

GEOLOGIC AND SOIL HAZARDS REPORT

Introduction

Encana Oil and Gas (USA) Inc. (Encana) has proposed to construct a High Mesa Water Treatment Facility to be located in the southeast quarter of the northwest quarter Section 36, Township 7 South, Range 96 West, of the Sixth Principal Meridian, Garfield County, Colorado. The site is more generally located to the southwest of the towns of Battlement Mesa and Parachute as shown on the **Close-up Topo Map** and **Vicinity Map**.

Land ownership in the vicinity of the proposed High Mesa Water Treatment Facility is shown on the **Adjacent Parcels Map** which has the topographic map set as the background. The site is located on High Mesa near the Peter and Bill Creek drainage, and south of the Dry Creek drainage as shown on the **Surface Water Map**. There are no permitted groundwater wells located in close proximity to the proposed site as shown on the **Groundwater Well Map**. There are three permitted water wells within one mile radius of the site. Two are located on the opposite side of the Pete and Bill Creek drainage, and the other one is located to the northwest.

Structural Geology

The water treatment site is located within the southern Piceance Basin, an irregularly-shaped geologic structural depression in the earth's crust resulting from the uplift of the Colorado Plateau and the Rocky Mountains. The Piceance Basin lies along the northwestern edge of the Colorado Plateau and encompasses approximately 4,055 square miles. It is bound to the east and northeast by the Grand Hogback Monocline and White River Uplift, to the northwest by the Uinta Mountains, to the south by the Gunnison Uplift and Uncompahgre-San Luis highlands, and to the southeast by the Sawatch Mountain Range (Grout and Verbeek, 1992).

Grand Mesa and Battlement Mesa are local erosional remnants of a large, late Tertiary (early Pliocene) basalt covered plain that was uplifted and incised and eroded by the Colorado River and Plateau Creek drainages. More than four thousand feet of sedimentary rock deposited during the Tertiary geologic period are exposed in the steep canyons, arroyos, and pediment surfaces adjacent to Battlement Mesa. Battlement Mesa consists of four small basalt-flow remnants at more than 10,000 feet in elevation where isolated flow remnants total less than a square mile in area, and are surrounded by slump blocks broken into basalt-block rubble. The physiography and bedrock of Battlement Mesa are similar to that of the Grand Mesa; however, Battlement Mesa is in a more advanced stage of degradation. Extensive pediments, commonly mantled by alluvial-fan gravel and mudflows, flank the north and west slopes of Battlement Mesa. These widespread surfaces slope steeply toward the Colorado River, which is located a little more than a mile to the north – northwest of the site (Yeend, 1969).

Bedrock Geology

The **Geology Map G-1** shows the bedrock and surficial geology. The bedrock beneath the site consists of the Tertiary age, (Paleocene to Eocene epochs) Wasatch Formation, and is characterized by thick intervals of poor to moderately indurated claystones and mudstones with lesser amounts of interbedded and discontinuous beds of siltstone, sandstone, and

conglomerate. The Wasatch Formation was deposited predominantly in a terrestrial to fluvial environment. Fine-grained clastic rocks, ranging from very light gray to light brownish gray, red, olive gray, and pale reddish brown and tan comprise more than 75 percent of the formation. Sandstones are generally discontinuous, commonly lenticular, and are yellowish gray, light gray to olive gray in color.

These sandstones are fluvial in origin and are commonly crossbedded and contain lenses of coarse sand and pebble conglomerate at channel bases (Madole and Streufert, 2003).

Surficial Geology

Pediment deposits consisting of older sand and gravel deposits of Pre-Bull Lake age mantle the Wasatch Formation to the northeast and southwest of the site location. High Mesa is covered by two lobes of pre-Bull Lake pediment gravels that consist of coarse poorly sorted gravels. The pediment gravel is commonly 20 feet to 30 feet thick; however, it is locally thicker, especially closer to the Colorado River. The gravel is composed of subangular to subrounded pebbles, cobbles, and boulders. Locally derived basalt boulders as much as 8 feet in diameter are common at the down slope edge of the pediments. Gravel colors of gray green, gray brown, and yellowish white, are formed from clasts of oil shale, siltstone, sandstone, and claystone derived from the Wasatch Formation and overlying Green River Formation. Crystalline rock types derived from sources to the east of the area are abundant in pediment gravel near the Colorado River (Yeend, 1969).

Two distinct levels of pediments are recognized; however, the older and higher level is only preserved in three localities. Flatiron Mesa (North Mamm Creek Quadrangle) and High Mesa (Grand Valley quadrangle) are the largest remnants of this older pediment surface. On Flatiron Mesa the pediment has a gradient of 280 feet per mile, and projects to 1,300 feet above the Colorado River. Remnants of the lower gravel-mantled pediment are more widespread and have gradients of 230 feet to 1,200 feet per mile with the steeper gradients closer to the mountain front (Yeend, 1969).

Remnants of pediments can be correlated based on similarities of surface elevations and their elevated positions with respect to lower surfaces that are physically continuous. The pediments were formed by streams and mudflows issuing from the highlands of Battlement Mesa. The streams were graded to the Colorado River which was flowing in a broad valley at an elevation of about 500 feet above its present valley. Differential downcutting by the Colorado River has been suggested for the development of these older pediments and the reason for the occurrence of the pediment remnants at different elevations above the Colorado River (Yeend,

1969). The proposed site is a mile southeast of the current flood plain and is at higher elevation as shown on the **Flood Plain Map**.

Soils

The **Soils Map S-1** shows the soil types in the vicinity of the site. Soils in the vicinity of the proposed water treatment site consist of the Potts Ildefonso Complex. The Potts-Ildefonso complex, occupies 3% to 12% slopes found as gently sloping to rolling soils on valley sides and mesas. These soils are formed in alluvium derived from basalt and or alluvium derived from sandstone and shale. Typical soil profiles include loam and clay loam to stony loam overlying very stony loam, which are well drained. Frequency of flooding or ponding is listed as 'None.' Surface runoff is slow, and the erosion hazard is moderate (Harman and Murray, 1985).

