Article 4-203.G.4 Geologic and Soils Hazard Report

Ursa Operating Company and Battlement Mesa Partners

Major Impact Review Application Battlement Mesa PUD Phase I BMC B

OA Project No. 014-1829

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NATURAL AND GEOLOGIC HAZARDS ASSESSMENT REPORT

URSA OPERATING COMPANY
BMC B PAD SITE – COUNTY ROAD 307
SW ¼, NW ¼, SECTION 18, T7S, R95W, 6TH P.M.
GARFIELD COUNTY, COLORADO

PREPARED FOR

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SEPTEMBER 2014

PROJECT NO. 014-1829

OLSSON ASSOCIATES

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Natural and Geologic Hazard Report Preface

Garfield County, Colorado, finalized the Land Use and Development Code (LUDC) with an effective date of July 15, 2013, last amended September 2, 2014. According to Section 7-108 Use of Land Subject to Natural Hazards of the Garfield County LUDC *"Land subject to identified Natural and Geologic Hazards, such as falling rock, landslides, snow slides, mud flows, radiation, flooding, or high water tables, shall not be developed unless it has been designed to eliminate or mitigate the potential effects of hazardous site conditions as designed by a qualified professional engineer and as approved by the County."*

The LUDC requires a Natural and Geologic Hazard Study be prepared by a qualified professional geologist and submitted with a development plan or plat. The LUDC defines a geologic hazard as "*A geologic phenomenon that is so adverse to past, current, or foreseeable construction or land use as to constitute a significant hazard to public health and safety or to property."*

The LUDC defines a Hazard Area as *"An area that contains or is directly affected by a geologic hazard, including but not limited to the following types of areas."*

A. Avalanche Area. "*A mass of snow or ice and other material that may become incorporated therein as such mass moves rapidly down a slope*."
B. Landslide Area. "*An area with demonstrably active mass movement of rock and soil where there is a distinct surface rupture or zone of weakness that separates the landslide material from more stable underlying material.*"
C. Mudflow Debris Area. "*An area subject to rapid mud and debris movement or deposit occurring after mobilization by heavy rainfall or snowmelt runoff. Such areas are formed by successive episodes of deposition of mud and debris.*"
D. Radioactive Area. "*An area subject to various types of radiation emission from radioactive minerals that occur in natural or manmade deposits of rock, soil, or water*."
E. Potentially Unstable Soils. "*An area of land identified as having soils that may cause damage to structures, such as buildings and roadways, as a result of over saturation or some other outside influence.*"

According to the Garfield County LUDC Section 4-203 Description of Submittal Requirements, the professional qualifications for preparation and certification of certain documents required by this Code are as follows:

> "*Geologist. Geology reports shall be prepared by either a member of the American Institute of Professional Geologists, a member of the Association of Engineering Geologists, or a qualified geotechnical engineer licensed in the State of Colorado."*

Currently, the State of Colorado does not require licensure or registration of geologists; however, Colorado Revised Statutes do require that geologic reports be prepared or authorized by a professional geologist, and the term “Professional Geologist” is defined in Colorado Statutes.

The references for these Statutes are shown here:

34-1-201. Definitions. As used in this part 2, unless the context otherwise requires:

(1) “Geologist” means a person engaged in the practice of geology.
(2) “Geology” means the science which treats of the earth in general; the earth’s processes and its history; investigation of the earth’s crust and the rocks and other materials which compose it; and the applied science of utilizing knowledge of the earth’s history, processes, constituent rocks, minerals, liquids, gases, and other materials for the use of mankind.
(3) “Professional geologist” is a person who is a graduate of an institution of higher education which is accredited by a regional or national accrediting agency, with a minimum of thirty semester hours (forty-five quarter) hours of undergraduate or graduate work in a field of geology and whose post baccalaureate training has been in the field of geology with a specific record of an additional five years of geological experience to include no more than two years of graduate work.
(4) 34-1-202. Reports containing geologic information. Any report required by law or by rule and regulation, and prepared as a result of or based on a geologic study or on geologic data, or which contains information relating to geology, as defined in Section 34-1-201 (2), and which is to be presented for any state agency, political subdivision of the state, or recognized state or local board or commission, shall be prepared or approved by a professional geologist as defined in Section 34-1-201(3).

Professional Geologist Certification

By means of this certification, I attest that:

- I am qualified to prepare a Natural and Geologic Hazard Study in accordance with the provisions of Section 7-207 of the Garfield County LUDC, and that I am a member of the American Institute of Professional Geologists per LUDC 4-203.
- Although I have not visited the proposed site, I am familiar with the geology and have performed field work in the area of the proposed Ursa Operating Company LLC BMC B Pad Well located in the SW ¼ NW ¼ Section 18, Township 7 South, Range 95 West, 6th Principal Meridian in Garfield County, Colorado.
- Although Colorado does not currently have a licensing board or registration program for professional geologists practicing in the state of Colorado, there are requirements within local and State statutes that require that geologic reports be prepared by a professional geologist. I attest that I meet the requirements of the Colorado Geological Survey's definition of a professional geologist having completed and met the educational requirements of the Colorado Geological Survey definition.
- I am a licensed Professional Geologist and Professional Geoscientist in other States, including Texas, Utah, and Wyoming which do have licensing programs for professional geologists.
- I have reviewed published geologic maps and reports applicable to this area and have considered the implications of these conditions in the context of the proposed development.
- This report has been prepared in accordance with good scientific principles and engineering practices including consideration of applicable industry standards, and with consideration of the requirements of the National Association of State Boards of Geology. The conclusions and recommendations contained in this report are based on information available and known to me at the time of this report. Good scientific principles and standard engineering practices were taken into consideration to in arriving at the conclusions and recommendations made in this report.

Prepared by

James W. Hix

James W. Hix, PG
Senior Geologist

Reviewed by

AMERICAN INSTITUTE OF PROFESSIONAL GEOLOGISTS CERTIFICATE NUMBER 7805 AIPG KEVIN J. TAYLOR CERTIFIED PROFESSIONAL GEOLOGIST

Kevin J. Taylor, PG
Senior Geologist

Date: 10/03/2014

Note: The PG's certification does not relieve the owner/operator of the facility of the duty to review this report or fully implementing the recommendations in accordance with all applicable Federal, State, and local requirements in order to achieve the desired goals or objectives.

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1.0 EXECUTIVE SUMMARY

Olsson Associates (Olsson) was contracted by Ursa Operating Company to assess natural and geologic hazards potentially present in the area of the proposed BMC B production well pad located in the SW ¼ NW ¼ Section 18, Township 7 South, Range 95 West, of the 6th Principal Meridian, Garfield County, Colorado. The site is at an elevation of about 5,090 feet above mean sea level (amsl). The site setting is shown on the attached BMC B Pad **Adjacent Land Use Map**.

