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# GEOLOGIC HAZARDS STUDY
# PROPOSED PIKE SOLAR FARM
# EAST OF BIRDSALL ROAD
# SOUTHEAST OF FOUNTAIN, COLORADO

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## PURPOSE AND SCOPE OF STUDY

This report presents the results of a Geologic Hazards Study for the proposed Pike Solar and Storage project. A regional map showing the project site is shown on Figure 1A and the Project site is shown in more detail on Figure 1B. The purpose of the study was to evaluate the geologic conditions and assess their potential impact on the project and surrounding properties. The study was conducted in accordance with our proposal for engineering geology services to JSI Construction Group LLC, dated July 1, 2021, Proposal No. P7-21-664.

A reconnaissance of the project site was conducted on August 11, 2021 and August 20, 2021 to obtain information on the geologic conditions of the site. Aerial photographs and published regional geologic, engineering geology, and mineral extraction maps were also reviewed. This report summarizes the data obtained during this study and references information from the geotechnical engineering report produced by Terracon Consultants, Inc., Terracon project number 23205109, dated February 5, 2021, and presents our conclusions, recommendations, and other geologic considerations based on the proposed construction and geologic conditions observed.

## PROPOSED DEVELOPMENT

We understand the proposed project will consist of a large-scale photovoltaic system consisting of photovoltaic modules aligned in arrays and affixed to single-axis tracking modules. The arrays will be arranged in multiple clusters and occupy a total area of around 1,200 acres. We understand that it is preferred to support the arrays on a steel W-section or channel C-section piles driven to an adequate embedment to provide sufficient vertical and lateral resistance to loads, although alternative foundations systems are being considered where feasible. The facilities will have various electrical enclosures and equipment pads as well as aggregate-surfaced access roads and staging areas, with array areas enclosed by a security fence. We anticipate that the site will be constructed at or near the existing elevations, and that minimal site grading will be required to accommodate the proposed construction.

The Array Areas are generally arranged in three groups, hereafter referred to as the North, Center, and South Array Areas, and can be further subdivided into 8 separate Array Areas, as seen on Figure 1B, with Array Area 1 in the North Array Area and Array Area 8 in the South Array Area.

If conditions are significantly different from those described above or depicted in this report, we should be notified to reevaluate the recommendations contained herein.

SITE CONDITIONS

The subject site is located in El Paso County, approximately 5 miles southeast of Fountain, Colorado, east of Interstate 25 and Fountain Creek. The site is located east of Birdsall Road and south of Squirrel Creek Road. The site occupies portions of sections 7, 18, 30, and 31 in Township 16 south, Range 64 west, Sixth Meridian of the Public Land Survey System and portions of sections 12, 13, 14, 23, 24, 25, and 36 in Township 16 south, Range 65 west, Sixth Meridian of the Public Land Survey System. The site lease boundary has an approximate area of just over 3,000 acres, although the solar arrays only take up an approximate area of around 1,200 acres. The site has a maximum length of approximately 4.5 miles north to south and a maximum width of approximately 2 miles from west extent to east extent. The site is primarily vacant rangeland, however there are several areas that have existing development within and nearby the subject site. The existing and active Fountain Landfill is located near the northwest corner of the project site. Colorado Springs Utilities operates the Williams Creek Substation located within the subject site directly south of Array Area 5. Colorado Springs Utilities also operates the Williams Creek Pump Station located east of the substation, situated between Array Areas 6 and 7. Outside of the subject site, near the southwest corner of the site west of Array Area 7, the Palmer Solar Site contains an existing PV solar array. In addition to these developments, the site is traversed by a variety of overhead utility easements and an underground pipeline easement running north-northwest to south-southeast across the site. The underground pipeline has an ancillary structure located in the vicinity of the northeast corner of Array Area 7. Calhan Reservoir is located approximately 4,000 feet west of Array Area 5. Several ranches are located within the general vicinity of the project site, including the Calhan Ranch located near Calhan Reservoir and Kane Ranch, which is located northeast of the subject site off of Squirrel Creek Road. The ephemeral Williams Creek flows through the site in several locations, generally flowing from north to south. A variety of unnamed tributaries and drainages can be found on the site, all generally flowing into Williams Creek. Several of these unnamed tributaries and drainages have been observed to contain man-placed earthen dams, often with associated retention basins. The topography of the subject site is variable across its extent, ranging from nearly level areas to gently to moderately sloping to moderately steep in areas, although moderately steep areas compose a small minority of the site topography. The site topography is best described as undulating to gently rolling. Steeper slopes are present along erosional features. Banks of Williams Creek and various unnamed tributaries have been observed to range in steepness, with some banks vertical. Erosional scarps and headward eroding gullies have been observed to be just as steep. The site generally slopes down to the south. There is an approximate elevation change of 260 feet across the site with the highest elevation near the northeast corner of the site and the lowest elevation near the southwest corner of the site

GEOLOGIC SETTING

The main geologic lithologies in the vicinity of the project area are shown on Figure 2A. This map is based on the published regional maps by White et al. (2017) and Scott et al. (1976). Figures 2B through 2D display the geologic features that were mapped in the field by Kumar & Associates, Inc. as part of our site reconnaissance on August 11 & 20, 2021.

The project site is located within the Colorado Piedmont of the Great Plains physiographic province. Structurally, this area is east of the Ute Pass and Rampart Range Faults, which bounds this portion of the Front Range. According to Robinson (1977), Trimble and Machette (1979), and Madole (2003), regional uplift east of the Front Range has exposed Upper Cretaceous-age gently northeast dipping claystone, siltstone, sandstone and thin coal beds representing a regressional sea sequence.

Several surficial deposits are indicated within the project site. The surficial deposits can generally be described as one of three deposits, which includes Quaternary aged valley-fill deposits (Qav), Quaternary aged alluvium deposits (Qa), and Quaternary aged eolian sands (Qes). Valley fill deposits (Qav) can be described as "gray to light-tan to brownish-gray, unsorted to poorly sorted, weakly stratified, sandy to silty clay deposited as valley fill in broad drainage swales on low hillsides" (White et al., 2017). This unit has been known to contain dispersed gravel clasts and Pierre Shale concretion fragments. Previous published work by Scott et al. (1976) indicates that the Piney Creek Alluvium, which is described as silty to gravelly humus-rich alluvium along all valleys, can be considered present within this valley-fill deposit. The thickness of this unit ranges from 5 feet thick in narrower drainageways to up to 20 feet thick in wider swales. Furthermore, White et al. (2017) state that the "unit contains expansive clays and may be prone to swelling". Alluvium deposits (Qa) are described as tan sand and clayey to silty sand with thin gravelly lenses and can be considered to contain alluvial deposits such as the Broadway, Slocum and Verdos alluviums. These alluviums are deposited on terraces and cut shelfs that range from modern stream bed elevation up to 250 feet above modern stream bed elevation. Thicknesses of this unit vary. Clay content of this unit is derived from expansive Pierre Shale and may be prone to swelling. Eolian sand (Qes) is described as tan to brown, well to moderately sorted, sand and minor silt deposited primarily by wind. Contains variable amounts of silt and clay and may contain loess. Maximum thickness of this unit is stated to be 20 feet.

Beneath these surficial deposits, the development is underlain by upper Cretaceous-age Pierre Shale. The Pierre Shale is characterized by an abundance of marine invertebrate fossils and expansive clay minerals and is best generally described as a dark-gray to olive-gray fossiliferous marine shale that was deposited during the transgression of the Middle to Late Cretaceous

Western Interior Seaway. Following the nomenclature of Scott and Cobban (1986) that was used by Madole and Thorson (2003) in the adjacent Elsmere quadrangle, the Pierre Shale has been divided by White et al. (2017) into informal zones. These zones include the cone-in-cone zone designated by C.S. Lavington (1933) and the Tepee zone designated by G.K. Gilbert (1897). The cone-in-cone zone of Lavington of the Pierre Shale consists of non-calcareous to silty shale with thinly interbedded bentonite layers and is stated by Scott and Cobban (1986) to be about 2,300 feet thick. Limestone and ironstone concretions are common, and cone-in-cone structures occur in tabular masses within concretions. The Tepee zone of Gilbert of the Pierre Shale is a very similar unit to the cone-in-cone zone; non-calcareous to silty shale with discoid-shaped concretions with bentonite beds up to 5 inches thick. Large irregular mounds of limestone, coquina, and limestone breccias identify this unit, and are indicative of methane-rich submarine vents and springs. Differential erosion of the softer surrounding shale forms cone-shaped mounds that are called “Tepee Buttes”, giving the zone its name. White et al. (2017) identify one of these limestone features within the area of Array Area 5. Thickness of this unit is stated to be about 1,350 feet. White et al. (2017) note that the “contacts between these two zones of the Pierre Shale could not be discerned in the field and were approximated based on those shown…” in previous work. As such, the Pierre Shale is mapped as a single unit for the purposes of this report. Furthermore, White et al. (2017) go on to say that due to expansive clay minerals, “swelling soils and bedrock are common hazards to development” and that, on moderately inclined slopes, “such as mesa bluffs and river banks, the Pierre Shale is prone to slope instability”.

