4.5 GEOLOGIC PROCESSES

A preliminary geotechnical engineering evaluation of the Project site was initially performed by Fugro Consultants, Inc. (December, 2013). The geotechnical engineering evaluation included an evaluation of geologic conditions and hazards, a site reconnaissance, and excavation and sampling to determine soil characteristics at specific locations within the Project site.

Additionally, a preliminary geologic hazards assessment of the Project site was prepared by Fugro Consultants, Inc. (January, 2014). The purpose of the preliminary geologic hazards assessment was to determine potential areas of geologic hazards that will need to be considered during the design of the East Cat Canyon Oil Field Redevelopment Project. The preliminary geologic hazards study included a desktop review of geologic maps and aerial photography of the site; as well as a site reconnaissance and preliminary soil borings.

The following environmental setting and potential impact analysis has been developed primarily from the results of these preliminary studies (Appendix S).

4.5.1 Environmental Setting

4.5.1.1 Topography

The topography of the area consists of a series of north-south aligned subdued hills with elevations ranging from approximately 500 to 1,000 feet above mean sea level. The geomorphology of the area consists of ridges and valleys with steep drainages and canyons. Cat Canyon Creek runs northerly through Cat Canyon to the west of the Project site. Long Canyon extends northerly to the east of the Project site. Refer to Figure 4.5-1 – Topographic Map of the Project Site.

4.5.1.2 Soils

Surface Geology. As shown in Figure 4.5-2 – Hazards Identification Map, surface geology of the Project site is comprised predominantly of Paso Robles Formation (QTp), Older Alluvium (Qoal), and Colluvium (Qcol) soils. The Paso Robles Formation is distinguished as non-marine and primarily consisting of poorly consolidated stream-deposited lenticular beds of gravel, sand, silt, and clay. The older alluvium materials consist of dense to very dense poorly graded sand, silty sand, clayey sand and sandy silt with gravel, sand, and silt. The colluvium deposits generally consist primarily of loose to medium dense poorly sorted mixtures of sand and gravel with some fine-grained materials.

Slope Stability/Landsliding. As shown on Figure 4.5-2 - Hazards Identification Map, geologic reconnaissance mapping of the Project site has identified several locations with geomorphology suggesting past landslides. No subsurface exploration has been performed to confirm the existence of the mapped landslides shown in Figure 4.5-2 - Hazards Identification Map, and according to Fugro Consultants, Inc. these mapped landslide are considered speculative.

Throughout the area, there are numerous manmade cut slopes created to facilitate historic oil production. Most of those slopes are relatively steep (1H:1V or steeper) and they commonly exhibit signs of raveling, slumping, and erosion. Deposits of colluvium are present on the

natural slopes throughout the area. Where thick deposits of colluvium were recognized, they have also been mapped in Figure 4.5-2 (map unit Qc). Where present on slopes, the colluvium is generally unstable and creep-prone.

Expansive Soils. Geologic units associated with expansive soils often exhibit poor to marginal stability characteristics. Expansive soils are clayey materials that expand when wetted. Geologic formations that are most often associated with expansive soil problems are the Rincon, Monterey, and Paso Robles. Most of the bedrock materials on the site are granular; therefore the colluvial and alluvial materials derived from them are also generally granular. Because there is likely to be a limited amount of clayey soil present on the site, the potential for highly expansive soils is limited. As indicated in the results of the preliminary geohazards investigation, geotechnical sampling and testing will be performed to confirm the presence or absence of expansive soil materials at the Project site.