The purpose of this report is to identify geologic conditions that may pose hazards to a land development project in order that appropriate mitigation or avoidance techniques may be implemented as described in the Garfield County LUDC. According to the Garfield County LUDC, Section 7-207, the types of natural and geologic hazards identified pertain to the following:

A. Utilities;
B. Development in Avalanche Hazard Areas;
C. Development in Landslide Hazard Areas;
D. Development in Rock-fall Hazard Areas;
E. Development in Alluvial Fan Hazard Areas;
F. Slope Development;
G. Development on Corrosive or Expansive Soils and Rock;
H. Development in Mudflow Areas; and
I. Development Over Faults.

This report presents Olsson findings following an evaluation of these and other geologic hazards potentially affecting the site and proposed development. The Ursa Operating Company site was found to be suitable for the proposed development with consideration of the following identified geologic hazards.

- The soils in the vicinity of the site are corrosive to both steel and concrete due to high salt content and the subsoil layers have a high shrink-swell potential.
- According to the Preliminary Geologic Map of the Grand Valley Quadrangle, Garfield County, the proposed site is located on Quaternary age (Holocene) alluvium, terrace deposits, and underlain by “pre-historic” mudflow and fan gravel deposits.
- The site is not mapped as being in an Alluvial Fan Hazard area, but is located on alluvial fan deposits associated with Monument Gulch and unnamed intermittent drainages.
- The site is not mapped within the FEMA 100-year flood plain, but is located within 400 feet of the Colorado River. It is about 1,000 feet northeast of Monument Gulch and 300 feet southwest of an unnamed intermittent drainage. These drainages are prone to flash floods.

The BMC B Pad can be constructed to compensate for these limitations and potential hazards. 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

Ursa Operating Company LLC (Ursa) contracted Olsson Associates (Olsson) to conduct a natural and geologic hazards assessment as part of the proposed development of the BMC B well pad. The proposed facility will be used to drill for and produce natural gas. The following sections provide information about the proposed development and the site geologic setting. The site surface and bedrock geology is shown on the **Geology Map**.

2.1 Project and Site Description

The proposed BMC B well pad is located to the south of the town of Parachute, Colorado off of County Road 300. The site is located in the SW ¼ NW ¼ Section 18, T7S, R95W, 6th P.M. and is located in parcel # 240913406004. The surface land is owned by Battlement Mesa Partners. The site is located west of the intersection of Stone Quarry Road (County Road 300) and River Bluff Road (County Road 307), in the community of Battlement Mesa.

2.2 Structural Geology

The BMC B well pad site is located in the southeastern part of the Piceance Basin. The Piceance Basin is an irregularly-shaped elongated basin formed by tectonic forces associated with the Laramide orogeny. These forces down warped the earth's crust and formed the Piceance Basin as a result of the uplift of the surrounding Colorado Rocky Mountains and the Colorado Plateau.

The Piceance Basin is the major structural geologic feature in the region. It is bound to the east by the Grand Hogback monocline, the White River Uplift to the northeast, the Gunnison Uplift to the south, the Uncompahgre Uplift to the south and southwest, the Douglas Creek Arch to the west-northwest, and the axial basin uplift to the north (Grout and Verbeek, 1992).

Sedimentary rocks in the southwestern Piceance Basin gently dip to the north - northeast except where this regional dip is interrupted by low-amplitude folds. Numerous small sub-parallel northwest trending folds have been identified in the Green River Formation within the basin.

There are no mapped faults shown in the area of the site on the Geologic and Structure Map of the Grand Junction Quadrangle, Garfield County, Colorado (Cashion, 1973) or on the Preliminary Geologic Map of the Grand Valley Quadrangle, Garfield County, Colorado (Donnell, Yeend, Smith, 1986). A fault is a fracture in rock along which movement has occurred. Mountains are bound by faults and are a visible indication of a structural weakness in the earth's crust. The Colorado Rocky Mountains are bound by faults; however, these faults are not always visible at the ground surface either because the fault trace is 'blind' meaning that the fault does not have surface expression since it does not cut across overlying sedimentary bedrock units, or that it has been buried and concealed by unconsolidated sediments deposited over the area where the faults are present. There are no known major faults that have been mapped in the area of the site.

2.3 Site Geology

According the Preliminary Geologic Map of the Grand Valley Quadrangle (Donnell, Yeend, Smith, 1986), bedrock mapped to the east of the project area consists of the Eocene and Paleocene-age Shire Member of the Wasatch Formation which consists of purple, lavender, gray, and brown claystone, with minor beds of fine- to medium-grained sandstone. The maximum exposed thickness of the Wasatch is approximately 1,200 feet.

The bedrock in the area of the site is covered with unconsolidated sediments of Quaternary age consisting of mud flow and fan gravel deposits. Weak claystone in the upper Wasatch Formation are responsible for the slope failure which resulted in slides and debris flows during a time when the climate was much wetter. These mudflow and fan gravel deposits consist of pebble, cobble, and boulder gravel in a gray matrix of coarse sand. The unit is poorly sorted and contains angular to subangular clasts of primarily unweathered basalt, but contains some sandstone, marlstone, siltstone, and claystone. The unit was largely derived from solifluction deposits located to the east of the quadrangle.

Modern alluvium, alluvial, and floodplain deposits consisting of mud, silt, sand, and gravel are also present along the Colorado River drainage covering the fan gravel deposits in the vicinity of the site. The alluvial and floodplain sediments are locally derived from coalescing fan deposits and sheet-wash deposits form terraces along the active Colorado River drainage, and also contain well-rounded, well-sorted, non-locally derived crystalline rocks transported from areas to the east. The gravel commonly ranges in thickness from 10 feet to 60 feet thick; however, it is locally up to 100 feet thick, especially near the Colorado River (Yeend, 1969).

Alluvial terrace and fan gravel deposits are present to the southwest of the site and in the northeast corner of Section 18. These deposits consist of grayish brown sandy-gravel consisting primarily of basalt and locally derived slabby siltstone, marlstone, and sandstone clasts that are moderately to poorly sorted, poorly stratified. The maximum thickness of this unit reaches 200 feet.

2.4 Soil

The Natural Resources Conservation Service (**NRCS**) **Soils Map** shows the area soil types. Soils, consisting of the following units, are within the study area around BMC B well pad:

- Arvada Loam, 6% to 20% slopes, Map Symbol 4: The Arvada loam is a deep, well drained, sloping soil formed on fans and high terraces at elevations between 5,100 feet and 6,200 feet above mean sea level. Typically the surface layer is a moderately alkaline, pale brown loam about three inches thick and the substratum is light brown to brown silty clay loam to a depth of 60 inches. Permeability is very slow, and available water capacity is high. Surface runoff is moderately rapid, and the erosion hazard is severe.

The Arvada loam soil is corrosive to steel and concrete due to the large amounts of clay and salts. Community development is limited by high shrink-swell potential, salinity, and steep slopes. Buried piping and structures onsite will need to have adequate cathodic protection to prevent corrosion due to the high salinity of these soils.