NRCS SOIL SURVEY

The United States Department of Agriculture Natural Resource Conservation Service (NRCS) Web Soil Survey indicates the subject site as overlain with a variety of over 10 different soils units. A list of the soil units present within the project lease boundary includes: Ascalon sandy Loam, Heldt clay loam, Keith silt loam, Midway clay loam, Olney sandy loam, Razor-Midway complex, Ustic Torrifluvents, Wilid silt loam, Fort loam, Fort sandy loam, and Manzanola silty clay loam. The locations of these soil units are shown on Figure 3. These soils have a runoff ranging from low to medium and are all considered well drained. They are within hydrologic groups B, C, and D. The parent material of these soils ranges from clayey to slope to mixed alluviums to alluviums over residuum weathered from shale to eolian and loess deposits. These soils are encountered in geomorphic positions ranging from hills to floodplains to stream terraces to interfluves and summit drainageways. The various characteristics of the soil units can be observed on the table on Figure 3.

POTENTIAL MINERAL RESOURCES

According to the “El Paso County – Aggregate Resource Evaluation Maps, El Paso County – Master Plan for Mineral Extraction” (1996), the subject site is indicated to contain areas of “floodplain deposit” and areas of no aggregate resources. The floodplain deposits, which are described as sand and gravel with minor amounts of silt and clay deposited by water along present stream courses, are associated with Williams Creek. These floodplain deposits are indicated to be present within the area of Array Area 1 and Array Area 8.

The United States Department of Agriculture Natural Resource Conservation Service (NRCS) Web Soil Survey indicates the subject site as overlain with a variety of soil units, as seen on Figure 3. The engineering rating on the ability of these soils to be used as a roadfill, gravel, and sand source is depicted on the following table.

| UNIT # | SOIL UNIT NAME | ROADFILL SOURCE | GRAVEL SOURCE | SAND SOURCE |
|---|---|---|---|---|
| 2 | Ascalon sandy loam | Good | Poor | Fair |
| 33 | Heldt clay loam | Poor | Poor | Poor |
| 39 | Keith silt loam | Fair | Poor | Poor |
| 54 | Midway clay loam | Poor | Poor | Poor |
| 61 | Olney sandy loam | Good | Poor | Fair |
| 75 | Razor-Midway complex | Poor | Poor | Poor |
| 101 | Ustic Torrifluvents, loamy | Good | N/A | Fair |
| 107 | Wilid silt loam | Poor | Poor | Poor |
| 118 | Fort loam | Fair | Poor | Fair |
| 119 | Fort sandy loam | Fair | Poor | Fair |
| 120 | Fort sandy loam | Fair | Poor | Fair |
| MZA | Manzanola silty clay loam | Poor | Poor | Poor |

The “El Paso County – Aggregate Resource Evaluation Maps, El Paso County – Master Plan for Mineral Extraction” (1996) indicates that the Fountain Landfill, located at the northwest corner of the subject site, has previously held a state permit to operate a sand and gravel quarry.

Evaluation of commercial feasibility of gravel, sand, or roadfill mining on the subject site is beyond the scope of this study.

GEOLOGIC SITE ASSESSMENT

The project site geology should not present major constraints or unusually high risks to the development or surrounding properties. There are, however, several conditions of a geologic nature that should be considered. These conditions, their potential risks, and suggestions to mitigate the potential risks are discussed below.

## POTENTIAL FLOODING

According to the "Flood Insurance Rate Map" (FIRM), map numbers 08041C0967G, 08041C0970G, 08041C1000G, 08041C1160G, and 08041C1180G produced by the Federal Emergency Management Agency (FEMA, 2018), the subject site is located in both unshaded regions of Zone X and shaded regions of Zone A. Unshaded regions of Zone X have been identified as areas of minimal flood hazard. Shaded regions of Zone A are designated as a Special Flood Hazard Area. These shaded regions of Zone A represent areas that are subject to inundation by the 1% annual chance flood, also known as the 100-year flood. The majority of the site is located within unshaded regions of Zone X, however, Special Flood Hazard Areas associated with Williams Creek and a handful of unnamed tributaries traverse the site in several locations, generally flowing from north to south. These Special Flood Hazard Areas are indicated on Figure 4. Floodplain migration can occur over time as a result of man-induced change, erosional processes or other natural factors. See the Potential Flooding and Site Grading and Surface Drainage sections in Development Considerations below for further discussion. No flood modeling was performed as a part of this study.

## SEASONALLY SHALLOW GROUNDWATER/SEASONAL SEEPAGE

Information from the Terracon geotechnical engineering report, Terracon project number 23205109, does not indicate shallow groundwater was encountered at the time of exploration over the majority of the site, with groundwater encountered in only one location. The location of groundwater encountered in the Terracon report appears to have been located within the vicinity of the Williams Creek drainage channel, on the path of the proposed access road between Array Area 1 and Array Area 2 in the North Array Area. Due to the abundance of drainages throughout the subject site, depth to groundwater is anticipated to vary across geographic locations of the site. The immediate vicinity of ephemeral creeks and drainages are expected to have relatively shallower depths to groundwater than surrounding upland terrain. Groundwater is also anticipated to fluctuate over time. Fluctuations in water level may occur with time, particularly after precipitation events and as a result of nearby irrigation practices after development. Evidence of seepage was not encountered during the preparation of this report. This area should be evaluated for seepage during a period of seasonally high flow. If seepage is encountered, it may need to be collected and diverted away from structures and access roads. Water may become perched upon impermeable layers, such as bedrock, particularly the claystone found at this site. The extent and amount of perched water beneath the site as a result of precipitation and inadequate surface drainage is difficult, if not impossible, to foresee.

PRE-EXISTING MAN-PLACED FILL

Existing fill was not encountered during the exploration associated with the Terracon geotechnical engineering report, Terracon project number 23205109, however, evidence of pre-existing man-placed fill was encountered during the site reconnaissance for this report. A handful of pre-existing man-placed earthen dams have been identified across the Center and South Array Areas. These earthen dams are located both in areas of no proposed development as well as transecting Solar Sites 3, 6, and 7 and often have a retention basin associated with the earth dam. These man-placed dams are shown in white on Figure 2B through 2D. It is our opinion that pre-existing man-placed fill should be considered unsuitable for support of the proposed foundations and roadways unless documentation is available stating the site fills were properly controlled to the compaction criteria presented in the applicable geotechnical engineering report. Any pre-existing man-placed fill should be evaluated prior to use as foundation support or other site grading uses. Uncontrolled or inadequately compacted fill presents risks of excessive or differential settlement of foundations or roadways constructed on the fill. Additionally, expansive clays within the fill could present the risk of heave upon wetting. Engineering risk from uncontrolled fill is typically mitigated by removal and replacement of the material. The vertical and lateral extent of man-placed fill on the development was not determined and is beyond the scope of our work for this report.

