colorado, New Mexico, and Utah and runs through the entire SLVFO study area. Highway 285 spans across southern to central Colorado from Englewood, Colorado to Espanola, New Mexico.

These highways would provide direct truck-transport of crude oil to access the nearest refineries located in Denver, Colorado and Gallup, New Mexico (Figure 25, Figure 26).

Railroads

The Colorado Pacific Rio Grande Railroad (CXRG) is an active rail line in the study area that extends from the east in Walsenburg, Colorado west to South Fork, Colorado and south from Alamosa, Colorado to Antonito, Colorado (CXRG, 2026). The rail line offers a variety of services including commercial freight transport, storage, and switching (CXRG, 2026). A railroad network map is shown in Figure 26.

This rail line could likely be used for the shipment of any potentially developed crude oil in the study area via tanker cars. The rail transportation route would be eastward over La Veta Pass toward Walsenburg, Colorado which feeds into north-to-south active rail lines that extend to the refinery located in Denver, Colorado and alternatively to other refiners in northwest Texas and Oklahoma. These rail lines located along the Colorado Front Range are operated by both Burlington Northern Santa Fe (BNSF) and Union Pacific railroad companies (BNSF, Union Pacific, 2026).

5.9 Electrical Transmission Lines

A network of high voltage electrical lines exists within the study area and is shown in Figure 27. Specifically, three independent high voltage, overhead AC lines of 230 kV, 115 kV, and 69 kV enter the SLVFO study area from the north and travel over Poncha Pass through a portion of BLM lands and then travel south toward Alamosa, Colorado mostly over private lands. The 230 kV line terminates near Center, Colorado while the 115 kV line extends south to Alamosa, Colorado and west to South Fork, Colorado over private lands parallel to highway 160. The 69 kV line branches out radially from Center, Colorado west through the San Juan National Forst to Creede, Colorado (also parallel to Highway 160) south to Antonito, Colorado, and east to Fort Garland, Colorado through private lands.

Oil and Gas Electrical Needs

Oil and gas facilities such as pumping jack motors, pumps, compressor engines, etc. are typically powered by electricity where it is available. These oil & gas facility pumps and motors can also use

natural gas produced on site as a source of their power. Electricity needs are discussed as follows from a hypothetical need that would potentially require the extension of high voltage transmission lines into the Rio Grande National Forest to develop the oil & gas resources within the SLVFO study area. The exact voltage needs per drill site required for pumping jacks that would pump oil and gas to the surface from the Niobrara Formation are difficult to quantify without knowing specific fluid level depths, site configurations, etc., but high voltage transmission lines would need to be added to the Rio Grande National Forest should wide-scale development occur.

Geothermal Electrical Needs

Geothermal energy production also requires electrical power needs to power to operate pumps, generators, separation facilities, etc. Geothermal energy plants, however, can generate electricity and send this energy back to the electrical grid. This is discussed further in Section 9.

6. Oil and Gas Occurrence Potential

6.1 RFDs Adjacent to SLVFO

Basin RFDs were reviewed for the areas surrounding the SLVFO study area including the neighboring San Juan and Paradox basins and the Raton and Dever basins. The period of investigation for the associated basin varies between 2005 to 2024 as follows, the dates of the most recent RFDs in the neighboring basins. Oil and gas production for Colorado portions of neighboring basins are reported for the period 2005 – 2024. 2025 production and production reports were not complete at the time this report was written so are not included. This assessment does not include the full production history of the neighboring basins. Oil and gas production data is included in the appendix and comes the ECMC. Production data from the New Mexico portion of the San Juan Basin comes from the values cited in the 2014 and 2025 RFDs (Engler et al.., 2014; Engler, 2025). Oil & gas production data is summarized by basins in tables in this section. The digital appendix also includes MS Excel files.

6.2 Oil & Gas Production by Basin

Raton Basin

The Raton basin in Colorado primarily produces natural gas from coal bed methane (CBM) reservoirs and virtually no oil. Natural gas production has declined 59% since 2005. This basin produced approximately 7.9% of all natural gas within Colorado but has dropped to only 2% as of 2024.

A total of approximately 4,316 bbl of oil was produced and 1,876,529,524 MCF (1,876.5 BCF) natural gas produced between 2005 through 2024. Oil production primarily came from the Niobrara Formation and Timpas Formation (not present within SLVFO). Roughly 85.3% of all natural gas production came from the Raton and Vermijo Formations which are CBM reservoirs and neither these formations nor CBM are known to be present within the SLVFO study area. Approximately 13.8% of natural gas was produced from the Dakota Formation, 2.7% from the Entrada Formation, and 0.01% from the Niobrara Formation. Natural gas production in the Raton Formation increased roughly by 20% whereas it decreased in the Vermijo (-90.1%), Dakota (-77.4%), and Entrada (-

64.0%) quite substantially. All three of these formations are present in the SLVFO area. Please see Table 8 for a summary of basin production.

Denver Basin, CO

The Denver basin in Colorado produces the overwhelming majority of oil and most gas within the State of Colorado. Oil and natural gas production have increased by a staggering 118-fold and 52-fold increase, respectively, since 2005! The Denver basin produced 97% of all crude oil and 55% of all natural gas within Colorado in 2024. This monumental increase is due to horizontal drilling and hydraulic fracturing in the Niobrara Formation, an unconventional oil & gas reservoir.

A total of approximately 1,825,577,260 bbl (1,825.6 MMbbl) of crude oil and 12,444,632,275 MCF (12.44 TCF) of natural gas has been produced in the Denver Basin since 2005. The Niobrara Formation and its members the Smoky Hills Chalk and Fort Hays Limestone account for the vast majority of both oil and natural production since 2005 with 67.9% and 62.6%, respectively. Co-mingled production from Carlile Shale and its member the Codell Sandstone along with the Niobrara Formation and its sub-members account for 24.9% oil production and 28.2% natural gas production since 2005. Other formations and their members account for the remaining production. The Dakota Sandstone which also present in the Denver basin and SLVFO area account for only 0.02% of oil production and 0.15% of gas production since 2005. Table 9 below summarizes the Denver Basin production.

San Juan Basin, CO

The San Juan basin in Colorado produces both oil and natural gas. Oil production has declined 72% since 2005 and natural gas production has declined 54% since 2005. This basin produced approximately 30% of all natural gas within Colorado in 2005 but has significantly declined to only 10% as of 2024. Formations present in both the San Juan basin and SLVFO area include the Dakota, Mesa Verde, and Mancos Formation.

A total of approximately 542,403 bbl (542.4 Mbbl) of oil was produced and 6,936,735,519 MCF (6,936.7 BCF) natural gas produced between 2005 through 2024. Most oil production, 57.7%, of all oil production came from the Dakota Formation but has decreased by 72.4% between 2005 and 2024. The Dakota Formation only produced 1% of the total volume of natural gas between 2005 and 2024 but also declined by 57.6% in this same time period. The Mesa Verde Formation produced 8.7% of total oil production and the Mancos Formation produced 3.2% of total oil production. Oil production in the Mesa Verde has declined by 56.4% whereas the production from the Mancos Formation has increased by 24.2% between 2005 and 2024. Nearly all natural gas production, 93.1%, came from the Fruitland Coal which is also a CBM reservoir and is not present in the SLVFO area. The Mesaverde Formation and Dakota Formation only accounted for a mere 4.4% and 1.0% of total gas production, respectively. The total natural gas production from the Mesaverde and Dakota declined by 47.9% and 57.6%, respectively, between 2005 and 2024. Natural gas production in the Mancos Formation increased drastically between 2005 and 2024. In 2024, the Mancos Formation gas production represented a 479-fold increase compared to 2005. Please see Table 10 for a summary of basin production.

San Juan Basin, NM

The San Juan basin in New Mexico produces both oil and gas from mostly unconventional reservoir types such as the Mancos Formation and Gallup Sandstone play where as conventional reservoir types such as the Dakota Formation and Mesaverde Group have decreased between 2005 and 2024. Total oil production and natural gas production from all reservoir types was 2.4 million bbl (2.4 MMbbl) and 1.0 TCF, respectively. Oil and gas production from all reservoir types increased to nearly 10 million bbl (10 MMbbl) whereas natural gas production declined to 0.47 TCF. In 2005, there was virtually no oil or gas production from the Mancos Formation and Gallup Sandstone but this has dramatically changed to approximately 9.2 million bbl (9.2 MMbbl), whereas formations such as the Dakota and others only accounted for approximately 0.8 million bbl (0.8 MMbbl) in 2024. Natural gas production from the Dakota Formation and Mesaverde Group has also declined appreciably since 2005.

Paradox Basin, CO

The Paradox basin primarily produces natural gas and a minor volume of oil. The basin's natural gas production has declined 23% while oil production declined 72% between 2005 and 2024. A total of 7,509,608,023 MCF (7,509.6 BCF) natural gas and 3,041,483 bbl (3,041.5 Mbbl) was produced between 2005 and 2024. 98.1% of the natural gas production came from the Leadville Formation which is not present in the SLVFO area. 64% of the oil production came from the Desert Creek Formation, 26% from the Ismay Formation (not present in SLVFO area). The Dakota Formation produced a mere 0.02% total production for the basin during this time. Table 11 summarizes this production.

Piceance Basin, CO

The Piceance basin in Colorado produces both oil and natural gas. Oil production has declined nearly 40% since 2005 whereas natural gas production has increased roughly 30% since 2005. This basin produced 21% of all natural gas within Colorado in 2005, doubling to 40% in 2013, and has decreased back to 19% as of 2024. The basin produced roughly 34% of all oil in Colorado in 2005 but has drastically decreased down to 2% in 2024. Formations present in both the Piceance Basin and SLVFO area include the Dakota, Niobrara, Mesa Verde, and Mancos Formation.

A total of approximately 122,176,397 bbl (122.18 MMbbl) of oil was produced and 12,063,337,828 MCF (12.06 TCF) natural gas produced between 2005 through 2024. Most oil production, 64.5%, of all oil production came from the Weber Formation but has decreased by 49% between 2005 and 2024. The vast majority of natural gas production, 89.8%, was produced from the Williams Fork Formation between 2005 and 2024. The Mancos Formation produced 2.3% of the total volume oil and 2.6% of natural gas between 2005 and 2024 but also declined by 43.1% and 22.7%, respectively, in this same time period. The Niobrara Formation produced 0.6% of oil and 1.2% of natural gas between 2005 and 2024 but has increased drastically during this same period by 24 and 1308 times, respectively. The Dakota Sandstone produced only 0.1% of il and 0.5% of natural between 2005 and 2024 and drastically decreased by 96.8% and 77.3% during this same period of time. Lastly, the Mesa Verde Formation produced only 0.07% of total oil production and 0.3% of total natural gas production from 2005 to 2024 and underwent declines of 69.5% and 65.6% during this period. Please see Table 12 for a summary of basin production.

7. Oil and Gas Development Potential

7.1 Adjacent Area RFDs and Potential Border Conflicts

The RFDs reviewed for the Raton, San Juan, Paradox, and Denver basins do not appear as though these producing basins would conflict with one another and cause border conflicts. The reasoning behind this is because these basins are separated by distances that greatly any exceed well spacing requirements and because the basins are separated by mountain ranges comprised largely of impermeable igneous and metamorphic rocks and are more than likely not hydraulically connected in the subsurface.

The Sangre de Cristo Mountains separate the SLVFO area from the Raton Basin. The nearest oil field and wells in the Raton Basin is the Sheep Mountain Field and although it is located 5 miles northeast of the SLVFO boundary, the nearest location with oil & gas potential is located on the San Luis Valley flood west of the Sangre de Cristo Mountains at a distance of 20 miles. This far exceeds well spacing requirements and leasing requirements with the ECMC.

The San Juan basin is largely separated by the San Juan Mountains. Although the San Juan Sag is present in both the SLVFO area and eastern San Juan Basin, the oil field boundaries and existing wells in the San Juan basin are such that it is not contiguous to the SLVFO area. The nearest oil field in the San Juan basin to the SLVFO is the Price Gramps Field, which is located 13 miles south, southwest of the SLVFO boundary. This distance is much farther than any allotted well spacing and leasing rules by the ECMC and therefore should not be an issue.

The Paradox basin is physically separated from the SLVFO area also not only by the San Juan Mountains but also the Sawatch Range. The nearest oil fields and oil & gas wells are located west of the Sawatch Range.

Lastly, the Denver basin and SLVFO area are separated by both the Sangre de Cristo Mountains and the Front Range. The nearest active field in the Denver Basin is located approximately 100 miles from the SLVFO area and it is too far to serve as any potential border conflict concern. In addition, Denver Basin oil fields and oil & gas wells are located east of the Front Range mountains.

7.2 Development Potential Map

Four areas are recognized as having some level of oil and gas development potential within the next 15-to-20-year times span as specified in document H-1624-1-Planning for Fluid Mineral Resources. Two areas are within the San Juan Sag basin and two are within the San Luis basin. By far the San Juan Sag basin has the greatest potential for activity is within the SLVFO. It is expected that large independent and major oil companies will be interested in this basin due to the magnitude of unconventional and conventional oil and gas potential. The San Luis basin plays are more poorly defined and therefore carry higher risk. It is expected that small independents, private parties and promoters willing to bare the higher risk will be interested in these plays.

The four play areas have been defined in Section 3 of this report. The justification for the classification of the oil and gas potential for each is as follows.

High Potential - Niobrara Formation Unconventional Play (San Juan Sag basin)

1) Source rock and maturation studies demonstrate the basin is actively generating hydrocarbons (Greis et al., 1997) and wells have oil and gas shows.

2) Average of 1.8% and maximum of 3.11% TOC (total organic carbon) from 37 samples (Greis et al., 1997).

3) Extensive unconventional development in San Juan and Denver-Julesburg basins.

4) Review of existing 2D and 3D seismic data shows that data quality in the basin (outside of volcanic calderas) is suitable for defining structure, guiding horizontal completions and rock physics mapping.

5) The Niobrara is interpreted to be within the prime oil generating depth window over a 465 square mile area and suggests hundreds of millions of net equivalent barrels of potential. The magnitude of this potential will attract attention.

Medium Potential – Dakota and Other Sands Conventional Development Play (San Juan Sag basin)

1) Over 3,800 feet of Mancos and Niobrara source rock at various maturation stages. Source rock studies demonstrate the basin is actively generating hydrocarbons (Greis et al., 1997) and wells have oil and gas shows.

2) Dakota Sandstone and other proven reservoirs within a 1,293 square mile area that were subjected to compressional tectonism and then overprinted with tensional tectonism indicate a high potential for structural traps.

3) Review of existing 2D and 3D seismic data shows that data quality in the basin (outside of volcanic calderas) is suitable for defining structure, gas detection, and rock physics mapping. The Niobrara unconventional play will require acquisition of large 3D seismic surveys which will reveal the conventional structural targets.

4) Price Gramps Oil Field is located 13 miles from the southern end of the play and has estimated ultimate recovery of 7.2 million barrels of oil from the Dakota sandstone at a depth of 1,100 feet.

Low Potential – Baca Graben Conventional Development Play (San Luis basin)

1) Two wells reported oil and gas shows in unknown formations along the eastern edge of the Baca graben.

2) The Baca graben is believed to be more than 3,500 feet deeper than the total depth of well State Land Board 1-32 (API: 00306001) or at least 13,000 feet. The untested depths of the Baca graben could contain source rocks of Cretaceous through Pennsylvanian age that would explain the oil and gas shows.

3) Existing 2D seismic data confirms good seismic quality in the Baca graben area. Modern reprocessing of existing data will improve the imaging of the Baca graben and may reveal reflections consistent with potential source rocks of Cretaceous through Pennsylvanian age.

4) The Baca graben covers 883 square miles and has only had 7 well penetrations to date and only two of these are over 6,000 feet deep.

Very Low Potential – Alamosa Formation Biogenic Gas Development Play (San Luis basin)

1) Biogenic gas in water wells is well established within a 323 square mile area.

2) Reservoir quality rocks are abundant, but seals and traps are tenuous.

3) Shallow depths to targets means low drilling costs but, shallow depths mean the gas in the formation is at low pressure and gas volumes are close to the reservoir volume.

4) Quality of gas cannot exceed 1,000 Btu. If inert gases are present the gas quality could be significantly less than 1,000 Btu.

8. RFD Baseline Scenario Assumptions and Discussion

Figure 28 illustrates the oil & gas development scenarios. It also shows the location of where land slopes are greater than 30%. Land development on slopes ≥ 30° offer both economic challenges in addition to posing greater risk of land erosion. Typically development on these slopes ≥ 30° are prohibited by both the BLM and USFS. Portions of these high sloped areas could nevertheless be developed because of the clustering of 9 to 10 Niobrara Formation horizontal wells in areas less than 30°. The average 10,000 foot laterals of these horizontal wells allowing for strategic placement under surficial slopes ≥ 30° is possible to develop the resource.

8.1 Surface Disturbance Due to Oil and Gas Activity on All Lands

Land surface disturbance has been estimated by review of surface impacts presented in the RFDs of the San Juan Basin, Paradox Basin, Raton Basin, and Denver Basin. In addition, well pad size has also been evaluated from ECMC Form 45 data which provides well pad size footprints and access road footprints in GIS shapefiles where the vast majority of this data comes from the Denver Basin and horizontal wells completed in Niobrara Formation and associated members (ECMC, 2026). Land disturbance estimates are broken down by well pads and access roads. The land disturbance associated with the construction of new oil & gas transmission pipelines.

8.2 Well Pad Size Estimates

Modern well pad construction practice accommodates multiple oil and gas wells on a single well pad location vs. single wells on single well pads and is especially useful in modern horizontal well drilling practice and unconventional reservoirs. This practice is used to occupy the least amount of land therefore minimize environmental impacts (DOE, 2016).

The estimated size of the well pads in the neighboring basins varies as follows. A summary of these well pad sizes are shown in Table 13. Well pads were determined to be roughly 1.5 acres per single well in the CO portion of San Juan Basin (Gault Group, Inc., 2006) and are for wells completed in conventional reservoirs (unspecified formations of completion). These well pad sizes were updated to vary in size by 2.5 acres per well to 3 acres for two wells (1.5 acres/well) across the CO portions of the San Juan and Paradox Basins (BLM San Juan Public Lands Office, 2009) and are mostly

focused on wells completed in the Gothic Shale Gas play but were also noted be a good representation for well pads in general in these basins and (unspecified which formations of completion). The estimated size of well pads in the NM portion of San Juan Basin are 7.1 acres with four wells (1.8 acres/well) where nearly all wells are horizontal wells completed in the Mancos and Gallup Group Plays (Engler et al.., 2025) Lastly, the size of well pads in the Denver Basin were determined to be 9.8 acres which host an average of 11 wells per pad (ECMC, 2026), or 0.9 acres per well) and these horizontal wells are virtually all completed in the Niobrara Formation and its associated members. This assessment assumes a well pad size of 10 acres that can accommodate up to 11 wells by comparison to a typical well pad for Niobrara Formation and associated members in the Denver Basin.

8.3 Access Road Size Estimates

The size of access roads varies slightly by basin. The size of the individual well pads from the CO portions of the San Juan and Paradox Basins are reported to be 2.4 acres (BLM San Juan Public Lands Office, 2009). The size of individual access roads and pipelines from well pads were estimated to be 3.6 acres for the NM portion of the San Juan Basin (Engler et al.., 2025). The average size of access roads for wells in the Denver Basin was determined to 1.8 acres per well pad (ECMC, 2026). This assessment assumes an access road impact size of 2 acres per well pad by comparison to a typical well pad for Niobrara Formation and associated members in the Denver Basin.

8.4 Facility Piping Footprint Estimates

The RFDs evaluated for this report appear to assume 1 acre of land disturbance for all flow lines and gathering lines for each well pad. This assessment assumes a facility piping impact size of one acre per well pad.

8.5 New Electrical Line Impact

As previously stated, additional electrical transmission lines would likely be needed should large scale commercial oil & gas development occur in the SLVFO. The quantification and layout of such electrical lines is beyond the scope of this study.

8.6 New Oil & Gas Pipelines

There are no oil or gas transmission lines within the SLVFO. Should future large-scale development of oil & gas resources occur within the SLVFO, oil and gas transmission lines would likely be needed and routed to nearby refineries as previously discussed in Section 5. Oil and gas transmission line routing and land impact quantification are beyond the scope of this study. It should be noted however that oil production has decreased over the past 20 years in the San Juan, Piceance, and Denver Basins where existing oil transmission lines are present. It might be possible that any new oil transmission line(s) could be routed to these facilities should they have sufficient operational integrity. Similarly, gas production in the San Juan, Paradox, and Raton Basins have decreased over the past 20 years. It might also be possible that any new gas transmission line(s) could be routed to these existing facilities should they have sufficient operational integrity.

8.7 Realistic Estimate of Wells and Land Impacts for 20 Years

Determining the actual number of oil & gas wells that will be drilled over the next 20 years is purely a best estimate based on numerous factors such as the actual drilling history that has occurred within the SLVFO, oil & gas occurrence potential rankings, and other factors including the presence of existing geologic and subsurface data. While other factors including the accurate prediction of future pricing of crude oil over the next 20 years is impossible, the EIA projects that crude oil demand will only slightly decrease from today's levels (EIA, 2026). These factors have been carefully considered in the following estimate.

SLVFO Drilling History and Average Wells Drilled Per Year

The SLVFO has only seen a total of 38 oil & gas wells drilled between 1910 through 2025 and no economic oil & gas discoveries have been made to date. This equates to a mere 0.33 wells per year, or rather an average of 7 wells drilled every 20 years. The most recent drilling history spanning from 2005 through 2025 only saw one well drilled in this period, or an average of 0.05 well per year, or 1 well drilled per 20 years. Overall, this existing drilling history is one of the most weighted elements in estimating the realistic number of oil & gas wells that will be drilled over the next 20 years.

Well Density and Seismic Data

Subsurface data is especially important to any future exploration work. Any exploration efforts would likely focus on the areas where the greatest number of wells have been drilled in addition to the presence of any seismic data. Most drilling activity over the past 40 years has occurred near the Del Norte area and it is reasonable to assume that any exploration would likely also include this area. In addition, although a fair amount of 2D seismic surveys have been performed across the San Luis Valley, the only 3D seismic surveys thus far have been performed around the Del Norte area. It would be fair to assume that future exploration work would likely also include this area.

Oil & Gas Well Type and Well Pad Size

The authors of study estimate that the most likely target formation of any future oil & gas development would be the Niobrara Formation and the Denver Basin serves as a logical comparison. The wells that would be completed in the Niobrara Formation correspond to the high oil and gas potential area. Wells completed in conventional formations such as the Dakota Sandstone and Mancos Formation correspond to the medium oil and gas potential area. Because the U.S. oil & gas industry focuses almost exclusively on unconventional reservoir development, it is less likely that these wells would be drilled.

Wells completed in the Niobrara Formation (high oil and gas potential area) and its associated members are drilled horizontally and are hydraulically fractured. The average horizontal length of these wells is approximately 10,000 feet (Section 3). Although up to 11 wells have been placed on well pads in the Denver Basin, a conservative value of 8 wells per pad is estimated. Based on the average horizontal lateral length of 10,000 feet and 8 wells per single well pad, these groups of wells are estimated to occupy four standard 640 acre-sections, or 2,560 acres. Since horizontal well laterals often exceed 10,000 feet in the Denver Basin, a second scenario is considered where wells

with 15,000 foot laterals with up to 8 wells per well pad. In this scenario, these longer laterals would cover up to six standard sections, or 3,840 acres.

Wells completed in conventional reservoirs such as the Dakota Sandstone or Mancos Formation (medium oil and gas potential area) are assumed to be vertically and or directionally. In this case, well spacing based on the spacing observed for the Dakota Sandstone and Mancos Formation in the San Juan basin. In this case, a conservative value of 4 wells on a 640 acre unit, or 160 acres/well is assumed.

High Oil & Gas Potential Area

The number of wells that would be drilled in the high oil & gas potential area is done through a probabilistic approach. A 90% probability is assumed for the high oil & gas potential area.

Medium Oil & Gas Potential Area

The number of wells that would be drilled in the high oil & gas potential area is done through a probabilistic approach. A 50% probability is assumed for the medium oil and gas potential area. Because most oil and gas wells drilled today are targeting unconventional reservoirs, an additional multiplication factor is applied. As previously stated, approximately, 94% of oil production and 92% of natural gas production in the lower 48 states came from horizontal wells (EIA, 2024). Since approximately 90% of today's U.S. oil and gas production comes from horizontal wells, it is assumed that 90% of these wells are targeting unconventional reservoirs and 10% of these wells are targeting conventional reservoirs. Therefore, 10% is multiplied by the above 50% probability.

Low and Very Low Oil & Gas Potential Areas

The number of wells that would be drilled in the low and very oil & gas potential areas are also done through a probabilistic approach and consideration of the federal land types within these areas. A 10% probability is assumed for the low oil & gas potential area and 1% in the very low oil & gas potential area. Because both the low and very low oil & gas potential areas have such a small amount of federal lands, no oil & gas wells are assumed to be drilled in either of these areas over the next 20 years.

Oil & Gas Wells and Impact Area Estimate

The oil & gas well and impact area assessment is calculated in Table 14. This table includes three specific areas in which oil & gas development activity is most likely to occur over the next 20 years. These areas are discussed as follows.

The authors of this study estimate that the most likely location that would undergo additional oil & gas exploration and development would focus around the Del Norte area where 3D seismic surveys have been performed in the San Juan Sag basin. This existing 3D seismic survey area covers approximately 31,243 acres in total where 1,318 acres occur on BLM land in the high oil & gas potential area and 1,984 acres of BLM land within the medium oil & gas potential area. It is most likely that at least one additional well pad would be developed, and the authors assume it would be approximately up to 13 acres total which would accommodate the well pad, access roads, piping, and facilities. The authors of the study estimate that it is most likely that wells would be completed in the Niobrara Formation and that up to 4 oil & gas wells drilled over the next 20 years. The

discovery of economic oil & gas in these wells in the SLVFO would change everything and lead to expanded oil & gas development in the SLVFO in the high and medium oil & gas potential areas.

The number of wells and land impacts for the high oil & gas potential area are shown in Table 14 and are presented as the estimated maximum development potential. The authors do not believe this scenario will occur in the next 20 years, but is rather presented for demonstration purposes. The high oil & gas potential area has 254,326 acres of BLM land and USFS land with slopes ≤ 30°. Horizontal wells with 10,000 foot laterals would yield an estimated 712 wells and 1,139 total acres of land impact for well pads, access roads, and facilities & piping. Horizontal wells with 15,000 foot laterals would yield an estimated 480 wells and 768 total acres impacted. Additional land impacts for electrical transmission lines and oil & gas transmission lines would also exist but are beyond the scope of this study.

