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1.0 INTRODUCTION

The primary objective of this investigation was to perform a structural analysis of Potrero Valley (i.e., lineament study and geologic mapping) to better understand the influence of local faulting and fracturing on groundwater flow in the area. Douglas M. Morton, PhD, a retired geologist from the U.S. Geological Survey and regional expert on the structural framework and geologic history of the Transverse and Peninsular Ranges of southern California, performed this lineament study under subcontract to Tetra Tech, Inc. The lineament study at Site 1 consisted of the following Tasks: Task 1 was an archival literature and stereographic aerial photography search followed by analysis of available literature; Task 2 was identification of lineaments on archival aerial photography; and Task 3 was a geologic field investigation of Site 1. This task included checking the location of previously mapped faults, examination of various lineaments, reconnaissance geologic investigation of Site 1 area and the area east of Site 1, and geologic mapping in selected areas. Emphasis was placed on the detection of faults that could be groundwater conduits or barriers in the alluviated central part of Site 1, especially in the Burn Pit Area.

Eleven major northwest striking faults and one major east striking fault were identified that could be relevant to groundwater conditions in the Potrero Valley area. The northwest striking faults are part of the right-lateral strike-slip San Jacinto Fault complex. Where exposed, the northwestern striking faults consist of multiple breaks over a width of up to several hundred feet. The east-striking Goetz fault was of interest because of the large inflow of water (32,000 gallons per minute (gpm)) that was encountered when the San Jacinto tunnel penetrated the hanging wall of the Goetz fault zone (MWD, 1939?). The Goetz fault zone, with an excellent exposure at 1 outcrop, is interpreted as being truncated by one of the younger northwest striking faults along the east side of Potrero Valley.

2.0 METHODLOGY

This section presents a summary of the three major tasks completed for the lineament study at Site 1.

2.1 TASK 1 - LITERATURE AND REVIEW

This task included reviewing past geologic and geophysical investigations of the Site 1 and Site 2 areas. This included published papers, unpublished theses, and results of earlier work conducted for Site 1 and Site 2. Material reviewed for this task is provided in the reference in Section 6.0. Figure 1 shows the distribution of faults within the general area of Site 1 and Site 2.

The only available geologic map of the San Jacinto 7.5' quadrangle that includes most of Site 1, is the Dibblee 2003 Santa Barbara Museum map. This map proved to be inaccurate in the area of Site 1. The only faults shown on the eastern side of Site 1 are the Goetz fault and 3 west-northwest striking faults and 3 short length northeast striking faults. An effort, consisting of several foot traverses, was made to authenticate the presence of the first fault north of the Goetz fault; no evidence was found to substantiate this fault. The Dibblee map shows no faults in the vicinity of Site 1 southwest of the Goetz fault. Henderson's (1939) paper gives some general information relevant to faults in the area of Site 1. His fault map of the area including Site 1 is conceptual in nature (e.g., Henderson shows the Potrero Fault as a very short length fault not extending east of the San Jacinto tunnel).

The Leighton report (1983) was briefly reviewed. The copy of the geologic map of the Leighton report (1983) is of small scale and difficult to use. Their orientation of the Goetz fault is about 45° from the orientation of the Goetz fault that can be measured east of the area of the Leighton map. No evidence was found for their 2 un-named faults cutting tonalite located north of their Goetz fault. Leighton shows the northern of the 2 faults extending northwest where the fault juxtaposes their sandstone, conglomerate, and fanglomerate beds (Ts2) against the sandstone, siltstone, and shale beds (Ts1). There is agreement a fault is located there but disagreement as to how the fault extends to the east. The Leighton map shows the Bedsprings fault with a strike of about N50°W cutting their Ts2 unit in a low hill just east of Potrero Creek. The only faults found on these hills had a strike of about N5°E. At the scale of their map the 2 faults they show near the Betatron and to the northwest appear reasonable, although a number of identified faults are not shown.

A number of 'Features' (faults) shown on the different geophysical lines of the Terra Physics' report (2008) are located close to fault locations in this report; the fault locations in this report were based only on extrapolation of geologic data and only after completion of the mapping were compared with the Terra Physics' report.

A primary source of accurate point data on the location of faults in the area of Site 1 is the geologic profile of the San Jacinto tunnel (Metropolitan Water District). This profile provides accurate locations of faults encountered in the tunnel and the apparent dip of the faults, but gives no information on the orientation (strike) of the faults. However, based on field data, the tunnel is oriented approximately normal to the strike of these faults between the San Jacinto adit (the southern base of Claremont ridge) and 2,500 feet north of the Potrero shaft (referred to as the “San Jacinto Tunnel Tailings Potrero Adit” on Figure 2).

2.2 TASK 2 - LINEAMENT STUDY

This task was principally examination of stereographic aerial photographs for presence of lineaments. Most of the aerial photographs examined were at a nominal scale of 1:24,000 and 1:16,000. An Abrams CB-1 Stereoscope was used for examining aerial photographs. Ages of aerial photographs examined are listed at the end of Section 6. Google Earth images, both vertical and oblique views, were used in conjunction with stereographic aerial photographic examination. Review of a 1938 vintage aerial photograph of the western end of the Site showed several strong linears present (near Area H, the former Sanitary Landfill). The significance of these linears will be discussed later.

2.3 TASK 3 - GEOLOGIC FIELD INVESTIGATION AND MAPPING

After reviewing relevant literature and aerial photographs, a reconnaissance geologic investigation was made in the general area of Site 1. The principal goal of the reconnaissance work was to determine the location of faults in the vicinity of Site 1 with special attention to the Burn Pit Area. A search was made for surface exposures of faults that were identified during the construction of the San Jacinto tunnel and determine how accurately the faults encountered in the tunnel could be projected to the ground surface. Faults of particular interest in the reconnaissance phase of the fieldwork included the Goetz, Bedsprings, and Potrero faults, all of which project into the general area of the Burn Pit Area. Several major faults east of Site 1 were not examined because they are too spatially removed to have any relevance to groundwater conditions in the area of Site 1. However, Henderson (1939) placed considerable importance on the McInnes fault (Figure 1). The location and orientation of the McInnes fault, was evaluated to determine if it could possibly be relevant to Site 1. Based on its location and general strike, the McInnes Fault does not appear to be relevant to Site 1 (see Figure 1).

After the reconnaissance work, detailed field work included examination and mapping of linear features that are recorded in the referenced material, lineations observed in aerial photographs during Task 2, as well as identification and location of other faults.

3.0 REGIONAL SETTING

Site 1 is located in the Potrero Creek drainage basin, an irregular-shaped basin primarily located in the northwestern part of the northern San Jacinto Mountains structural block uplift. This uplift culminates in the high summit elevations of the San Jacinto Mountains east of Site 1. The Potrero Creek drainage basin is bounded on the south by a bedrock ridge, here informally termed the Claremont ridge, which reaches summit elevations of 4,000 feet above mean sea level (msl). The south front of Claremont ridge is the high and steep Claremont Fault scarp that rises abruptly 2,500 feet above the floor of the San Jacinto Valley. The Claremont Fault scarp is cut by scarps of faults extending southeast from Site 1 (Figure 1). Most of the steep south-facing Claremont Fault scarp has failed by massive landsliding (Morton and Sadler, 1989). To the east of the Potrero Creek drainage basin are the high elevation peaks of the northern San Jacinto Mountains.

Potrero Creek has several discrete physiographic reaches. The southern reach, Massacre Canyon, is an antecedent drainage eroded through sedimentary rocks and into basement rock as this part of the San Jacinto Mountains structural block was uplifted in the past 1.2-1.5 megaannum (“Ma” or unit of time equal to a million years). The lowest reach of Potrero Creek, from the mouth of Massacre Canyon at Gilman Springs Road, is at an elevation of 1,540 feet msl and increases only 10 feet in elevation over a distance of 800 feet up canyon. Above this low gradient reach the canyon floor increases from 1,550 feet msl to 1,750 feet msl over the next 2,400 feet. Above Massacre Canyon is a more subdued topography with Potrero Creek gaining 240 feet elevation over a distance of 16,000 feet. Near an elevation of 1,960 feet msl, Potrero Creek enters the broad open area of Potrero Valley. In Potrero Valley, Potrero Creek is joined by 3 major streams emanating from the high San Jacinto Mountains to the east of Potrero. The elevation at the north end of Potrero Valley is about 2,100 feet msl and the elevation at the east side of the valley is 2,200 feet msl. North of the Potrero, Potrero Creek has an unusual course extending high up the center of Noble Creek alluvial fan on the south side of the San Bernardino Mountains at the crest of San Gorgonio Pass. Within a half mile to the east of upper Potrero Creek is the west end of the Whitewater drainage that terminates at the north end of the Salton Sea and within a half mile to the west is the eastern headwaters of the Santa Ana River drainage basin.

3.1 GENERAL SITE GEOLOGY

The area of Site 1 is underlain by continental sedimentary rocks that are flanked by a variety of basement rocks (see Figure 2, Geologic map). Basement rocks south of Potrero Valley along Claremont ridge are mostly metasedimentary and metaplutonic rocks and lesser amounts of biotite monzogranite, and biotite-hornblende tonalite. The biotite-hornblende tonalite is not the same as the tonalite located east and north of Potrero Valley and underlies most of the San Jacinto Mountains to the east of Site 1. Metasedimentary rocks are mostly biotite and hornblende schist and gneiss with minor marble bodies. Metaplutonic rocks include meta-biotite monzogranite and metadioritic rocks. East and north of Potrero Valley, basement rocks are largely biotite-hornblende tonalite with scattered septa of schist and minor marble. West of Potrero Valley is biotite monzogranite, biotite schist, and lesser amounts of marble; these rocks are the continuation of the metamorphic rocks and biotite monzogranite exposed on Claremont ridge.

Most of the sedimentary rocks in the area of Site 1 are considered to be part of the Miocene age Mount Eden formation of Frick (1921). Pliocene sedimentary rocks of the lower part of the San Timoteo formation of Frick (1921) are exposed primarily on the north side of Potrero Valley with some local areas underlain by probable San Timoteo formation west of Potrero. Both the Mount Eden and San Timoteo formations consist of lithified and relatively low permeability rocks. The Mount Eden formation consists of less permeable deposits than those of the San Timoteo formation.

Clasts within the Mount Eden formation are of local derivation. In the area of Potrero Valley, most of the Mount Eden formation consists of thick and crudely-bedded, well-indurated, coarse-grained sandstone, pebbly sandstone, cobbly sandstone, and lesser amounts of conglomerate. Major facies changes are common and extensive within the Mount Eden formation. Subdivision of the Mount Eden formation was not attempted due to the amount of time such an effort would require. An example of extreme facies changes are the thick discontinuous deposits of locally derived landslide boulder breccia (Photograph 1) south of Potrero Creek, on the north side of Claremont ridge. Most of the Mount Eden formation is less fractured than the underlying basement rocks. Figure 2 shows the general area where each photograph was taken and identifies the general features referenced throughout the text.

West and north of Potrero Valley are sedimentary beds that lithologically differ from typical Mount Eden and San Timoteo formations, but are similar to what is mapped as Mount Eden formation south of Site 2 in Laborde Canyon. These beds may be uppermost Mount Eden or basal San Timoteo formations, however here they are given the informal name Potrero beds to distinguish them from typical lithologies of Mount Eden and San Timoteo formations. West of Potrero these beds are thick bedded, gray arkosic sandstone, pebbly sandstone, and conglomeratic sandstone with local reddish sandstone. These rocks are not as well indurated as typical Mount Eden formation lithologies. Within Potrero Valley, in Area B, Rocket Motor Production Area, the low hills are underlain by grayish coarse-grained sandstone, pebbly sandstone, and conglomerate with 2 small occurrences of typical sandstone of Mount Eden formation in the southeastern and northern part of the hills. North of Potrero Valley, in the southern part of Area A, Eastern Aerojet Range (Avanti), the beds include conglomerate and pebbly sandstone that is gray to reddish in color. These beds appear to disconformably overlie Mount Eden formation rocks. The contact between the Mount Eden formation and Potrero beds is exposed on the east side of the entrance road just north of the branching paved road.

