APPENDIX G

GEOLOGY – SOILS TECHNICAL STUDY REPORT

GEOLOGY AND SOILS IMPACTS ANALYSIS

Pixley Groundwater Banking Project
Tulare County, California

Soils and Geology

December 21, 2015
Project FR1416066A

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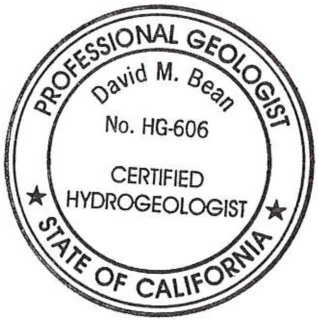

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Principal Hydrogeologist

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GEOLOGY AND SOILS IMPACTS ANALYSIS

Pixley Groundwater Banking Project
Tulare County, California

ABBREVIATIONS

(CEQA)	California Environmental Quality Act
(CISN)	California Integrated Seismic Network
(CVP)	Central Valley Project
(FKC)	Friant-Kern Canal
(SVWBA)	South Valley Water Banking Authority
(SWPPP)	Stormwater Pollution Prevention Plan
(um/s)	Micro-meters per second

1.1 INTRODUCTION AND OBJECTIVES

Amec Foster Wheeler Environment & Infrastructure, Inc., has prepared this report on behalf of the Project Proponent South Valley Water Banking Authority (SVWBA), to assess the impacts to geology and soils, for the proposed Pixley Groundwater Banking Project in southern Tulare County, California (Figure 1).

The SVWBA, as the lead agency at the local level, is preparing a document pursuant to California Environmental Quality Act (CEQA) to examine the environmental impacts of the construction and operation/maintenance of the Pixley Groundwater Banking Project, which would include the following primary structures/features:

1. An approximately 532-acre (surface area) Recharge Basin facility capable of the direct recharge of approximately 45,000 acre-feet per year. Basin will be excavated approximately 4-5 feet below adjacent grade and surrounded by a 1 to 2-foot berm built up from surrounding grade. This will allow the capture of up to 4 to 5 feet of water.

2. A well field of 11 recovery wells located within the Recharge Basins boundary with the capability to recover approximately 25,400 acre-feet of water over an 8 month period;

3. A new 48-inch turnout from the west bank of the Friant-Kern Canal (FKC);

4. A 4.5-mile long, 48-inch diameter, bi-directional, concrete pipeline to convey water via gravity delivery from the new FKC turnout to the in-lieu service area and Recharge Basins. This main pipeline will also support recovery of water from the recovery wells and convey that water back to the FKC.

5. A pumping plant and regulating basin area with associated electrical and control facilities to boost water from the recovery wells east to the FKC to meet scheduled irrigation deliveries of Central Valley Project (CVP) contractors and others within the Deer Creek, White River, Poso Creek, and Kern checks of the FKC.

6. Grower turnouts, related control facilities, connecting pipelines, and up to five groundwater recovery wells within a 3,539 acre in-lieu service area. The in-lieu service area has an effective recharge capacity of up to approximately 6,500 acre-feet per year. The five wells would have a potential to recover approximately 8,500 acre-feet of water over an 8-month period to be returned to the FKC.

7. A new 48-inch turnout to be built as an extension of the existing Harris Ditch Turnout on Deer Creek. This new turnout structure from Deer Creek will allow water to be diverted from Deer Creek into the Recharge Basins for direct recharge.

8. The creation of a Monitoring Committee comprised of neighboring landowners and others interested in the Bank's operations as part of this Project. It will monitor the Bank's operations and the changes to groundwater conditions created by the Bank

and will recommend immediate steps that shall be taken should anything regarding Bank operations rise to a level of concern, including but not limited to:

a. Reduce the volume of water being pumped by the Project when the neighbors' wells are running;

b. Rotate which wells in the well field are running to spatially move the cones of depression to avoid pumping close to neighbors' wells that may be running.

c. Move the season of extraction to a time of year when the neighbors' wells are not running.

This environmental compliance document will also examine the environmental effects of approval of a program of groundwater banking and recovery, including necessary contracts and supporting actions to provide the ability to place into groundwater storage up to 30,000 acre-feet of water per year. Ten percent of the water placed into storage would not be returnable and left to improve groundwater conditions in the area. Up to 90,000 acre-feet of water could be stored at any one time. Up to 30,000 acre-feet of water could be returned to banking partners in any one year.

