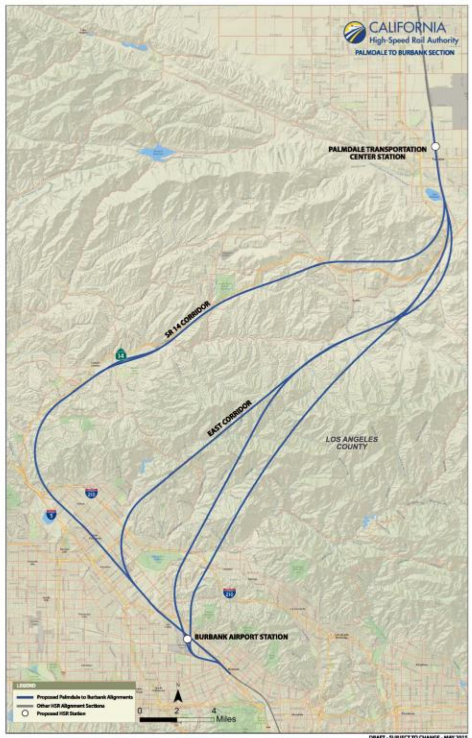
HIGH SPEED RAIL AUTHORITY

PHASE 1
GROUNDWATER STUDY
PALMDALE TO BURBANK SECTION



March 2016

California State University, Fullerton
Department of Geological Sciences

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PHASE 1
GROUNDWATER STUDY
PALMDALE TO BURBANK SECTION

Authored by

W. Richard Laton, Ph.D., PG, CHg

Reviewed by

Prepared in Cooperation with and
Submitted to

California High-Speed Rail Authority

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TABLE OF CONTENTS

1.0 Introduction

The California High-Speed Rail Authority (Authority) is responsible for planning, designing, building and operation of the first high-speed rail system in the nation. California's electric high-speed rail will connect the mega-regions of the state, contribute to economic development and a cleaner environment, create jobs and preserve agricultural and protected lands. By 2029, the system will run from San Francisco to the Los Angeles basin in under three hours at speeds capable of over 322 kilometers per hour (kmph)(200 miles per hour(mph)). The system will eventually extend to Sacramento and San Diego, totaling 1,288 kilometers (km) (800 miles (mi)) with up to 24 stations. In addition, the Authority is working with regional partners to implement a statewide rail modernization plan that will invest billions of dollars in local and regional rail lines to meet the state's 21st century transportation needs [REF]

The Palmdale to Burbank Project Section connects the Antelope Valley to the San Fernando Valley in Southern California. Two distinct high-speed rail corridors with multiple alignment options are currently being considered: SR 14 Corridor and East Corridor.

This report will focus only on the Palmdale to Burbank Sections of the overall project. Additionally this report focusses on groundwater and the potential impacts the high-speed rail system will have on this resources.

1.1 Location of Study Area

The following is an excerpt from the California High-Speed Rail Authority, Palmdale to Burbank Supplemental Alternative Analysis Report, June 2015.

In the City of Palmdale, all East Corridor alignment alternatives would begin at-grade on the west side of Sierra Highway near Avenue O. The alternatives would run parallel to and approximately 61 meters (m) (200 feet (ft)) west of the existing railroad ROW and continue south at-grade before approaching the existing PTC. The alternatives would accommodate the proposed HSR station in the vicinity of Avenue Q, 0.4 km (0.25 mi) south of the existing PTC. South of the PTC, the alternatives would continue at-grade and enter the existing 6th Street East ROW. The alternatives would remain in the 6th Street East ROW for approximately one mile before approaching Avenue R. South of Avenue R, the alternatives would continue through developed and undeveloped areas, crossing Sierra Highway at East Avenue S. South of Avenue S, the alternatives would continue east of Lake Palmdale and cross over Una Lake. Near Una Lake and Lake Palmdale, the alternatives would enter the San Andreas Fault Zone. The crossing of this fault must be essentially "at-grade," i.e. on low embankment, in shallow cut, or at-grade. Up to this point, all the East Corridor alternatives are identical (See Figure XX).

1.1.1 E1a Alignment Alternative

South of Lake Palmdale, this alternative would pass over the California Aqueduct. South of the California Aqueduct, this alternative would continue south and cross the interchange between Sierra Highway and SR14, approximately 100 m (330 ft) east of SR14. Continuing south, the alternative would cross an existing parking lot and vacant areas before crossing the intersection of Sierra Highway and Angeles Forest Highway. Approximately 76.2 m (250 ft) south of the intersection of Sierra Highway and Angeles Forest Highway, the alternative would cross the Metrolink Antelope Valley line. The alternative would continue south running between West Carson Mesa Road and Angeles Forest Highway, crossing Vincent View Road to the east of the Vincent Grade/Acton Metrolink Station. The alternative would run to the west of the Vincent Substation (an electrical substation operated by Southern California Edison).

South of Vincent Substation, the alternative would enter an approximately 3.0 km (1.9 mi) tunnel, rising to an at-grade profile outside the Angeles National Forest approximately 0.6 km (0.4 mi) east of the intersection of Aliso Canyon Road and West Avenue Y8.

The alternative would continue above ground for approximately 0.8 km (0.5 mi), crossing Aliso Canyon Road, and then enter a tunnel approximately 2.6 km (1.6 mi) long, partially within the Angeles National Forest boundary. As the alternative comes out of the Angeles National Forest boundary, the alignment becomes at-grade again for 4.8 km (3 mi). The alternative would cross Arrastre Canyon Road, Moody Truck Trail, Bootlegger Canyon Road, and one watercourse. This above-ground section roughly parallels the Santa Clara River in Soledad Canyon. At its closest point, the alternative is approximately 0.4 km (0.25 mi) from the Santa Clara River.

Approximately 1 km (0.6 mi) west of Bootlegger Canyon Road, this alternative would enter a 27.5 km (17.1 mi) tunnel which would pass under the San Gabriel Mountains and San Gabriel Mountains National Monument. The E1a/b alignment presented in this SAA is shifted to the west, and is in a longer tunnel than the E1 alignment presented at the public open house meetings in December 2014. As design for this alternative advances, every effort will be made to utilize existing service roads for construction and maintenance access where possible, but some re-grading may be necessary to meet access requirements to portals and other structures, as well emergency access/egress for first responders.

The tunnel continues under the northeast part of the Community of Pacoima in the City of Los Angeles and would end at approximately Montague Street just north of its intersection with San Fernando Road. The alternative would be in trench through existing industrial and commercial areas, and would then cross the channelized Tujunga Wash. South of Tujunga Wash the alternative would merge with Metrolink's Antelope Valley Line corridor, and follow it until the Burbank Airport Station, with grade separating cross streets as necessary.

1.1.2 E1b Alignment Alternative

South of Lake Palmdale, this alternative would pass over the California Aqueduct. South of the California Aqueduct, this alternative would cross Pearblossom Highway and the Metrolink Antelope Valley line near Pearblossom Highway's intersection with SR14. South of East Carson Mesa Road, this alternative would enter an approximate 1.9 km (1.2 mi) tunnel, rising to an at-grade and viaduct profile as it passes east of the Vincent Substation. South of Vincent Substation, the alternative would cross Angeles Forest Highway and enter an approximate 3.2 km (2.0 mi) tunnel bearing southwest. Part way into this tunnel, the alternative would enter the Angeles National Forest.

At the other end of the tunnel, the alternative would continue above ground for approximately 0.8 km (0.5 mi), crossing Aliso Canyon Road, and then enter a tunnel approximately 2.7 km (1.7 mi) long, partially within the Angeles National Forest boundary. As the alternative comes out of the Angeles National Forest boundary, the alignment would be at-grade again for 4.3 km (2.7 mi). The alternative would then cross Arrastre Canyon Road, Moody Truck Trail, Bootlegger Canyon Road, and one watercourse. This above-ground section roughly parallels the Santa Clara River in Soledad Canyon. At its closest point, the alternative is approximately 0.4 km (0.25 mi) from the Santa Clara River.

Approximately 1 km (0.6 mi) west of Bootlegger Canyon Road, this alternative would enter a 27.5 km (17.1 mi) tunnel which would pass under the San Gabriel Mountains and San Gabriel Mountains National Monument. The E1a/b alignment presented in this SAA has shifted to the west, and is in a longer tunnel than the E1 alignment presented at the public open house meetings in December 2014. As design for this alternative advances, every effort will be made to utilize existing service roads for construction and maintenance access where possible, but some re-grading may be necessary to meet access requirements to portals and other structures, as well emergency access/egress for first responders.

The tunnel continues under the northeast part of the Community of Pacoima and would end at approximately Montague Street just north of its intersection with San Fernando Road. The alternative would be in trench through existing industrial and commercial areas, and would then cross the channelized Tujunga Wash. South of Tujunga Wash, the alternative would merge with Metrolink's Antelope Valley Line corridor, and follow it until the Burbank Airport Station, with grade separating cross streets as necessary.

1.1.3 E2a Alignment Alternative

South of Lake Palmdale, this alternative would pass over the California Aqueduct. South of the California Aqueduct, this alternative would continue south and would cross the interchange between Sierra Highway and SR14, approximately 91.4 m (300 ft) east of SR14. Continuing south, the alternative would cross an existing parking lot and vacant areas, before crossing the intersection of Sierra Highway and Angeles Forest Highway. Approximately 76 m (250 ft) south of the intersection of Sierra Highway and Angeles Forest Highway, the alternative would cross the Metrolink Antelope Valley line. The alternative would continue south running between West Carson Mesa Road and Angeles Forest Highway, crossing Vincent View Road to the east of the Vincent Grade/Acton Metrolink Station. The alternative would run to the west of the Vincent Substation.

South of Vincent Substation, the alternative would enter an approximately 2.4 km (1.5 mi) tunnel, rising to an at-grade profile outside the Angeles National Forest approximately 0.6 km (0.4 mi) east of the intersection of Aliso Canyon Road and West Avenue Y8.

The alternative would continue above ground for approximately 0.8 km (0.5 mi), crossing Aliso Canyon Road, and then enter a tunnel approximately 2.6 km (1.6 mi) long, partially within the Angeles National Forest boundary. As the alternative comes out of the Angeles National Forest boundary, the alignment becomes at-grade again for three miles. The alternative would cross Arrastre Canyon Road, Moody Truck Trail, Bootlegger Canyon Road, and one watercourse on viaduct. This above-ground section approximately parallels the Santa Clara River in Soledad Canyon. At its closest point, the alternative is approximately 0.4 km (0.25 mi) from the Santa Clara River.

This alternative then enters an approximate 19 km (12 mi) tunnel in a similar location to the start of the E1a's 27.5 km (17.1 mi) tunnel, but bears a more southerly direction through the San Gabriel Mountains and San Gabriel Mountains National Monument. As design for this alternative advances, every effort will be made to utilize existing service roads for construction and maintenance access where possible, but some re-grading may be necessary to meet access requirements to portals and other structures, as well emergency access/egress for first responders.

The tunnel's south portal is outside of the Angeles National Forest boundary in the Lake View Terrace neighborhood along Dominica Avenue. Through the Lake View Terrace area, this alternative would pass through the Lake View Terrace neighborhood at-grade and on structures in-between Wheatland and Dominica Avenues. The alternative would cross on a viaduct profile over Foothill Boulevard, the Interstate (I) 210 freeway, and Tujunga Wash. South of the Tujunga Wash, the alternative would cross Wentworth Street, and then enter a four mile tunnel under the Shadow Hills neighborhood and turn east on a 257 kmph (160 mph) curve. The alternative then enters the City of Burbank in cut-and-cover tunnel, continuing to an underground Burbank Airport Station.