Most occurrences of San Timoteo formation are located in the northern part of Site 1. Lithologies of the San Timoteo formation are grayish colored, and overall much thinner bedded and finer-grained than those of the Mount Eden formation and the Potrero beds. In general in the area of Site 1, the San Timoteo formation lithologies erode to form more gentle topography and broader stream courses than the Mount Eden formation lithologies. Fine-grained sandstone, siltstone, and clayey siltstone are commonly hackly fractured. Medium- to coarse-grained sandstone beds are less fractured than the finer-grained rocks and generally more resistant to erosion. Clasts within the San Timoteo formation are derived from basement rocks that are characteristic of the rocks north of San Gorgonio Pass and the eastern San Gabriel Mountains. An elongate thin body of gray sedimentary rocks that appear to be San Timoteo formation is located just west of Area H (Sanitary Landfill). The linear nature of this occurrence suggests it may be structurally controlled southwest of Area H (see Figure 2; geologic map). A channel-filling deposit of gray sedimentary rocks that appear to be San Timoteo formation is exposed on the east-facing wall of a gorge cut in Mount Eden formation southwest of Area H. Two poorly exposed bodies of San Timoteo formation are located north of Area F (LPC Test Services Area) and east of the Dellamont fault (see Figure 2). Although topographically high, the block capped by the 2 bodies of San Timoteo formation is structurally a graben.

A variety of thin sedimentary deposits occur on many low-gradient surfaces underlain by Mount Eden formation and to a lesser extent on Potrero beds. These deposits include coarse-grained sand, gravel and pebbly sand with common to abundant cobbles. Based on elevation differences these deposits are of various ages but probably most are of probable late Pleistocene age. These deposits are widespread in some areas such as the gravelly cover on the surface of the ‘Landing Strip’ area in Area I. These thin deposits obscure large areas of Mount Eden formation. An example of these deposits obscuring geology is the channel-filling deposit of San Timoteo formation on the east-facing wall of a gorge cut in Mount Eden formation southwest of Area H. Due to these thin deposits the San Timoteo formation rocks cannot be mapped away from the canyon (see Figure 2, geologic map and Photographs 2 and 3). Due to time constraints there was no attempt to systematically map all these deposits.

3.2 STRUCTURAL GEOLOGY

Beaumont Site 1 is situated between two major structural features of southern California; the San Andreas Fault to the north, and the San Jacinto Fault to the south. Both faults are right-lateral strike slip faults that have considerable off-set. Since Beaumont Site 1 is sandwiched between these two major structural features, it is not unexpected that subsequent faulting and structural discontinuities would be present in the area between these two major fault zones. A review of the geologic literature for the area suggests that numerous northwest-southeast striking faults are present. Detailed mapping by MWD during construction of the San Jacinto Tunnel (the Colorado River Aqueduct) showed numerous faults and fractures present along the length of the tunnel. While attitudes were not recorded for each of the major breaks identified in the tunnel walls, projection of these faults and fractures to the surface was made and are the basis for much of the geologic mapping that was conducted during this investigation. A review of the geologic literature and the alignment of the mapped faults through and around Potrero Valley suggest that there were at least 3 periods of faulting that occurred in the area of Beaumont Site 1. Cross-cutting relationships of some of the major faults surrounding the study area show that the oldest period of faulting consisted of north to northwest striking faults (McInnes and McMullen faults). These faults are truncated by more recent east-west striking faults that appear to have some left-lateral strike-slip component (particularly the Lawrence Fault). A third period of tectonic activity appears to have resulted in the production of northwest-southeast oriented faults that have right-lateral strike-slip components and have apparently truncated some of the more east-west oriented faults (Goetz fault being truncated by Fault F just south of the Burn Pit Area, see Figures 1 and 2). Dominant northwest-southeast oriented faults and shear zones are expected in a structural setting where the generally east-west oriented, right lateral strike slip movement of the San Andreas Fault is present to the north of the Potrero Valley block and the northwest-southeast striking, right-lateral movement of the San Jacinto Fault Zone is situated along the southern boundary of the Potrero Valley block. Third and youngest of the fault sets have some expression in the Quaternary alluvium and suggest that the more recent northwest-southeast oriented faults are relatively young.

3.3 FAULTS IDENTIFIED WITHIN BEAUMONT SITE 1

All faults examined in Site 1 except for the south side of Claremont ridge are devoid of any primary surface fault morphology such as fault scarps. East of Site 1 is an apparent curving fault scarp of the Potrero fault zone. Surface expressions of faults in the Potrero area are limited to secondary erosional features.

Faults in the Site 1 area constitute 3 fault domains. Faults of the oldest domain are represented by the northwest striking and relatively shallow northeast dipping McMullen (also spelled McMullin) fault located northeast of Site 1 (see Figure 1). The next oldest fault domain is west striking faults that include the Lawrence Fault located in the northeastern part of Site 1 (see Figure 1). The McMullen fault is left laterally offset about 2,000 feet by the Lawrence fault.

The youngest fault domain consists of northwest striking faults, interpreted as part of the San Jacinto Fault complex. The San Jacinto related faults are relatively young, originating only 1.2-1.5 Ma ago (Matti and Morton, 1993; Morton and Matti, 1993). These faults occur over a width of more than 6 miles from the Casa Loma Fault on the west to fault F along the southeastern end of Site 1 (see Figure 1). Faults of the San Jacinto Fault complex have right-lateral separation (displacement) and commonly with minor dip-slip separation. Most faults consist of en echelon breaks (steps). When viewed along strike, if the en echelon break steps to the right, extension occurs between the 2 overlapping faults producing a pull-apart basin; if the break steps to the left, compression occurs between the 2 faults. The length of the en echelon break approximates the lateral separation of the fault zone. Based on empirical data on the Elsinore and San Jacinto Fault Zones, the vertical component of displacement in a right-stepping en echelon break is about 10 percent of the horizontal displacement (offset) determined for the fault. As an example, the pull-apart basin south of Site 1 in the San Jacinto Fault zone that is located between the Claremont Fault and the Casa Loma Fault has tectonically subsided nearly 1.8 miles; the horizontal offset on the San Jacinto Fault zone is 16 to 18 miles. The complex-appearing horst-like feature located between features D and F on Figure 4 in the *Seismic reflection/refraction survey to detect possible bedrock structural features/faults surrounding the burn pit, former Lockheed Beaumont Site 1* (Terra Physics, 2008) could be reflecting compression due to a left step in a right-lateral fault.

The Claremont strand of the San Jacinto Fault Zone is the dominant fault in the general area of Site 1. The steep south side of Claremont ridge is merely the slightly eroded Claremont Fault scarp. The fault is located at the mouth of Massacre Canyon. Massive bedrock landslides obscures the exact location of the Claremont Fault from 2,000 feet southeast of the mouth of Massacre Canyon for a distance 4 miles southeast, nearly to Soboba Hot Springs. The Claremont Fault is not relevant to groundwater issues in the Potrero area. A number of hillside scarps on the steep south side of Claremont ridge are a combination of tectonic and landslide origin (Morton and Sadler, 1989). The fault scarps project into the Potrero Valley area.

North of the Claremont Fault, twenty faults have been recognized in the San Jacinto Fault complex. However, only the northern 11 of these faults, Fault A through F on Figure 1 and Figure 2, are relevant or possibly relevant to the Potrero Valley area. The remaining 9 faults are not shown on Figure 1. The relevant 11 faults in Site 1 have a relatively consistent northwest strike ranging from N37°W to N54°W and averaging N44°W. All these faults dip northward, most at angles of 70° to 80°.

3.3.1 The Major Faults

Fault A.

Fault A is well exposed near the crest of Claremont ridge 2,600 feet northwest of the San Jacinto tunnel alignment where sediments of the Mount Eden formation are in fault contact with biotite monzogranite. Where measured on Claremont ridge the strike is about N60°W and has a dip of 73°NE (Photograph 4); the dip of the fault in the San Jacinto tunnel is 70°NE. The average strike through Site 1 is about N50°W. This fault projects to the area at the south end of the elongate body of San Timoteo formation just west of Area H (Sanitary Landfill). The fault may continue northwest joining the western fault of the Lower Potrero fault in the vicinity of the 'Landing Strip' in Area I. Where fault A is projected across Potrero Creek there is a slight change in vegetation in Potrero Creek.

Lower Potrero fault zone.

Located 1,000 to 2,000 feet northeast of Fault A, is the Lower Potrero fault zone of Metropolitan Water District (MWD, 1939?). The Lower Potrero fault zone consists of 2 faults spaced 200 to 800 feet apart. To the southeast, the zone crosses Claremont ridge straddling Claremont Peak. Northwest of Claremont ridge the western of the 2 faults extends to Area H (Sanitary Landfill) where the proximity of the fault is marked by dark gray soil. The fault crosses the lower end of the "Landing Strip" in Area I and is marked by gray sediment exposed in road cuts west of the "Landing Strip". In this area the fault may be a combined Fault A and Lower Potrero fault. Where the western fault of the Lower Potrero fault zone crosses Potrero Creek, there is a moderate change in vegetation. The eastern fault of the Lower Potrero fault zone projects into a northwest trending canyon between Potrero Creek and a hill of basement rock. No change in vegetation was noted where the fault is projected to cross Potrero Creek.

Fault B

Fault B, located about 1,600 feet northeast of the Lower Potrero fault zone, has little expression north of Potrero Creek. Where Fault B is projected to cross Potrero Creek there is a major change in vegetation. One or both of 2 measured faults, one exposed on the northeast side of the 'Large Motor Test Bay (Feature F-39, Photographs 5, 6, and 7), and the other immediately east of the 'Small Motor Vertical Bay (Photograph 8), appear to be the northward continuation of Fault B.

Fault C

Fault C, located in the southwestern part of Site 1 has moderate erosional topographic expression and appears to form the contact between Mount Eden formation on the west and metamorphic rocks on the east. There appears to be little if any expression of a fault north of Potrero Creek. The fault is projected to coincide with a brush filled linear depression in Mount Eden formation (Photograph 9).

Dellamont fault

The Dellamont fault is a prominent member of the San Jacinto Fault complex related structures. The Dellamont fault southeast of Site 1 has a readily visible topographic expression where it extends through a saddle on the east side of Dellamont peak. The fault northwest of Dellamont peak is located along a stream course west of the San Jacinto tunnel alignment where it apparently offsets the Mount Eden formation contact with basement rocks. The fault is also marked by a major break-in-slope with the northeast side down. Further northwest it is obscured by 2 landslides. Northwest of the landslides, the fault extends along a stream course. North of Potrero Creek the fault is represented by several faults well exposed in a road cut southwest of the road to the Betatron building (Photographs 10, 11, 12, 13, and 14 and Figure 3). Further northwest the fault is well exposed in a stream bank where reddish Mount Eden formation is in contact with grayish Mount Eden formation (Photograph 15). The dip of the fault in the stream bank is 80° NE. Northwest of Site 1 the Dellamont fault extends north of Interstate 10 west of Beaumont where it is located at the western part of the Beaumont plain fault complex (Figure 1).

Fault D

The location of Fault D is poorly constrained on the north side of Claremont ridge. It apparently is located in a stream course before reaching Potrero. North of Potrero Creek, 2 parallel faults located just beyond the start of the road leading to the Betatron Building appear to be the northward extension of Fault D. The first fault seen on the entrance road has red-colored Mount Eden formation on the northeast side of the fault and greenish-tan Mount Eden formation on the southwest side (Photograph 16). The second fault has reddish-colored Mount Eden formation on the southwest side. A third fault well exposed immediately east of the Betatron building (Photograph 17) is probably the west side of the D Fault zone; this would make a 200 foot wide set of faults. Two faults exposed in young alluvium in a vertical bank of Potrero Creek appear to be faults associated with the Fault D zone (Photographs 18 and 19). About 600 feet northwest of the Betatron Building, Fault D appears to split with a western branch joining the Dellamont fault and an eastern branch continuing along strike. Locally the continuation of Fault D is well exposed in a gully as a 6-foot-thick zone that dips 77° to the northeast. Although the area where the splay of Fault D merges with the Dellamont fault is a topographic high, structurally it is a graben based on 2 occurrences of San Timoteo formation. The San Timoteo formation is restricted to the area between the 2 faults and does not occur on topographically high ground northwest of the Dellamont fault.

Fault E

Fault E is not well exposed in any area inspected and is arbitrarily positioned based on its location in the San Jacinto Tunnel and it’s projection from this location to the north.

Potrero fault zone

The Potrero fault zone was named by MWD for the 2 closely spaced (400 feet apart) faults encountered immediately northeast of the Potrero shaft. About 6,000 feet southeast of the San Jacinto tunnel alignment the Potrero fault zone merges with 2 faults, the Bedsprings and Fault F, located northeast of the Potrero fault zone. Southeast of where the faults merge, the fault zone consists of a well defined linear feature that was easily traced about 6,000 feet further southeast.