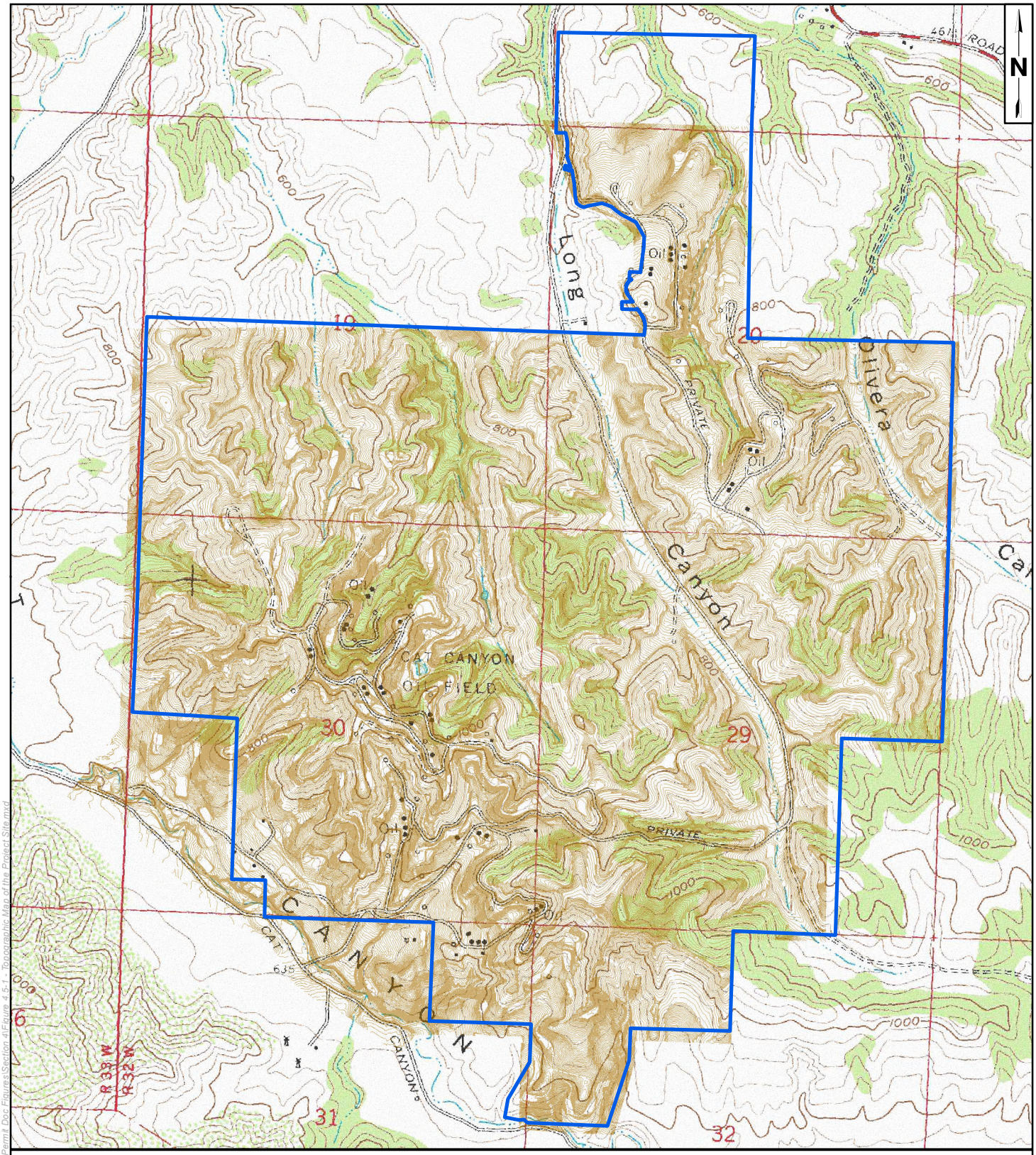
4.5.1.3 Geologic Structure

The eastern portion of the Cat Canyon Oil Field is situated within the Santa Maria Oil District between the Santa Ynez and San Rafael mountains. The geologic structure of the area is characterized by a predominantly flat lying to slightly folded sequence of Pliocene and Pleistocene formations, which are unconformably underlain by structurally deformed and folded Miocene and older formations. In the Project site, only the Plio-Pleistocene units are exposed and they include the Careaga and Paso Robles Formations.

The Careaga Formation is the oldest (Pliocene age) geologic unit exposed in the Project site as shown in Figure 4.5-2 - Hazards Identification Map. In that area, the Careaga Formation is divided into two members; the Cebada and the Graciosa Members. The Cebada fine-grained lower member consists primarily of very uniform fine-grained to very-fine-grained massive sandstone, which is light gray to yellow in color. Small stringers of shale pebbles and fossils are abundant. Fugro Consultants, Inc. (2012) reported that the Cebada member attains a maximum thickness about 250 feet, and thins to the north in the subsurface. The upper member of the Careaga Formation is referred to as the Graciosa Member and in the Project site commonly consists of coarse-grained sandstone with thin stringers of gravel. That member attains a maximum thickness of about 100 feet in the southerly part of the Project site and thins out to zero thickness to the northeast (Fugro Consultants, Inc., 2012).

The Pleistocene-age Paso Robles Formation crops out in most of the Project site and conformably overlies the Careaga Formation. The Paso Robles Formation is gently folded (with dips less than about 10 degrees) and is over 500 feet thick in the Project site. The Paso Robles Formation is non-marine and primarily consists of poorly consolidated stream-deposited lenticular beds of gravel, sand, silt, and clay. The formation is exposed in numerous cut slopes throughout the Project site and consists of very poorly sorted and heterogeneous (i.e., a wide range of grain size materials) mixtures of cobbles, gravel, and sand in a clay matrix.

Older alluvial deposits are present on the tops of ridges and hills between Cat Canyon Road, Long Canyon Road, and Olivera Canyon Road. Those deposits are of late Pleistocene age and primarily consist of mixtures of gravel, sand, and silt. In many locations, the older alluvial deposits are well cemented. Deposits of recent colluvium and alluvium are also present in the Project area in the tributary canyons and valley floors. Throughout the oil field area, local deposits of artificial fill are present.



Aera Energy LLC Property

2' Topographic Contour Line

Source: Fugro Consultants, Inc., USGS 7.5" Topo Quad, DPSI 2013
Land Survey
Coordinate System: NAD 1983 StatePlane California V FIPS 0405 Feet
Notes: This map was created for informational and display purposes only.