The number of wells and land impacts for the medium oil & gas potential area are also shown in Table 14 and are presented as the estimated maximum development potential. The authors also do not believe this scenario will most likely occur in the next 20 years but is rather presented for demonstration purposes. The medium oil & gas potential area covers 480,947 acres of BLM land and USFS land with slopes ≤ 30°. However, 87,816 acres of wilderness land also occupy this area making the total potential developable area 393,131 acres. This would include an estimated 246 wells and 554 acres of land impact for well pads, access roads, and facilities & piping. Additional land impacts for electrical transmission lines and oil & gas transmission lines would also exist but are also beyond the scope of this study.

9. Geothermal Energy Potential

This section focuses on the existing geothermal resources within the SLVFO area and potential direct use of geothermal resources and potential power production from geothermal resources. This section does not evaluate the use of passive geothermal uses such as heat pumps that can be applied to building heating and cooling systems because such systems can be applied everywhere regardless of the presence of geothermal resources.

Elevated heat flow, high geothermal gradients, and widespread thermal manifestations indicate geothermal potential within the SLVFO. A variety of low temperature geothermal resources exist within the SLVFO such as naturally occurring hot springs (thermal springs) in addition to the utilization of higher temperature geothermal waters from shallow depth wells that are applied to a variety of aquaculture and recreational bathing spas. The greatest geothermal resources are those that have not yet been developed including the subsurface heat which may offer the potential for electrical power generation.

9.1 Geothermal and Potential Electricity Production

The potential to generate electricity from geothermal resources depends on many factors including the resource temperature, the amount of power that could be produced from the resource, and the proximity to consumers of power / electricity.

Electricity Consumption Projections

The EIA anticipates that total U.S. electricity consumption is only expected to grow from 2025 through 2050 (EIA, 2026). Namely, total electricity consumption in billion kilowatt-hours (kWh) is expected to grow by approximately 35% from a range of modeling cases including high electricity demand economic growth through low economic growth considerations (EIA, 2026). Figure 801 illustrates the EIA's total electricity consumption projections by all sectors.

A key area that the EIA has included in their 2026 Annual Energy Outlook looks at the role of commercial data centers and their electricity consumption. The EIA projects that electricity consumption by these commercial data centers is anticipated to drastically increase with estimates of approximately a 5-fold increase from the billion kWh of consumption than they used in 2025. Figure 29 illustrates the EIA's projections for electricity consumption from commercial data centers. Geothermal resources are one of renewable and clean energy sources that can supply the vast amount of power needed for these data center facilities. A new 150 MW geothermal plant and data center owned by Meta is currently being developed by XGS Energy approximately 200 miles south of the SLVFO in Los Lunas, New Mexico just north of Albuquerque, New Mexico (XGS, 2026) which shares the geologic basin of the Rio Grande Rift.

Power Production from Geothermal Energy

Geothermal heat can be converted to energy by transferring the heat of a geothermal resource through a turbine generator that generates electricity. A brief examination of the main types of geothermal power production are discussed as follows. In each type of power plant system, hot geothermal fluids are produced from a geothermal reservoir and pumped to the surface to generate steam, which is then sent though a turbine to generate electricity. Lastly, these geothermal fluids are collected at the surface and pumped back into the geothermal reservoir using injection wells at the surface. Figure 30 illustrates these different geothermal power plant types.

Dry Steam Power Plant

This type of system converts heat from the highest temperature geothermal resources (437 °F and above) to produce dry steam with no liquid water directly into a turbine at the surface to produce electricity (Teverra, 2024).

Flash Steam Power Plant

This system type produces a combination of superheated water and steam from geothermal reservoir temperatures above approximately 356 °F where produced liquid water is then sent to a separation vessel at the surface and flashed to steam which are then sent to a turbine to produce electricity (Morgan, 2024).

Binary Power Plant

This type of system uses geothermal reservoir temperatures below 356 °F where produced geothermal fluids are sent to a heat exchanger at the surface where it heats and vaporizes a secondary fluid with a boiling point lower than that of water which is then sent through a turbine to generate electricity (Morgan, 2024). Two variants of this system exist: one that uses organic chemicals as a secondary fluid (Rankine cycle system) and one that uses a mixture of ammonia and water (Kalina cycle system) (Morgan, 2024).

Limits to Drilling

In theory, the Earth's subsurface temperatures are high enough at any geographic surface location such that high temperatures could be used to generate power / electricity virtually at any location. The limitation is the depth to which these sufficiently high temperatures occur and can be reached within the technical and economical limits of drilling technology. Geothermal resources and heat sources at accessible depths are more commonly found in the mountainous regions of the western U.S. and areas associated with active volcanic activity. The general maximum depth of wells drilled in Colorado is 5 km (16,404 feet) (Teverra, 2024). Geothermal drilling technology and maximum achievable depth limits are expected to increase in the coming decades.

Low Temperature Geothermal Heat

For the purposes of power / electricity generation, low temperature geothermal resources are those temperatures from geothermal resources less than 302 °F (Taverra, 2024). It has been demonstrated that electricity production from geothermal resources in Colorado is technically possible at fluid temperatures above 190 °F from the Rocky Mountain Oil Field Testing Center (ORC) (Teverra, 2024). However, a temperature of 300 °F is considered the lower limit to for high temperature electricity generation such as flash steam, EGS, or CLG (Teverra, 2024).

Enhanced Geothermal Systems and Closed Loop Geothermal Systems

Enhanced or engineered geothermal systems (EGS) refers to a man-made reservoir created to increase the technical and economic success of a geothermal resource and is a dominant research area and development currently being funded by the U.S. DOE Geothermal Technologies Office (Teverra, 2024). Hydraulic fracturing is often applied to increase geothermal reservoir permeability where pre-existing fractures exist and allows fluids to better circulate through the fractures and transport heat to the surface and ultimately be used to generate electricity (Teverra, 2024).

Closed loop geothermal (CLG) are a type of EGS that is designed to circulate fluids within a closed loop wellbore and exchange heat through conduction of the surrounding bulk rock to the wellbore (Teverra, 2024). CLG systems allow for extracting heat from low-permeability formations in which the working fluid does not permeate the reservoir but requires high temperature rock formations for power production which only exist at significant drilling depths (Teverra, 2024). There is some debate as to whether CLG systems are a technically viable approach to power generation but are mentioned here regardless (Teverra, 2024).

9.2 Thermal Springs, Geothermal Water, and Uses

Some examples of thermal springs and wells utilized for geothermal water are briefly mentioned as follows. Tables in the Appendix contain a summary of the locations of these thermal springs and wells. These features are also included in Figures 32 and Figure 32.

Thermal Springs

There are many naturally occurring thermal springs documented within the SLVFO study area. Examples of these include Mineral Hot Springs and in Saguache County which have been documented to discharge low volumes of water (5 GPM and below) up to 140 °F as perennial springs (Morgan and Rogers, 2024). Another example are the Valley View Hot Springs also in

Saguache County which also flow perennially with discharge up to 100 GPM up to 99 °F (Morgan and Rogers, 2024).

Geothermal Water from Wells

A handful of water wells utilize higher temperature groundwater for recreational and aquaculture purposes. One example of this is The Sand Dunes Recreation hot spring pools in Hooper receive warm water ranging from 109 °F to 113 °F from a well depth of approximately 1,300 feet (TVD) (Morgan and Rogers, 2024). This well previously supplied warm water for cultivating catfish in the late 1970s (Coe, 1980). Examples of aquaculture include Colorado Gators Reptile Park which also historically utilized geothermal waters to cultivate Tilapia in the late 1970s (Coe, 1980) but expanded to an alligator and reptile refuge in 1980s (City of Alamosa, 2026). Another example of aquaculture utilizing geothermal waters is Colorado Catch, LLC in Conejos County which has cultivated striped bass for over 20 years (Colorado Catch, 2026).

9.3 Thermal Gradient, Heat Flow, and Depth to Temperature Maps

Geothermal energy potential is quantified through a variety of methods including by drilling with evaluation of subsurface thermal gradients, terrestrial heat flow mapping, and depth-temperature mapping. Such data and efforts have been performed extensively by Southern Methodist University (SMU), the National Laboratory of the Rockies (NLR), formerly the Renewable Energy Lab (NREL), and the Colorado Geological Survey (CGS). These agencies and data sources were evaluated in the following assessment.

Geothermal Gradient

The geothermal gradient within the SLVFO study area is presented in Figure 31 and is presented based on the evaluation performed by the CGS (Berkman and Watterson, 2010). The geothermal gradient is simply the natural temperature increase with increasing depth of the Earth. The geothermal gradient map by Berkman and Watterson (2010) was developed through the evaluation of subsurface temperature measurements in wells, namely oil & gas wells. The geothermal gradient in the SLVFO is non-homogeneous with areas of higher gradients in the San Juan Sag and portions of the northern and central San Luis Valley (Figure 30). Figure 32 also shows the two geothermal lease boundaries from the BLM with the first near the town of Creede and the second near the town of Villa Grove. These geothermal lease boundaries are inactive and closed.

Temperature and Depth

A map showing the depth to 212 °F is shown in Figure 32 and is based on the work by the CGS (Berkman and Watterson, 2010). The shallowest depths to 212 °F occur near Creede in the San Juan Sag at a depth of approximately 4,000 feet (TVD) and near Villa Grove in the San Luis Valley also at 4,000 feet (TVD). 212 °F is reached at approximately 5,000 feet (TVD) depths in the central portion of the study depths near the towns of Del Norte and Alamosa.

Figure 33 illustrates the depth to 302 °F within the SLVFO study area, where temperatures above 300 °F are believed to be the realistic minimum for high temperature geothermal power production as previously noted. 14 of the 38 oil & gas drilled within the SLVFO included a temperature log. The depth to 302 °F for these wells was determined using corrected geothermal gradients from and

corrected bottomhole temperatures available in Appendix D (Morgan, 2024) of the Geothermal in Colorado: Resources, Use Strategies, and Impact Considerations Report (ECMC; CGS; Teverra, 2024). Apparent temperatures of 302 °F at or below 10,000 feet appear to be localized in a few locations of the SLVFO both on federal and non-federal lands in the SLVFO.

9.4 Geothermal Supply Curve Estimates

Researches at the National Renewable Energy Laboratory (NREL) and National Laboratory of the Rockies (NRL) developed what is known as the Renewable Energy Potential (reV) model which evaluates solar power potential, wind energy potential, and most recently geothermal energy potential across the U.S. The model evaluates geothermal energy potential through what are referred to as supply curves (NREL, 2023). These supply curves look at energy capacity (MW), energy generation (MWh), the levelized cost of energy (LCOE), the levelized cost of transmission (LCOT), and other information for each reV site (NREL, 2023).

The model is quite sophisticated and it evaluates potential geothermal energy at varying subsurface depths under a number of factors including the following. Specifically, the geothermal supply curves have accounted for resource depth, geothermal plant type, drilling costs per well, geothermal plant efficiency, etc. among many factors (NREL, 2024). The model also accounts for land development type and excludes areas that prohibit land occupancy such as steeply sloped areas and environmentally sensitive land types (NREL, 2024).

An online tool called the Geothermal Energy Atlas was also developed by the NRL that includes potential power at varying depths of 4 km, 5 km, 6 km, and 7 km (NRL, 2026). Figure 33 also illustrates the reV model supply curves at a depth of 5 km (16,400 feet) in terms of energy capacity for the SLVFO study area for an EGS, binary system type. The average energy capacity across the SLVFO at a depth of 16,400 feet varies greatly by location from 0.5 MW to over 700 MW. The highest geothermal energy capacity appears to be toward the center of the SLVFO in the San Luis Valley and also in Costilla County. In terms of federal land, the highest apparent geothermal energy capacity is located near the town of Villa Grove in Saguache, County. Additional averages are provided for the high, medium, and low geothermal energy potential in Section 9.6.

9.5 Economic, Permitting, and Other Incentives

The State of Colorado recently formed an inter-state compact for geothermal energy development with Arizona, Utah and Nevada called the “Mountain West Geothermal Consortium” (Cleantechnica, 2026). The objective of this consortium is to align regulatory policies across states in order to help streamline the permitting process. In addition, the BLM recently approved a categorical exemption for geothermal energy exploration which allows for small-scale exploration disturbances up to 10 acres (BLM, 2026). This categorical exclusion supports the goals of Executive Order 14156, in the “Declaring a National Emergency” for U.S. domestic energy development and supports the current focus in an all of the above approach to developing the U.S. energy supply. These actions serve to signal to business that both the state of Colorado and BLM are welcoming of geothermal energy development.

9.6 Geothermal Reasonable Foreseeable Development Scenario and Land Impacts

Geothermal Energy Potential

The geothermal energy potential was evaluated across the SLVFO using the BLM planning document H – 1624-1 (2013). Additional considerations such as the depth to 302 °F and energy curves at 5 km (16,400 feet) were also evaluated as part of the occurrence potential. The geothermal energy potential is broken down into high, medium, and low potential areas and are shown in Figure 34. Table 15 summarizes the geothermal energy potential by area.

High Potential

The high geothermal energy potential area correlates to the San Luis Valley in addition to foothills of the Sangre de Cristo Mountains including areas such as the locations of known thermal springs such as the Mineral Hot Springs. A 90% probability is assumed for actual geothermal development in the next 20 years.

Medium Potential

Medium geothermal energy potential areas occur within the San Juan Sag and represents only a small area overall. A 50% probability is assumed for actual geothermal development in the next 20 years. However, given the small number of geothermal power plants in the U.S., development is assumed to only occur in the highest of potential areas and no geothermal development is expected to occur in these areas in the next 20 years.

Low Potential

Low geothermal energy potential area represents slightly more than half of the SLVFO and covers most of the San Juan Sag in addition to the Sangre de Cristo Mountains. Geothermal energy development is not expected to occur in the low potential area in the next 20 years.

Development and Land Impact

The developmental impacts to land that would occur at a geothermal energy plant (EGS) site would include similar elements to oil & gas development. These would also include land impacts from well pads, access roads, land for piping & facilities, and power plants.

A representative average of site size for geothermal power plant sites is approximately 1 to 8 acres per MW (Massetti et al., 2017) of development, or 4.5 acres per MW. However, EGS sites typically occupy 1 to 3 acres per MW (Eureka, 2026), or roughly 2 acres per MW.

The total estimated land impact on federal land is estimated to be up to 644 acres. Given that geothermal energy development and EGS sites in particular are currently in their infancy, only one site would be expected to be developed, if any at all. Furthermore, the geothermal energy potential at the depth of 16,400 feet assumes the full energy potential. Equipment efficiencies would further decrease the energy extraction potential and therefore decrease the land impact size even further.

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TABLES

Table 1, Land Type by Management Agency, SLVFO Area

Land Type / Management Agency	Acreage	% of SLVFO Area
BLM / Federal	75,515	1.6%
LOCAL / State of Colorado & Local Agencies	18,013	0.4%
NPS / Federal	16,261	0.3%
Wilderness Land on NPS / Federal	73,176	1.5%
Net* NPS / Federal	-56,915	-1.2%
PRI / State of Colorado & Local Agencies	3,510,282	72.6%
STA / State of Colorado	4,096	0.1%
USFS + USFS_LU / Federal	1,195,168	24.7%
Wilderness on USFS / Federal	393,634	8.1%
Net* USFS + USFS_LU / Federal	801,534	16.6%
USFW / Federal	13,567	0.3%
	4,832,901	100.0%

Explanation:

BLM: Bureau of Land Management

PRI: Private Land

STA: State Lands

USFS: United States Forest Service

USFS_LU: United States Forest Service, Land Use

USFW: United Stated Fish & Wildlife Service

Wilderness: Land off limits to mineral leasing

Net*: Acreage - Wilderness. Not double counted.

Table 2, Target Formation Unit and Well Spacing

Formation	Well Type	Basin	State	Unit Spacing (Acres)	Wells / Unit	Well Spacing (Well/Acre)	Infill Well Spacing / Dense (Well/Acre)
Dakota Sandstone	Vertical	San Juan	CO	640	4	160	-
		San Juan	NM	160	1	160	80
		Raton	CO	160	1	160	-
		Raton	CO	320	1	320	-
		Raton	*CO*	*240*	*1*	*240*	-
		Denver	CO	320	1	320	40
Mancos Formation	Horizontal	San Juan	CO	1,280	8	160	-
		San Juan	CO	5,088	33	154	-
		San Juan	CO	1,160	13	89	-
		San Juan	*CO*	*2,509*	*18*	*134*	-
		San Juan	NM	40	1	40	-
		San Juan	NM	40	4	10	-
Niobrara	Horizontal	Denver	CO	8,750	71	123	-
				640	1	640	-
				640	24	27	-
				3,343	*40*	*263*	-

Explanation

Values in *italics* represent an average value.

Table 3, Hydraulic Fracturing Treatment Average Water Volume for Selected Formations in Neighboring Basins (Frac Focus, 2026)

Target Formation	Basin	State	Hydraulic Fracturing Treatment Water Volume, Average		
			(gal)	(bbl)	(Acre-ft)
Dakota Sandstone	Piceance	CO	422,901	10,069	1.30
	San Juan	CO	113,531	2,703	0.35
Mancos Formation	Piceance	CO	6,783,903	161,522	20.82
	San Juan	CO	22,634,577	538,919	69.46
Niobrara Formation	Piceance	CO	12,369,320	294,508	37.96
	Denver	CO	6,841,519	162,893	21.00

Table 4, API Gravity of Oils, Target Formations

Target Formation	Basin	State	API Gravity (API°)	Approx. Depth (ft, TVD)
Dakota Sandstone	Piceance	CO	45	9,500
	San Juan	CO	36	7,300
Mancos Formation	Piceance	CO	46	10,000
	San Juan	CO	32	2,600
Niobrara Formation	Piceance	CO	48	11,500
	Denver	CO	50	7,100

Table 5, Produced Water TDS of Selected Formations in Neighboring Basins. USGS Produced Water Database (2021)

Basin	State	Counties	Formation	Avg. Sample Depth (ft)	TDS, Avg. (mg/L)	# Wells
Denver	CO	Adams, Boulder, Weld	Niobrara	7,135	20,856	5
Piceance	CO	Garfield, Mesa, Rio Blanco	Dakota Sandstone	4,946	25,770	44
San Juan	CO	La Plata, Archuleta		7,338	13,298	9
San Juan	NM	San Juan, Rio Arriba, McKinley		5,930	28,894	78
Raton	CO	Huerfano		3,748	13,448	2
Piceance	CO	Rio Blanco	Mancos Formation	2,700	17,464	25
San Juan	CO	La Plata		2,618	10,800	1
San Juan	NM	San Juan, Rio Arriba		5,930	4,558	10
Paradox	CO	Montezuma		575	34,852	4

Explanation

Only showing samples with electrical charage balance of 0.0 or near-zero.

Table 6, Niobrara Formation Well, Denver Basin Hyperbolic Decline Characteristics. Adapted from EIA (2022).

State	Formation / Play	County	Initial Crude Oil Production Rate (bbl/day)	Initial Dry Natural Gas Production Rate (MCF/day)	Initial Decline Rate	Hyperbolic Parameter	Estimated Ultimate Recovery (EUR) of Crude Oil (Mbbl/well)	Estimated Ultimate Recovery (EUR) of Dry Natural Gas (MMcf/well)
CO	Niobrara-Codell	Adams	569	1,561	0.151	0.451	196	538
CO	Niobrara-Codell	Arapahoe	1,178	1,477	0.485	0.885	284	356
CO	Niobrara-Codell	Broomfield	818	2,137	0.125	0.239	249	651
CO	Niobrara-Codell	Weld	476	1,853	0.127	0.299	155	604
		Average	760	1,757	0.21*	0.55*	221	537

Explanation:

* Initial decline rate and hyperbolic parameter matching average EUR values for oil and natural gas.

Table 7, Refinery Distance to SLVFO

Refinery Owner	Refinery Location	SLVFO Centroid to Refinery Distance (miles)
Suncor Energy, Inc.	Commerce City, CO	164
Western Refining, Inc.	Gallup, NM	204
Valero Energy Corp.	Sunray, TX	256

Table 8, Raton Basin, CO Production Summary 2005 - 2024

Year	Oil (bbl)	Gas (MCF)	Water (bbl)
2005		106,392,785	135,074,510
2006		121,279,708	175,148,856
2007		137,495,815	159,926,306
2008		151,038,083	121,341,200
2009		148,200,064	108,441,271
2010	394	136,939,283	98,037,801
2011	868	126,288,366	76,656,242
2012	585	117,895,189	65,457,301
2013	1,196	108,292,341	59,301,864
2014	1,240	101,393,909	55,693,013
2015		93,025,382	45,874,940
2016	33	81,898,304	38,941,134
2017		76,578,983	38,397,759
2018		70,106,143	36,881,752
2019		57,615,715	31,783,885
2020		51,937,158	29,630,466
2021		49,528,471	32,281,051
2022		48,219,420	35,399,490
2023		49,102,594	34,189,012
2024		43,301,811	31,338,191
Total	4,316	1,876,529,524	1,409,796,044
% Δ 2005 - 2024	-	-59.3%	-76.8%

Oil Production % by Formation

Formation / Play, Reported Production	%	% Δ 2005 - 2024
Niobrara-Timpas	41.3%	-
Niobrara	37.2%	-
Timpas	15.1%	-
Apishapa	6.4%	-
	100.0%	

Gas Production % by Formation

Formation / Play, Reported Production	%	% Δ 2005 - 2024
Raton-Vermijo	34.0%	23.5%
Vermijo	31.9%	-90.1%
Raton	19.4%	20.9%
Dakota	11.1%	-77.4%
Entrada	2.7%	-64.0%
Others	0.9%	-
	100.0%	

Table 9, Denver Basin, CO Production Summary 2005 - 2024

Year	Oil (bbl)	Gas (MCF)	Water (bbl)
2005	15,491,395	237,833,605	53,287,745
2006	16,618,245	249,567,277	55,411,325
2007	17,851,149	254,795,312	56,314,990
2008	21,418,173	277,416,916	62,086,228
2009	22,069,475	279,064,759	57,942,506
2010	24,657,851	283,867,327	61,709,944
2011	30,784,767	304,077,287	68,565,214
2012	40,675,610	330,674,419	71,983,242
2013	58,014,797	363,321,596	74,990,342
2014	87,505,295	442,319,986	87,811,190
2015	114,687,780	597,566,699	93,488,082
2016	108,564,476	681,193,083	83,795,365
2017	123,045,940	710,655,074	99,008,173
2018	161,778,591	828,827,204	119,859,473
2019	184,549,662	1,018,104,119	129,712,424
2020	165,079,727	1,117,870,461	102,127,400
2021	148,443,542	1,090,790,102	108,218,150
2022	155,613,276	1,077,232,089	109,854,298
2023	161,685,426	1,109,497,557	110,462,120
2024	167,042,083	1,189,957,403	110,826,329
Total	1,825,577,260	12,444,632,275	1,717,454,540
% Δ 2005 - 2024	978.3%	400.3%	108.0%

Oil Production % by Formation

Formation / Play, Reported Production	%	% Δ 2005 - 2024
Niobrara & Members	67.9%	910435.3%
Niobrara & Members + Carlile Shale & Members	24.9%	485398.6%
Others	7.2%	-
Dakota Formation	0.02%	-97.8%
	100.0%	

Gas Production % by Formation

Formation / Play, Reported Production	%	% Δ 2005 - 2024
Niobrara & Members	62.6%	18397.9%
Niobrara & Members + Carlile Shale & Members	28.2%	262103.1%
Others	9.1%	-
Dakota Formation	0.15%	-99.9%
	100.0%	

Table 10, San Juan Basin, CO Production Summary 2005 - 2024

Year	Oil (bbl)	Gas (MCF)	Water (bbl)
2005	37,429	460,784,832	23,677,322
2006	36,883	445,042,056	24,763,331
2007	38,927	428,991,042	24,979,875
2008	40,675	433,870,223	23,725,327
2009	39,401	436,857,661	25,284,695
2010	36,457	434,104,008	32,397,890
2011	38,741	426,088,355	24,025,952
2012	37,034	406,508,086	23,913,608
2013	33,252	374,214,114	23,767,028
2014	32,227	349,780,327	22,957,813
2015	26,127	335,831,032	23,941,815
2016	19,976	316,281,058	23,385,951
2017	18,812	306,184,430	23,403,267
2018	18,261	311,825,474	20,422,963
2019	17,769	291,267,123	19,633,368
2020	17,355	262,619,191	17,205,689
2021	17,165	243,351,377	17,136,948
2022	14,875	231,336,585	17,307,189
2023	10,522	227,570,773	17,029,522
2024	10,515	214,227,772	15,414,786
Total	542,403	6,936,735,519	444,374,339
% Δ 2005 - 2024	-71.9%	-53.5%	-34.9%

Oil Production % by Formation

Formation / Play, Reported Production	%	% Δ 2005 - 2024
Dakota	57.7%	-72.4%
Gallup	20.8%	-77.6%
Mesa Verde	8.7%	-56.4%
Mancos Shale	3.2%	24.2%
Others	9.7%	-
	100.0%	

Gas Production % by Formation

Formation / Play, Reported Production	%	% Δ 2005 - 2024
Fruitland Coal	93.1%	-54.4%
Mesa Verde	4.4%	-47.9%
Dakota	1.0%	-57.6%
Others	1.5%	-
	100.0%	

Table 11, Paradox Basin, CO Production Summary 2005 - 2024

Year	Oil (bbl)	Gas (MCF)	Water (bbl)
2005	287,113	367,508,893	636,534
2006	309,713	381,961,174	744,639
2007	260,367	374,536,444	1,076,530
2008	237,868	369,435,631	1,191,875
2009	207,682	400,238,440	1,385,276
2010	183,744	261,056,876	1,653,921
2011	199,639	466,204,012	1,811,352
2012	185,373	451,244,254	739,578
2013	158,192	291,557,619	743,002
2014	131,558	372,819,174	990,676
2015	112,728	511,593,005	1,332,459
2016	99,815	439,151,798	1,599,478
2017	101,949	472,045,403	1,443,113
2018	89,618	425,687,276	967,302
2019	77,956	456,436,608	1,122,247
2020	67,026	303,103,073	589,412
2021	75,281	279,392,639	579,870
2022	86,330	309,371,465	1,048,619
2023	91,854	293,620,138	629,919
2024	77,677	282,644,101	796,707
Total	3,041,483	7,509,608,023	21,082,509
% Δ 2005 - 2024	-72.9%	-23.1%	25.2%