Since this alternative does not join Metrolink's Antelope Valley Line at the Bob Hope Airport, additional tracks would have to be constructed south of the underground Burbank Airport Station to provide a route for HSR trains to join the Antelope Valley Line and ultimately lead to LAUS. To accomplish this, the route will be constructed in cut section and will join the Metrolink Ventura County Line east of North Hollywood Way, and then curve to the south at West Burbank Boulevard to begin joining the Antelope Valley Line. A 0.4 km (0.25 mi) south of West Burbank Boulevard, this alternative would join the Metrolink Antelope Valley Line. The curves required for merging with the Ventura County Line and then the Antelope Valley Line corridors have reduced speeds of 161 kmph (100 mph).

1.1.4 E2b Alignment Alternative

South of Lake Palmdale, this alternative would pass over the California Aqueduct. South of the California Aqueduct, this alternative would cross Pearblossom Highway and the Metrolink Antelope Valley line near Pearblossom Highway's intersection with SR14, requiring new HSR structures. South of East Carson Mesa Road, this alternative would enter an approximate 1.9 km (1.2 mi) tunnel, rising to an at-grade profile as it passes east of the Vincent Substation. South of Vincent Substation, the alternative would cross Angeles Forest Highway and enter an approximate 2.9 km (1.8 mi) tunnel bearing southwest. Part way into this tunnel, the alternative would enter the Angeles National Forest.

At the other end of the tunnel, the alternative would continue above ground for approximately 0.8 km (0.5 mi), crossing Aliso Canyon Road, and then enter a tunnel approximately 2.7 km (1.7

mi) long, partially within the Angeles National Forest boundary. As the alternative comes out of the Angeles National Forest boundary, the alignment is at-grade again for 4.8 km (3 mi). The alternative would cross Arrastre Canyon Road, Moody Truck Trail, Bootlegger Canyon Road, and one watercourse on new structures. This above-ground section approximately parallels the Santa Clara River in Soledad Canyon. At its closest point, the alternative is approximately 0.4 km (0.25 mi) from the Santa Clara River.

This alternative then enters an approximately 19.3 km (12 mi) tunnel in a similar location to the start of the E1a’s 27.5 km (17.1 mi) tunnel, but bears a more southerly direction through the San Gabriel Mountains. As design for this alternative advances, every effort will be made to utilize existing service roads for construction and maintenance access where possible, but some re-grading may be necessary to meet access requirements to portals and other structures, as well emergency access/egress for first responders.

The tunnel’s south portal is outside of the Angeles National Forest boundary in the Lake View Terrace neighborhood along Dominica Avenue. Through the Lake View Terrace area, this alternative would pass through the Lake View Terrace neighborhood at-grade and on structures in-between Wheatland and Dominica Avenues. The alternative would cross on a viaduct over Foothill Boulevard, the I-210 freeway, and Tujunga Wash. South of the Tujunga Wash, the alternative would cross Wentworth Street, and then enter a four mile tunnel under the Shadow Hills neighborhood and turn east on a 258 kmph (160 mph) curve. The alternative then enters the City of Burbank in cut-and-cover tunnel, continuing to an underground Burbank Airport Station.

Since this alternative does not join Metrolink’s Antelope Valley Line at the Bob Hope Airport, additional tracks would have to be constructed south of the underground Burbank Airport Station to provide a route for HSR trains to join the Antelope Valley Line and ultimately lead to LAUS. To accomplish this, the route will be constructed in cut section and will join the Metrolink Ventura County Line east of North Hollywood Way, and then curve to the south at West Burbank Boulevard to begin joining the Antelope Valley Line. A 0.4 km (0.25 mi) south of West Burbank Boulevard, this alternative would join the Metrolink Antelope Valley Line. The curves required for merging with the Ventura County Line and then the Antelope Valley Line corridors have reduced speeds of 161 kmph (100 mph).

1.1.5 E3a Alignment Alternative

South of Lake Palmdale, this alternative would pass over the California Aqueduct. South of the California Aqueduct, this alternative would continue south and would cross the interchange between Sierra Highway and SR14, approximately 77.7 m (255 ft) east of SR14. Continuing south, the alternative would cross an existing parking lot and vacant areas, before crossing the intersection of Sierra Highway and Angeles Forest Highway. Approximately 76.2 m (250 ft) south of the intersection of Sierra Highway and Angeles Forest Highway, the alternative would cross the Metrolink Antelope Valley line. The alternative would continue south running between West Carson Mesa Road and Angeles Forest Highway, crossing Vincent View Road to the east of the Vincent Grade/Acton Metrolink Station. The alternative would run to the west of the Vincent Substation.

South of Vincent Substation, the alternative would enter a 2.6 km (1.6 mi) tunnel, rising to an at-grade profile outside the Angeles National Forest approximately 0.8 km (0.5 mi) east of the intersection of Aliso Canyon Road and West Avenue Y8. The alternative continues above ground in a southwesterly direction for approximately 0.8 km (0.5 mi), crossing Aliso Canyon Road. The alternative then enters a 21 km (13 mi) long tunnel from the outside of the Angeles National Forest. The E3a/b alignment presented in this SAA is shifted to the east as compared to the E3 alignment presented at the public open house meetings in December 2014. As design for this alternative advances, every effort will be made to utilize existing service roads for construction and maintenance access where possible, but some re-grading may be necessary to meet access requirements to portals and other structures, as well emergency access/egress for first responders.

The alternative continues in a tunnel heading southwest through the Angeles National Forest, entering the City of Los Angeles east of the Lake View Terrace neighborhood. The tunnel alignment passes under the I-210 Freeway, Green Verdugo Reservoir, and La Tuna Canyon Road, where it curves east to continue in a southern direction.

The alternative emerges from the tunnel to a cut-and-cover profile approximately 61 m (200 ft) south of I-5. The alternative continues in a cut-and-cover profile between Claybeck Avenue and North Hollywood Way through an existing residential neighborhood. South of San Fernando Boulevard, the cut-and-cover portion of the alternative continues south, roughly parallel to North Hollywood Way, to the Burbank Airport Station.

Since this alternative does not join Metrolink's Antelope Valley Line at the Bob Hope Airport, additional tracks would have to be constructed south of the HSR station to provide a route for HSR trains to join the Antelope Valley Line and ultimately lead to Los Angeles Union Station. To accomplish this, the route will join the Metrolink Ventura County Line east of North Hollywood Way, and then curve to the south at West Burbank Boulevard to begin joining the Antelope Valley Line. A 0.4 km (0.25 mi) south of West Burbank Boulevard, this alternative would join the Metrolink Antelope Valley Line. The curves required for merging with the Ventura County Line and then the Antelope Valley Line corridors have reduced speeds of 161 kmph (100 mph).

1.1.6 E3b Alignment Alternative

South of Lake Palmdale this alternative would pass over the California Aqueduct. South of the California Aqueduct, this alternative would cross Pearblossom Highway and the Metrolink Antelope Valley line near Pearblossom Highway's intersection with SR14, requiring new bridge structures. South of East Carson Mesa Road, this alternative would enter an approximately 1.9 km (1.2 mi) tunnel, rising to an at-grade profile as it passes east of the Vincent Substation. South of Vincent Substation, the alternative would cross Angeles Forest Highway and enter an approximately two mile tunnel bearing southwest. Part way into this tunnel, the alternative would enter the Angeles National Forest.

At the other end of the tunnel, the alternative would continue above ground for approximately 0.8 km (0.5 mi), crossing Aliso Canyon Road, and then enter a tunnel approximately 21 km (13 mi) long, from the outside of the Angeles National Forest. The E3a/b alignment presented in this SAA is shifted to the east as compared to the E3 alignment presented at the public open house meetings in December 2014. As design for this alternative advances, every effort will be made to utilize existing service roads for construction and maintenance access where possible, but some re-grading may be necessary to meet access requirements to portals and other structures, as well emergency access/egress for first responders.

The alternative continues in a tunnel heading southwest through the Angeles National Forest, entering the City of Los Angeles east of the Lake View Terrace neighborhood. The tunnel alignment passes under the I-210 Freeway, Green Verdugo Reservoir, and La Tuna Canyon Road, where it curves east to continue in a southern direction.

The alternative emerges from the tunnel to a cut-and-cover profile approximately 61 m (200 ft) south of I-5. The alternative continues in a cut-and-cover profile between Claybeck Avenue and North Hollywood Way through an existing residential neighborhood. South of San Fernando Boulevard, the cut-and-cover portion of the alternative continues south, roughly parallel to North Hollywood Way, to the Burbank Airport Station.

Since this alternative does not join Metrolink's Antelope Valley Line at the Bob Hope Airport, additional tracks would have to be constructed south of the HSR station to provide a route for HSR trains to join the Antelope Valley Line and ultimately lead to Los Angeles Union Station. To accomplish this, the route will join the Metrolink Ventura County Line east of North Hollywood Way, and then curve to the south at West Burbank Boulevard to begin joining the Antelope Valley Line. A 0.4 km (0.25 mi) south of West Burbank Boulevard, this alternative would join the Metrolink Antelope Valley Line. The curves required for merging with the Ventura County Line and then the Antelope Valley Line corridors have reduced speeds of 161 kmph (100 mph).

1.2 Adjudicated Basin Boundaries

California groundwater basins are identified based on geographical and hydrological conditions, and political boundary lines are also considered whenever practical [DWR, 1980]. The state of California is divided into 11 separate hydrologic regions [DWR, 2003]. Within these regions there are a total of 431 groundwater basins. Of the 431 groundwater basins, 24 of them are further divided into 108 sub-areas [DWR, 2003]. The Palmdale to Burbank section starts in the Antelope Valley Groundwater Basin, crosses near the Acton Valley Groundwater Basin and the Santa Clara River Valley East Groundwater Sub-basin and ends in the San Fernando Valley Groundwater Basin.

The San Fernando Valley Groundwater Basin is part of the Upper Los Angeles River Area (ULARA) adjudication. The adjudication started in 1955 and was finalized in 1979. The basin is comprised of four distinct groundwater basins and their adjoin hill and mountain watershed areas make up the ULARA. These are the San Fernando, the Sylmar, the Verdugo and the Eagle Rocks groundwater basins (See Figure XX)[ULARA Watermaster, 2014].

Both Acton and Santa Clara River Valley East are non-adjudicated groundwater basins at the present time.

Antelope Valley Groundwater Basin was recently adjudicated, December 2015. The Antelope Valley Basin stretches from the base of the San Gabriel Mountains to the base of the Tehachapi Mountains to Edwards Air Force Base to the Los Angeles county line to the east (See Figure XX)[REF].

1.3 Purpose and Goals

The California High Speed Rail Authority (Authority) is conducting a study related to groundwater issues in the Palmdale to Burbank Section. This section includes track alignment alternatives that generally follow the alignment of State Route 14 as well as alignments which follow a more direct route through the San Gabriel Mountain range. All of the routes being considered would include extensive tunneling efforts. It is anticipated that there could be interaction between the tunneling activities and existing groundwater resources in all of these alternatives.

The focus of the study would be to explore the interaction between groundwater resources in the San Gabriel Mountain range, and the San Fernando and Antelope Valley aquifer systems. The study would develop a desktop level groundwater model of this interaction. This study would supplement and would be in addition to the geologic/hydrogeological technical studies to be done to support the Palmdale to Burbank environmental document.

This information will be used to consider the potential impacts to groundwater and understand how to properly implement the project.

2.0 Background

2.1 Regional Climate

The climate within the Los Angeles County varies between subtropical on the Pacific Ocean side of the San Gabriel Mountain range to arid in the Mojave Desert. Nearly all precipitation occurs during the months of December through March. Precipitation during summer months is infrequent, and rainless periods of several months are common. Snowfall at elevations above 1,524 m (5,000 ft) is frequently experienced during the winter storms, but the snow melts rapidly except on higher peaks and the northern slopes. Snow is rarely experienced on the coastal plain [LACDPW, 2015].