EXPANSIVE/COLLAPSIBLE SOILS & BEDROCK

Swelling soils and bedrock have been found to occur on this site, as well as compressible soils. The Terracon geotechnical engineering report, Terracon project number 23205109, indicates that clay soils and bedrock at the subject site have a nil to high swell potential. Pierre Shale is known to have expansive properties, and soils derived from this bedrock unit may also have expansive properties. White et al. (2017) note that Valley-fill alluvium and other alluviums present on the site are derived from Pierre Shale and are prone to swelling. These alluviums are mapped to occur within Array Areas 2, 3, 7, & 8 and within the vicinity of Array Areas 4, 5, & 6, as seen on Figure 2A. Pierre Shale is known to underlie the entire site at varying depths. Such materials are stable at their natural moisture content but will undergo high volume changes with changes in moisture content. Expansive materials may cause distress to structures or pavement if changes in moisture content occur. Overexcavation and replacement or moisture conditioning of expansive materials are standard construction practices commonly used in this area for mitigation of moisture sensitive soils. The claystone will be expansive when placed in a compacted condition and is not suitable for use as nonexpansive fill. Terracon also indicates the presence of collapsible soils within the subject site. Eolian sands within the region are known to be prone to collapse, although lab testing from the Terracon geotechnical engineering report also found lean clays with collapsible properties. White et al. (2017) state that "windblown sediments are generally dry, of low density, high porosity, and can have a meta-stable grain-to-grain structure; soils with such properties may be prone to collapse and settlement upon wetting". The locations of Eolian deposits are shown on Figure 2A, and generally correlates to the locations of loose soil encountered by Terracon. Swell/consolidation characteristics of the soil and bedrock are expected to vary across the development.

SUBSURFACE MINING

The Colorado Geological Survey indicates the nearest historic mine in the area to be located approximately 8 miles north of the subject site. This historic mine, part of the Franceville Coal Mine, operated in the late 19$^{th}$ century and extracted an annual average of 20,000 tons of lignite in 1898, the last year of its operation (Colorado State Mining Directory, 1898). This mine is part of the Colorado Springs Coal Field, which encompasses a southwest portion of the Denver Basin, and historically removed approximately 16 million tons of coal from the Laramie Formation (Roberts, 2007). The Colorado Springs Coal Field trends northwest to southeast through Colorado Springs, from just south of the US Air Force Academy to just north of the Colorado Springs Airport, continuing southeast then east from there (El Paso County – Master Plan for Mineral Extraction, 1996). Subsidence has been an issue related to these historic mines as relatively shallow tunnels are located beneath densely populated neighborhoods through the Colorado Springs area. The subject site, however, displayed no evidence of mine subsidence at the surface, and the risk is considered minimal as the site is not within a close proximity (8 miles) to any known historic mines.

SEISMICITY

The Rampart Range Fault, a high-angle generally north-south trending reverse fault, and the Ute Pass Fault, generally characterized by several northwest-southeast trending reverse faults, are mapped approximately 19 miles northwest and 12 miles west, respectively, of the subject site. According to the "Preliminary Quaternary Fault and Fold Map and Database of Colorado" by Widmann, Kirkham and Rogers (1998), there is evidence that the Rampart Range Fault may have moved between 600,000 and 30,000 years ago, and the Ute Pass Fault may have ruptured during the last 750,000 years. The largest historic earthquake in the project region occurred in 1882. It was located in the northern Front Range and had an estimated magnitude of M6.4 ± 0.2 and a maximum intensity of VII. Historic ground shaking at the project site does not appear to have exceeded Modified Mercalli Intensity VI (Kirkham and Rogers, 2000). Modified Mercalli Intensity VI ground shaking should be expected during a reasonable exposure time for the development, but the probability of stronger ground shaking is low. Intensity VI ground shaking is felt by most people and causes general alarm, but results in negligible damage to structures of good design and construction. According to the Colorado Geological Survey (Kirkham and Rogers, 1981), Colorado Springs should be considered as Zone 2 in the Uniform Building Code (UBC) scheme of seismic zonation.

Using estimated shear wave velocities for the subgrade materials encountered based on standard penetration testing from the Terracon geotechnical engineering report, Terracon project number 23205109, calculations indicate that the seismic soil profile within the upper 100 feet at the subject site should be considered Class C, *very dense soil and soft rock*, and Class D, *stiff soil*, as described in the 2015 International Building Code, unless site specific shear wave velocity studies show otherwise. Based on the subsurface profile and the anticipated ground conditions, liquefaction is not a design consideration. Using the USGS National Earthquake Hazard Reduction Program online database, the following probabilistic ground motion values are reported for the subject site.

| Site Class C, V*ery Dense Soil and Soft Rock* | |
|---|---|
| Intensity Measure Type | Intensity Measure Level<br>2 percent in 50 Years |
| 0.2 Sec. Spectral Acceleration $S_s$ | 0.166 |
| 1.0 Sec. Spectral Acceleration $S_1$ | 0.059 |

| Site Class D, *Stiff Soil* | |
|---|---|
| Intensity Measure Type | Intensity Measure Level<br>2 percent in 50 Years |
| 0.2 Sec. Spectral Acceleration $S_s$ | 0.164 |
| 1.0 Sec. Spectral Acceleration $S_1$ | 0.059 |

The USGS National Earthquake Hazard Reduction Program online database also indicates a peak ground acceleration (PGA) of 0.081 for site class C, *very dense soil and soft rock*, and 0.080 for site class D, *stiff soil*, at the subject site. The PGA is the lower of the deterministic or the probabilistic value with a 2% exceedance probability for a 50-year exposure time at the project site (statistical recurrence interval of 2,500 years).

EROSIONAL FEATURES

Erosion is a prominent geologic process occurring on the subject site. Erosional Features are shown on Figure 2B through 2D, indicated as black lines and polygons. Erosional scour and headward erosion were observed across much of the subject site and were very common in the vicinity of drainages and the ephemeral waterways. Many of the erosional features are associated with slopes greater than 30 percent. Slopes varied on a location-to-location basis, however, many slopes on erosional surfaces were found to be near vertical. The progression of these erosional features is anticipated to continue if not mitigated by site grading, landscaping or other means. If site development concentrates surface water flow over these features, accelerated erosion should be expected and the project civil engineer should evaluate possible methods to mitigate the potential for erosion.

SLOPES GREATER THAN 30 PERCENT

Slopes across the subject site were found to vary from level to near vertical. The majority of these slopes are less than 5 feet in height, although several slopes were found to have a greater height. Steeper slopes were often found to be associated with surficial erosion. These slopes appear to be stable and no signs of recent mass wasting were observed. Channel scour along waterways was found to contribute to near vertical slopes. Slopes greater than 30 percent associated with erosional features are shown on Figure 2B through 2D. Erosion is expected to progress along these steeper slopes unless mitigation techniques including site grading, landscaping or other means are initiated.

RADIOACTIVE GASES

According to the Environmental Protection Agency (EPA) and the El Paso County Department of Health, elevated levels of radon gas (4pCi/L or more) have been found in buildings in El Paso County. Radon is a radioactive gas that forms from the natural breakdown of uranium in soil, rock, and water. Radon tends to accumulate in poorly ventilated areas below ground level; however, radon may accumulate inside any above or below grade construction. According to the EPA, radon levels in buildings can be reduced by several methods, including pressurization of the building using a heating, ventilation and air-conditioning system, sealing of cracks in the foundation walls and floor slabs which may allow entry of radon, and using active soil depressurization (ASD) systems. Radon risk and potential mitigation measures should be evaluated by an industry professional based on structure type and potential risk in accordance with established guidelines.

DEVELOPMENT CONSIDERATIONS

Presented below is a discussion of geologic and geotechnical engineering related development considerations, including identified geologic hazards.

Potential Flooding:

Special flood hazard areas have been identified on the subject site. These flood hazard areas also have the potential to migrate from their current location. As such, we recommend that a floodplain buffer be considered in the development design. In areas with less elevation change between proposed development and the floodplain, a buffer of 50 feet would reduce the risk from potential flooding, while a buffer of 25' in areas of increased elevation separation between development and the floodplain should be sufficient. We recommend that site grading and surface drainage features are incorporated into the site design to reduce the potential for flooding. Design features such as rip-rap or other erosional armor may decrease the risk of floodplain migration as well. See the Site Grading and Surface Drainage section below for further discussion. No flood modelling was performed as a part of this study.

Expansive/Collapsible Soils/Bedrock:

The Terracon geotechnical engineering report, Terracon project number 23205109, indicates that the native clay soils and claystone bedrock encountered near the assumed foundation bearing elevation at this site have a nil to high swell potential upon wetting under a surcharge load of 500 psf. Shallow foundations placed directly on or near expansive materials similar to that encountered at this site can experience movement causing structural distress if the materials are subjected to changes in moisture content. Typically, a structural fill layer is intended to provide separation between the expansive materials and thereby reduce the potential for foundation and slab movement. Increasing the thickness of this structural fill layer will further reduce the potential for uplift.

