

Rule 908.b(7) Geologic and Hydrologic Data

**LINN Operating Inc.
O-29 Centralized E&P Waste
Management Facility**

OA Project No. 014-1565

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Nicholson GeoSolutions, LLC

3433 East Lake Drive
Centennial, CO 80121

**Geologic Hazard Report for the Berry Petroleum Company
29-17 Produced Water Injection Well Facility**

Potential geologic hazards in the area of the 29-17 produced water injection well facility include slumping of excavation walls, erosive soils, landslides, flooding, and earthquakes. The 29-17 injection well is located on the existing O-29 well pad near Little Creek in the Garden Gulch area. The suitability of the soils in the area is identified as being very limited in regard to the construction of shallow excavations. The potential for earthquakes in western Colorado is considered to be low (CGS 2012). The facility is located above the level of occasional flooding of Little Creek.

Surficial Geology and Soils

The proposed location of the produced water facility is underlain by the Uinta Formation and the Parachute Creek member of the Green River Formation. Beds of the Uinta Formation alternate with tongues of with the underlying Green River Formation in this area. The Uinta Formation consists of marlstone (oil shale), sandstone, siltstone, and mudstone and the Parachute Creek Member consists of claystone, marlstone, and shale (Hail et al, 1989; Hail 1992; Tweto 1979). The 29-17 injection well facility location is underlain by soils of the soils of the Northwater-Adel complex, 5 to 50 percent slopes, Parachute-Irigul complex, 5 to 30 percent slopes, and Parachute-Irigul-Rhone association, 25 to 50 percent slopes (NRCS 2012). The Northwater-Adel complex soil is described as deep, well drained loam, channery loam, and extremely channery loam that extend to depths of about 60 inches. The Parachute-Irigul complex and Parachute-Irigul-Rhone association soils are described as well drained, shallow (17 to 29 inches) loam, channery loam and extremely channery loam. These soils all have an erosion factor K_w of 0.20, which generally means that the water erosion potential is low to moderate. Limitations of these soils in relation to the proposed project are discussed below.

Limitations of Soils for Intended Uses

The Natural Resources Conservation Service (NRCS) provides information regarding the suitability or limitations of soils for the proposed use, including shallow excavations. The Northwater-Adel complex, Parachute-Irigul complex, and Parachute-Irigul-Rhone association are rated as very limited for this purpose. The primary limitations identified by the NRCS for shallow excavations are based on the shallow depth to hard bedrock, steep slopes, and the potential for cutbanks to cave. The injection well is located on a well pad that was constructed several years ago and appears to be stable. An existing lined water storage pit is located south of the injection well on the well pad.

Landslides and Debris Flows

The primary geologic hazards in the Garden Gulch area are landslides and debris flows. The Garden Gulch Member of the Green River Formation has been eroded into steep slopes and cliffs along Garden Gulch and other drainages and the loose materials that form the slopes facing the creek are largely at the angle of repose. Several large slide zones have developed along the access road to the facility (the Garden Gulch Road) and on other roads in the area. In addition, small debris flows consisting of loose soil and rock emerge from steep drainages after large precipitation events and cover portions of the access roads.

The area where the 29-17 injection well facility has been built is near the confluence of Little Creek and an unnamed tributary to Little Creek, where slope angles are lower. In addition, the well pad has been previously leveled with no loss of slope stability. Therefore, landslides are not considered to be a threat to the facility. The Garden Gulch Road crosses areas where landslides and debris flows have occurred and could potentially be affected by future landslides.

Siesmicity and Earthquakes

Approximately 400 earthquakes of magnitude 2.5 or greater have occurred in Colorado since 1867 (CGS 2012). However, most of these earthquakes have been below magnitude 3.0 and have not caused significant damage. Most of the largest earthquakes in Colorado history were associated with the injection of waste liquids at the Rocky Mountain Arsenal during the 1960s. In addition, the Colorado Earthquake and Fault Map shows that no faults considered to be potentially active occur on the Roan Plateau (CEHMC 2008), although at least two earthquakes with a magnitude of 5.0 have occurred within the Piceance Basin. Given the lack of potentially active faults on the Plateau, the potential for a damaging earthquake to occur near the proposed facility is considered to be very low.

Flooding

Flooding along Little Creek occurs occasionally. The 29-17 injection well facility has been built on the O-29 well pad, which is located above the high water level from flooding along the creek. The access road to the well pad crosses a low area adjacent to Little Creek and its unnamed tributary that flows into Little Creek just below the well pad. Flooding along Little Creek could potentially impact the low portion of the access road to the facility but not the water storage and injection well site itself.

Summary and Conclusions

Potential geologic hazards in the area of the 29-17 produced water injection well facility and access road include slumping of excavation walls, erosive soils, landslides, and earthquakes. The soils at the facility have a low to moderate water erosion potential; therefore, excessive soil erosion is not expected. Landslides could potentially occur along the access road to the facility, but not at the facility itself. The potential for a damaging earthquake to strike the facility is considered to be very low. Flooding along Little Creek could potentially impact the low portion of the access road to the facility but not the water storage and injection well site itself. Based on

the available geologic information, there is little or no expected impact to the facility resulting from geologic hazards.

References

Colorado Geological Survey, Earthquakes in Colorado, accessed at

<http://geosurvey.state.co.us/hazards/Earthquakes/Pages/Earthquakes.aspx>; July 30, 2012

Colorado Earthquake Hazard Mitigation Council, 2008, Colorado Earthquake Hazards, accessed at http://geosurvey.state.co.us/hazards/Earthquakes/Documents/Earthquake_Map_2008.pdf; July 31, 2012

Hail, W.J., O'Sullivan, R.B., and Smith, M.C., 1989, Geologic map of the Roan Plateau area, northwestern Colorado: U.S. Geological Survey, Miscellaneous Investigations Series Map I-1797-C, scale 1:50000.

Hail, W.J., 1992, Geology of the central Roan Plateau area, northwestern Colorado: U.S. Geological Survey, Bulletin 1787-R, scale 1:164000.

Tweto, Ogden, 1979, Geologic map of Colorado: U.S. Geological Survey, scale 1:500000.

U. S. Department of Agriculture, Natural Resources Conservation Service, 2012, Custom Soil Resource Report for Rifle Area, Colorado, Parts of Garfield and Mesa Counties, Web Soil Survey; generated on August 16, 2012.

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HYDROLOGIC REPORT

**LINN O-29 CENTRALIZED EXPLORATION AND PRODUCTION
WASTE MANAGEMENT FACILITY
SW ¼ SE ¼ SECTION 29, T5S, R96W, 6 P.M.
GARFIELD COUNTY, COLORADO**

PREPARED FOR:

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NOVEMBER 2014

PROJECT No. 014-1565

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1.0 EXECUTIVE SUMMARY

Olsson Associates (Olsson) was contracted by Linn Operating Inc. to assess the centralized E&P waste management facility associated with the injection well located in the SW ¼ SE ¼ Section 29, Township 5 South, Range 96 West, of the 6th Principal Meridian, Garfield County, Colorado. The site is at an elevation of about 7,919 feet above mean sea level (amsl) as shown on the attached **Figure T-1 - Topographic Map**.

The purpose of this report is to assess hydrologic features within the vicinity of the site per the Colorado Oil and Gas Conservation Commission (COGCC) Rule 908. Centralized E&P Waste Management Facilities, permit requirements, specifically 908.b(7)B. Hydrologic data which includes assessment of the following information:

- i. Surface water features within two (2) miles;*
- ii. Depth to shallow groundwater and major aquifers;*
- iii. Water wells within one (1) mile of the site boundary and well depth, depth to water, screened intervals, yields, and aquifer name;*
- iv. Hydrologic properties of shallow groundwater and major aquifers including direction of flow, flow rate, and potentiometric surface;*
- v. Existing quality of shallow groundwater;*
- vi. An evaluation of the potential for impacts to nearby surface water and groundwater.*

This report presents Olsson findings following an evaluation of these and other hydrogeologic conditions potentially affecting the site and proposed development. The Linn Operating O-29 (Site) was found to be suitable for the proposed development with consideration of the following hydrologic conditions.

- The Linn O-29 is located on a point between two tributaries of Little Creek.
- The Linn O-29 site is located on the Uinta Formation. The Uinta Formation and underlying Parachute Creek member of the Green River Formation host the Uinta – Animas aquifer, a regionally important bedrock aquifer.
- The depth to groundwater in this area is variable and is expected to lie at depths of more than 50 feet bgs as based on information available from the Colorado Division of Water Resources. If the surface water impoundment and the associated tanks are properly constructed, lined, and operated so that overflows do not occur and liners are intact, the bedrock aquifer and surface water should not be impacted.
- Alluvial aquifers are not expected in the vicinity of the site and therefore are not expected to be impacted by operation of the Linn O-29 site.
- If the surface water impoundment was to overflow or a breach were to occur in the liner as a result of site operations, surface water in Little Creek could be adversely impacted. Surface water flows to the northeast toward the North Fork of Parachute Creek. Shallow groundwater, where present, is expected to follow topography and flow to the northeast.

This report should be read in its entirety, including but not limited to the conclusions and recommendations in section 4.0.