0 900 1,800
FEET

PROJECT NAME: EAST CAT CANYON OIL FIELD REDEVELOPMENT PROJECT	TOPOGRAPHIC MAP OF THE PROJECT SITE	FIGURE 4.5-1
PROJECT NUMBER: 1002-0455 / DATE: September 2014		

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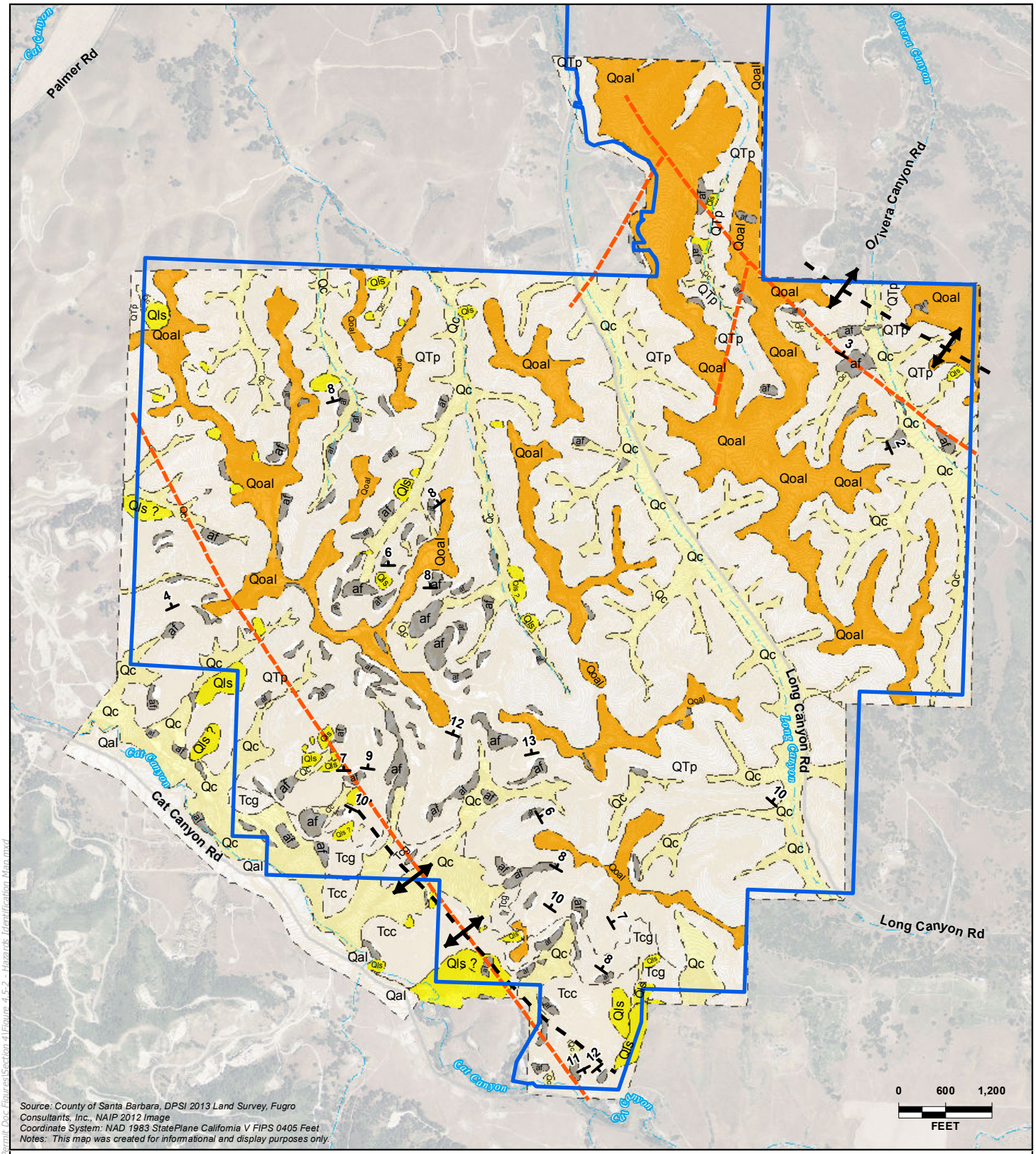

Source: County of Santa Barbara, DPSI 2013 Land Survey, Fugro Consultants, Inc., NAIP 2012 Image
Coordinate System: NAD 1983 StatePlane California V FIPS 0405 Feet
Notes: This map was created for informational and display purposes only.

- Aera Energy LLC Property
- Anticline Axis (inferred)
- Concealed Fault (inferred)
- Strike and Dip of Bedding
- Topographic Contour Line
- af - Artificial Fill
- Qc - Colluvium
- Qls - Landslide Deposites
- Qoal - Older Alluvium
- Qal - Modern Alluvium
- QTp - Paso Robles Formation
- Tcc - Carreaga Formation (Cebada Fine-Grained Member)
- Tcg - Carreaga Formation (Graciosa Coarse-Grained Member)

PROJECT NAME: EAST CAT CANYON OIL FIELD REDEVELOPMENT PROJECT	HAZARDS IDENTIFICATION MAP	FIGURE 4.5-2
PROJECT NUMBER: 1002-0455 / DATE: September 2014		

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4.5.1.4 Faults

The East Cat Canyon Oil Field Redevelopment Project site is located within the seismically active Central Coast region, but outside the Special Studies Zone defined by the Alquist-Priolo Special Studies Zones Act of 1972. There are a number of active faults in the region that have the potential to produce strong ground motion at the site (Table 4.5-1 - Faults Located Within the Vicinity of the Project Site and Figure 4.5-3 - Regional Fault Map). The closest active fault is the San Luis Range; a reverse fault located approximately three miles from the Project site with a potential for a 7.2 magnitude event.

The Fugro Consultants, Inc. geologic hazards assessment indicates the concealed northeast-dipping, normal fault mapped through the southwestern portion of the area is unnamed on published maps (California Division of Oil and Gas, 1974), but locally referred to as the Fuglar fault. Additionally, the concealed northeast-dipping, normal fault mapped through the northeastern portion of the Project site is referred to as the Garey fault (Hall, 1981). Please refer to Figure 4.5-4 - Faulting at the Project Site, for a map of these faults.