Potential banking partners include Friant Division CVP contractors, Reclamation, CVP contractors within the Cross Valley, Delta-Mendota, San Luis Unit and Exchange Contractor service areas, the Kern County Water Agency and/or its member units, the Dudley Ridge Water District, the Tulare Lake Basin Water Storage District, and other water agencies, entities or individuals within the Friant Division of the CVP.

Pixley Irrigation District also intends to use the proposed facilities to deliver irrigation water from the FKC or from Deer Creek to the new service area (the in-lieu service area) and to direct recharge via the Recharge Basins at times when the proposed facilities are not obligated for use by banking partners.

2.0 REGIONAL SETTING

Generally, the proposed Project area is located on the North American Plate 15 miles west of the Sierra Nevada foothills and 70 miles east of the San Andreas transform fault system along the Coast Ranges. Along the western margin of the Sierra Nevada foothills are a series of accreted arc terranes that were subsequently intruded by plutons of the Sierra Nevada batholith. Contact between the two terranes is deep beneath the Great Valley. Farther west, the coastal range is characterized by marine greywackes and mélanges overlain by the coast range thrust; the upper plate consists of ophiolite overlain by the Great Valley Mesozoic turbidite sequence (Dickinson, 1996). The proposed Project area is located within the Great Valley geomorphic province, which is a large, elongate, northwest-trending trough extending more than 430 miles. Sedimentation within the valley consists of several thousand feet of marine and non-marine sedimentary rock derived from Mesozoic through recent age erosion of the Coast Ranges and the Sierra Nevada Mountains (Tulare County, 2012). The proposed Project area is underlain by part of the Great Valley Sequence, primarily younger unconsolidated Quaternary age alluvial fan deposits derived from the Sierra Nevada foothills.

3.0 LOCAL SETTING

Land use within the Central Valley is dominated by agricultural use. The proposed Project is located in a low-density, scattered, rural residential development area, where vineyards, pistachios, almonds, alfalfa, and cotton are grown. The alluvial fan deposits that comprise the soils of the proposed Project area create a relatively flat (about 0.3 percent slope) surface (Figure 1). This nearly flat surface extends throughout the floor of the Central Valley. The soil types within the proposed Project area share moderate to well drained characteristics, with the exception of the Centerville Clay, which is approximately 3.8 percent of the proposed Project area (Figure 2).

4.1 EXISTING CONDITIONS

4.2 SEISMICITY

There are no known earthquake faults within the proposed project area. The nearest active fault identified by the Alquist-Priolo Earthquake Fault Zone map is the Pond-Poso Creek Fault located 15 miles southwest of the proposed Project area.

The Pond-Poso Creek fault consists of a 2/3 mile-wide zone of northwesterly trending normal faults, downthrown to the southwest and dipping approximately 50 to 70 degrees. Visible fault scarps suggest that a 2-mile segment of the fault is active. Subsurface data indicate that repeated movement has occurred along this fault since the Eocene and possibly the Paleocene. An upper limit to historic offset (as of 1974) was established with a fault trench. At a depth of approximately 10 feet from ground surface, 9 inches of vertical offset was observed (LADWP, 1974). From borehole data, approximately 50 feet of vertical offset is interpreted at a depth of 875 feet (Holzer, 1980). The Los Angeles Department of Water and Power identified several small epicenters, none greater than 4.0 magnitude, near the Pond-Poso Creek Fault. Groundwater withdrawal and subsequent ground subsidence have been proposed as the cause of historical offset (Holzer, 1980).

The Alquist-Priolo Earthquake Fault Zone map identifies three other faults, the Kern Front, New Hope, and Premier faults, within 30 miles of the proposed Project area. The Kern Front, New Hope, and Premier faults have been identified as active, northwest striking, westerly dipping, normal faults that cut Quaternary deposits. They are located between 24 and 30 miles southeast of the proposed Project area along the western flank of the Sierra Nevada foothills. None of these faults are considered major faults, and none show evidence of pre-historic Holocene displacement (Smith, 1983). It has been determined that the reactivation of these faults are a result of fluid withdrawal from the Kern Front oil field (Smith, 1983).

