WLA

Review of

"Final Report, Walnut Creek Water Treatment Plant Expansion, Seismic Study—Phase II", by Geomatrix Consultants, dated October 1998

For
East Bay Municipal Utility District
375 Eleventh Street
P.O. Box 24055, MS #610
Oakland, CA 94607-4240

By
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(925) 256-6070

July 19, 1999

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Mr. Fred M. Starr
East Bay Municipal Utility District
375 Eleventh Street
P.O. Box 24055, MS #610
Oakland, CA 94607-4240

Subject: **Review of "Final Report, Walnut Creek Water Treatment Plant Expansion, Seismic Study—Phase II", by Geomatrix Consultants, dated October 1998.**

Dear Mr. Starr:

The enclosed report summarizes our technical peer review of the report noted above. In general, we find that the approach and level of effort completed by Geomatrix Consultants (Geomatrix) for assessing fault-rupture hazards at the Walnut Creek Water Treatment Plant (WCWTP) is commendable, considering logistical and technical constraints at the site. The majority of the conclusions made by Geomatrix are reasonable, although many are based on data that can be interpreted in several alternative ways. Consideration of alternative tectonic models of the site region may influence the interpretation of fault rupture length, and thus the maximum earthquake and amount of coseismic displacement at the WCWTP. As summarized below, our primary review comments relate to fault characterization issues that may specifically influence the assessment of fault-rupture hazards at the WCWTP.

Because little is known about the seismic characteristics of the Franklin fault, understanding the relationships among major faults within the WCWTP region is critical to adequately evaluating the maximum earthquake magnitude for the Franklin fault, and thus to estimating amounts of coseismic displacement at the WCWTP. Geomatrix interprets that the WCWTP lies within a regional strike-slip duplex in the northern East Bay Hills, and that the Franklin fault is primarily a dextral strike-slip fault. Geomatrix should provide a compilation of previously mapped fault traces at both regional and local scales, in order to show alternative interpretations of the location and kinematic role of the Franklin fault and associated faults in the WCWTP vicinity. It is our opinion that available data suggesting other reasonable interpretations should be more explicitly acknowledged. For example, we believe that the Franklin fault at the WCWTP may contain a left-stepover, and thus the West fault may be more than a secondary strand of the fault. In addition, regional relations support the interpretation that the Franklin fault is at most 22 km long, rather than 29 km long as interpreted by Geomatrix.

Geomatrix interprets that the Franklin fault is active according to the Division of Safety of Dams (DSOD), which considers a fault active if it has had at least one episode of movement in the past 35,000 years. We concur that the Franklin fault, and the West fault at the WCWTP, should be considered active faults using DSOD criteria. We also concur with Geomatrix that the Central and East faults at the WCWTP should be considered "conditionally active" faults. Based on the results of trenching at the site, surface rupture may occur along faults within a 1400-ft-wide zone at the WCWTP. We concur that rupture along the West fault will extend beneath the proposed clearwell expansion and note that the possibility of rupture beneath the 9MG storage proposed tanks has not been precluded. The results of this study also demonstrate that the West fault and Franklin fault cross the Mokelumne Aqueduct directly northwest of the WCWTP in a 1000-ft-wide zone. We concur with Geomatrix that such a rupture is less likely than rupture along the Hayward or Calaveras faults, but the likelihood of surface rupture cannot be properly evaluated. Geomatrix judges that the Maximum Credible Earthquake on the Franklin fault is M_W 6 3/4, which is based, in part, on empirical relations between magnitude and surface rupture length and an estimated fault length of 29 km. However, it is our opinion that the fault is only 22 km long, which yields an earthquake magnitude of M_W 6.6. We also calculate a magnitude of M_W 6.4 based on empirical relations between magnitude and fault rupture area, and an assumed downdip fault width of 12 km. Based in part on these calculations, we judge that the Maximum Credible Earthquake on the Franklin fault is M_W 6 1/2.

Geomatrix estimates a range in coseismic displacement for the Franklin fault of 2.3 to 4.3 ft, and assumes that 30 to 50% of the total slip (1.3 to 2.1 ft) could occur on the West, Central, and East faults. In general, we concur with this determination, although we believe that Geomatrix should acknowledge the amount of uncertainty in these estimated values of coseismic displacement. We calculate that the range (two standard deviations) in coseismic displacement on the West, Central, and East faults is 0.0 to 3.4 ft, assuming a surface rupture length of 29 km and a Maximum Credible Earthquake of M_W 6 3/4. However, using a surface rupture length of 22 km and a Maximum Credible Earthquake of M_W 6 1/2, we estimate that the mean displacement along the West, Central, and East faults is 0.5 to 1.2 ft. The two-standard-deviation range in displacement for the faults is 0.0 to 2.5 ft. Although the maximum amount of displacement within this range is only slightly higher than the maximum value given by Geomatrix, we believe that the incorporation of uncertainty in the estimation is more robust and defensible. Geomatrix should acknowledge the uncertainty inherent in the regressions, and incorporate this uncertainty in their estimates of coseismic displacement.

It is a pleasure to provide this technical review. Please feel free to contact us at (925) 256-6070 if we can be of further assistance.

Respectfully,
WILLIAM LETTIS & ASSOCIATES, INC.

William R. Lettis
Principal Geologist

Keith I. Kelson
Principal Geologist

Enclosure (5)
WRL/lap

TABLE OF CONTENTS

Page

Executive Summary 1

1.0 General Overview 2

1.1 Data Presentation Issues 2
- Regional Fault Compilation 2
- Local Fault Compilation 4
- Trench-wall Logs 4

1.2 Significant Fault Characteristic Issues 4
- Tectonic Setting and Relations with Other Major Faults 4
- Activity of the Franklin Fault 5
- Maximum Magnitude of the Franklin Fault 5
- Probable Modes and Locations of Fault Rupture at the WCWTP 5
- Coseismic Displacement of the WCWTP 6

2.0 Review of Section 1.0 6

3.0 Review of Section 2.0 6

3.1 Regional Style of Deformation in the Northern East Bay Hills 7
3.1.1 Tectonic Model for the Northern East Bay Hills 8

3.2 Structural Characteristics of the Franklin Fault 10
3.2.1 Tectonic Setting of the Franklin Fault 11
3.2.2 The Inferred Link of Franklin Fault and Northern Calaveras Fault 12

3.3 Implications for Maximum Earthquake Magnitude 13
3.4 Slip Rate of the Franklin Fault 13
3.5 Activity of the Franklin Fault 14
3.6 Previous Studies at the WCWTP and Vicinity 14

4.0 Review of Section 3.0 14

4.1 Plates 1, 2, and 3 15
4.2 Quaternary Stratigraphy 16
4.3 Local Bedrock Structure 17

Page

4.4 Slickenside Kinematic Indicators....18
4.5 Results of Trenching Studies - West Fault....19
- Offset of Burn Horizon in Trench 4a....19
- Offset of Alluvium 1 - Bedrock Contact in Trench 4b....20
- Offset of Alluvium 1 - Bedding Contact in Trench 10c....21

4.6 Results of Trenching Studies - Central Fault....21
4.7 Results of Trenching Studies - East Fault....22
4.8 Results of Trenching Studies - Other Faults....22
4.9 Origin of Observed Deformation....23