In mountain areas, the steep canyon slopes and channel gradients promote a rapid concentration of storm runoff. Depression storage and detention storage effects are minor in the rugged terrain. Soil moisture during a storm has a pronounced effect on runoff from the porous soils supporting a good growth of deep-rooted vegetation such as chaparral. Soil moisture deficiency is greatest at the beginning of a rainy season, having been depleted by the evapotranspiration process during the dry summer months. Precipitation during periods of soil moisture deficiency is nearly entirely absorbed by soils, and except for periods of extremely intense rainfall, significant runoff does not occur until soils are wetted to capacity. Due to high infiltration rates and porosity of mountain soils, runoff occurs primarily as subsurface flow or interflow in addition to direct runoff. Spring or base flow is essentially limited to portions of the San Gabriel Mountain range. Consequently, most streams in the County are intermittent [LACDPW, 2015].

The study area is located within three evapotranspiration (ETo) zones. Zone 9 (South Coast Marine to Desert Transition) which represents the area between marine and desert climates. Zone 14 (Mid-Central Valley and the Southern Sierra Nevada, Tehachapi, and High Desert Mountains) is characterized by high summer sunshine and winds. Zone 17 covers the "High Desert Valleys," which is considered by CIMIS [2012] to be high desert near Nevada and Arizona. Groundwater resources in the study area take on a particular resonance when one considers that the rate of water loss due to evapotranspiration is greater than annual precipitation in the low lying areas and the opposite at the higher elevations. (Figure XX).

2.2 Vegetation

Vegetation varies throughout the study area. The upper mountain areas consist of various species of brush and shrubs known as chaparral. Most trees found on mountain slopes are oak, with alder, willow, and sycamore found along streambeds at lower elevations. Pine, cedar, and juniper are found in ravines at higher elevations and along high mountain summits.

Grasses are the principal natural vegetation on the hills. Much of the hill land and nearly all of the valley land in the densely populated portion of the County south of the San Gabriel Mountains has been converted to urban and suburban use [LACDPW, 2015].

3.0 Geology

3.1 Western San Gabriel Mountains

The San Gabriel Mountains are a narrow range of basement rock forming an east-west barrier between the Mojave Desert and the Los Angeles Basin. The mountain range has risen rapidly being less than two million years old and is still rising. The highest peaks in the range are in the eastern portion of the range which includes Mt. San Antonio (Mt. Baldy) at 3,068 m (10,066 ft) above sea level. These high mountains are north of San Gabriel Canyon and the mountain system descends to lower crest heights westward toward Soledad Canyon. A lower set of mountains is present south of San Gabriel Canyon and a separate range called Verdugo Mountain lies between Burbank and Tujunga Wash. The mountain system is cut by many northeast trending faults and bounded by active northwest and east-west faults known to have generated earthquakes of substantial magnitude in the past.

Overall, the mountainous terrain is steep and rugged and has experienced rapid downcutting creating narrow steep river valleys with waterfalls and has abundant ancient and recently active landslides that can block or divert drainages. Extensive alluvial fans spread out from the southern flanks of the mountain range into the San Fernando, San Gabriel and San Bernardino Valleys as well as onto the Mojave Desert. These broad coarse fans hold abundant water and are the forebay recharge regions of the large groundwater basins in the valleys mentioned above.

Uplift and erosion of the mountain range has exposed rocks from the lower crust dated as Proterozoic (1.19 billion years old). Additionally, the uplift has exposed Miocene age granitic rocks in the eastern portion; rocks thoughts to have crystallized at a depth of 12-20 km (7.5 – 12.4 mi). The uplift is accommodated by active extensive fault systems along the periphery of the mountains including the San Andreas System of lateral right-slip faulting between the San Gabriels and the Mojave Desert and the Sierra Madre-Raymond Hill-Cucamonga system of thrust faults upon which the San Gabriel Mountains are overriding the Los Angeles Basin and Perris Block rocks of the Peninsular Ranges. The San Gabriel Fault System within the San Gabriel Range separates the Mountain Block into two separate Ranges with a long narrow river valley occupying the fault zone for most of its trace from Soledad Basin to the eastern San Gabriel Mountains.

3.2 Rock Units along Routes

The rocks underlying the proposed routes for the HSR are easily grouped into the sedimentary and volcanic rocks of the SR-14 route and the igneous and metamorphic rocks of the eastern routes. The rocks along the SR-14 route include the deep marine sedimentary rocks of the Eastern Ventura Basin. These are an uplifted and folded sequence of Miocene to Pliocene age marine and non-marine sedimentary and volcanic rocks that lie on exposed Proterozoic syenites at the eastern end of the route. As the route alignments merge to the east the rocks of the Vazquez Rocks Miocene Volcanic basin underlie the routes until they cross the various strands of the San Andreas Fault Zone and drop onto the young sediments of the Antelope Valley and Palmdale. The eastern Routes cross through various igneous rock formations of Cretaceous and older age and the anorthosite complex that forms the bulk of the route alignment and western San

Gabriel Mountains. The more western route will involve tunneling through the active Placerita Oil Field while the eastern routes will go through an area once actively mined for gold and other metals.

3.2.1 SR-14 Rock Sequence

This western route will parallel the existing 5 freeway to the 210 interchange where it will enter a tunnel. Tunneling is proposed to begin as the route crosses the Santa Susana fault zone, a thrust fault that extends westerly to the Oak Ridge system in Ventura. This thrust system is active and inclined to the north. The upper plate rocks of marine sediments are thrust over marine rocks and recent alluvium of the San Fernando Valley. The bored section will enter marine rocks of the Pico Formation and Towsley Formation. These are marine conglomerates, sandstones and shales described by Kew (1924) and Winterer and Durham (1962) that are oil bearing and which here lap eastward onto diorite gneiss rocks of Mesozoic age. The initial section of the tunnel may enter this layered gneissic rock below the Towsley Formation.

The tunnel route bends to the east following SR-14 and will cross the San Gabriel fault as the route straightens. The San Gabriel fault is a northwest trending strike-slip fault largely active in Miocene to Pliocene times (Crowell, 1952) but thought to be still active now, (Petersen and Wesnousky, 1994). The fault is a zone of shearing that is mostly vertical and a source of large scale lateral movement. Active faults can be barriers to groundwater flow and can also be conduits for flow. Eastward from the fault zone, the route traverses more of the Towsley Formation sandstones and shales then the continental conglomerates and sandstones of the Saugus Formation, Mint Canyon Formation, Tick Canyon Formation. These rock units were initially described by Hershey (1902) and Winterer and Durham (1954, 1962). Unconformably below the Tick Canyon Formation are the volcanic conglomerates and sandstones of the Vasquez Formation with a thick sequence of andesitic and basaltic volcanic flow rocks below the sedimentary sequence. This group of Soledad Basin sediments and volcanic rocks are folded and faulted and lie nonconformably on syenite, gneiss and granodiorite of Triassic and older age. The Vasquez Formation was first named by Sharp (1936).

Several northeast trending faults cut the Soledad Basin group of rocks including the Mint Canyon, Tick Canyon and Aqua Dulce faults. These are normal faults down to the southeast. The entire sequence is block faulted down to the east by a north northwest trending normal fault with a thick basaltic sequence of the Vasquez Formation repeated to the east. As the route goes through the Acton Basin it is mainly through Triassic granodiorite of the Mount Lowe Intrusive Suite of rocks with isolated basalts of the Vasquez throughout the region. The Mount Lowe Granodiorite was originally described and named by Miller (1934), then termed the Mount Lowe Intrusion by Barth and Ehlig (1988) as a broader description of the rock sequence and dated at 220 ±14 my by Silver (1971) making it Triassic. It is unusual in age for a granitic formation in Southern California and unusual in appearance being uniformly light colored with large hornblende and feldspar phenocrysts throughout.

As the route turns north into Palmdale, it will emerge from the tunnel and cross the San Andreas Fault System. The San Andreas System is a series of vertical right-lateral strike-slip faults trending northwest and continuous through the Transverse Ranges. It is active and experiences large earthquakes associated with significant offset during major events. The faults are major barriers to groundwater flow and confining zones between the strands maintain large lakes known as sag ponds supported by lateral flows of groundwater within the fault zone.

3.2.2 Eastern Routes Rock Sequence

Three corridors are planned from the Burbank Station through the San Gabriel Mountains. Each of these will cross the Verdugo, Sierra Madre, Santa Susana, San Gabriel and San Andreas Fault zones as well as several secondary northeast trending faults in the mountains. Only one route is planned through the Verdugo Mountains which are composed of Cretaceous granodiorite rocks. The deepest sections of the tunnel will be as much as 2 km (3,500 ft) deep. The two northern tracks will begin tunneling in the alluvial area of San Fernando Valley then turn northeast and cross the Sierra Madre thrust fault system. These routes enter rocks of the Towsley Formation (marine sandstones, conglomerates and shales) and a folded sequence of the Saugus Formation before crossing the southeast trending San Fernando fault, a thrust fault that is part of the Santa Susana-Oak Ridge thrust fault system. Both thrust systems dip to the north under the mountains. Rocks between the thrust fault systems and the San Gabriel Fault are Cretaceous granodiorite and Mesozoic hornblende diorite. These are equidimensional rock units that are not formally named into rock formations. They are portions of the Southern California Batholith, a long association of middle composition granitic rock plutons. Directly adjacent to the San Gabriel fault are a thin depositional basin of Saugus Formation sandstones and conglomerates. Where the three routes cross the San Gabriel fault, the fault is a wide zone of shearing with separate faults about a kilometer or two apart.

Once across the San Gabriel fault zone, the routes will enter Mesozoic diorite gneiss and grandodiorite before crossing into the Mendenhall gneiss and the anorthosite-gabbro complex. Mendenhall gneiss, first named and mapped by Oakshott (1958) and dated as older than 1,200 Ma, it is a linear band of layered dark felsic gneiss and granulite with augen gneiss in places. The anorthosite-gabbro complex is a gray to greenish black gabbroic anorthosite to norite composition and usually has a layered appearance. The rock is Proterozoic but younger than the Mendenhall Gneiss and has been dated at 1,200 Ma by Barth and others (1995). As the routes move eastward they will traverse northeast trending vertical normal faults, primarily the Transmission Line fault. Once across that fault the routes enter rocks of the Triassic age Mount Lowe Intrusives. These rocks were described above.

3.3 Faulting

Active faults are present throughout the project area and vary from thrust style faulting to large offset strike-slip faulting. In addition, a large number of inactive to undetermined activity normal and reverse faults are also present. Active faults can create several types of hazards for the rail system including strong shaking (greater than 1.0g accelerations), seismically induced landslides or rock bursts, changes in groundwater and groundwater flow, liquefaction, rail deflection, and direct offset causing severed power and rail lines. Although earthquake and fault behavior can be predicted with some statistical accuracy, the timing of earthquakes is still not predictable in terms useful to society. The ability to respond to earthquake initial seismic ground motions has been shown to allow for some safety to rail systems by stopping the train automatically when compressional waves first strike; however, the system still must survive the strong shearing motions which follow.

3.3.1 Active Thrust Faults

A thrust fault is a low angle reverse structure on which the upper plate of rocks is pushed over the lower plate rocks on angles less than about 25º. Faults steeper than this are called Reverse Dip-Slip faults. The Verdugo, Sierra Madre and Santa Susana-San Fernando faults are active thrust faults that the rail system must cross. Slip motions are primarily vertical although some lateral or oblique motion can accompany the movement. The Verdugo fault lies parallel to the Verdugo Mountains in the San Fernando Valley and strikes northwest. The Sierra Madre fault zone parallels the base of the San Gabriel Mountains, one of several strands that parallel the southern base of the San Gabriel Mountains from Malibu to Cucamonga. The Santa Susana fault traces east from the Santa Susana Mountains into the north end of the San Fernando Valley and then as the San Fernando fault which crosses the valley and terminates near the San Gabriel fault around Tujunga Wash.