2.0 GENERAL SITE LOCATION AND BACKGROUND

Linn Operating Inc. (Linn) contracted Olsson Associates (Olsson) to conduct a hydrologic assessment as part of the proposed development of the Linn O-29 centralized exploration and production (E&P) waste management facility for management of produced water for disposal in the onsite injection well. The proposed facility will be used to store and dispose of produced water and other approved E&P water wastes. The site will consist of a surface water impoundment pit and the associated tanks for water storage. The following sections provide information about the hydrologic setting. The site location is shown on **Figure SL-1 – Site Location Map**.

2.1 Project and Site Description

The Linn O-29 injection well pad is located approximately 12 miles to the northwest of the town of Parachute, Colorado. Access to the site is gained off of Garden Gulch Road. The site is located in the SW ¼ SE ¼ Section 29, T5S, R96W, 6th P.M. at an elevation of approximately 7,919 feet amsl.

2.2 Surface Waters

The site is located on a point between the north and south fork drainages of Little Creek. Willow Creek is located to the north, and Bear Run is located further north. Light Gulch is located to the northeast. House Log Gulch is located to the south, and Circle Dot Gulch is located further south within a two mile radius of the site. Surface water flow is directed to the northeast and these surface waters drain to the North Fork of Parachute Creek approximately three (3) miles to the northeast. **Figure SW-1 – Surface Water Map** shows the site relative to surface water features within two miles of the site.

2.3 Shallow Groundwater

Shallow groundwater does not appear to be present in the vicinity of the site based on a review of information from the Colorado Division of Water Resources (DWR) for permitted water wells in the area. Several monitoring holes permitted by Encana Oil and Gas are shown to the north of the site. The total depths of these wells are listed at between 24 feet and 34 feet below ground surface (bgs), but static water levels were not listed for these wells and the indication in the boring logs is that these wells were dry. The surface elevations of these wells range from 5,895.2 feet to 6,179.54 feet amsl (DWR, 2014). The permitted water wells within one mile of the site are shown on **Figure PW-1 – Permitted Water Wells**.

Marathon Oil Company has several monitoring holes permitted in Section 32, with total depths that range from 191 feet to 239 feet bgs. The static water levels in these wells are listed at between 171 feet and 233 feet bgs. The elevations of these wells range from 8,333.2 feet to 8,364.1 feet. Bargath LLC has three canceled well permits for wells located just outside the one mile radius to the southeast. The depths of these wells were reported at between 14 feet and 20.5 feet bgs, and static water levels reported at between 4.5 feet and 11 feet bgs. Elevations of these wells range from 5,378 feet and 5,389 feet (DWR, 2014).

Shallow groundwater is expected to follow topography and flow to the northeast. A potentiometric surface map cannot be created since there are no monitoring wells in the

immediate vicinity of the site. Since groundwater in the bedrock is fracture controlled, it is also likely that the water levels would be influenced by the presence of fractures and impermeable layers and would be expected to discharge at locations where these layers crop out in the sides of the canyons. Many such springs are known to occur in the area along the main drainages.

2.4 Major Aquifers

The site is located on the Roan Plateau northwest of the town of Parachute. The geology at the surface of the site is the Tertiary Uinta Formation which is exposed at the surface over most of the Piceance Creek basin. The Piceance Creek basin, located in western Colorado, occupies parts of central Garfield County and Rio Blanco County. It is bound by the Uinta uplift to the north, the White River uplift to the east, the Sawatch Uplift to the southeast, and the Douglas Creek Arch to the west (Czyewski, 1999). The hydrogeology is shown on **Figure H-1**.

The Uinta Formation and underlying Green River Formation contain the Uinta-Animas aquifer (Robson and Banta, 1995). The Uinta Formation consists of intertongued beds of sandstone, siltstone, and marlstone. According to published geologic maps, the Uinta Formation is the bedrock unit present beneath the Linn O-29 site. The maximum thickness of the Uinta Formation is 500 feet.

The Tertiary age Parachute Creek member of the Green River Formation underlies the Uinta Formation. The Parachute Creek member has a maximum thickness of 1,800 feet. The Parachute Creek member is the most important hydrogeologic unit in the basin for groundwater resources. The Parachute Creek member consists primarily of kerogen rich dolomitic marlstone, referred to as "oil shale" (Czyewski, 1999) (Robson and Banta, 1995).

The Uinta-Animas aquifer in the Piceance Basin consists of silty sandstone, siltstone, and marlstone, which is largely impermeable, but in some parts of the aquifer much of the intergranular space within these rocks was filled by sodium and calcium bicarbonate cements. Fractures and dissolution of carbonate minerals produces substantial secondary permeability.

The Parachute Creek member has been divided into three zones based on lithology, hydrology, and geophysical characteristics. These zones include 1) the upper aquifer, 2) the Mahogany zone, and 3) the lower aquifer. The upper and lower aquifers are separated by the Mahogany zone as a confining unit that contains more kerogen and is less permeable than the surrounding aquifers. However, the Mahogany zone is locally fractured and permits some communication between the two aquifer systems. The vertical hydraulic conductivity of the Mahogany zone has been estimated to be as much as 0.37 feet per day (ft/day) (Weeks and others, 1974). The lower aquifer is underlain by a high resistivity zone of brine water near the center of the basin.

The Garden Gulch member, Douglas Creek member, and Anvil Points member of the Green River Formation and the underlying Wasatch Formation form a thick confining unit, thousands of feet thick, and that separates the Uinta-Animas aquifer from the underlying Mesaverde aquifer (Robson and Banta, 1995).

Alluvium deposited along Parachute Creek and major tributaries is locally an important aquifer where the accumulated thickness of the alluvium is thick enough to contain sufficient groundwater yield. The alluvium consists primarily of larger sedimentary clasts of sandstone,

marlstone, and siltstone that have fallen from the cliffs of the Uinta and Green River Formations, as well as clay, silt, and sand-sized particles that have eroded from the sedimentary formations.

2.5 Hydrologic Setting

Aquifers in the Piceance Basin are recharged almost entirely from precipitation that falls within the basin. Snow accumulates in the winter months at higher elevations within the basin and melts in the spring supplying runoff to surface water drainages and infiltration and recharge to the aquifers. In the summer, thunderstorms provide rainfall on the upland areas between stream valleys; however, summer rainfall is typically not available for aquifer recharge due to direct runoff or evapotranspiration. The principal source of groundwater recharge is the infiltration of precipitation and snowmelt. Recharge occurs in areas where more porous and permeable rocks crop out at the surface, primarily near the margins of the basin.

The alluvium occurring along the primary streams and their tributaries constitute locally important aquifers. The volume of water withdrawn from the alluvial aquifers is small as compared to that produced from the major bedrock aquifers. In parts of the basin, the alluvial aquifers are hydraulically connected to the deeper aquifers. Groundwater is discharged from the upper aquifer to the alluvium through the valley floors and springs along the valley walls. Groundwater is discharged from the lower aquifer in areas where the lower aquifer crops out in low topographic areas in the northern part of the basin, and by vertical seepage across the Mahogany zone. Hydraulic conductivity for the upper Piceance Basin aquifer unit ranges from 0.8 to 1.2 feet per day, while the hydraulic conductivity of the Mahogany confining unit is less than 0.01 feet per day, and the hydraulic conductivity in the lower Piceance Basin aquifer unit ranges from 0.1 to 1.1 feet per day (Topper et al, 2003).

The potentiometric surface maps for the upper Piceance Basin aquifer and the lower Piceance Basin aquifer are shown in the Ground Water Atlas of Colorado (Topper et al, 2003) in Figure 6.2-14 and 6.2-15. Groundwater flow is directed to the northeast in the vicinity of the site, but is shown as radial in the Roan Cliffs near Parachute Creek.

2.6 Groundwater Quality

The total dissolved solids (TDS) concentrations in the alluvial aquifer typically increases from approximately 250 milligrams per liter (mg/l) in recharge areas, to about 25,000 mg/l in the downstream discharge areas as a result of the solution of soluble minerals and recharge to the alluvial aquifer from the deeper aquifers. The water quality of the upper and lower aquifers is distinct as a result of the hydrogeologic conditions of the two aquifers. The groundwater in the upper aquifer is of a sodium bicarbonate type that degrades in quality with depth and increased distance from the recharge points. The TDS in groundwater from the upper part of Piceance Basin aquifer generally ranges from 500 mg/l to more than 1,000 mg/l. Concentrations in the lower aquifer exceed 10,000 mg/l where extensive fracturing of the saline zone that underlies the aquifer has resulted in upward migration of brine (Czyzewski, 1999).

2.7 Flood Plain

Flash floods are a potential issue during intense summer thunderstorms that slowly move over the Roan Plateau, or if snowmelt were to occur rapidly. The site is located at an elevation of 7,919 feet which is in an upland area well above area drainages that would be prone to flooding. There is much greater chance of flooding along the Little Creek, Light Gulch, or other streams that flow to the northeast toward the North Fork of Parachute Creek.

3.0 ASSESSMENT OF POTENTIAL IMPACTS

The following sections present the assessment of potential impacts to groundwater and surface water in the vicinity of the proposed Linn O-29 site.

3.1 Bedrock Aquifer

The Uinta Formation and underlying members of the Green River Formation constitute a regionally important aquifer. The Uinta–Animas aquifer underlies the site. All of the DWR permitted water wells within one mile of the site are identified as being used for groundwater monitoring and are owned by oil and gas companies. The groundwater in this aquifer is fracture controlled and is variable and difficult to determine where groundwater will be present. The few wells to the north of the site show that groundwater was not encountered down to depths ranging from 24 feet to 34 feet bgs.