5.0 Review of Section 4.0....25

5.1 Methodology and Assumptions....25
5.2 Modes of Coseismic Ground Rupture....26
5.3 Intensity and Location of Ground Rupture....26
5.4 Location of Future Displacements at WCWTP....27

6.0 Review of Section 5.0....29

7.0 References....31

List of Tables

1 Calculated values of coseismic displacement based on regressions and standard deviations using input parameters given by Geomatrix....28
2 Calculated values of coseismic displacement based on regressions and standard deviations using input parameters estimated herein....28

List of Figures

1 Late Cenozoic structures in the East Bay Hills, Livermore Valley, and Diablo Valley regions....3
2 Cross section through the WCWTP site....24

Plate ....(in pocket)

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July 19, 1999

EXECUTIVE SUMMARY

This report summarizes our technical peer review of the subject seismic study performed by Geomatrix Consultants, Inc. (Geomatrix) for the East Bay Municipal Utility District (EBMUD) Walnut Creek Water Treatment Plant site (WCWTP). The study was conducted to evaluate fault rupture hazards for a proposed expansion of the existing clearwell and other proposed facilities at the WCWTP. The principal objectives of the study were to: (1) evaluate the presence or absence of active traces of the Franklin fault beneath locations of the proposed expansion facilities; and (2) assess the origin (e.g., tectonic *vs.* landslide) of shearing observed west of the existing facilities during previous studies (i.e., the "West fault"). In addition, Geomatrix characterized the seismogenic potential of the Franklin fault, including estimates of maximum magnitude, slip rate, displacement per event.

Traces of the Franklin fault (also called the Southhampton fault by some authors) have been mapped close to the WCWTP by previous workers. Geomatrix concludes that the Franklin fault has been active during the past 35,000 years and consists of a primary fault trace and numerous secondary fault traces at the site. The primary fault trace lies directly northeast of the site and does not constitute a surface fault-rupture hazard. However, several secondary traces lie beneath the site and/or the proposed expansion facilities and may constitute a surface fault-rupture hazard. Geomatrix further concludes that the observed faulting at the site is tectonic in nature and is not the result of landsliding. Geomatrix assigns a slip rate of 0.2 to <1 mm/yr for the fault with a maximum magnitude of M_W 6 3/4 based on total fault length. Geomatrix estimates that the maximum earthquake may produce surface fault rupture of about 1 to 2 feet on the secondary faults beneath the site.

In general, the conclusions reached by Geomatrix are reasonable, although many are based on interpretations of scant data that could also be interpreted in several other ways. In particular, we believe that the tectonic model adopted to explain the activity of the Franklin fault and secondary structures is inadequately documented, and not consistent with current knowledge of the area. We discuss the basis for this conclusion in detail below. Correct interpretation of the

tectonic setting of the Franklin fault is critical for evaluating maximum earthquake potential, slip rate, and displacement per event. However, reinterpretation of the tectonic setting will not alter the fundamental conclusion that the Franklin fault likely is an active fault (i.e., active in the past 35,000 years) and that one or more traces of the Franklin fault (primary or secondary) underlie parts of the WCWTP and the proposed expansion facilities. Because the report is fairly lengthy, we first provide an overview of our review comments, and then provide more detailed comments on specific sections of the report.

1.0 GENERAL OVERVIEW

As noted above, we find that the conclusions made by Geomatrix are reasonable, although many are based on data that can be interpreted in several alternative ways. Our principal review comments relate to: (1) the presentation of data (existing and developed by Geomatrix) that allow for an adequate technical review; and (2) primary fault characterization issues that influence the assessment of fault-rupture hazards at the WCWTP.

1.1 Data Presentation Issues

- Regional Fault Compilation

Because little is known about the seismic characteristics of the Franklin fault, understanding the regional tectonic setting of the WCWTP is critical to adequately assessing the potential for fault rupture at the site. Existing information on the location, activity, and sense of slip on the Franklin fault is important for assessing the likelihood of rupture along the fault and possible associated secondary structures. Assessment of the length of the Franklin fault is required to evaluate the maximum earthquake magnitude and thus the expected amount of coseismic displacement on the fault and associated strands. Geomatrix illustrates the map pattern of major faults within the northern East Bay Hills based on an interpretation of several previous workers' mapping (their Figure 2-2). Because the interpretation shown on their Figure 2-2 is critical for assessing fault length (and thus maximum earthquake magnitude and coseismic displacement), Geomatrix should provide a basis for this interpretation. Geomatrix should include a figure or series of figures that provide a regional compilation of previously mapped fault traces, to ensure that all possible fault locations have been adequately characterized and to document the fault interpretation provided on Figure 2-2. Alternative interpretations of the location of the southern end of the Franklin fault, for example, are important for judging the maximum expected earthquake. Similarly, the interpretation that the WCWTP lies within a regional strike-slip duplex associated with the Franklin, northern Calaveras, Lafayette, and Bollinger faults is consistent with Figure 2-2, but is not consistent with the locations and intersections of these faults shown by other workers (Figure 1). Geomatrix should provide additional justification for identifying the fault traces shown on their Figure 2-2 as the primary structural features in the northern East Bay Hills.