When the Potrero fault zone was penetrated by the San Jacinto tunnel there was a rapid increase of about 7,000 gallons per minute (gpm) of groundwater inflow at the tunnel face; flow almost immediately decreased to about 2,000 gpm after the fault was penetrated. The western and apparently the major fault of the Potrero fault zone is inferred to be located just west of an isolated outcrop of biotite-hornblende tonalite (see Figure 2, Geologic Map); this tonalite appears the same as the widespread tonalite to the east and unlike tonalite to the west. The second (northeast) Potrero fault appears to be located about 400 feet to the northeast where several faults are exposed; there appears to be no control on the location of this fault further northwest.

Albeit troublesome, the best exposed fault located in at least close proximity to the Potrero fault is oriented about 45° to the strike of the Potrero fault (Photograph 20). The orientation of this fault may be a result of rotation between the 2 faults constituting the Potrero fault zone. A change in the nature of Mount Eden beds 2,000 feet northwest of the Potrero shaft is interpreted to be the location of the Potrero fault. The Potrero fault projects northwestward into Potrero Valley. Dense growths of sedges on a slightly elevated oxbow stream bed at 33° 51’ 40.6” 116° 56’ 27.2” suggests relatively high groundwater, likely due to a nearby fault. Geometrically the Potrero fault is the most likely fault in this area.

Bedsprings fault

Along the San Jacinto tunnel alignment 1,400 feet northeast of the Potrero fault is the Bedsprings fault. This fault was a major groundwater barrier. When penetrated by the San Jacinto tunnel the inflow of water at the tunnel face increased from about 2,500 gpm to 10,000 gpm; north of the Bedsprings fault inflow at the tunnel face remained at about 8,000 gpm until penetrating Fault F where the flow increased by about 11,000 gpm. The inflow only decreased to about 10,000 gpm north of the fault; this 10,000 gpm inflow was maintained until the Goetz fault zone was reached and inflow irregularly increased to the peak of 32,000 gpm when the hanging wall of the Goetz fault zone was penetrated.

Along the western edge of the Bedsprings stream channel, 200 feet southwest from the small isolated outcrop of tonalite (UTM coordinates 506500 E 3742500 N), is a lush vegetation growth suggesting relatively high groundwater. It is interpreted that the Bedsprings fault passes though or adjacent to this area of lush vegetation. According to the geophysical survey of Terra Physics (2008), the fault projects to about 100 feet southeast of geophysical feature H, approximately 800 feet northwest of this vegetated area.

Fault F

Fault F is interpreted as passing adjacent to an area of black soil at UTM coordinates 506850 E 3746150 N. This location is where the Goetz fault is interpreted to terminate against Fault F. Fault F projects nearly midway between the closely spaced (about 150 feet) geophysical features P, Q, and R as illustrated in the Terra Physics report (2008). At about 2,400 feet northwest of the geophysical line that includes features P, Q, and R, the projection of Fault F is coincident with geophysical feature D and about 150 feet southeast of geophysical feature E identified by Terra Physics (2008). Geophysical features D, E, and F may be produced by a left-step in Fault F; if this is the case the fault shown on the geologic map would be located further northeast near geophysical feature F and the northwest continuation of the fault would be near geophysical feature D where Fault F is currently shown. There is no obvious evidence for the location of this fault's projection further northwest. No evidence of Fault F was found in the low hills in the area of the Motor Washout Area (Feature B-9), the Propellant Mix Station (Feature B-10), or the Mix Station Control Bunker.

Goetz fault

The Goetz fault is interpreted to be a member of the west striking faults that appear to be older than the northwest striking San Jacinto related faults southwest of the Goetz fault. The canyon in which the Goetz fault is located is a well developed canyon that clearly indicates an older age of the Goetz than the San Jacinto related faults. Interest in the Goetz fault is largely based on the great volume of water that was encountered when the San Jacinto tunnel penetrated the fault. When the tunnel penetrated the hanging wall of the southern fault of the Goetz fault zone the daily average groundwater inflow at the tunnel heading was about 11,000 gpm. The inflow increased in a series of alternating higher and lower inflows over a tunnel-alignment distance of 1,500 feet culminating in the peak inflow of 32,000 gpm when the hanging wall of the northern fault was penetrated. In the tunnel the apparent thickness of the Goetz fault zone is 1,600 feet; the actual thickness is about 40 percent less. The Goetz fault zone consists of a southern shear zone about 100 feet thick. A second shear zone is located 1,100 feet to the northeast along the tunnel alignment. About 300 feet further northeast is a low angle fault, the northern fault of the Goetz fault zone. This low angle dipping fault produced the high water discharge when the hanging wall was penetrated. Projecting the northern low angle fault to the surface the apparent width of the faults bounding the zone is about 500 feet.

In contrast to the San Jacinto related faults that were penetrated by the tunnel at about 90°, the Goetz fault was penetrated at an angle of about 30°. It is not clear to what extent, if at all, penetrating the Goetz fault zone at the low angle (about 30°) contributed to the large volume of groundwater that was discharged.

A rather exhaustive search was made to locate Goetz faults. Only 2 Goetz fault exposures east of Site 1 were located. These 2 faults are very different from one another. The northern fault is the most planar fault seen in the area of Site 1 (Photographs 21, 22, and 23). The fault includes about 10 feet of brecciated rock and several inches of finely comminuted gouge. The fault juxtaposes schist on the south against tonalite on the north. The fault strikes N 80°-85° E and dips 50° to the north. The low dip suggests this may be the surface expression of the northern low-angle hanging-wall fault encountered in the San Jacinto tunnel. The southern fault is a very unusual zone of disrupted rock with slickensides in a wide variety of orientations (Photographs 24 and 25). Measurements of a few slickensides are, N65°E, 81°NW, N47°E, 70°NW, N48°E, 77°NW, N13°E, 72°NW, N80°E, 43°NW, Due North, dipping 52°E, N5°W 68°NE. Little confidence can be placed on the accurate orientation of this zone. Guilt by spatial association, this fault is drawn parallel to the northern fault. Both faults are interpreted as being terminated by Fault F.

Lawrence Fault

The east-northeast striking Lawrence Fault is topographically well defined east of the northeast corner of Site 1. A long linear set of major drainages are eroded in tonalite along the fault. The size and continuity of these drainages indicate the Lawrence Fault is an old fault. By comparison, the canyon in which the Goetz fault is located is less well developed than the drainages developed along the Lawrence Fault. Lateral movement of the Lawrence Fault is left lateral. About 2.5 miles east of the northeast corner of Site 1 the McMullen fault is left-laterally offset about 2,000 feet by the Lawrence Fault.

The topographic expression of the Lawrence Fault greatly diminishes as it extends westward from tonalite to sedimentary rocks. The Lawrence Fault projects across the entry road in Site 1 in an area with artificial fill which obscures the location of the fault. West from the entrance road the Lawrence Fault is projected in curving fashion to pass though a topographic low. Discolored soil west of the topographic low is suggestive that the fault reaches Potrero Creek. Where the fault crosses the topographic low there are Potrero beds to the south and Mount Eden formation to the north. Mount Eden formation is overlain by shallow dipping strata of the Potrero beds north of the topographic low; at the topographic low the only sense of displacement is up on the north side of the fault.

An alternate location for the Lawrence Fault in Site 1 is 1,600 feet to the north of the mapped location. The Lawrence Fault at the more northern location requires a major change in the strike of the fault extending from the east. This northern locality is where the Leighton report (1983) map locates the

Lawrence Fault. This northern fault is well exposed in Potrero beds (Photographs 26 and 27). To the east of the well exposed fault is a curious break that appears to be a sand-filled break (Photographs 28, 29, and 30) in alluvium on the east side of Potrero Creek interpreted as a fault feature.

During the geologic mapping, the location of the Lawrence Fault shown on the geologic map was preferred over the location further north because this location is the more reasonable projection of the Lawrence Fault from the east; the northern location requires more deviation from the projection of the fault from the east. The shown location on the geologic map introduces some discomfort due to the somewhat sinuous location of the Lawrence Fault between Potrero Creek and the entrance road. Both the geologic map (Figure 2) and the Leighton report (1983) geologic map show a fault in the low saddle where Figure 2 locates the Lawrence Fault. If the Lawrence Fault is located further north than shown on Figure 2, the fault in the low saddle probably follows a course similar to that shown on Figure 2, rather than the course shown on the Leighton map.

McInnes fault zone

Due to the emphasis placed on the McInnes fault by Henderson (1939) a quick examination was made of the McInnes fault to be assured it is not relevant to Site 1 (see Figure 1). The McInnes fault zone is a major fault based on its physiographic expression. A northwest striking fault zone, it may be related to the McMullen fault zone located about 2 miles to the northeast. Based on quick examination of the McInnes fault, it is well marked by lush vegetation near the east side of the San Jacinto 7.5’ quadrangle. The McInnes fault zone produced little inflow when penetrated by the San Jacinto tunnel; the fault was apparently penetrated from north to south which reduced the damming effect of the fault. The age relationship of the McInnes fault to the Lawrence Fault is unknown. The location and orientation of the McInnes fault precludes any relevance to the Potrero area. Twelve relatively small faults encountered by the San Jacinto tunnel that are located northeast of the McInnes Fault Zone are also not relevant to Site 1 geology and groundwater flow.

3.3.2 Minor Faults

A number of minor faults of various orientations were found. Northeast striking faults occur at the Testing/Instrumentation Personnel Bunker (Feature F-45, Photograph 31) and at the low hills where the Leighton report map showed their northwest oriented Bedsprings fault (Photograph 32). A large number of north striking faults are located just west of where the road into Potrero branches (33° 52’ 22.2”; 116° 55’ 59.5”). Exposed in the northern road between the branch and the site of the old Potrero ranch house and the low hills north of the old ranch house site are a number of minor north striking faults in the Mount Eden formation. Fault orientations range between N40°W and N32°E and dip at steep angles both to the east and west. None of these faults were found in the tonalite exposed along the abandoned and eroded old road bed just to the south. The only deformation found in the tonalite were a few northwest oriented linear zones of incipient mylonitic fabric (Photograph 33); the texture of this deformed rock appears to be protoclastic indicating a very old age, probably Cretaceous.

4.0 LINEAMENTS

The results of the lineament study are discussed in this section along with the orientations as determined by the Rose diagrams included at the back of this report.

4.1 ROSE DIAGRAMS

Rose diagrams provide a general summary for the orientation of lineaments recorded during the investigation of Site 1. Rose diagrams 1, 2, and 3 are of lineaments recorded in basement rocks, both plutonic and metamorphic. Rose diagram 4 is of lineations in the Mount Eden formation between west of Area 'H' to the southwestern part of Area F. Rose diagram 5 is of lineations in the Mount Eden formation in the southeast part of Area F. Rose diagram 6 gives the orientation of individual faults measured west of the Goetz fault. Rose diagram 7 is the generalized bearing of major faults west of the Goetz fault. Obvious from the Rose diagrams there is little variation in the orientation of lineaments regardless of age. Lineaments in foliated Paleozoic age metamorphic rocks have a mean orientation (bearing) of 308.5 (N51.5ºW). This fabric is at least Cretaceous in age. Lineaments in tonalite east of Potrero have a mean orientation (bearing) of 317.5º (N42.5ºW) and tonalite north of Potrero have a mean orientation of 318.2º (N41.8ºW). The age of these lineaments is about 90 million years. Lineations in the Mount Eden formation between west of Area H to southwestern part of Area F have a mean orientation of 327.2º (N32.8ºW). Lineations in the southeast part of Area F have a mean orientation of 332.8º (N27.2ºW). Bearing of major faults west of the Goetz fault have a mean orientation of 315.6º (N44.4ºW). Bearing of individually measured faults west of the Goetz fault, including faults in young alluvium, have a mean orientation of 321.5º (N38.5ºW). The dominant structural grain is northwest oriented in the area of Site 1, and ranges in age from Cretaceous to latest Pleistocene and/or Holocene.

4.2 LINEAMENTS LOCATED ON IMAGES

Most lineaments measured strike northwest. Lineaments are more abundant in basement rocks than in Mount Eden formation and the Potrero beds. Much of the Mount Eden formation north of Potrero Creek is obscured by a cover of thin layers of gravely sediments restricting greatly any observations of lineaments.