2.5 Hydrologic Setting

The site is located on a terrace above the Colorado River flood plain. The Colorado River is located approximately 400 feet to the north. The Monument Gulch creek drainage is located approximately 1,000 feet to the southwest. There is an unnamed intermittent drainage 300 feet to the east northeast of the site. These surface water features are shown on the **Surface Water Map**.

2.6 Aquifers

The Wasatch Formation locally yields water to wells in some areas, but is generally considered a confining unit. The Tertiary sedimentary rocks in the Piceance Basin are generally fine-grained and well cemented resulting in very small hydraulic conductivity in the rock matrix. Sandstone and siltstone generally occur in lenticular bodies and locally have moderate hydraulic conductivities which range from 0.001 to 0.01 foot per day. These lenses of sandstone and siltstone are often widely spaced and not interconnected which further limits the volumes of groundwater the formation can yield to wells. In some areas, fracturing during the structural deformation that occurred when the Piceance Basin was uplifted and through dissolution of cementing minerals has enhanced the permeability and hydraulic conductivity in parts of the Piceance Basin aquifer system (Topper et al, 2003).

Water well depths in the area typically range from 50 feet to 150 feet below ground surface along the Colorado River and 151 feet to 300 feet below ground surface (bgs) in areas further south of the Colorado River. Static water levels reportedly range between 40 feet and 60 feet bgs based on a review of permitted water wells in the vicinity of the site.

Surficial aquifers are present in the alluvium along the Colorado River and its major tributaries. The depth to groundwater is expected to be less than 20 feet in close proximity to the Colorado River. This alluvium is typically too thin, narrow, and discontinuous to be considered a major aquifer, although in some areas the alluvium is locally important as surficial aquifers (Banta and Robson, 1995). Groundwater within the unconsolidated sediments in the area of the proposed site is controlled by the thickness of the sediments and the depth to the top of the Wasatch bedrock. The estimated groundwater flow direction in the vicinity of the site is likely to be sub-parallel with the Colorado River, flowing north-northwest toward the Colorado River through the center and northern part of the proposed site. These deposits are shown on the **Geology Map**.

3.0 NATURAL AND GEOLOGIC HAZARD ASSESSMENT

The following sections present the assessment of geologic hazards in the vicinity of the proposed Water Impoundment. The **Adjacent Land Use Map** shows the location of the BMC B Well Pad site in relation to the affected parcel and local roads.

3.1 Utilities

Above-ground utility facilities located in Hazard Areas are to be protected by barriers or diversion techniques approved by a qualified professional engineer. The determination to locate utility facilities above ground will be based upon the recommendation and requirements of the utility service provider and approved by the County. Except for potential flooding, above-ground utilities, such as transformers, are not expected to be affected by geologic or other natural hazards.

Trenches for water pipelines, natural gas pipelines, and electrical lines are expected to be associated with the proposed development. The slopes and corrosive soil may pose technical challenges to the installation of these utilities; however, it is expected that these limitations can be overcome with proper design and installation.

There are existing natural gas wells in the area, the Battlement Mesa waste water treatment facility to the west of the site and River Bluff Road (County Road 307) to the south. A boat storage facility is located to the south and houses are located to the east and southeast of the site.

3.2 Avalanche Hazard Area

Winters are cold in the mountainous areas of Garfield County, and valleys are colder than the lower parts of adjacent mountains due to cold air drainage. Average seasonal snowfall in Garfield County is 50 inches. The greatest snow depth at any one time during the period of record from 1951 to 1974 was 29 inches recorded at Rifle, Colorado approximately 25 miles to the east-northeast of the proposed site.

Avalanches are not expected to affect the proposed natural well site since it is located at an elevation of approximately 5,160 feet amsl. Areas in eastern Garfield County are at higher elevations, receive more snow pack, and are, therefore, more prone to avalanches in certain years.

Avalanches are the most dangerous geologic hazard in Colorado resulting in injuries, loss of life, and about $100,000 in direct property damage, and indirect economic losses in the millions of dollars annually. However, the avalanche prone areas include the Park Range and Flat Tops in northeastern Garfield County, Colorado, to the north of Glenwood Springs. Glenwood Springs, near the east edge of the area, averages about one degree cooler than Rifle and receives about five inches more precipitation per year (Harman and Murray, 1985).

3.3 Landslide Areas or Potential Landslide Hazard Areas

The site is located on mudflow and fan gravel deposits overlain by younger terrace deposits, alluvial, and floodplain deposits. There are earthflow and soil creep deposits mapped to the

south of the site in southern half of Section 19, but these deposits are not mapped in Section 18, Township 7 South, Range 95 West. Movement of the extensive earthflow and soil creep slopes has ceased, except for local occurrences of very recent slumps and mudflows. Solifluction deposits are extensive in the Rulison 7.5-minute quadrangle located to the east, but are only found in a small area on the east side of the Parachute (Grand Valley) 7.5-minute quadrangle (Yeend, Donnell, Smith, 1986).

According to Map 24 – Surface Geology map, Geologic Hazards Identification Study (Lincoln Devore, 1975-1976), there are no landslides shown to the south of Interstate 70 in the Parachute – Battlement Mesa area. Landslide areas are shown to the northwest of the town of Parachute (Garfield County, Surface Geology, 2007).

3.4 Rockfall Areas

The site is not located within an area that has been mapped as having rockfall or potential for rockfall. Potential rockfall areas are present along the steep drainages incised by Monument Creek to the south and southeast or at higher elevations to the south on Battlement Mesa.

3.5 Alluvial Fan Hazard Areas

The site is located in an area that is not mapped as being in an alluvial fan hazard area according to the Garfield County Surficial Geology, 2007. The site is located on alluvium, floodplain, alluvial terrace, and fan gravel deposits and is underlain by older mudflow and fan gravels according to the Preliminary Geologic Map of the Grand Valley Quadrangle (Donnell, Yeend, Smith, 1986). The site is on the northeastern part of an alluvial fan created by Monument Gulch and other unnamed intermittent drainages. These deposits lie about 100 feet above the Colorado River flood plain.

3.6 Unstable or Potentially Unstable Slopes

According to the Garfield County Slope Hazard Study Areas 1, 2, & 3 map, parts of the area north of the Colorado River and the town of Parachute, Colorado have been mapped as being in an area of major slope hazard. The map does not show the area south of the Colorado River and in the vicinity of the site as being identified in a slope hazard area.

The slope hazard map recommends that site specific investigations should be conducted to assess active landslide areas. Geologic studies may include intensive drilling and sophisticated strength testing, stability analyses, and monitoring of soil, rock, and groundwater conditions. Mitigation may be possible, but likely will be expensive, may require special siting, and will involve some risk. Avoidance may be recommended for projects of lower economic value (Garfield County, Slope Hazard Study 2002).