Impacts to groundwater in the bedrock aquifer can be prevented by proper construction and operation of the surface water impoundment including proper lining of the pit, and a lined secondary containment for the tanks. Installation of perimeter groundwater monitoring wells may be required by the COGCC for a change in use to a centralized E&P Waste Management facility per rule 908.

If a leak were to occur in the liner, there is a high probability that the bedrock aquifer could be impacted. It can be difficult to determine where the impacted groundwater may discharge; however, it may impact surface water or springs in the area.

It is expected that shallow groundwater follows topography and would flow to the northeast toward the confluence with the North Fork of Parachute Creek. Local structural controls may influence groundwater flow in deeper aquifers and can result in different flow directions.

The presence of shallow groundwater, if present, and groundwater conditions including flow direction and water quality would require assessing site specific conditions. This would require the installation of onsite monitoring wells which was beyond the scope of this hydrology review.

3.2 Alluvial Aquifers

No alluvial aquifers are present in the immediate vicinity of the facility. Therefore, alluvial aquifers are not expected to be adversely impacted by the operations at the Linn O-29 site. Alluvial aquifers are present along Parachute Creek and the major tributary streams that feed into the North Fork of Parachute Creek. Alluvial sediments are not expected to be of sufficient thickness to host an alluvial aquifer along the segments of Little Creek due to the elevation of this stream and expected gradient toward the rim of the North Fork of Parachute Creek.

3.3 Surface Water

The site is located on a point between two tributaries of Little Creek. If the surface water impoundment were to overflow, the pit liner breach, or a tank rupture, it is very likely that it would adversely impact surface water in Little Creek. If a leak were to occur in the surface impoundment liner, it may impact surface water in Little Creek.

4.0 Conclusions and Recommendations

The following conclusions and recommendations are based on a review of the available hydrology information for the for the Linn O-29 surface water impoundment and injection facility.

- The Linn O-29 is located on a point between two tributaries of Little Creek.
- The Linn O-29 site is located on the Uinta Formation. The Uinta Formation and underlying Parachute Creek member of the Green River Formation host the Uinta – Animas aquifer, a regionally important bedrock aquifer.
- The depth to groundwater in this area is variable and is expected to lie at depths of more than 50 feet bgs as based on information available from the Colorado Division of Water Resources. If the surface water impoundment and the associated tanks are properly constructed, lined, and operated so that overflows do not occur and liners are intact, the bedrock aquifer and surface water should not be impacted.
- Alluvial aquifers are not expected in the vicinity of the site and therefore are not expected to be impacted by operation of the Linn O-29 site.
- If the surface water impoundment was to overflow or a breach was to occur in the liner as a result of site operations, surface water in Little Creek could be adversely impacted. Surface water flows to the northeast toward the North Fork of Parachute Creek. Shallow groundwater, where present, is expected to follow topography and flow to the northeast.

The COGCC may require the installation of groundwater monitoring wells at the site to demonstrate that shallow groundwater is not impacted as a condition of the approval of the application for a centralized E&P waste management facility per rule 908. The pit will need to be properly constructed, lined, and operated in accordance with COGCC Rules.

5.0 References

- Cashion, W.B., 1973, Geologic and Structure Map of the Grand Junction Quadrangle, Colorado and Utah, USGS, Map I-736, scale 1:250,000
- Czyzewski, Gene, 1999, Colorado Ground-Water Atlas, Chapter 12, The Piceance Creek Basin, Colorado Ground-Water Association, pp 63 – 66.
- Hail, W.J., Jr., 1982, Preliminary Geology of the Circle Dot Gulch Quadrangle, Garfield County, Colorado, USGS Miscellaneous Field Studies, Map MF-1293, Scale 1:24,000
- Hail, W.J., Jr., 1992, U.S.G.S. Bulletin 1787-R, *Geology of the Central Roan Plateau Area, Northwestern, Colorado*, 26 p.,
- Robson, S.G. and Banta, E.R., 1995, U.S.G.S. *Hydrologic Investigations Atlas 730-C, Groundwater Atlas of the United States, Segment 2, Arizona, Colorado, New Mexico, Utah*, 32 p.
- Topper, R., Spray, K. L., Bellis, W.H., Hamilton, J.L., Barkman, P.E., *Ground Water Atlas of Colorado*, Colorado Geologic Survey, 2003, Special Publication 53, 210 p.
- Weeks, J.B., 1974, Water Resource of Piceance Creek Basin, Colorado, in Energy resources of the Piceance Creek Basin, Colorado, twenty-fifth field conference: Denver, Rocky Mountain Association of Geologists.

Online References

- Colorado Oil and Gas Conservation Commission <http://cogcc.state.co.us/>
- Natural Resources Conservation Service - Soil Survey <http://www.nrcs.usda.gov/>
- Garfield County
 - Slope Hazards: <http://garfield-county.com/geographic-information-systems/documents/6439291200422slopehaz.pdf>
 - Soil Hazards: <http://garfield-county.com/geographic-information-systems/documents/64335291200423soilhaz.pdf>
 - Surficial Geology of Garfield County: <http://garfield-county.com/geographic-information-systems/documents/geologic-hazards/24surfgeo.pdf>
- Colorado Geological Survey website: <http://geosurvey.state.co.us/hazards>
- Colorado Geological Survey website: <http://geosurvey.state.us/land/Pages/ProfessionalGeologist>
- Colorado Department of Public Health and Environment: http://co-radon.info/CO_radon_map.html

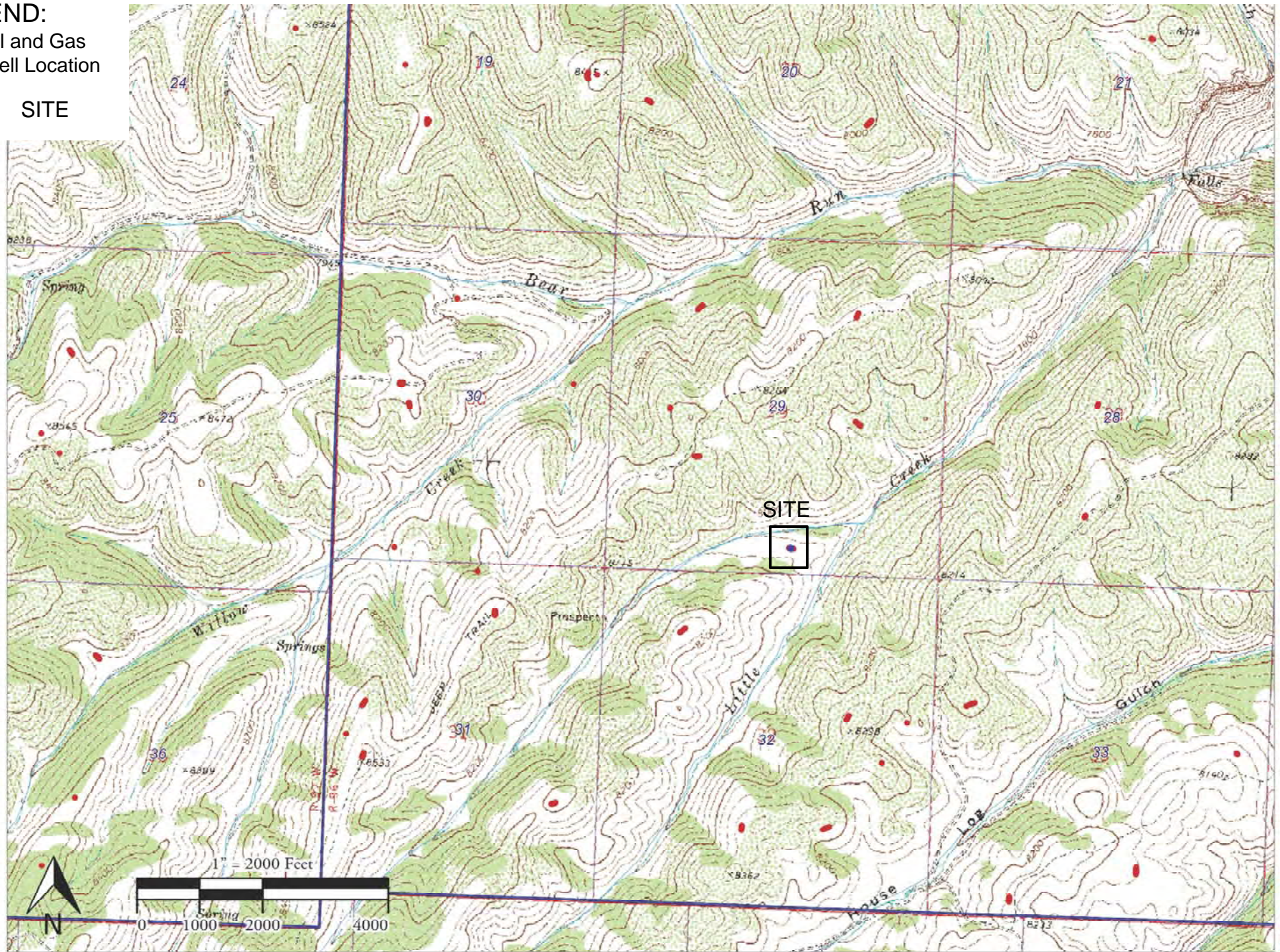
FIGURES

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LEGEND:

- Oil and Gas Well Location

□ SITE



PROJECT NO: 014-1565

DRAWN BY: JWH

DATE: 11/4/2014

SITE LOCATION MAP

Linn O-29 Centralized E&P Waste Management Facility
SW ¼ SE ¼ 29 T5S R96W - Garfield County, Colorado

OLSSON
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Golden, Colorado 80403
TEL 303.237.2072
FAX 303.237.2659

FIGURE

T-1

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LEGEND:

● Oil and Gas Well Location

● Water Well Location

□ SITE



PROJECT NO: 014-1565

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DATE: 11/4/2014

SITE LOCATION MAP

Linn O-29 Centralized E&P Waste Management Facility
SW ¼ SE ¼ 29 T5S R96W - Garfield County, Colorado

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FIGURE

SL-1

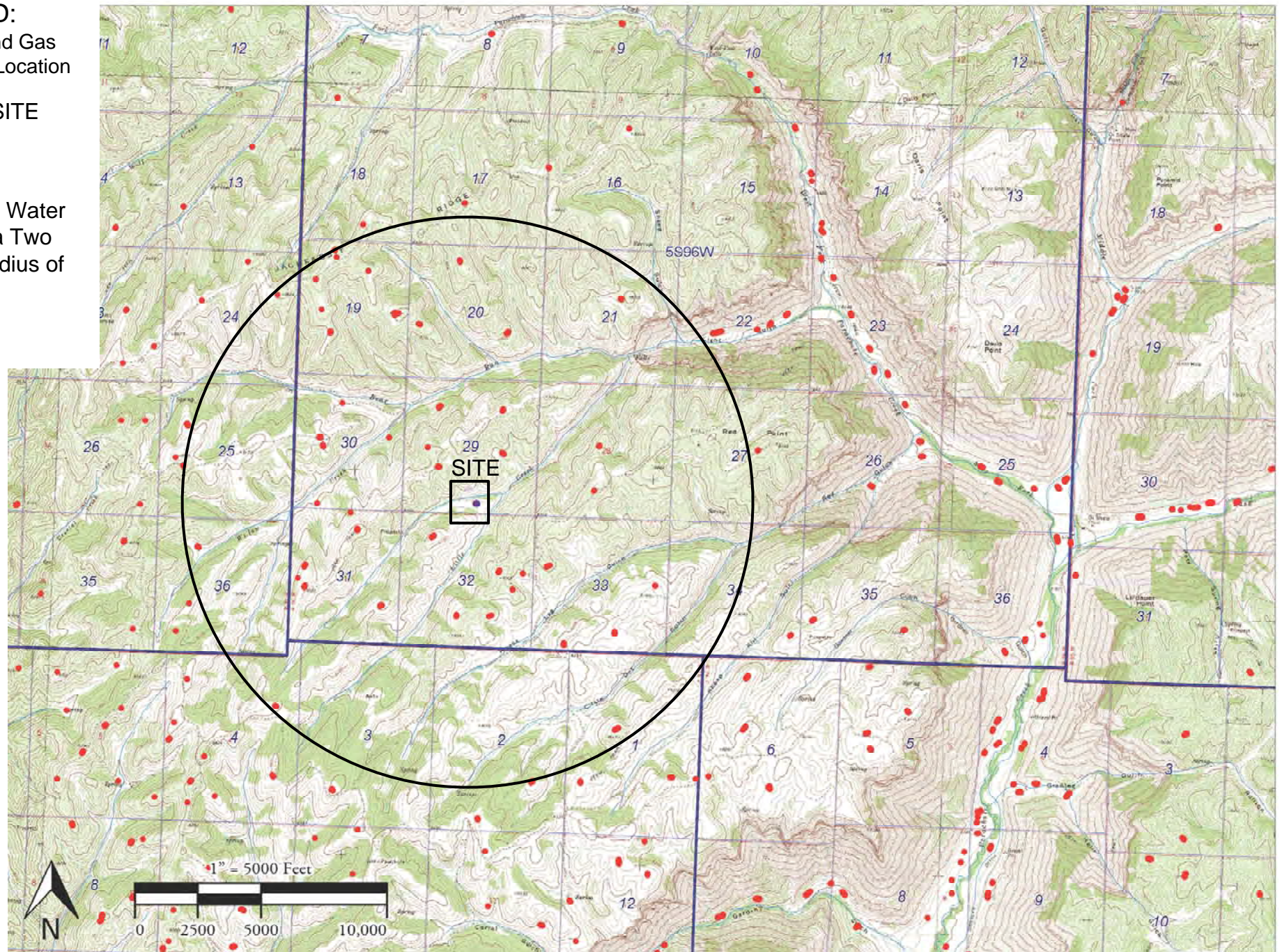
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LEGEND:

● Oil and Gas Well Location

□ SITE

Surface Water Within a Two Mile Radius of the Site



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SURFACE WATER MAP

Linn O-29 Centralized E&P Waste Management Facility
SW ¼ SE ¼ 29 T5S R96W - Garfield County, Colorado

OLSSON
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Golden, Colorado 80403
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FIGURE

SW-1

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LEGEND:

● Oil and Gas Well Location

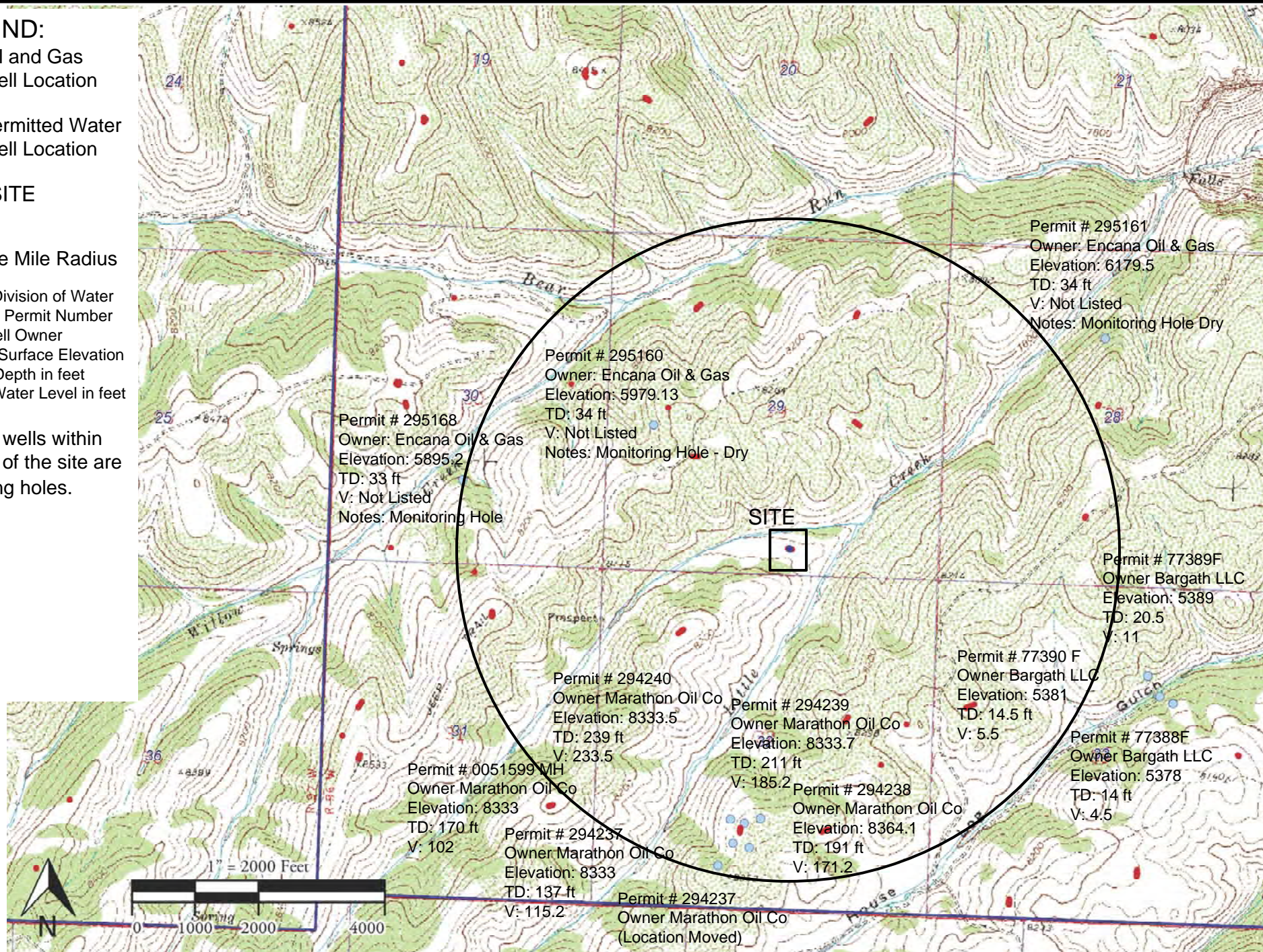
● Permitted Water Well Location

□ SITE

○ One Mile Radius

Permit # Division of Water Resources Permit Number
Owner: Well Owner
Elevation: Surface Elevation
TD: Total Depth in feet
V: Static Water Level in feet

Note: All wells within one mile of the site are monitoring holes.