A number of lineaments in the Mount Eden formation are visible in 1938 aerial photos southeast and northwest of the Area H Sanitary Landfill (Figure 4). These lineations are interpreted as a mix of joints and faults. Lineaments in metamorphic rocks east of the Area H Sanitary Landfill were not recorded. Subsequent to the 1938 aerial photographs, photographs show numerous man-made lineaments. Images examined dating from the early 1970s to 2000 show considerable surface disruption from Area F to west of Area I. The disruptions appear to be produced by various engineering activities affecting the surface materials. Visible on Google Earth images (2009) are a number of lineations in the Mount Eden formation in the southeastern part of Area F.

4.3 JOINT LINEAMENTS

Within the batholithic rocks lineations produced by joint sets are common. Most granitic rocks of the Peninsular Ranges batholith have a conjugate joint set. One joint set strikes northwest and the second northeast. In most plutons, the northwest striking joint set is dominant. Dominant joints in granitic rocks east and north of Potrero Valley are quite consistent in orientation. Joint lineaments measured in tonalite east of Potrero have a mean orientation (Vector mean) of 317.5º (N42.5ºW) and are shown in Rose Diagram 1. Joint lineaments measured in tonalite north of Potrero have a mean orientation (Vector mean) of 318.2º (N41.8ºW) and are shown in Rose Diagram 2.

Joints in tonalite in the Mount Davis area (see Figure 1) west of Potrero basin in the headwater area of Lambs Canyon and Laborde Canyon have a similar orientation to the principal joint set on the north and east side of Potrero Valley. Principal joints in the Mount Davis area have bearings ranging in orientation from about 320º to 300º (N40ºW to N60ºW) and average about 310º (N50ºW). Based on the consistency of orientation of the principal joint direction in tonalite between the east side of the Potrero valley and the Mount Davis area indicates the dominate joint orientation in tonalite beneath the Quaternary and Tertiary sediments in the Potrero valley area should be between about 300º (N60ºW) to 320º (N40ºW). All joints measured dip steeply to the northeast or northwest.

4.4 FOLIATION LINEAMENTS

Lineaments in schistose rocks in the area of Site 1 are parallel to foliation planes in schist. Lineaments in schist septa within tonalite north of Potrero valley have a mean orientation (Vector mean) of 308.5º (N51.2ºW) and are shown in Rose Diagram 3. The bearings of foliation in schistose rocks west of Potrero valley range between 298º (N62ºW) to 327º (N33ºW) and average 314º (N46ºW). Extensive large-scale landsliding in the metamorphic rocks south of Potrero Valley gives rise to out-of-place foliation orientations.

Based on the measurements in tonalite and schist, basement rock lineaments have a consistent northwest orientation that average about 310° to 320° (N40°W to N50°W). All foliations measured dip steeply, mostly to the northeast.

5.0 GROUNDWATER FLOW

Based on historic records during construction of the San Jacinto tunnel, construction of the tunnel had a profound affect on groundwater in the Potrero area. During construction of the San Jacinto tunnel the daily average groundwater inflow recorded at the tunnel heading gives a reasonable insight to the groundwater barriers produced by faults intersected by the tunneling. Unequivocal analysis is complicated by the number of headings used in the tunneling, the east portal at Cabazon, Cabazon shaft (8,200 feet from east portal), the Lawrence adit at 35,700 feet from the east portal, the Potrero shaft at 52,300 feet, and the west portal at 67,800 feet. It appears that 6 headings were being driven simultaneously from 1934-1936 (there apparently was a little work done at the west portal during 1933); the east portal and west portal, 2 headings each from the Cabazon and Potrero shafts. Two headings from the Lawrence adit were apparently started later in 1938. Tunneling was apparently completed in 1939. The Potrero Adit is situated closest to and along strike of the major structural features associated with Site 1 and the BPA. The next closest adits include the West Portal Adit approximately 2.9 miles southwest of the BPA and the Lawrence Adit, approximately 3.1 miles to the northeast. Since these adits are located perpendicular to the orientation of the faults that cross the Site and are considerably distant from any portion of the impacted groundwater at the Site, they are not considered preferential pathways or conduits that would influence groundwater flow at the Site.

Headings at the east portal and Cabazon adit (over 7.5 miles east of Potrero Valley) encountered no appreciable ground water until reaching the Twin Pines fault (about 6 miles east of Potrero Valley) where there was a little over 2,000 gpm increase and an additional 1,000 gpm increase at an unnamed fault about 500 feet south of the Twin Pines fault. Flow of water remained relatively steady at about 4,000 gpm until the tunnel head reached the Ranger Station Fault (about 4.5 miles east of Potrero Valley) where there was a dramatic increase of 12,000 gpm. Water flow decreased to about 9,000 gpm of inflow over 4,000 feet until about 1,100 feet from the hanging wall of the McMullin Fault (see Figure 1) where the inflow increased to a peak of 8,500 gpm. There was a very sharp drop of about 6,000 gpm 300 feet southwest of the McInnes fault. The heading driven south from the Lawrence adit encountered only a 2,000 gpm increase in flow midway though the McInnes fault. The northwest striking Twin Pines and Ranger Station Faults are located beyond the Potrero Creek drainage basin and have no bearing on groundwater conditions in Potrero Valley.

The Potrero shaft was driven close to the hanging wall of the Potrero fault zone and bottomed just south of the footwall of the fault. Headings were being driven from the Potrero shaft in late 1934. The north heading penetrated the hanging wall of the Potrero Fault zone about 200 feet north of the shaft. Penetration of the hanging wall produced a very short duration discharge spike of about 8,000 gpm followed by a very rapid decrease in inflow to about 2,500 gpm. Inflow remained relatively constant for 1,700 feet from the hanging wall of the Potrero Fault until the hanging wall of the Bedspring fault was encountered and the flow again increased by about 8,000 gpm. This increase remained relatively constant across the section of tunnel where fault F was mapped and then increased again when the tunnel reached the foot wall of the Goetz Fault.

At the footwall of the Goetz Fault Zone the face was producing about 11,000 gpm. The flow increased dramatically over a distance of about 1,600 feet by 21,000 gpm for a total peak discharge of 32,000 gpm when the hanging wall of the Goetz Fault Zone was penetrated; this increase of 21,000 gpm is by far the greatest increase at any part of the tunnel. Inflow of water decreased back to 11,000 gpm over a distance of 4,000 feet from the hanging wall of the Goetz Fault.

As shown in the various maps presented in this report, numerous faults cross the Beaumont Site 1 area. Many of these faults are oriented in a northwest-southeast direction consistent with the regional geologic structure. While shallow groundwater in the vicinity of the Burn Pit Area does not appear to be influenced by these faults shallow groundwater west of this area is influenced by the faults. Groundwater and surface water flow down Potrero Valley through Massacre Canyon is influenced by the faults that parallel Bedsprings drainage and cross Potrero Creek. Offset beds of recent alluvium exposed in Potrero Creek indicate that many of the northwest striking faults are relatively young. Faults D and E, and the Potrero and Bedsprings faults likely play a role in controlling groundwater flow in the alluvium and downgradient movement of impacted groundwater. Most faults are mapped based on the presence of vegetation that is indicative of shallow groundwater (sedges, mule fat, and willows) and suggests that many of the faults appear to block the flow of groundwater and/or force the groundwater near the surface. Evidence of this can be seen in the concentration of groundwater contours in the area where the two drainages converge (see Figure 5).

Again, while the water table groundwater contours presented in Figure 5 do not suggest that the faults are having an influence on shallow groundwater flow beneath the Burn Pit Area, deep groundwater flow in the Burn Pit Area is still not well understood. Based on detailed mapping of the faults in the Burn Pit Area, the Goetz fault does not cross the Burn Pit Area, nor does it project east of the Burn Pit Area as depicted in the Leighton report (1983). Based on the results of this study, Fault F appears to pass through the center of the Burn Pit Area and appears to be the only mapped fault that would likely come into direct contact with impacted groundwater from the Burn Pit Area.

The San Jacinto Tunnel extends 13 miles from Cabazon on the east to Gilman Hot Springs on the west and at the closest point is approximately three quarters of a mile (about 4,000 feet) from the southern most corner of the Burn Pit Area. The tunnel was constructed in the 1930s to provide a transport mechanism for Colorado River water to be conveyed into southern California. The San Jacinto Tunnel conveys approximately 550,000 acre feet of Colorado River per year (Colorado River Board of California, 2000, and MWD, 2009). As discussed above, during the construction of the San Jacinto Tunnel in the 1930s, large amounts of groundwater seepage were noted. These large amounts decreased within several years of construction. Current estimates indicate a total of 5,000 acre feet per year of groundwater seeps into the tunnel along the entire 13-mile length (Eastern Municipal Water District, 2002 and 2008). This tunnel seepage equals about 1 percent of the total flow through the tunnel.

Groundwater modeling performed to better understand groundwater flow and contaminant transport within Potrero Valley started with defining the water budget present at the site. Based on a review of previous documents, precipitation data, and available information on the site hydrology, the Beaumont Site 1 conceptual site model indicates that during the period from 1992 through 2008, total recharge and flow in the Site 1 aquifer was estimated to average 246 acre-feet-per year (afy) with 110 afy due to recharge over the valley floor and 136 afy due to diffuse recharge from creeks (primarily the Bedsprings drainage). Total discharge and flow in the Site 1 aquifer for the same period (1992 through 2008) is estimated to average 218 afy with 139 afy due to evapotranspiration in riparian areas, 71 afy due to discharge down Potrero Creek, and about 8 afy due to leakage into the underlying Mt. Eden formation. From 1992 through 2008, it is estimated that aquifer storage increased by about 28 afy in Potrero Valley. The model showed that downward flow from the shallow groundwater system into the deeper granitic basement rock averaged only about 3 afy during the same period.

Annual average Potrero Creek stream flow has been estimated by the California Department of Water Resources as 1,230 afy (Leighton, 1983). Given that Potrero Creek flow is the dominant source of recharge for the aquifer at Site 1, this stream flow of 1,230 afy places a constraint upon the reasonable volume of aquifer flow that could be expected.

As discussed above, the groundwater contours do not indicate that shallow groundwater beneath the Burn Pit Area is being influenced in a significant way by the mapped faults. This is also supported by the contaminant plumes. The Site 1 plumes act as tracers of groundwater flow, especially the conservative chemicals of concern (COCs) like 1,4-dioxane, that are not subject to transformations or adsorption. The plume morphology indicates that the COCs have migrated approximately 7,200 feet to the northwest from the BPA and Rocket Motor Production Area source areas but the COCs have migrated less than 150 feet vertically downward. Thus, the plume morphology provides strong evidence that the majority of the groundwater at Site 1 is moving laterally to the northwest towards Potrero Creek, and not vertically downwards towards the granitic basement. Further, the total seepage along the 13 mile length of the tunnel is estimated to be 5,000 afy. During groundwater modeling of the Potrero it was estimated that a total of 3 afy of groundwater flows into the granitic basement across the entire model area. Although, only a portion of the 3 afy should migrate toward the tunnel, if all of it did it would represent 0.00054% of the flow in the tunnel.

Given the sites position between two major fault systems, it was not unexpected that numerous faults would be found during this study. And while it appears that those faults do have a significant influence on movement of shallow groundwater near the confluence of Bedsprings and Potrero Creeks, the faults do not appear to have a significant influence on groundwater flow beneath the Burn Pit Area.