According to the Soil Survey of the Rifle Area, Colorado, the Potts Ildefonso suitability for sanitary facilities is considered moderate to severe for septic tank absorption fields and sewage lagoon areas due to slow percolation, slope, and large stones in the Ildefonso, and for trench and area sanitary landfill sites the suitability is considered slight for the Potts, and moderate to severe for the Ildefonso due to large stones and slope, and also potential for seepage. For building site development with shallow excavations the suitability is listed as slight to severe due to large stones in the Ildefonso (Harman and Murray, 1985).

The description of these soils under water management indicates that for Pond reservoir areas that the Potts-Ildefonso complex is susceptible to seepage, and potentially not suited due to slope. For embankments and levees piping is indicated for the Potts soil, and large stones are indicated as an issue with the Ildefonso (Harman and Murray, 1985).

Geologic Hazards

Geologic Hazards in the Parachute – Battlement Mesa area include the following:

- Unstable slopes and potentially unstable slopes;
- Debris flows and Mudflow deposits;
- Landslide deposits;
- Slump blocks, talus, and solifluction (slow downhill movement) deposits;
- Ground Subsidence; and
- Collapsible soils, expansive soils, and other soil hazards.

The areas to the north and west of the town of Parachute have been mapped as an area with major slope hazard. The areas to the southwest and west of the towns of Parachute and Battlement Mesa and south of the Colorado River have not been mapped as part of the Garfield County slope hazard study prepared by Lincoln-Devore Testing Laboratory 1975-1976.

According to the Geologic Map of Surficial Deposits in the Grand and Battlement Mesas Area, Delta, Mesa, and Garfield Counties, Colorado, mudflows and fan gravels are located to the north of High Mesa and extend to the north and northeast toward Morrisania Mesa. Areas of slump blocks, talus, and solifluction deposits are located to the southeast of High Mesa at the higher elevations of Battlement Mesa.

Earth flow and soil creep are widespread on the north and west-facing slopes below Grand and Battlement Mesas. The earth movements are a combination of earthflow and soil creep that are almost exclusively restricted to areas underlain by the claystone-rich members of the Wasatch Formation. The abrupt slope change at the Green River-Wasatch contact generally marks the upper limit of these deposits.

Expansive soils are not expected to be a hazard in the vicinity of the proposed water treatment facility. Evaporite deposits present elsewhere in Garfield County are not exposed at the surface near the proposed site, so evaporite sink holes are not expected to be a hazard affecting the site. Ground subsidence due to other factors, such as historic underground mining is also not expected to be a hazard at the proposed High Mesa Water Treatment Facility.

Collapsible soils may be a geologic hazard in the vicinity of the site. Collapsible soils are dry, low-density, high porosity soils that can spontaneously compact when they become wet. Also known as hydrocompaction, this phenomenon manifests itself as a ground settlement and has been responsible for damage and distress for structures in the towns of New Castle, Silt, Rifle, and Parachute along the Colorado River corridor. Cretaceous and Tertiary age formations consisting of poorly indurated bedrock with high percentages of clay and silt, that is easily eroded and sediment yield is high may pose a risk for collapsible soils. Sediments derived from these formations have the characteristics of collapsible soils when deposited in alluvial fans, as colluvium, alluvium, and eolian deposits. Site specific shrink-swell and swell-consolidation tests should be performed to determine if there is a high collapse potential or if settling after wetting while the soil is under a constant load is determined to be an issue.

Conclusions

Based on the available published information that Olsson reviewed for the proposed water treatment facility, it does not appear that there are any significant geologic hazards in the immediate vicinity of the proposed High Mesa Water Treatment Facility location. In the area along the north side of Battlement Mesa and the south side of the Colorado River, there are unstable slopes, landslide deposits, mudflow and debris flow deposits, fan deposits, talus slopes, and block slumps. The talus slopes and the block slumps are located in areas higher on Battlement Mesa where claystone units within the Wasatch Formation are overlain with basalt and have failed due to weakness of the underlying claystone. Alluvial fan deposits are also present along the Colorado River corridor.

Landslide, mudflow, debris flow, and solifluction deposits are found on the side slopes of mesas and valleys where basalt, sandstone, and claystone colluvium have been transported downslope due to gravity or through a combination of water and gravity loading sediments on an unstable slope down cut by the Colorado River. These deposits are located on steep slopes between the proposed water treatment site and the town of Battlement Mesa, but do not appear to be geologic hazards in the area of the proposed Encana High Mesa Water Treatment Facility.

According to the Colorado Geological Survey Collapsible soil susceptibility map viewer (EG-14) collapsible soils are a potential geologic hazard in the area and sediments derived from Cretaceous and Tertiary age bedrock have the characteristics of collapsible deposits in certain depositional environments. According to the 1985 Soil Survey of the Rifle Area, of Colorado, the

Potts – Ildefonso complex does pose some issues for construction and water management due to potential slope, seepage, piping, and large rocks. These issues will need to be taken into consideration and addressed for the engineering, design, and construction of the Encana High Mesa Water Treatment Facility.