Oil Production % by Formation

Formation / Play, Reported Production	%	% Δ 2005 - 2024
Desert Creek	64%	-70.9%
Ismay	26%	-72.1%
Others	10.73%	-
Dakota	0.02%	-
	100.0%	

Gas Production % by Formation

Formation / Play, Reported Production	%	% Δ 2005 - 2024
Leadville	98.1%	-18.5%
Others	1.9%	-
	100.0%	

Table 12, Piceance Basin, CO Production Summary 2005 - 2024

Year	Oil (bbl)	Gas (MCF)	Water (bbl)
2005	6,636,995	319,071,882	109,542,892
2006	6,873,588	414,998,207	118,163,046
2007	7,419,323	527,910,111	127,217,001
2008	7,615,295	667,631,092	131,337,612
2009	7,386,547	723,601,885	141,558,362
2010	7,368,539	790,510,060	146,230,900
2011	7,516,711	824,479,750	151,054,151
2012	7,811,408	855,905,541	155,639,751
2013	6,949,419	767,770,825	153,428,980
2014	6,914,953	736,032,227	155,313,257
2015	6,220,677	648,693,478	151,644,136
2016	6,000,024	596,303,438	155,505,500
2017	5,402,281	586,349,243	136,277,934
2018	5,414,778	614,031,474	145,143,716
2019	5,186,874	606,918,654	140,378,227
2020	4,783,299	554,194,964	127,067,497
2021	4,223,742	505,629,109	113,205,955
2022	4,157,989	468,997,007	112,210,788
2023	4,296,433	440,005,900	117,963,977
2024	3,997,522	414,302,981	117,619,117
Total	122,176,397	12,063,337,828	2,706,502,799
% Δ 2005 - 2024	-39.8%	29.8%	7.4%

Oil Production % by Formation

Formation / Play, Reported Production	%	% Δ 2005 - 2024
Weber	64.5%	-49.0%
Williams Fork	27.7%	15.7%
Mancos	2.3%	-43.1%
Niobrara	0.6%	2392%
Dakota	0.1%	-96.8%
Mesa Verde	0.07%	-69.5%
Others	4.7%	-
	100.0%	

Gas Production % by Formation

Formation / Play, Reported Production	%	% Δ 2005 - 2024
Weber	0.1%	-99.5%
Williams Fork	89.8%	37.6%
Mancos	2.6%	-22.7%
Niobrara	1.2%	130822%
Dakota	0.5%	-77.3%
Mesa Verde	0.3%	-65.6%
Others	5.5%	-
	100.0%	

Table 13, Well Pad Size Estimates

Formation	Well Type	State	Basin[Refernce]	Average Well Pad Size (Acres)	Average Number of Wells per Pad	Average Well Pad Size / Number of Wells	Access Road Size (Acres)	Access Road Size (Acres)
Conventional, Unspecified	Unspecified	CO	San Juan[1]	1.5	1	1.5	-	-
Gothic Shale Gas Play	Unspecified	CO	San Juan, Paradox[2]	2.5	1	2.5	2.4	-
Gothic Shale Gas Play	Unspecified	CO	San Juan, Paradox[2]	3	2	1.5	2.4	-
Mancos & Gallup Plays	Horizontal	NM	San Juan[3]	7.1	4	1.8	-	3.6
Niobrara & Members	Horizontal	CO	Denver[4]	9.8	11	0.9	1.8	

Explanation

[1] Gault Group, Inc. (2006)

[2] BLM San Juan Public Lands Office (2009)

[3] Engler et. al (2025)

[4] CECMC, Form 45 GIS Data (2026)

Table 14, Estimated Number of Wells and Land Disturbance Impacts: High and Medium Oil and Gas Potential Areas

3D Seismic Area (Most Realistic Scenario): High Potential, Niobrara Formation

Land Type	Area, A1 (Acres)
3D Seismic Data	31,243
Non-Federal Land	27,941
Federal Land, High Potential	1,318
Federal Land, Med. Potenital	1,984
Net 3D Seismic Area	3,302

H Wells in Area (Acres)	Well Pads	Wells / Pad	# Wells	Well Pad Impact (Acres)	Access Road Impact Acres / Well Pad	Total Access Road Impact (Acres)	Piping Impact, Acres / Well Pad	Total Piping Impact (Acres)	Total Acre Impact Acres
1,280	1	4	4	10	2	2	1	1	13
2,560	1	4	4	10	2	2	1	1	13
3,840	1	4	4	10	2	2	1	1	13

High Oil & Gas Potential: Niobrara Formation (Commercial Discovery & Full Development)

Land Type	Area, A2 (Acres)
Total Area	297,402
Federal Land, Potenital	254,791
Federal Land, Raster	254,326
Wilderness Area	0
Net Developable Area	254,326

H Wells in Area (Acres)	Well Pads	Wells / Pad	# Wells	Well Pad Impact (Acres)	Access Road Impact Acres / Well Pad	Total Access Road Impact (Acres)	Piping Impact, Acres / Well Pad	Total Piping Impact (Acres)	Total Acre Impact Acres
2,560	89	8	712	890	2	160	1	89	1,139
3,840	60	8	480	600	2	108	1	60	768

Medium Oil & Gas Potential: Conventional Reservoirs (Commercial Discovery & Full Development)

Land Type	Area, A3 (Acres)
Total Area	530,980
Federal Land, Potenital	482,824
Federal Land, Raster	480,947
Wilderness Area	87,816
Net Developable Area	393,131

Well Spacing (Wells / Acre)	Well Pads	Wells / Pad	# Wells	Well Pad Impact (Acres)	Access Road Impact Acres / Well Pad	Total Access Road Impact (Acres)	Piping Impact, Acres / Well Pad	Total Piping Impact (Acres)	Total Acre Impact Acres
160	123	2	246	185	2	246	1	123	554

High potential occurrence assumes 90% probability and targets unconventional reservoirs.

Medium potential occurrence assumes 50% probability; 10% chance of wells targeting conventional reservoirs.

3D Seismic Area uses medium potential 50% probability

10,000 foot laterals: 8 wells per 4 sections, or 2,560 acres.

15,000 foot laterals: 8 wells per 6 sections, or 3,840 acres.

Table 15, Geothermal Energy Development Potential and Land Impacts

Geothermal Energy Potential	Total Area (Acres)	Federal Lands (BLM, USFS, USFW) (Acres)	Wilderness Area (Acres)	Net Area 30° (Acres)	Average Geothermal Energy Capacity (MW)	Estimated Land Impact (Acres)
High	1,853,344	348,744	-	348,744	358	644
Medium	261,836	158,367	-	158,367	156	0
Low	2,717,721	2,092,441	466,810	1,625,631	50	0

Explanation:

Average geothermal energy represents the energy from the power supply curves at 5km depth (16,400 feet).

High geothermal energy potential assumes a 90% probability of being developed.

Average land impact size for U.S. geothermal sites is approximately 4.5 acres/MW.

Average land impact size for EGS is approximately 2 acres/MW.

PLATES

FIGURES

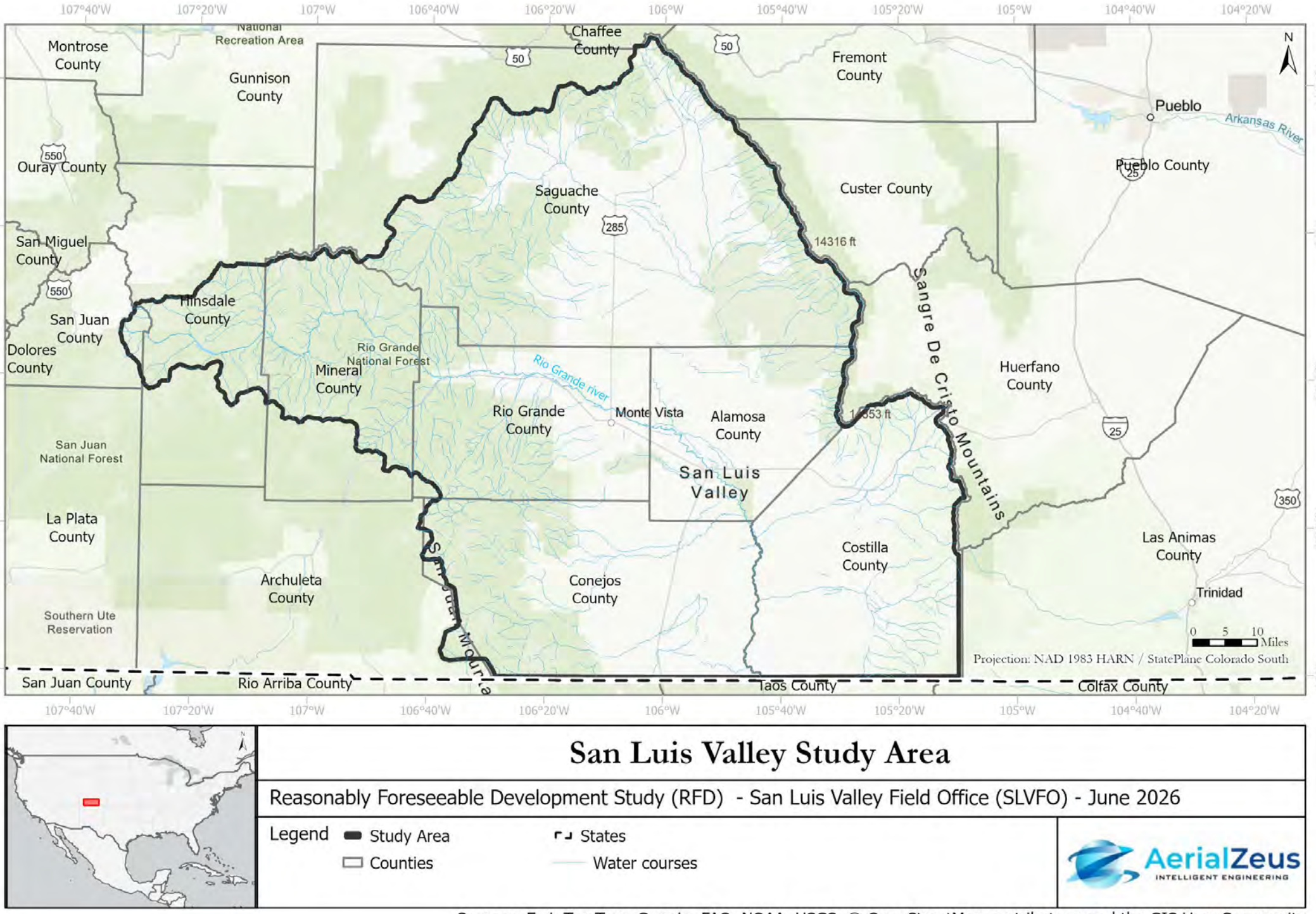


Figure 1, SLVFO Area Map

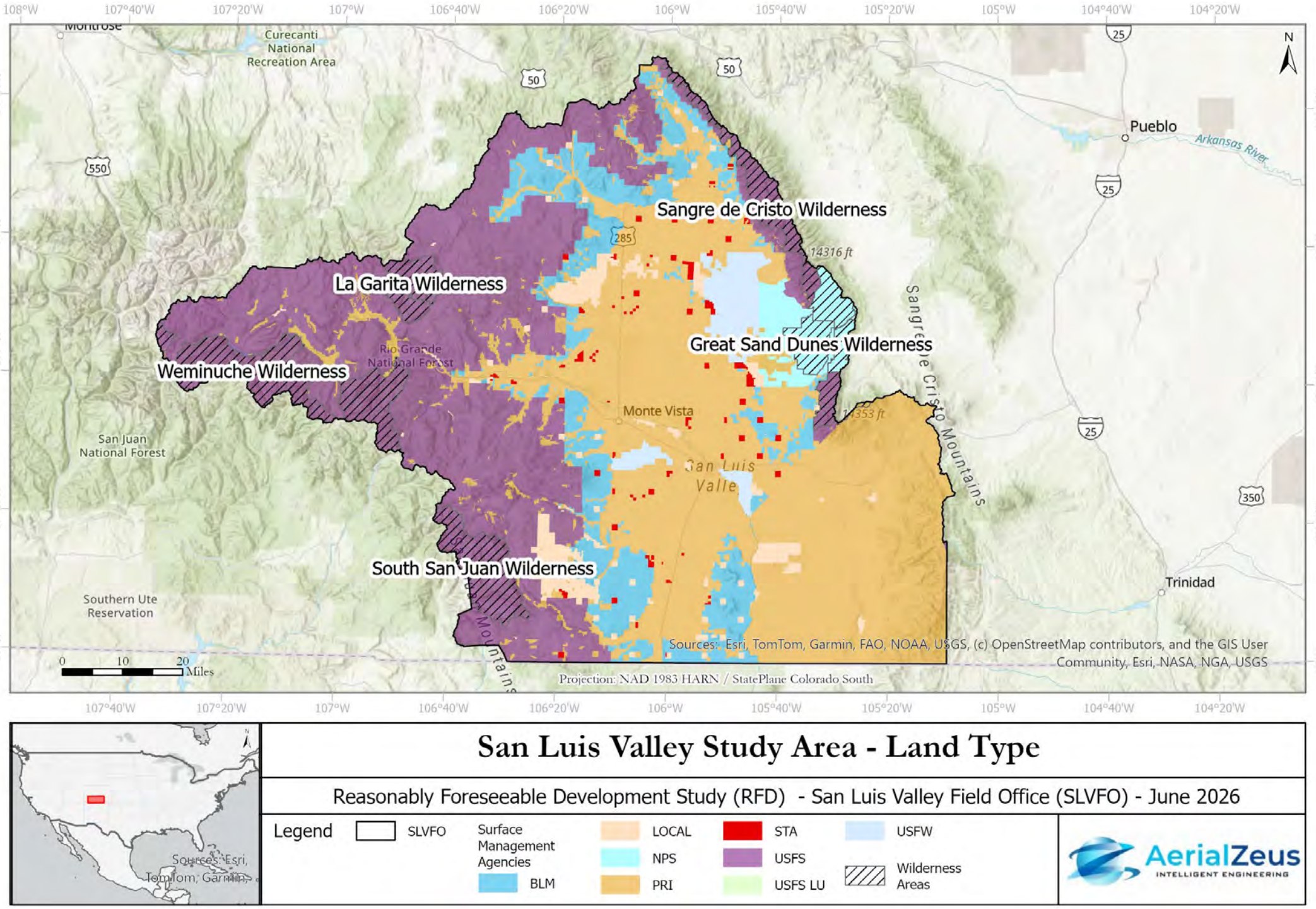
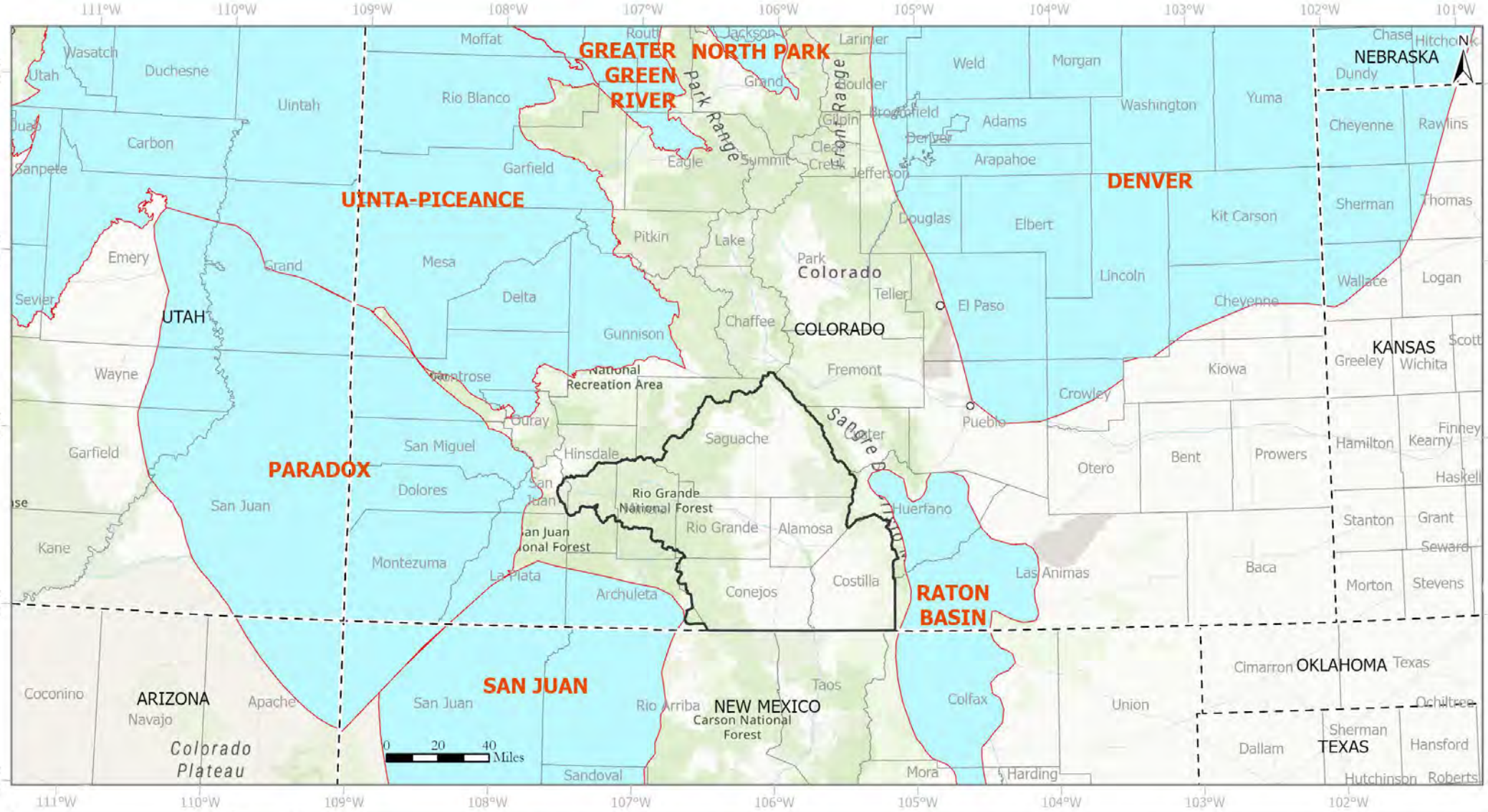


Figure 2, Land Types within SLVFO Area



San Luis Valley Study Area - Sedimentary Basins

Reasonably Foreseeable Development Study (RFD) - San Luis Valley Field Office (SLVFO) - June 2026

Legend

- Study Area
- Counties
- States
- Sedimentary Basins

Projection: NAD 1983 HARN / StatePlane Colorado South

AerialZeus INTELLIGENT ENGINEERING

Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, (c) OpenStreetMap contributors, and the GIS User Community, Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

Figure 3, Sedimentary Basin Producing Oil & Gas In Proximity to SLVFO Area

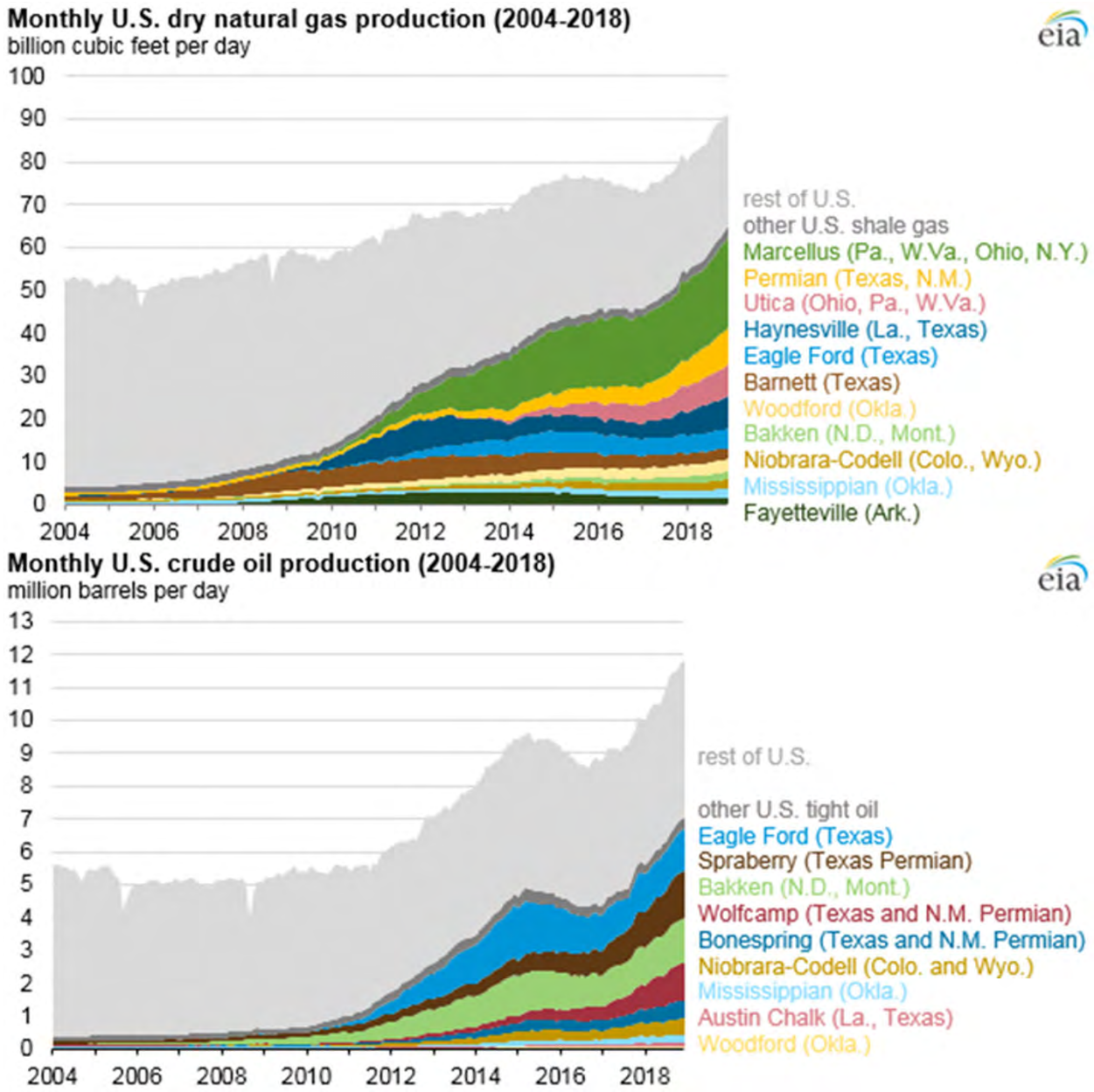


Figure 4, U.S. Dry Natural Gas and Oil Production vs. Time. (Adapted from EIA, 2019)

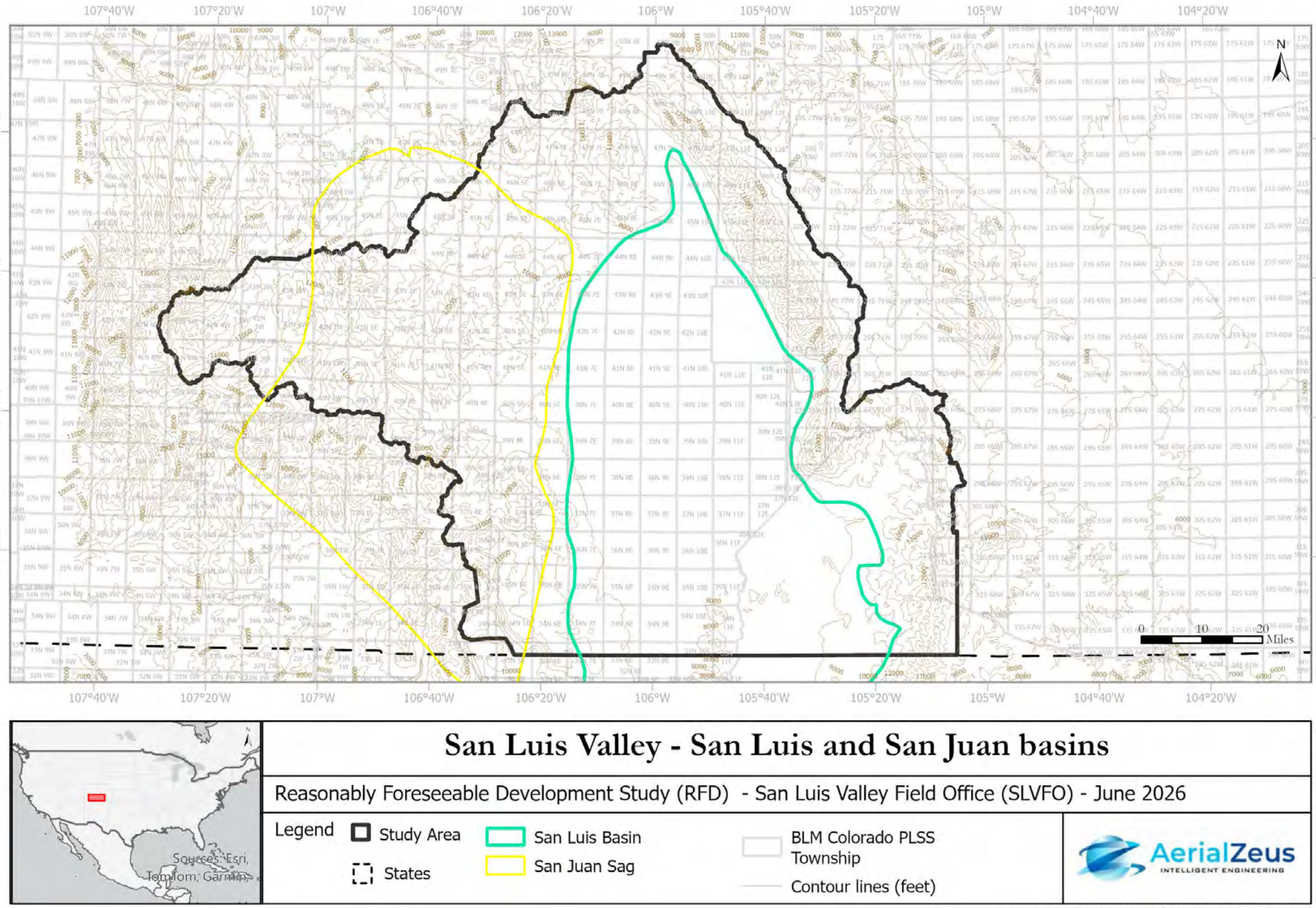


Figure 5, San Luis Valley and San Juan Sag Basins Map as Defined by MS-33 (2002)