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STEREO AERIAL PHOTOGRAPHY EXAMINED

1938 (partial coverage)

1948, 1:31,500 scale

1962

1974

1980

1984

1990

1991

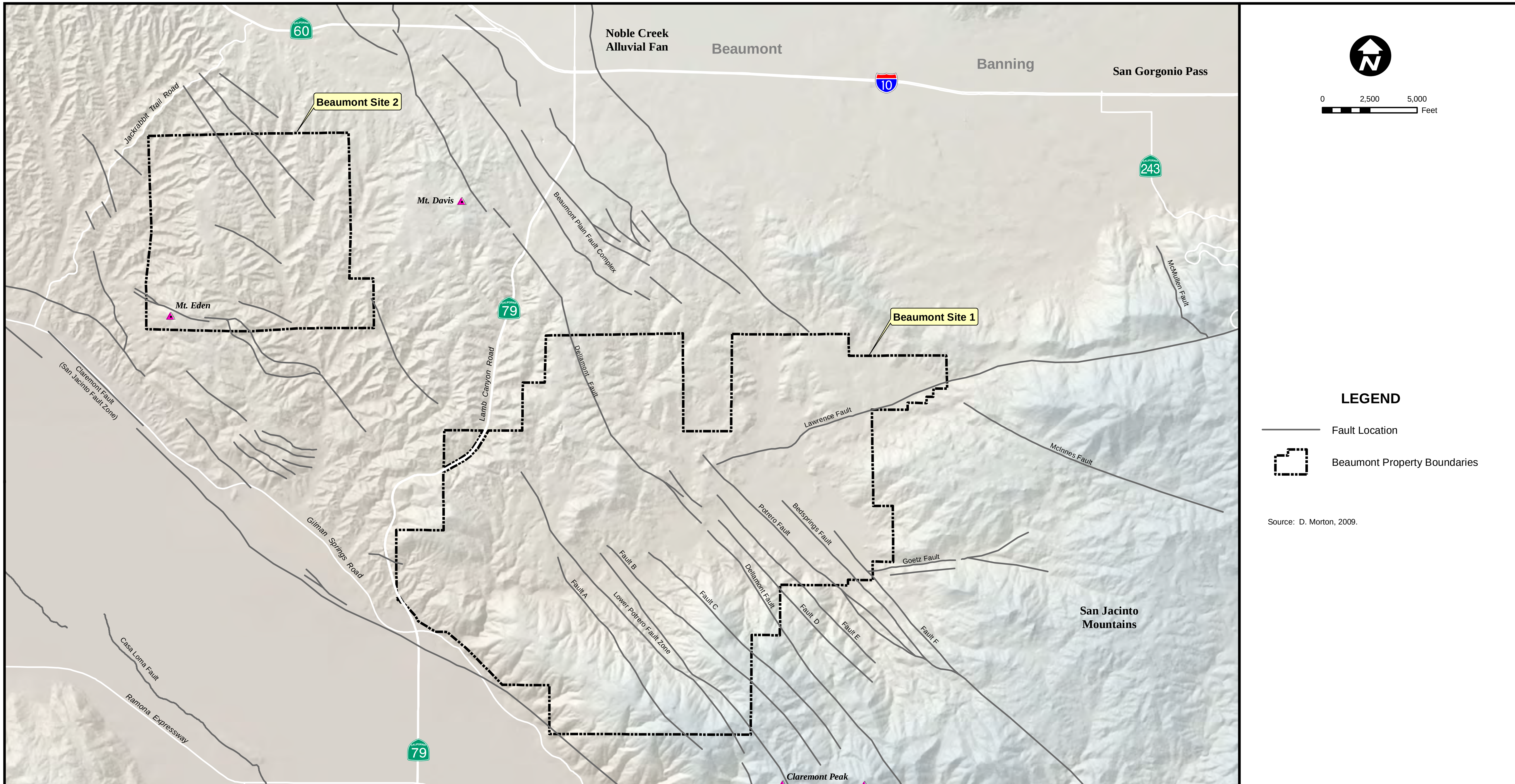
1995

2000

2005

2009 Google Earth images, not stereo

FIGURES



X:\GIS\Lockheed 23521-0502\Region_Site 1.mxd

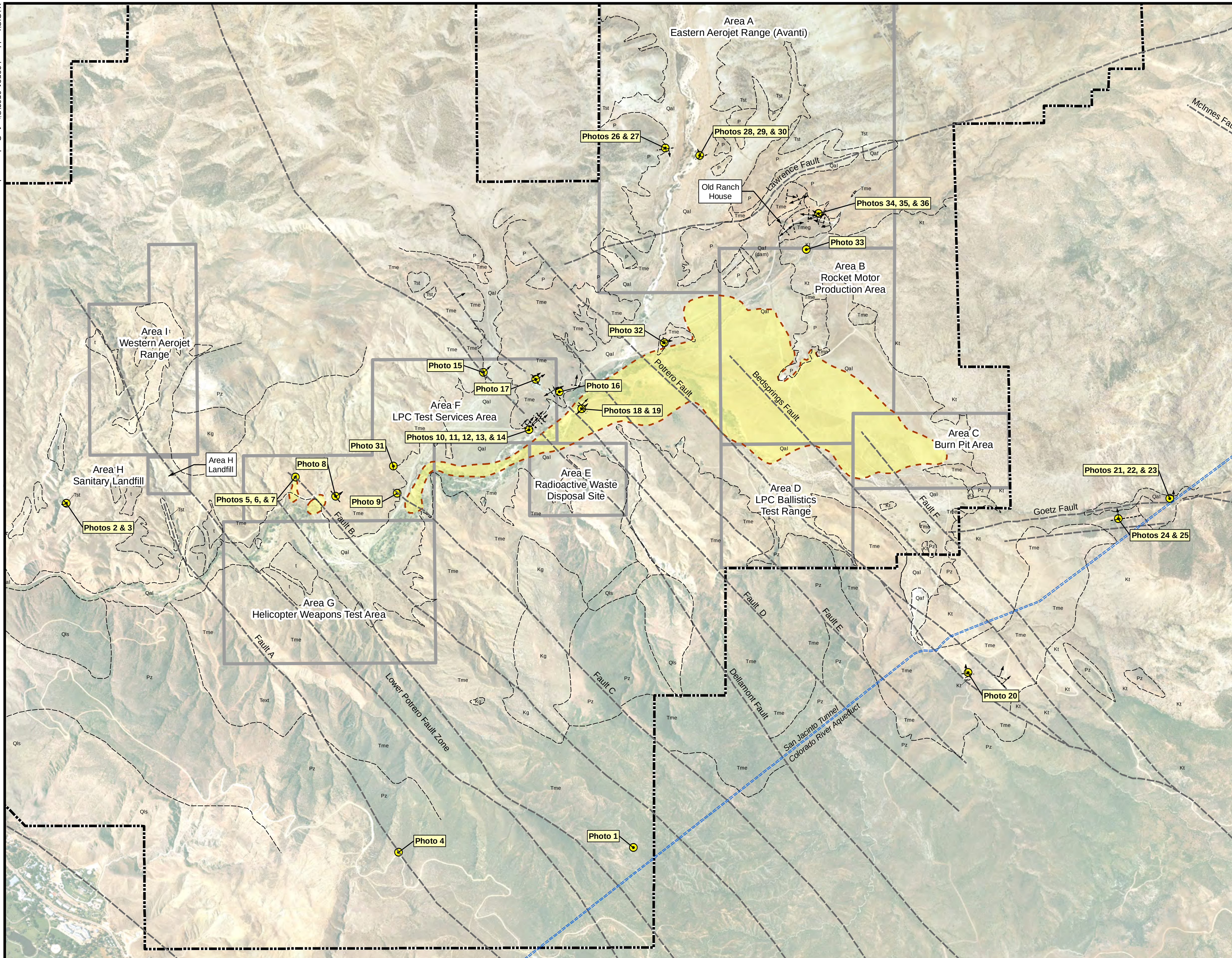
Beaumont Site 1

Figure 1

Regional Fault Map, Lockheed Beaumont Sites 1 and 2

TETRA TECH

X:\GIS\Lockheed 23521-0502\Site 1_Geology.mxd



LEGEND

- Photo Location
- San Jacinto Tunnel (Colorado River Aqueduct)
- Fault, Accurately Located Showing Dip
- Contact, Approximately Located
- Fault, Approximately Located
- Extent of COPC Contamination in Groundwater (Second Quarter, 2009)
- Beaumont Site 1 Property Boundary
- Historical Operational Area Boundary

Qaf - Artificial Fill/San Jacinto Tunnel Tailings, Potrero Adit.
Qal - Undifferentiated Quaternary alluvial deposits along canyon floors
Qls - Quaternary landslide deposits
T - Thin gravel deposits
Tst - Undifferentiated San Timoteo formation
P - Potrero beds
Tme - Undifferentiated Mount Eden formation
Kg - Cretaceous biotite monzogranite
Kt - Cretaceous biotite-hornblende tonalite
Pz - Undifferentiated Paleozoic schist, gneiss, and marble

Source: D. Morton, 2009.

Beaumont Site 1

Figure 2

Geologic Map
Lockheed Beaumont Site 1

TETRA TECH

X:\GIS\Lockheed 23521-0502\Strike_Dip.mxd

0 100 200
Feet

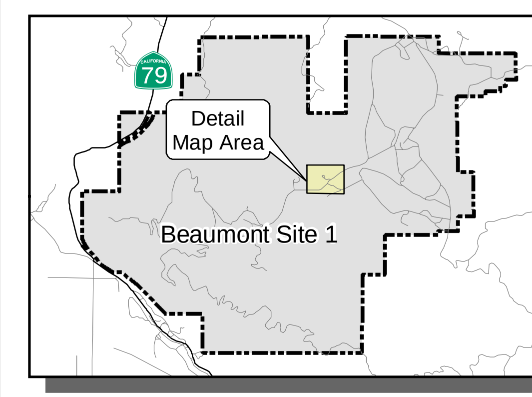
LEGEND

Photo Location

Field Mapped Fracture

Fault, Approximately Located

Source: D. Morton, 2009.
Coordinates are UTM, NAD83, Zone 11N, meters.



Beaumont Site 1

Figure 3

Map Showing Fractures Measured in the Area of the Betatron Facility, Lockheed Beaumont Site 1

TETRA TECH

X:\GIS\Lockheed 23521-0502\Aerial.mxd

N

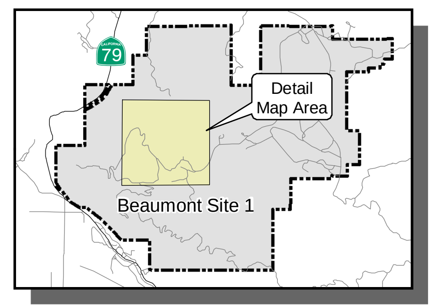
0 500 1,000
Feet

Adapted from: June 1938 aerial photograph.

LEGEND

Linement Location

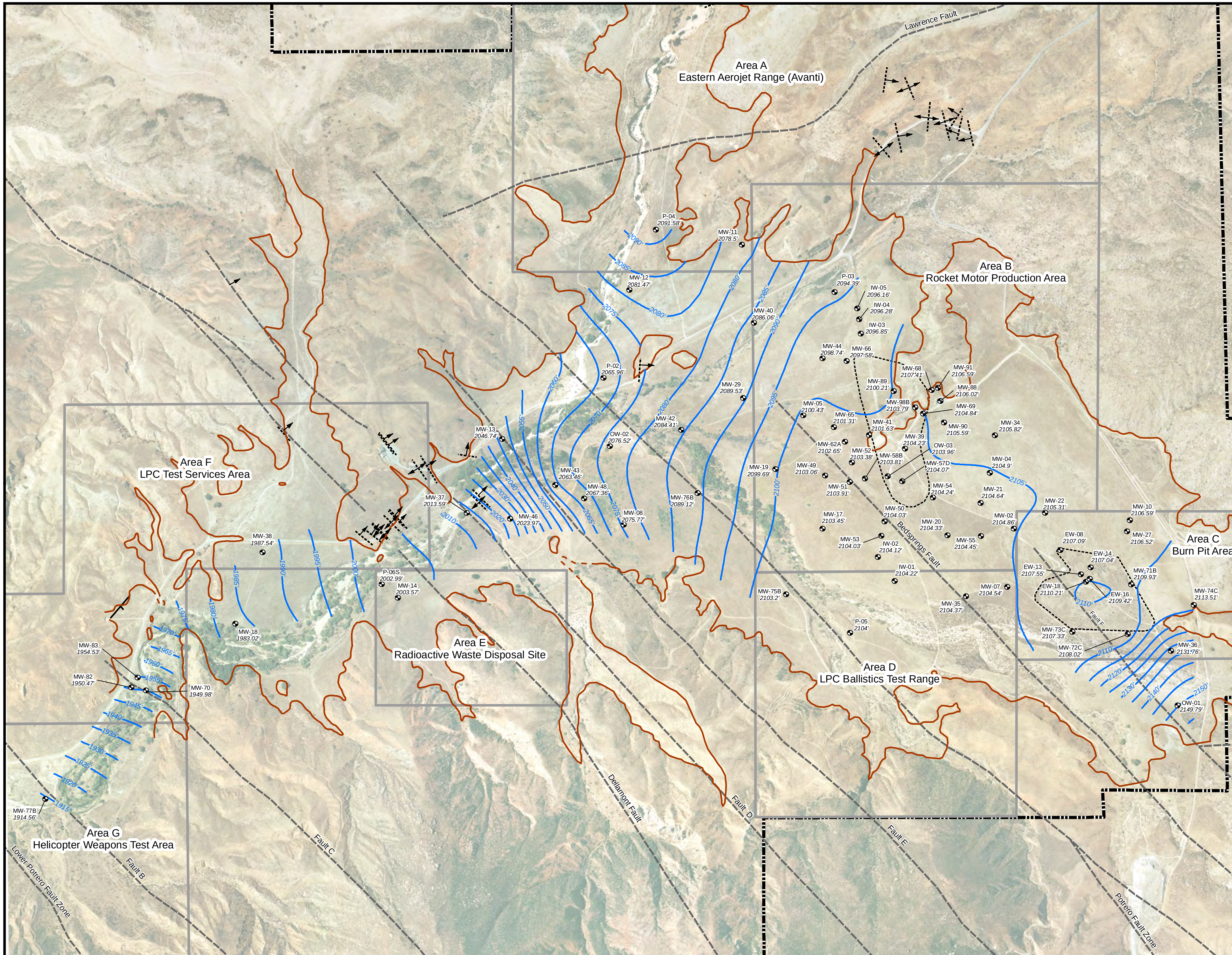
Source: D. Morton, 2009.