James W. Hix
Senior Geologist

References

- Grout, Marilyn A. and Verbeek, Earl R., 1992, U.S.G.S. Bulletin 1787-Z, Fracture History of the Divide Creek and Wolf Creek Anticlines and Its Relation to Laramide Basin-Margin Tectonism, Southern Piceance Basin, Northwestern Colorado, 32 p.
- Harman, Jerry B. and Murray, Donald J., 1985, Soil Survey of Rifle Area, Colorado, Parts of Garfield and Mesa Counties, Colorado: U.S. Department of Agriculture, Soil Conservation Service, in cooperation with the Colorado Agricultural Experiment Station, 149 p. two plates, and 20 map sheets.
- Madole, Richard F. and Streufert, Randall K., 2003, Open-File Report 01-2 Geologic Map of the Gibson Gulch Quadrangle, Garfield County, Colorado, Colorado Geological Survey, Department of Natural Resources, Denver, CO, 18 p. and accompanying map.
- Yeend, Warren E., 1969, Quaternary Geology of the Grand and Battlement Mesas Area, Colorado, U.S.G.S. Professional Paper 617, Description, Distribution, and Geologic History of Surficial Deposits on and adjacent to Grand and Battlement Mesa, western Colorado, p 47, Plate 1

Online References

- Colorado Oil and Gas Conservation Commission <http://cogcc.state.co.us/>
- Colorado Geological Survey <http://cgsmaps.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>


FIGURES



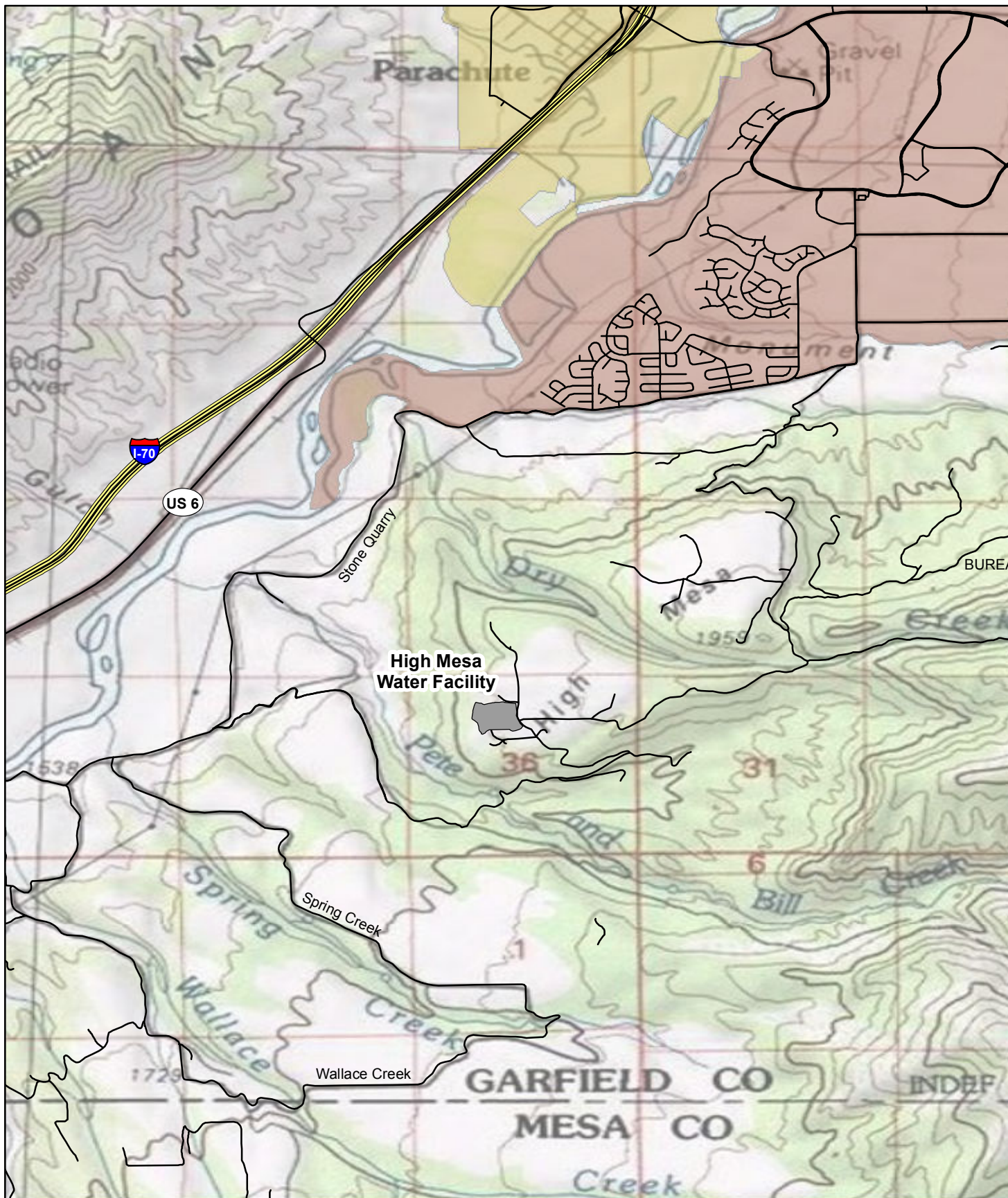
Legend

-  High Mesa Water Park
-  Access Roads

Close-up Topo Map
High Mesa Water Treatment Facility
Garfield County, Colorado
Encana Oil & Gas (USA), Inc.