A cross-section of the Olivera Canyon Area of the Cat Canyon Oil Field (California Division of Oil and Gas, 1961) shows that the Garey fault only cuts rocks older than early Pliocene; therefore, that fault is not considered active. A cross-section of the east area of the Cat Canyon Oil Field (California Division of Oil and Gas, 1961) shows a similar pre-early Pliocene age for the Fuglar fault through the southwestern area, but California Division of Oil and Gas (1974) suggests that additional faulting (with a different sense of slip) may extend upward into the base of the Careaga Formation rocks of late Pliocene age. In either case, the Fuglar fault is not considered active. Consequently, neither of the two onsite faults are considered likely to pose a ground-surface fault-rupture hazard.

Table 4.5-1. Faults Located within the Vicinity of the Project Site

Fault Name	Fault Type	Distance from Project Site (miles)	Potential Magnitude
San Luis Range	Reverse	3	7.2
Casmalia (Orcutt Frontal)	Reverse	5	6.7
Los Alamos - West Baseline	Thrust	5	6.9
Lions Head	Reverse	8	6.8
Santa Ynez	Strike Slip	21	7.2
Los Osos	Reverse	23	7.0
Hosgri	Strike Slip	26	7.3
San Juan	Strike Slip	29	7.1
Red Mountain	Reverse	31	7.4
Mission Ridge-Arroyo Parida - Santa Ana	Reverse	35	6.9
North Channel	Thrust	36	6.8

Table 4.5-1. Faults Located within the Vicinity of the Project Site

Fault Name	Fault Type	Distance from Project Site (miles)	Potential Magnitude
Rinconada	Strike Slip	36	7.5
Pitas Point	Reverse	37	7.3
San Andreas	Strike Slip	40	8.1
Santa Ynez (East)	Strike Slip	43	7.2

Source: Fugro Consultants, Inc., 2014

4.5.2 Regulatory Setting

4.5.2.1 State

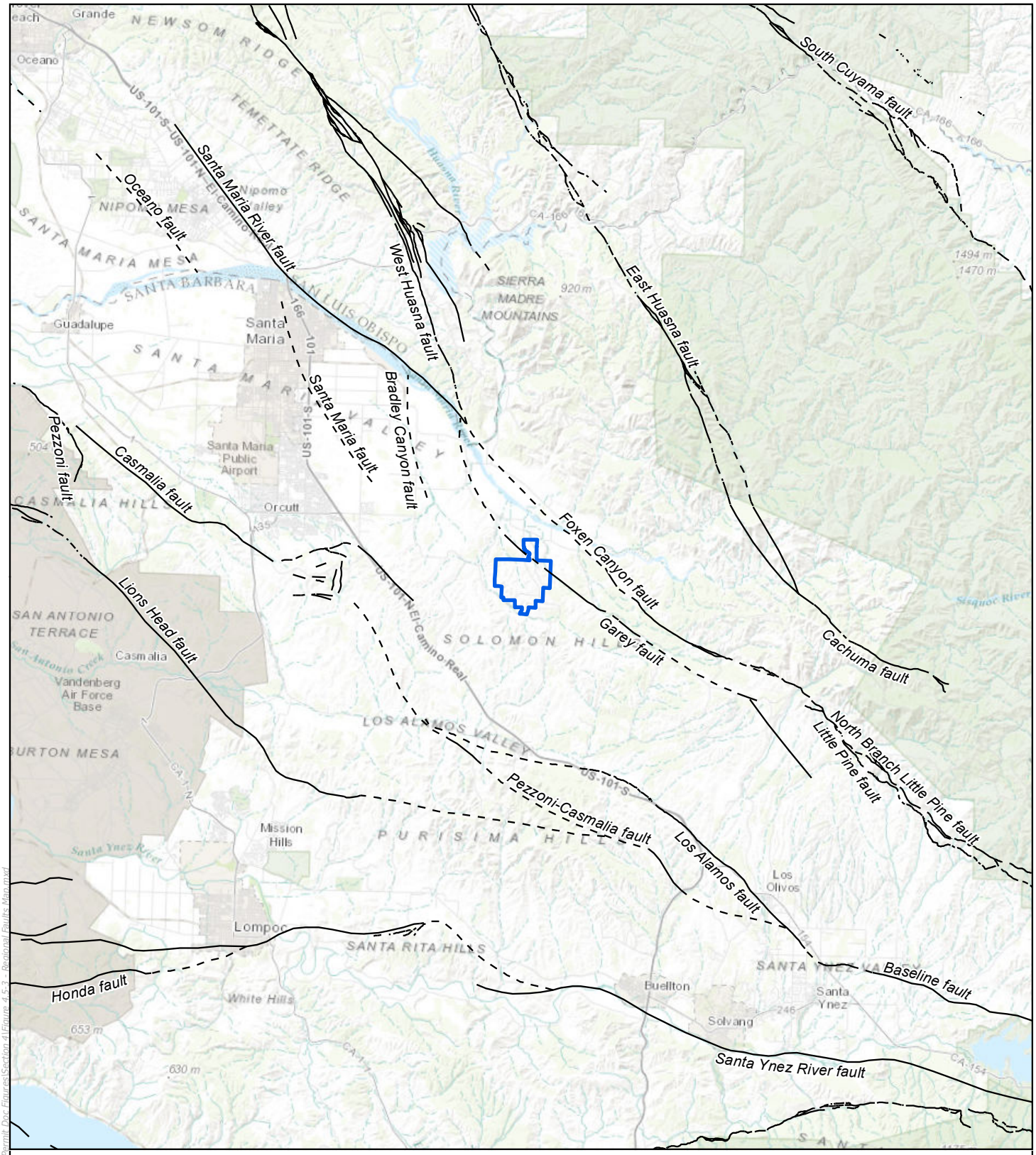
The following regulations apply to geologic hazards identification and avoidance within the State of California.