Additionally, the San Andreas (56 miles west from proposed Project area), Owens Valley (70 miles east from proposed Project area), White Mountains fault zone (80 miles east from proposed Project area), Ortigalita, Nunez (110 miles northeast from proposed Project area), and White Wolf (75 miles south from proposed Project area) faults are considered active. The portion of the San Andreas Fault closest to the proposed Project area was last active in 1966 and has produced magnitude earthquakes varying from 6.0 to 7.9. In 1872, the Owens Valley fault ruptured the ground surface for about 60 miles producing a magnitude 7.4 earthquake. The White Mountains fault zone was last active in 1986 and produced a magnitude 6.4 earthquake. The Nunez fault was last active in 1983 and produced a magnitude 6.4 earthquake event. The White Wolf fault produced a magnitude 7.3 earthquake in 1952 (Jennings and Saucedo, 1999). The Ortigalita fault historically ruptures by fault creep, meaning that it migrates continually at a slower rate (USGS, 2007). There is no known damage in the Project area from these earthquakes.

Ground shaking is the primary seismic hazard in the valley portion of Tulare County, including the proposed Project area. Earthquake damage caused by ground shaking is determined by the magnitude of an earthquake, the depth of focus, the distance from the fault, the intensity and duration of shaking, the local groundwater and soil conditions, topography, and the design and quality of materials and workmanship in construction.

The California Integrated Seismic Network (CISN) is a partnership among federal, state, and university agencies involved in California earthquake monitoring. CISN publishes maps and data that track the frequency and magnitude of ground shaking events throughout California. The peak ground acceleration, which is the measure of how hard the earth shakes in a given geographic area, has been identified by the California Geological Survey for the proposed Project area to have a 10 to 20 percent probability of exceeding 6 percent of the acceleration of gravity in 50 years (USGS, 2008). Tulare County is characterized as Severity Zone “Nil” and “Low” for ground shaking events (Tulare County, 2012).

4.3 SOILS

Permeable soils are essential in recharge basins to allow percolation from surface water into groundwater. Locations with a high capacity for recharge, based on the saturated hydraulic conductivity of the soils, provide suitable conditions for significant recharge. The Akers-Akers saline Sodic complex soil that comprises 65.9 percent of the proposed recharge basins possess moderately slow to rapid saturated hydraulic conductivity, while the Hanford sandy loam that is found in 31.5 percent of the proposed recharge basins possesses moderately rapid to very rapid saturated hydraulic conductivity. The soils of the in-lieu area possess saturated hydraulic conductivity values that range from very slow to very rapid, with the majority of the area (69 percent) being characterized by moderately slow to very rapid hydraulic conductivity. Saturated hydraulic conductivity values for all soils found within the proposed Project area are summarized in Table 1, and a distribution of the soil types is shown on Figure 2.

Expansive soils are characterized by the ability to significantly swell or shrink as a result of variation in soil moisture content. Soil moisture content can vary due to circumstance, including, perched water, agricultural irrigation, and rainfall. Hazards to the proposed Project associated with expansive soils include the potential for damage to levees, wells, and pipeline connections constructed on soils that can significantly expand or contract with changes in soil water content. The proposed Project area contains three soil types that are considered to have low "shrink-swell" potential, five soil types considered to have moderate shrink-swell potential, one soil type considered to have high shrink-swell potential, and one soil type that is too variable to categorize. The majority of the soil types in the proposed Project area (95 percent) are considered to have moderate to low shrink-swell potential. The majority (97 percent) of recharge basins have soils types that are considered to have low shrink-swell potential. Soils and their shrink-swell potential is summarized in Table 1.

The Centerville clay, located in the northeastern portion of the in-lieu area, and on an approximate 1,750 foot section of Avenue 80 where the proposed main trunk pipeline is proposed to be constructed, is considered to have high shrink-swell potential (Figure 2). Expansion and contraction of soils with high shrink-swell characteristics, including the Centerville clay, could damage buildings, foundations, and infrastructure including pipelines due to settlement and uplift.