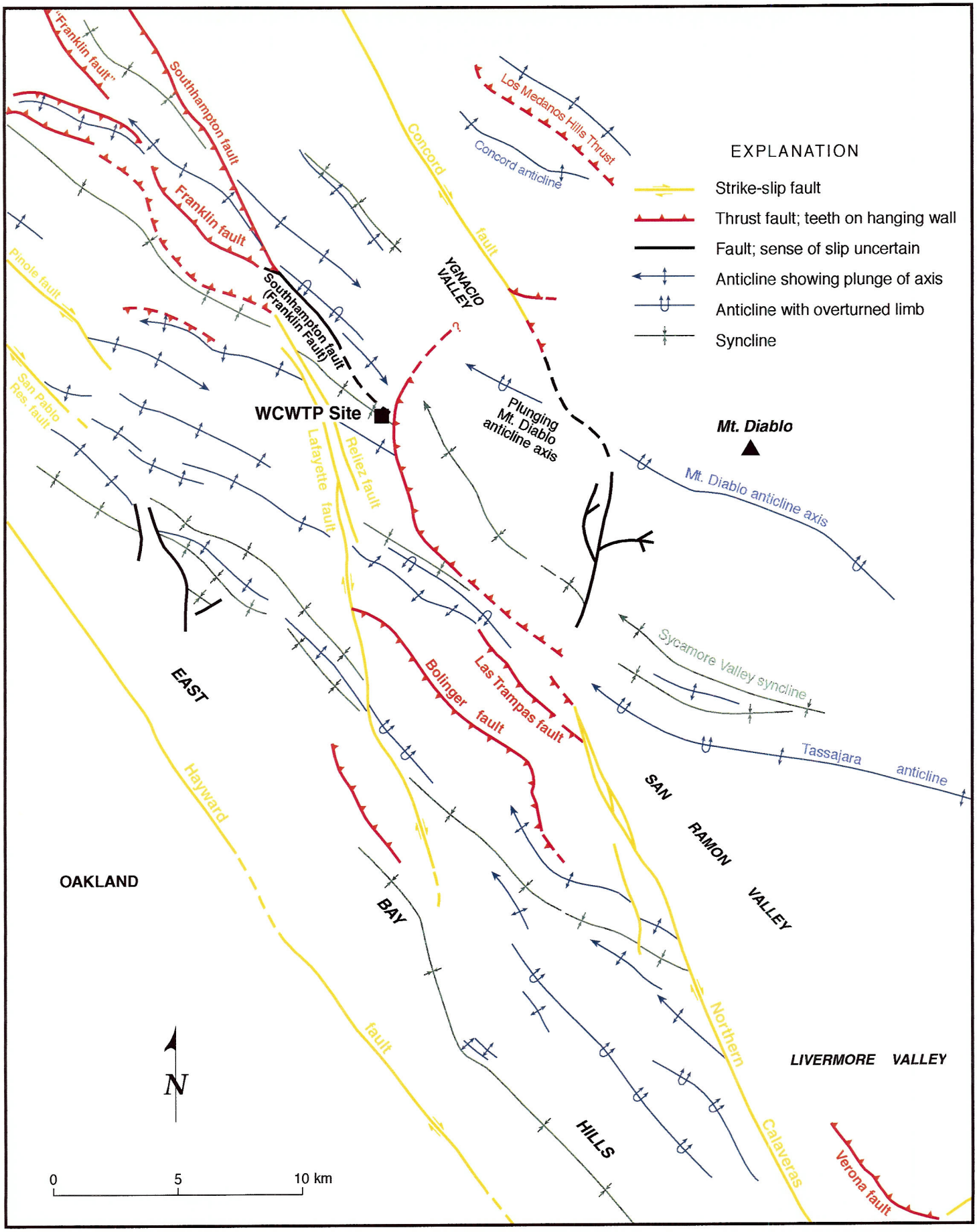


Figure 1. Late Cenozoic structures in the East Bay Hills, Livermore Valley, and Diablo Valley regions (modified from Crane, 1995).

- Local Fault Compilation

Similarly, illustrating the locations of major and minor fault traces identified by previous workers at the WCWTP is critical for assessing fault rupture hazard and understanding how the data developed by Geomatrix augments previous interpretations. While Appendix A of the Phase I report by Geomatrix (1995) contains several figures that show previously mapped fault traces in the local site vicinity, these figures are difficult to read, are at different scales, and are inadequate for identifying major faults interpreted by previous workers and Geomatrix. Geomatrix should provide a figure that clearly illustrates a compilation of previously identified faults and folds in the WCWTP site vicinity, at a scale comparable to that of Plate 3. This figure would make the report easier to read, and would help support their interpretations of fault locations and activities.

- Trench-wall Logs

Geomatrix presents 16 plates in Appendix A that illustrate relations encountered in the numerous trenches at the WCWTP. The level of effort in documenting these exposures meets generally accepted standard of practice, and the overall presentation of the data is adequate. The plates are slightly modified copies of original logs of the trench walls. Several of the logs are difficult to read, however, and none contains a horizontal datum to measure elevations between features on different sheets of the same plate. For example, the difference in the elevation of the base of Alluvium 1 between trenches 10a and 10f cannot be accurately evaluated. Geomatrix should strive to improve the readability of the trench logs. In addition, the logs were clearly generated by several different field geologists, and differences in the level of detail and types of features shown on adjacent trenches (e.g., trenches 5 and 10a) likely is related to the logs being completed by different workers rather than actual differences in the geology. While we acknowledge that the inherent variability in logging is a problem in such a large trenching effort, Geomatrix should strive to improve the consistency of the trench logs among workers, and ensure that interpretations made from the logs are reasonably consistent.

1.2 Significant Fault Characteristic Issues

- Tectonic Setting and Relations with Other Major Faults

As noted above, understanding the relationships among major faults within the WCWTP region is critical for adequately evaluating the maximum earthquake magnitude for the Franklin fault, and thus for estimating amounts of coseismic rupture at the WCWTP. Geomatrix interprets that the WCWTP lies within a regional strike-slip duplex in the northern East Bay Hills, and that the Franklin fault is primarily a dextral strike-slip fault. It is our opinion that available data suggest other reasonable interpretations, which should be acknowledged. For example, Plate 3 suggests that the Franklin fault (as mapped by Geomatrix) may contain a left-stepover encompassing the

WCWTP, and that the West fault is the bordering primary fault of this stepover rather than a secondary fault strand. Lastly, regional relations indicate that the Franklin fault (as mapped by Geomatrix) is truncated by the east-dipping Mt. Diablo fault about 1 km southeast of the WCWTP (Figure 1). This scenario suggests a probable fault length of 22 km, rather than the 29-km-long fault interpreted by Geomatrix.

- Activity of the Franklin Fault

Geomatrix interprets that the Franklin fault is active according to criteria of the Division of Safety of Dams (DSOD), which considers a fault active if it has had at least one episode of movement in the past 35,000 years. This interpretation is based on previous trenching by ESA (1983) at a site located about 21 km northwest of the WCWTP, and on evidence of displacement within the past approximately 31,000 years on the West fault at the WCWTP. We concur that the Franklin fault, and the West fault at the WCWTP, should be considered active faults using DSOD criteria. We also concur with Geomatrix that the Central and East faults at the WCWTP should be considered "conditionally active" faults, which means that the displacement history during the past 35,000 years is not known with sufficient certainty to consider the fault active or inactive.

- Maximum Magnitude of the Franklin Fault

Geomatrix judges the Maximum Credible Earthquake on the Franklin fault to be M_W 6 3/4, which is based, in part, on empirical relations between magnitude and surface rupture length and an estimated fault length of 29 km. In our opinion, the fault more likely is less than 22 km long, extending from the Carquinez Strait on the northwest to Interstate 680 near Ygnacio Valley Road on the southeast (about 1 km southeast of the WCWTP; Figure 1). This fault length yields an earthquake magnitude of M_W 6.6 using the same empirical relations. We also calculate a magnitude of M_W 6.4 based on empirical relations between magnitude and fault rupture area, and an assumed downdip fault width of 12 km. Given these calculations and the numerous bends in the Franklin fault and intersections with other faults, we judge the Maximum Credible Earthquake on the Franklin fault to be M_W 6 1/2.

- Probable Modes and Locations of Fault Rupture at the WCWTP

We concur with Geomatrix that there are three likely modes of deformation at the WCWTP, and concur that faulting along the West, Central, and East faults would have the greatest impact on existing and proposed facilities. It is our opinion that right-reverse displacement along these strands is the most likely style of deformation at the site. We concur that rupture along the West fault likely would extend through the proposed clearwell expansion facility, and that rupture along the Central fault may occur beneath existing facilities in the central part of the WCWTP. Rupture on the East fault strands or on the main trace of the Franklin fault would not occur

beneath existing facilities. However, there is evidence of shearing west of the West fault that may project northwestward toward the location of two proposed 9-million-gallon storage tanks. It is our opinion that the possibility of surface rupture along this shear zone has not been adequately addressed by Geomatrix.