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PERMITTED WATER WELLS MAP

Linn O-29 Centralized E&P Waste Management Facility
SW ¼ SE ¼ 29 T5S R96W - Garfield County, Colorado

OLSSON
ASSOCIATES

4690 Table Mountain Drive #200
Golden, Colorado 80403
TEL 303.237.2072
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FIGURE

PW-1

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LEGEND:

● Oil and Gas Well Location

● Permitted Water Well Location

□ SITE

Tu – Uinta Formation

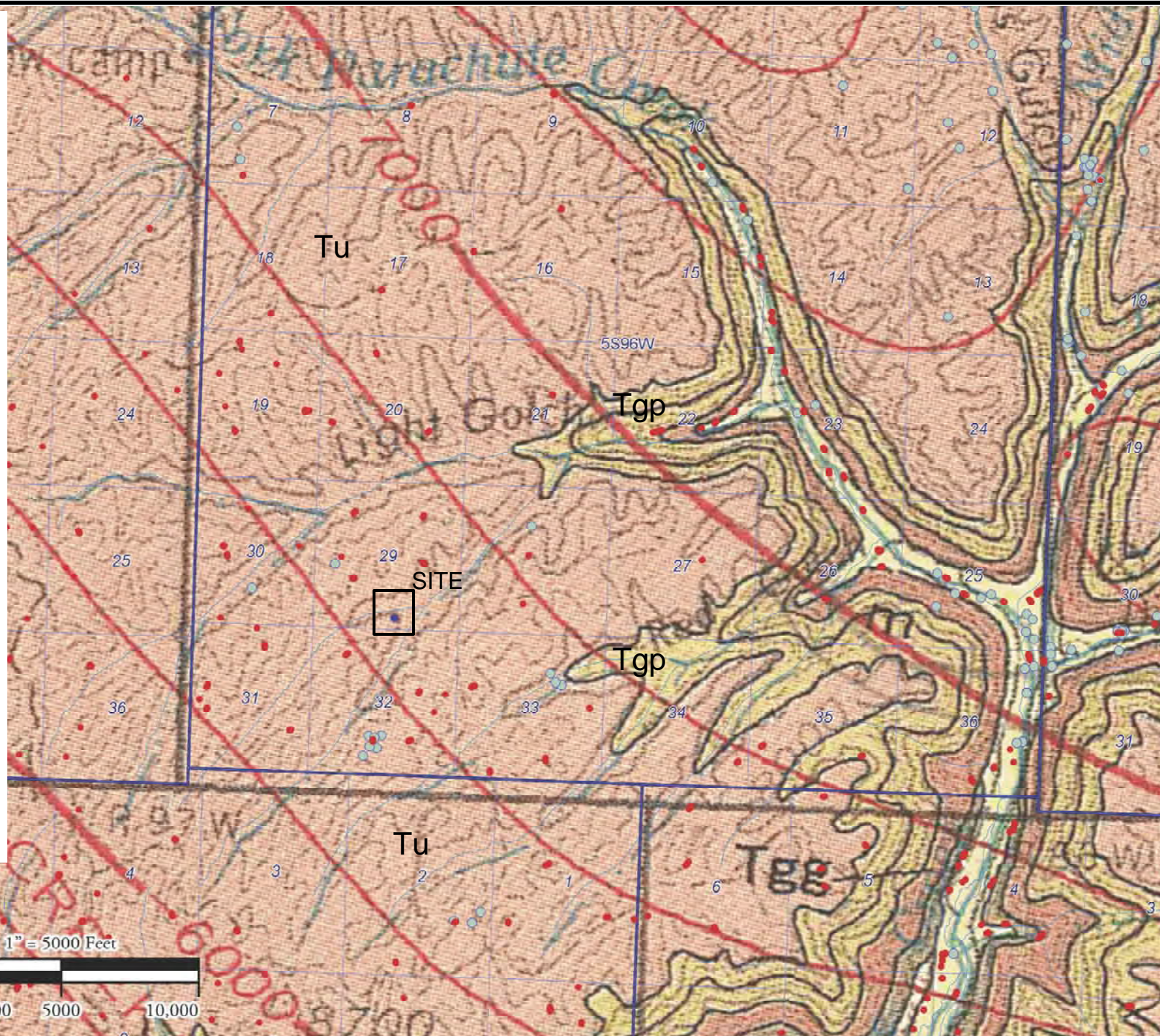
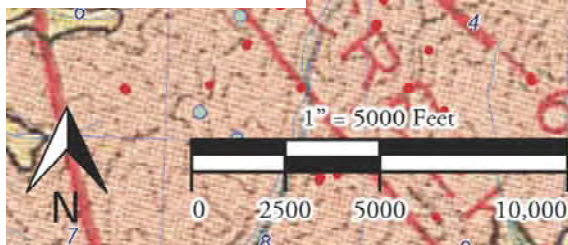
Tgp – Parachute Creek Member - Green River Formation

Tgg – Garden Gulch Member Green River Formation

M Mahogany Zone

Structure Contours drawn on top of the Dakota Sandstone

Base Map from the Geologic and Structural Map of the Grand Junction Quadrangle, Colorado and Utah (Cashion, 1973)



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DATE: 11/4/2014

HYDROGEOLOGIC MAP

Linn O-29 Centralized E&P Waste Management Facility
SW ¼ SE ¼ 29 T5S R96W - Garfield County, Colorado

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ASSOCIATES

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FIGURE

H-1

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United States
Department of
Agriculture



NRCS

Natural
Resources
Conservation
Service

A product of the National
Cooperative Soil Survey,
a joint effort of the United
States Department of
Agriculture and other
Federal agencies, State
agencies including the
Agricultural Experiment
Stations, and local
participants

Custom Soil Resource Report for Douglas-Plateau Area, Colorado, Parts of Garfield and Mesa Counties



August 16, 2012

Preface

Soil surveys contain information that affects land use planning in survey areas. They highlight soil limitations that affect various land uses and provide information about the properties of the soils in the survey areas. Soil surveys are designed for many different users, including farmers, ranchers, foresters, agronomists, urban planners, community officials, engineers, developers, builders, and home buyers. Also, conservationists, teachers, students, and specialists in recreation, waste disposal, and pollution control can use the surveys to help them understand, protect, or enhance the environment.

Various land use regulations of Federal, State, and local governments may impose special restrictions on land use or land treatment. Soil surveys identify soil properties that are used in making various land use or land treatment decisions. The information is intended to help the land users identify and reduce the effects of soil limitations on various land uses. The landowner or user is responsible for identifying and complying with existing laws and regulations.

Although soil survey information can be used for general farm, local, and wider area planning, onsite investigation is needed to supplement this information in some cases. Examples include soil quality assessments (<http://soils.usda.gov/sqi/>) and certain conservation and engineering applications. For more detailed information, contact your local USDA Service Center (<http://offices.sc.egov.usda.gov/locator/app?agency=nracs>) or your NRCS State Soil Scientist (http://soils.usda.gov/contact/state_offices/).

Great differences in soil properties can occur within short distances. Some soils are seasonally wet or subject to flooding. Some are too unstable to be used as a foundation for buildings or roads. Clayey or wet soils are poorly suited to use as septic tank absorption fields. A high water table makes a soil poorly suited to basements or underground installations.

The National Cooperative Soil Survey is a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local agencies. The Natural Resources Conservation Service (NRCS) has leadership for the Federal part of the National Cooperative Soil Survey.

Information about soils is updated periodically. Updated information is available through the NRCS Soil Data Mart Web site or the NRCS Web Soil Survey. The Soil Data Mart is the data storage site for the official soil survey information.

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How Soil Surveys Are Made

Soil surveys are made to provide information about the soils and miscellaneous areas in a specific area. They include a description of the soils and miscellaneous areas and their location on the landscape and tables that show soil properties and limitations affecting various uses. Soil scientists observed the steepness, length, and shape of the slopes; the general pattern of drainage; the kinds of crops and native plants; and the kinds of bedrock. They observed and described many soil profiles. A soil profile is the sequence of natural layers, or horizons, in a soil. The profile extends from the surface down into the unconsolidated material in which the soil formed or from the surface down to bedrock. The unconsolidated material is devoid of roots and other living organisms and has not been changed by other biological activity.

Currently, soils are mapped according to the boundaries of major land resource areas (MLRAs). MLRAs are geographically associated land resource units that share common characteristics related to physiography, geology, climate, water resources, soils, biological resources, and land uses (USDA, 2006). Soil survey areas typically consist of parts of one or more MLRA.

The soils and miscellaneous areas in a survey area occur in an orderly pattern that is related to the geology, landforms, relief, climate, and natural vegetation of the area. Each kind of soil and miscellaneous area is associated with a particular kind of landform or with a segment of the landform. By observing the soils and miscellaneous areas in the survey area and relating their position to specific segments of the landform, a soil scientist develops a concept, or model, of how they were formed. Thus, during mapping, this model enables the soil scientist to predict with a considerable degree of accuracy the kind of soil or miscellaneous area at a specific location on the landscape.

Commonly, individual soils on the landscape merge into one another as their characteristics gradually change. To construct an accurate soil map, however, soil scientists must determine the boundaries between the soils. They can observe only a limited number of soil profiles. Nevertheless, these observations, supplemented by an understanding of the soil-vegetation-landscape relationship, are sufficient to verify predictions of the kinds of soil in an area and to determine the boundaries.