Alquist-Priolo Act. The Alquist-Priolo Act was passed in 1972 "to mitigate the hazard of surface faulting to structures for human occupancy." The Act establishes criteria used to estimate fault activity in California and requires the State Geologist to establish regulatory zones (known as Earthquake Fault Zones) around the surface traces of active faults and to issue appropriate maps to affected cities, counties and areas within the State.

Seismic Hazards Mapping Act. According to the California Geological Survey - Seismic Hazards Zonation Program, the Seismic Hazards Mapping Act was enacted to "govern the exercise of city, county and State agency responsibilities to identify and map seismic hazard zones and to mitigate seismic hazards to protect public health and safety in accordance with the provisions of Public Resources Code, Section 2690 *et seq*. (Seismic Hazards Mapping Act)." The Seismic Mapping Act requires that in order to receive approval, a project must meet specific criteria including the following:

- "A project shall be approved only when the nature and severity of the seismic hazards at the Project site have been evaluated in a geotechnical report and appropriate avoidance and minimization measures have been proposed.

  The geotechnical report shall be prepared by a registered civil engineer or certified engineering geologist, having competence in the field of seismic hazard evaluation and mitigation. The geotechnical report shall contain Site-specific evaluations of the seismic hazard affecting the project, and shall identify portions of the Project site containing seismic hazards. The report shall also identify any known off-Site seismic hazards that could adversely affect the Site in the event of an earthquake. The contents of the geotechnical report shall also be required to include specific sections such as a project description and recommendations for appropriate avoidance and minimization measures as required in Section 3724(a).



LEGEND:

Aera Energy LLC Property — Quaternary Fault - - Inferred Quaternary Fault

0 2.5 5
MILES

Source: DPSI 2013 Survey, USGS Faults, ESRI Online Basemap
Coordinate System: NAD 1983 StatePlane California V FIPS 0405 Feet
Notes: This map was created for informational and display purposes only.

PROJECT NAME: EAST CAT CANYON OIL FIELD REDEVELOPMENT PROJECT	REGIONAL FAULTS MAP	FIGURE 4.5-3
PROJECT NUMBER: 1002-0455 / DATE: September 2014		

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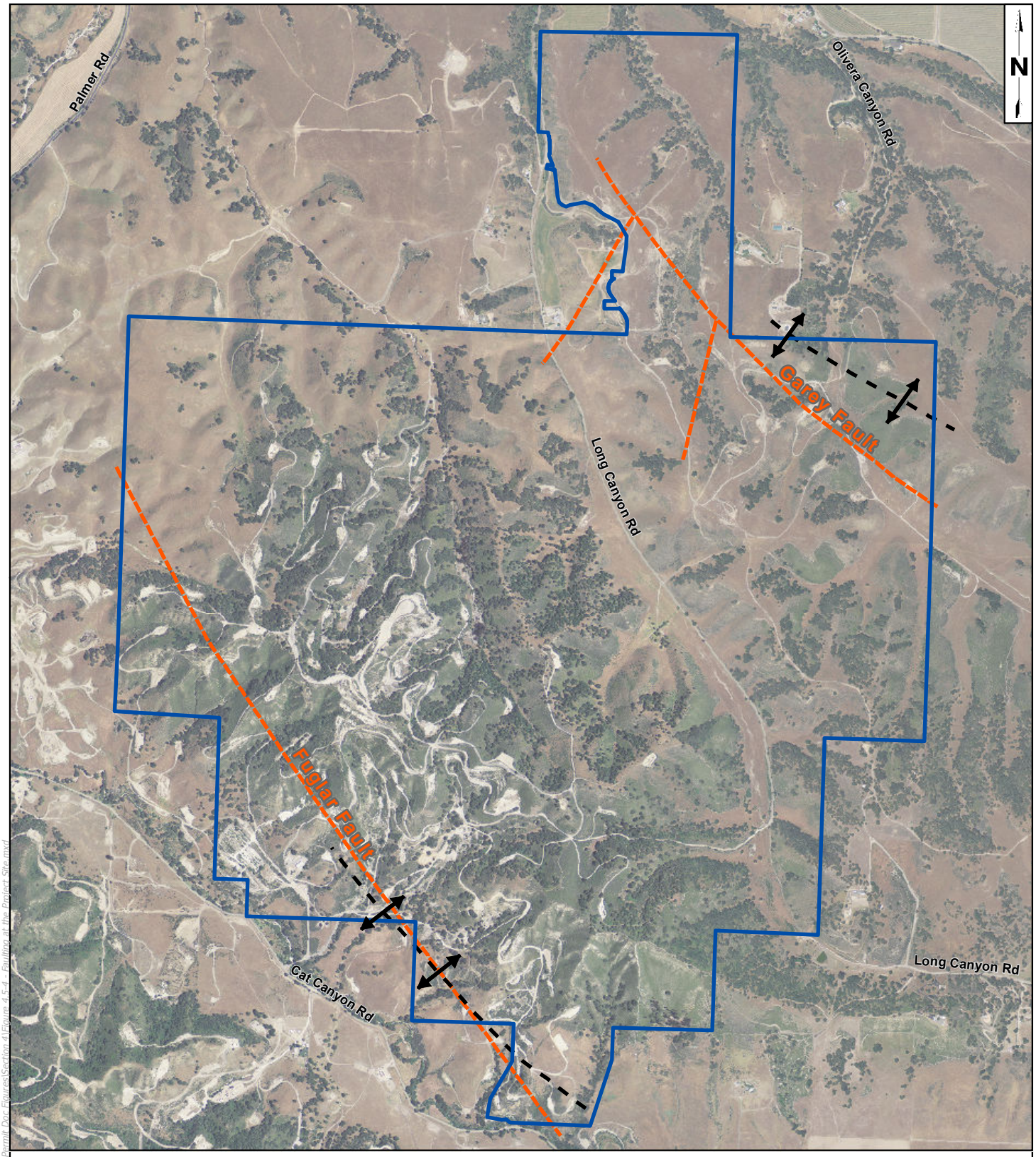