Beaumont Site 1

Figure 4
1938 Aerial Photograph Showing Lineaments in the Lower Potrero Canyon Area

TETRA TECH



LEGEND

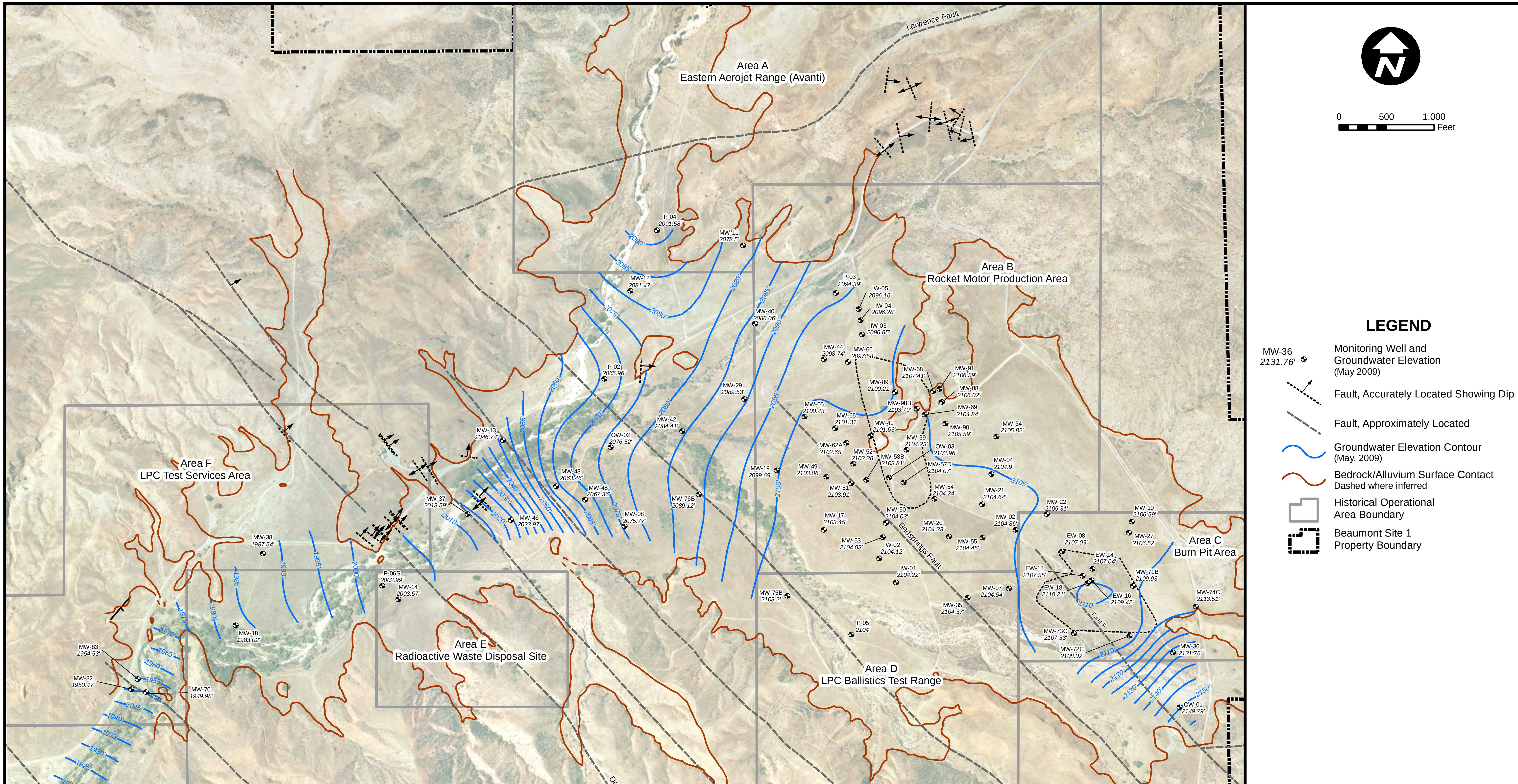
- MW-36 2131.76' — Monitoring Well and Groundwater Elevation (May 2009)
- Fault, Accurately Located Showing Dip
- Fault, Approximately Located
- Groundwater Elevation Contour (May, 2009)
- Bedrock/Alluvium Surface Contact, Dashed where inferred
- Historical Operational Area Boundary
- Beaumont Site 1 Property Boundary

Beaumont Site 1

Figure 5

May 2009 Groundwater Contour with Lineament Study Faults

TETRA TECH



Beaumont Site 1

Figure 6

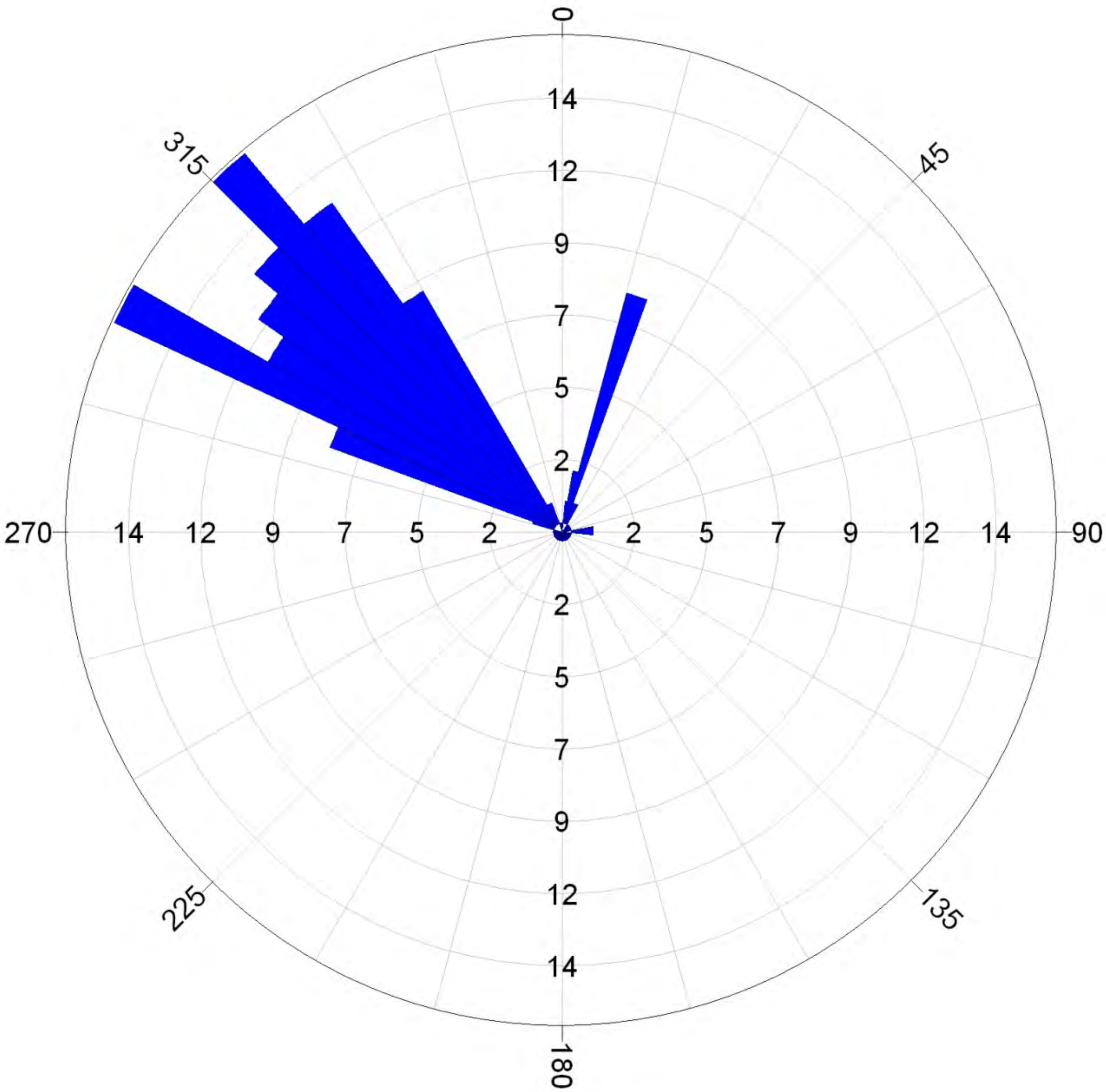
May 2009 Groundwater Contour with Lineament Study Faults

TETRA TECH

X:\GIS\Lockheed 23521-0502\Faults w-Q209 GW.mxd

ROSE DIAGRAMS

X:\GIS\LOCKHEED\23521-0502\LINEATION_1.CDR



Statistical Summary

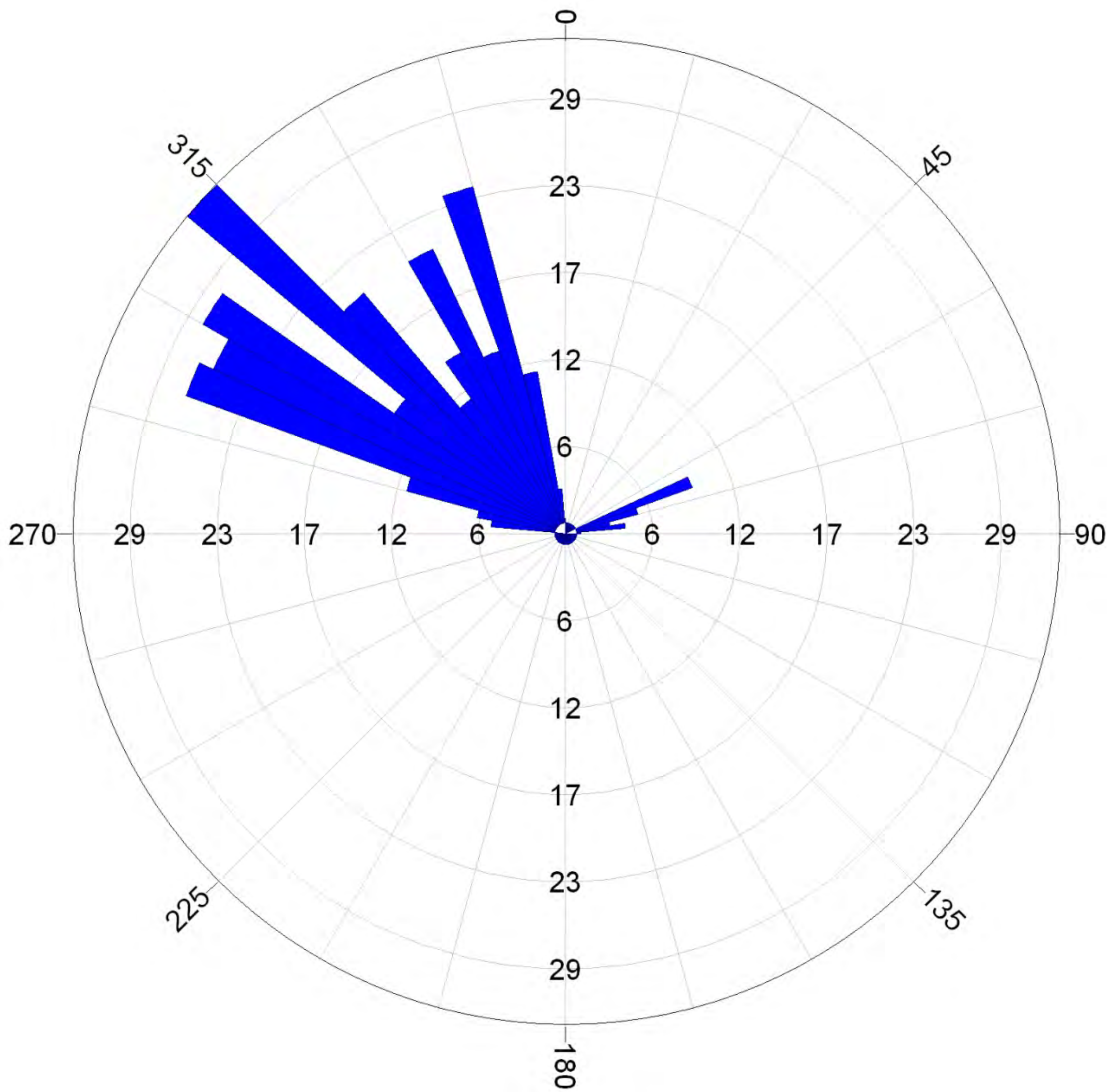
Calculation Method:	Frequency
Class Interval:	5.0 Degrees
Azimuth Filtering:	Deactivated
Data Type:	Unidirectional
Population:	117
Maximum Percentage:	13.7 Percent
Mean Percentage:	5.3 Percent
Standard Deviation:	5.0 Percent
Vector Mean:	317.5 Degrees
Confidence Interval:	5.2 Degrees
	(95 Percent)
R-mag:	0.88