3.3.1.1 Verdugo fault

The Verdugo fault is mostly buried or concealed under the alluvium of the San Fernando Valley along the southwest side of the Verdugo Mountains. The fault can be traced through southern Verdugo hills near Verdugo Wash and south to its juncture with the Eagle Rock fault then ultimately south where the structure merges into the Raymond Hill fault, a portion of the Malibu Coast-Sierra Madre-Raymond Hill-Cucamonga frontal thrust system. The fault is a reverse fault that dips to the northeast and is capable of a Mw 6.0-6.8 earthquake. It is 21 km (13 mi) long and has an average slip rate of 0.5 millimeters (mm) (0.02 inches (in)) per year and has surface rupture features dated as Holocene but older in the northwest segment of the fault (SCEDC, 2013; Jennings, 1994: Wesnousky, 1986).

3.3.1.2 Sierra Madre fault

Sierra Madre fault is one of several stands of the Malibu Coast-Cucamonga fault system or frontal fault system along which the San Gabriel and Santa Monica Mountains have been uplifted. The fault is a system of five segments arcing south east to east from the Vasquez Creek area near the San Gabriel fault to the area of Duarte. These segments are referred to as Segments A (Vasquez Creek), B, C, D (Duarte) and E which ties into other east trending faults near Upland. The total system is about 75 km (47 mi) long with each segment about 15 km (9.3 mi). The zone has had earthquakes along it in recent time and has Holocene rupture surfaces along the traces. It is anticipated to earthquakes of Mw 6.0-7.0 and has an average slip rate of 0.36 to 4.0 mm (0.014 to 0.157 in) per year (SCEDC 2013; Jennings, 1994; Wesnousky, 1986; Petersen and Wesnousky, 1994).

3.3.1.3 Santa Susana-San Fernando fault system

These are true thrust faults that dip northeast and extend through the Santa Susana Mountains and across the San Fernando Valley to Tujunga Wash near Sunland. The San Fernando fault is

17 km (10.6 mi) long and was the fault along which the Mw 6.6 San Fernando Earthquake of February 9, 1971 occurred. It moves at a rate of 5 mm (0.2 in) per year and is capable of Mw 6.0-6.8 events every 100-300 years (SCEDC, 2013; Jennings, 1994; Wesnousky, 1986; Petersen and Wesnousky, 1994).

3.3.2 Active Strike-slip Faults

Strike-slip faults are lateral faults that move either with right offset or left offset. Along the course of the rail routes are two such faults the San Gabriel and San Andreas fault zones, both of which are active faults. Both faults are right-lateral faults and both are composed of a zone of fault strands that parallel one another. These faults have offset rock units great distances and are part of the transform fault offset between the spreading ridges in the Gulf of California and the Juan de Fuca plate off Oregon and Washington. They are elements of the tectonic fabric of western north America and related to one another historically and tectonically. The San Andreas Fault is therefore a plate boundary fault separating the North American Plate with the Mojave Desert from the Pacific Plate with the San Gabriel Mountains. The San Gabriel fault zone is likely connected to the San Andreas fault at depth at its northern end and is thought to once have been the main plate boundary in Miocene and Pliocene time before the modern San Andreas was formed (Crowell, 1952; Crowell, 1982)

3.3.2.1 San Gabriel fault

The San Gabriel fault system is an old fault system that stretches from the Ridge Basin to the eastern San Gabriel Mountains. The fault is thought to tie into the San Andreas fault at depth to the north and may continue east of the San Gabriel Mountains as the Banning fault (Crowell, 1982; Morton, 1985). The fault splits into a north and south branch as the Vasquez Creek branch of the Sierra Madre fault system and is somehow obscured by the frontal fault system in the east. The northern branch continues past the intersection with the Sawpit-Clamshell fault through the eastern San Gabriel Mountains associated with the east and west branches of the San Gabriel River. The fault is a right lateral strike-slip fault that was primarily active in Miocene and Pliocene time but currently tends to be more active along the eastern branch of the system. However, Crowell (1962) reported upwards of 32 km (20 mi) of right lateral movement while Paschall and Off (1961) accounted for 4,267 m (14,000 ft) of accumulated breccia (Violin Breccia) on the north side of the fault through a dip-slip motion. Crowell (1982) further claimed that strike slip motion was the primary mechanism of the fault system with about 48 km (30 mi) of offset and with motion transferring from the San Gabriel fault to the San Andreas system at about the time of the Hungry Valley Formation. This formation is about 5 My old and was originally thought not to be cut by the San Gabriel fault until Weber (1982) showed faulted sections along the fault route. Current thinking is that the fault remains active particularly in the west where slip of 1 to 5 mm (0.04 to 0.2 in) a year may be happening (SCEDC 2013). The fault system dips steeply north.

3.3.3 San Andreas Fault Zone

The most significant structure in the study area is the active right-lateral strike-slip San Andreas Fault cutting through PalmdaleValley [SCEC, No date]. Sieh [1978] has demonstrated that this fault has had multiple large magnitude earthquakes in historical times. Large earthquakes of this nature have been shown to alter groundwater conditions [Townley and Allen, 1939]. Through the Palmdale area, the San Andreas forms en echelon surface breaks within which Lake Palmdale (a sag pond) is confined. Other branches of the system such as the Cemetery fault, Little Rock fault and Nadeau fault are concealed and possibly inactive older branches but may still impact groundwater and groundwater flow. These faults parallel the active trace of the San Andreas.

3.3.4 Inactive Faults

Several northeast trending normal faults are present at spaced intervals in the western San Gabriel Mountains including the Magic Mountain, Transmission Line and Clamshell-Sawpit Canyon (possibly active), Fox Creek and Mill Creek faults. Each of the faults is about 15-18 km (9.3 to 11.2 mi) long and are continuous vertical breaks that offset rock units.

4.0 Groundwater

4.1 Aquifer Boundaries

The project crosses several groundwater basins. The Palmdale to Burbank section starts in the Antelope Valley Groundwater Basin, crosses near the Acton Valley Groundwater Basin and the Santa Clara River Valley East Groundwater Sub-basin and ends in the San Fernando Valley Groundwater Basin. These groundwater basins typically follow watershed boundaries, but in some cases are geopolitical boundaries. This is best represented by the boundary between the Antelope Valley and El Mirage Valley groundwater basins.

4.1.1 Antelope Valley Groundwater Basin

The Antelope Valley groundwater basin is bounded by the Garlock fault zone to the northwest, the San Andreas Fault zone to the southwest, and by a drainage divide to the north through the low hills, ridges, and buttes that separate it from the Freemont Valley groundwater basin [DWR, 2004]. The eastern portion of the Antelope Valley groundwater basin is directly adjacent to the El Mirage Valley groundwater basin.

Lacustrine clay beds form deposits approaching a thickness of 122 m (400 ft) and comprise a zone of low permeability separating groundwater into an upper and lower aquifer. The upper aquifer is unconfined and provides the primary groundwater source for the Antelope Valley [DWR, 2004]. The lower aquifer is semi-confined where overlain by the lacustrine and upper aquifer deposits [Leighton and Phillips 2003].

Recharge to the Antelope Valley groundwater basin is primarily from surface water runoff infiltrating from the surrounding San Gabriel Mountains and foothills. The majority of the runoff is contributed by Big Rock Wash and Little Rock Creeks which rapidly percolates through alluvial fan systems [DWR, 2004].

Before development, the primary source of groundwater discharge from the Antelope Valley groundwater basin was through evapotranspiration and springs. Urban and agricultural groundwater development is now the primary source of discharge from the Antelope Valley groundwater basin [Leighton and Phillips 2003].

4.1.2 Acton Valley Groundwater Basin

Groundwater within the basin is considered unconfined and found within the shallow alluvium and stream deposits [DWR, 2004]. The basin is bounded by the Sierra Pelona on the north and the San Gabriel Mountains to the south, east and west. The valley itself is drained via the Upper Santa Clara River. Flow within the basin is generally to the south.

The alluvium deposits are of Holocene age and have a maximum thickness of 69 m (225 ft) near the City of Acton. The Terrace deposits reside along the low lying flanks of the foothills and the upper reaches of the river. The maximum thickness is on the order of 64 m (210 ft) towards the north of the City of Acton [DWR, 2004].

Recharge to the basin is from deep percolation of direct precipitation on the valley floor and runoff in the Santa Clara River and its tributaries. The basin also according to Slade, 1990 receives recharge via subsurface inflow.

4.1.3 Upper Santa Clara River Valley East Groundwater Basin

The Santa Clara River Valley East groundwater sub-basin is bound by Piru Mountains to the north, impervious rocks of the Modelo and Saugus Formations to the west, on the south by Santa Susana Mountains and on the south and east by the San Gabriel Mountains. Like the Acton Valley Groundwater Basin, the Santa Clara River Valley East basin is drained by the Santa Clara River as well as several smaller streams [DWR, 2006].

Groundwater within this basin is generally unconfined in the alluvium, but may be confined or semi-confined with in the Saugus Formation [Slade, 2002]. The alluvium and terrace deposits are the same as the Acton Valley basin deposits. The Saugus Formation is late Pliocene to early Pleistocene in age. This formation consists of as much as about 2,591 m (8,500 ft) of poorly consolidated, weakly indurated, poorly sorted, sandstone, siltstone, and conglomerate. The lower member of this rock unit is referred to as the Sunshine Ranch member. This member is not widely used for municipal or irrigation needs as the well yields are considered low. The upper member of the Saugus Formation contains lens of conglomerate and sandstone interbedded with mudstones. Well yields are typically greater in this member [Slade, 2002].

Groundwater can vary in depth greatly across the basin. With maximum depths to base of the fresh water being about 457 m (1,500 ft) northeast of the San Gabriel fault, 1,676 m (5,500 ft) between the San Gabriel and Holser faults, and about 1,524 m (5,000 ft) southeast of the Holser fault [Slade, 2002]. These faults appear to not to impact groundwater flow [Slade, 2002].

Recharge to the Saugus Formation is from infiltration of rainfall on the exposed formation and percolation of water from the alluvial aquifer [Slade, 2002]. Recharge to the alluvial aquifer is primarily from infiltration of runoff waters in the Santa Clara River and its tributaries [DWR, 1968].

4.1.4 Upper Los Angeles River Groundwater Basin

The groundwater basin is referred to as the San Fernando Valley Groundwater Basin and was adjudicated in 1979. The basin is bounded on the north and northwest by the Santa Susana Mountains, on the north and northeast by the San Gabriel Mountains, on the east by the San Rafael Hills, on the south by the Santa Monica Mountains and Chalk Hills, and on the west by the Simi Hills. The valley is ultimately drained via the Los Angeles River and its tributaries [DWR, 2004].

The groundwater in this basin resides within the lower Pleistocene Saugus Formation; Pleistocene and Holocene age alluvium and are primarily unconfined with some confinement within the Saugus Formation in the western part of the basin and in the Sylmar and Eagle Rock areas [CSWRB 1962].

The Holocene age alluvium deposits range in thickness of about 30.5 m (100 ft) in the north to a maximum of 274 m (900 ft) near the City of Burbank. Most of these deposits originate from coalescing alluvial fans emanating from the surrounding mountains [DWR, 2004].