LEGEND:

Aera Energy LLC Property — Concealed Fault (inferred) — Anticline Axis (inferred)

0 900 1,800
FEET

Source: DPSI 2013 Survey, Fugro Consultants, Inc., NAIP 2012 Image
Coordinate System: NAD 1983 StatePlane California V FIPS 0405 Feet
Notes: This map was created for informational and display purposes only.

PROJECT NAME: EAST CAT CANYON OIL FIELD REDEVELOPMENT PROJECT		FAULTING AT THE PROJECT SITE	FIGURE 4.5-4
PROJECT NUMBER: 1002-0455	DATE: September 2014		

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- Prior to approving the Project, the lead agency shall independently review the geotechnical report to determine the adequacy of the hazard evaluation and proposed avoidance and minimization measures and to determine the requirements of Section 3724(a), above, are satisfied. Such reviews shall be conducted by a certified engineering geologist or registered civil engineer, having competence in the field of seismic hazard evaluation and mitigation."

Uniform Building Code. The Uniform Building Code defines regions of the United States within seismic zones to determine the potential for seismic activity at various locations. These maps are then used to determine the extent from which future development would be required to comply with design and engineering standards.

California Building Code. The California Building Code provides the State with a minimum standard of building design to protect structures from potential impacts related to geologic hazards. Chapter 23 of the Building Code contains specific guidelines for seismic safety, while Chapter 29 of the Building Code regulates the excavation, foundation and retaining walls of developments. In addition, Chapter 33 contains specific requirements for building and construction in order to protect the public from hazards associated with construction related debris or materials.

4.5.2.2 Local

Conformance with the County of Santa Barbara's Grading and Building Codes is considered generally satisfactory with respect to geologic hazards (County of Santa Barbara, 1979). The County's Grading Ordinance (County of Santa Barbara, 2010) applies to new grading, excavations, fills, cuts, borrow pits, stockpiling, and compaction of fill, "…where the transported amount of materials…exceeds 50 cubic yards or the cut or fill exceeds 3 feet in vertical distance to the natural contour of the land."

In addition, the Santa Barbara County Comprehensive Plan includes several policies to ensure protection against geologic hazards, adequate setbacks and avoidance of erosion-causing activities along coastal bluffs, and minimization of grading and landform alteration. The Seismic Safety and Safety Element recommends an adequate site-specific investigation be performed where the possibility of soil or geologic problems exist.

4.5.3 Impact Assessment Standards

Pursuant to Santa Barbara County's Adopted Thresholds and Guidelines Manual (October 2008), impacts related to geological resources may have the potential to be significant if the proposed Project involves any of the following characteristics:

1. The Project site or any part of the Project is located on land having substantial geologic constraints, as determined by Santa Barbara County Planning and Development or County Public Works Department. Areas constrained by geology include parcels located near active or potentially active faults and property underlain by rock types associated with compressible/collapsible soils or susceptible to landslides or severe erosion. "Special Problems" areas designated by the Board of Supervisors have been established based on geologic constraints, flood hazards and other physical limitations to development;

2. The Project results in potentially hazardous geologic conditions such as the construction of cut slopes exceeding a grade of 1.5 horizontal to 1 vertical;

3. The Project proposes construction of a cut slope over 15 feet in height as measured from the lowest finished grade; and

4. The Project is located on slopes exceeding 20 percent grade.

4.5.4 Impact Analysis

4.5.4.1 Fault Rupture and Strong Ground Shaking

The potential for strong ground shaking at the site is considered moderate, with the preliminary 475-year and 2,475-year return period ground motions estimated at about 0.26 gravity and 0.49 gravity, respectively. Although the Project site is located within the seismically active Central Coast region, it is outside of the Special Studies Zone defined by the Alquist-Priolo Special Studies Zones Act of 1972. Additionally, neither of the two onsite faults are considered active or likely to pose a ground-surface fault-rupture hazard. Based on this information as well as the design of the Project as outlined within avoidance and minimization measure GEO-1, no significant impact due to fault rupture or ground shaking will result.