- Coseismic Displacement at the WCWTP

Geomatrix estimates a range in coseismic displacement for the Franklin fault of 2.3 to 4.3 ft, and assumes that 30 to 50% of the total slip (1.3 to 2.1 ft) could occur on the West, Central, and East faults. Using the same approach, we calculate a range in possible surface-rupture displacement along the secondary faults of 0.7 to 2.1 ft. However, Geomatrix should acknowledge the amount of uncertainty in these estimated values of coseismic displacement. Based on standard deviations given in published empirical relations, we calculate that the range (two standard deviations) in calculated coseismic displacement on the West, Central, and East faults is 0.0 to 3.4 ft, assuming a surface rupture length of 29 km and a Maximum Credible Earthquake of M_W 6 3/4. However, using a surface rupture length of 22 km and a Maximum Credible Earthquake of M_W 6 1/2, we calculate a range in mean displacement along the Franklin fault of 1.6 to 2.4 ft, and a two-standard-deviation range of 0.0 to 5.8 ft. Assuming that 30 to 50% of the total slip could occur on any of the secondary faults, we estimate a mean displacement of 0.5 to 1.2 ft, and a range in displacement of 0.0 to 2.5 ft for the West, Central, and East faults. Although the maximum amount of displacement within this range is only slightly higher than the maximum value given by Geomatrix, we believe that the incorporation of uncertainty in the estimation makes the range of 0.0 to 2.5 ft more robust and defensible. Geomatrix should acknowledge the uncertainty inherent in the regressions, and revise interpretations in the report that are based on amounts of coseismic displacement.

2.0 REVIEW OF SECTION "1.0 INTRODUCTION"

No comments.

3.0 REVIEW OF SECTION "2.0 GEOLOGIC AND SEISMIC SETTING"

Geomatrix cites previous mapping and structural interpretations to conclude that the Franklin fault is a 29-km-long structure that consists of a northern branch and southern branch. According to Geomatrix, the southern Franklin fault extends northward from the Tice Valley area south of Walnut Creek to the vicinity of the Highway 24 / Interstate 680 interchange. This southern branch is interpreted to link the Holocene-active northern Calaveras fault with the northern Franklin fault, which extends roughly from an area just south of the WCWTP site northward to the Carquinez Strait. The interpreted connection between the southern Franklin fault and the northern Calaveras fault is used to support the conclusion that the Franklin fault is an active

seismic source and has sufficient potential rupture length to generate a M_W 6 3/4 earthquake (Appendix B).

Geomatrix relies extensively on existing geologic maps of the northern East Bay Hills to conclude that the Franklin fault extends along the base of a northeast-facing scarp north of the WCWTP, and is kinematically linked to the northern Calaveras fault. The report acknowledges that some of the previous mapping used to develop this interpretation presents conflicting depictions of the structure, and thus there is considerable uncertainty in the location of the Franklin fault and its relationship to nearby structures in the northern East Bay Hills. Geomatrix concludes that the Franklin fault is the probable seismogenic structure that triggers slip on secondary faults that pass through the site, although they acknowledge that their study does not directly constrain the activity of the Franklin fault.

In our view, Geomatrix does not adequately document the tectonic interpretation of the Franklin fault and its relationship to "secondary" faults on the WCWTP site. The authors acknowledge the study is deficient in this regard by stating that the regional context of the late Pleistocene- to Holocene-active "West fault" on the WCWTP site is "not fully established to a high degree of confidence". The following comments provide the basis for our opinion that the report does not adequately describe the tectonic setting of the WCWTP.

3.1 Regional Style of Deformation in the Northern East Bay Hills

Geomatrix states that their discussion of Quaternary deformation focuses on strike-slip faults of the San Andreas system, which are the most active structures in the region. In our opinion, however, the large-scale structure of the northern East Bay Hills is dominated by crustal shortening through folding and reverse faulting. For example, a major syncline passes through the WCWTP site, and the faults mapped through the site by Geomatrix are subparallel to the axis of this and other late Cenozoic folds in the Walnut Creek area. Geomatrix does not address the origin and significance of the folds and their relationship with the Franklin fault, nor the possible presence of a blind thrust fault or faults beneath the folds. This is particularly relevant to the assessment of fault hazards at the WCWTP site, because Geomatrix interprets that secondary faults at the site have accommodated components of extension rather than contraction in late Quaternary time. The Franklin fault, which also is subparallel to the trends of major fold axes, is mapped by some workers as a thrust fault. The general conclusion of the Geomatrix report, however, is that the Franklin fault primarily accommodates strike-slip displacement. The interpretations and conclusions in the report are not adequately documented and are difficult to reconcile with previously mapped patterns of regional contractional deformation in the northern East Bay Hills. Below we present an alternative tectonic model for the Franklin fault that is consistent with all available data and our current understanding of the tectonic setting of the northern East Bay Hills.

3.1.1 Tectonic Model for the Northern East Bay Hills

The northern East Bay Hills is a region of youthful, rugged topography bounded on the west by the Hayward fault, and on the southeast by the northern Calaveras fault. Late Cenozoic deformation in the northern East Bay Hills between these strike-slip faults is dominated by northeast-southwest-directed crustal shortening (Aydin and Page, 1984). Major thrust faults in the northern East Bay Hills, such as the Las Trampas and Bollinger faults, and associated folds are oriented about 45° to the northern Calaveras fault, and locally exhibit a right-stepping, en echelon geometry (Crane, 1995). The folds deform strata that are Pliocene in age, and younger folding has not been precluded. The coeval development of folds and strike-slip faults during late Cenozoic time indicates that regional deformation of the northern East Bay Hills generally can be characterized as "transpressional" (Unruh and Lettis, 1997).

In contrast to areas of the western San Joaquin Valley, where thrust faults and folds are subparallel to strike-slip faults of the San Andreas system, contractional structures in the northern East Bay Hills are oriented approximately 45° to the northern Calaveras fault. Also, the strike of the northern Calaveras fault and structures to the east such as the Concord, Greenville and Mt. Lewis strike-slip faults, range from about N20°W to almost due north, which is about 15° to 30° more northerly than the Hayward and San Andreas faults at this latitude. These observations led Unruh and Lettis (1997) to propose that the northern East Bay Hills and areas to the east are part of a distinct seismotectonic domain, characterized by a more northward orientation of dextral shear strain than in areas to the west. In addition to strike-slip faults that have more northerly orientations, a kinematic consequence of the different strain regime east of the Hayward fault is a tendency of strike-slip faults to form restraining left-stepovers that conserve slip along strike and minimize interactions with other structures (Unruh and Lettis, 1997).

Based on examination of map-scale structures, the geometry of folds and thrust faults in the northern East Bay Hills is consistent with the hypothesis that crustal shortening in this region is associated with restraining stepovers among strike-slip faults (Figure 1). Specifically, previous workers have noted that the northern Calaveras fault dies out as a well-defined surface fault at about the latitude of Alamo (Simpson et al., 1992). Although some maps show the fault as continuing northward to Walnut Creek, most workers agree that the surface trace of the Holocene northern Calaveras fault diminishes significantly as a geomorphic feature north of Danville. The kinematic model of Unruh and Lettis (1997) suggests that much of the slip on the northern Calaveras fault is distributed among contractional structures and strike-slip faults in the northern East Bay Hills. For example, the Las Trampas and Bollinger thrust faults can be traced from the northern end of the northern Calaveras fault northwestward into the interior of the East Bay Hills. These thrust faults either merge into or are truncated by the Lafayette and Reliez Valley faults, which strike north-northwest, parallel to the northern Calaveras fault, and exhibit evidence for at least several kilometers of dextral offset. The overall pattern of folding and strike-slip faulting is consistent with the hypothesis that at least some dextral slip from the northern

Calaveras fault is transferred westward via the Bollinger and Las Trampas thrust faults in a restraining step-over to the Lafayette-Reliez Valley faults. The pattern of right-stepping, en echelon thrust faulting and folding continues northward of both the northern Calaveras fault and the Bollinger fault into the Walnut Creek-Pleasant Hill area, which suggests that additional slip is accommodated northward and westward of the northern Calaveras fault in the northern East Bay Hills by distributed folding and thrust faulting. A pattern of right-stepping, en echelon folds also can be inferred from geologic maps of areas west of the Lafayette and Reliez Valley faults, suggesting that this kinematic style is characteristic of much of the interior of the northern East Bay Hills, and is similar to the Mt. Diablo fold-and-thrust belt to the east (Unruh and Lettis, 1997).