Table 1: Proposed Project Area Soil Types

Entire Proposed Project Area

Soil Type	Shrink Swell Potential	Acres in Proposed Project Area	Percent of Project Area	Saturated Hydraulic Conductivity um/s
Colpien loam	Moderate	1534.1	37.1%	1.41 – 42.34
Flamen loam	Moderate	495.1	12.0%	0.42 – 14.11
Hanford sandy loam	Low	484.6	11.7%	14.11 – 141.14
Akers-Akers, saline-Sodic complex	Low	437.6	10.6%	1.41 – 42.43
Biggriz-Biggriz, saline-Sodic complex	Moderate	387.5	9.4%	1.41 – 14.11
Crosscreek-Kai association	Moderate	369.2	8.9%	0.07 – 42.34
Centerville clay high	High	159.6	3.9%	0.42 – 4.23
Exeter loam	Moderate	106.3	2.6%	0.07 – 141.14
Calgro-Calgro, saline-Sodic complex	Low	96.8	2.3%	0.07 – 141.14
Riverwash	Variable	61.1	1.5%	
Total		**4132**	**100.0%**	

<u>**Recharge Basins**</u>

Soil Type	Shrink Swell Potential	Acres in Proposed Project Area	Percent of Project Area	
Hanford sandy loam	Low	181.2	31.5%	14.11 – 141.14
Akers-Akers, saline-Sodic, complex	Low	379.5	65.9%	1.41 – 42.34
Riverwash	Variable	15.3	2.7%	
Total		**576.0**	**100.0%**	

5.0 PROPOSED PROJECT IMPACT ANALYSIS

a. Would the proposed project expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving:

i. RUPTURE OF A KNOWN EARTHQUAKE FAULT

Seismically induced ground failures occur when ground movements are substantial enough to result in severe distress or infrastructure failure. Ground failure includes surface rupture of faults, sediment-stability failure due to soil liquefaction, lateral spreading, seismically induced landslides, and differential settlement.

Fault rupture occurs when fault displacement extends upward to the ground surface creating a visible offset. Ruptures may occur suddenly with earthquake events, or slowly over time due to fault creep. Fault ruptures have potential to damage structures, both above and below ground surface, and pose a threat of injury that could result in the loss of life. Fault ruptures are likely to occur along known faults. Surface fault rupture within the proposed Project area is highly unlikely, as no faults have been identified (see Section 4.1). The Project would not substantially increase human or environmental exposure to risk of loss, injury, or death as a result of fault ruptures, therefore, the impact of fault ruptures is considered less than significant.

ii. STRONG SEISMIC GROUND SHAKING

The proposed Project is expected to experience minimal effects from earthquake ground shaking due to the Project’s distance of greater than 50 miles from any major fault, and the lack of any known faulting in the Project area (see Section 4.1). The Project would not substantially increase human or environmental exposure to risk of loss, injury, or death as a result of ground shaking, therefore, the impact of ground shaking is considered less than significant.

iii. SEISMIC-RELATED GROUND FAILURE

Liquefaction is a process by which water-saturated sediments briefly lose strength and behave as a viscous fluid rather than a solid. Soils with poor drainage characteristics and soils where groundwater levels are at or near (30 feet) ground surface are at the greatest risk of liquefaction.

Liquefaction-induced lateral spreading is a lateral movement of gradually sloping ground as a result of liquefaction in near-surface soils during an earthquake.

The application of surface water during recharge conditions will raise groundwater elevations and increase soil saturation at or near ground surface. However, as described above in Section 3.0, soils within the Project area are moderately well, to well-drained, and groundwater levels average approximately 300 feet below ground surface. The ground surface at the proposed project area is relatively flat exhibiting average slopes of less than 1 percent (see Section 3.0).

Settlement can occur in loose unsaturated sandy soils during periods of strong seismic ground shaking. Settlement of sufficient magnitude to cause significant structural damage is normally associated with rapidly deposited alluvial soils or improperly founded or poorly compacted fill. These areas are known to undergo extensive settling with the addition of irrigation water. The soils of the proposed Project area are alluvial fan deposits that have been slowly deposited over the last several 100,000 years (see Section 2.0). Therefore, the proposed Project would not expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving ground failure or liquefaction. The impact of seismic related ground failure including liquefaction at the proposed Project area is considered less than significant.

iv. LANDSLIDES

Seismically induced landslides can occur in hillside areas and along creeks. The likelihood of seismically induced landslides in the proposed Project area is highly unlikely due to the relatively low chance of significant ground shaking and nearly flat ground surface. The Project would not expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving landslides, therefore, the impact of landslides is considered less than significant (see Sections 3.0 and 4.1).