Several structures disturb groundwater flow through the basin. A step in the basement resulting from movement on the Verdugo fault and/or the Eagle Rock fault causes a groundwater cascade down to the south near the mouth of Verdugo Canyon [CSWRB 1962]. To the north, the Verdugo fault is a partial barrier to flow that causes a change in water levels in the Hansen Spreading Grounds [CSWRB 1962]. Differences in rock type along the Raymond fault create a barrier to groundwater flow from the Eagle Rock area toward the Los Angeles River Narrows and may cause rising water conditions there [CSWRB 1962]. Other unnamed faults cause changes in levels of basement and groundwater in the Sunland, Chatsworth, and San Fernando areas and at the mouths of the Little Tujunga and Big Tujunga Canyons [CSWRB 1962]. The Little Tujunga syncline affects groundwater movement in the northern part of the basin and folds associated with the Northridge Hills, Mission Hills and Lopez faults also affect groundwater movement. Subsurface dams in the Pacoima Wash near Pacoima and in Verdugo Canyon are barriers to groundwater flow [CSWRB, 1962].

Recharge to the basin is from a variety of sources including the spreading of imported water and runoff that occurs in the Pacoima, Tujunga, and Hansen Spreading Grounds [ULARAW, 2014]. Runoff contains natural streamflow from the surrounding mountains, precipitation falling on impervious areas, reclaimed wastewater, and industrial discharges [ULARAW, 2014].

5.0 Conclusions

5.1 Geology

1. The rock sequence along the northern SR-14 route is mostly soft sedimentary formations that contain the Placerita oil field. When the route gets near Acton it will go into volcanic flow rocks and igneous and metamorphic rocks. The eastern routes will be almost entirely in igneous and metamorphic rocks.

2. Several northwest and northeast trending faults, both active and inactive, are present along the routes. These faults may create crushed zones and fractures that may hold large quantities of water and may impact the flow of groundwater. Impacts of the faults may cause groundwater flow along the fault traces or may create barriers to groundwater flow.

3. Fractured rock groundwater may be restricted to a certain depth throughout the crystalline rock areas but where groundwater is entrained in the fault systems it could travel to great depths and be quite old.

5.2 Groundwater

1. Based on a preliminary review of the data and background reports, there appears to be little to no information that would suggest any groundwater system impacts exist along these routes.

2. Knowledge of groundwater within the Antelope Valley and San Fernando Valley groundwater basins is generally well known. However, groundwater information from the higher elevations of the San Gabriel Mountains is less known. Little to no monitoring wells exists at the higher elevations.

3. In order to understand the groundwater resources within the San Gabriel Mountains the information from the new test wells will need to be analyzed.

4. It is reasonable to expect that geologic faults within the area impact groundwater flow. Exactly what that impact is (barrier or semi-barrier) is not known at this time.

5. Stratigraphic boundaries in the subsurface may also impact groundwater flow. This may or may not isolate various "pockets" of groundwater at depth. This could cause confined conditions at depth.

6. Impacts to the mountain front recharge due to tunneling operations may be very important to the lower lying groundwater basins. This water is calculated within the overall water budgets of the associated adjudicated groundwater basins.

7. Regional water budgets will need to be evaluated/calculated in order to quantify mountain front recharge to the lower adjudicated groundwater basins.

8. An understanding of the recharge mechanisms for groundwater within the higher elevations of the San Gabriel Mountains will need to be evaluated. Slope, soil development and exposed bedrock weathering will need to be reviewed to develop an opinion as to quantity of runoff vs water available for recharge. Additionally, this will need to be reviewed to see if infiltrated water reaches depths sufficient to be intercepted by the tunneling operations.

5.3 Un-resolved Issues for Future Research

1. Completion of the deep test wells. Collection of associated data; depth to groundwater, groundwater pressures at depth and geologic information.

2. All private and municipal well logs should be scanned and location mapped. The State of California, DWR should be contacted and arrangements made to locate these logs.
    a. Review depth of wells to better understand what depth pumping is occurring.

3. Locate the groundwater flow model for Antelope Valley Groundwater Basin Adjudication.

4. Locate the groundwater flow model for the San Fernando Groundwater Basin when it becomes available in April 2016.

5. Review historical reports as they relate to springs within the study area.

6. Review DOG well logs from state database. This should allow for information at depth.

7. Review surface water discharge from all area streams and rivers. As this might be limited, review historical information.

8. Locate and review historical precipitation data for the study area. Calculate averages in a cross-sectional view across the project area.

9. Gain a better understanding of the vegetation across the study area.

10. Future groundwater recharge from adjacent mountains should focus on infiltration and runoff capacities of soils and bedrock fractures of the project area. This work should also identify spring water contribution to and out of the groundwater system.

11. Return flow (groundwater recharge) from agricultural activities. Irrigation practices have vastly improved since the 1900's. With improved irrigation practices comes more efficient use of water. However, the return flow associated with these practices is not fully understood. Understanding the quantity of return flow will provide a better understanding of the overall groundwater budget.

12. A key well program will need to be established and maintained in order to further delineate groundwater quality and water level and chemistry changes. This will help with overall water resources management within the project area.

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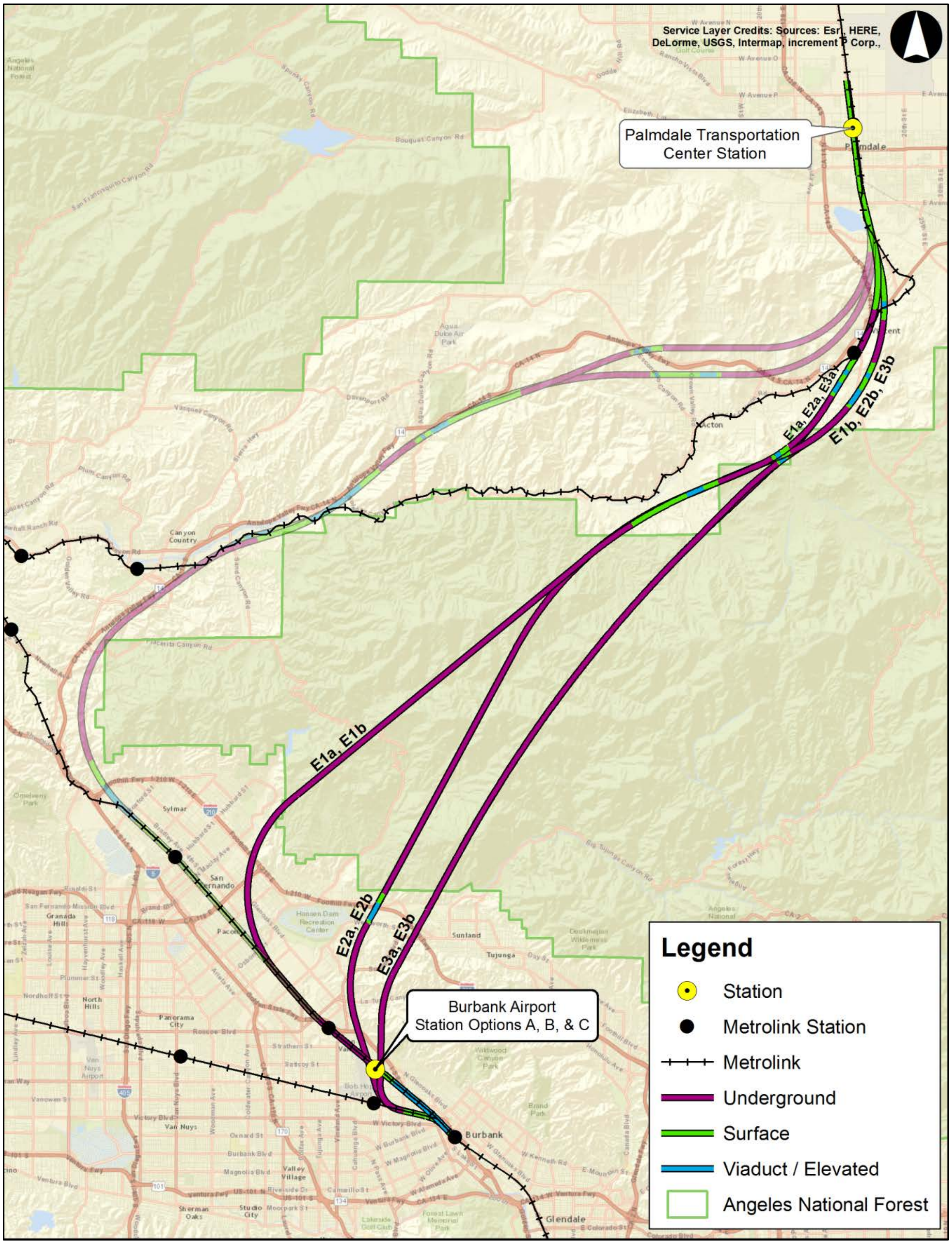
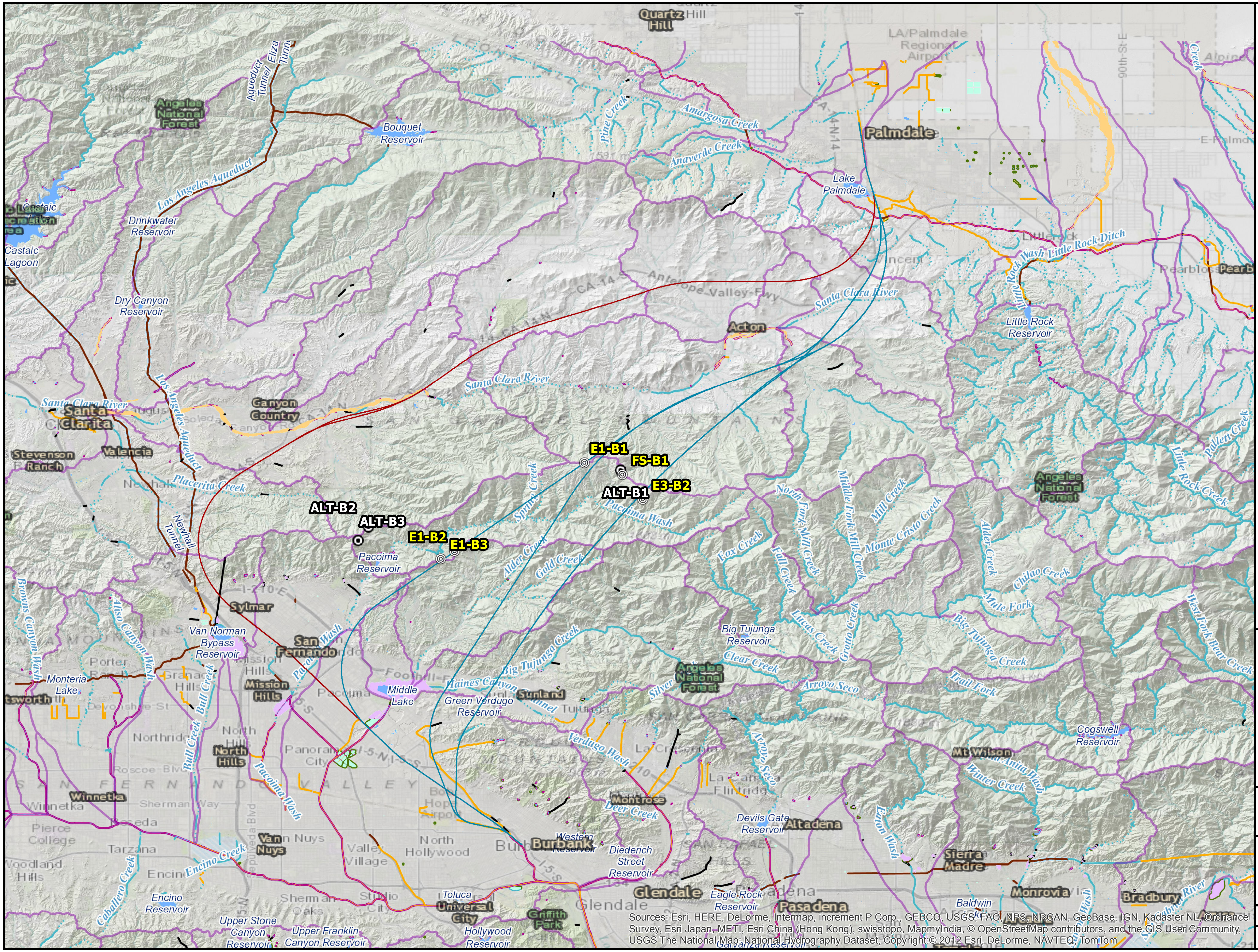