Alternatively, Geomatrix states that there is "strong evidence" that the northern Calaveras fault transfers the majority of its displacement eastward in a releasing stepover with the Concord fault. Although this hypothesis cannot be definitively disproven at present, there is no clear, positive evidence in support of this model. For example, active extensional structures such as normal faults and graben have not been mapped in the region between the northern Calaveras and Concord faults. Analogous releasing stepovers among strike-slip faults in eastern California with slip rates of about 2 to 4 mm/yr are associated with prominent normal faults and active extensional basins. We suggest that if such structures were present in the Walnut Creek-Concord area they would be perceptible. In fact, uplifted and folded Neogene bedrock in the Walnut Creek area suggest that active crustal shortening is occurring in this region, rather than crustal extension and basin subsidence. Swarms of seismicity in the Danville and Alamo area have been suggested as evidence for an extensional stepover, but detailed analyses of focal mechanisms indicates that the causative faults are northeast-striking left-lateral faults, not normal faults (Oppenheimer and Macgregor-Scott, 1992). Instead, the seismicity data arguably show that such a stepover may not exist, and that the seismicity reflects a lateral tear fault in the Mt. Diablo fold and thrust bearing no relation to the northern Calaveras fault (Unruh and Sawyer, 1998; Unruh and Lettis, 1997). In summary, we believe that the lack of positive evidence for active crustal extension in the region between the northern Calaveras and Concord faults suggests that a simple right releasing stepover model is not adequate to explain the apparent northward decrease in slip along the northern Calaveras fault south of Walnut Creek.

To summarize, the northern East Bay Hills is a region of late Cenozoic transpressional deformation dominated by folding and reverse faulting, but also containing a component of dextral shear. Folds and thrust faults in the northern East Bay Hills are kinematically related to, and ultimately driven by, strike slip on the bordering Hayward and northern Calaveras faults. We believe that a significant component of dextral slip on the northern Calaveras and Hayward faults probably is transferred onto faults and folds within the East Bay Hills (Aydin and Page, 1984). In this model, there is a greater likelihood that seismogenic blind thrust faults are present beneath the major folds in the East Bay Hills, and the activity (i.e., slip rate) of known reverse faults may be greater than previously inferred.

3.2 Structural Characteristics of the Franklin Fault (section 2.2.1)

The location of the Franklin fault interpreted by Geomatrix primarily relies on the mapping of Saul (1973), Dibblee (1980), and Graymer and others (1994), with some acknowledgment of work by Lawson (1914), Jennings (1975, 1994), Earth Science Associates (1983), Crane (1995), and Haydon (1995). There are considerable differences in interpretation and fault nomenclature among all of these workers (as might be expected). However, none of the figures in the Geomatrix report clearly illustrates the reasonable range in fault locations and geometries that has been developed by these previous workers.

We strongly recommend that Geomatrix provide a compilation map showing locations of previously mapped fault traces at and near the WCWTP. In this manner, an assessment of fault geometry and the kinematic association of individual fault strands can be made, and the compilation map will document that all possible fault traces at the site have been properly identified and evaluated. Appendix A of the Phase I report by Geomatrix (1995) contains several figures that show previously mapped fault traces in the local site vicinity, although these figures do not provide adequate geologic data to support the regional structural model presented by Geomatrix. The figures are presented at different scales and level of detail, and it is very difficult to independently verify that all possible fault traces have been evaluated at the site. Figure 2-2 presents the structural model preferred by Geomatrix, but the fault pattern in the area is known to be considerably more complex than shown on this figure. For example, compare Figure 2-2 of the report with Figure 1 of this review. In particular, their Figure 2-2 emphasizes the major known and interpreted strike-slip faults in the study region, but does not include Pliocene and Pleistocene folds and thrust faults. Adequate representation of these structures is important for fully evaluating the geometry of the Franklin fault and its activity in the modern tectonic setting. This is important because alternative interpretations of the same previous mapping may yield very different structural models, which, in turn, influences subsequent interpretations of fault geometry, fault activity, and possible earthquake magnitudes near the WCWTP.

Geomatrix states that the detailed maps provided by Crane (1995) are primarily compilations of previous work, and does not acknowledge several important new observations made by Crane (1995) that bear directly on our understanding of the tectonic setting of the Franklin fault. Crane's mapping differs in detail from the Geomatrix depiction of the location and geometry of the Franklin fault and its kinematic linkage with the Calaveras and Southhampton faults (Figure 2-2). For example, in the Briones Hills northwest of Alhambra Valley, the Franklin fault is mapped by Crane (1995) as a northeast-dipping thrust fault that forms the southwestern structural boundary of an uplifted and folded block that is cored by Cretaceous marine sediments of the Great Valley group. This block is referred to informally as the "Franklin High" by Crane (1995), apparently in reference to the structural relief represented by the exposed Cretaceous strata within the block. The northwest-trending "Franklin High" is bounded on the northeast by the southwest-dipping Southhampton fault. The "Franklin High" narrows to the southeast, and Crane (1995) shows the Franklin and Southhampton faults merging at the southeast tip of the

"Franklin High" just south of Alhambra Valley. Southeastward from this point, Crane (1995) shows only the southwest-dipping Southhampton fault continuing southward toward Walnut Creek and across the WCWTP. In Crane's mapping, therefore, it is the Southhampton fault that is present at the WCWTP; this interpretation is diametrically opposed to the relationship between the two faults inferred by Geomatrix.

This interpretation is supported by a trench investigation performed by ESA (1983) along the Franklin fault within the "Franklin High". ESA (1983) shows that the Franklin fault dips to the northeast, opposite to the near-vertical to southwest dip of the fault described by Geomatrix at the WCWTP. Thus, the dip of the "Franklin" fault at the WCWTP site is opposite to that along the Franklin fault north of its intersection with the Southhampton fault, but is similar to the dip direction of the Southhampton fault north of this same intersection. These data support the interpretation that the faults at the site may be continuous with the Southhampton fault to the north. Plate 2 of ESA (1983) shows the Franklin fault is truncated by the Southhampton fault about 5 km northwest of the WCWTP site.