The clay and claystone found on the subject site will be expansive when placed in a compacted condition and are not suitable for use as non-expansive fill. Placement of excavated claystone should be limited to nonstructural areas such as landscape areas to the extent practical. If necessary elsewhere, placement of clay and claystone should be limited to deeper fills. Claystone placed as fill should only be used if it is processed into a soil like material, with a maximum particle size of 3 inches. Swelling soils and bedrock is considered a geologic hazard, and mitigation should take place to prevent undesirable movement of movement-sensitive structures.

Loose, collapsible soils are known to occur on the subject site. If collapsible soils are encountered during construction, some form of mitigation should be undertaken to prevent risk to the development. Mitigation techniques range from overexcavation and replacement to chemical additives, with overexcavation and replacement acting as a common, cost-effective method to reduce risk within this region.

Pre-existing Man-placed Fill:
Pre-existing man-placed fill has been observed within the subject site. Given the unknown history of the fill placement, it is our opinion that it should be considered unsuitable for support of the proposed foundations and roadways unless documentation is available stating the site fills were properly controlled to the compaction criteria presented in the applicable geotechnical engineering report. We recommend the existing fill, where present below movement-sensitive structures, be overexcavated, moisture conditioned, and placed back properly compacted, assuming the existing fill meets fill material specifications set out in the applicable geotechnical engineering report.

Erosional Features:
Erosional features should be protected from further accelerated erosion. It may be feasible for accelerated erosion to be mitigated by re-grading the slopes to 3:1 (horizontal to vertical) or flatter, and revegetating or otherwise protecting the new slopes from erosion. These areas may cause concentrated surface flow over erosional features and through the subject site. If this is the case, concentrated surface flows should be collected or diverted away from development areas. Kumar and Associates, Inc. understands that proposed site grading will mitigate the majority of the observed erosional features within the vicinity of development. Recommendations from the Site Grading and Surface Drainage section below should be followed to reduce impacts resulting from concentrated surface flow over erosional features.

Slopes Greater Than 30 Percent:
Based on our review of the current site conditions, the information provided, and our experience in the area, the proposed site plan is feasible from a geotechnical viewpoint. From Kumar and Associates, Inc's understanding of the development, proposed site grading activities will not place structural features near steep slopes and will mitigate some slopes greater than 30 percent as a part of site grading. Permanent slopes should not be steeper than 3:1 (horizontal to vertical, and

should not exceed 30 feet in height. Slopes will generally be stable at a 2:1 ratio; however, slopes at this ratio will be prone to increased surface erosion and it will be difficult to maintain vegetation on them, further increasing erosion. Observed slopes greater than 30 percent do not show signs of mass movement and appear stable, and should not be adversely affected by the proposed development if the site grading recommendations below are followed.

Site Grading and Surface Drainage:

Proper surface drainage is very important for acceptable performance of the development during the proposed construction and after construction has been completed. Development plans should attempt to place structures relatively high with respect to the surrounding ground. Grading to accommodate the collection and diversion of surface drainage away from building and pavement locations is recommended. Site grading modifications should be planned to provide positive surface drainage away from all building and pavement areas and wetting of subgrade soils should be prevented. The ponding of water should not be allowed in backfill material or in a zone within 20 feet of the foundation walls of the structure, whichever is greater. We recommend a minimum slope of 6 inches in the first 10 feet in unpaved areas. Site drainage beyond the 10-foot zone should be designed to promote runoff and reduce infiltration. A minimum slope of 3 inches in the first 10 feet is recommended in paved areas. These slopes may be changed as required for handicap access points in accordance with the Americans with Disabilities Act. Surface diversion features should be provided around staging areas and roadways to prevent surface runoff from flowing across developed surfaces. The likelihood of maintaining relatively stable foundations and floor slabs for the life of the project will be significantly increased by planning a well-drained development with little to no irrigation adjacent to structures. Drainage recommendations provided by local, state and national entities should be followed based on the intended use of the structure. The use of proper drainage will also reduce potential runoff impacts to surrounding properties.

Fill should not contain concentrations of organic matter or other deleterious substances. A geotechnical engineer should evaluate the suitability of proposed imported fill materials prior to placement.

Permanent slopes should not be steeper than 3:1 (horizontal to vertical). The risk of slope instability will be significantly increased if seepage is encountered in cuts. If seepage is encountered in permanent excavations, and investigation should be conducted to determine if the seepage will adversely affect the cut stability. Good surface drainage should be provided for all permanent cuts and fills to direct the surface runoff away from the slope faces. Cut and fill slopes and other stripped areas should be protected against erosion by revegetation or other means. Fills should be benched into hillsides that exceed 4:1 (horizontal to vertical). Site grading should be planned to provide positive surface drainage away from all building and pavement areas. No formal stability analyses were performed to evaluate the slopes recommended above. Published literature and our experience with similar cuts and fills indicate the recommended slopes should have adequate factors of safety. If a detailed stability analysis is required, we should be notified.