Figure 2.3-1
East Corridor Alignment Alternatives and Station Options



Legend

Test Well (Alternate)

Test Well (in progress)

Alignments

SubSection

East Corridor

SR14 Corridor

2-digit HU

See Figure xx: for geologic descriptions

Watershed Map

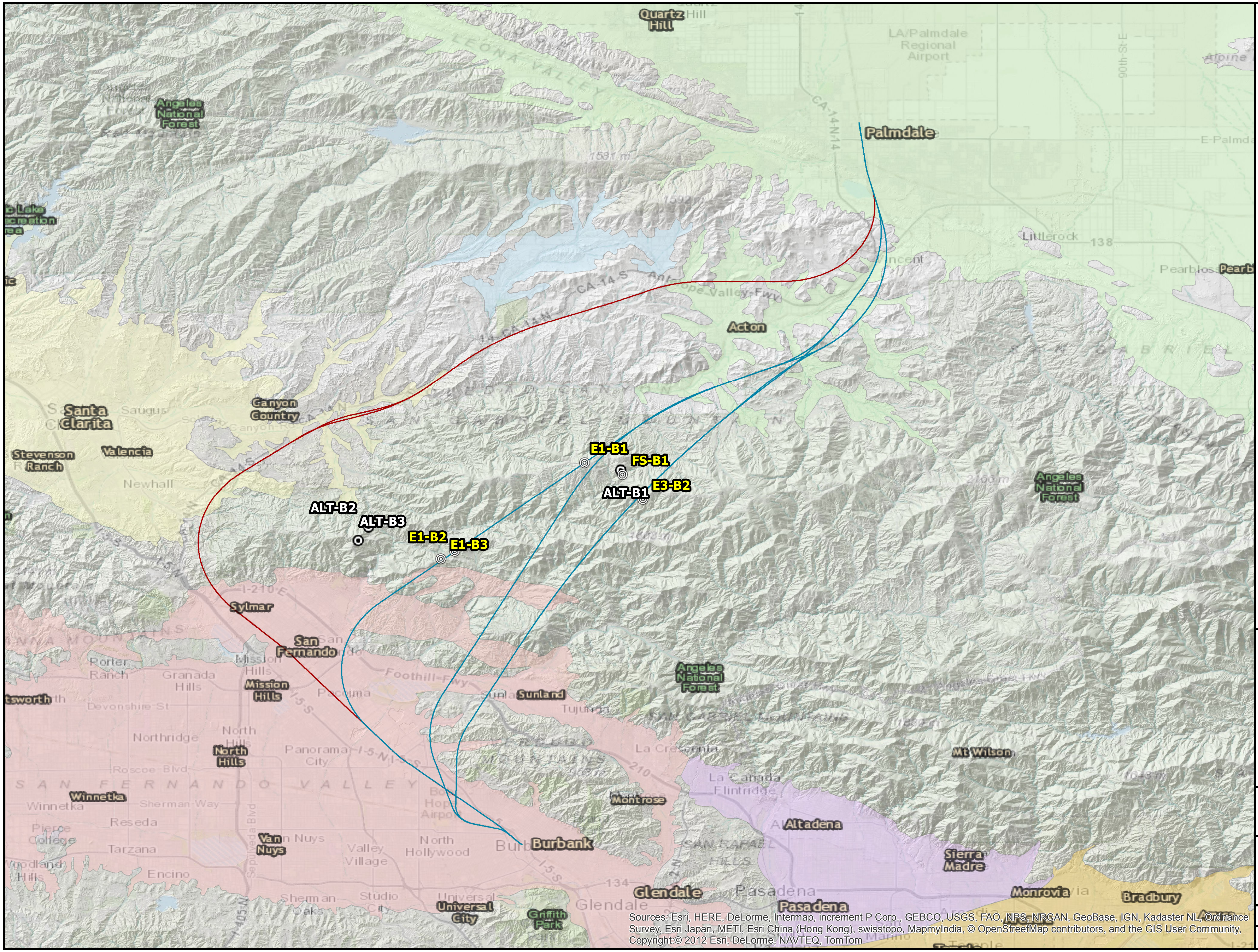
High Speed Rail Authority

Miles: 0, 1.25, 2.5, 5

CALIFORNIA STATE UNIVERSITY FULLERTON

GEOLOGICAL SCIENCES CSUFULLERTON

Project:	High Speed Rail	Figure: 1-1
Date:	3/9/2016	



Legend

- Test Well (Alternate)
- Test Well (in progress)

Alignments

SubSection

- East Corridor
- SR14 Corridor

Basin_Name

- ACTON VALLEY
- ANTELOPE VALLEY
- RAYMOND
- SAN FERNANDO VALLEY
- SAN GABRIEL VALLEY
- SANTA CLARA RIVER VALLEY

DWR Groundwater Basins

High Speed Rail Authority

Miles 0 1.25 2.5 5

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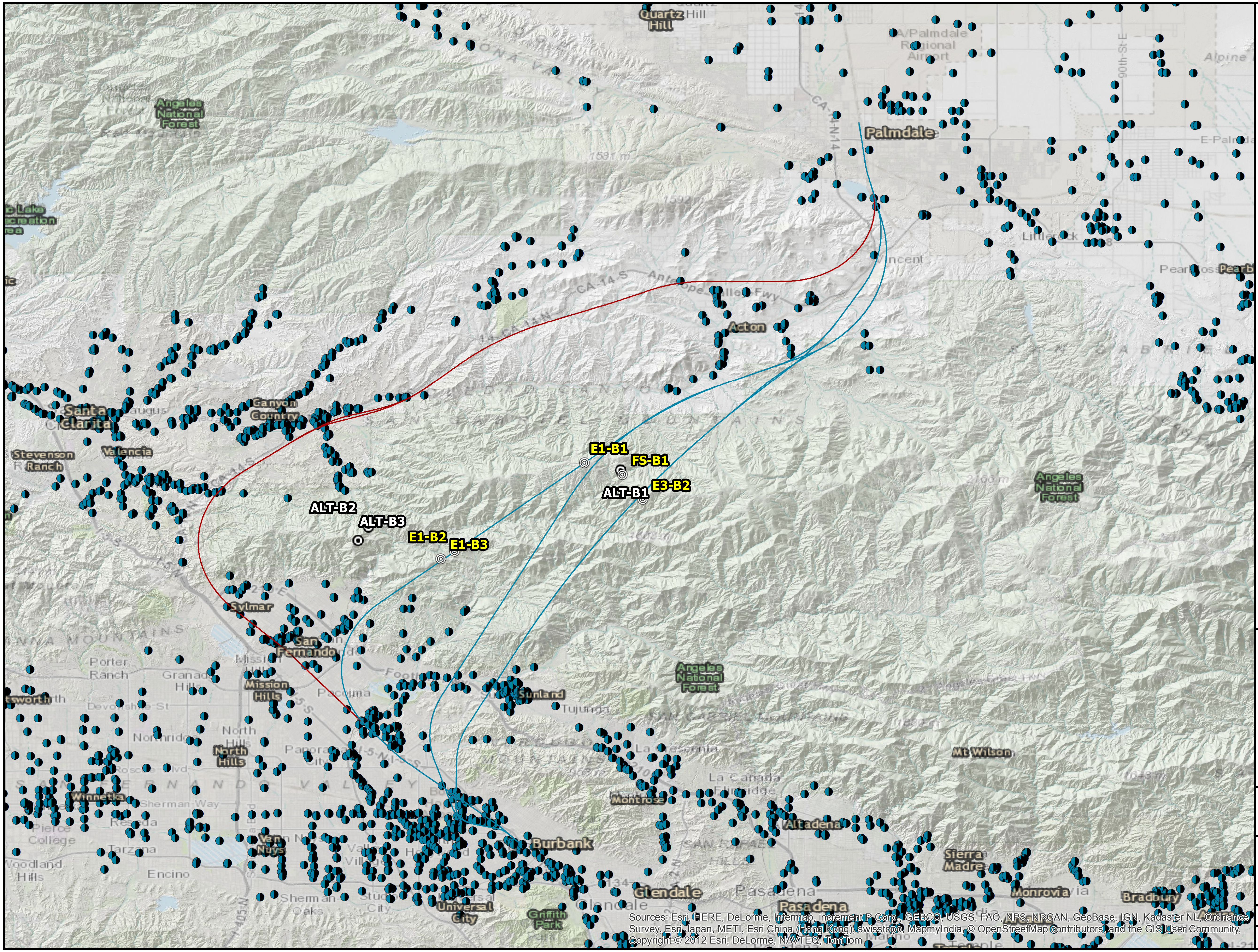
Project:	High Speed Rail	Figure: 1-1
Date:	3/9/2016	



Legend

- Test Well (Alternate)
- Test Well (in progress)

Alignments

SubSection

- East Corridor
- SR14 Corridor
- LADPW Wells

See Figure xx: for geologic descriptions

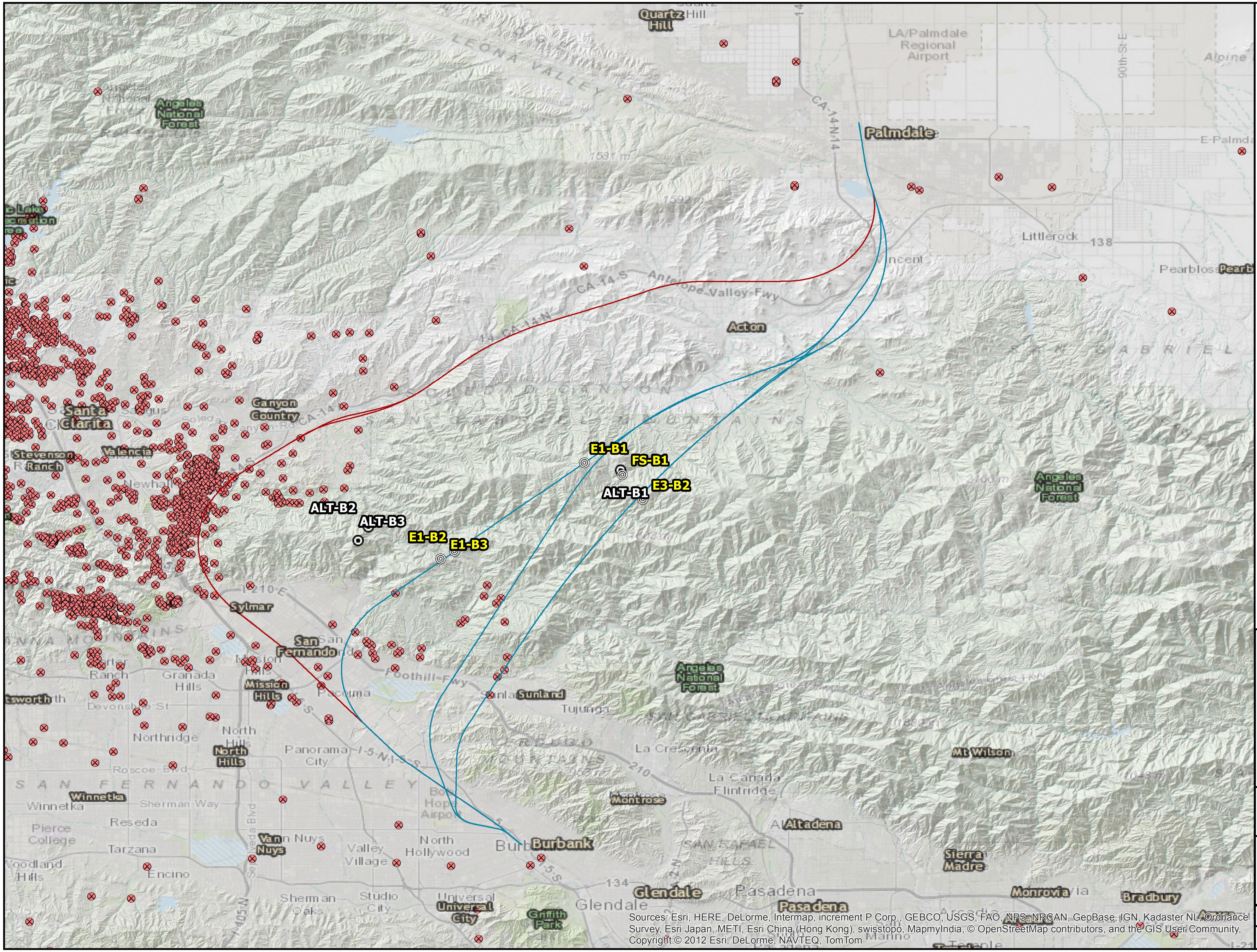
LADPW Well Map

High Speed Rail Authority

Miles: 0, 1.25, 2.5, 5

California State University Fullerton — Geological Sciences CSU Fullerton

Project:	High Speed Rail	Figure:
Date:	3/9/2016	1-1



Legend

Test Well (Alternate)