0 0.125 0.25
 Mile





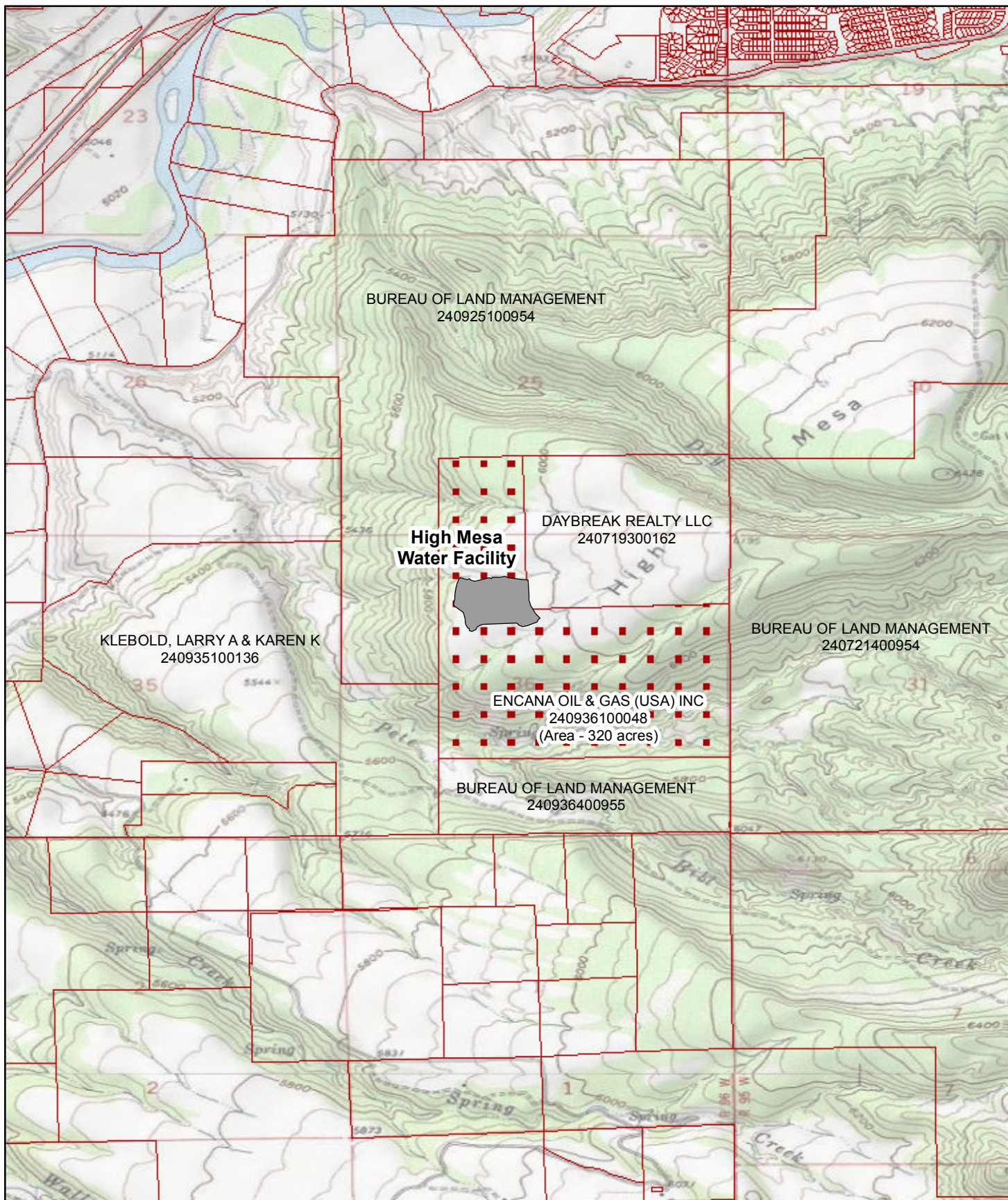
Legend

- High Mesa Water Park
- Local Roadways
- Major Highways
- Battlement Mesa
- Parachute

Vicinity Map
 High Mesa Water Treatment Facility
 Garfield County, Colorado
 Encana Oil & Gas (USA), Inc.