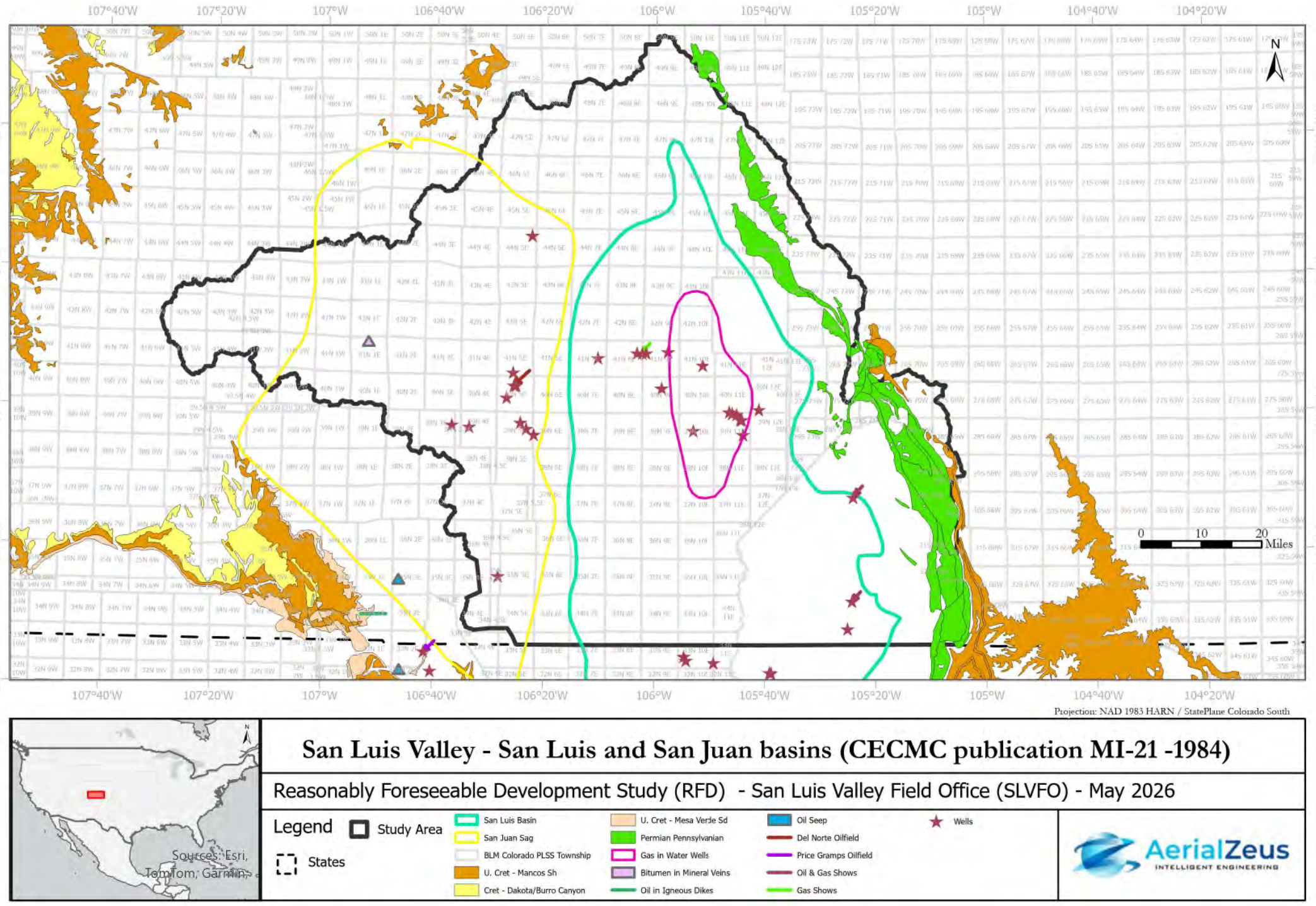


Figure 6, San Luis Valley and San Juan Sag Basins: Source Rock Outcroppings Map

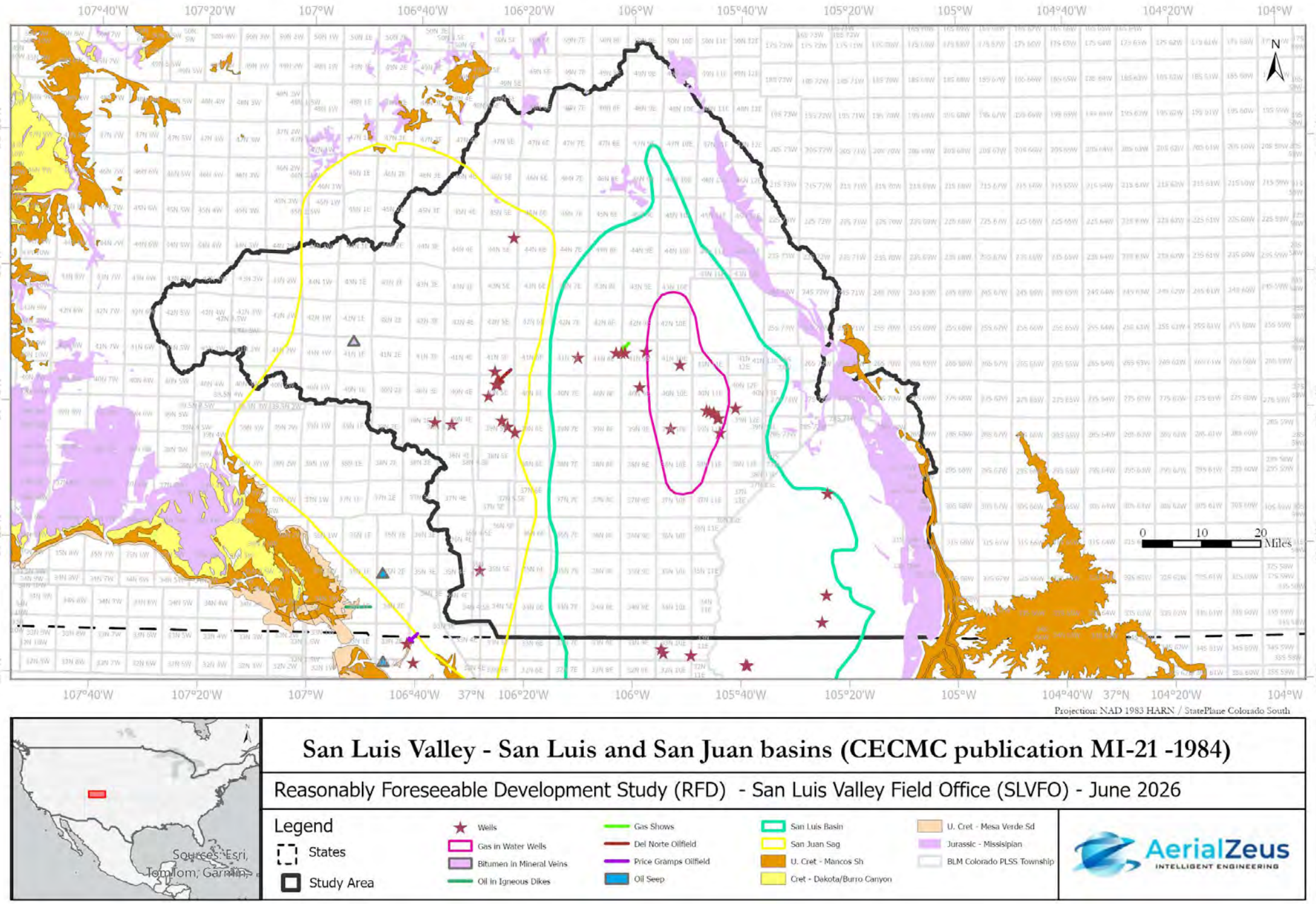


Figure 7, Oil & Gas Source Rock and Reservoir Rock Outcroppings and Volcanic Calderas

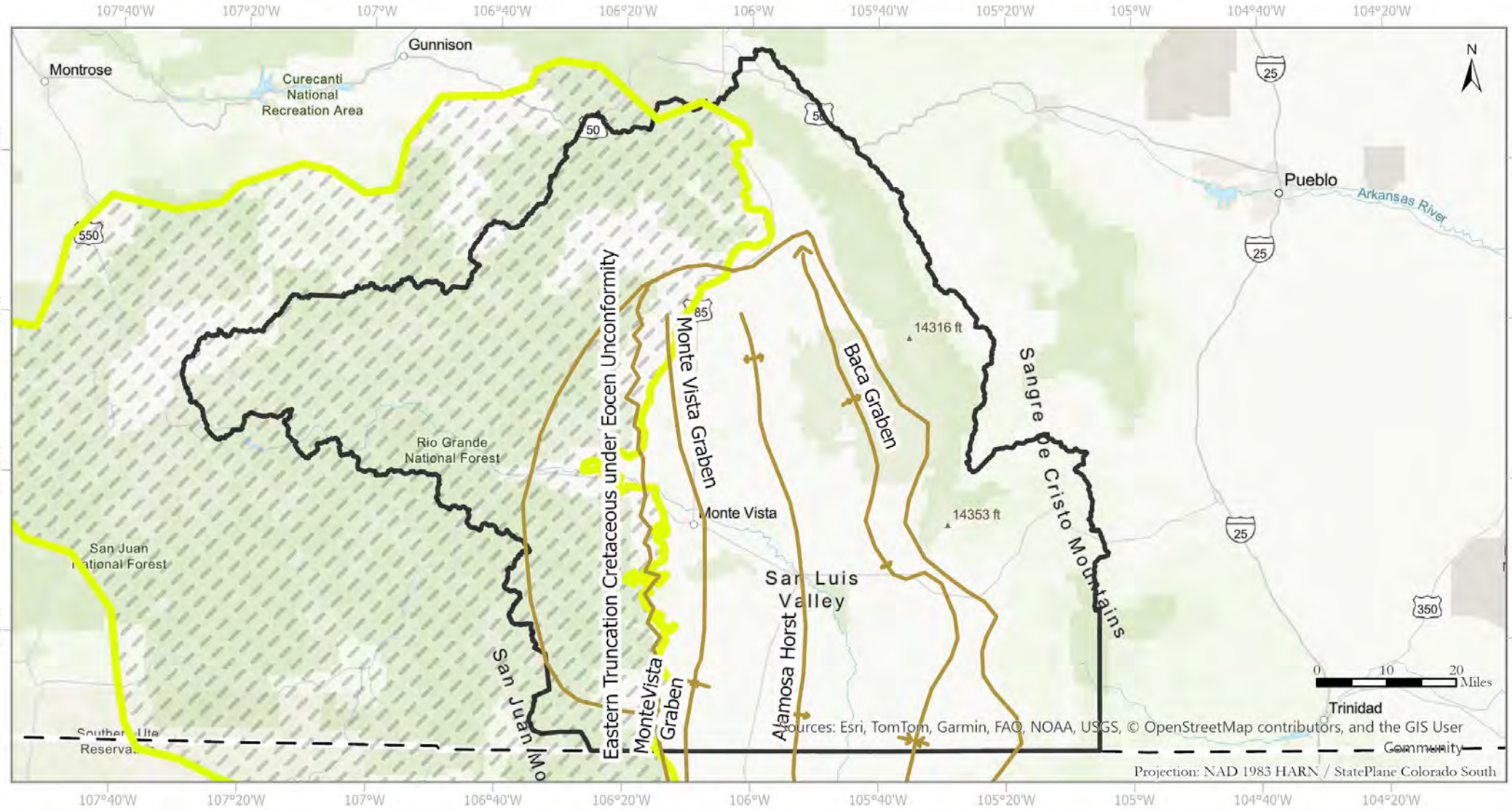


Figure 8, Map of San Luis Basin and San Juan Sag with Structural Axes

San Luis Valley

Period	Phase	Stratigraphic Unit	Unit Thickness (ft)	Physical Characteristics	Hydrogeologic Unit	Hydrologic Characteristics
Quaternary	Modern-Glaciation	Alluvium	0-120??	Well to poorly-sorted, uncemented sands, silts and gravels along modern streams and as valley-fill	Unconfined Aquifer RGDSS Layer 1	
		Eolian sand	0-400??	Well-sorted sands forming active and stabilized dunes		
		Alluvial fans		Poorly-sorted, rounded to sub-angular gravels, sands and silt fanning out into the valley where streams leave the mountains; four levels of fans are recognized with the youngest at stream level, a second 2-12 feet above modern stream level, a third as moderately dissected terraces about 40 feet above modern stream levels and a fourth as strongly dissected terraces 69-90 feet above modern stream level that can have a caliche layer near the surface		
Neogene	Extension	Alamosa Formation	0-2,000	Interbedded, discontinuous blue, gray and green clays and dark sands; sands are dominantly fine-grained; uppermost clay divides valley into upper unconfined aquifer and lower confined aquifer	Uppermmost clay	
					Confined Aquifer RGDSS Layer 2	Confined aquifer is that below the uppermost clay layer in the Alamosa Formation
		Servilleta Basalt	0-660	Thin flows of tholeitic basalt, vuggy, and local vesicle pipes at the top of the Santa Fe Formation and Los Pinos Formation in southern part of the valley		
		Santa Fe Formation	>5,800	Variegated tan, pink, buff, orange to brick-red maroon claystone, siltstone, and poorly-sorted sandstone and conglomerate, with interbedded volcanic flows of the San Juan Mountains and Taos Plateau; top of the unit is dominantly conglomerate and sandstone, while bottom is dominantly siltstone and shale; deposits are cross-bedded and channel cut	Confined Aquifer RGDSS Layer 3	Interbedded volcanic flows have different aquifer characteristics from the valley-fill deposits; where unfractured, lava flows can form aquitards
		Hinsdale Basalt	0-980	Lava flows, flow breccia, and pyroclastic deposits of of basaltic to andesitic composition interlayered with the Los Pinos Formation and predating the Servilleta Basalt of the Taos Plateau.		Fractured to unfractured lava flows, fracturing enhances permeability
		Los Pinos Formation	0-660	Conglomerate, sandstone, and mud-flow breccias containing clasts of volcanic rocks derived from the San Juan volcanic field to the west; recognized in the southwest part of the valley and may be equivalent to, and interfingers with, the Santa Fe Formation found further to the east		Relatively low hydraulic conductivity and may form aquitard
Paleogene	Transition	San Juan volcanic field rocks: Ash-flow tuffs	0-2,000	Multiple ash-flow tuffs erupted from volcanic centers in the San Juan volcanic field to the west between 26 and 30 million years ago and predate formation of the rift graben; major tuffs include the Treasure Mountain Tuff, Masonic Park Tuff, Fish Canyon Tuff, and Carpenter Ridge Tuff	Confined Aquifer	
		San Juan volcanic field rocks: Conejos Formation	0- 5,000	Lava flows and volcaniclastic rocks of intermediate composition derived from strato-volcanoes in the San Juan volcanic center between 30 and 35 million years ago; heterogenous assemblage of flows, flow breccias, debris flow deposits, stream-laid conglomerate and sandstone, and rare ash-flow tuffs		
Cretaceous	Laramide	Blanco Basin-Vallejo formations	0-2,300	Red to reddish-brown, nonvolcanic sandy mudstone,coarse arkosic sandstone, and conglomerate	Confined Aquifer	
		San Juan Basin Laramide aged formations are present locally in structural blocks within the San Luis Valley in what is often called the *"San Juan Sag"*				
	Interior Seaway	Regional Cretaceous Seaway shale-dominated formations form multiple hydrogeologic units, most are confining units; only recently recognized in the Crestone area as isolated ouctrops and in deep borehole stratigraphic tests				
Jurassic Triassic	Mesozoic Sandstones	No strata recognized in this area				
Permian Pennsylvanian	Ancestral Rocky Mountains	Ancestral Rocky Mountains event marine and non-marine sedimentary formations form multiple hydrogeologic units in the Eagle Basin-Central Colorado Trough are present in the uplifted Sangre de Cristo Mountains and mountains west of Villa Grove				
Mississippian Devonian Silurian Ordovician Cambrian	Paleozoic Carbonates	Older Paleozoic sedimentary formations preserved in the Ancestral Rocky Mountains event Eagle Basin-Central Colorado Trough are present in the uplifted Sangre de Cristo Mountains and mountains west of Villa Grove				
Precambrian	Precambrian	Crystalline rocks of igneous and metamorphic origin in mountainous region			Crystalline bedrock	

Table 12a-02-01. San Luis Valley stratigraphic chart,detailed. Colorado Geological Survey ON-010 Colorado Groundwater Atlas.

Sources: Emery (1971); Stevens and Lipman (1975); Huntly (1976); Thompson and Lipman (1984); Brister and Gries (1996); Watkins (1996); Harmon and others [HRS] (2012); Raynolds and Hagadorn (2017)