Mitigation Measure: No Mitigation is required

b. Would the proposed project result in soil erosion or the loss of topsoil?

Erosion occurs as bare soils are worn away and transported to another area when exposed to water or wind. Construction of the recharge basins would require minor grading and compaction of soils on the relatively flat ground surface. Surface erosion and loss of topsoil can follow disturbances caused by grading, which could loosen soil and activate or hasten the loss of soils. Erosion and sediment control measures, if properly prescribed, implemented, and maintained, including a Stormwater Pollution Prevention Plan (SWPPP) in accordance with the Clean Water Act are expected to reduce erosion rates during and after construction. By implementing the requirements of a SWPPP, substantial soil erosion or the loss of topsoil is considered less than significant.

Mitigation Measure: No Mitigation is required

c. Would the proposed project be located on a geologic unit or soil that is unstable, or that would become unstable as a result of the Project, and potentially result in on- or off-site landslide, lateral spreading, subsidence, liquefaction, or collapse?

Ground failures including landslide, lateral spreading, subsidence, and liquefaction occur in geologic units where strong ground shaking may occur. The relatively seismically stable setting of the proposed Project area, the depth to groundwater of approximately 300 feet, the relatively flat ground surface, and the moderately well to well-drained characteristics of the soil create an environment where ground failure is unlikely to occur (see Section 4.1). The proposed project will not be located on a geologic unit or soil that is unstable or that would become unstable as a result of the Project, and potentially result in on- or off-site landslide, lateral spreading, subsidence, liquefaction, or collapse (Figure 2). Therefore, the impact is considered less than significant.

Mitigation Measure: No Mitigation is required

d. Would the proposed project be located on expansive soil defined in Table 18-1-B of the Uniform Building Code, creating substantial risks to life or property?

The Centerville clay, a soil type with high shrink-swell potential, is present in a small portion (3.8 percent of the proposed Project area) of the in-lieu service area (Figure 2). Special engineering considerations should be taken in the construction of any structure or pipeline in the northeastern portion of the proposed in-lieu area as shown in Figure 2. A small portion of the in-lieu service area will be located on an expansive soil. However, because expansive soils at the proposed project would not create a substantial risk to humans and the use of proper construction and engineering techniques will eliminate the possibility of damage to structures, the impact of expansive soils is considered less than significant

MITIGATION MEASURE: No Mitigation is required**.**

e. Would the proposed project leave soils incapable of adequately supporting the use of septic tanks or alternative wastewater disposal systems in areas where sewers are not available for the disposal of waste water?

The construction and operation of the 576-acres of recharge basins would leave that area incapable of adequately supporting the use of septic tanks or alternative wastewater disposal systems. The high permeability of the soils at the Project area would not leave the soils, located a distance of 50 feet or greater from the recharge basins, incapable of adequately supporting the use of septic tanks or alternative waste water disposal systems.