3.2.1 Structural Setting of the Franklin Fault (p. 15)

Geomatrix states that the Franklin fault (their definition) has a "zigzag" geometry that is closely mimicked by the Lafayette fault (p. 16). However, Geomatrix incorrectly includes the Bollinger fault as part of the Lafayette fault. The Lafayette and Bollinger faults clearly are separate faults that accommodate regional strain differently. The Lafayette fault is a north-trending strike-slip fault, and the Bollinger fault is a northwest-trending reverse fault. There is no regional "zigzag" pattern formed by these faults. Geomatrix further concludes that the northern Calaveras, Franklin, Lafayette, and Bollinger faults collectively comprise a strike-slip duplex. They state that "the recognition of this distinctive structural feature in the Walnut Creek area is important because it demonstrates a structural connection between the Franklin and Calaveras faults" (p. 16).

In our view, this conclusion is not adequately supported in the report. None of the late Cenozoic folds mapped in this region by previous workers are shown on Figure 2-2. There is no discussion of the kinematics of deformation that produced these structures, which is needed to assess the structural model postulated by Geomatrix for internal consistency. Geomatrix should include a map drawn specifically for the purpose of illustrating and documenting the structural features that comprise the interpreted strike-slip duplex. In addition, Geomatrix should specifically compare the predictions of their structural model with the observations and data collected at the WCWTP, including but not limited to fault orientations, fold orientations, kinematic indicators such as slickenlines, and other relevant structural features.

3.2.2 The Inferred Link Between the Franklin Fault and the Northern Calaveras Fault

South of the WCWTP, Geomatrix interprets that the southern part of the Franklin fault (the Southhampton fault of Crane [1995]) is linked with a north-striking fault that extends southward from Walnut Creek to Tice Valley (e.g., their Figure 2-2). This structure generally places Eocene strata on the east against Miocene and younger strata to the west. The north-striking fault has been interpreted by some workers to be the suspected northern continuation of the northern Calaveras fault, and is inferred by Geomatrix to form the kinematic link between the northern Calaveras fault south of Danville and the Franklin fault in the vicinity of the WCWTP. In contrast, Crane (1995) interprets the north-striking fault as an east-dipping thrust fault that likely continues to the southeast and merges with the northwest-striking "blind" thrust fault at depth beneath the Tassajara anticline south of Danville (Figure 1) (Unruh and Sawyer, 1998). This interpretation is consistent with the presence of the Stone Valley syncline to the east, within the hanging-wall block of the east-dipping thrust fault. This interpretation also is consistent with models for uplift of Mt. Diablo as a southwest-vergent anticline above a blind, northeast-dipping thrust fault (Crane, 1995; Unruh and Sawyer, 1998). In our opinion, this interpretation is more consistent with the available information than the model favored by Geomatrix that the north-striking "southern Franklin fault" is the kinematic link between the northern Calaveras and northern Franklin faults. This alternative model, therefore, supports the interpretation that the Franklin fault and Calaveras fault are not directly connected, and that the Franklin fault is more highly segmented and shorter in total fault length than indicated by Geomatrix.

The Phase 1 study by Geomatrix (1995) briefly discussed Crane's (1995) interpretation that the north-striking fault is the emergent Mt. Diablo thrust fault. Geomatrix inferred from the map relations shown by Crane (1995) that the thrust fault may "truncate" the northern Calaveras fault. However, Geomatrix later appears to discount this observation in their Phase 2 study by extending the Franklin fault southward to a connection with the northern Calaveras fault.

The map relations shown by Crane (1995) also suggest that the northern Calaveras fault may transfer its slip to a series of right-stepping, more westerly trending *en echelon* folds and thrust faults. These faults include the Bollinger and Las Trampas thrust faults near San Ramon, and the Franklin and Southhampton faults in the Martinez-Pacheco area. In this model, the northern Calaveras fault may not continue north of the Las Trampas thrust fault as a strike-slip fault.

Thus, the Franklin fault appears to be a thrust or reverse fault, perhaps with a component of dextral slip, that accommodates crustal shortening in the northern East Bay Hills (Figure 1). The fault is highly segmented and is disconnected from the northern Calaveras fault by a prominent thrust sheet associated with growth of the Mt. Diablo anticline. As discussed below, these observations have significant implications for assessing total fault length and estimating the maximum earthquake and displacement per event for the Franklin fault at the WCWTP.

3.3 Implications for Maximum Earthquake Magnitude

Geomatrix concludes that the Franklin fault extends from the southern margin of Carquinez Strait to an intersection with the northern Calaveras fault near San Ramon, for a total fault length of 29 km (Figure 2-2). They acknowledge the possibility that the fault may be segmented but conservatively use the total fault length to estimate a Maximum Credible Earthquake of M_W 6 3/4.

In our opinion, there is significant uncertainty in the length of the Franklin fault. It is highly unlikely that the fault extends south of the WCWTP to a linkage with the northern Calaveras fault. As described above, the Franklin fault appears to be highly segmented. The fault mapped at the WCWTP may in fact be the Southhampton fault and not the Franklin fault, although these two faults likely are part of the same fault system (Figure 1). In our opinion, the Franklin fault conservatively extends from the southern margin of Carquinez Strait to the WCWTP, for a total fault length of 22 km. If we consider only the Southhampton segment of the fault system, the fault length is 16 to 18 km. Assuming a seismogenic crustal width of 12 km, and using the empirical regressions between magnitude and surface rupture length and fault rupture area by Wells and Coppersmith (1994), we judge the Maximum Credible Earthquake for the Franklin fault to be M_W 6 1/2, rather than the value of M_W 6 3/4 used by Geomatrix.

3.4 Slip Rate on the Franklin Fault (Appendix B)

The structural and tectonic interpretation of the Franklin fault (as described above) has important implications for assessing slip rate on the fault. In Appendix B, Geomatrix compares the geomorphic expression of the Franklin fault to "other known strike-slip faults" in the San Francisco Bay area. In particular, Geomatrix compares the geomorphic expression of the Franklin fault to the Greenville fault with an assumed slip rate of 0.1 to 0.5 mm/yr to conclude that the Franklin fault has a slip rate on the order of tenths of millimeters per year.

We do not concur with the rationale used by Geomatrix to assess the slip rate on the Franklin fault for two primary reasons. First, the Franklin (or Southhampton) fault may be primarily a northeast dipping oblique reverse fault and not a strike-slip fault. Reverse faults typically have less pronounced geomorphic expression than strike-slip faults. Thus, comparing the geomorphic expression of a reverse fault to a strike slip fault can lead to a significant underestimate of slip rate. Second, recent studies suggest that the Greenville fault likely has a slip rate of about 2 to 4 mm/yr; significantly higher than Geomatrix's (1993) estimate of 0.1 to 0.5 mm/yr. Thus, even if the comparison of the Franklin fault to the Greenville fault were valid, the estimate of slip rate on the Franklin fault would be significantly more uncertain, potentially as high as 2 to 4 mm/yr.

In our opinion, current knowledge of the tectonic setting of the northern East Bay Hills suggests that most, if not all, of the slip on the northern Calaveras fault is accommodated by strike-slip and reverse faults in the northern East Bay Hills. Dextral slip on the northern Calaveras fault

transfers across a left-restraining stepover to the Lafayette-Reliez strike-slip fault along the Las Trampas and Bollinger reverse faults. Dextral slip on the Lafayette-Reliez fault, subsequently transfers to the Carquinez Strait area (possibly the southern extension of the West Napa fault) along the Franklin, Southhampton and other reverse faults. The total slip would be distributed across each of these faults, with up to 1 to 2 mm/yr on each fault.