The Arvada Loam soils are found on 6% to 20% slopes. Engineering, design, and construction practices of the proposed development are expected to mitigate the limitation of slopes at the site since the site is located within an area developed for other land uses, including development of natural gas well pads. The site may require mitigation for slope, and will be graded and constructed for this purpose. The site is in an area near the Colorado River with slopes that are not as steep as surrounding areas.

3.7 Corrosive or Expansive Soils and Rock

According to the Soil Survey of the Rifle Area, the Arvada loam soils are corrosive to both steel and concrete. Sedimentary rock containing high salt content, such as chloride or sulfate, and soils derived from these rock types, may also be corrosive to concrete or metal, causing damage to structures built upon them. The Arvada loam is alkaline with pH greater than 7.8 to more than 8.4 standard units. The salinity in the Arvada loam is typically less than 4 millimhos per centimeter; however salinity may increase with depth. These conditions are a potential hazard present in the vicinity of the site.

Some Tertiary and Cretaceous age sedimentary rocks with high clay content are capable of accepting water into their chemical structure and expanding many times their volume when dry. These sedimentary rocks, and soils formed from these rock types, may expand or contract as they become wet and then dry out resulting in damage to structures built upon them.

The substrate of Arvada loam soils have a high shrink-swell potential which pose a limitation for some community and recreational development, but are not expected to adversely impact the proposed well construction.

3.8 Mudflow and Debris Fan Areas

The site is located in an area of mud flow and fan gravel deposits overlain by alluvium and flood plain deposits, and alluvial terrace deposits. The site is located on a terrace near the Colorado River drainage. These deposits are Holocene in age and future mud slides are a potential hazard if the area were to receive heavy rains. These flows are expected to originate from higher elevations to the south and would follow the drainages to lower elevations closer to the Colorado River floodplain.

Wetter conditions at the end of the last ice age were most likely responsible for the development of the extensive mudflows and fan deposits peripheral to Battlement Mesa. Glacial conditions that existed on the Grand Mesa during the Pleistocene did not exist on Battlement Mesa at this time. Abundant annual runoff is suspected in creating high pore-water pressures within the Wasatch Formation shale and claystone to cause slope failure, especially on north-facing slopes where evaporation was at a minimum (Yeend, 1968). More recent slumps and mud flows that have occurred south of Plateau Creek near Collbran developed in glacial till.

The proposed BMC B Pad is located on a parcel developed for outdoor storage, and there is other development in the area including a public works yard to the west and River Bluff Road (County Road 307) to the south and east. The Battlement Mesa waste water treatment facility is located further to the west of the site. There are housing developments located to the northeast and southeast of the site.

3.9 Development Over Faults and Risk of Seismic Activity

There are no major faults shown in the Grand Valley area on the Geologic and Structure Map of the Grand Junction Quadrangle, Colorado and Utah (Cashion, 1973). There are no mapped faults shown on the Preliminary Geologic Map of the Grand Valley Quadrangle, Garfield County, Colorado (Donnell, Yeend, and Smith, 1986) in the immediate vicinity of the site.

The Piceance Basin and other Tertiary age basins of the Colorado Plateau are defined by monoclines, at least along one margin. The Grand Hogback, to the east near the town of Rifle, is such a monocline which is thought to have formed by reactivation of pre-existing, steeply dipping fault zones in the Precambrian basement rock. Recent seismic data suggests that some of the monoclines, especially in the Rocky Mountain foreland near the boundary with the Colorado Plateau, overlie a west-, southwest-, or south-directed thrust fault system. These blind thrust faults transect older Mesozoic and Paleozoic sedimentary rocks that resulted from two major deformational events associated with the uplift of the ancestral Rocky Mountains. The Grand Hogback monocline formed above the tip of a blind, Precambrian basement rock thrust fault wedge which moved southwest and west-southwest into the Piceance basin (Grout and Verbeek, 1992).

Colorado is considered a region of minor earthquake activity; however, there is uncertainty due to the relatively short historic record. According to the USGS Colorado Earthquake History online, newspaper accounts were the primary source of earthquake data in Colorado prior to 1962. Few earthquakes have been reported in this part of Colorado. A very minor earthquake occurred in the northwestern part of Colorado on November 22, 1982 at 3:09 a.m. MST. The magnitude 2.9 earthquake was located about 18 miles northeast of the town of Rifle and was felt at a fish hatchery in the area.

The largest quake in the area occurred on April 22, 1984 and had a magnitude of 3.1 on the Richter scale. The quake was felt in Carbondale and in Glenwood Springs. Of the hundreds of quakes that occurred in the Carbondale area during that time period, 12 were reported as felt.

3.10 Flood Prone Areas

The facility is not shown within the FEMA 100 year flood hazard zone based on the Flood Plain Map in the Vicinity of the Town of Parachute, Garfield County, Colorado, or a Firmette Map generated from the FEMA data. The Colorado River flood plain is located approximately 400 feet to the north of the site. The unnamed drainage and the Monument Gulch drainage are shown as having Zone A – 100-year flood plains located along their banks These areas are also prone to flash floods. The flood plain along the Colorado River is shown in relation to the BMC B Pad on the attached **Flood Plain Map**.

3.11 Collapsible Soils

Collapsible soils are another type of subsidence that occurs in parts of western Colorado where unconsolidated sediments are present. This ground settlement can damage man-made structures such as foundations, pavements, concrete slabs, utilities, and irrigation works. Collapsible soils have not been mapped in the area and are not expected to be encountered in the vicinity of the site.

3.12 Mining Activity

A review of the Grand Valley 7.5-minute quadrangle did not show any significant mining activities in close proximity to the proposed BMC B Pad site. Oil shale mining was conducted north of the town of Parachute, and there are sand and gravel operations along the Colorado River. There are no mining activities shown in the immediate area of the site. Natural gas wells are shown in the surrounding areas of the proposed BMC B Pad site.

3.13 Radioactivity

Naturally occurring radioactive materials are not expected to be an issue at the site. Colorado oil and gas operations are not known to have a significant problem with naturally occurring radioactive materials (NORM) or technologically enhanced naturally occurring radioactive materials (TENORM); however, there have been some instances where pipe scale has contained radium and associated radon gas. A NORM survey including site specific testing could be performed to further assess the radon potential at the site to serve as a baseline assessment if used pipe or pipe scale is to be disposed offsite in the future.

Olsson reviewed the Colorado Bulletin 40, Radioactive Mineral Occurrences of Colorado which states that nearly all of Garfield County's uranium production came before 1954, and most of that came from the Rifle and Garfield mines. Both of these mines were located along the same ore body near the town of Rifle. These occurrences were all hosted in the Jurassic Morrison and Entrada Formations, and the Triassic-Jurassic Navajo Sandstone, or the Triassic Chinle Formation which are known to contain uranium and vanadium deposits in the county and in the Colorado Plateau in general (Nelson-Moore, Collins, and Hornbaker, 1978). These formations lie at great depth in the vicinity of the site and are stratigraphically below the depth of the Wasatch Formation.