4.5.4.2 Soil Liquefaction and Seismically Induced Settlement

The older alluvium, and Paso Robles and Carreaga Formations located beneath the Project site are not likely to be susceptible to earthquake induced liquefaction or seismic settlement. The colluvial and alluvial soils could be susceptible to liquefaction. However, the depth to groundwater at the locations explored exceeded a depth of 30 feet and liquefaction is not a hazard for soils located above the groundwater level. Based on this information as well as the design of the Project as outlined within avoidance and minimization measure GEO-1, no significant impact due to soil liquefaction or seismically induced settlement will result.

4.5.4.3 Hydroconsolidation Potential

Due to their age, the Paso Robles and Carreaga Formation materials and older alluvium are not likely to be subject to hydroconsolidation. However, deposits of colluvium and alluvium on the site may be susceptible to hydroconsolidation. Through design of the Project as outlined within avoidance and minimization measure GEO-1, no significant impact due to hydroconsolidation will result.

4.5.4.4 Subsidence Due to Fluid Withdrawl

Subsidence is a lowering of the ground surface elevation as a result of withdrawal of fluids, including groundwater, oil, or gas. Withdrawal of such fluids can result in a net decrease in the pore pressure, thus allowing the soil grains to pack closer together. This closer grain packing results in less volume and the lowering of the ground surface. The oil reservoir at the Project site lies within a geologic anticline at a depth of approximately 3,000 feet, and overlain by a capstone of impermeable rock materials. Therefore, petroleum production activities are not anticipated to result in ground subsidence due to fluid withdrawal.

4.5.4.5 Landsliding and Slope Stability

As shown on Figure 4.5-2 - Hazards Identification Map, several locations on-site have geomorphology that suggests the presence of past landsliding. Specifically, landslide deposits have been mapped within the southern portion of the Project site.

Additionally, as shown on Figure 4.5-5 - Proposed Disturbance Areas in Relation to Slopes at the Project Site, approximately 151.5 acres or 50.3 percent of the Project disturbance areas are located on slopes at or greater than 20 percent grade. Areas cut at a 20 percent grade or higher will result in an impact related to geologic hazards in accordance with the County of Santa Barbara thresholds. As such, recommendations by Fugro Consultants, Inc. within their preliminary geohazards assessment pertaining to cut slopes will be adhered to. Specifically, if possible, areas with suspected landslide geomorphology will be avoided. Areas of colluvium on slopes above proposed developments will be removed or supported. Because most of the earth materials on the site are generally granular and uncemented (thus increasing the potential for surface erosion), proposed cut slopes will be graded at inclinations of 2 horizontal to 1 vertical (2H:1V) or flatter.

Additionally, the ground surface will be prepared to receive fill by removing vegetation, non-complying fill, topsoil, and other unsuitable materials, scarifying to provide a bond with new fill and, where slopes are steeper than 20 percent and the height is greater than 5 feet, by benching into sound bedrock or other competent material as determined by a geotechnical engineer. The bench under the toe of a fill on a slope steeper than 20 percent will be at least ten feet wide and five feet of the lowermost bench will be exposed beyond the toe of the hillside fills. The area beyond the toe of fill shall be sloped for sheet overflow or a paved drain shall be provided. When fill is to be placed over a cut, the bench under the toe of fill will be at least ten feet wide. The cut will be made before placing the fill and the cut will be approved by the soils engineer or engineering geologist or both as a suitable foundation for fill.

If structures are proposed in areas of possible landsliding, subsurface exploration will be performed to confirm the presence and geometry of the landslide deposits, and to evaluate the stability of the materials. If landslide deposits are confirmed and their natural stability is found to be inadequate, Project-incorporated avoidance and minimization measures which include removal and replacement with compacted fill, providing structural support, or compacted-fill buttressing will reduce potential impacts to less than significant.

4.5.4.6 Expansive Soils

There is likely to be a limited amount of clayey soil present on the Project site; therefore, the potential for highly expansive soils is limited.

4.5.5 Project-Incorporated Avoidance and Minimization Measures

The following Project-incorporated avoidance and minimization measures are based upon recommendations detailed in both Fugro Consultants, Inc.'s December 2013 Phase I Services, Preliminary Geotechnical Engineering Study, East Cat Canyon Oil Field, Sisquoc Area, Santa Barbara County, California and Fugro Consultants, Inc.'s January 2014 Preliminary Geologic Hazards Evaluation, East Cat Canyon Oil Field, Sisquoc Area, Santa Barbara County, California (Appendix S).

- **GEO-1. Geologic Hazards Recommendations.** Aera Energy LLC will implement the following during Project construction and operations:

  a) If structures are proposed in areas of possible landsliding, subsurface exploration will be performed to confirm the presence and geometry of the landslide deposits, to evaluate the stability of the materials;

  b) If landslide deposits are confirmed and their natural stability is found to be inadequate, Aera will either avoid those areas or implement measures recommended by a geotechnical engineer, such as removal and replacement with compacted fill, providing structural support, or compacted-fill buttressing;

  c) Areas of colluvium on slopes above proposed developments will be removed or supported;

  d) The overexcavation and remedial grading will be planned to remove existing artificial fill and colluvial soils beneath proposed structures and areas of development;