3.5 Activity of the Franklin Fault (section 2.2.2)

Geomatrix interprets that the Franklin fault is an active fault according to DSOD criteria, on the basis of data given by ESA (1983) from the Franklin Ridge trench site (located about 21 km northwest of the WCWTP), an assumed structural linkage between faults observed at the WCWTP and the Franklin Ridge site, and on offset late Pleistocene (31,000 years old) strata observed along the West fault at the WCWTP. We concur that the Franklin fault at the WCWTP is an active fault according to DSOD criteria. However, we base this opinion on data developed by Geomatrix at the WCWTP, rather than a structural model linking the faults at the WCWTP and Franklin Ridge site.

3.6 Previous Studies at the WCWTP and Vicinity (section 2.3)

This section is difficult to follow because there is no figure of the site vicinity showing previous workers' fault locations, nor many of the features referred to in the text. For example, the three possible fault locations given by Marliave (1955) cannot be discerned because they are described using site topographic features, not shown on Figure 1-2. At a minimum, the report should include a compilation figure showing the locations of fault traces mapped by other workers (Lawson, 1914; Marliave, 1955; Saul, 1973; Dibblee 1980; Graymer et al., 1994; Crane 1995; Haydon, 1995). A compilation figure of previously mapped fault traces is required to ensure that all possible fault traces have been properly evaluated and is standard of practice in a surface fault rupture investigation.

4.0 REVIEW OF SECTION "3.0 FIELD INVESTIGATION OF FAULT-RUPTURE HAZARD AT WCWTP"

The primary goal of the field investigation was to evaluate fault-rupture hazard at the WCWTP. A secondary goal was to assess whether the previously identified West fault has a tectonic or landslide origin. The investigative approach included geologic mapping, analysis of aerial photography, and documenting road-cut and trench exposures. Overall, this approach is appropriate to achieve these goals. Considering technical and logistical constraints, and the amount of cultural modification at the site, Geomatrix exercised considerable care and judgment in selecting the number and locations of trenches and road cuts to evaluate fault rupture hazards at the WCWTP. In our opinion, the trench locations are well sited and the excavation process followed a logical, rational sequence. In addition, the degree of modification of the site and vicinity makes detailed geologic mapping difficult, and Geomatrix performed a commendable job

in providing the information shown on Plates 1, 2, and 3. In the sections below, we provide a few comments concerning minor inconsistencies shown on these plates, followed by more substantive issues based on the geologic data from the mapping and trenching investigations.

4.1 Plates 1, 2, and 3

Based on our field reconnaissance, the geologic units depicted on Plate 1 appear reasonable. It is apparent that the subsurface information provided by the trenching is necessary for adequate bedrock mapping, primarily because there are limited surface exposures of geologic units and because several of the rock units are similar in color, lithology and weathering characteristics. For example, during our limited field visit, we observed variations in the rock types within the Hambre Formation that appear to be comparable to the variations between the Hambre Formation and other units (e.g., lower Briones, upper Briones, Meganos). Without detailed subsurface information, we doubt whether these units can be definitively distinguished, and this may explain why previous workers have disagreed on the distribution of rock units at the site.

There are three inconsistencies on Plate 1 that are noteworthy. First, the main trace of Franklin fault is concealed (dotted map pattern) directly east of the site, where it separates Eocene Meganos Formation and artificial fill. The mapped fault trace should not separate these units, but instead be shown as buried by fill or inferred in bedrock. Topography shown on this map and our field reconnaissance indicates that fill extends to the base of the slope between the existing house pads. Notably, this implies that the present-day topography is not necessarily a valid indicator of local fault location. The reasoning for the location of this fault trace is unclear; presumably it is based on pre-development mapping, although documentation for the fault is not provided by Geomatrix. Second, the West fault between trenches 4a and 10c is shown as a solid line that traverses artificial fill. This line should be dotted to indicate that it is overlain by fill. Third, near the eastern end of the site access road on Larkey Lane, Plate 1 shows a north-trending fault trace that offsets a marker bed within the Hambre Formation. This "cross" fault is shown to be truncated by both the Central and East faults. The map shows about 250 ft of apparent dextral separation of the marker bed along the cross fault. This relatively large offset implies that the Central and East fault have had even larger amounts of displacement. These relations are inconsistent with the interpretation by Geomatrix that this cross fault is a minor fault, and that the Central and East faults are relatively minor secondary faults with minimal implied displacement.

The presentation of geologic data on Plate 2 is quite good, because it highlights detailed information available from the trench maps and allows Plate 1 to stand as an uncluttered geologic map. Although we did not check the consistency of all of the fault and bedding orientations between Plate 2 and the trench maps, those that we did check are consistent.

Plate 3 presents the geologic data for the site vicinity. The plate shows the distribution of remnants of the "geomorphic surface" at the site as map unit Qt. The report notes that this

surface "was the focus of [the] trenching studies" (p. 28), because it provides a datum to evaluate fault displacement. The report notes that the "geomorphic surface" includes both an "erosional surface that is cut onto older alluvium and Tertiary bedrock, and a younger terrace" (p. 28). In our opinion, the presence of two alluviums beneath the mapped surface shows that there is at least one other "surface" associated with the "geomorphic surface" as mapped. Thus, the mapped "surface" actually includes at least three surfaces (the bedrock surface, the top of the buried alluvium, and the top of the younger alluvium or terrace tread). Thus, we believe that Plates 1, 2, and 3 should show the distribution of either the different Quaternary alluvial deposits at the site, or the various surfaces associated with these deposits. Lastly, the extent of the Qt surface depicted on Plate 1 (between trenches 4a and 2f) is inconsistent with the extent shown on Plate 3. On Plate 1, the area south of trench 4a is shown as being underlain by artificial fill, which is about 3 to 5 ft thick based on exposures in trenches 1, 10c, and 10d. On Plate 3, the Qt surface is shown as extending southward beyond trench 4a and across the West fault.

4.2 Quaternary Stratigraphy

As noted above, the various geomorphic surfaces presumably used as "strain gauges" in the site vicinity are not fully depicted on the plates. The mapped "geomorphic surface" at the site is interpreted to be a remnant of a large regional-scale surface, for which remnants are shown on Plate 3. The origin of this regional surface, and the deposits associated with it, is unclear. A fluvial (stream channel) origin is indicated, and the alluvium directly beneath the surface (Alluvium 2) is interpreted to have been deposited by a meandering stream less than about 31,000 years ago. Because there are no large drainage basins uphill of the site, it is most reasonable to assume that this meandering stream was an ancestral Walnut Creek or Las Trampas Creek, and thus that the site vicinity has been uplifted significantly within the past approximately 31,000 years. There is about 200 ft of relief presently between the site and the sloping valley floor of Walnut Creek, suggesting a very rough minimum uplift rate of about 2 mm/yr. This uplift, although seemingly high, may have been accommodated along the Franklin and/or Southhampton faults. If the alluvium is instead a result of a small alluvial fan generated by the small drainage basins uphill of the site, then a lower rate of uplift is suggested. This latter interpretation is consistent with the paleoflow indicators shown on Plate 1.