The Colorado Department of Public Health and Environment (CDPHE) has posted a statewide radon potential map on their website based on data collected by the EPA and the U.S. Geological Survey. Garfield County and most of Colorado has been mapped as being within Zone 1 – High Radon Potential, or having a high probability that indoor radon concentrations will exceed the EPA action level of 4 picocuries per liter (pCi/L).

Radon is not expected to be a significant problem at the proposed site since the development will not include any permanent structures, personnel will not be onsite for extended periods, and the site will not be developed with structures containing basements or substructures in which radon can accumulate.

4.0 Conclusions and Recommendations

The following conclusions and recommendations were made following a review of the available site data for natural and geologic hazards in the vicinity of BMC B Pad site located in Garfield County, Colorado.

- Geological hazards are not expected to be associated with the installation of buried utilities at the BMC B Pad. Corrosive soil may be a limitation to this construction, but this limitation should be able to be overcome with proper engineering, design, and construction. Cathodic protection for buried piping may reduce corrosion resulting from salts in these soils.
- Avalanche conditions are not expected to be a hazard in the area of the site.
- The site is located on alluvium and terrace gravels overlying pre-historic mud flow and fan gravel deposits. The site is within the town limits for Battlement Mesa and there are existing wells and other structures in the area including the Battlement Mesa waste water treatment facility and housing developments to the northeast and southeast of the site. The mud flow, terrace, and fan gravels are not expected to constitute a geologic hazard for the BMC B Pad development.
- Rockfall areas are not present in the area of the site and are not expected to be a geologic hazard affecting the site.
- The site is not in an area mapped as an alluvial fan hazard area; however, the site is underlain by alluvium and fan gravels, and the floors of creeks on the northwest side of Battlement Mesa are mantled with alluvial gravel. Alluvial fans have been deposited at the mouths of Monument Gulch and other nearby streams.
- Slope is a not expected to be a geologic hazard affecting development of the BMC B Pad site.
- The Arvada loam soils are corrosive to both steel and concrete, and the subsoil has a high shrink-swell potential. Corrosive and expansive soils are potentially present in the vicinity of the proposed BMC B Pad site which is a limitation for some site development.
- Collapsible soils are not present in the vicinity of the proposed BMC B Pad site.
- No significant faults have been mapped or are known in the BMC B Pad site.
- The site is not mapped as being within the 100 year flood plain. Flash flooding is a hazard for lower elevations along Monument Gulch and areas along the Colorado River. Areas immediately adjacent to these streams are located within the 100 year flood plain and are prone to flood risks.
- There are no mining activities shown in the vicinity of the site. Natural gas well drilling has been conducted in the area since the 1960s.
- There are no significant radioactive mineral deposits known in the immediate area of the site. The presence of NORM may be an issue with exploration and production and could be an issue with used pipe scale or used equipment. Radioactive materials are not expected to pose a significant hazard at the site.

5.0 References

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- Yeend, W.E., 1969, Quaternary Geology of the Grand and Battlement Mesas Area, Colorado, USGS Professional Paper 617, 50 p, 1 plate.

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- 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

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FIGURES

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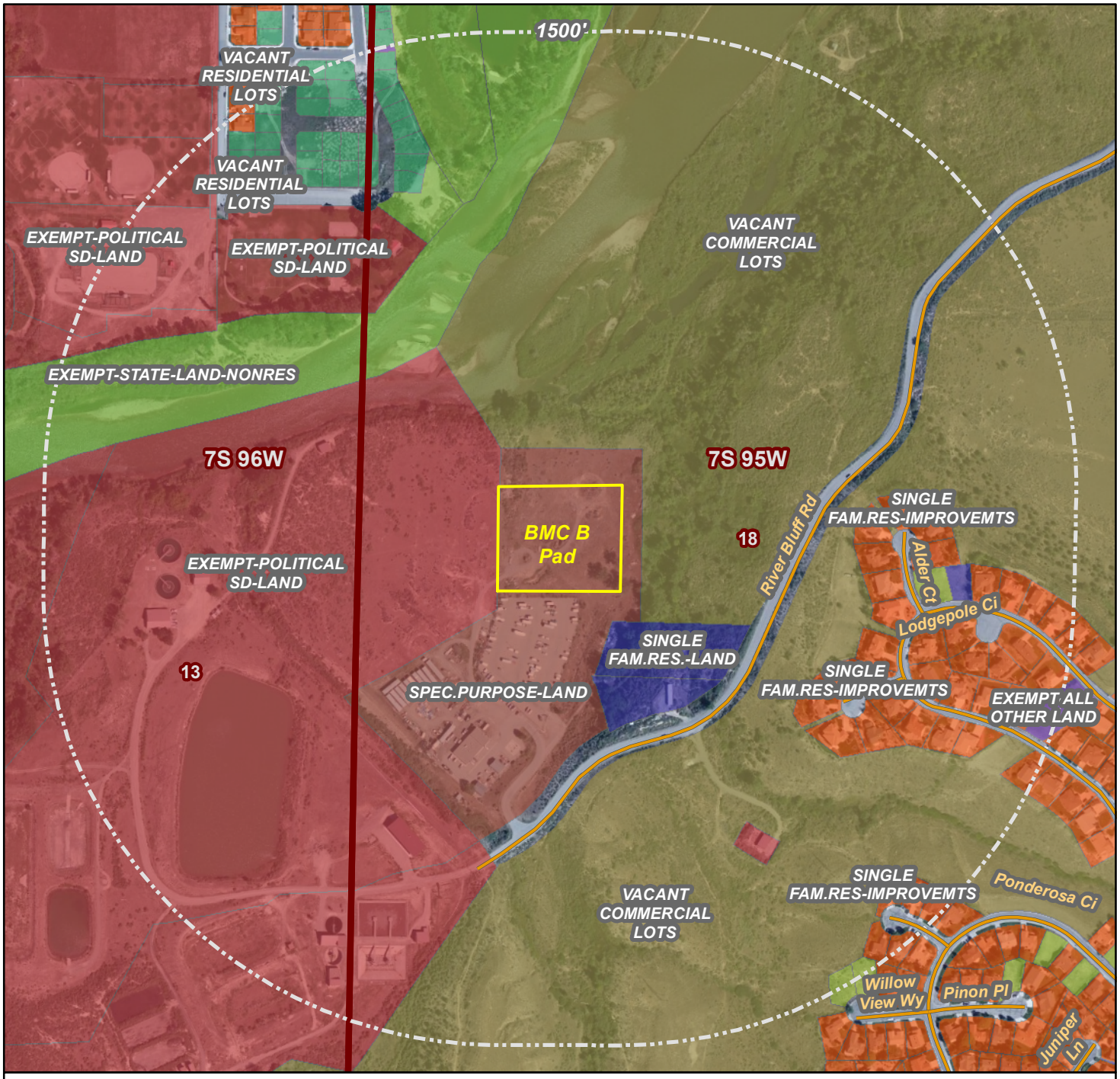