Figure 9 San Luis Valley Stratigraphy

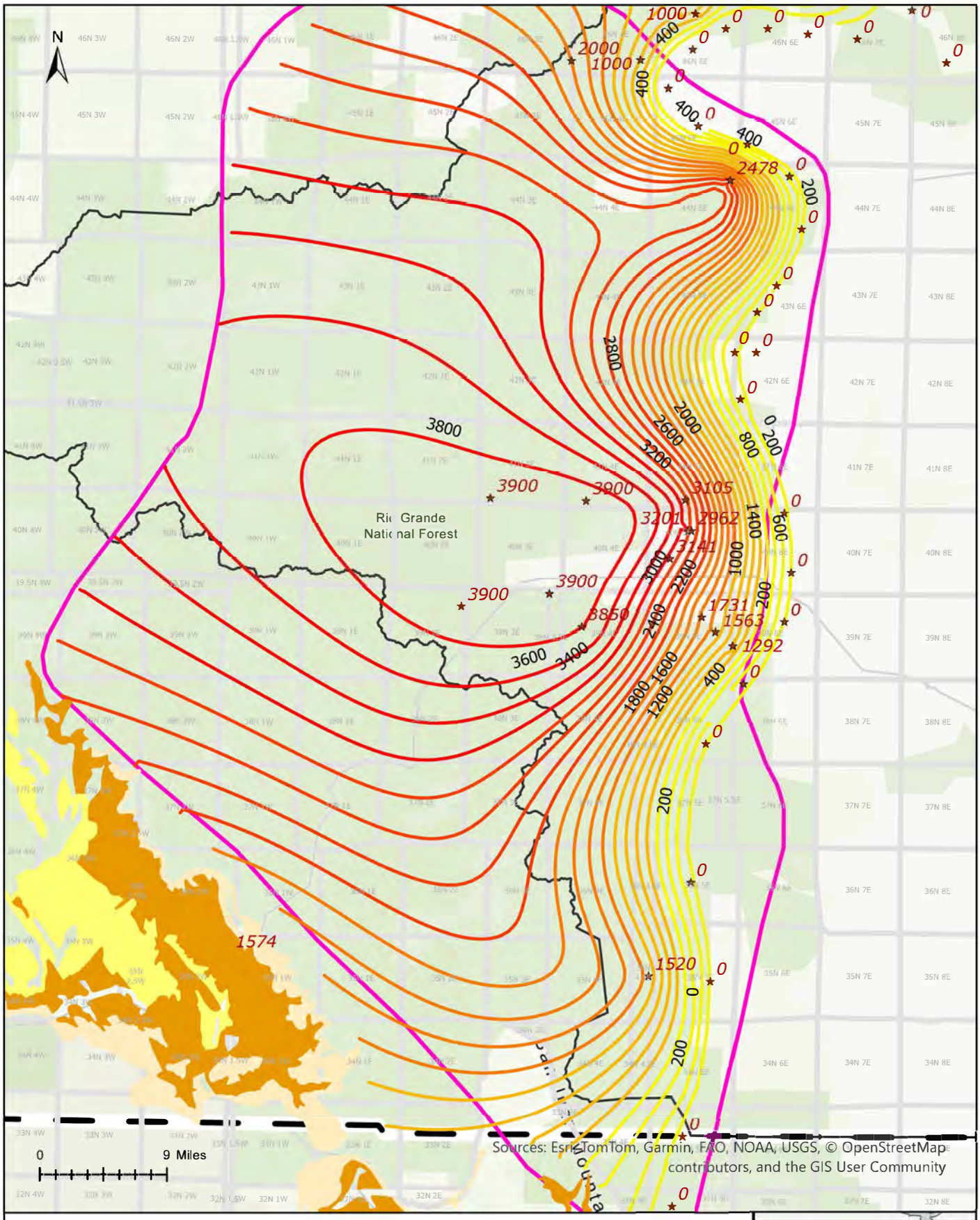


Figure 10, Isochore Map: Top Mancos Formation to Dakota Sandstone

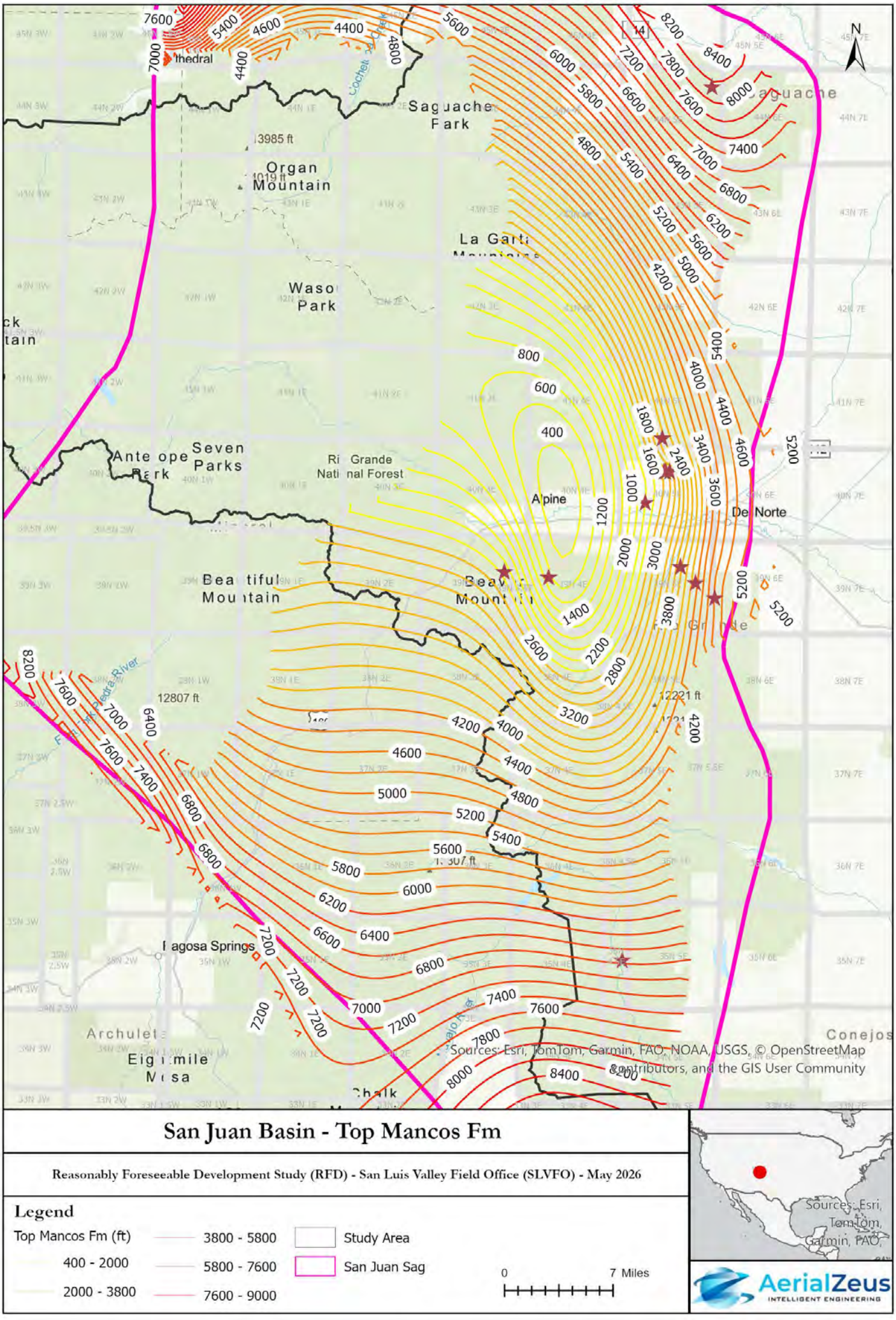


Figure 11, Structure Contour Map, Top of Mancos Formation

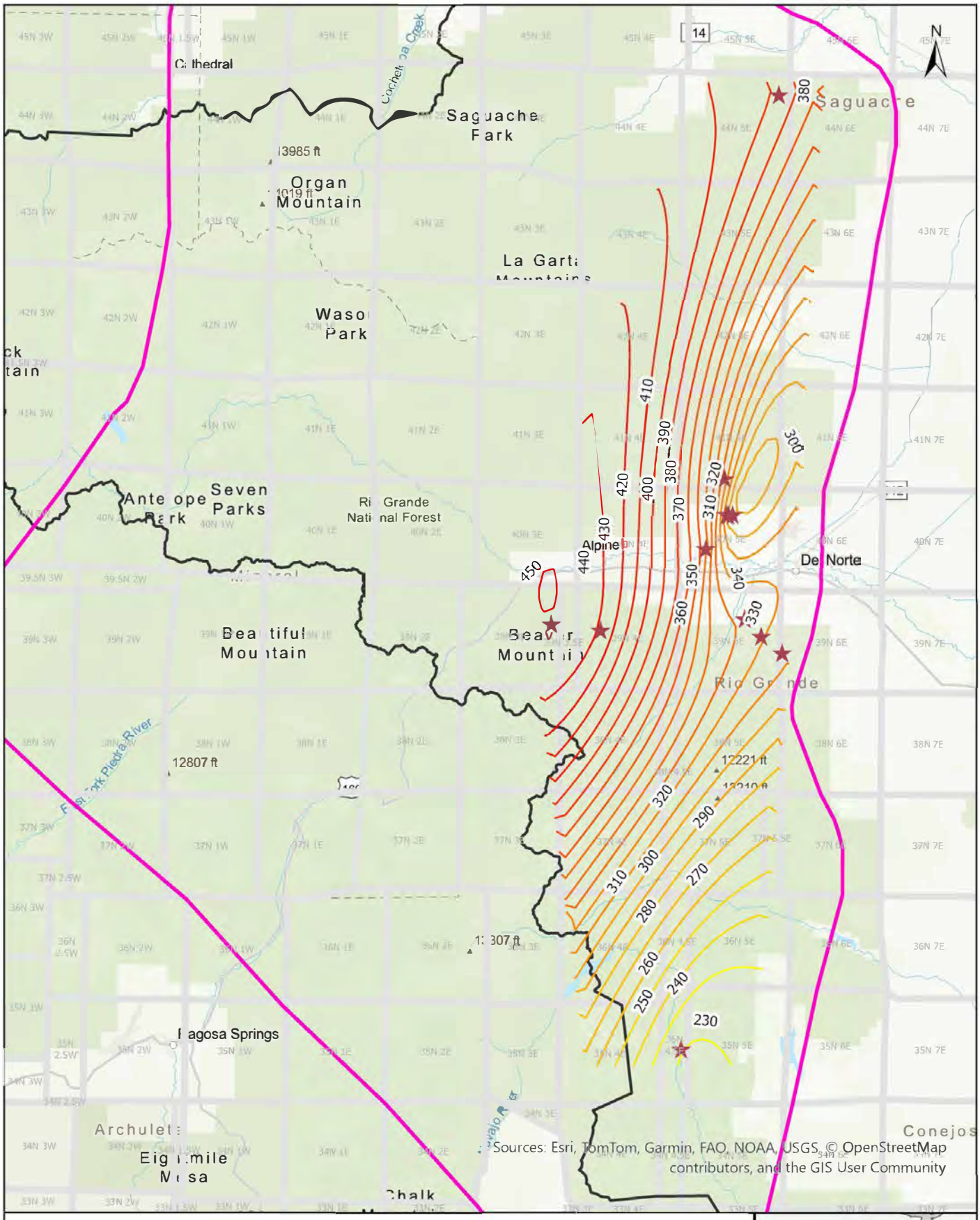


Figure 12, Isochore Map, Niobrara Formation

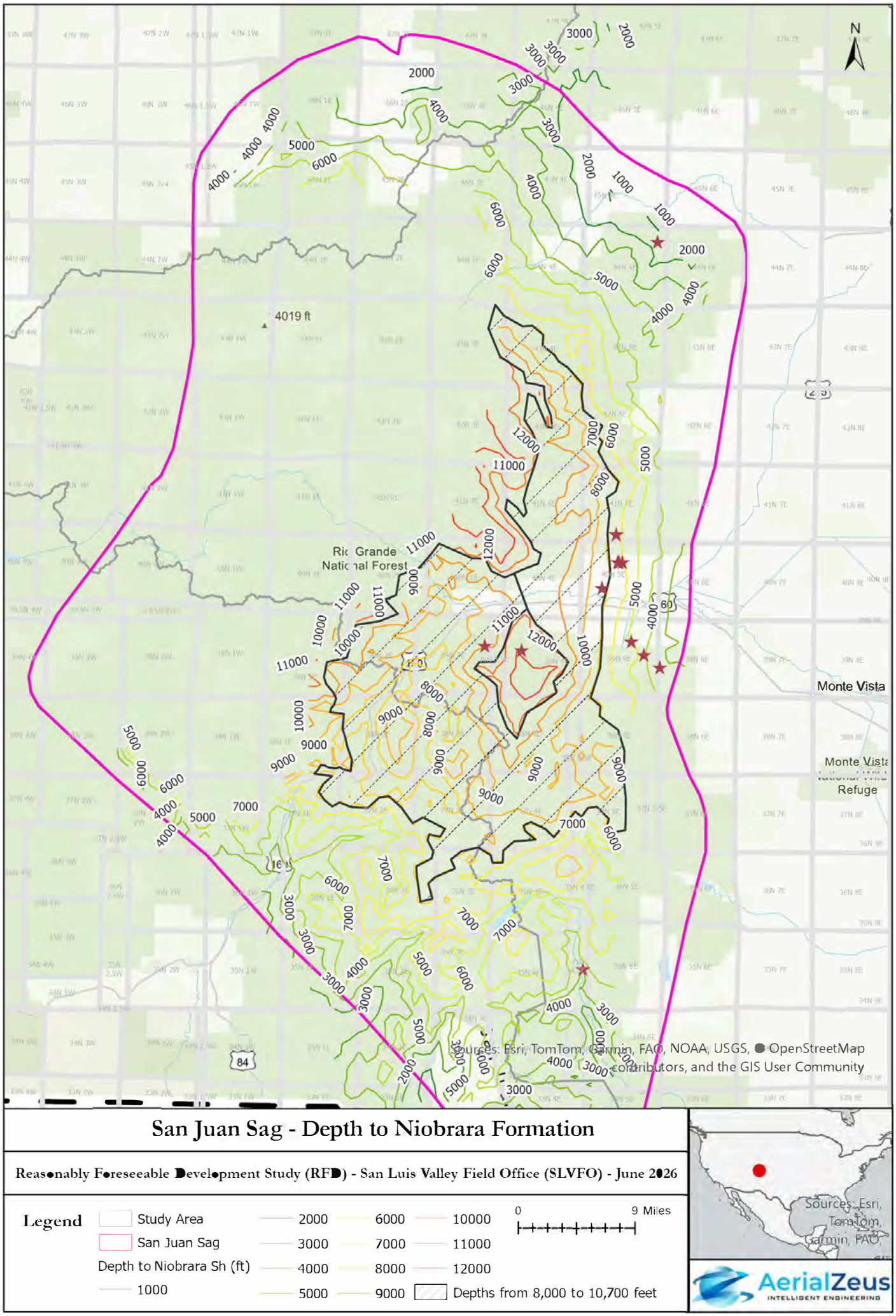


Figure 13, Depth to Niobrara Formation Map

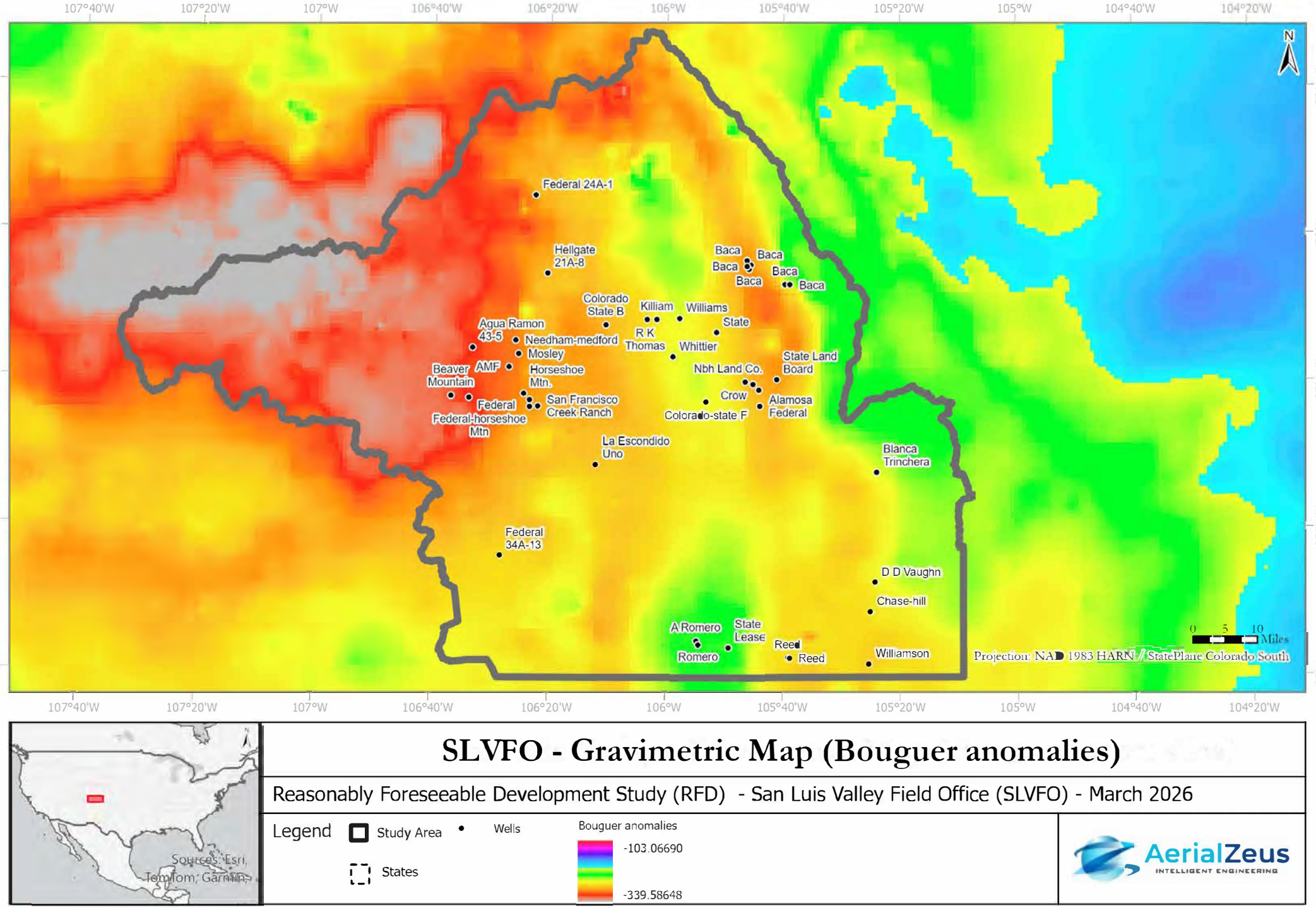


Figure 14, Gravimetric Map of the SLVFO Area with Bouguer Anomalies and Oil & Gas Wells

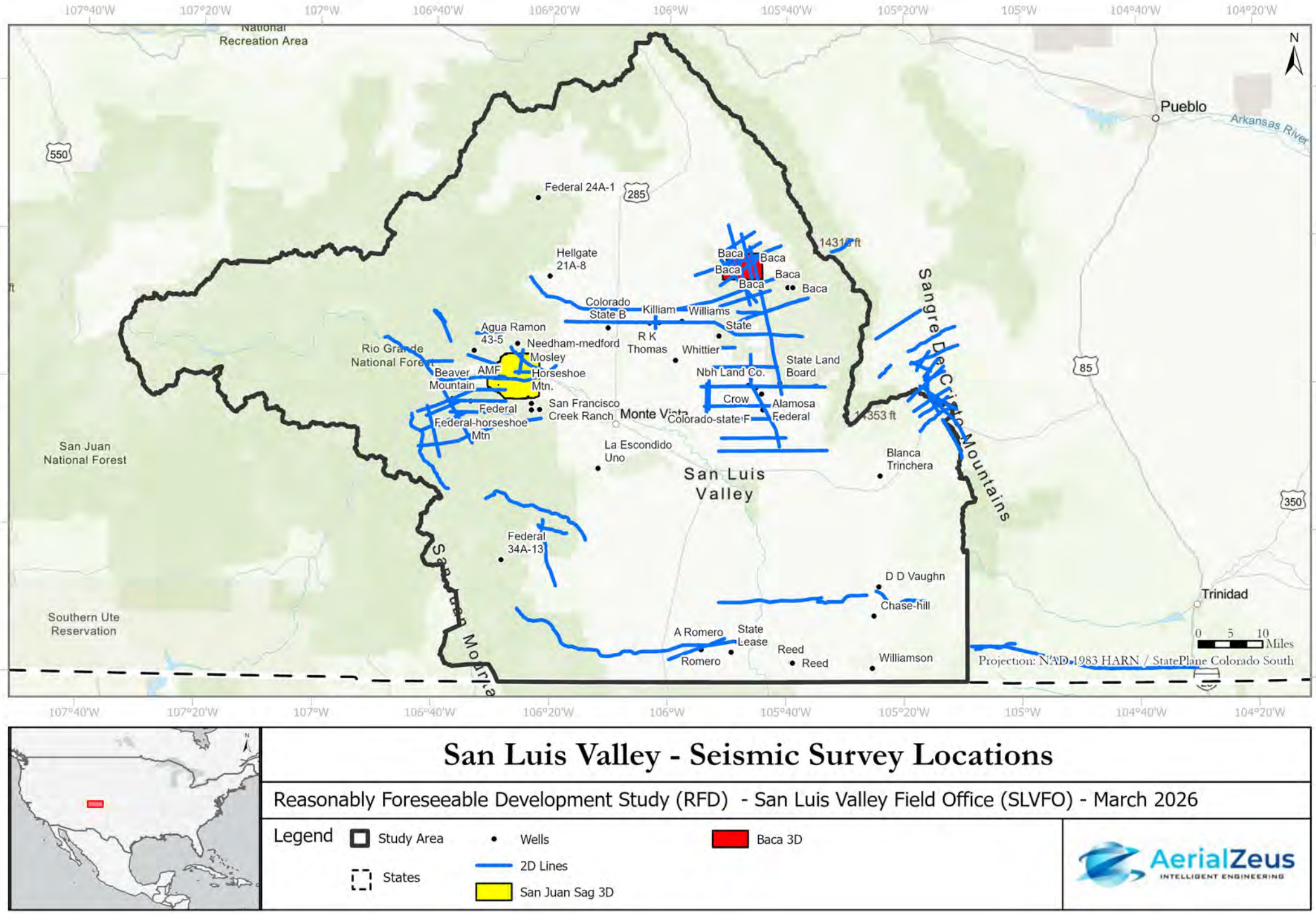


Figure 15, 2D and 3D Seismic Survey Locations in SLVFO Area





San Luis Valley - Seismic Survey Locations

Reasonably Foreseeable Development Study (RFD) - San Luis Valley Field Office (SLVFO) - April 2026

Legend: Study Area; States; Wells; SLVFO; 2D Lines

AerialZeus INTELLIGENT ENGINEERING

Projection: NAD 1983 HARN / StatePlane Colorado South

Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

Figure 16, Alamosa Horst Seismic Survey Locations

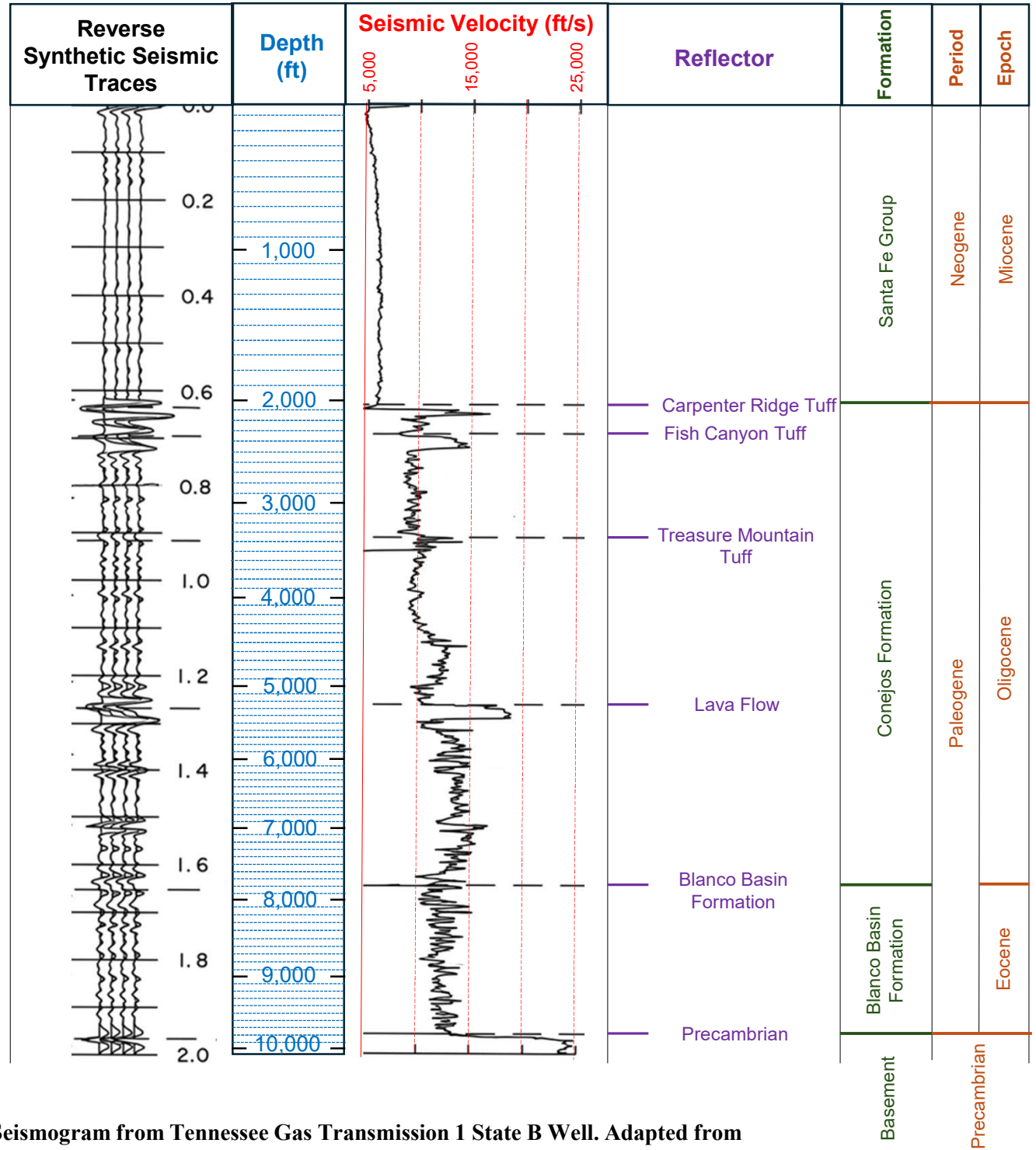


Figure 17, Synthetic Seismogram from Tennessee Gas Transmission 1 State B Well. Adapted from Brister and Gries (1994).

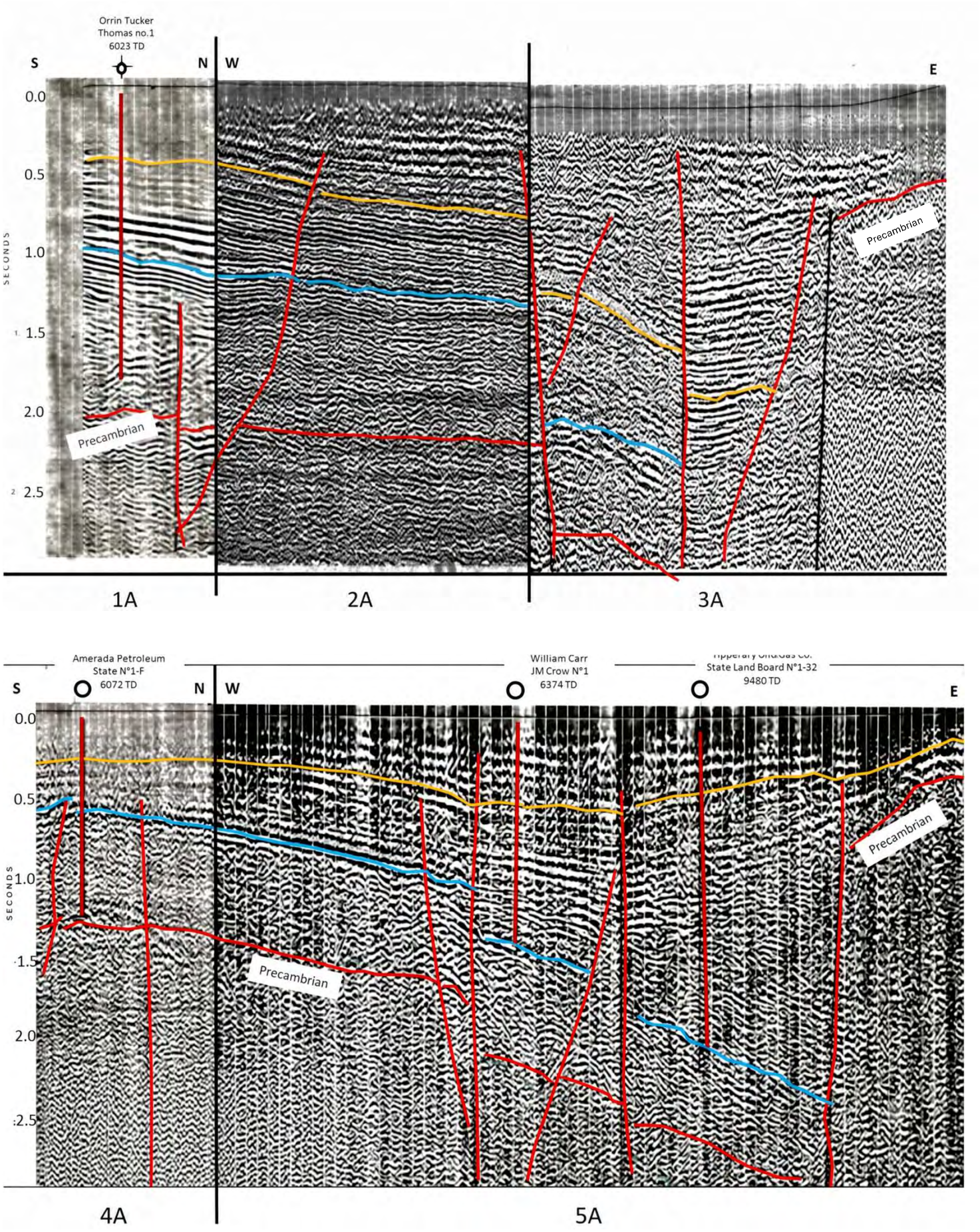


Figure 18, Composed Seismic Lines 1A, 2A, 3A, 4A, 5A. Adapted from Stoughton (1977).

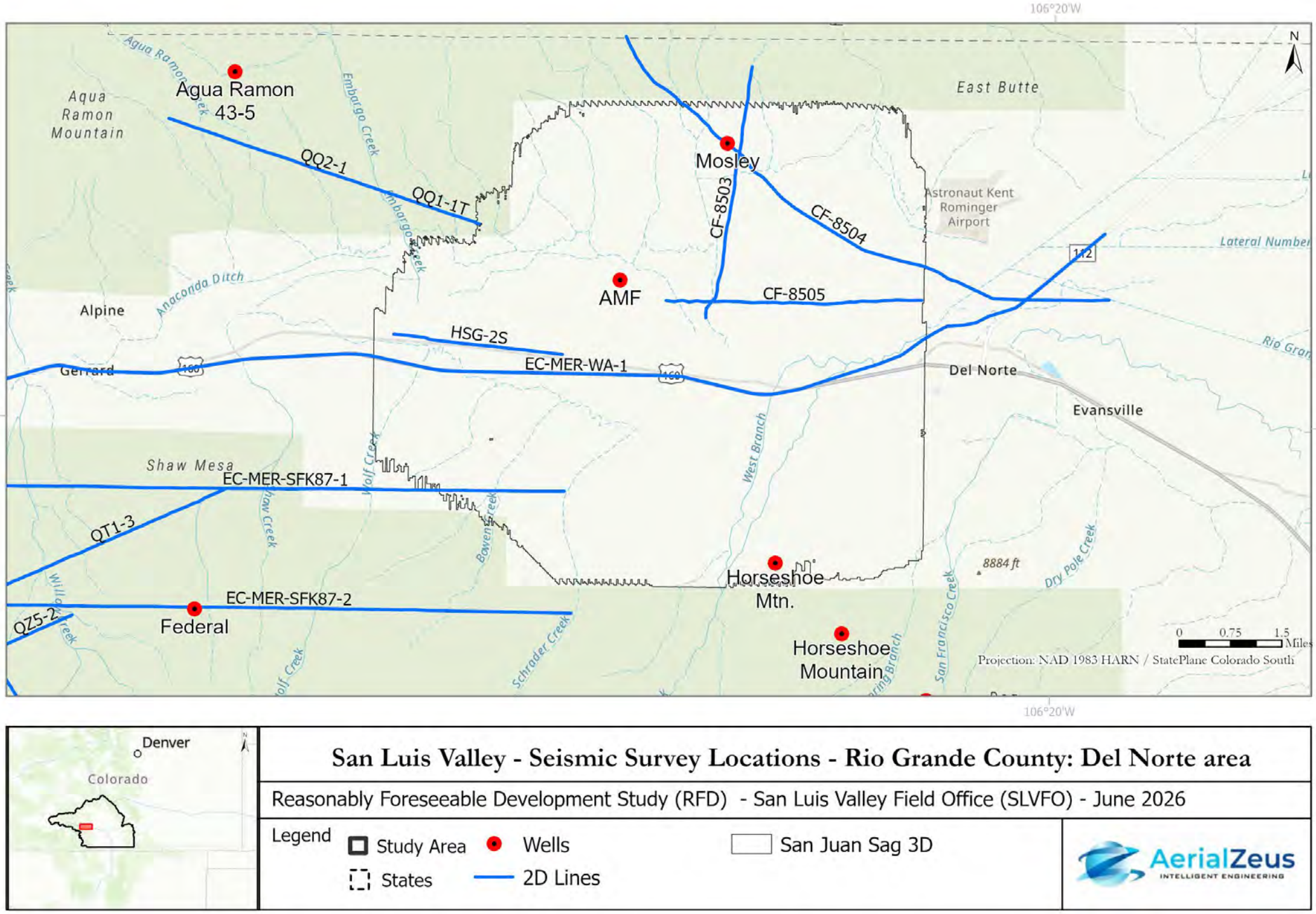


Figure 19, Detailed Seismic Survey Map near Del Norte

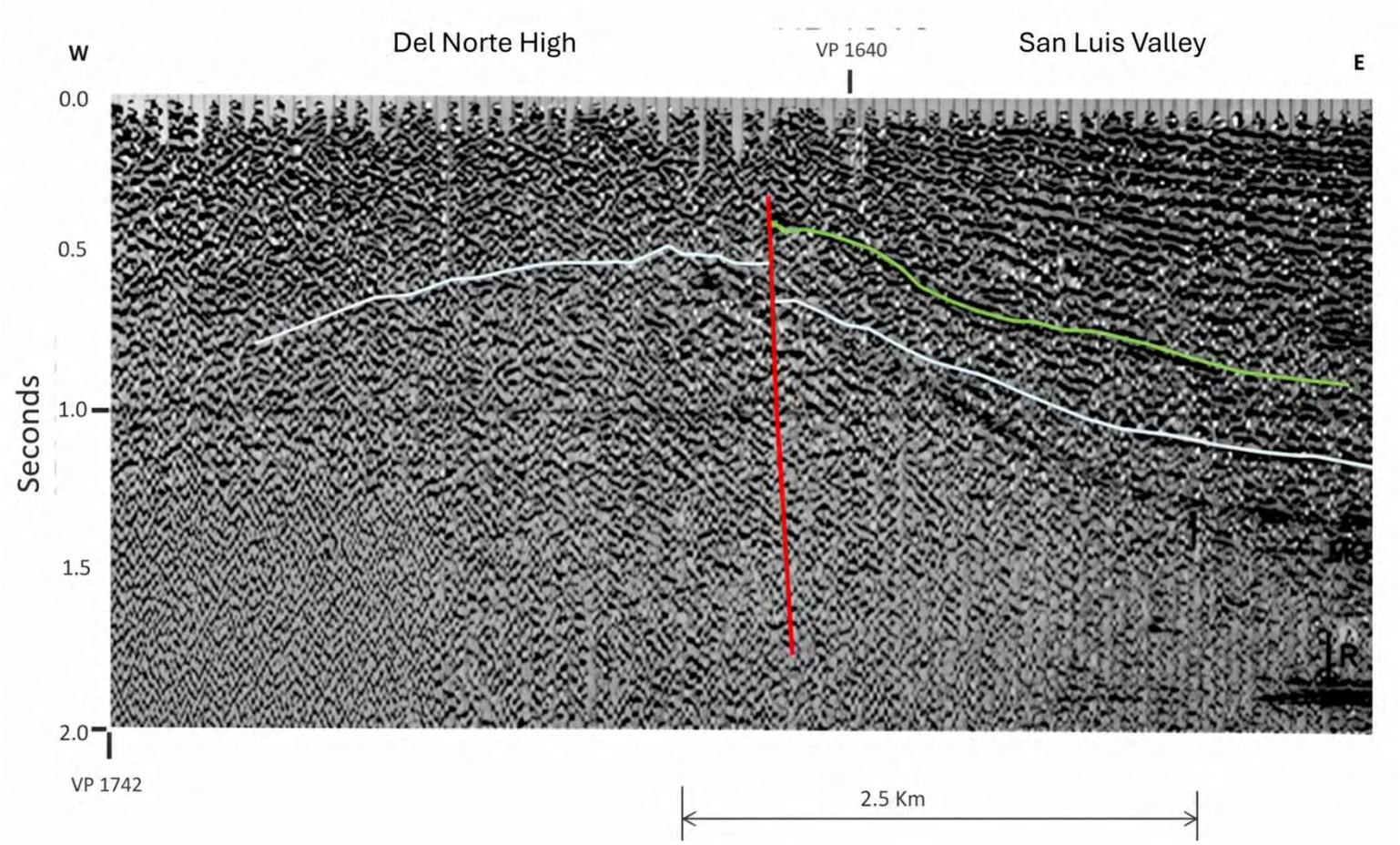


Figure 20, Seismic Section between the San Luis Valley and Del Norte High (modified from Tandon et al. 1999)