MITIGATION MEASURE: No Mitigation is required

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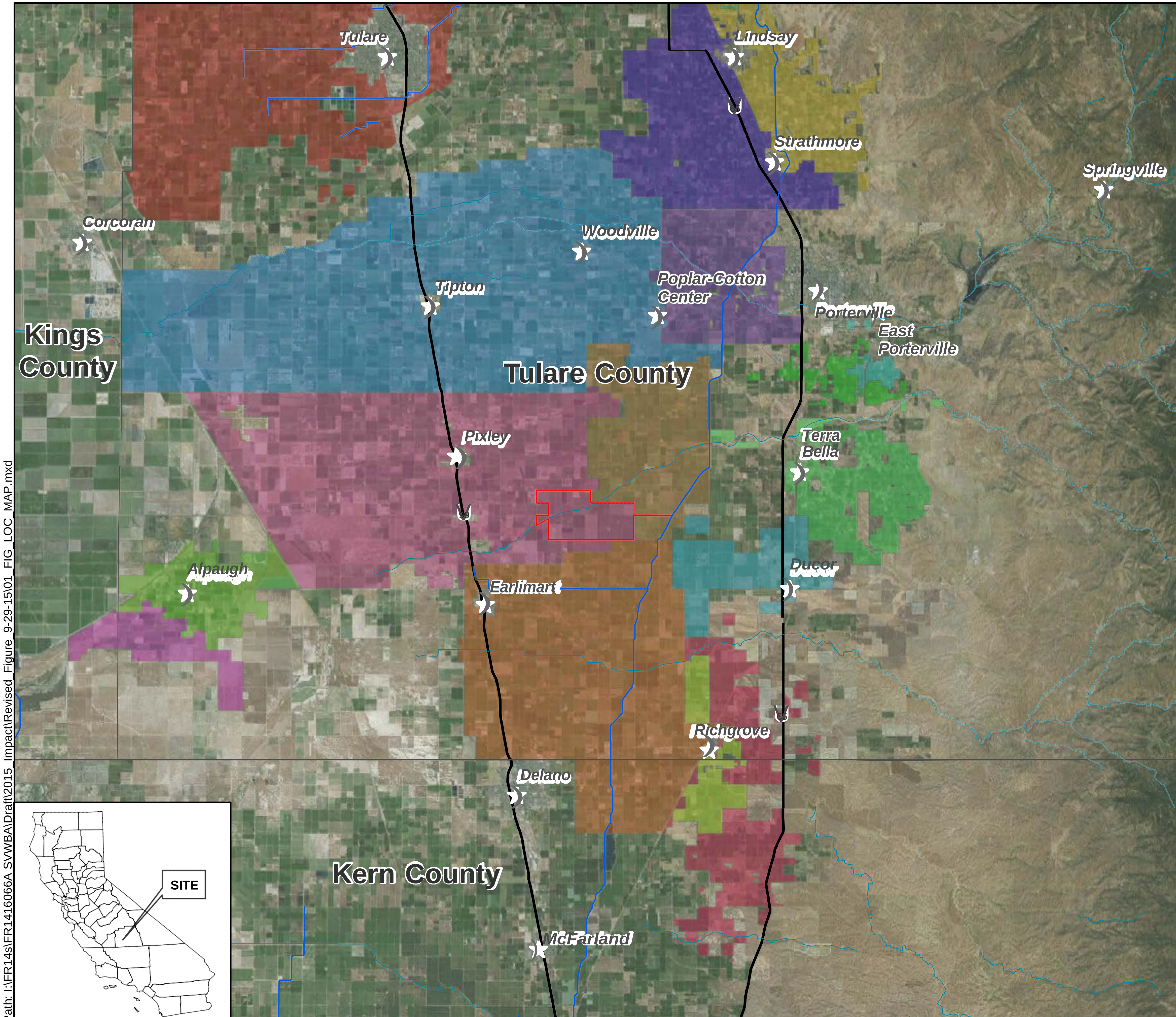


Explanation

- Proposed ground water banking project
- County boundary
- Canal
- Rivers and streams
- Major roads

Water Districts

- Alpaugh I.D.
- Alta I.D.
- Atwell Island W.D.
- Delano-Earlimart I.D.
- Ducor I.D.
- Exeter I.D.
- Ivanhoe I.D.
- Kern-Tulare W.D.
- Lewis Creek W.D.
- Lindmore I.D.
- Lindsay-Strathmore I.D.
- Lower Tule River I.D.
- Pixley I.D.
- Porterville I.D.
- Rag Gulch W.D.
- Saucelito I.D.
- St. Johns W.D.
- Tea Pot Dome W.D.
- Terra Bella I.D.
- Tulare I.D.
- Vandalia I.D.