## LIMITATIONS

This study has been conducted for exclusive use by the client for geotechnical related design and construction criteria for the project. The conclusions and preliminary recommendations submitted in this report are based upon the data obtained from the exploratory borings, the site reconnaissance, published regional geology information, the proposed type of construction and our experience in the area. Our services do not include determining the presence, prevention or possibility of mold or other biological contaminants (MOBC) developing in the future. If the client is concerned about MOBC, then a professional in this special field of practice should be consulted. This report may not reflect subsurface variations that occur, and the nature and extent of variations across the site may not become evident until site grading and excavations are performed. If during construction, fill, soil, bedrock, or water conditions appear to be different from those described herein, Kumar & Associates, Inc. should be advised at once so that a re-evaluation of the recommendations presented in this report can be made. Kumar & Associates, Inc. is not responsible for liability associated with interpretation of subsurface data by others.
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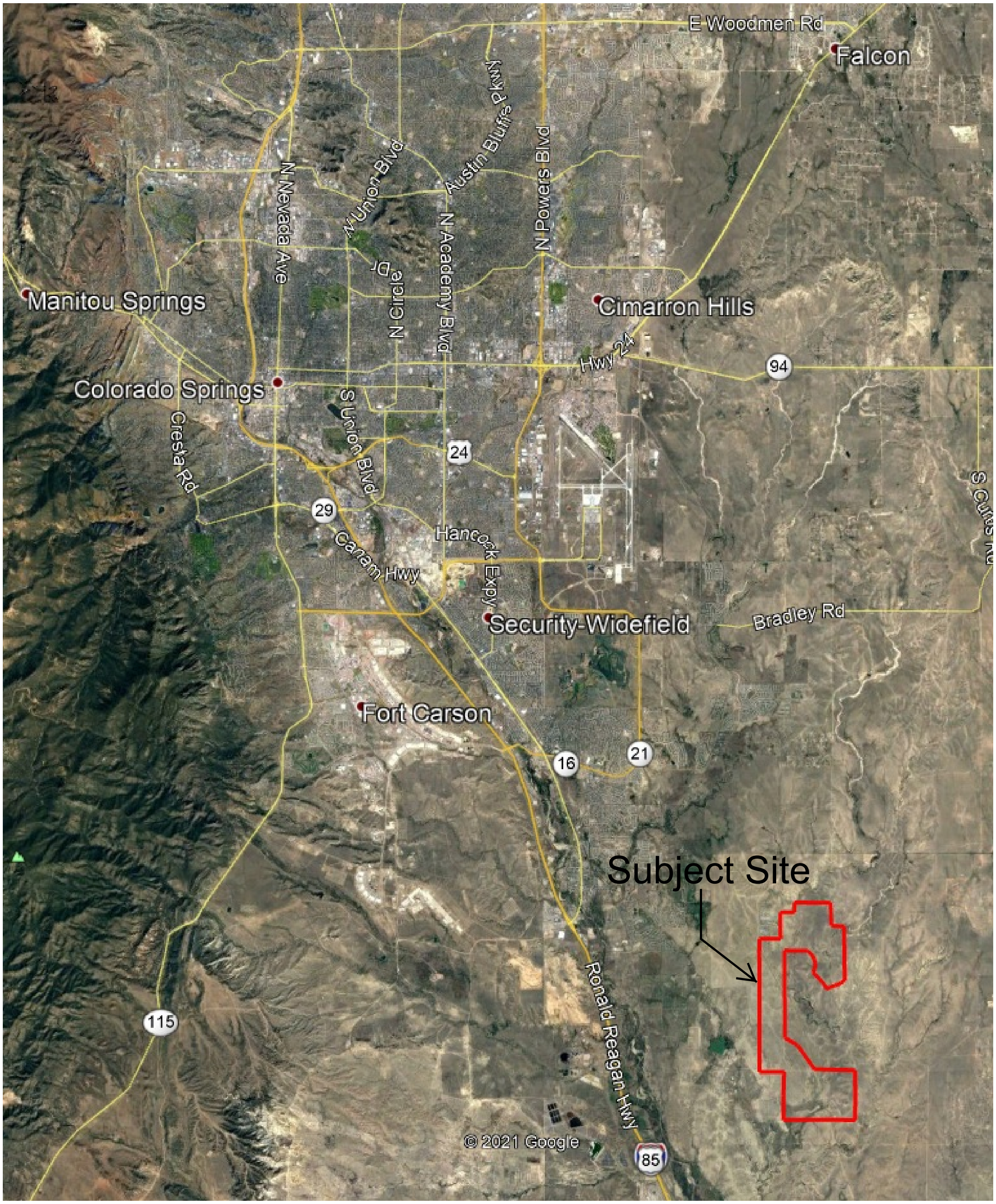
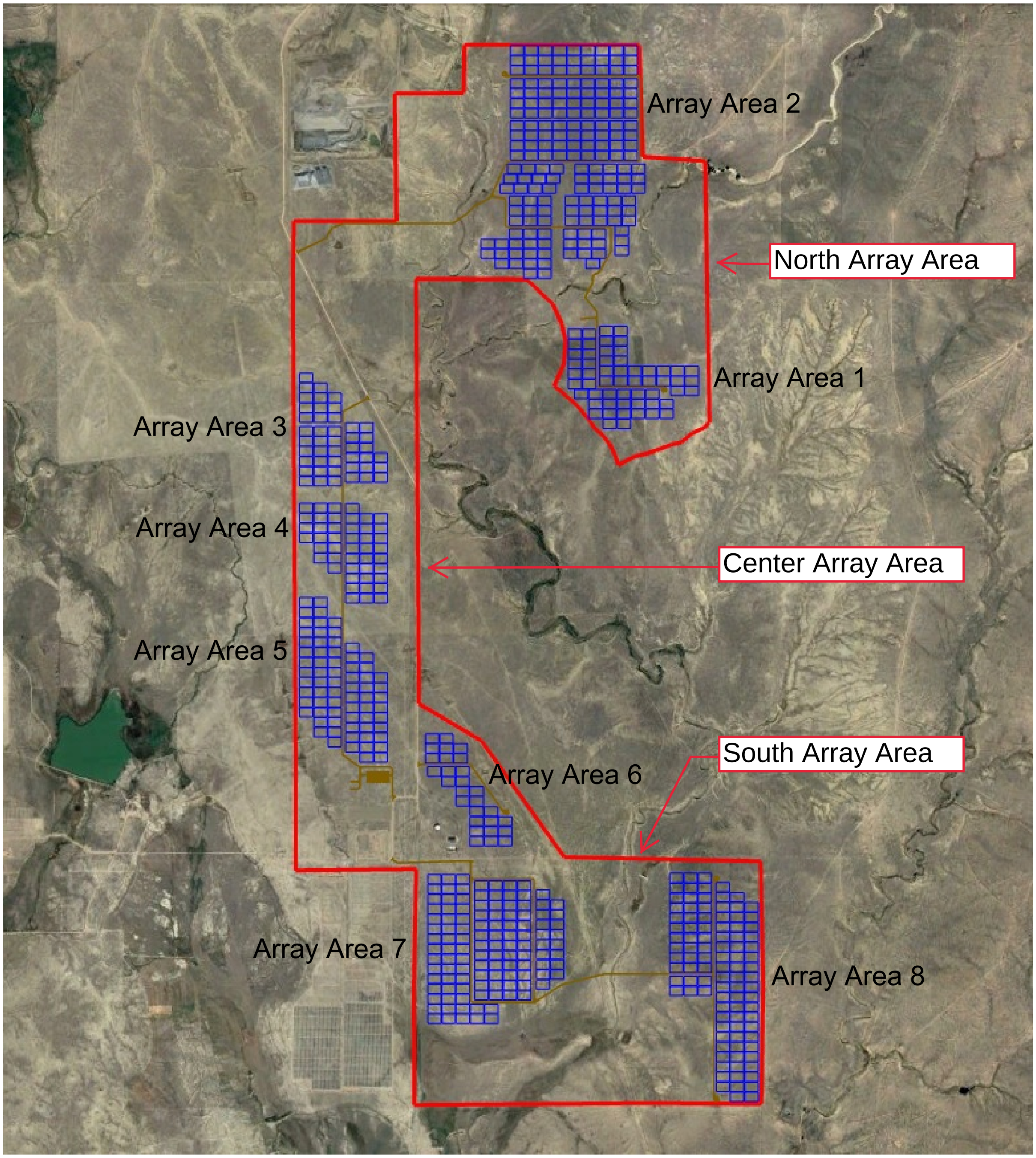