Soil scientists recorded the characteristics of the soil profiles that they studied. They noted soil color, texture, size and shape of soil aggregates, kind and amount of rock fragments, distribution of plant roots, reaction, and other features that enable them to identify soils. After describing the soils in the survey area and determining their properties, the soil scientists assigned the soils to taxonomic classes (units). Taxonomic classes are concepts. Each taxonomic class has a set of soil characteristics with precisely defined limits. The classes are used as a basis for comparison to classify soils systematically. Soil taxonomy, the system of taxonomic classification used in the United States, is based mainly on the kind and character of soil properties and the arrangement of horizons within the profile. After the soil scientists classified and named the soils in the survey area, they compared the

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individual soils with similar soils in the same taxonomic class in other areas so that they could confirm data and assemble additional data based on experience and research.

The objective of soil mapping is not to delineate pure map unit components; the objective is to separate the landscape into landforms or landform segments that have similar use and management requirements. Each map unit is defined by a unique combination of soil components and/or miscellaneous areas in predictable proportions. Some components may be highly contrasting to the other components of the map unit. The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The delineation of such landforms and landform segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, onsite investigation is needed to define and locate the soils and miscellaneous areas.

Soil scientists make many field observations in the process of producing a soil map. The frequency of observation is dependent upon several factors, including scale of mapping, intensity of mapping, design of map units, complexity of the landscape, and experience of the soil scientist. Observations are made to test and refine the soil-landscape model and predictions and to verify the classification of the soils at specific locations. Once the soil-landscape model is refined, a significantly smaller number of measurements of individual soil properties are made and recorded. These measurements may include field measurements, such as those for color, depth to bedrock, and texture, and laboratory measurements, such as those for content of sand, silt, clay, salt, and other components. Properties of each soil typically vary from one point to another across the landscape.

Observations for map unit components are aggregated to develop ranges of characteristics for the components. The aggregated values are presented. Direct measurements do not exist for every property presented for every map unit component. Values for some properties are estimated from combinations of other properties.

While a soil survey is in progress, samples of some of the soils in the area generally are collected for laboratory analyses and for engineering tests. Soil scientists interpret the data from these analyses and tests as well as the field-observed characteristics and the soil properties to determine the expected behavior of the soils under different uses. Interpretations for all of the soils are field tested through observation of the soils in different uses and under different levels of management. Some interpretations are modified to fit local conditions, and some new interpretations are developed to meet local needs. Data are assembled from other sources, such as research information, production records, and field experience of specialists. For example, data on crop yields under defined levels of management are assembled from farm records and from field or plot experiments on the same kinds of soil.

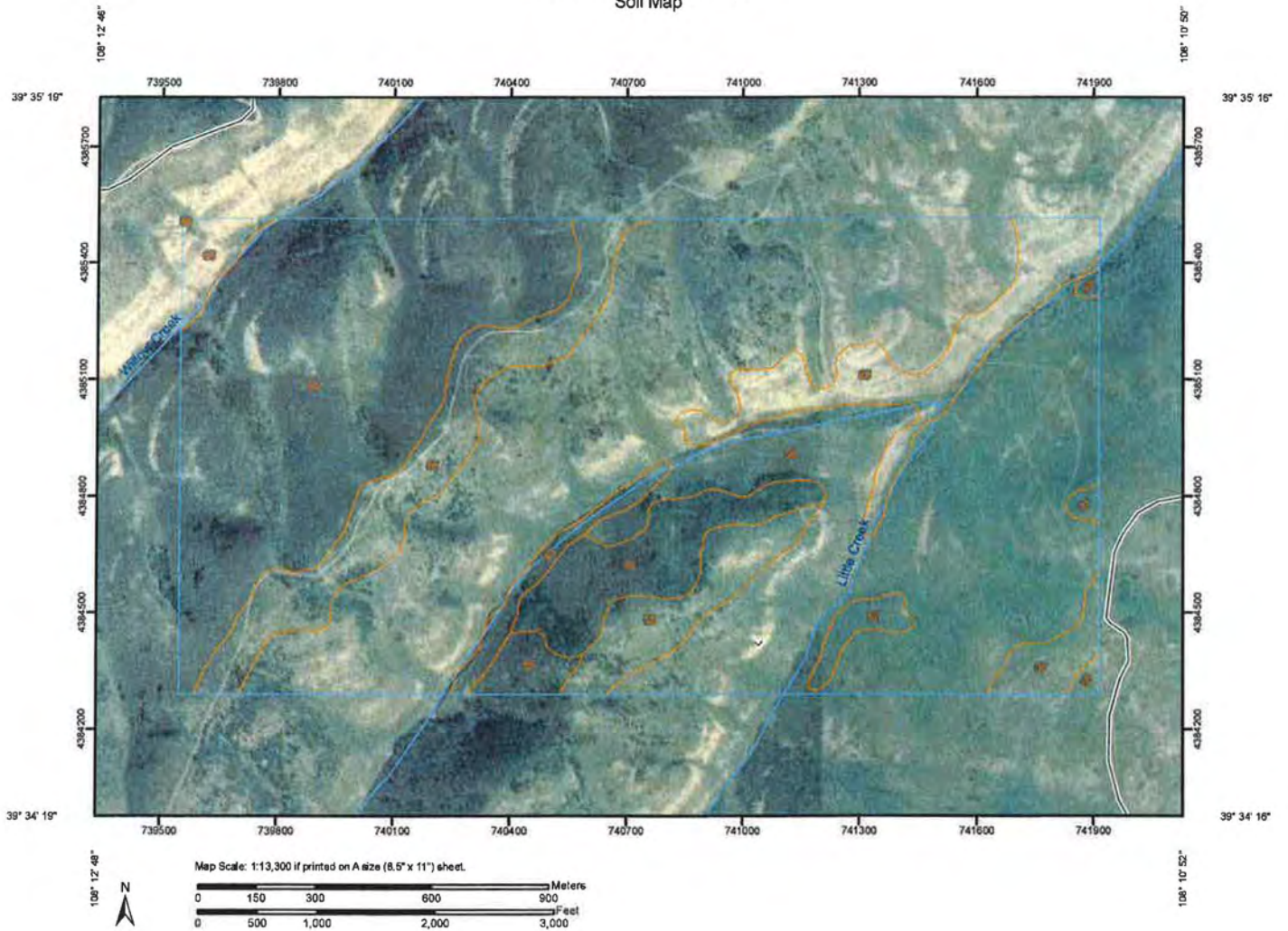
Predictions about soil behavior are based not only on soil properties but also on such variables as climate and biological activity. Soil conditions are predictable over long periods of time, but they are not predictable from year to year. For example, soil scientists can predict with a fairly high degree of accuracy that a given soil will have a high water table within certain depths in most years, but they cannot predict that a high water table will always be at a specific level in the soil on a specific date.

After soil scientists located and identified the significant natural bodies of soil in the survey area, they drew the boundaries of these bodies on aerial photographs and identified each as a specific map unit. Aerial photographs show trees, buildings, fields, roads, and rivers, all of which help in locating boundaries accurately.

Soil Map

The soil map section includes the soil map for the defined area of interest, a list of soil map units on the map and extent of each map unit, and cartographic symbols displayed on the map. Also presented are various metadata about data used to produce the map, and a description of each soil map unit.

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Soil Map



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MAP LEGEND

Area of Interest (AOI)			Very Stony Spot
	Area of Interest (AOI)		Wet Spot
Soils			Other
	Soil Map Units	Special Line Features	
Special Point Features			Gully
	Blowout		Short Steep Slope
	Borrow Pit		Other
	Clay Spot	Political Features	
	Closed Depression		Cities
	Gravel Pit	Water Features	
	Gravelly Spot	Streams and Canals	
	Landfill	Transportation	
	Lava Flow		Rails
	Marsh or swamp		Interstate Highways
	Mine or Quarry		US Routes
	Miscellaneous Water		Major Roads
	Perennial Water		Local Roads
	Rock Outcrop		
	Saline Spot		
	Sandy Spot		
	Severely Eroded Spot		
	Sinkhole		
	Slide or Slip		
	Sodic Spot		
	Spoil Area		
	Stony Spot		

MAP INFORMATION

Map Scale: 1:13,300 if printed on A size (8.5" x 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:24,000.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: <http://websoilsurvey.nrcs.usda.gov>
Coordinate System: UTM Zone 12N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Douglas-Plateau Area, Colorado, Parts of Garfield and Mesa Counties
Survey Area Data: Version 5, Feb 1, 2006

Date(s) aerial images were photographed: 8/29/2005, 6/30/2005

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Douglas-Plateau Area, Colorado, Parts of Garfield and Mesa Counties (CO682)			
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
52	Northwater-Adel complex, 5 to 50 percent slopes	37.4	5.2%
55	Parachute-Irigul complex, 5 to 30 percent slopes	80.1	11.2%
56	Parachute-Irigul-Rhone association, 25 to 50 percent slopes	541.8	75.7%
57	Parachute-Rhone loams, 5 to 30 percent slopes	1.5	0.2%
63	Silas loam, 1 to 12 percent slopes	9.3	1.3%
65	Torriorthents, cool-Rock outcrop complex, 35 to 90 percent slopes	45.8	6.4%
Totals for Area of Interest		715.9	100.0%

Map Unit Descriptions

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

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The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a *soil series*. Except for differences in texture of the surface layer, all the soils of a series have major horizons that are similar in composition, thickness, and arrangement.

Soils of one series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

An *association* is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An *undifferentiated group* is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example.