0 0.25 0.5 1
 Mile

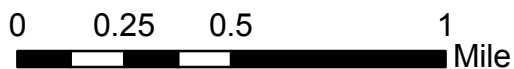


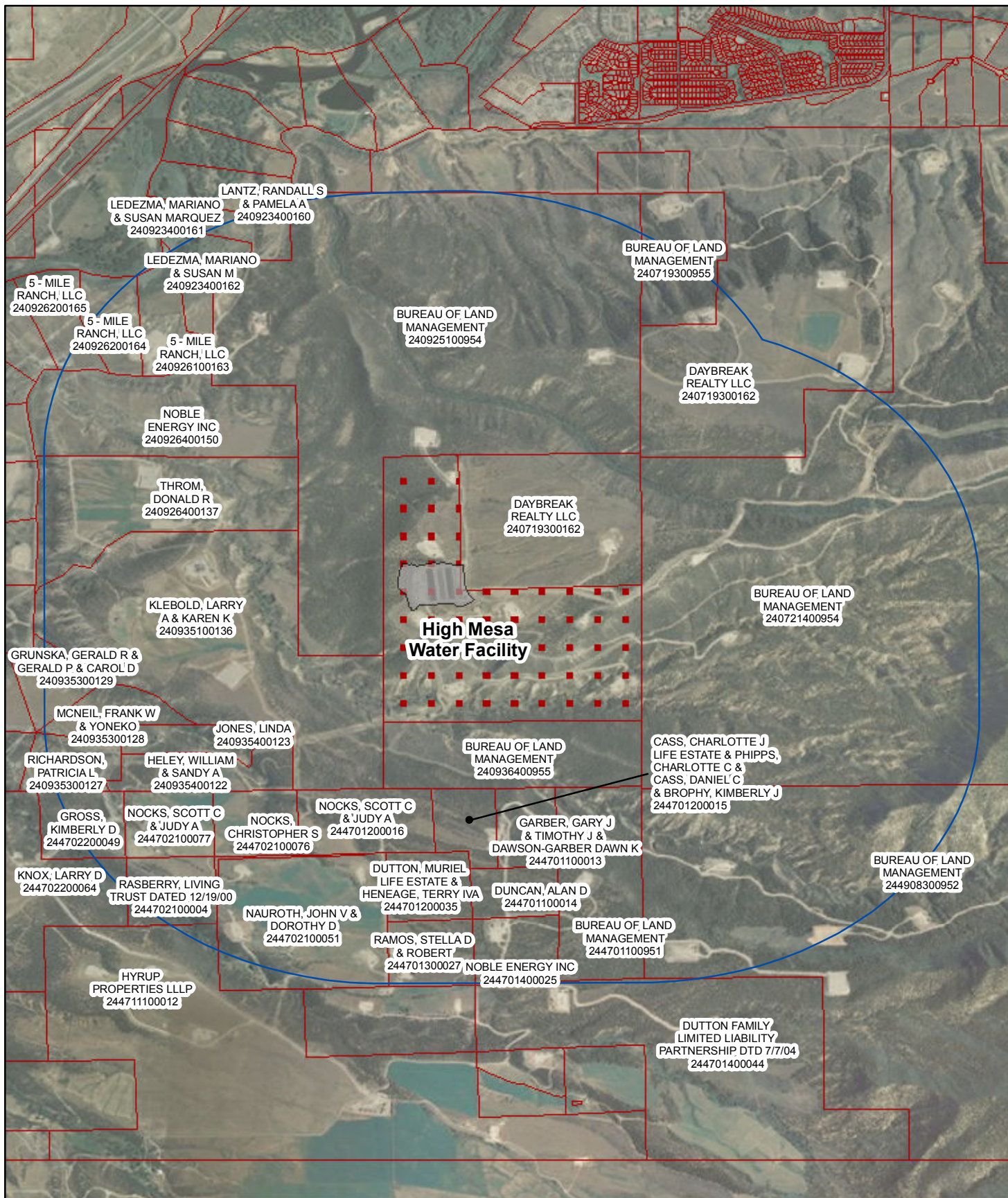


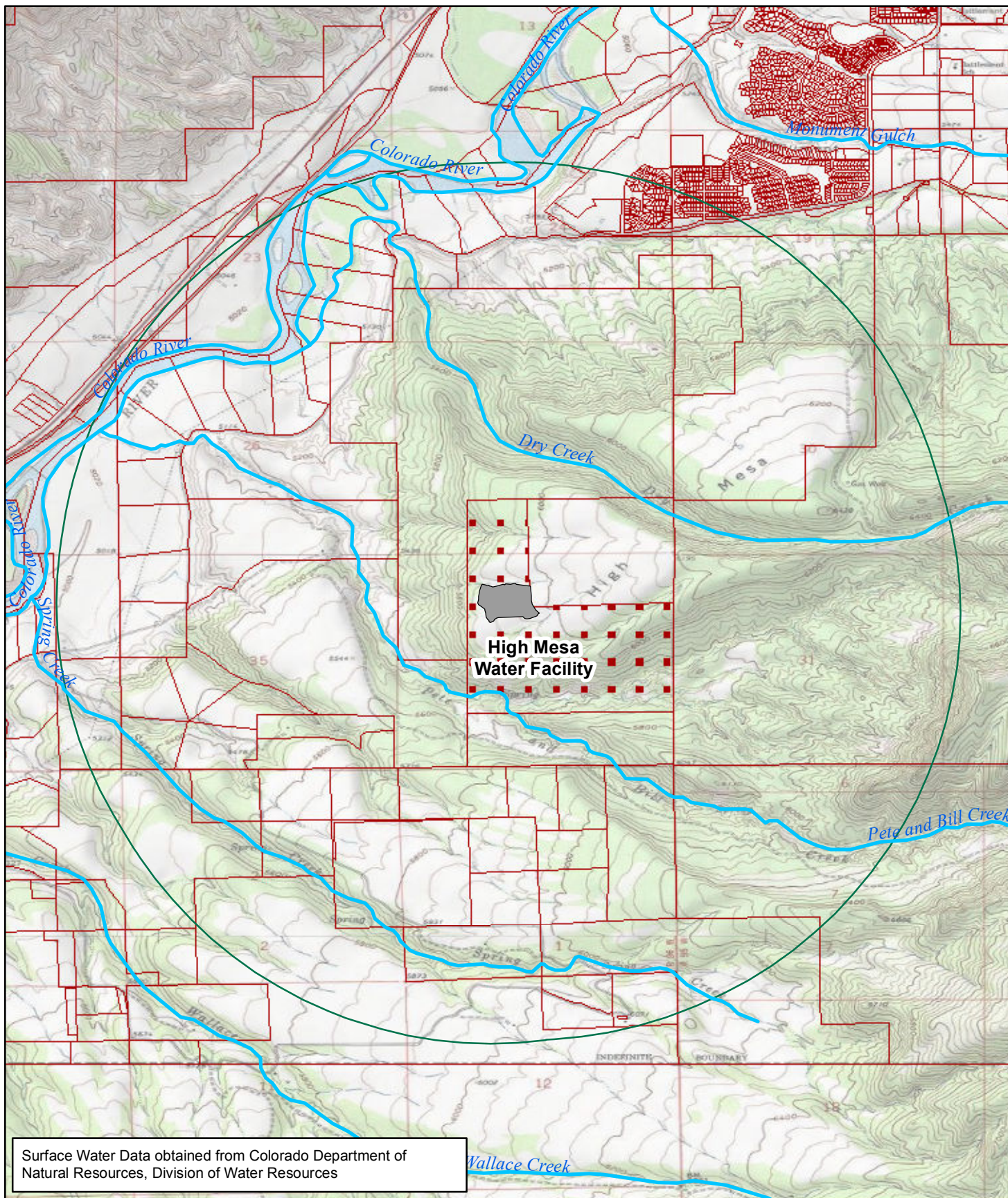
Legend

- High Mesa Water Park
- Garfield County Parcels
- 240936100048 (Area: 320 acres)

Adjacent Parcels Map
 High Mesa Water Treatment Facility
 Garfield County, Colorado
 Encana Oil & Gas (USA), Inc.