Adjacent Land Use

- EXEMPT ALL OTHER LAND
- EXEMPT-POLITICAL SD-LAND
- EXEMPT-STATE-LAND-NONRES
- SINGLE FAM.RES-IMPROVEMTS
- SINGLE FAM.RES.-LAND
- SPEC.PURPOSE-LAND
- VACANT COMMERCIAL LOTS
- VACANT PUD LOTS
- VACANT RESIDENTIAL LOTS

Proposed BMC B Pad
Township
Section
County Road

0 250 500 Feet

N

F:\Projects\014-1829\GIS\MXD\ALU-1 BMC B Pad Surficial Geology Map.mxd

Project Number: 014-1829	**Adjacent Land Use Map** Ursa Operating Company BMC B Pad Garfield County, CO Sec 18, T7S, R95W, 6th PM	Figure **ALU-1**
Drawn By: JWH		
Revision Date: 9/30/2014		

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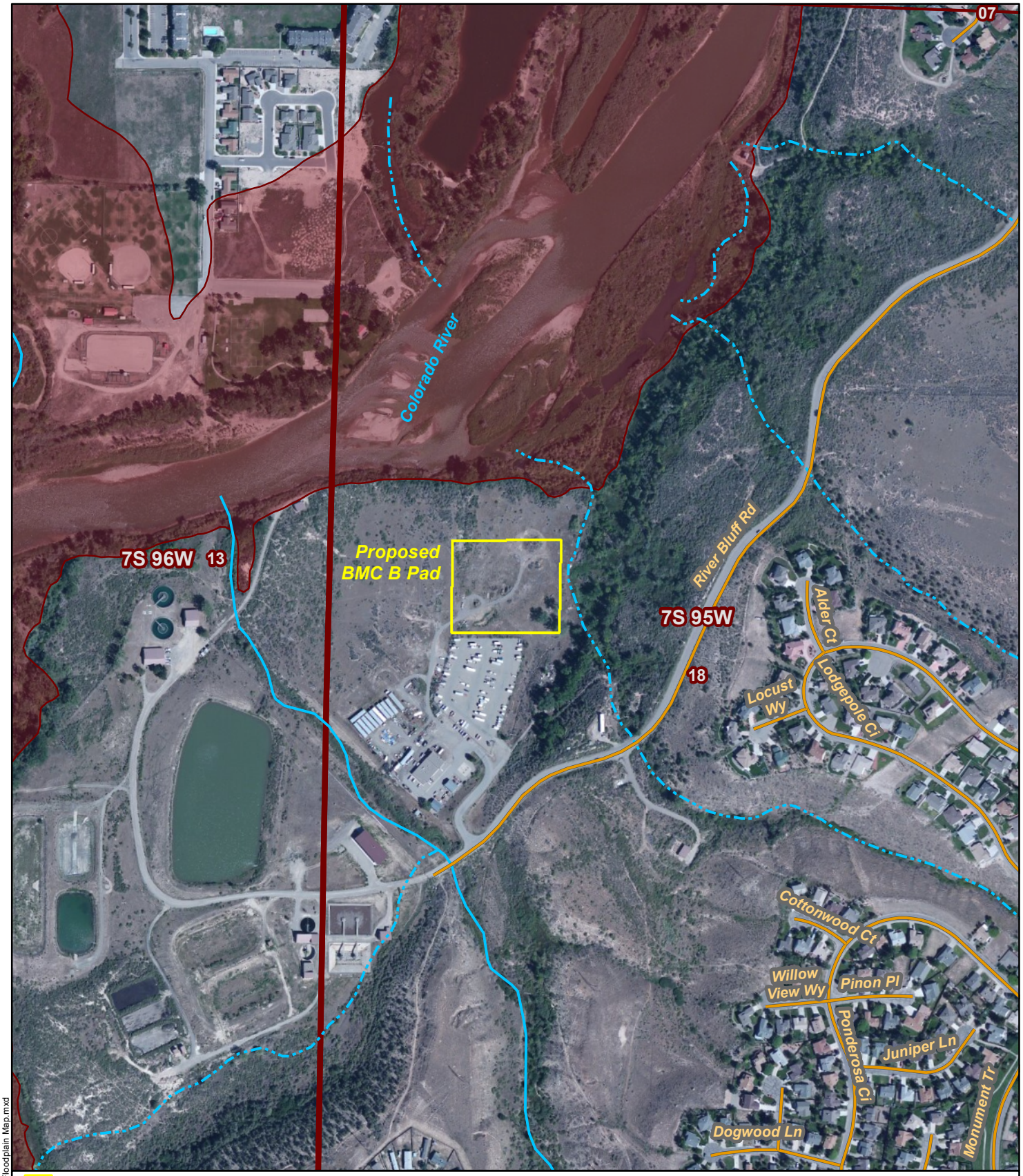

Proposed BMC B Pad
Township
Section
County Road

Hydrography
Perennial Stream
Intermittent Stream
100/500 Year Combined Floodplain

DISCLAIMER : This Geographic Information System (GIS) and its components are designed as a source of reference for answering inquiries, for planning and for modeling. GIS is not intended, nor does it replace legal description information in the chain of title and other information contained in official government records such as the County Clerk and Recorders office or the courts. In addition, the representations of locations in this GIS cannot be substituted for actual legal surveys.

0 250 500 Feet

N

F:\Projects\014-1829\GIS\MXD\FP-1 BMC B Pad Floodplain Map.mxd

Project Number: 014-1829	**100/500 Year Floodplain Map** Ursa Operating Company BMC B Pad Garfield County, CO Sec 18, T7S, R95W, 6th PM	Figure **FP-1**
Drawn By: JWH		
Revision Date: 9/30/2014		