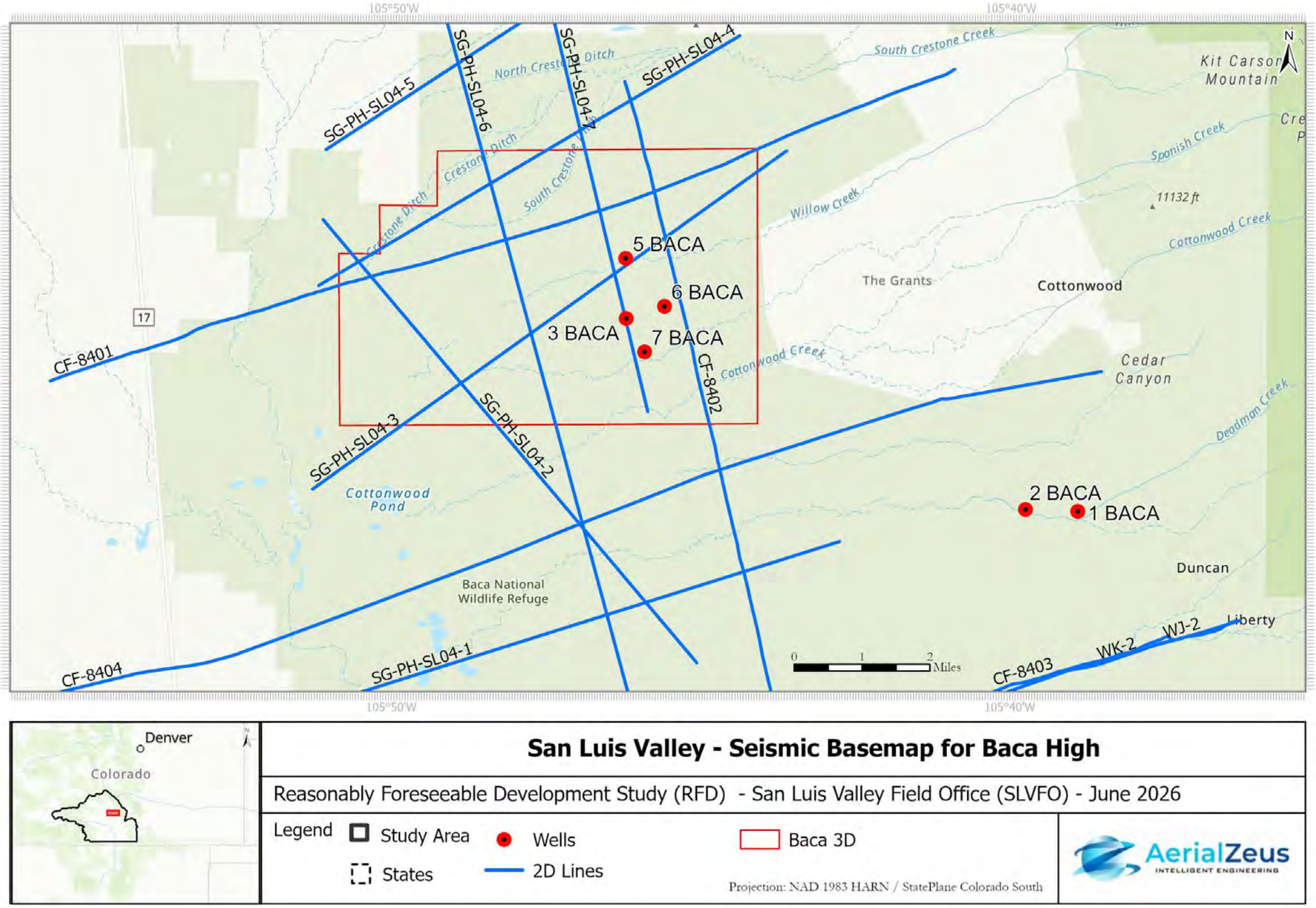


Figure 21, Seismic Survey Map for Baca High Area

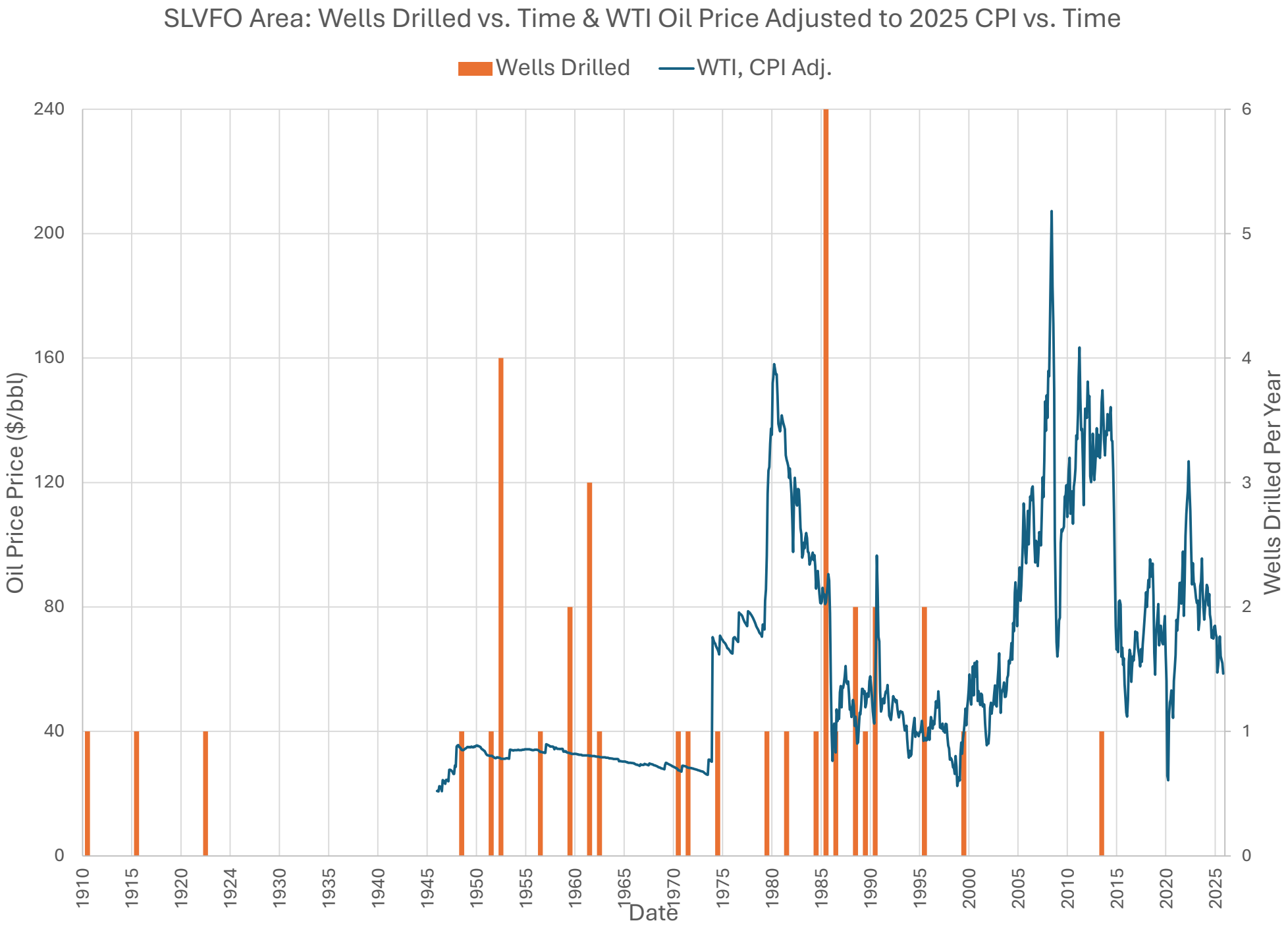
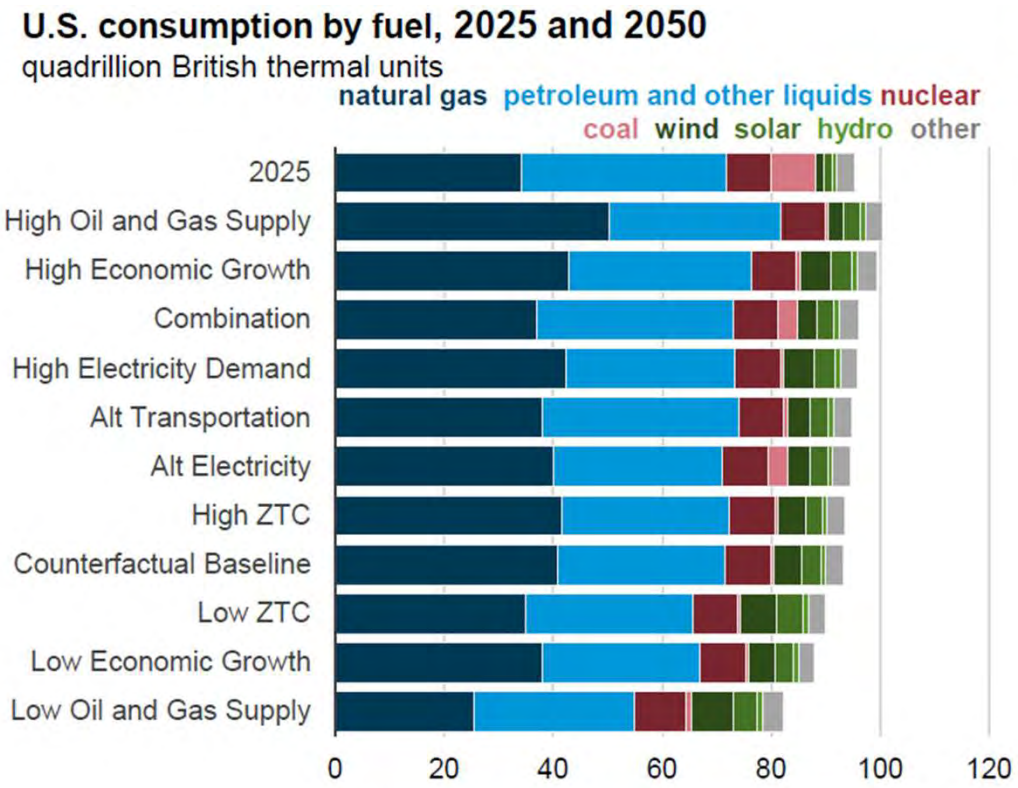


Figure 22, SLVFO Area Wells Drilled & WTI Crude Oil Price vs. Time



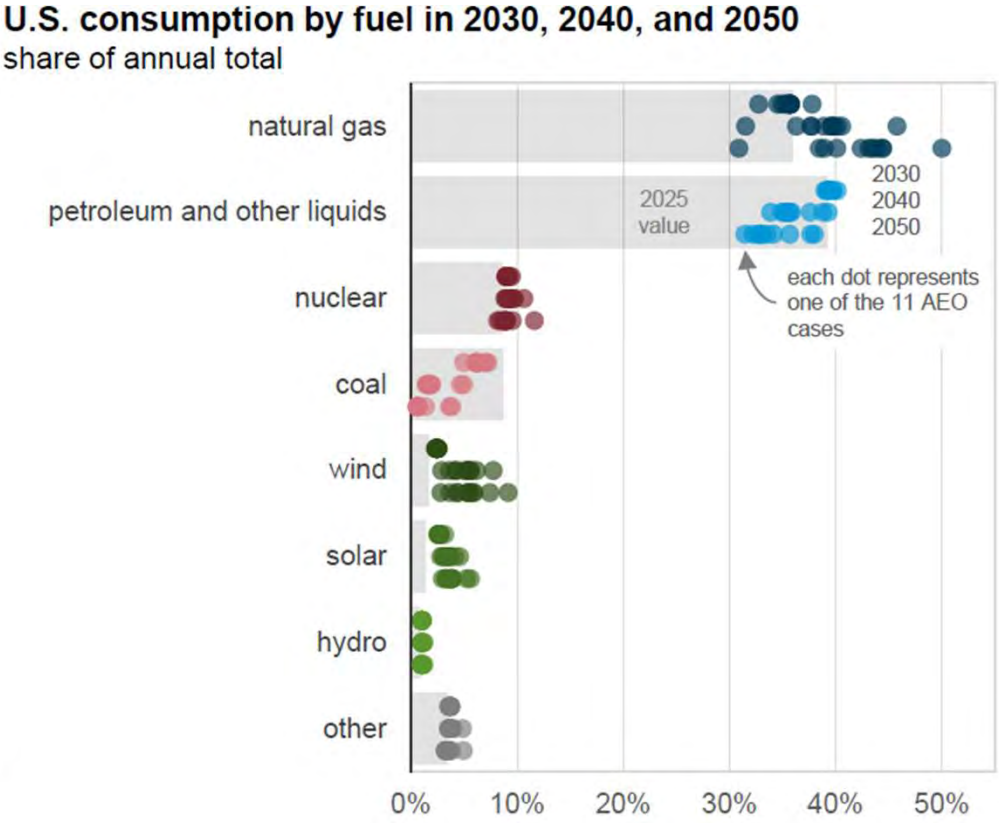


Figure 23, U.S. Energy Consumption by Fuel Type 2025 to 2050. Adapted from the EIA (EIA, 2026).