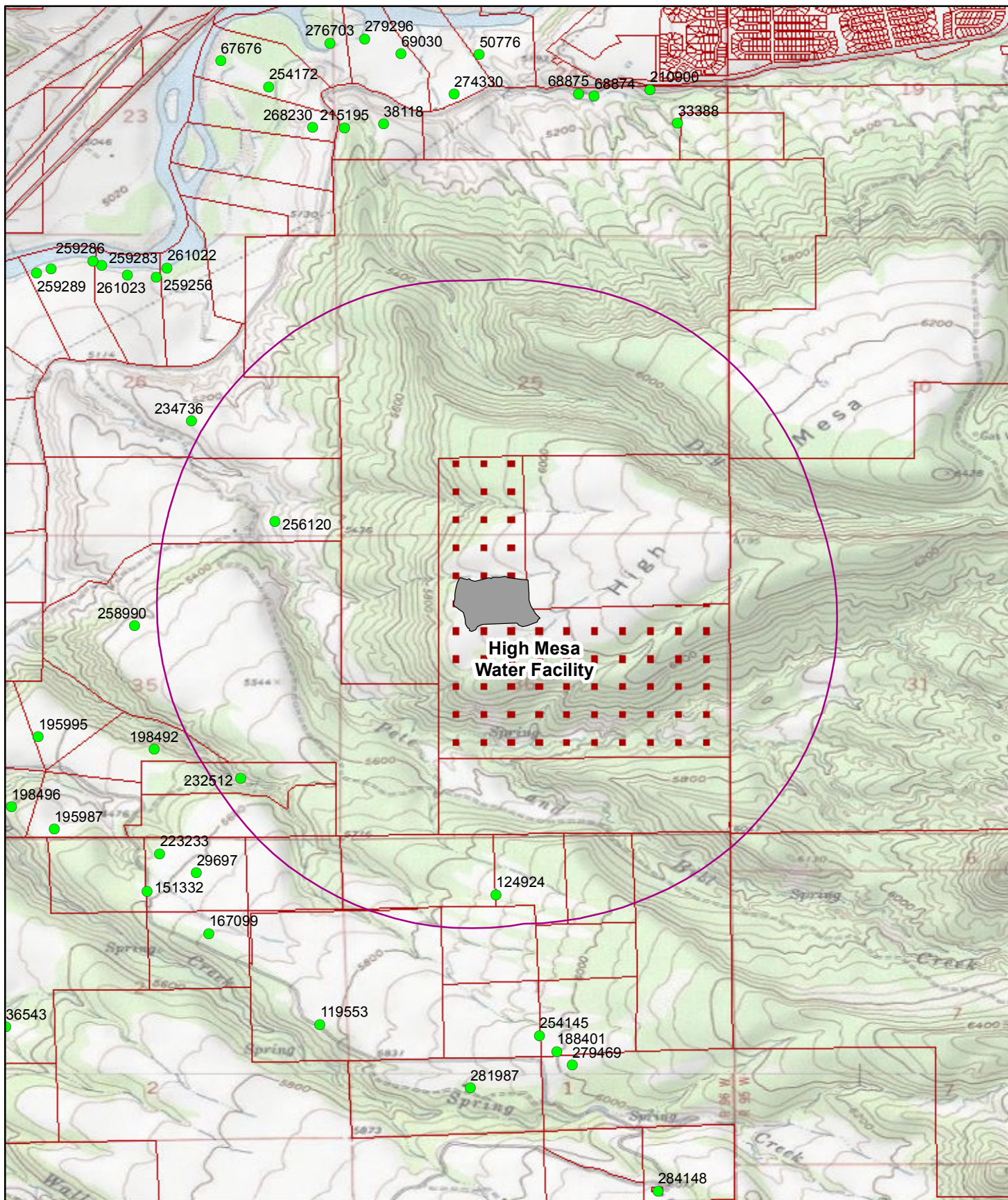
Legend

- Surface Water
- High Mesa Water Park
- 2 Mile Buffer
- Garfield County Parcels
- 240936100048 (Area: 320 acres)

Surface Water Map
 High Mesa Water Treatment Facility
 Garfield County, Colorado
 Encana Oil & Gas (USA), Inc.