Not To Scale

| 21-7-604 | Kumar & Associates | Vicinity Map | Fig. 1A |
|---|---|---|---|

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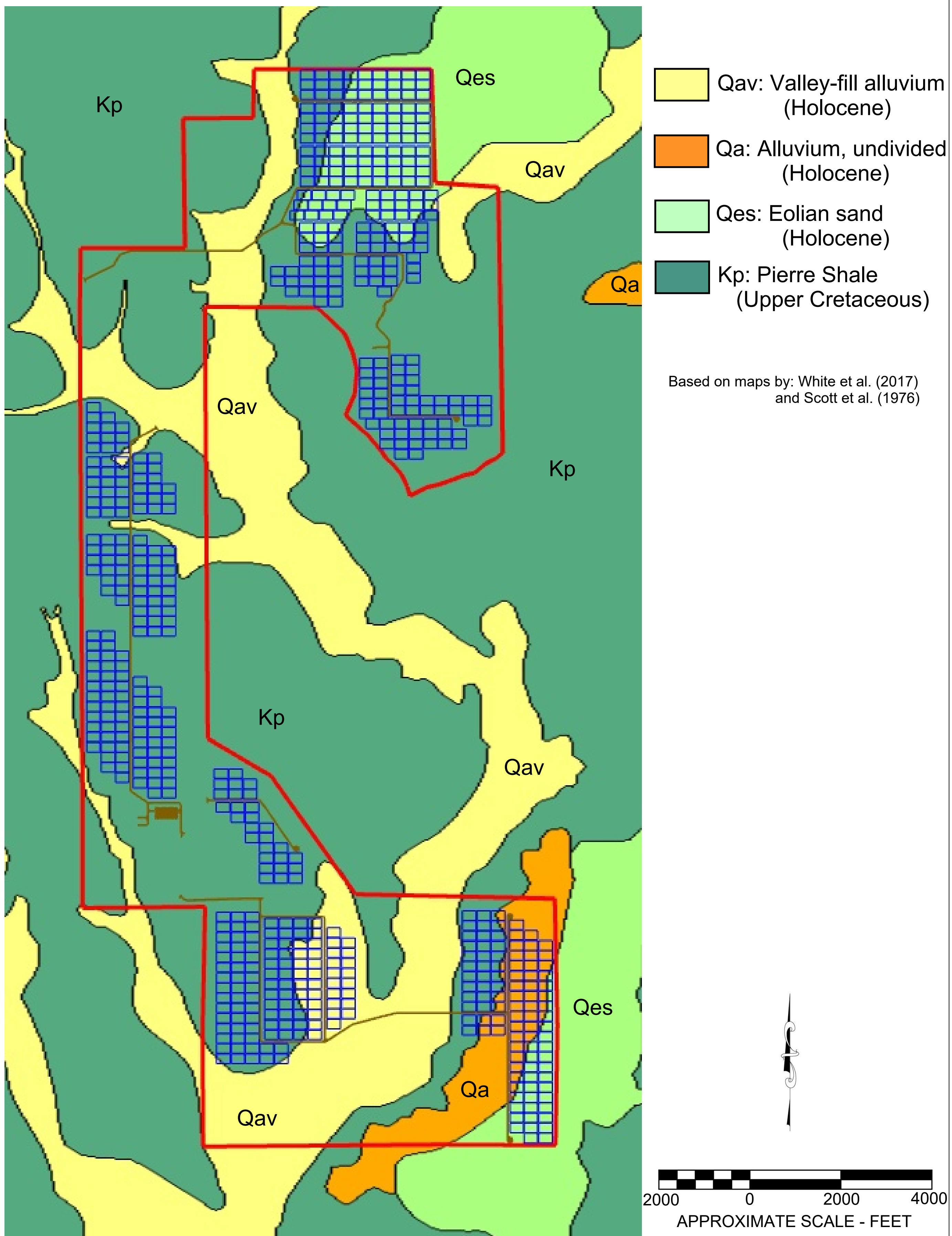
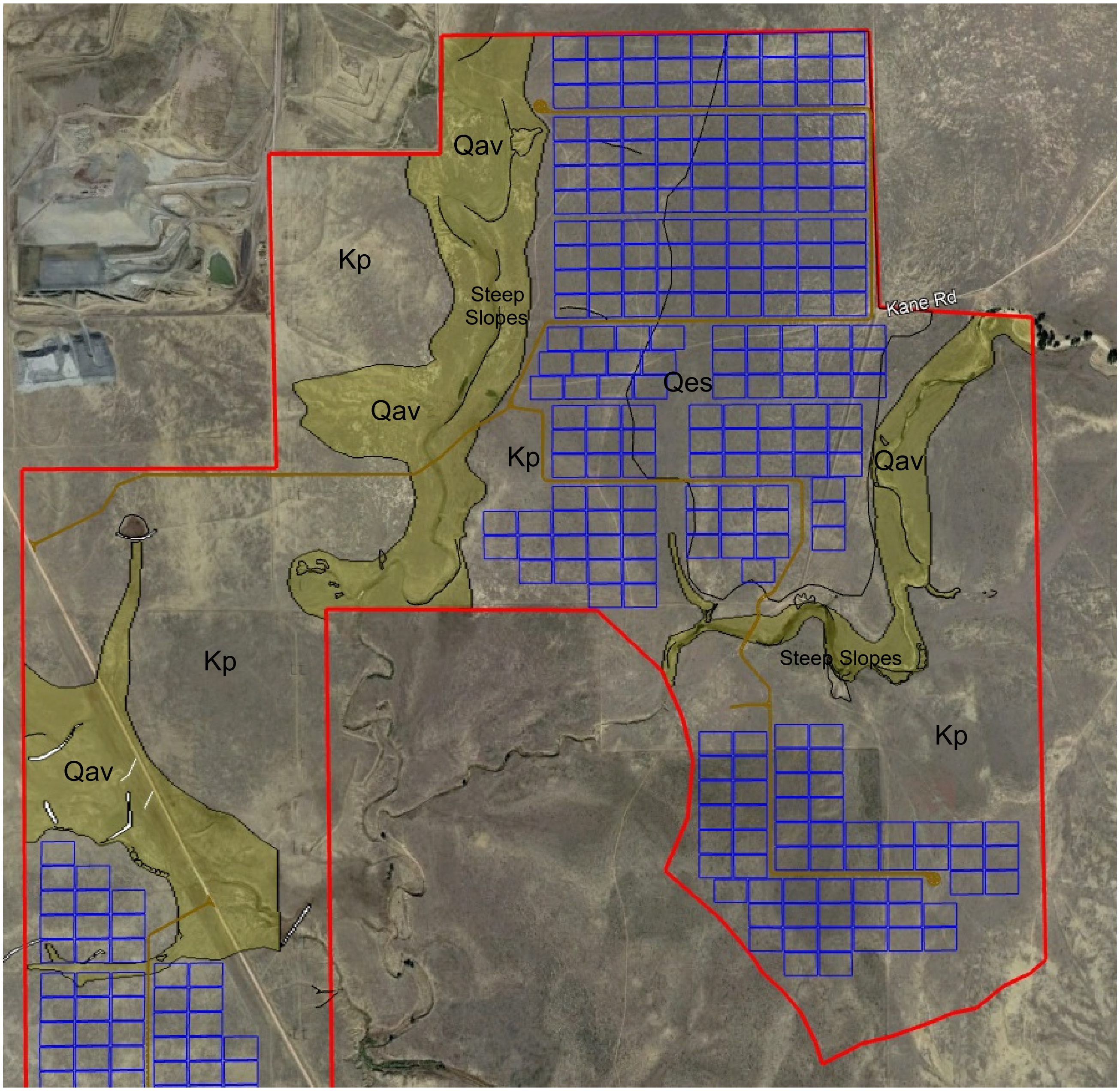
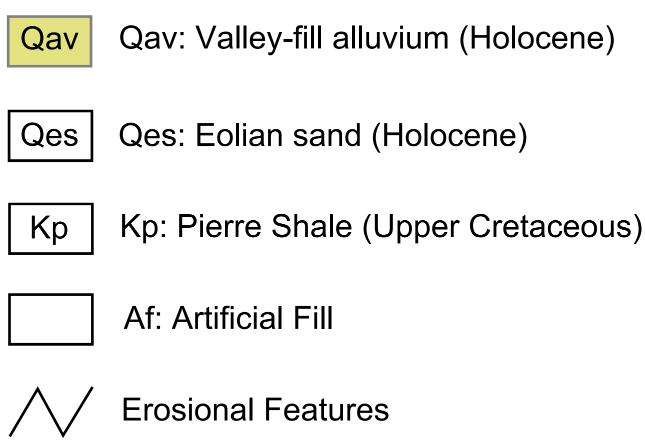
APPROXIMATE SCALE - FEET

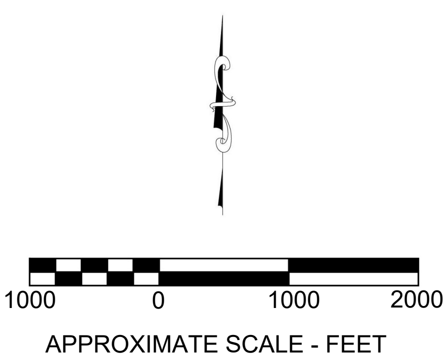
| 21-7-604 | Kumar & Associates | Proposed Development | Fig. 1B |
|---|---|---|---|