Beaumont Site 1

Rose Diagram 1
Bearing of Lineations in Tonalite East of Potrero

TETRA TECH

X:\GIS\LOCKHEED\23521-0502\LINEATION_2.CDR



Statistical Summary

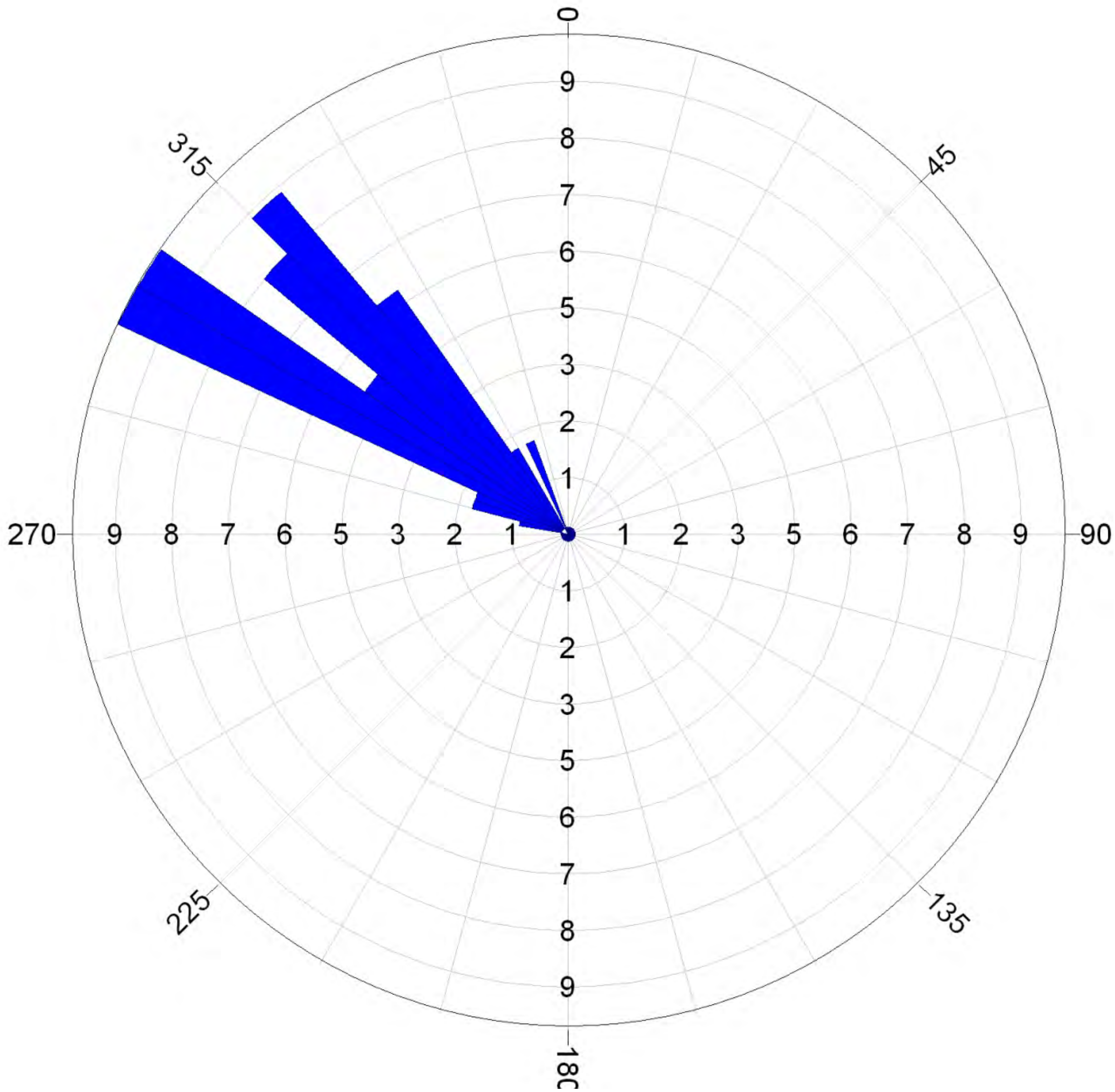
Calculation Method:	Frequency
Class Interval:	5.0 Degrees
Azimuth Filtering:	Deactivated
Data Type:	Unidirectional
Population:	291
Maximum Percentage:	11.3 Percent
Mean Percentage:	4.5 Percent
Standard Deviation:	3.4 Percent
Vector Mean:	318.2 Degrees
Confidence Interval:	3.9 Degrees
	(95 Percent)
R-mag:	0.84

Beaumont Site 1

Rose Diagram 2
Bearing of Lineations in
Tonalite North of Potrero

TETRA TECH

X:\GIS\LOCKHEED\23521-0502\LINEATION_3.CDR



Statistical Summary

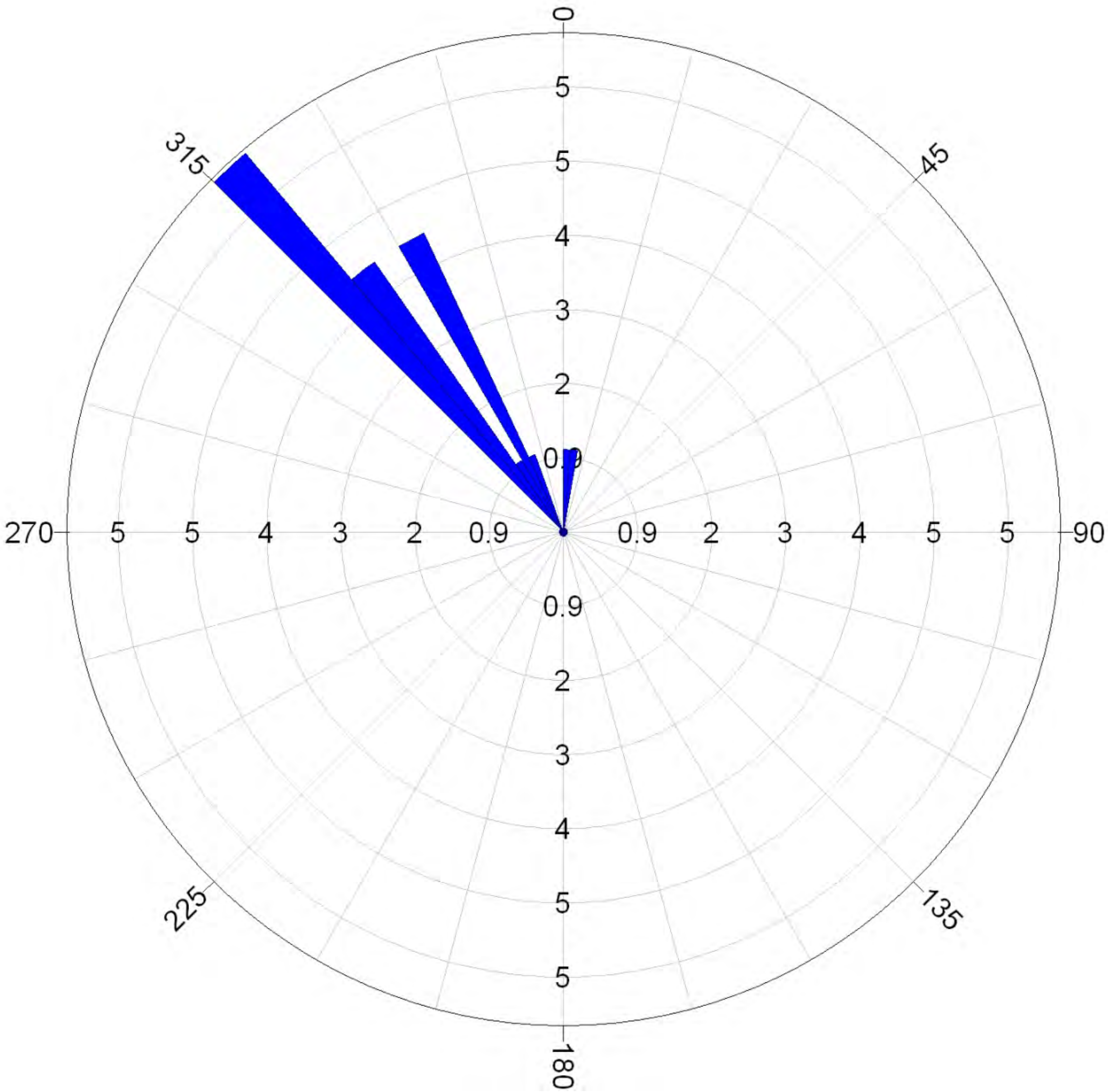
Calculation Method:	Frequency
Class Interval:	5.0 Degrees
Azimuth Filtering:	Deactivated
Data Type:	Unidirectional
Population:	57
Maximum Percentage:	17.5 Percent
Mean Percentage:	9.1 Percent
Standard Deviation:	6.3 Percent
Vector Mean:	308.5 Degrees
Confidence Interval:	3.0 Degrees
	(95 Percent)
R-mag:	0.98