Ursa OPERATING COMPANY

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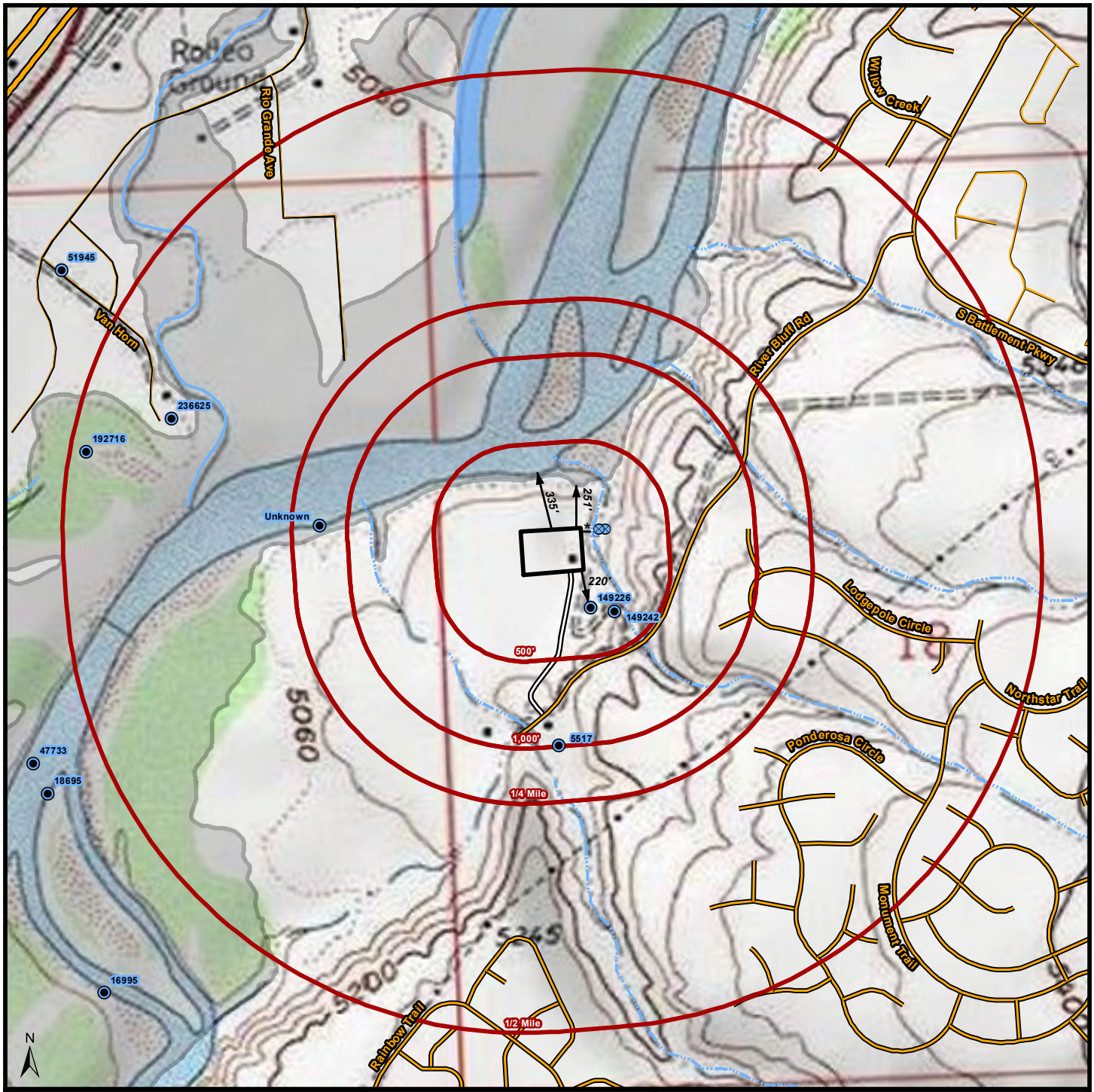

HYDROGRAPHY: FEATURE	PRESENT WITHIN 1,000 ft
Ditch	No
Floodplain	*Yes - 251 ft*
Groundwater Depth	*Approx. 40 ft*
Intermittent Stream	*Yes - 58 ft **
Perennial Stream	*Yes - 335 ft*
Riparian Area	No
Spring	*Yes - 101 ft **
Water Body	No
Watershed	No
Water Well	*Yes - 220 ft*
Wetland	*Yes - 67 ft **

Notes / Comments:

0 500 1,000
Feet

Ursa OPERATING COMPANY

Form 2A - Attachment E

Topographic Map Showing Surface Waters

BMC B

39.43894 -108.04647
Section 18, Township 7 South, Range 95 West

Proposed Development
Proposed Access
Local Roads
County Roads

HRL Compliance Solutions, Inc.
Environmental Consultants

Author: M. Spinelli
Revision: 2
Date: 4/2/2015

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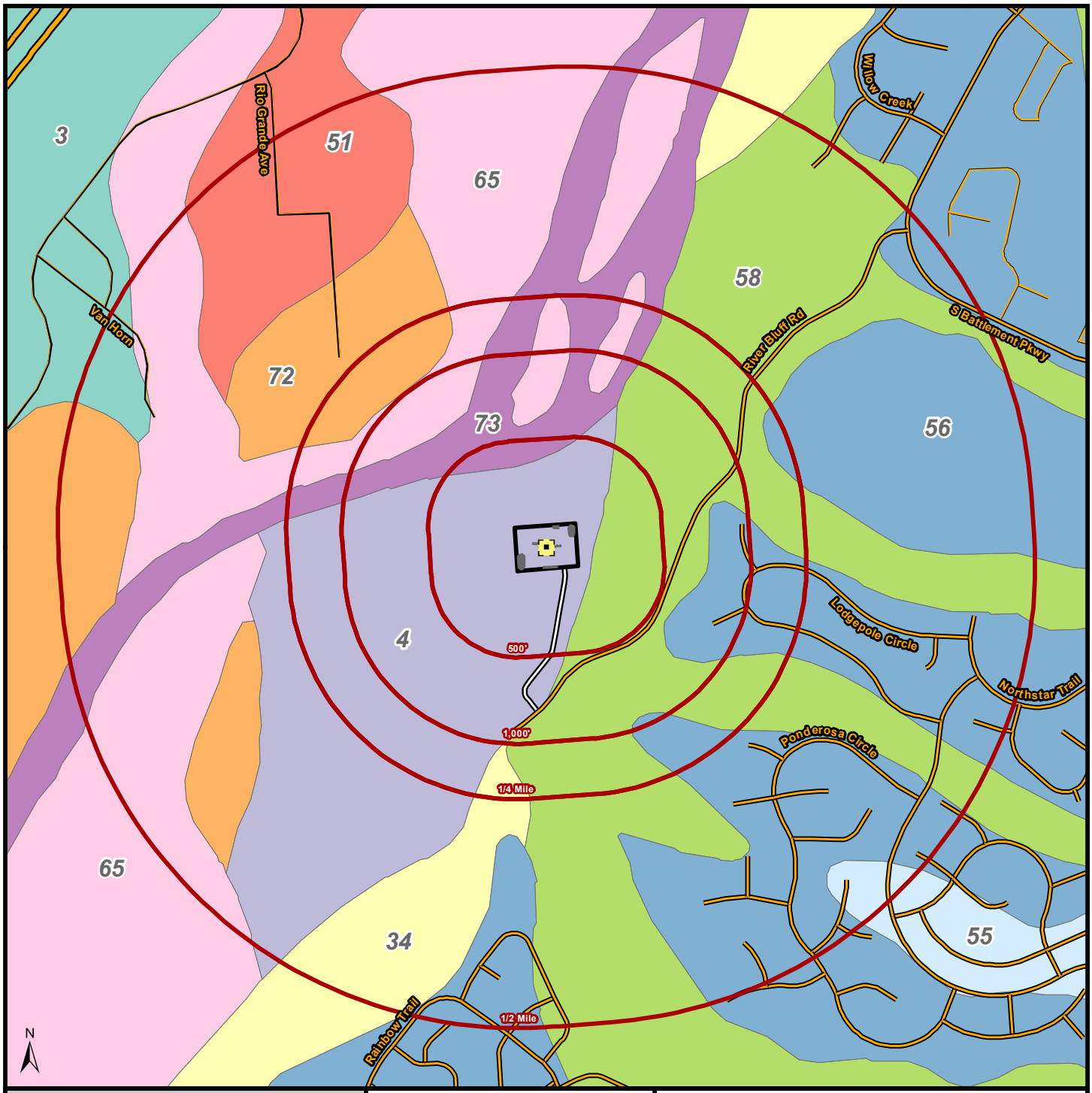