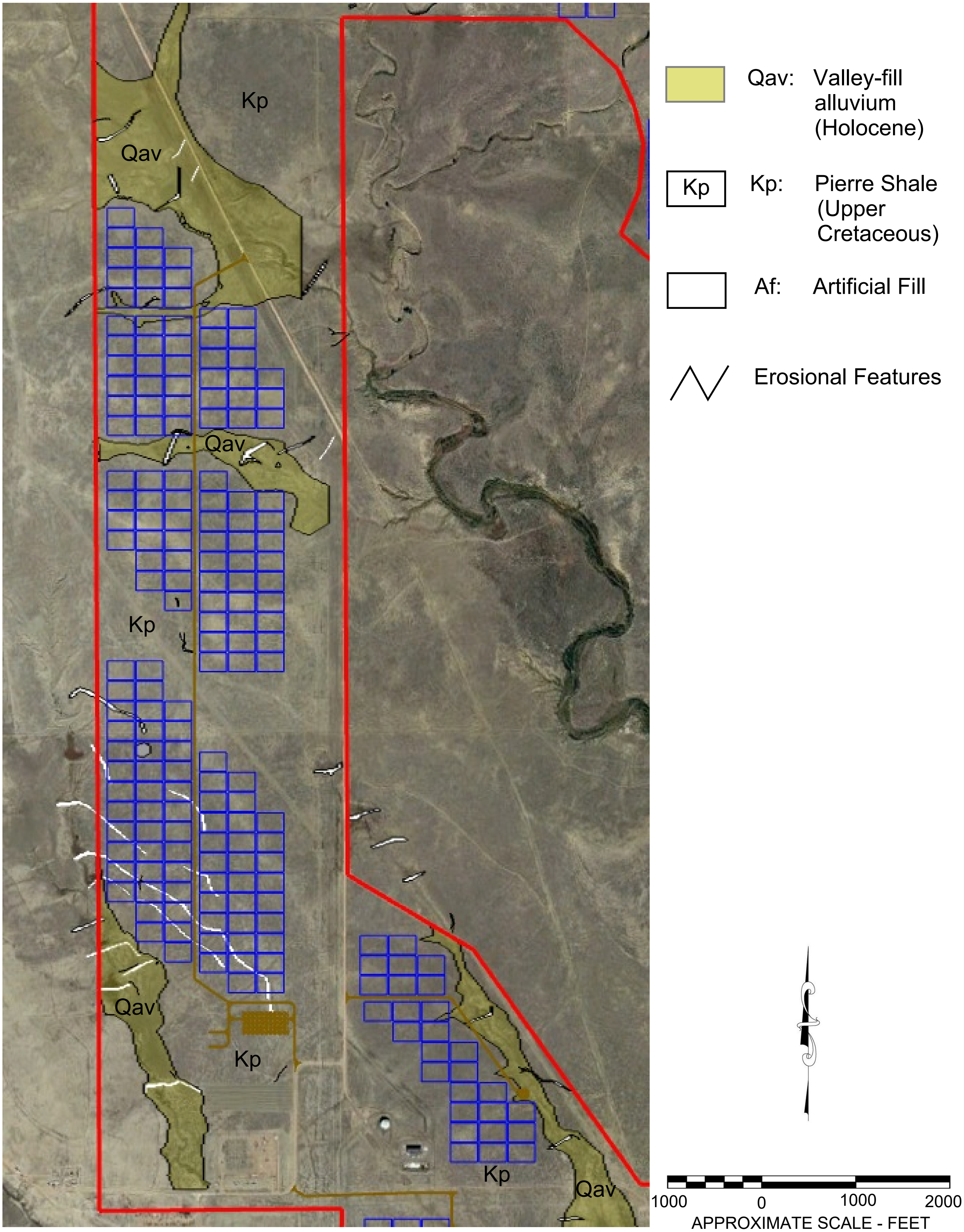

| 21-7-604 | Kumar & Associates | Geologic Map | Fig. 2A |
| --- | --- | --- | --- |



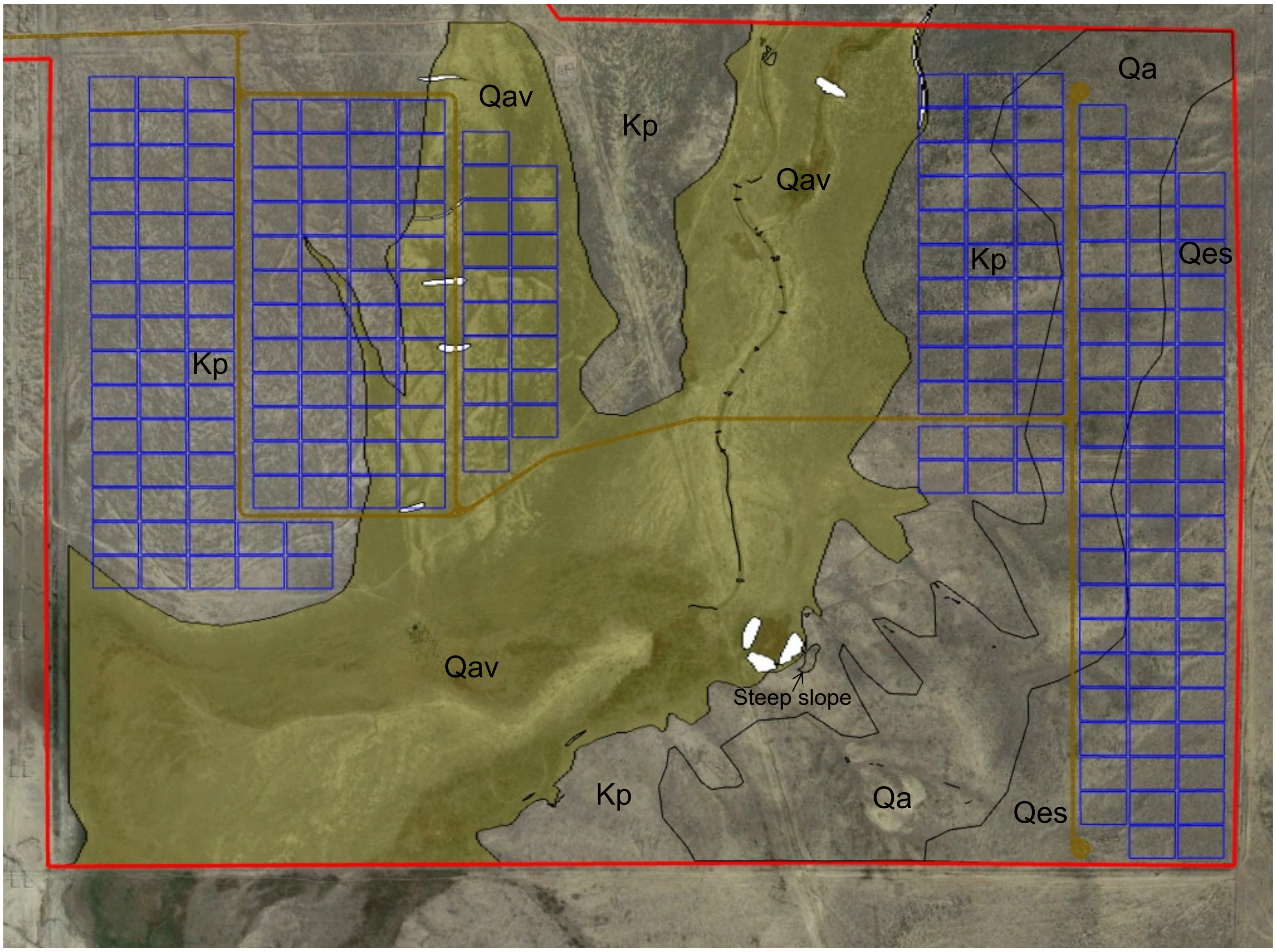




| 21-7-604 | Kumar & Associates | Mapped Geology - North Array Area | Fig. 2B |
|---|---|---|---|




| 21-7-604 | Kumar & Associates | Mapped Geology - Center Array Area | Fig. 2C |
|---|---|---|---|