Some surveys include *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.

Douglas-Plateau Area, Colorado, Parts of Garfield and Mesa Counties

52—Northwater-Adel complex, 5 to 50 percent slopes

Map Unit Setting

Elevation: 7,700 to 8,400 feet
Mean annual precipitation: 18 to 25 inches
Mean annual air temperature: 36 to 40 degrees F
Frost-free period: 45 to 75 days

Map Unit Composition

Northwater and similar soils: 50 percent
Adel and similar soils: 40 percent

Description of Northwater

Setting

Landform: Mountainsides
Landform position (two-dimensional): Footslope, backslope, toeslope
Landform position (three-dimensional): Mountainflank
Down-slope shape: Concave
Across-slope shape: Linear
Parent material: Colluvium derived from sedimentary rock and/or residuum weathered from sedimentary rock

Properties and qualities

Slope: 5 to 50 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water capacity: Moderate (about 7.0 inches)

Interpretive groups

Land capability (nonirrigated): 7e

Typical profile

0 to 28 inches: Loam
28 to 48 inches: Very channery loam
48 to 60 inches: Extremely channery loam

Description of Adel

Setting

Landform: Swales, hills
Landform position (two-dimensional): Footslope
Landform position (three-dimensional): Base slope
Down-slope shape: Concave
Across-slope shape: Concave, linear
Parent material: Colluvium derived from sedimentary rock

Properties and qualities

Slope: 5 to 50 percent

Custom Soil Resource Report

Depth to restrictive feature: More than 80 inches

Drainage class: Well drained

Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high
(0.57 to 1.98 in/hr)

Depth to water table: More than 80 inches

Frequency of flooding: None

Frequency of ponding: None

Calcium carbonate, maximum content: 5 percent

Available water capacity: Very high (about 17.9 inches)

Interpretive groups

Land capability (nonirrigated): 7e

Typical profile

0 to 20 inches: Clay loam

20 to 31 inches: Clay loam, loam

31 to 60 inches: Clay loam, loam

55—Parachute-Irigul complex, 5 to 30 percent slopes

Map Unit Setting

Elevation: 7,600 to 8,800 feet

Mean annual precipitation: 18 to 22 inches

Mean annual air temperature: 36 to 40 degrees F

Frost-free period: 65 to 90 days

Map Unit Composition

Parachute and similar soils: 60 percent

Irigul and similar soils: 30 percent

Description of Parachute

Setting

Landform: Mountains

Landform position (two-dimensional): Shoulder, summit

Landform position (three-dimensional): Mountaintop

Down-slope shape: Linear

Across-slope shape: Convex

Parent material: Residuum weathered from shale and siltstone and/or residuum weathered from sandstone and shale

Properties and qualities

Slope: 5 to 30 percent

Depth to restrictive feature: 20 to 40 inches to paralithic bedrock

Drainage class: Well drained

Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)

Depth to water table: More than 80 inches

Frequency of flooding: None

Frequency of ponding: None

Available water capacity: Low (about 4.0 inches)

Custom Soil Resource Report

Interpretive groups

Land capability (nonirrigated): 6e
Ecological site: Mountain Loam (R048AY228CO)

Typical profile

0 to 10 inches: Loam
10 to 25 inches: Very channery loam, extremely channery loam
25 to 29 inches: Unweathered bedrock

Description of Irigul

Setting

Landform: Hills
Landform position (two-dimensional): Backslope, shoulder, toeslope, summit, footslope
Landform position (three-dimensional): Crest
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Residuum weathered from sandstone and shale

Properties and qualities

Slope: 5 to 30 percent
Depth to restrictive feature: 5 to 20 inches to lithic bedrock
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water capacity: Very low (about 1.3 inches)

Interpretive groups

Land capability (nonirrigated): 7e
Ecological site: Loamy Slopes (R048AY303CO)

Typical profile

0 to 6 inches: Channery loam
6 to 13 inches: Very channery loam
13 to 17 inches: Unweathered bedrock

56—Parachute-Irigul-Rhone association, 25 to 50 percent slopes

Map Unit Setting

Elevation: 7,600 to 8,800 feet
Mean annual precipitation: 18 to 22 inches
Mean annual air temperature: 36 to 40 degrees F
Frost-free period: 65 to 80 days

Map Unit Composition

Parachute and similar soils: 35 percent
Irigul and similar soils: 30 percent

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Rhone and similar soils: 20 percent

Description of Parachute

Setting

Landform: Mountains

Landform position (two-dimensional): Summit, shoulder

Landform position (three-dimensional): Mountaintop

Down-slope shape: Linear

Across-slope shape: Convex

Parent material: Colluvium derived from sandstone and shale and/or residuum weathered from siltstone

Properties and qualities

Slope: 25 to 50 percent

Depth to restrictive feature: 20 to 40 inches to paralithic bedrock

Drainage class: Well drained

Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)

Depth to water table: More than 80 inches

Frequency of flooding: None

Frequency of ponding: None

Available water capacity: Low (about 4.0 inches)

Interpretive groups

Land capability (nonirrigated): 7e

Ecological site: Brushy Loam (R048AY238CO)

Typical profile

0 to 10 inches: Loam

10 to 25 inches: Very channery loam, extremely channery loam

25 to 29 inches: Unweathered bedrock

Description of Irigul

Setting

Landform: Hills

Landform position (two-dimensional): Toeslope, summit, footslope, backslope, shoulder

Landform position (three-dimensional): Crest

Down-slope shape: Convex

Across-slope shape: Convex

Parent material: Residuum weathered from sandstone and shale

Properties and qualities

Slope: 25 to 50 percent

Depth to restrictive feature: 5 to 20 inches to lithic bedrock

Drainage class: Well drained

Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)

Depth to water table: More than 80 inches

Frequency of flooding: None

Frequency of ponding: None

Available water capacity: Very low (about 1.3 inches)

Interpretive groups

Land capability (nonirrigated): 7e

Ecological site: Loamy Slopes (R048AY303CO)

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Typical profile

0 to 6 inches: Channery loam
6 to 13 inches: Very channery loam
13 to 17 inches: Unweathered bedrock

Description of Rhone

Setting

Landform: Hills, mountains
Landform position (two-dimensional): Backslope, shoulder, summit, footslope
Landform position (three-dimensional): Mountainflank, side slope
Down-slope shape: Concave
Across-slope shape: Concave
Parent material: Colluvium derived from sandstone and shale and/or residuum weathered from sandstone and shale

Properties and qualities

Slope: 25 to 50 percent
Depth to restrictive feature: 40 to 60 inches to paralithic bedrock
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water capacity: Moderate (about 7.5 inches)

Interpretive groups

Land capability (nonirrigated): 7e
Ecological site: Brushy Loam (R048AY238CO)

Typical profile

0 to 10 inches: Loam
10 to 39 inches: Channery loam
39 to 55 inches: Very channery loam
55 to 59 inches: Unweathered bedrock

57—Parachute-Rhone loams, 5 to 30 percent slopes

Map Unit Setting

Elevation: 7,600 to 8,800 feet
Mean annual precipitation: 18 to 22 inches
Mean annual air temperature: 36 to 40 degrees F
Frost-free period: 45 to 75 days

Map Unit Composition

Parachute and similar soils: 55 percent
Rhone and similar soils: 35 percent

Description of Parachute

Setting

Landform: Mountains

Landform position (two-dimensional): Summit, shoulder

Landform position (three-dimensional): Mountaintop

Down-slope shape: Linear

Across-slope shape: Convex

Parent material: Hard residuum weathered from sandstone and siltstone

Properties and qualities

Slope: 5 to 30 percent

Depth to restrictive feature: 20 to 40 inches to paralithic bedrock

Drainage class: Well drained

Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)

Depth to water table: More than 80 inches

Frequency of flooding: None

Frequency of ponding: None

Available water capacity: Very low (about 2.8 inches)

Interpretive groups

Land capability (nonirrigated): 6e

Ecological site: Mountain Loam (R048AY228CO)

Typical profile

0 to 10 inches: Loam

10 to 25 inches: Very channery loam

25 to 29 inches: Unweathered bedrock

Description of Rhone

Setting

Landform: Hills, mountains

Landform position (two-dimensional): Backslope, shoulder, summit, footslope

Landform position (three-dimensional): Mountainflank, side slope

Down-slope shape: Concave

Across-slope shape: Concave

Parent material: Colluvium derived from sandstone and shale and/or residuum weathered from sandstone and shale

Properties and qualities

Slope: 5 to 30 percent

Depth to restrictive feature: 40 to 60 inches to paralithic bedrock

Drainage class: Well drained

Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)

Depth to water table: More than 80 inches

Frequency of flooding: None

Frequency of ponding: None

Available water capacity: Moderate (about 7.5 inches)

Interpretive groups

Land capability (nonirrigated): 6e

Ecological site: Mountain Loam (R048AY228CO)

Typical profile

0 to 10 inches: Loam
10 to 39 inches: Channery loam
39 to 55 inches: Very channery loam
55 to 59 inches: Unweathered bedrock

63—Silas loam, 1 to 12 percent slopes

Map Unit Setting

Elevation: 7,800 to 8,400 feet
Mean annual precipitation: 20 to 25 inches
Mean annual air temperature: 36 to 40 degrees F
Frost-free period: 65 to 90 days