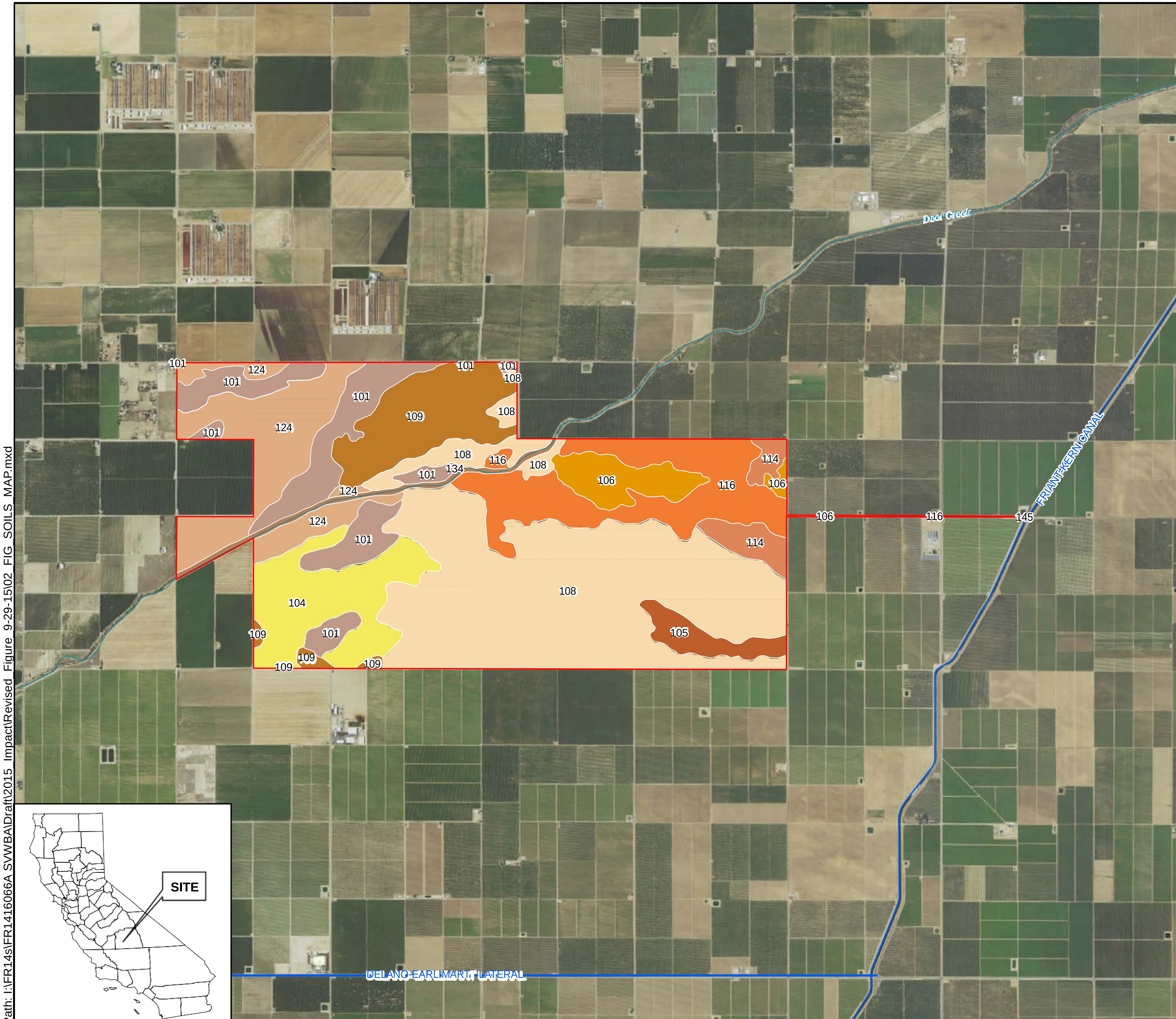
Miles
0 2.25 4.5 9

Basemap modified from ESRI online shared content, aerial imagery web mapping services.

LOCATION MAP
PIXLEY GROUNDWATER BANKING PROJECT
Geologic and Hydrologic Impacts Analysis
Tulare County, California

amec foster wheeler

Date: 12/17/2015	Project No. FR141606A	Figure
Submitted By: DMB	Drawn By: JWT	1



Explanation

Proposed ground water banking project

Canal

Rivers and streams

Soil Type

101 - Akers-Akers, saline-Sodic, complex

104 - Biggriz-Biggriz, saline-Sodic, complex

105 - Calgro-Calgro, saline-Sodic, complex

106 - Centerville clay

108 - Colpien loam

109 - Crosscreek-Kai association

114 - Exeter loam

116 - Flamen loam

124 - Hanford sandy loam

134 - Riverwash

145 - Water-perennial

Miles

0 0.35 0.7 1.4

Basemap modified from ESRI online shared content, aerial imagery web mapping services.

SOIL MAP
PIXLEY GROUNDWATER BANKING PROJECT
Geologic and Hydrologic Impacts Analysis
Tulare County, California

amec foster wheeler

Date: 12/16/2015	Project No. FR141606A	Figure
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