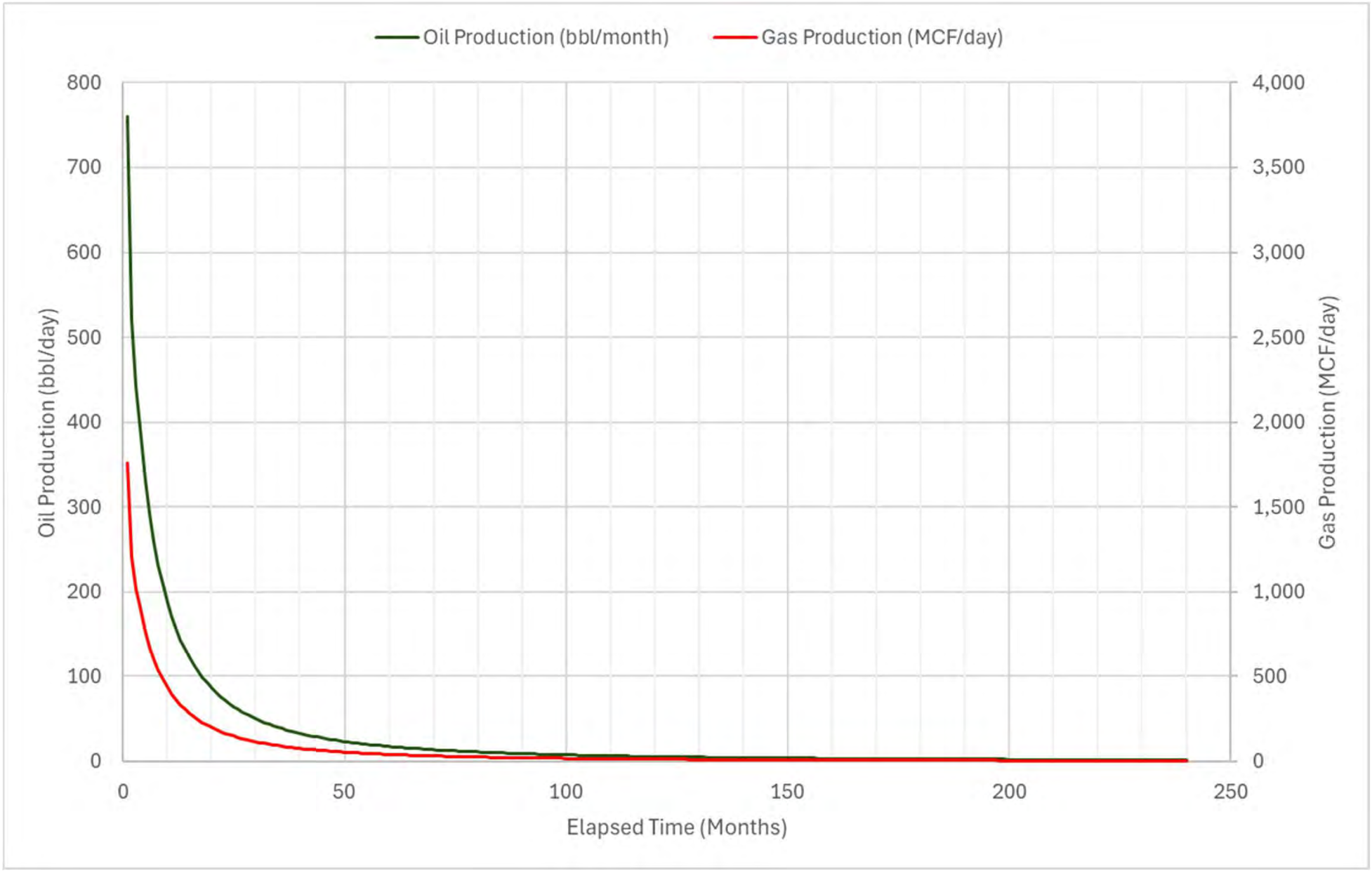


Figure 24, Niobrara Formation Well, Denver Basin Hyperbolic Decline

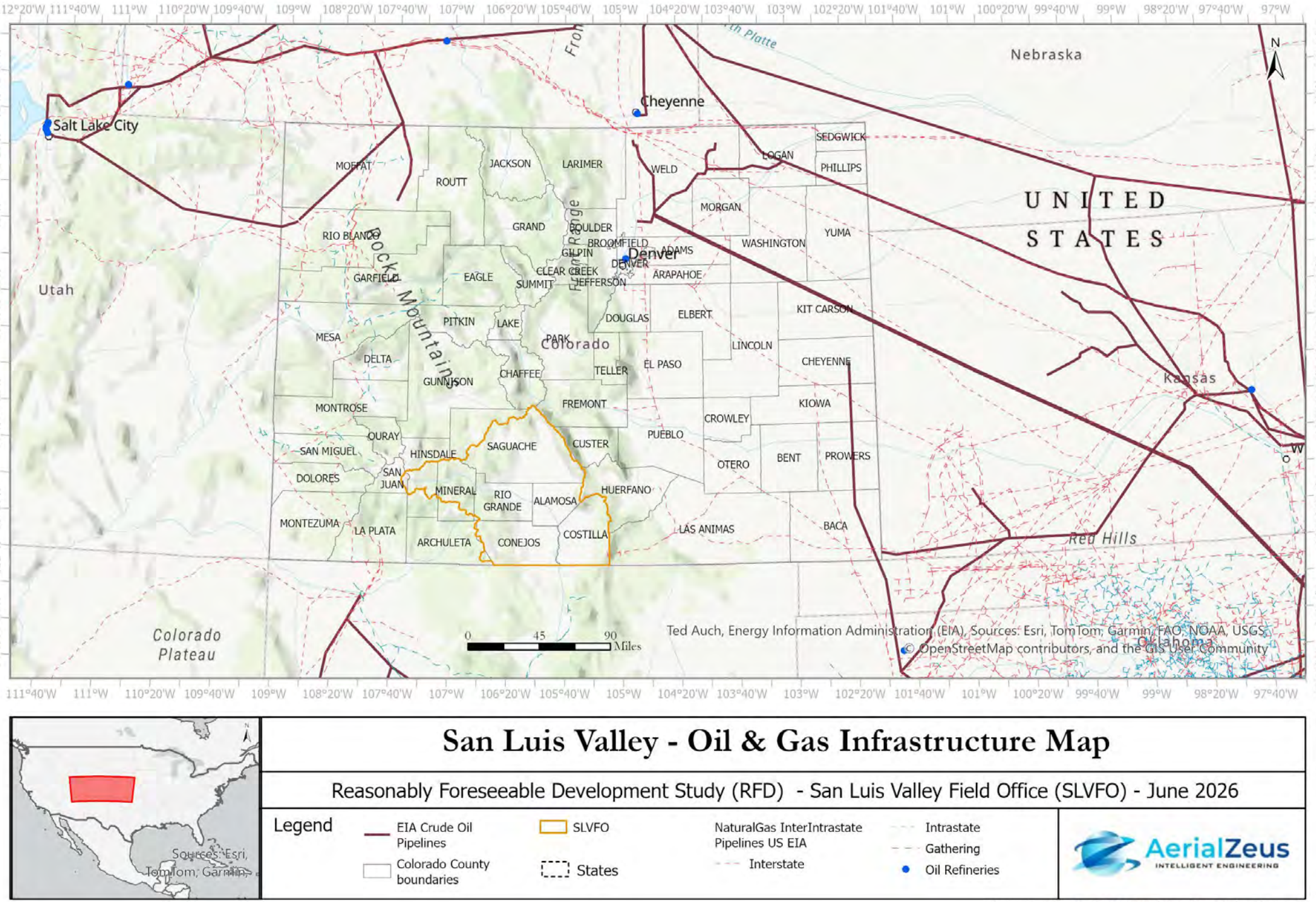


Figure 25, SLVFO Oil & Gas Infrastructure Map

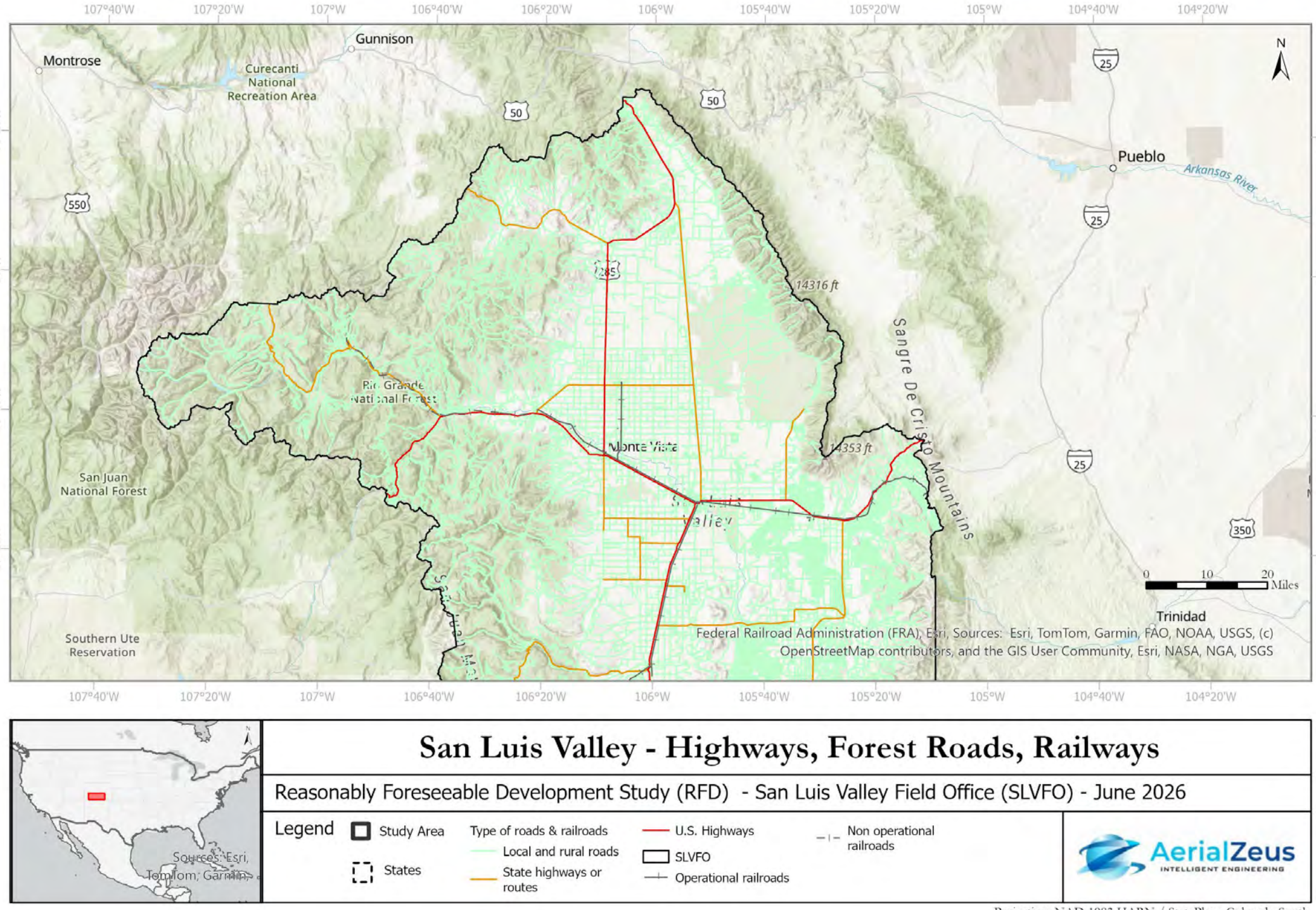


Figure 26, Roads, Highways, and Railways Infrastructure Map

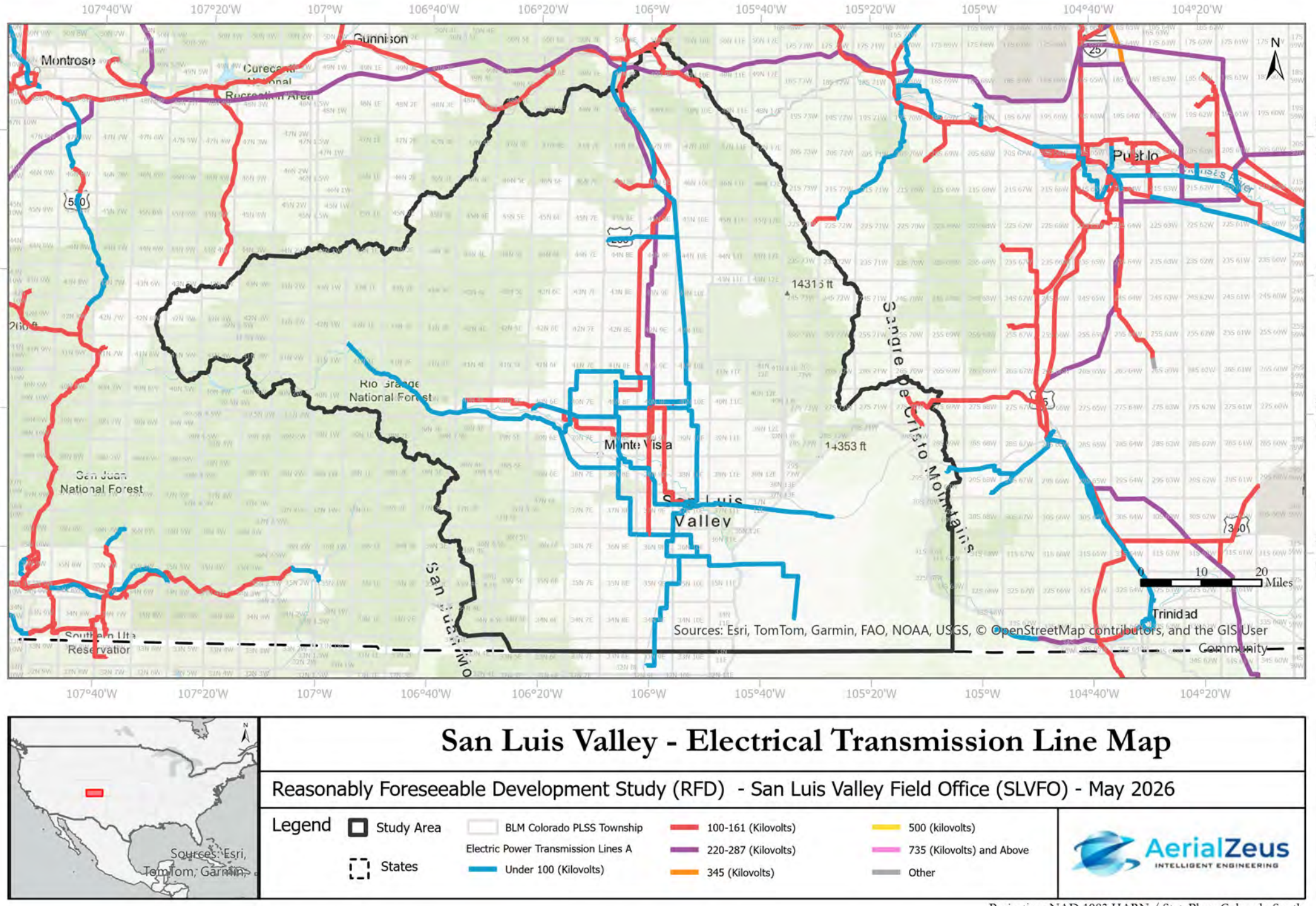


Figure 27, SLVFO Electrical Transmission Line Map

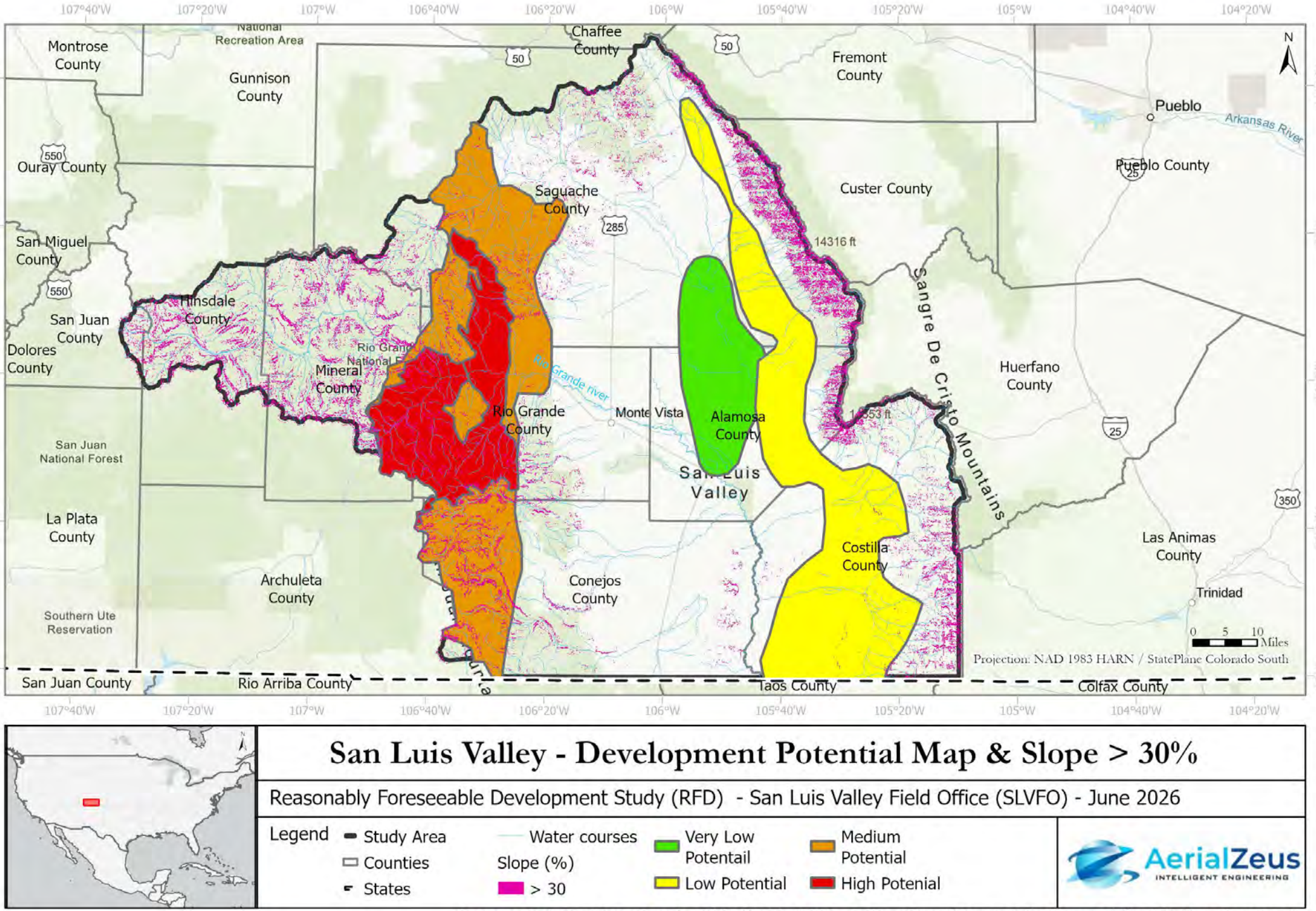


Figure 28, SLVFO Development Potential Map & Slope > 30%

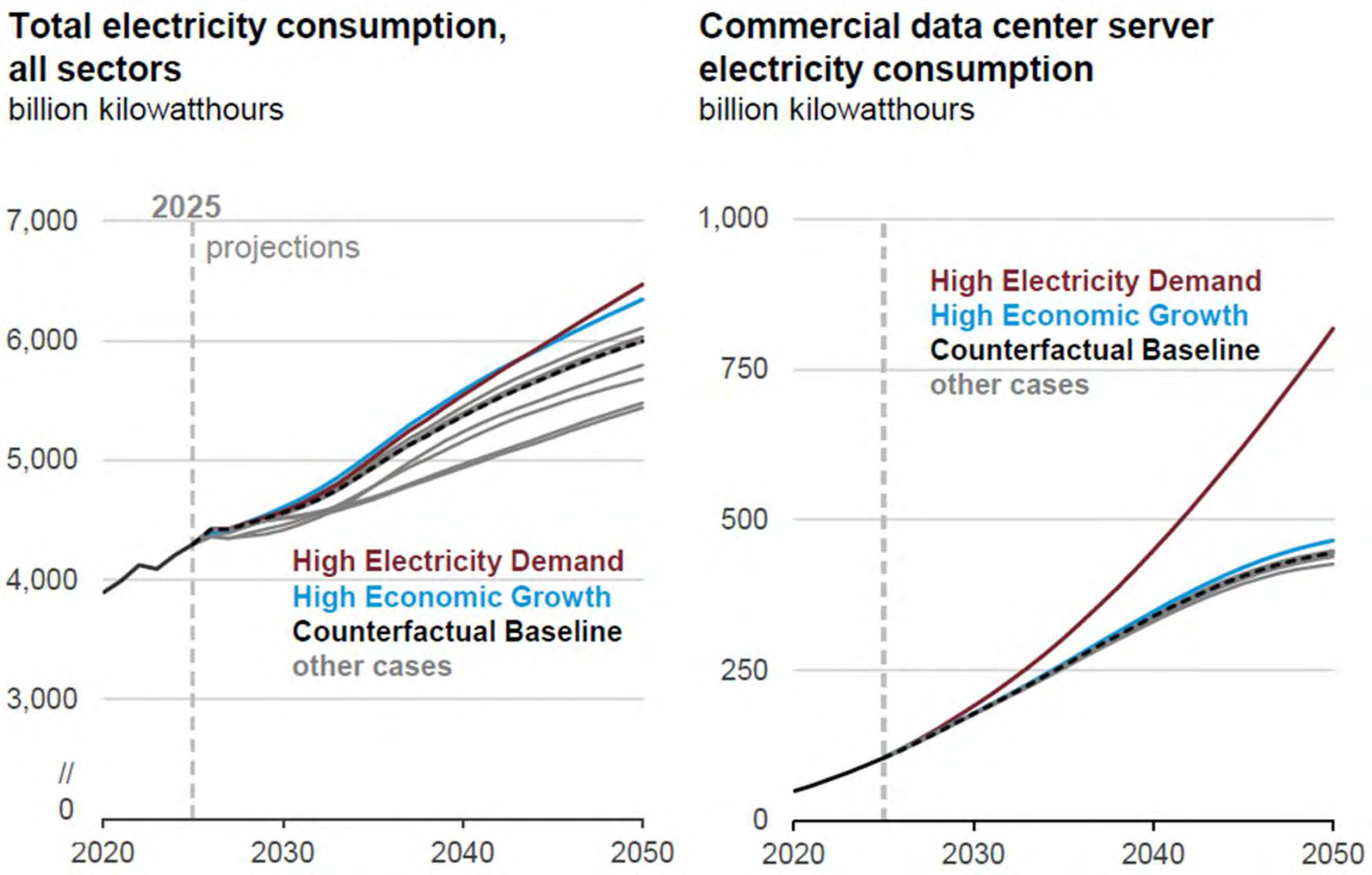


Figure 29, U.S. Total Electricity Consumption and Commercial Data Center Server Electricity Consumption, 2025 to 2050. Adapted from the EIA (EIA, 2026).

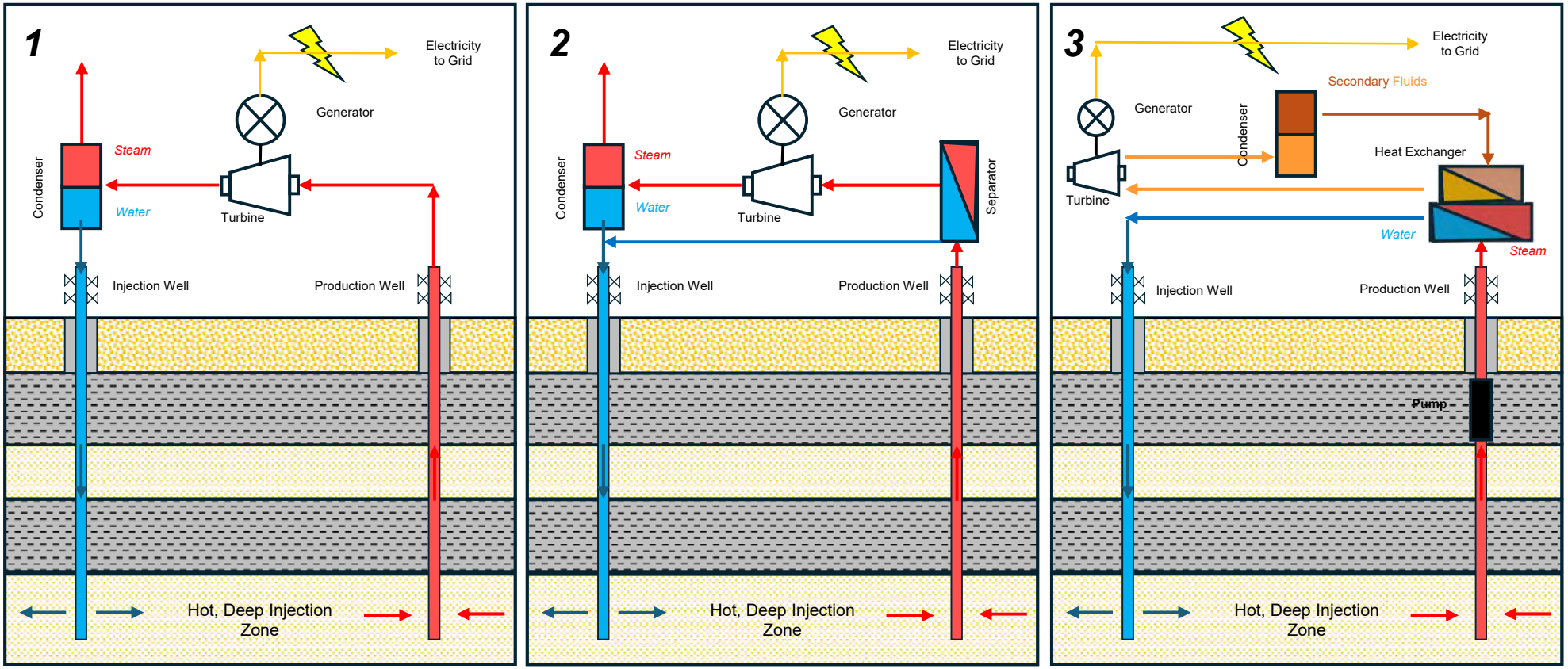


Figure 30, Three Basic Types of Geothermal Power Plants for Generating Electricity: 1) Dry Steam Power Plant 2) Flash Steam Power Plant 3) Binary Power Plant. Adapted from Morgan (2024).

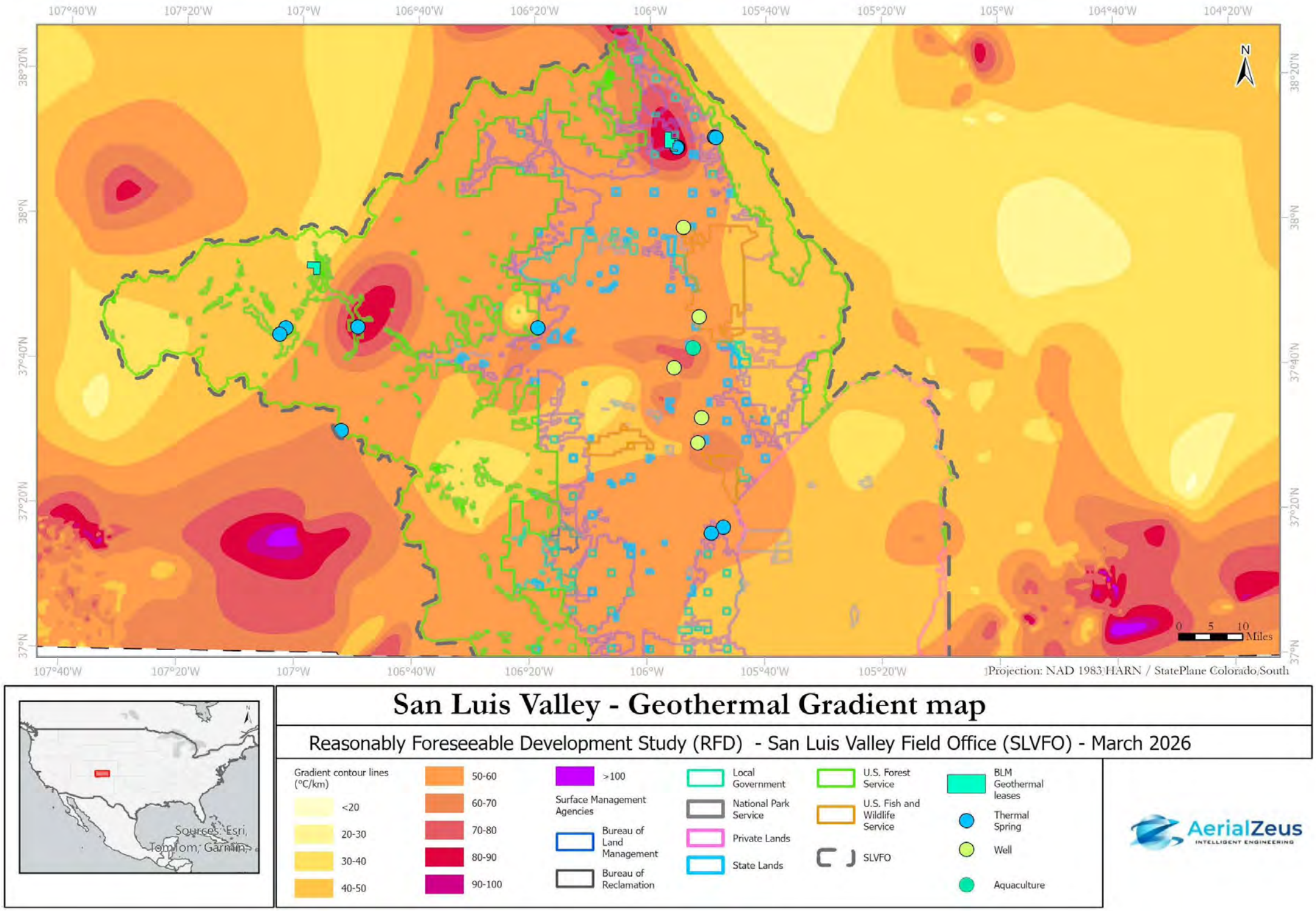


Figure 31, Geothermal Gradient Map

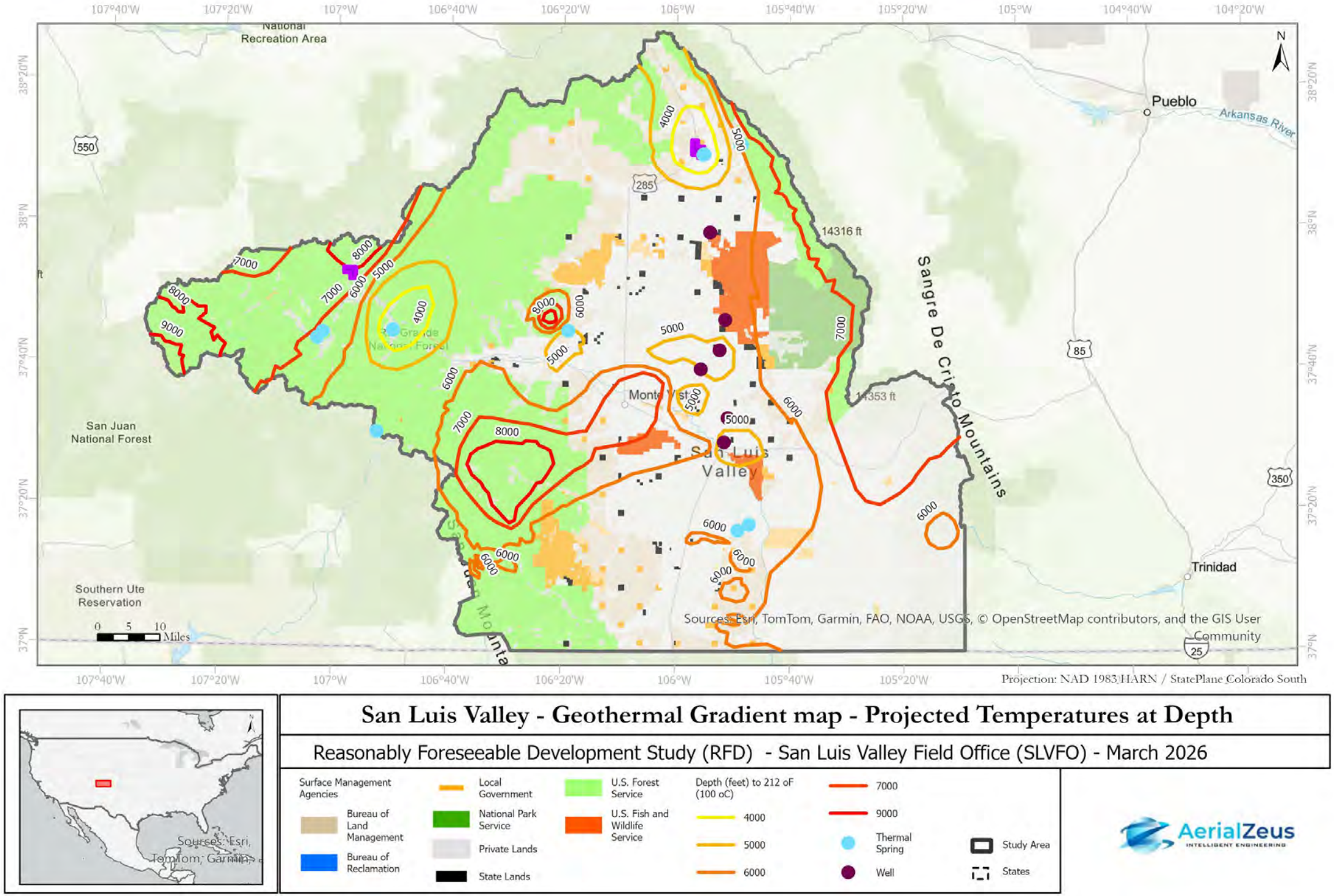
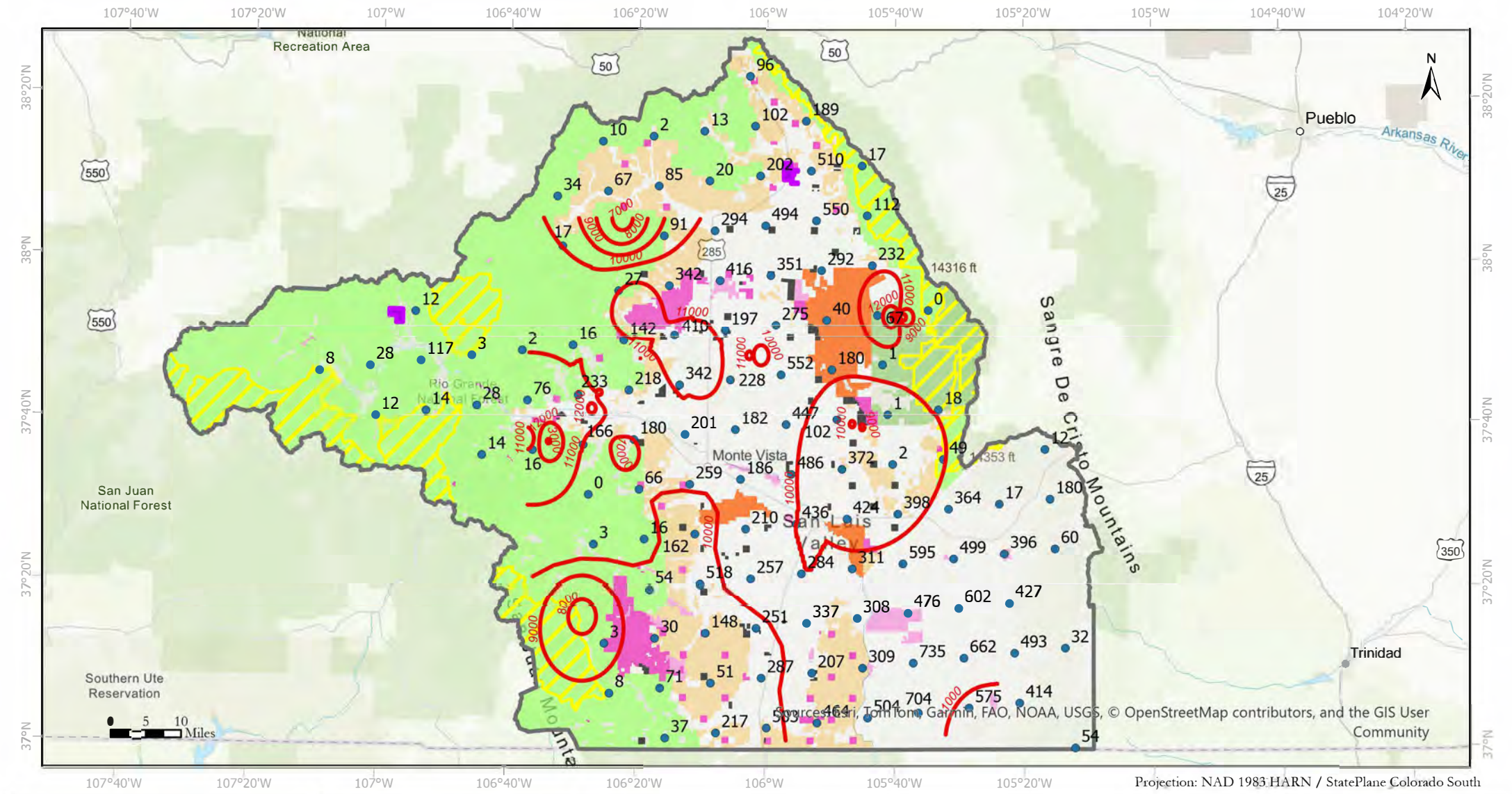