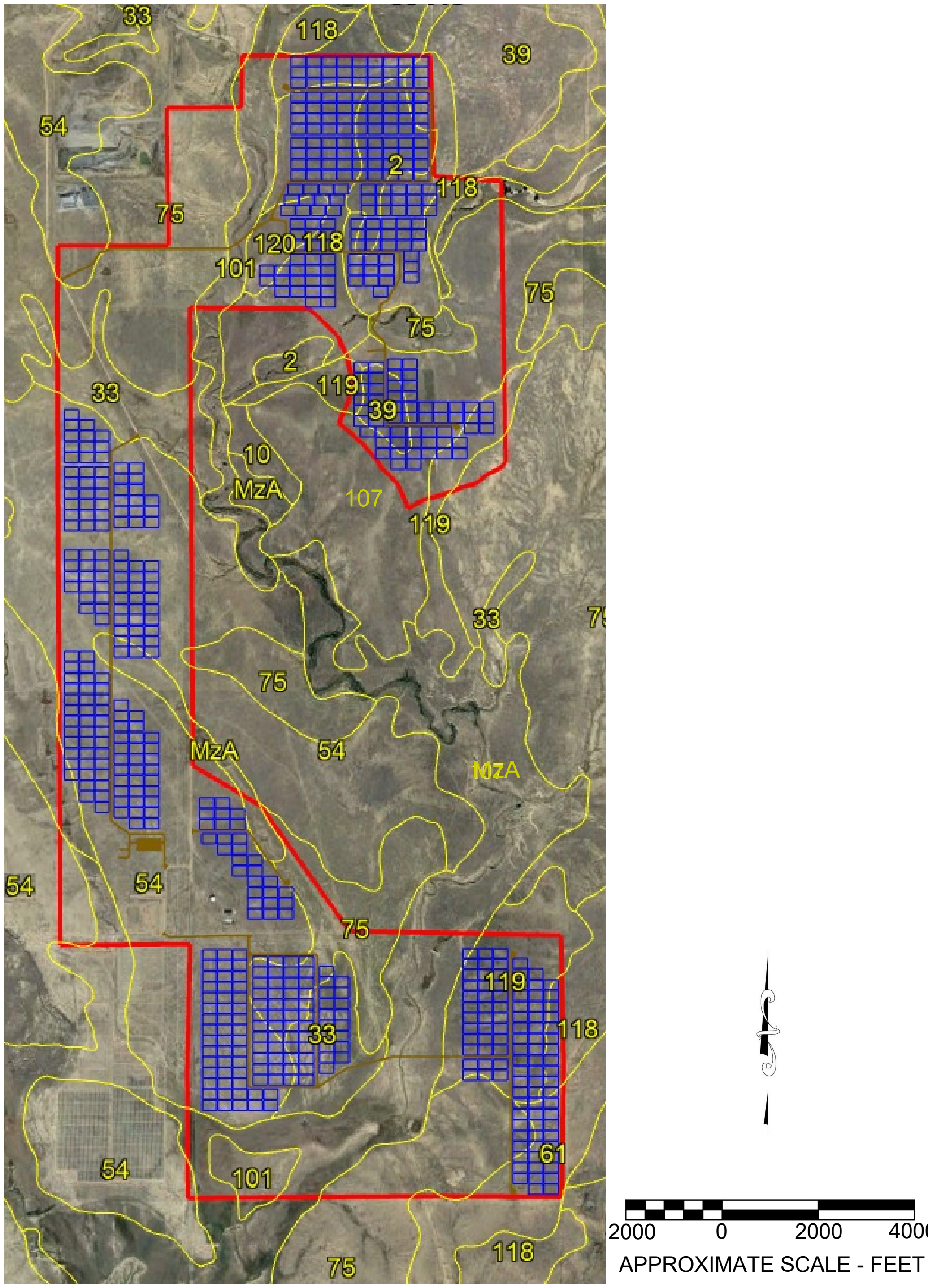



| | |
|---|---|
| Qav | Qav: Valley-fill alluvium (Holocene) |
| Qa | Qa: Alluvium, undivided (Holocene) |
| Qes | Qes: Eolian sand (Holocene) |
| Kp | Kp: Pierre Shale (Upper Cretaceous) |
| | Af: Artificial Fill |
| | Erosional Features |

1000 0 1000 2000

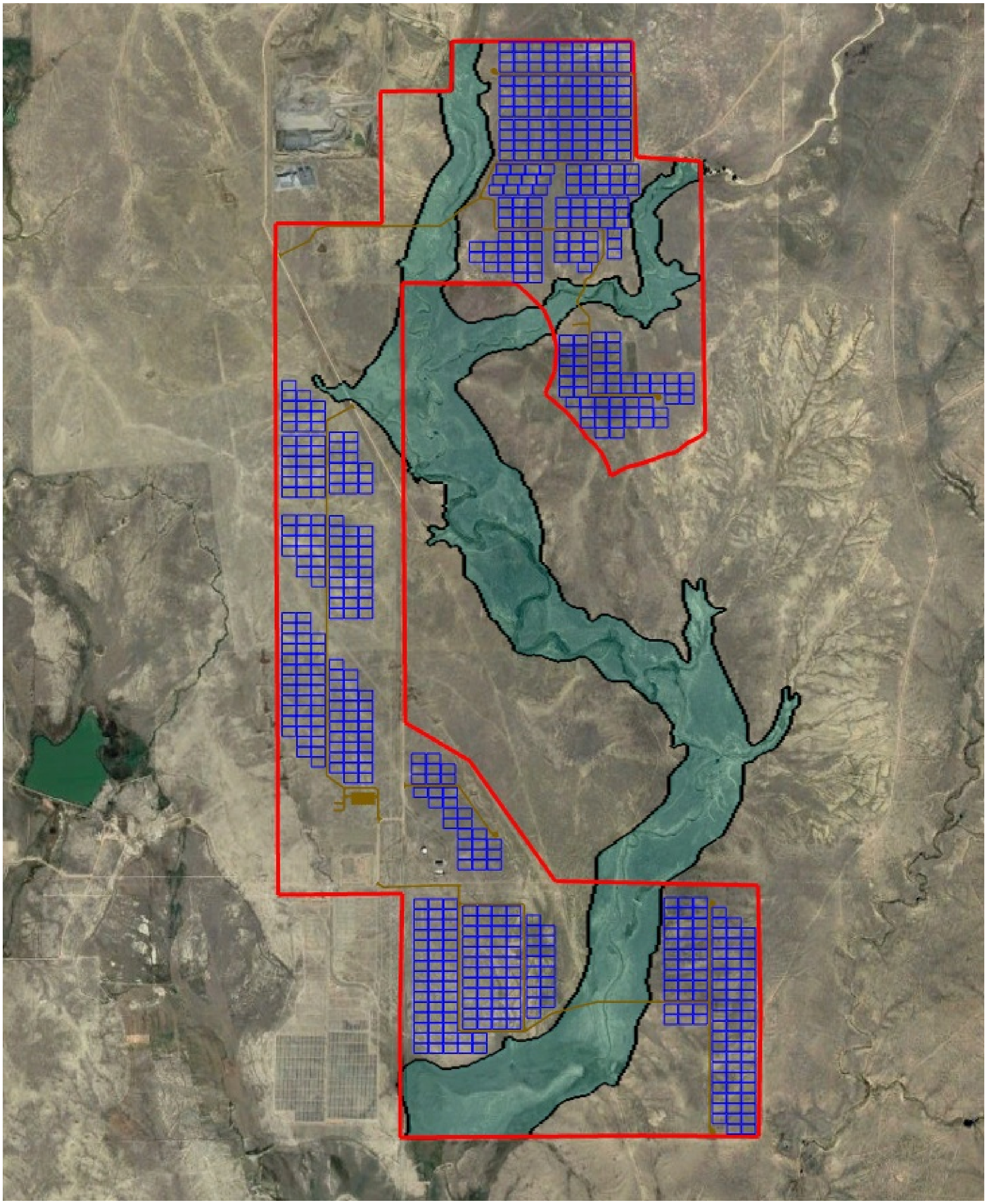
APPROXIMATE SCALE - FEET

| 21-7-604 | Kumar & Associates | Mapped Geology - South Array Area | Fig. 2D |
|---|---|---|---|




| UNIT # | SOIL UNIT | ROADFILL SOURCE | GRAVEL SOURCE | SAND SOURCE | RUNOFF | DRAINAGE | HYDROLOGIC GROUP | PARENT MATERIAL |
|---|---|---|---|---|---|---|---|---|
| 2 | Ascalon sandy loam | Good | Poor | Fair | Low | Well Drained | Group B | Mixed alluvium and/or eolian deposits |
| 33 | Heldt clay loam | Poor | Poor | Poor | Low | Well Drained | Group C | Clayey alluvium derived from shale |
| 39 | Keith silt loam | Fair | Poor | Poor | Low | Well Drained | Group C | Silty eolian deposits |
| 54 | Midway clay loam | Poor | Poor | Poor | Medium | Well Drained | Group D | Slope alluvium over residuum weathered from shale |
| 61 | Olney sandy loam | Good | Poor | Fair | Medium | Well Drained | Group B | Eolian sands |
| 75 | Razor-Midway complex | Poor | Poor | Poor | Medium | Well Drained | Group D | Clayey slope alluvium over residuum weathered from shale |
| 101 | Ustic Torrifluvents, loamy | Good | N/A | Fair | Low | Well Drained | Group B | Sandy, clayey, stratified loamy |
| 107 | Wilid silt loam | Poor | Poor | Poor | N/A | Well Drained | Group C | Loess and/or eolian deposits |
| 118 | Fort loam | Fair | Poor | Fair | Low | Well Drained | Group C | Loamy alluvium and/or eolian deposits |
| 119 | Fort sandy loam | Fair | Poor | Fair | N/A | Well Drained | Group B | Alluvium and/or eolian deposits |
| 120 | Fort sandy loam | Fair | Poor | Fair | N/A | Well Drained | Group B | Alluvium and/or eolian deposits |
| MZA | Manzanola silty clay loam | Poor | Poor | Poor | N/A | Well Drained | Group C | Alluvium derived from shale |

| 21-7-604 | Kumar & Associates | NRCS Soil Survey Soils | Fig. 3 |
|---|---|---|---|



SPECIAL FLOOD HAZARD AREAS: Subject to inundation by the 1% annual chance flood (100-year flood).

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APPROXIMATE SCALE - FEET

| | | | |
|---|---|---|---|
| 21-7-604 | Kumar & Associates | Special Flood Hazard Areas | Fig. 4 |