0 0.25 0.5 1
 Mile

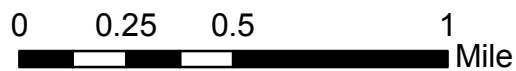


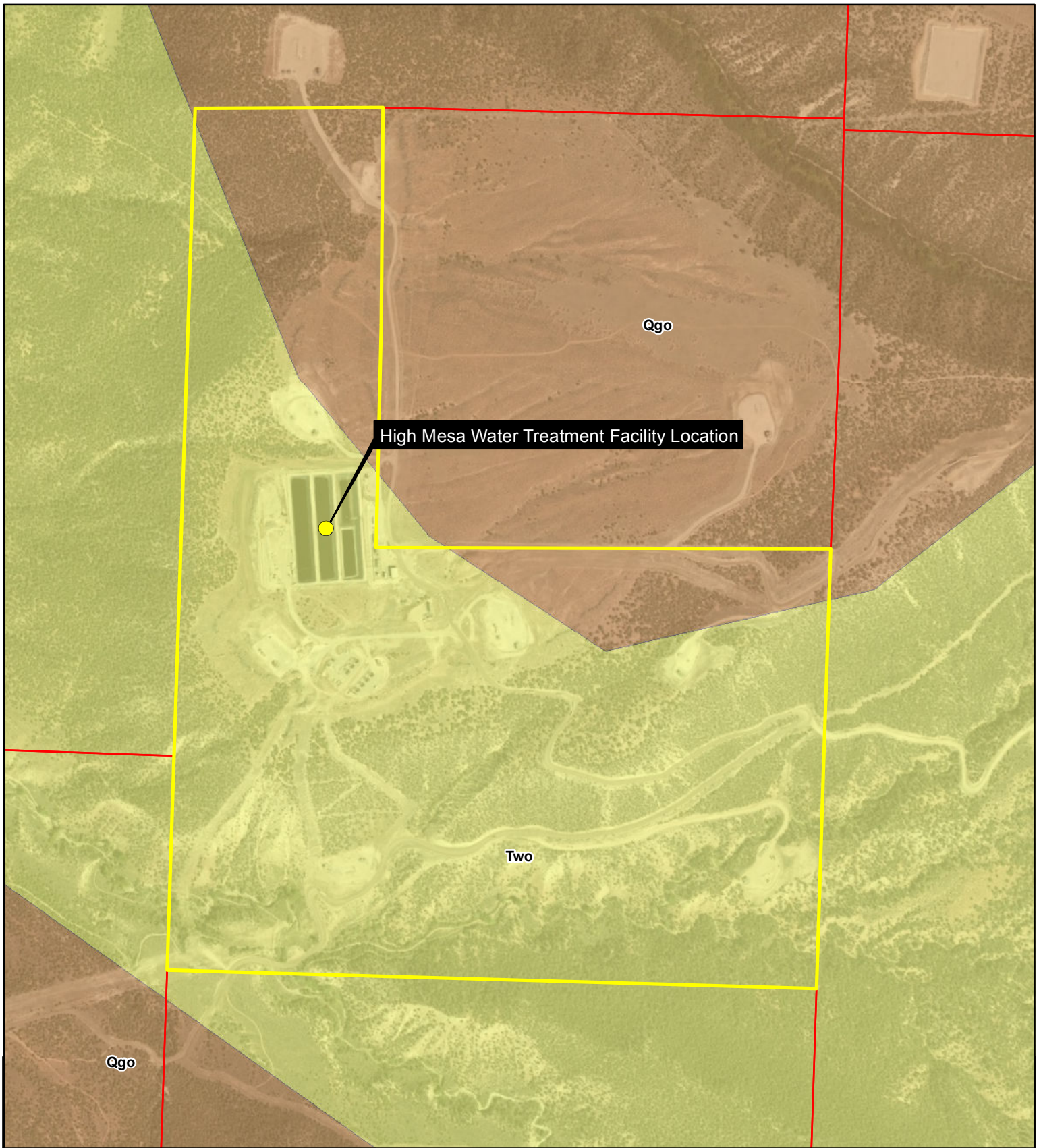


Legend

- Groundwater Wells
- High Mesa Water Park
- 1 Mile Buffer
- Garfield County Parcels
- 240936100048 (Area: 320 acres)

Groundwater Well Map
 High Mesa Water Treatment Facility
 Garfield County, Colorado
 Encana Oil & Gas (USA), Inc.





Legend

- High Mesa Water Treatment Facility Location
 - Affected Parcel
 - Parcels
- Geology Type**
- Qgo - Older gravels and alluviums (Pre-Bull Lake age)
 - Two - Wasatch formation and Ohio creek formation



0 215 430 860 Feet

PROJECT NO:	013-2067
DRAWN BY:	Jenna Muhlbach
DATE:	8/19/2013

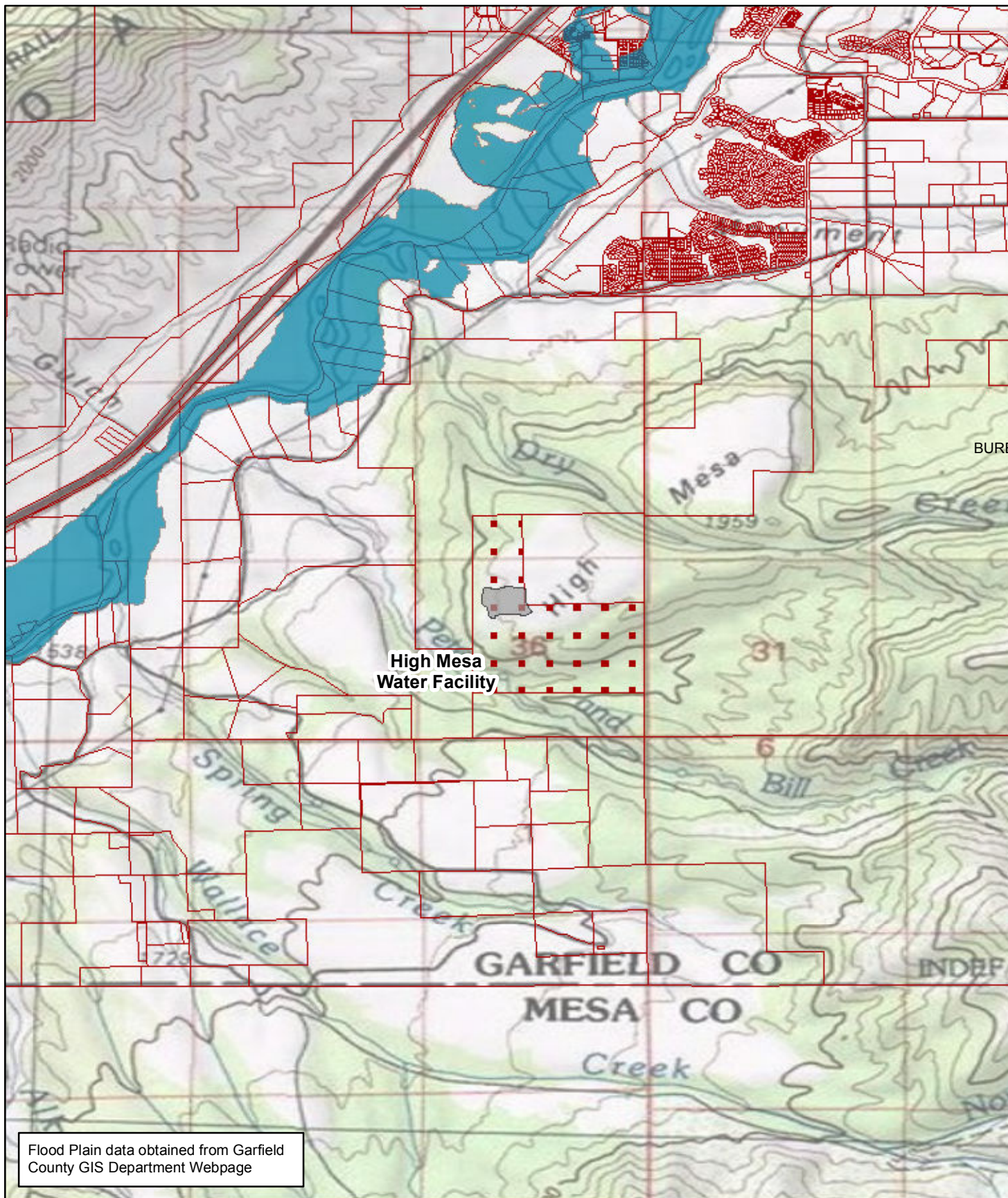
GEOLOGY MAP
HIGH MESA WATER TREATMENT
FACILITY
ENCANA OIL & GAS (USA), INC.
GARFIELD COUNTY, COLORADO