Figure 32, Depth to 212 °F, SLVFO Map





San Luis Valley - Geothermal Energy Potential - Capacity (MW) at 5km Depth

Reasonably Foreseeable Development Study (RFD) - San Luis Valley Field Office (SLVFO) - August 2026

Surface Management Agencies
- Bureau of Land Management
- Bureau of Reclamation
- Local Government
- National Park Service
- Private Lands
- State Lands
- U.S. Forest Service
- U.S. Fish and Wildlife Service
- Depth 302F
- EGS Supply Curves (a_5km_eg10)
- Wilderness Areas
- Study Area
- States

AerialZeus INTELLIGENT ENGINEERING

Figure 33, Depth to 302° F and Geothermal Energy Potential at 5km Depth

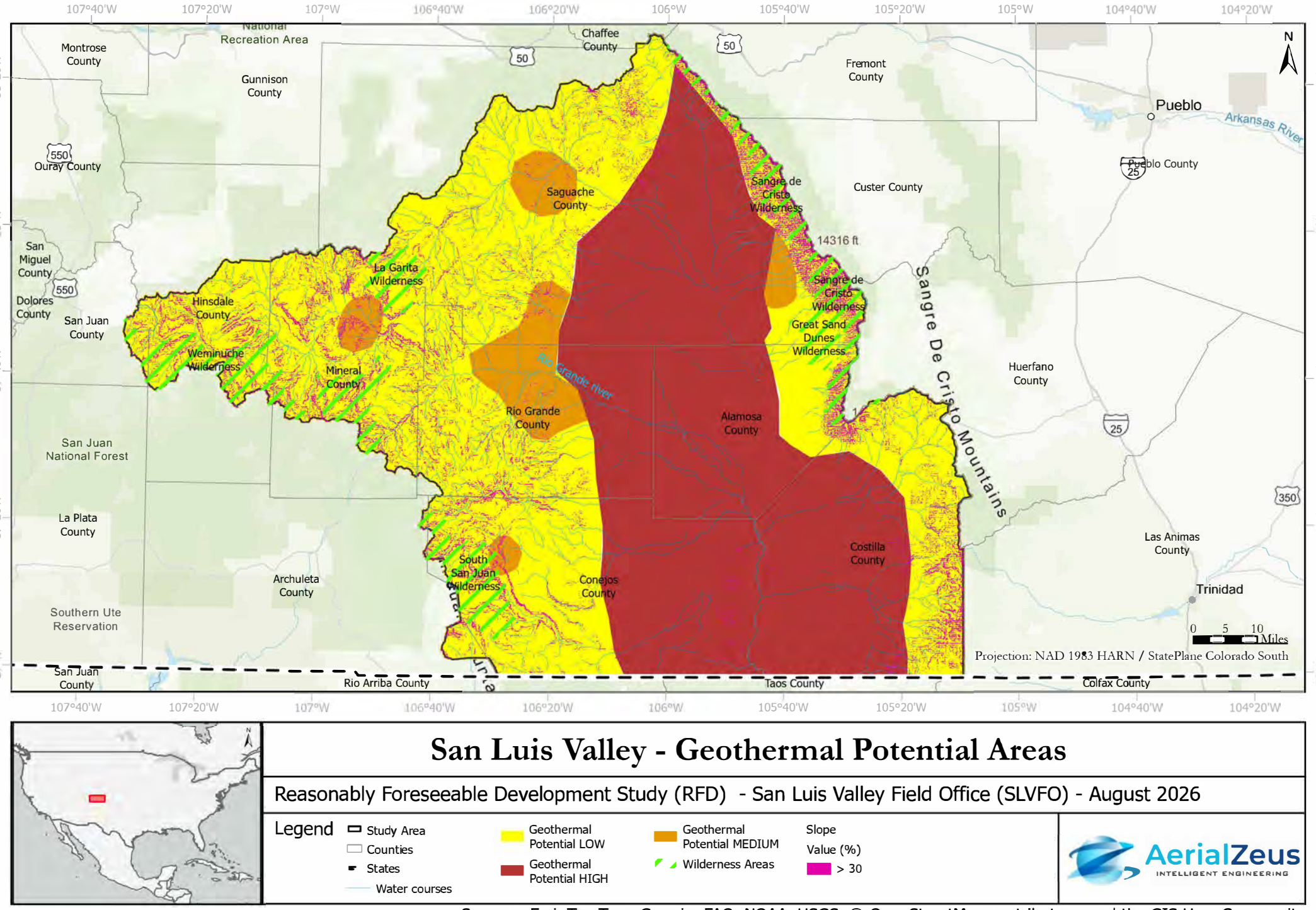
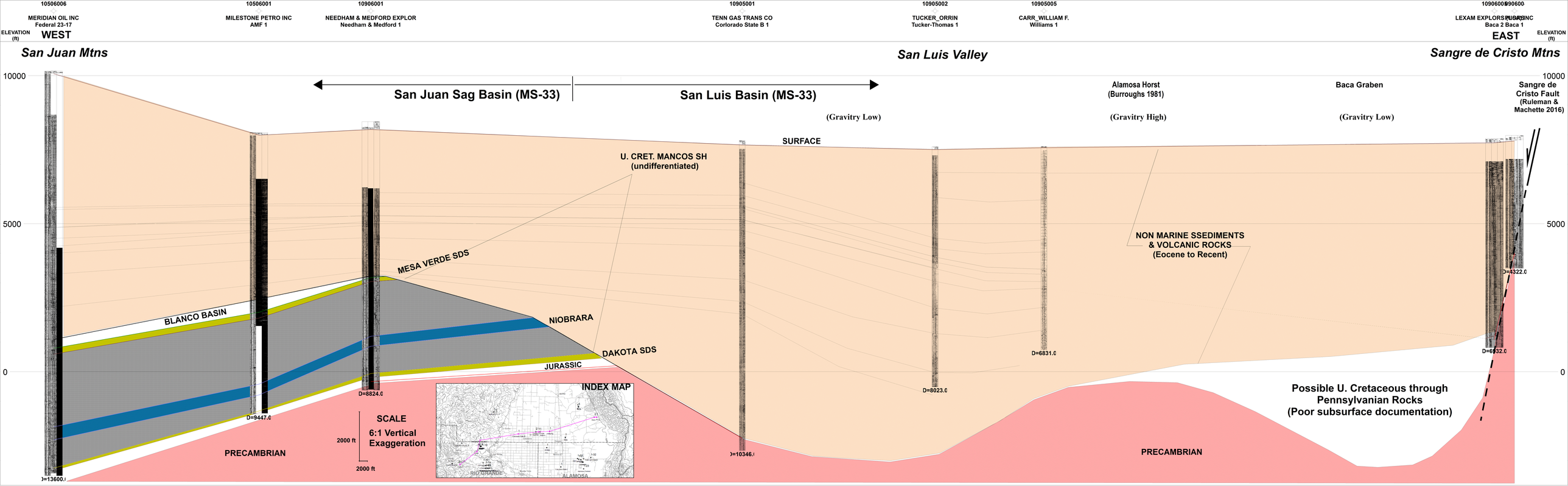


Figure 34, Geothermal Energy Potential in SLVFO


10506006
MERIDIAN OIL INC
Federal 23-17
10506001
MILESTONE PETRO INC
AMF 1
10906001
NEEDHAM & MEDFORD EXPLOR
Needham & Medford 1
10905001
TENN GAS TRANS CO
Corlorado State B 1
10905002
TUCKER_ORRIN
Tucker-Thomas 1
10905005
CARR_WILLIAM F.
Williams 1
10906000
LEXAM EXPLORATION INC
Baca 2 Baca 1
ELEVATION (ft)
WEST
EAST
San Juan Mtns
San Luis Valley
Sangre de Cristo Mtns
10000
5000
0
San Juan Sag Basin (MS-33)
San Luis Basin (MS-33)
Alamosa Horst
(Burroughs 1981)
Baca Graben
Sangre de Cristo Fault
(Ruleman & Machette 2016)
(Gravitry Low)
(Gravitry High)
(Gravitry Low)
SURFACE
U. CRET. MANCOS SH
(undifferentiated)
MESA VERDE SDS
BLANCO BASIN
NIOBRARA
DAKOTA SDS
JURASSIC
PRECAMBRIAN
NON MARINE SSEDIMENTS
& VOLCANIC ROCKS
(Eocene to Recent)
Possible U. Cretaceous through
Pennsylvanian Rocks
(Poor subsurface documentation)
D=13600.0
D=9447.0
D=8824.0
D=10346.0
D=8023.0
D=6831.0
D=6932.0
D=4322.0
SCALE
6:1 Vertical
Exaggeration
2000 ft
2000 ft
INDEX MAP
RIO GRANDE
ALAMOSA

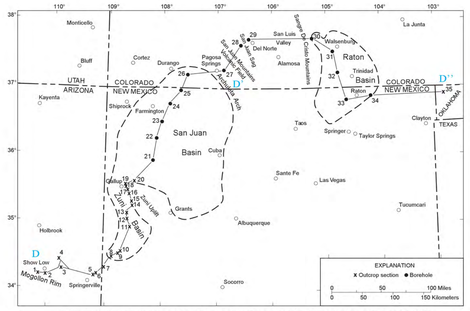
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

MISCELLANEOUS FIELD STUDIES MAP MF-2382
Version 1.0
SHEET 3 OF 3

D — SW — 615 mi (990 km) along the line of section or 450 mi (724 km) end point to end point — NE — D''

ARIZONA | NEW MEXICO — NEW MEXICO | COLORADO — COLORADO | NEW MEXICO — NEW MEXICO | OKLAHOMA

San Juan Basin — Pagosa Springs — San Juan Sag — San Luis Valley — Sangre de Cristo Mountains — Raton Basin — Oklahoma Panhandle



INDEX MAP SHOWING LOCATION OF CROSS SECTIONS

STAGE	part	MOLLUSCAN FOSSIL-ZONE
Maas. (part)	upper	1 *Jeletzkytes nebrascensis*
	upper	2 *Hoploscaphites nicolletti*
	upper	3 *Hoploscaphites birkelundi*
	lower	4 *Baculites clinolobatus*
	lower	5 *Baculites grandis*
	lower	6 *Baculites baculus*
	lower	7 *Baculites eliasi*
Campanian	upper	8 *Baculites jenseni*
	upper	9 *Baculites reesidei*
	upper	10 *Baculites cuneatus*
	upper	11 *Baculites compressus*
	upper	12 *Didymoceras cheyennense*
	upper	13 *Exiteloceras jenneyi*
	upper	14 *Didymoceras stevensoni*
	upper	15 *Didymoceras nebrascense*
	middle	16 *Baculites scotti*
	middle	17 *Baculites reduncus*
	middle	18 *Baculites gregoryensis*
	middle	19 *Baculites perplexus*
	middle	20 *Baculites* sp. (smooth)
	middle	21 *Baculites asperiformis*
	middle	22 *Baculites mclearni*
	middle	23 *Baculites obtusus*
	lower	24 *Baculites* sp. (weak flank ribs)
	lower	25 *Baculites* sp. (smooth)
	lower	26 *Scaphites hippocrepis* III
	lower	27 *Scaphites hippocrepis* II
	lower	28 *Scaphites hippocrepis* I
	lower	29 *Scaphites leei* III
Santonian	upper	30 *Desmoscaphites bassleri*
	upper	31 *Desmoscaphites erdmanni*
Coniacian	upper	32 *Clioscaphites choteauensis*
	low	33 *Clioscaphites vermiformis*
	low	34 *Clioscaphites saxitonianus*
	up.	35 *Scaphites depressus*
	up.	36 *Scaphites ventricosus*
	low	37 *Forresteria allisundi*
	low	38 *Forresteria peralta*

STAGE	part	MOLLUSCAN FOSSIL-ZONE
Turonian	upper	39 *Prionocyclus germari*
	upper	40 *Scaphites nigricollensis*
	upper	41 *Scaphites whitfieldi*
	upper	42 *Scaphites ferronensis*
	upper	43 *Scaphites warreni*
	middle	44 *Prionocyclus macombi*
	middle	45 *Prionocyclus hyatti*
	middle	46 *Prionocyclus praecox*
	lower	47 *Collignoniceras woollgari*
	lower	48 *Mammites nodosoides*
	lower	49 *Vascoceras birchbyi*
	lower	50 *Pseudaspidoceras flexuosum*
	lower	51 *Watinoceras devonense*
Cenomanian	upper	52 *Nigericeras scotti*
	upper	53 *Neocardioceras juddi*
	upper	54 *Burroceras clydense*
	upper	55 *Eucalycoceras septemseriatum*
	upper	56 *Vascoceras diartianum*
	upper	57 *Damesgoniceras cumbum*
	upper	58 *Damesgoniceras albertense*
	upper	59 *Damesgoniceras problematicum*
	upper	60 *Damesgoniceras pondi*
	middle	61 *Plesiacanthoceras wyomingense*
	middle	62 *Acanthoceras amphibolum*
	middle	63 *Acanthoceras bellense*
	middle	64 *Acanthoceras muldoonense*
	middle	65 *Acanthoceras granerosense*
	middle	66 *Conlinoceras tarrantense*
		(Gap in biostratigraphic record)
	lower	67 *Neogastroplites maclearni*
	lower	68 *Neogastroplites americanus*
	lower	69 *Neogastroplites muelleri*
	lower	70 *Neogastroplites cornutus*
	lower	71 *Neogastroplites haasi*
Aban (pt)	upper pt.	72 *Inoceramus belluensis*
	upper pt.	73 *Inoceramus comancheanus*

[Maas. = Maastrichtian; low. = lower; mid. = middle; up. = upper; pt = part]

Ma — Fossil zone number — Tertiary

65.4 — 66 — 70 — 75 — 80 — 83 — 85 — 90 — 95 — 99 — 104 — 105 — 110 — 111 — 112

Raton Formation (part)

Vermejo Formation

Trinidad Sandstone

Baculites eliasi
Baculites jenseni
Baculites reesidei

Kirtland Shale

Baculites compressus
Didymoceras cheyennense

Fruitland Formation

Exiteloceras jenneyi
Didymoceras stevensoni
Didymoceras nebrascense

Pictured Cliffs Sandstone

Huerfanito Bentonite Bed

Baculites scotti

Cliff House Sandstone (Kch)

Lewis Shale

Baculites gilberti, Baculites perplexus

La Ventana Tongue, Kch

Baculites asperiformis
Baculites mclearni

Cliff House Sandstone (Kch)

Mesaverde Group (Kmv)

Menefee Formation

Haresiceras mancosense

Present-day erosion surface in general area

Point Lookout Sandstone

Satan Tongue, Km

Hosta Tongue, Kpl

Texanites texanus

Gibson Coal Member, Kcc

Dalton Sandstone Member, Kcc

Dalton Sandstone Member, Kcc

Platyceramus stantoni *Magadiceramus subquadratus crenelatus* *Platyceramus stantoni*

Mulatto Tongue, Km

Borrego Pass Lentil, Kcc

Cremnoceramus deformis

El Vado Sandstone Member, Km equivalents

Crevasse Canyon Formation (Kcc)

Dilco Coal Member, Kcc

Cremnoceramus crectus

Prionocyclus germari *Prionocyclus germari*

Gallup Sandstone

Prionocyclus novimexicanus

Scaphites whitfieldi *Scaphites whitfieldi*

Gallup Sandstone

Prionocyclus wyomingensis

Inoceramus dimidius *Lopha lugubris*

Scaphites warreni
Prionocyclus macombi

Pescado Tongue, Km

Juana Lopez Member, Km

Spathites puercoensis

Fite Ranch Sandstone Member, Kth

Prionocyclus percarinatus ?

Tres Hermanos Formation (Kth)

Carthage Member, Kth

Collignoniceras woollgari

Atarque Sandstone

Mytiloides mytiloides

Mammites nodosoides

Atarque Sandstone Member, Kth

Rio Salado Tongue, Km

Neocardioceras juddi
Metoicoceras geslinianum

Watinoceras coloradoense

Metoicoceras mosbyense

Dakota Sandstone (Kd)

Twowells Tongue, Kd

Pycnodonte aff. P. kellumi

Plesiacanthoceras wyomingense
Tarrantoceras sellardsi

Calycoceras canitaurinum

Whitewater Arroyo Tongue, Km

Acanthoceras amphibolum

Paguate Tongue, Kd

Exogyra trigeri

Clay Mesa Tongue, Km

Inoceramus prefragilis

Calycoceras canitaurinum

Paguate Tongue, Kd

Clay Mesa Tongue, Km

Dakota Sandstone (Kd) (upper part)

Mancos Shale (Km)

NIOBRARA Fm

Niobrara Formation equivalent

Graneros Member, Km

Cubero Tongue, Kd

Burro Canyon Formation ?

Eroded

Eroded

Eroded

Eroded

San Juan Sag Basin

Cretaceous section between the San Juan Sag and the Raton Basin is restored on this cross section; it was removed by latest Cretaceous-early Tertiary erosion.

Present-day erosion surface in general area

Pierre Shale

Scaphites hippocrepis III
Scaphites hippocrepis II
Scaphites hippocrepis I

NIOBRARA Fm

Niobrara Formation (Kn)

Smoky Hill Shale Member, Kn

Desmoscaphites bassleri
Desmoscaphites erdmanni
Clioscaphites choteauensis
Clioscaphites vermiformis
Cladoceramus undulatoplicatus

Protexanites bourgeoisianus, Magadiceramus subquadratus

Cremnoceramus crectus, Cremnoceramus deformis

Fort Hays Limestone Member, Kn

Prionocyclus germari, Mytiloides incertus

unnamed shale member, Kc (above) and Juana Lopez Member, Kc (below)

Prionocyclus hyatti

Carlile Shale (Kc)

Blue Hill Member, Kc

Fairport Member, Kc

Collignoniceras woollgari

Codell Sandstone Member, Kc

Collignoniceras woollgari

Bridge Creek Limestone Member, Km

Bridge Creek Limestone Member, Kgh

Greenhorn Limestone (Kgh)

Vascoceras birchbyi
Metoicoceras geslinianum

Hartland Shale Member, Kgh

Lincoln Member, Kgh

Graneros Shale

Conlinoceras tarrantense

Romeroville Sandstone

Pajarito Formation

Mesa Rica Sandstone

Dakota Sandstone (lower part)

Glencairn Formation

Inoceramus comancheanus, Texigryphaea tucumcarii, Eopachylioscus marcianus

Long Canyon Sandstone Bed of Glencairn Formation

Lytle Formation

Tertiary

UPPER CRETACEOUS

Maastrichtian: upper

Campanian: lower, middle, upper

Santonian: upper

Coniacian: low, mid, upper

Turonian: lower, middle, upper

Cenomanian: lower, middle, upper

LOWER CRETACEOUS (part)

Albian

EXPLANATION

Continental strata
Marine sandstone
Marine carbonate rocks
Continental and nearshore marine strata
Marine shale and siltstone
Hiatus
Contact of formation or member—Dashed where presence is uncertain
Unconformity
*45 Fossil zone—Asterisk indicates that zone was dated radiometrically (Obradovich, 1993)

SECTION D-D'', EAST-CENTRAL ARIZONA TO THE OKLAHOMA PANHANDLE

REGIONAL STRATIGRAPHIC CROSS SECTIONS OF CRETACEOUS ROCKS FROM EAST-CENTRAL ARIZONA TO THE OKLAHOMA PANHANDLE

By
C.M. Molenaar, W.A. Cobban, E.A. Merewether, C.L. Pillmore, D.G. Wolfe, and J.M. Holbrook

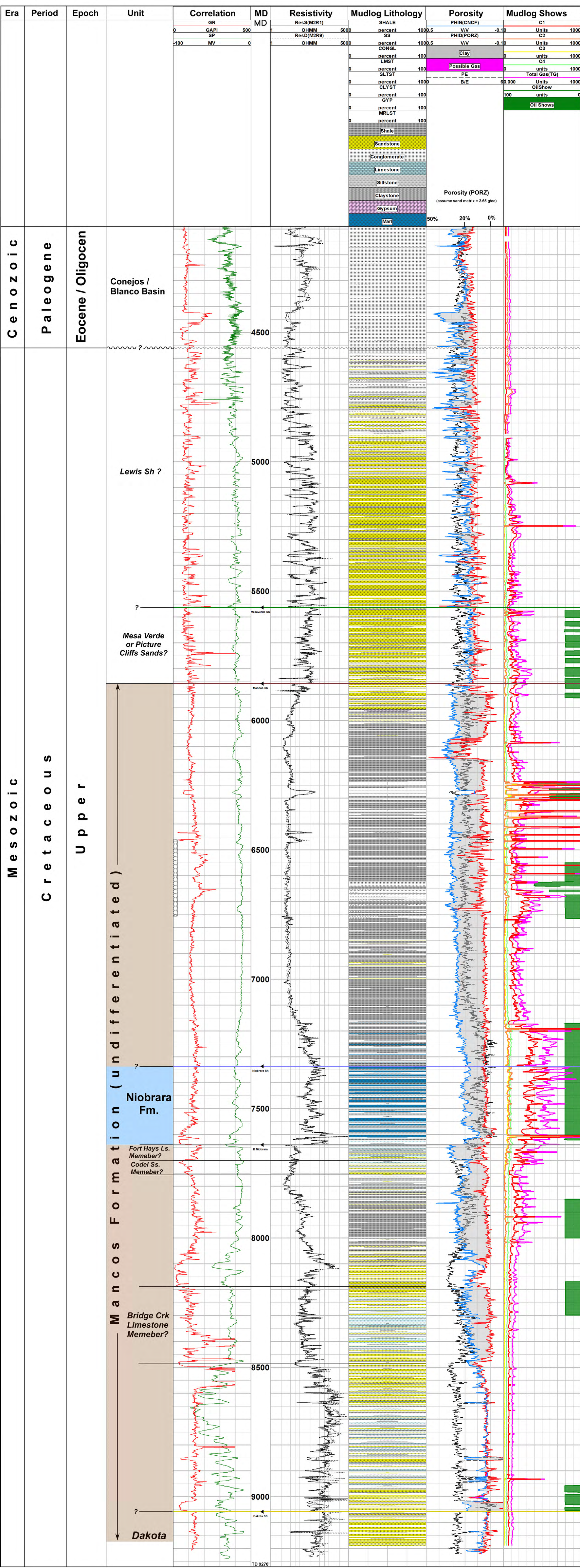
2002

Manuscript approved for publication November 1, 2001

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This map was produced on request, directly from digital files, on an electronic plotter

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1-888-ASK-USGS



TYPE LOG
Del Norte Oilfield
SAN JUAN SAG BASIN

First Liberty Energy
Basin #1
API# 10506019

Sec 9-T40N/R5E N.M.P.M.
Rio Grande County, Colorado

WELL TESTS AND COMPLETIONS

Basin #1 (10506019)

D&A

6460'
6560'
6568'

Tested water, oil and gas at low rates by swabbing. Highest oil cut (% oil) was 45%. Well was not placed on production.

6550-56' Hydraulically fractured with 1901 bbl carrier fluid and 246,280 lbs of 30/50 sand proppant.

Jynnifer #1 (10506003)

Produced 1855 BO

6620'
6636'
6672'
6686'

6620-36' Perforated and hydraulically fractured with 400 sacks of sand proppant in Nov. 1985. Initial production reported as 30 BOPD and 80 MCF gas per day.

6672-86' Perforated and treated with 1500 gals of 15% HCl acid in Nov. 1991. Well reported to produce 20 BWPD after treatment.

7710'
7718'

7710-18' No reported results for this perforated zone.

TYPE LOG FOR NIOBRARA FORMATION

Bottom Hole Temperatures
(from logging runs)
4805' = 140 °F
9234' = 224 °F

Correlation	Depth	Resistivity	Lith (Mudlog)	Porosity	SHOWS
GR	MD	ResS(M2R1)	0 percent 100	PHIN(CNCF)	C1
0 GAPI 500		1 OHMM 500	Shale	0.5 V/V -0.1	0 Units 1000
SP		ResD(M2R9)	Sandstone	PHID(PORZ)	C2
-100 MV 0		1 OHMM 500	Conglomerate	0.5 V/V -0.1	0 Units 1000
			Limestone	Clay	C3
			Siltstone	Possible Gas	0 units 1000
			Claystone	PE	C4
			Gypsum	0 B/E 60	0 units 1000
			Marl	(PORZ using 2.65 grain density)	Total Gas(TG)
					0.000 Units 1000
					OilShow
					100 units 0
					Oil Shows

DEL NORTE OILFIELD
First Liberty Energy Inc.
"Basin" #1
API# 10506019
NE SE Sec. 9 - T40N/R5E
Rio Grand Co., CO

Sample Description by Wellsite Geologist

Mancos Fm.

Computed Temperature
7337" = 188 °F

Niobrara Fm.

Computed Temperature
7640" = 194 °F

Mancos Fm.
Fort Hays Ls. Mmbr.

7100
7200
7300
7400
7500
7600
7700

Niobrara Sh

B Niobrara

TD=9270.00

SH aa w/incr amt MRLST mot gybrn/m-ltgy sft-firm plty-blky vcarb incr slchky mcalc; no oilstn, or live oil; flor-none; cut-vweak slow mlky residual cut

MRLST mot gybrn-crm/ltgy sft plty fis slchky carb slbent intbd w/in SH aa incr pyr; no oilstn, or live oil; flor-none; cut-vweak slow mlky residual cut

MRLST mot gybrn-crm/ltgy sft plty fis slchky carb slbent intbd w/in SH aa incr pyr; no oilstn, or live oil; flor-none; cut-vweak slow mlky residual cut

MRLST aa mot gybrn-crm/ltgy sft plty fis chky vcarb bent intbd w/in SH gybrn sft plty pyr; no oilstn, or live oil; flor-none; cut-vweak slow mlky residual cut

MRLST aa mot gybrn-crm/ltgy sft plty fis chky vcarb bent intbd w/in SH gybrn sft plty pyr; no oilstn, or live oil; flor-none; cut-vweak slow mlky residual cut

MRLST mot gybrn-crm/mgy sft plty fis vchky vcarb bent intbd w/SH aa ; no oilstn, or live oil; flor-none; cut-vweak slow mlky residual cut

MRLST mot gybrn-crm/mgy-incr dkgy vsft plty fis vchky vcarb bent intbd w/SH aa ; no oilstn, or live oil; flor-none; cut-vweak slow mlky residual cut, no change in smpl cut from above; no visible live oil in smpl; possible fracture at 7600-7610