Map Unit Composition

Silas and similar soils: 85 percent

Description of Silas

Setting

Landform: Alluvial fans, valley floors
Down-slope shape: Concave, linear
Across-slope shape: Linear, concave
Parent material: Mixed rock alluvium derived from sedimentary rock

Properties and qualities

Slope: 1 to 12 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Moderately well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.60 in/hr)
Depth to water table: About 42 to 72 inches
Frequency of flooding: Rare
Frequency of ponding: None
Available water capacity: High (about 10.6 inches)

Interpretive groups

Land capability (nonirrigated): 6c
Ecological site: Mountain Swale (R048AY245CO)

Typical profile

0 to 18 inches: Loam
18 to 60 inches: Clay loam

65—Torriorthents, cool-Rock outcrop complex, 35 to 90 percent slopes

Map Unit Setting

Elevation: 6,200 to 8,500 feet
Mean annual precipitation: 16 to 20 inches
Mean annual air temperature: 42 to 44 degrees F
Frost-free period: 85 to 100 days

Map Unit Composition

Torriorthents, cool, and similar soils: 50 percent
Rock outcrop: 40 percent

Description of Torriorthents, Cool

Setting

Landform: Canyons, ridges, hills, mountains
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Mountainflank, side slope
Down-slope shape: Concave, linear
Across-slope shape: Linear, convex
Parent material: Colluvium derived from limestone and siltstone and/or colluvium derived from sandstone and shale and/or residuum weathered from limestone and siltstone and/or residuum weathered from sandstone and shale

Properties and qualities

Slope: 35 to 90 percent
Depth to restrictive feature: 4 to 60 inches to lithic bedrock
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to high (0.06 to 2.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 15 percent
Maximum salinity: Very slightly saline to slightly saline (4.0 to 8.0 mmhos/cm)
Available water capacity: Very low (about 1.6 inches)

Interpretive groups

Land capability (nonirrigated): 7e

Typical profile

0 to 2 inches: Channery loam
2 to 13 inches: Very channery loam, channery loam
13 to 17 inches: Weathered bedrock

Description of Rock Outcrop

Setting

Landform: Canyons, hills, mountains, ridges
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Free face, free face
Down-slope shape: Concave, linear

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Across-slope shape: Linear, convex

Properties and qualities

Slope: 35 to 90 percent

Depth to restrictive feature: 0 inches to lithic bedrock

Capacity of the most limiting layer to transmit water (Ksat): Very low (0.00 to 0.00 in/hr)

Available water capacity: Very low (about 0.0 inches)

Interpretive groups

Land capability (nonirrigated): 8s

Typical profile

0 to 60 inches: Unweathered bedrock

References

- American Association of State Highway and Transportation Officials (AASHTO). 2004. Standard specifications for transportation materials and methods of sampling and testing. 24th edition.
- American Society for Testing and Materials (ASTM). 2005. Standard classification of soils for engineering purposes. ASTM Standard D2487-00.
- Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deep-water habitats of the United States. U.S. Fish and Wildlife Service FWS/OBS-79/31.
- Federal Register. July 13, 1994. Changes in hydric soils of the United States.
- Federal Register. September 18, 2002. Hydric soils of the United States.
- Hurt, G.W., and L.M. Vasilas, editors. Version 6.0, 2006. Field indicators of hydric soils in the United States.
- National Research Council. 1995. Wetlands: Characteristics and boundaries.
- Soil Survey Division Staff. 1993. Soil survey manual. Soil Conservation Service. U.S. Department of Agriculture Handbook 18. <http://soils.usda.gov/>
- Soil Survey Staff. 1999. Soil taxonomy: A basic system of soil classification for making and interpreting soil surveys. 2nd edition. Natural Resources Conservation Service, U.S. Department of Agriculture Handbook 436. <http://soils.usda.gov/>
- Soil Survey Staff. 2006. Keys to soil taxonomy. 10th edition. U.S. Department of Agriculture, Natural Resources Conservation Service. <http://soils.usda.gov/>
- Tiner, R.W., Jr. 1985. Wetlands of Delaware. U.S. Fish and Wildlife Service and Delaware Department of Natural Resources and Environmental Control, Wetlands Section.
- United States Army Corps of Engineers, Environmental Laboratory. 1987. Corps of Engineers wetlands delineation manual. Waterways Experiment Station Technical Report Y-87-1.
- United States Department of Agriculture, Natural Resources Conservation Service. National forestry manual. <http://soils.usda.gov/>
- United States Department of Agriculture, Natural Resources Conservation Service. National range and pasture handbook. <http://www.glti.nrcs.usda.gov/>
- United States Department of Agriculture, Natural Resources Conservation Service. National soil survey handbook, title 430-VI. <http://soils.usda.gov/>
- United States Department of Agriculture, Natural Resources Conservation Service. 2006. Land resource regions and major land resource areas of the United States, the Caribbean, and the Pacific Basin. U.S. Department of Agriculture Handbook 296. <http://soils.usda.gov/>

Custom Soil Resource Report

United States Department of Agriculture, Soil Conservation Service. 1961. Land capability classification. U.S. Department of Agriculture Handbook 210.



Background Radiation Survey of the O-29 Well Pad

Introduction

Background radiation is the natural radioactivity of an area. Background radiation varies due to the influence of natural mineral deposits, building materials, elevation, and topography. In Western Colorado, the typical background levels range from 8 to 30 microrentgens per hour ($\mu\text{R/h}$). The most common outside background levels in Mesa County are 10 to 15 $\mu\text{R/h}$ (CDPHE 2012). A meter reading 30 percent higher than the local background level could be considered significant and require investigation.

The 29-17 injection well is located on the existing O-29 well pad in the Garden Gulch area that is underlain by the Parachute Creek member of the Green River Formation and soils of the Northwater-Adel complex, 5 to 50 percent slopes, Parachute-Irigul complex, 5 to 30 percent slopes, and Parachute-Irigul-Rhone association, 25 to 50 percent slopes (Hail et al, 1989; NRCS 2012). Facilities present on the pad include well heads, a water storage pit, gas processing facilities, and four storage tanks.

Survey Objectives and Design

The objective of a gamma survey is to evaluate natural radiation levels, to determine if radioactive materials including uranium mill tailings are present on individual properties, to acquire sufficient data to evaluate the gamma levels and health risks, and to document the location and conditions of radioactive materials, if present. The gamma surveys may also locate natural soils, rocks, or ores that have elevated gamma radiation and have the potential to increase indoor radon levels.

The survey was conducted using a Ludlum Model 3 radiation meter. Transects were walked on the surface of the well pad, surrounding berms, and soil borrow area on the west side of the well pad. The meter probe was kept about 4 inches above the ground while slowly walking along the transects to detect any large changes in radiation. At approximately 75-foot intervals, the meter probe was placed on the ground surface and the maximum meter reading recorded after about 10 seconds. A second reading was also recorded at one meter above the ground surface. Each location was recorded using a hand-held GPS receiver. Background readings collected from nearby locations in the Garden Gulch area ranged from 15 to 21 $\mu\text{R/h}$.

At three survey locations, a sample of soil and rock was collected from a depth of 0-4 inches and sent to Pace Analytical Services, Inc. of Greensburg, PA for analysis of gamma-emitting

radionuclides, including forms of uranium, thorium, Ra228, Ra226, and Pb210. The soil sample locations were chosen to be representative of a range of meter results at the site based on the ground level readings. The results of the soil analyses are pending and will be used to establish a relationship between the meter readings and the activities of the gamma-emitting radionuclides in the soil and rock of the area.

Results

Figure 1 provides the meter readings at ground level across the site. The background radiation at ground level ranges from 14 to 24 $\mu\text{R/h}$. Figure 2 provides the meter readings at one meter height. The readings taken at one meter height ranged from 14 to 20 $\mu\text{R/h}$, but were not significantly different from those collected at ground level and showed no direct correlation to those readings. No readings were more than 30% of the maximum background radiation measured nearby.

Conclusions

The survey shows that natural background radiation at the O-29 site is typical for Western Colorado. The radiation levels range from 14 to 24 $\mu\text{R/h}$, with no spots of greater radiation detected. The readings taken at one meter height were not significantly different from those at ground level.

REFERENCES

Hail, W.J., O'Sullivan, R.B., and Smith, M.C., 1989, Geologic map of the Roan Plateau area, northwestern Colorado: U.S. Geological Survey, Miscellaneous Investigations Series Map I-1797-C, scale 1:50000.

U. S. Department of Agriculture, Natural Resources Conservation Service, 2012, Custom Soil Resource Report for Rifle Area, Colorado, Parts of Garfield and Mesa Counties, Web Soil Survey; generated on August 16, 2012.

Colorado Department of Health and Environment, Hazardous Materials and Waste Management Division' UMTRA (Uranium Mill Tailings Remedial Action) Program Issues Gamma Radiation Survey Procedures, accessed at <http://www.cdphe.state.co.us/hm/umtra/gammaradiation>

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DRAWN BY:	A. Leonard
CHECKED BY:	D. Nicholson
FILE NAME:	O-29.mxd

Berry Petroleum Company

Radiological Survey
O-29 Well Pad
Garfield Co., Colorado

FIGURE

1

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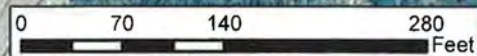


Legend

(19) Background radiation at one meter height (microrentgens per hour)

Soil Sample Location

Water Pit



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Berry Petroleum Company

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FIGURE
2

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