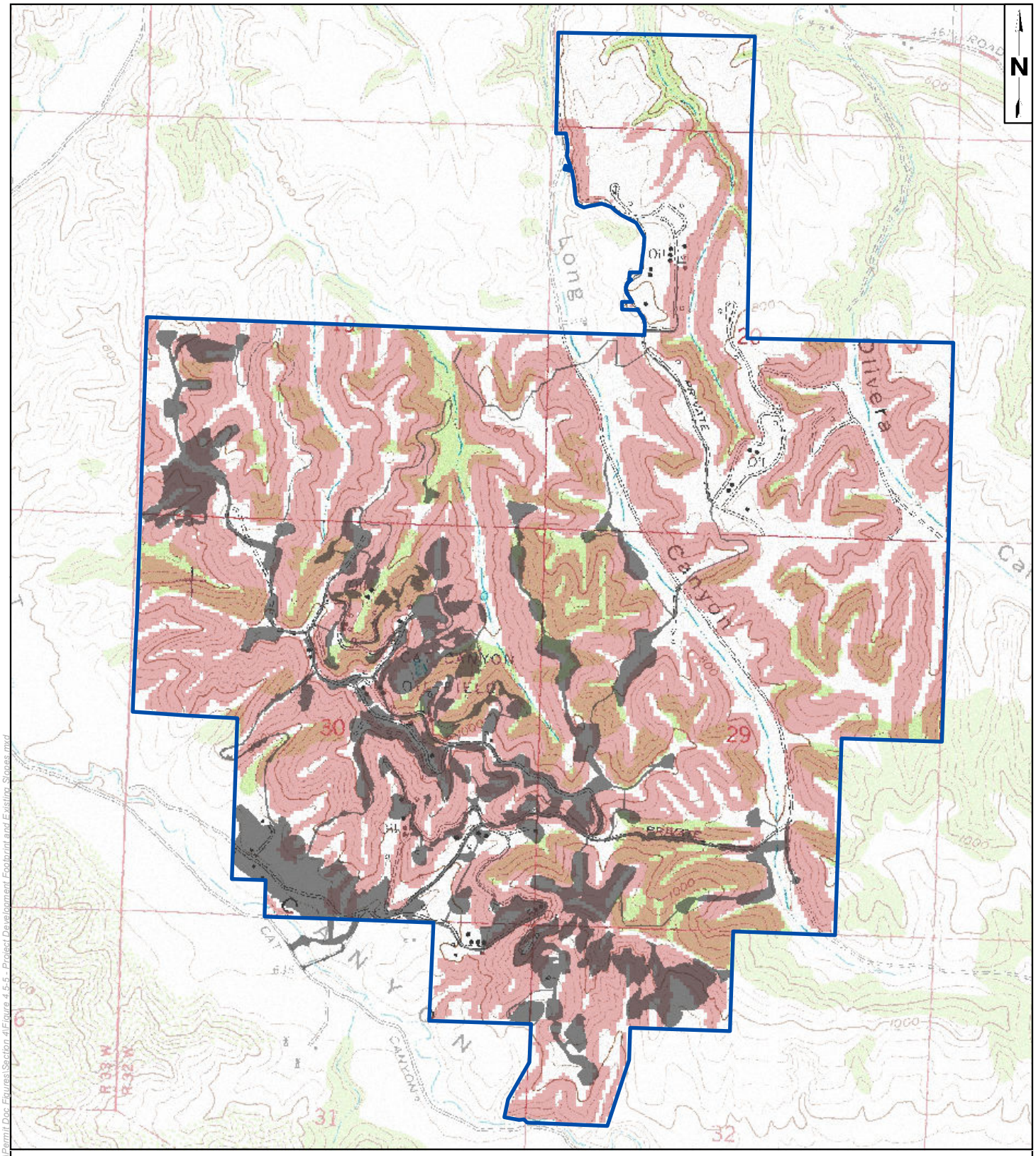
  e) Proposed cut slopes will be graded at inclinations of 2 horizontal to 1 vertical (2H:1V) or flatter; unless steeper inclinations are approved in the Grading Plan review.

  f) Site-specific geotechnical exploration and analyses will be conducted as needed to determine the potential for liquefaction, seismic settlement, and hydroconsolidation;

  g) A Project-specific grading and erosion control plan will be designed to minimize erosion and sedimentation;

  h) Geotechnical sampling and testing will be performed as necessary to confirm the presence or absence of expansive soil materials at the Project site; and

  i) Aera Energy LLC will adhere to recommendations detailed in both Fugro Consultants, Inc.'s December 2013 Phase I Services, Preliminary Geotechnical Engineering Study, East Cat Canyon Oil Field, Sisquoc Area, Santa Barbara County, California and Fugro Consultants, Inc.'s January 2014 Preliminary Geologic Hazards Evaluation, East Cat Canyon Oil Field, Sisquoc Area, Santa Barbara County, California (Appendix S).



LEGEND:

Aera Energy LLC Property | Project Footprint | Area of Slope >20%

0 900 1,800
FEET

Source: DPSI 2013 Survey, TJ Cross 8-20-2014, USGS Topo, Spec Services 2011
Coordinate System: NAD 1983 StatePlane California V FIPS 0405 Feet
Notes: This map was created for informational and display purposes only.

PROJECT NAME: EAST CAT CANYON OIL FIELD REDEVELOPMENT PROJECT	PROJECT DEVELOPMENT FOOTPRINT AND EXISTING SLOPES	FIGURE 4.5-5
PROJECT NUMBER: 1002-0455 / DATE: September 2014		

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