NRCS SOILS KEY:

MAP SYMBOL	SERIES NAME
3	Arvada loam (1-6% slopes)
4	Arvada loam (6-20% slopes)
34	Ildefonso stony loam (25-45%)
51	Olney loam, (6-12% slopes)
55	Potts loam (3-6% slopes)
56	Potts loam (6-12% slopes)
58	Potts-Ildefonso complex (12-25%)
65	Torrifluvents (nearly level)
72	Wann sandy loam (1-3% slopes)
73	Wann sandy loam (3-6% slopes)

Notes / Comments:

0 500 1,000
Feet

Ursa OPERATING COMPANY

Form 2A - Attachment H

NRCS Soils Map

BMC B

39.43894 -108.04647
Section 18, Township 7 South, Range 95 West

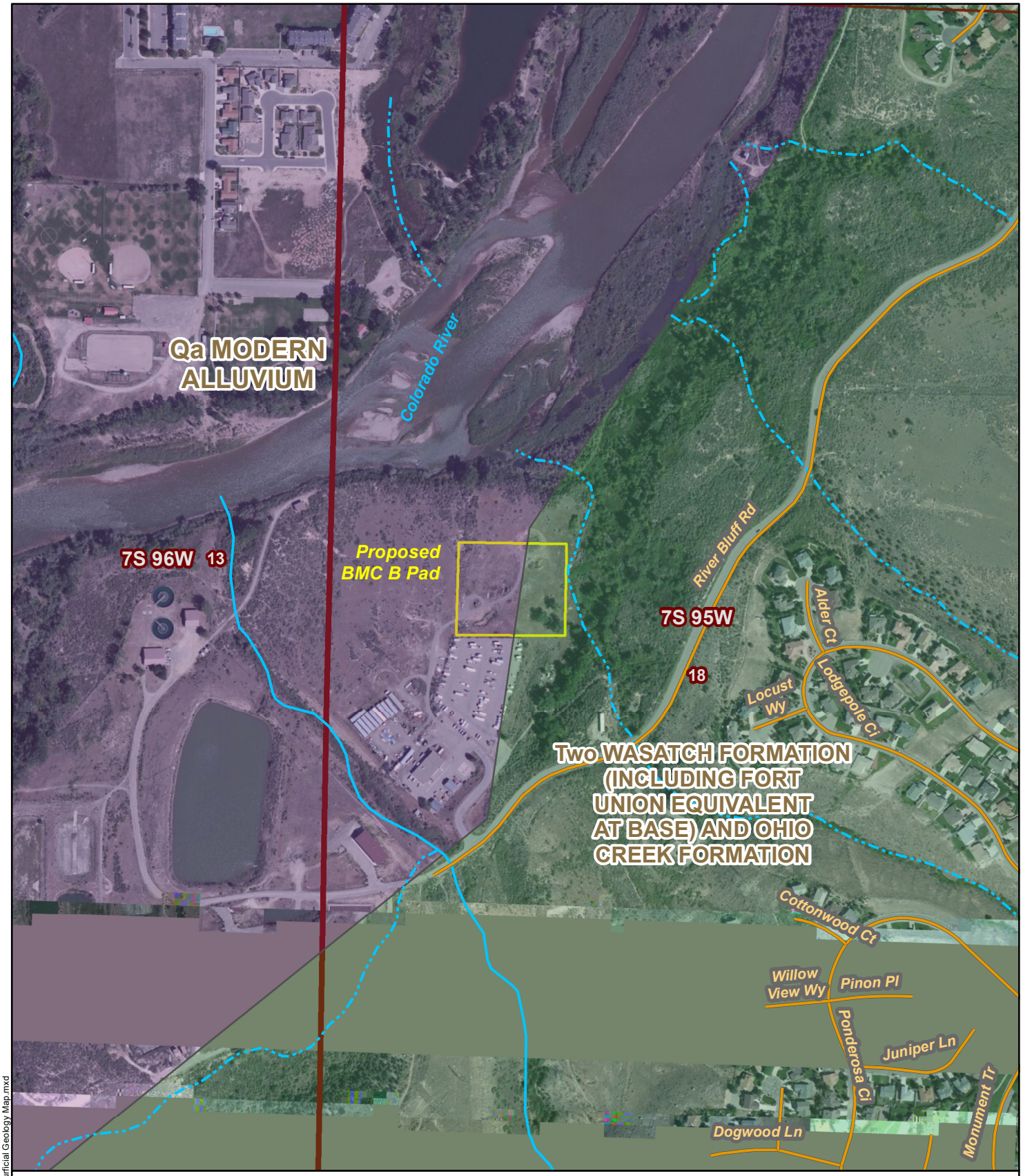
Approx. Center
Proposed Development
Proposed Access
County Roads
Local Roads

HRL Compliance Solutions, Inc.
Environmental Consultants

Author: M. Spinelli
Revision: 1
Date: 4/2/2015

Attachment H – NRCS Soil Survey, Rifle Area

Map Symbol 4 – Arvada loam (6-20% slopes)	
Deep, well drained, sloping soils found on fans and high terraces.	
Elevation	5,100 to 6,200 feet
Average Annual Precipitation	Approximately 12 inches
Average Annual Air Temp	Approximately 48 degrees F
Frost Free Days	Approximately 120 days
Permeability	Very Slow
Available Water Capacity	High
Effective Rooting Depth	60+ inches
Surface Runoff	Moderately Rapid
Erosion Hazard	Severe
Native Vegetation: Mainly sagebrush, greasewood, and wheatgrass.	
Development is limited by the high shrink-swell potential, salinity, and steep slopes. This soil is in capability subclass VIIs, nonirrigated.	



Proposed BMC B Pad
Township
Section
County Road

Hydrography
Perennial Stream
Intermittent Stream

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0 250 500 Feet

N

Project Number: 014-1829	**Geology Map** Ursa Operating Company BMC B Pad Garfield County, CO Sec 18, T7S, R95W, 6th PM	Figure **G-1**
Drawn By: JWH		
Revision Date: 10/10/2014		

Ursa OPERATING COMPANY

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