Beaumont Site 1

Rose Diagram 3
Lineations in Metamorphic Rocks
North of Potrero

TETRA TECH

X:\GIS\LOCKHEED\23521-0502\LINEATION_4.CDR



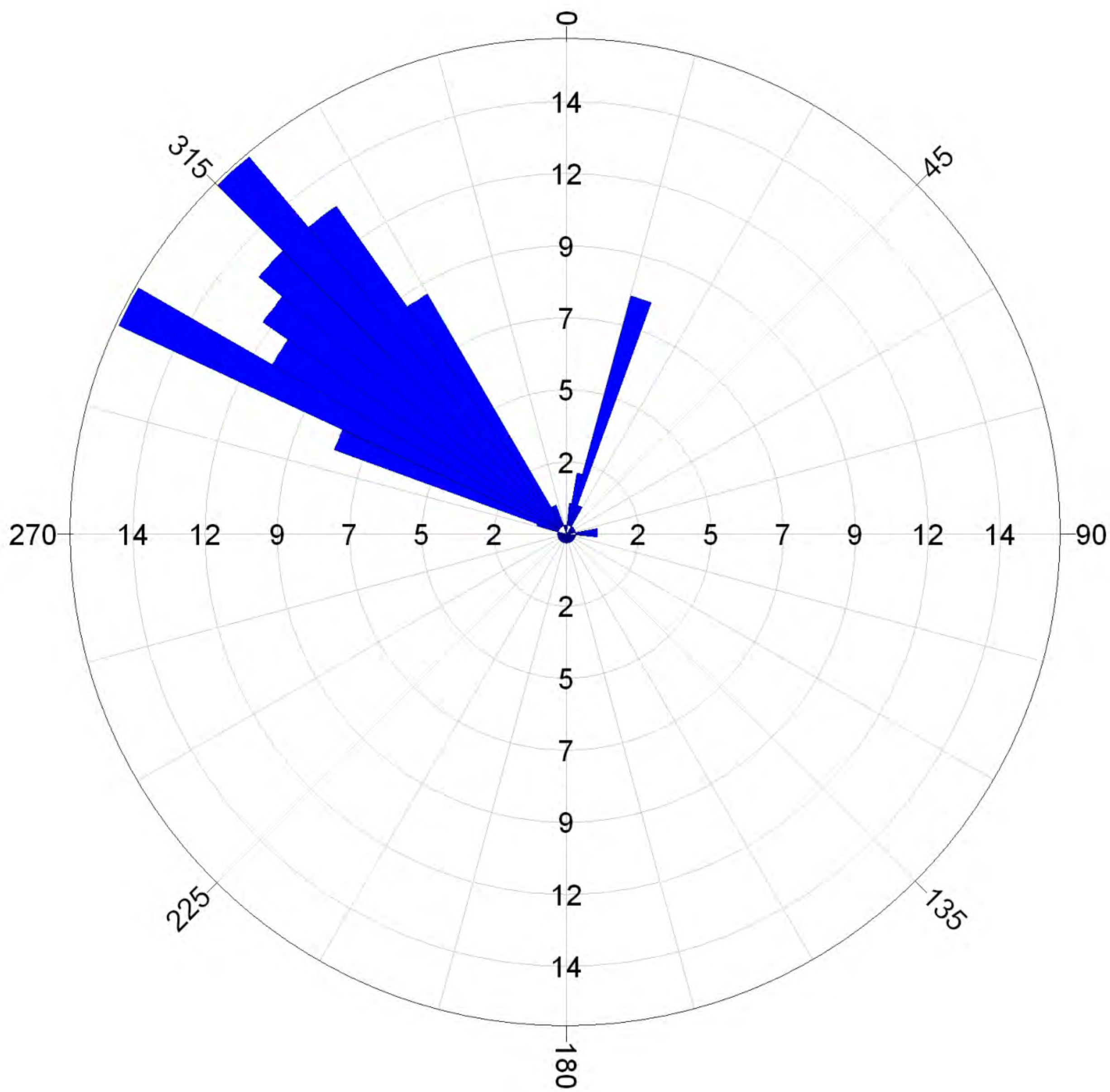
Statistical Summary

Calculation Method:	Frequency
Class Interval:	5.0 Degrees
Azimuth Filtering:	Deactivated
Data Type:	Unidirectional
Population:	18
Maximum Percentage:	33.3 Percent
Mean Percentage:	14.3 Percent
Standard Deviation:	11.5 Percent
Vector Mean:	327.2 Degrees
Confidence Interval:	6.5 Degrees
	(95 Percent)
R-mag:	0.97

Beaumont Site 1

Rose Diagram 4
Bearing of Lineations Between West of Area 'H' to Southwestern Part of Area F

TETRA TECH



Statistical Summary

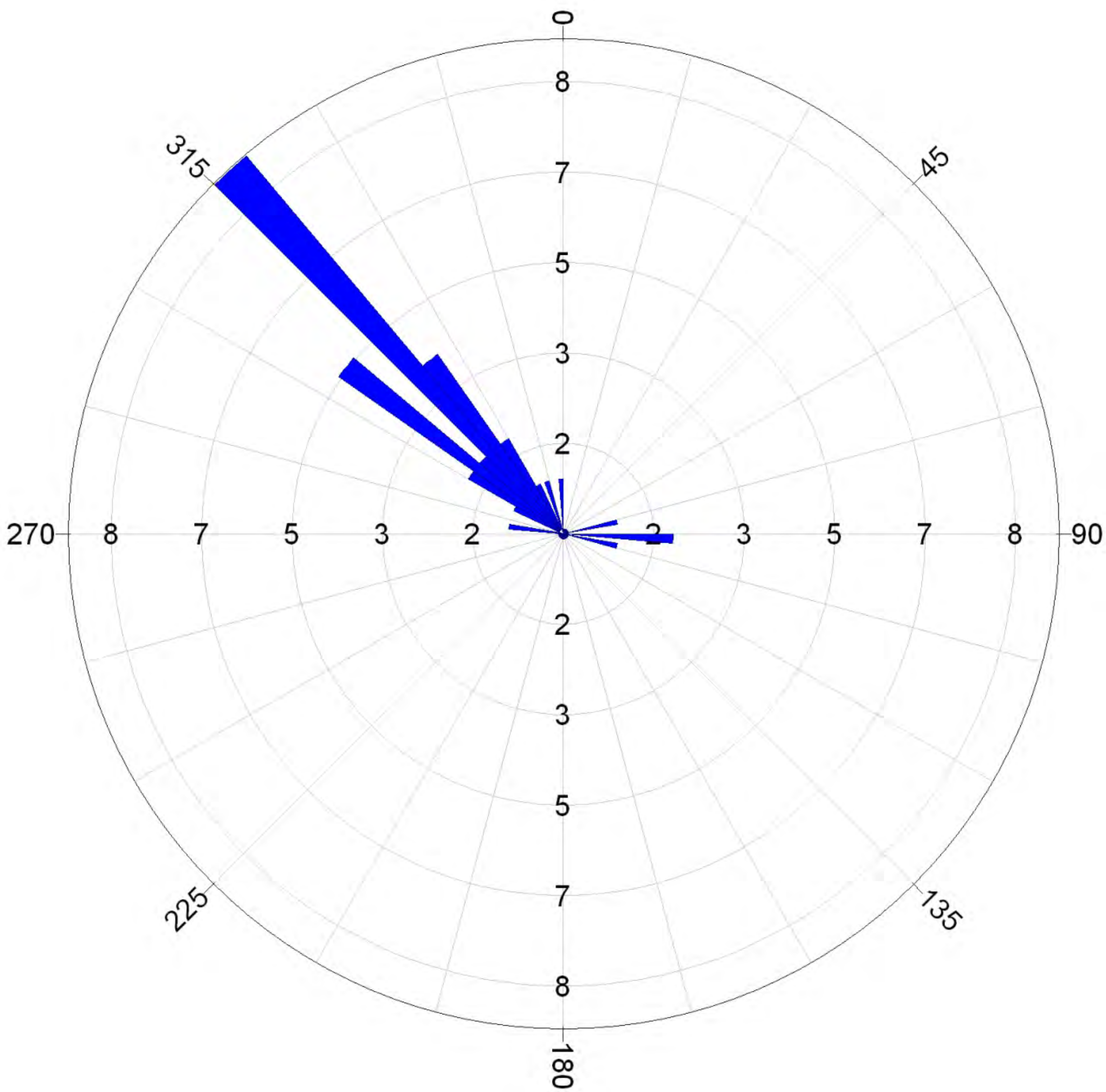
Calculation Method:	Frequency
Class Interval:	5.0 Degrees
Azimuth Filtering:	Deactivated
Data Type:	Unidirectional
Population:	117
Maximum Percentage:	13.7 Percent
Mean Percentage:	5.3 Percent
Standard Deviation:	5.0 Percent
Vector Mean:	317.5 Degrees
Confidence Interval:	5.2 Degrees
	(95 Percent)
R-mag:	0.88

Beaumont Site 1

Rose Diagram 5
Bearing of Lineations in Southeast Part of Area 'F'

TETRA TECH

X:\GIS\LOCKHEED\23521-0502\LINEATION_6.CDR



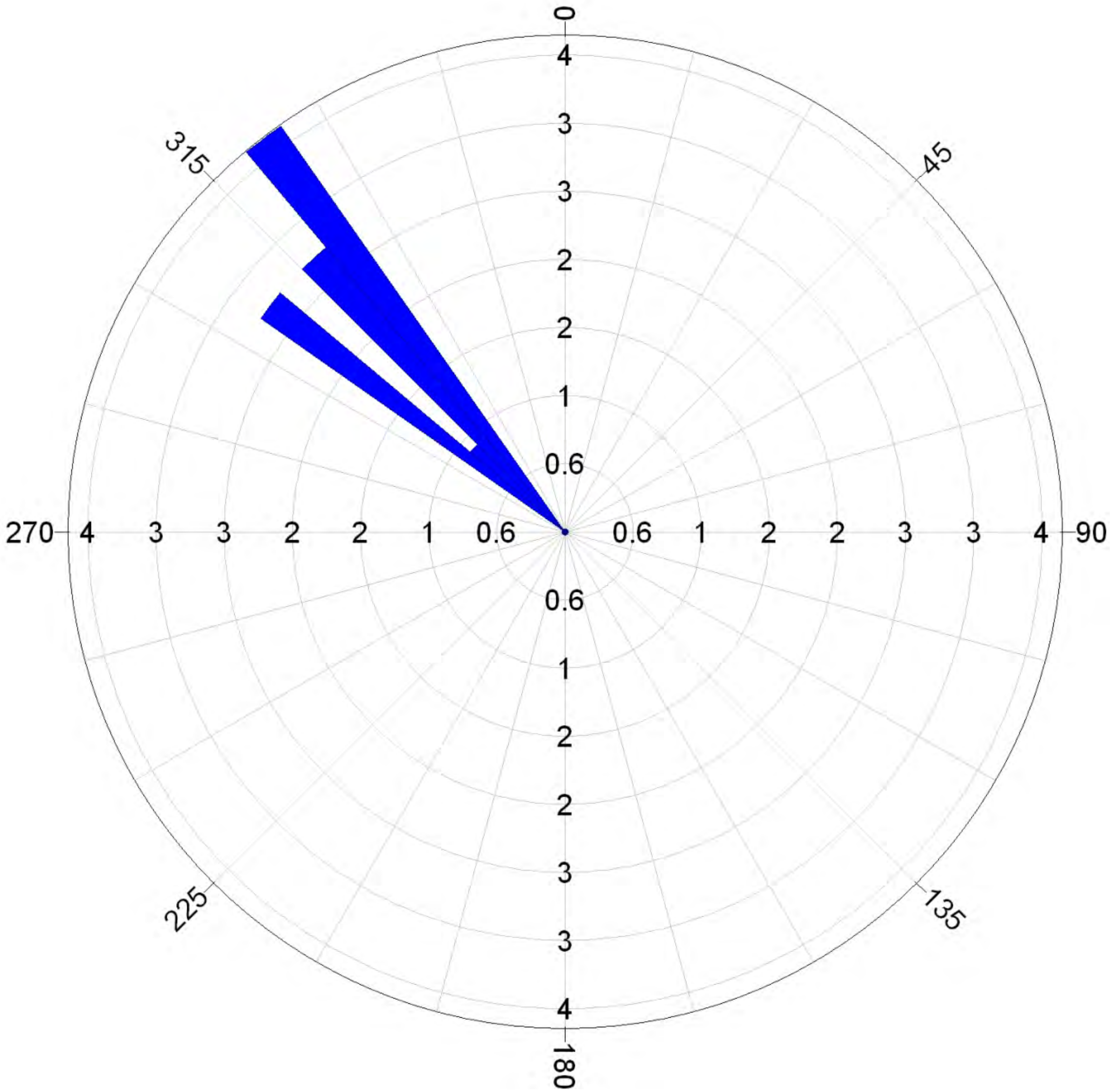
Statistical Summary

Calculation Method:	Frequency
Class Interval:	5.0 Degrees
Azimuth Filtering:	Deactivated
Data Type:	Unidirectional
Population:	33
Maximum Percentage:	27.3 Percent
Mean Percentage:	7.1 Percent
Standard Deviation:	6.9 Percent
Vector Mean:	321.5 Degrees
Confidence Interval:	13.6 Degrees
	(95 Percent)
R-mag:	0.78

Beaumont Site 1

Rose Diagram 6
Bearing of Measured Fault
West of the Goetz Fault

TETRA TECH



Statistical Summary

Calculation Method:	Frequency
Class Interval:	5.0 Degrees
Azimuth Filtering:	Deactivated
Data Type:	Unidirectional
Population:	11
Maximum Percentage:	36.4 Percent
Mean Percentage:	25.0 Percent
Standard Deviation:	11.4 Percent
Vector Mean:	315.6 Degrees
Confidence Interval:	4.8 Degrees
	(95 Percent)
R-mag:	0.99

Beaumont Site 1

Rose Diagram 7
Generalized Bearing of Major Faults West of the Goetz Fault

TETRA TECH