Test Well (in progress)

Alignments

SubSection

East Corridor

SR14 Corridor

CA DOGG Wells

See Figure xx: for geologic descriptions

CA DOGG Well Map

High Speed Rail Authority

Miles 0 1.25 2.5 5

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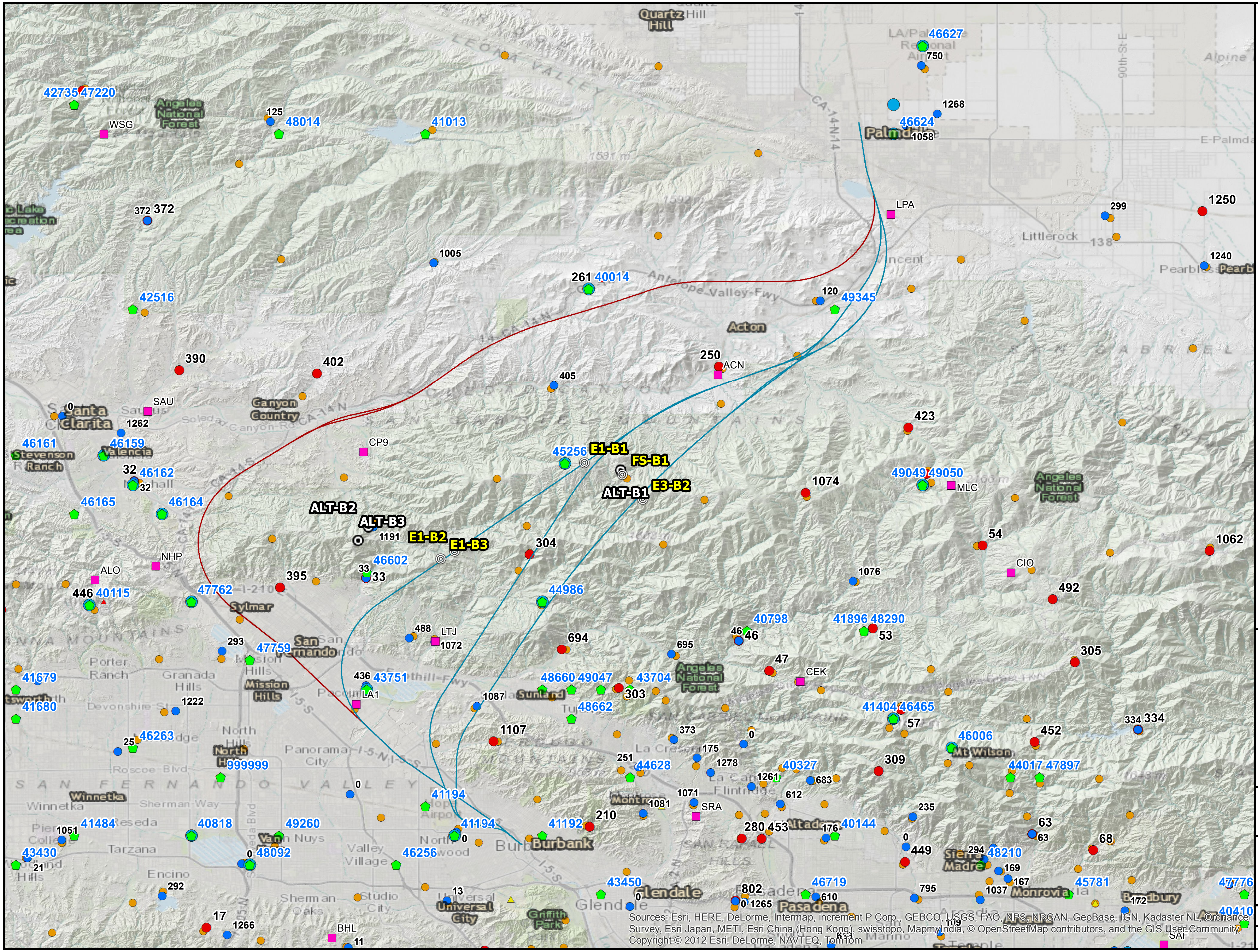
Project: High Speed Rail	**Figure:** 1-1
Date: 3/9/2016	



Legend

- Test Well (Alternate)
- Test Well (in progress)

Alignments

SubSection

- East Corridor
- SR14 Corridor
- NOAA Daily
- NOAA 1hr
- NOAA 15min
- CIMIS Gages
- CDEC Gages
- LADPW Daily Gage
- LADPW Alert Gage
- LADEP Historic Gage

Rain Gage Map Map

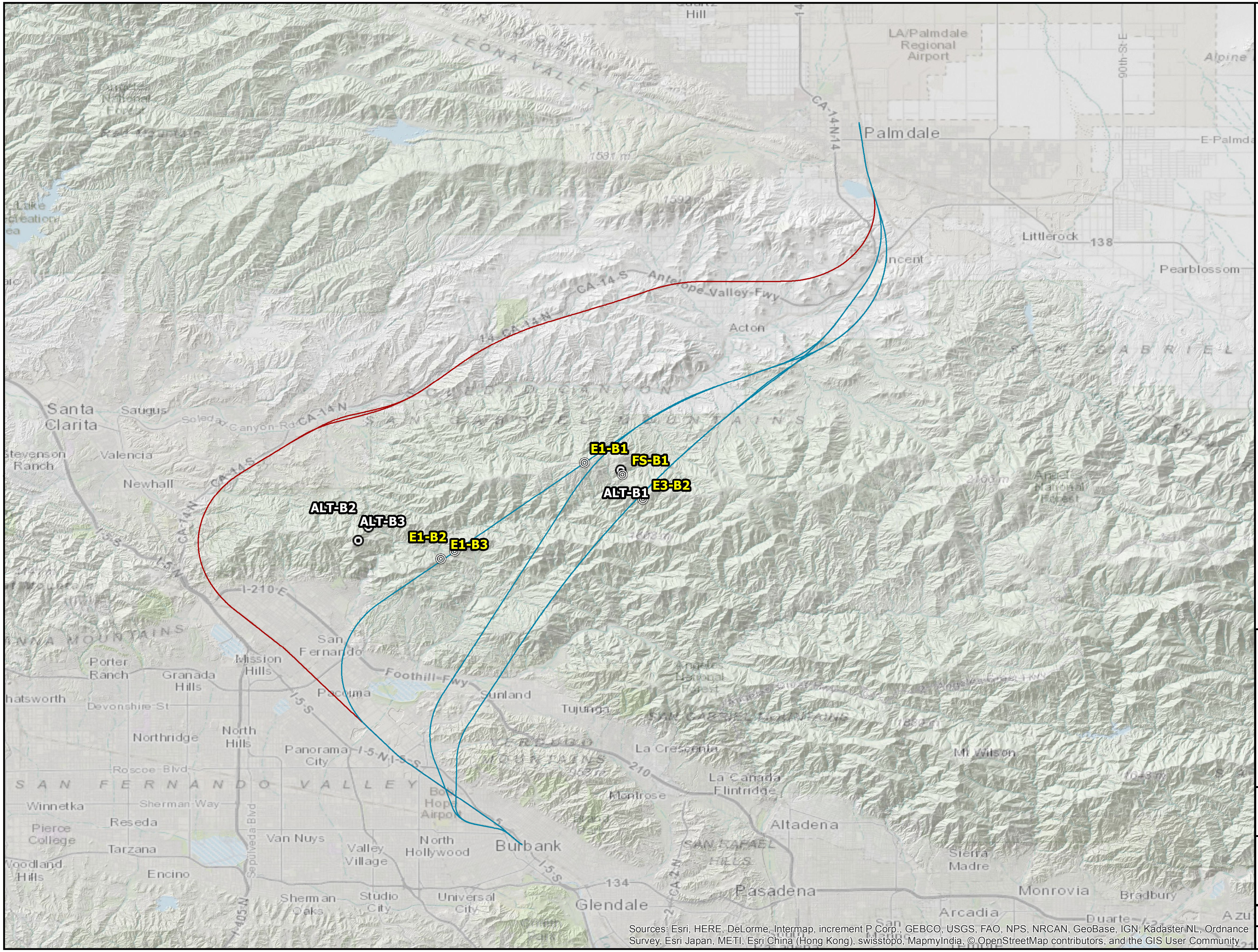
High Speed Rail Authority

0 1.25 2.5 5 Miles

CALIFORNIA STATE UNIVERSITY FULLERTON

GEOLOGICAL SCIENCES CSU FULLERTON

Project: High Speed Rail	Figure:
Date: 3/9/2016	1-1



Legend

- Test Well (Alternate)
- Test Well (in progress)