760 HORIZON DR.,
 SUITE 102
 GRAND JUNCTION,
 CO 81506
 TEL 970.263.7800
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FIGURE

G - 1



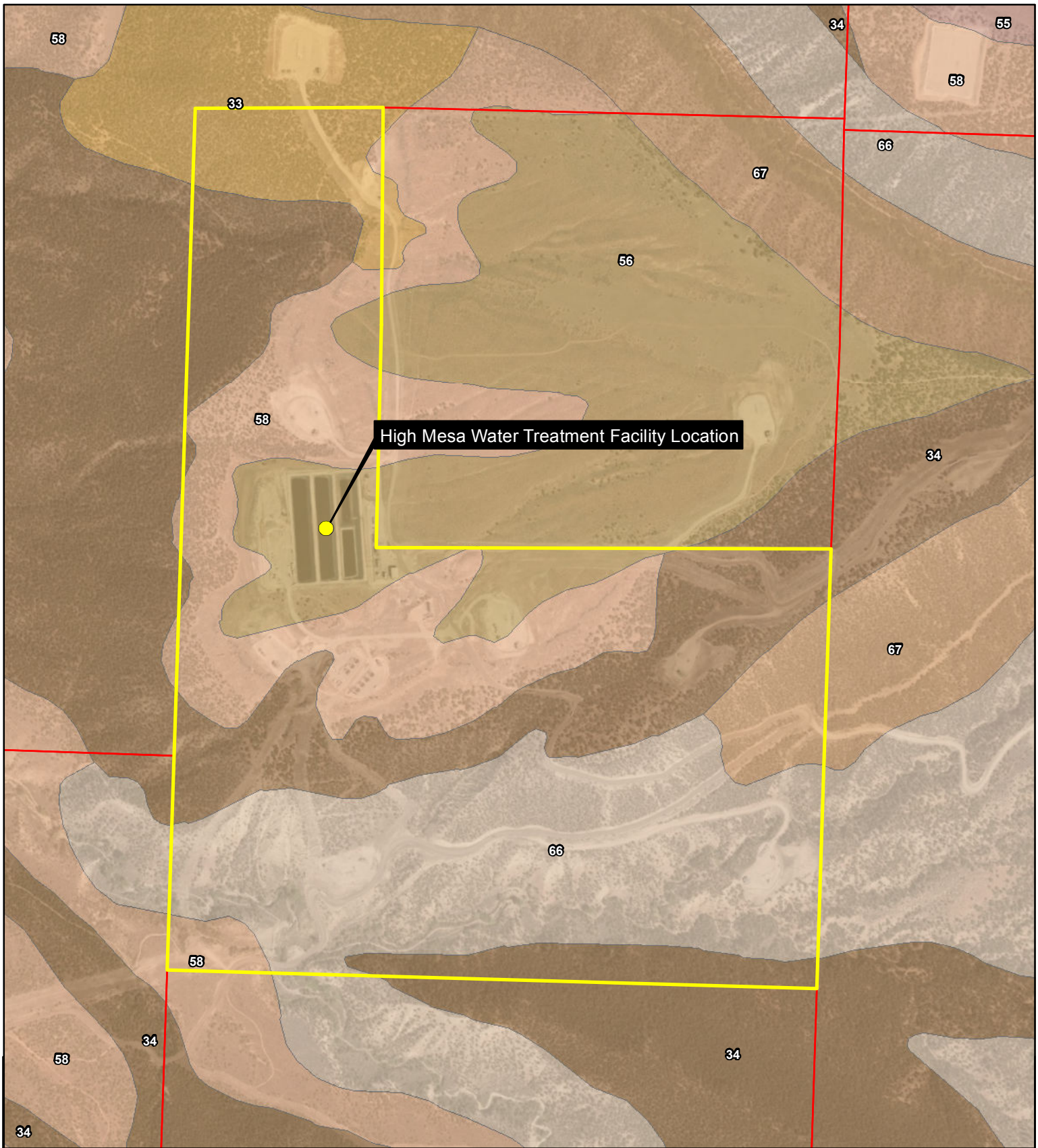
Legend

- High Mesa Water Park
- Flood Plain
- Garfield County Parcels
- 240936100048 (Area: 320 acres)

Flood Plain Map
 High Mesa Water Treatment Facility
 Garfield County, Colorado
 Encana Oil & Gas (USA), Inc.

0 0.25 0.5 1 1.5
 Mile





Legend

- High Mesa Water Treatment Facility Location
 - Affected Parcel
 - Parcels
- Soil Type**
- | | |
|--|--|
| <ul style="list-style-type: none"> 33 - Ildefonso stony loam, 6-25% slopes 34 - Ildefonso stony loam, 25-45% slopes 55 - Potts loam, 3-6% slopes 56 - Potts loam, 6-12% slopes | <ul style="list-style-type: none"> 58 - Potts-Ildefonso complex, 12-25% slopes 66 - Torriorthents-Camborthids-Rock outcrop complex, steep 67 - Torriorthents-Rock outcrop complex, steep |
|--|--|



0 205 410 820 Feet

PROJECT NO: 013-2067

DRAWN BY: Jenna Muhlbach

DATE: 8/19/2013

SOILS MAP
HIGH MESA WATER TREATMENT
FACILITY
ENCANA OIL & GAS (USA), INC.
GARFIELD COUNTY, COLORADO



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FIGURE

S - 1