Alignments

SubSection

- East Corridor
- SR14 Corridor

Test Wells

High Speed Rail Authority

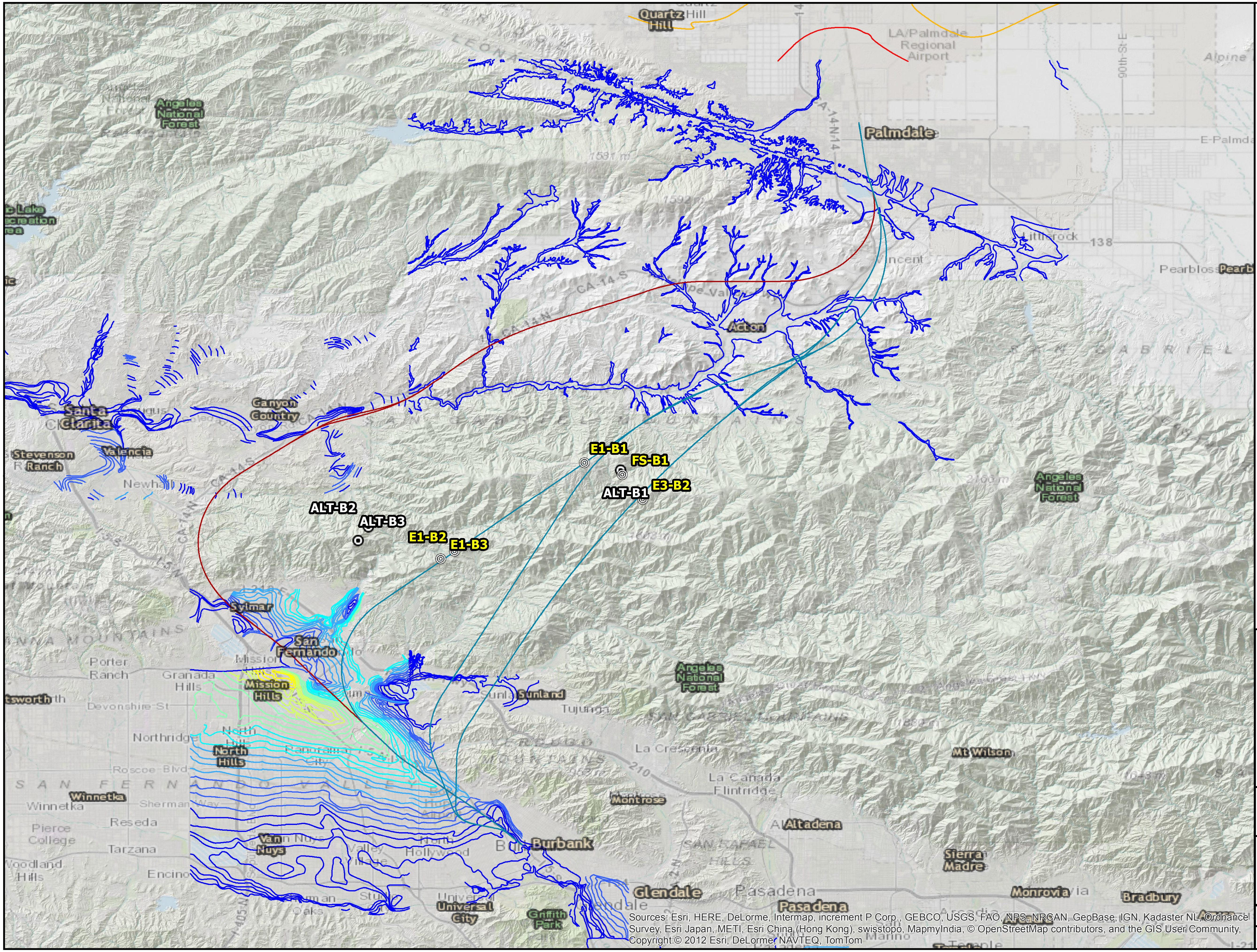
Miles: 0, 1.25, 2.5, 5

CALIFORNIA STATE UNIVERSITY FULLERTON — GEOLOGICAL SCIENCES CSUFULLERTON

Project: High Speed Rail

Date: 3/9/2016

Figure: 1-1



Legend

- Test Well (Alternate)
- Test Well (in progress)

Alignments

SubSection

- East Corridor
- SR14 Corridor

Depth to groundwater (feet)

- 0 - 40
- 41 - 80
- 81 - 120
- 121 - 160
- 161 - 200
- 201 - 240
- 241 - 280
- 281 - 320
- 321 - 360
- 361 - 400

Depth to Groundwater

High Speed Rail Authority

Miles: 0, 1.25, 2.5, 5

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GEOLOGICAL SCIENCES CSUFULLERTON

Project: High Speed Rail
Date: 3/9/2016
Figure: 1-1

Legend

- Test Well (Alternate)
- Test Well (in progress)

Alignments

SubSection

- East Corridor
- SR14 Corridor

See Figure xx: for geologic descriptions

Geologic Map

High Speed Rail Authority

Miles: 0 1.25 2.5 5

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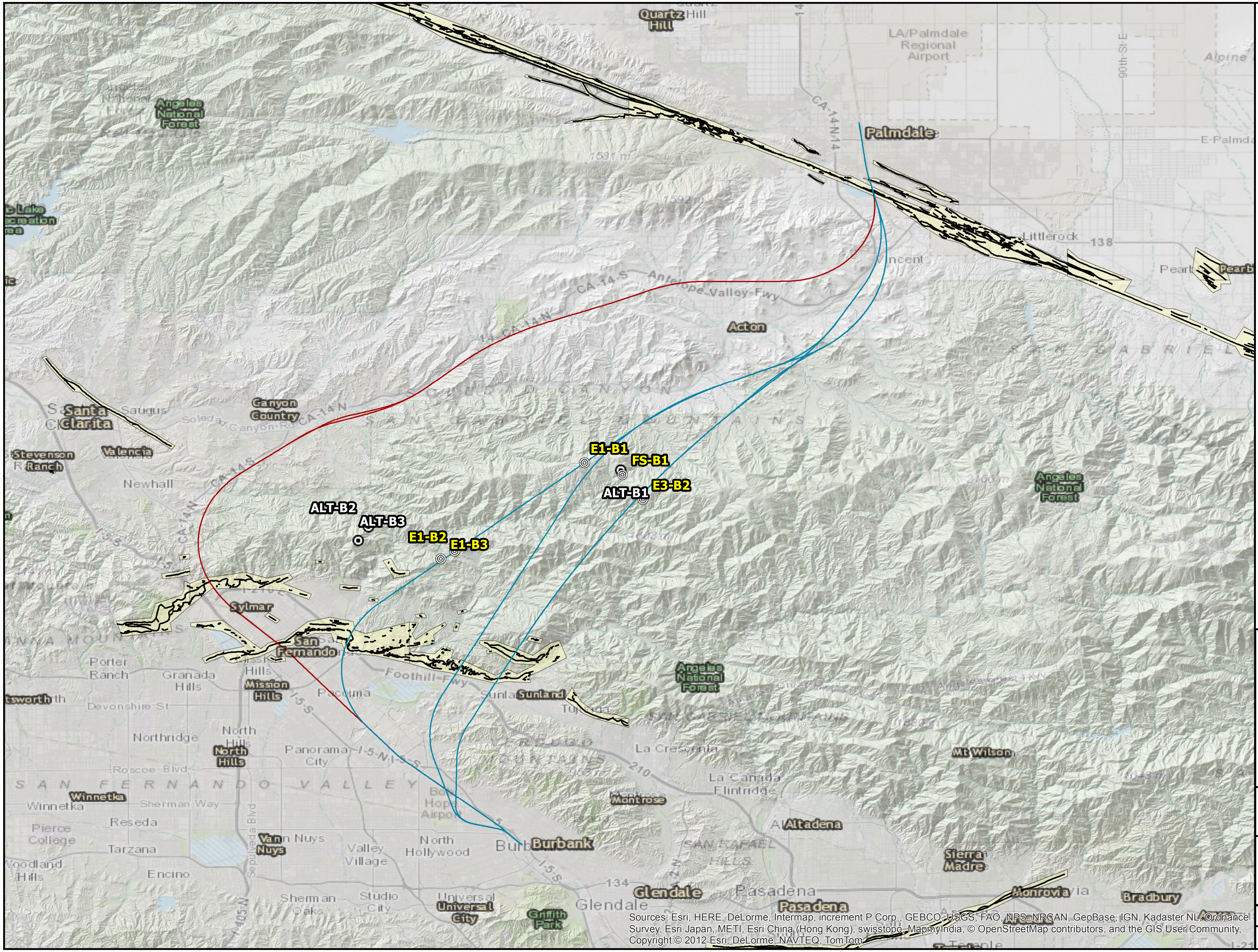
GEOLOGICAL SCIENCES CSUFULLERTON

Project: High Speed Rail	**Figure:** 1-1
Date: 3/9/2016	



Legend

Test Well (Alternate)

Test Well (in progress)

Alignments

SubSection

East Corridor

SR14 Corridor

AP Faults

AP Zones

AP Zones and Fault Map

High Speed Rail Authority

CALIFORNIA STATE UNIVERSITY FULLERTON

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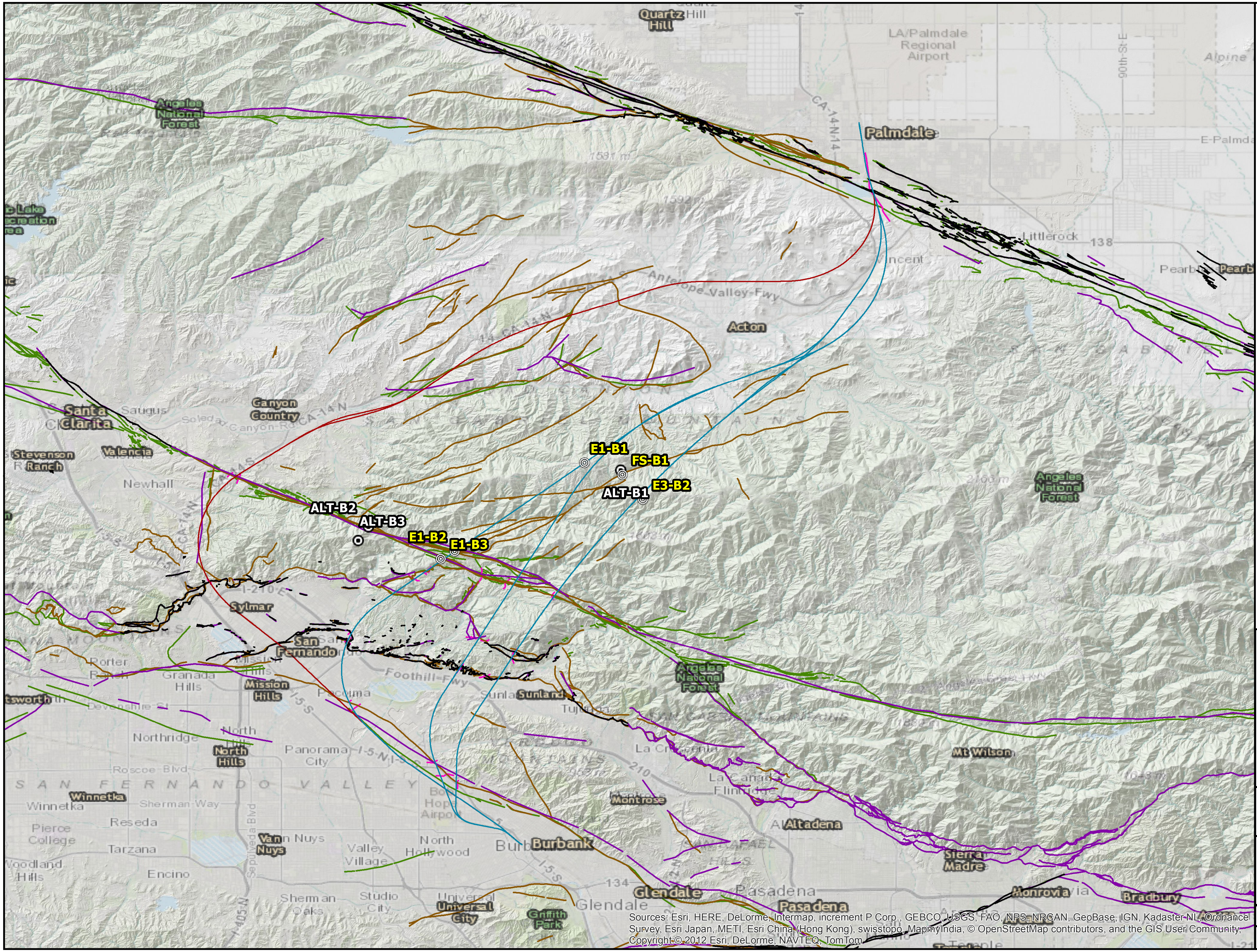
Project: High Speed Rail

Date: 3/9/2016

Figure: 1-1



Legend

- Test Well (Alternate)
- Test Well (in progress)

Alignments

SubSection

- East Corridor
- SR14 Corridor
- AP Faults
- CGS Faults
- Dibblee Faults
- Geophysic Faults
- USGS Faults

Fault Map

High Speed Rail Authority

Miles: 0, 1.25, 2.5, 5

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Project: High Speed Rail	Figure:
Date: 3/9/2016	1-1