Also, Plate 3 shows the distribution of multiple Qt surface remnants north and northeast of the WCWTP. These surface remnants are at various elevations, with the relief between adjacent remnants ranging up to as much as 150 ft. If these remnants are in fact parts of a regional-scale surface (see p. 29), then there has been substantial tectonic displacement to produce this relief between each terrace remnant. Alternatively, if these remnants are not correlative, they may be related to several erosional or depositional events of various ages. This is important to the interpretation of fault-rupture hazard at the WCWTP, because the West fault and the main trace of the Franklin fault traverse the area containing surface remnants mapped by Geomatrix. Several individual remnants are traversed by fault traces, but do not show prominent geomorphic evidence (e.g., scarps) of surface rupture (with the exception of the surface remnant at the site,

see below). In contrast, several terrace remnants are separated by the West fault and the Franklin fault and occur at different elevations across the faults. If these are correlative remnants, they may provide information on the timing and activity of the faults. As mapped on Plate 3, the surface remnants provide a conflicting and inconsistent picture of movement along these fault strands.

At the WCWTP site, the geomorphic surface shown on Plates 1 and 3 provides evidence of northeast-down vertical separation across the West fault. Based on trenches 10c, 1, 3, 4a, and 4b, the West fault lies along the northeast side of a northwest-trending linear ridge. Southwest of the fault, this linear ridge is underlain by less than 2 feet of artificial fill, about 2 to 3 ft of Alluvium 1, and sandstone bedrock (Plate A-1). Closer to the fault, Alluvium 1 pinches out, and Alluvium 2 overlies bedrock. At the fault, unfaulted Alluvium 2 directly overlies bedrock. Northwest of the fault, bedrock is overlain again by both Alluvium 1 and Alluvium 2. Thus, stratigraphic relations suggest that Alluvium 1 on the southwest side of the fault is substantially higher in elevation than on the northeast side of the fault. The amount of vertical separation of the base of Alluvium 1 is difficult to evaluate from the trench logs because horizontal datums are not given on the various map sheets. The occurrence of Alluvium 1 beneath the linear ridge southwest of the fault is inconsistent with the paleoflow direction indicated for the alluvium on Plate 1. All in all, the presence of the linear ridge, the northeast-facing scarp along the West fault, and the stratigraphic relations in trench 1 support an interpretation of east-down vertical separation across the West fault. This sense of separation is consistent with right-reverse displacement on the West fault, and is inconsistent with the interpretation of right-normal displacement along the fault made by Geomatrix.

4.3 Local Bedrock Structure

In the WCWTP vicinity, Geomatrix interprets the West, Central, and two East faults as secondary faults that are structurally associated with the Franklin fault, and likely move in conjunction with the Franklin fault. The WCWTP lies within a zone of secondary deformation bordered by the West fault and the main strand of the Franklin fault. As shown on Plate 3, the northwest-striking secondary faults merge together to the southeast with the more northerly trending main trace of the Franklin fault about 2000 ft southeast of the WCWTP. To the northwest, these faults merge with the interpreted main strand of the Franklin fault within about 4000 ft northwest of the WCWTP (see Plate 3). Near Geary Road, Geomatrix infers a single, north-northwest-trending main trace of the Franklin fault. Plate 3 also shows the presence of a syncline developed in Hambre Formation sandstone between the Central and East faults. Bedding attitudes shown on Plate 3 also suggest a syncline between the West and Central fault. These synclines appear to be parallel to the fault traces mapped by Geomatrix.

Given this map pattern, we interpret that the WCWTP lies within a local left-step along the Franklin fault. North and south of this stepover, the Franklin fault strikes about N15W to N25W (Plate 3). Within the stepover, faults strike generally N30W to N50W, although some

local reaches strike about N80W. The stepover is about 1800 ft wide, based on projections of the main traces of the Franklin fault north and south of the stepover. Given that movement on the Franklin fault is most likely right-reverse, the map pattern of the West, Central, and East faults suggests that the WCWTP lies within a restraining left-stepover that experiences localized crustal shortening during movement on the Franklin fault.

The stepover, therefore, is bounded by the main trace of the Franklin fault on the east and the "West" fault on the west. In this model, both fault traces would be considered primary traces of the Franklin fault. Alternatively, Geomatrix interprets the West fault to be a secondary, southwest-dipping right-normal oblique fault (p. 32). This interpretation appears to be based on the juxtaposition of upper Miocene bedrock on the west and older, lower Miocene bedrock on the east. However, it is our opinion that normal displacement on the West fault is inconsistent with the presence of a left-stepover, as described above. Instead, the fault geometry in the site vicinity would suggest right-reverse oblique movement on northwest-striking faults within the stepover. In addition, the presence of synclinal folds that parallel faults within the stepover suggest that local contraction has occurred in the site vicinity. These relations argue for a significant component of reverse displacement on the West, Central, and East faults at the WCWTP.

4.4 Slickenside Kinematic Indicators

As describe above, the West, Central, and East faults appear to form a local left-step in the Franklin fault. If the Franklin fault accommodates a significant component of dextral slip, as inferred by Geomatrix, then the left step represents a restraining geometry that predictably should accommodate local contractional deformation. This prediction is contrary to the conclusion of Geomatrix that the West fault has accommodated a component of normal slip and extensional deformation.

To further test these two models, we evaluated slickenside data presented by Geomatrix on the log of Trench 4a. Thirteen sets of paired shear plane/slickenside data are tabulated on this log, and they generally are taken from both northwest- and northeast-striking faults. All slickensides indicate an oblique sense of slip on the faults. As reported, the slickensides indicate only the orientation of slip in the fault plane; no shear sense indicators are presented to document which side of the fault moved up relative to the other side. We thus made the assumption that shear planes with a northwest strike most likely accommodated a component of dextral strike-slip displacement, and that northeast-striking shear planes accommodated a sinistral component of slip. This assumption is consistent with northwest dextral shear associated with distributed plate motion. Given the assumptions described above, the slickenside data consistently indicate a reverse component of slip on the shear planes exposed in Trench 4a. None of the slickensides indicates normal-oblique slip on the faults. In general, the slickenside data indicate a transpressional style of deformation, consistent with both the observed strike-slip faulting and late Cenozoic folding in the northern East Bay Hills.

The Geomatrix report acknowledges that the interpreted right-normal oblique displacement on the West fault is anomalous with respect to the regional patterns of late Cenozoic folding, and the report suggests that the apparent extensional deformation is related to extension parallel to the axis of a fold. This model is problematic, however, because extension parallel to fold axes only is observed across the crests of *anticlines*, and the West fault on the WCWTP property is associated with a major *syncline*. The same mechanical theory that predicts extensional deformation along the axes of anticlines predicts contractional deformation (i.e., thrust and reverse faulting) along the axes of synclines.

To summarize, we agree with the conclusion in the report that the slickenside data indicate significant components of oblique slip on the faults crossing the WCWTP site. Based on our analysis of the data, however, we find that the deformation includes a component of reverse slip and crustal shortening, consistent with the "transpressional" tectonic setting of the northern East Bay Hills and the possible presence of a restraining stepover in the trace of the Franklin fault in the vicinity of the WCWTP. We conclude that the data do not support the interpretation of normal faulting related to folding in the site vicinity.

4.5 Results of Trenching Studies – West Fault (section 3.5.1)

The West fault is identified at the WCWTP, in part, on the basis of several trench exposures that show southwest-dipping shear zones up to 30 ft wide in sandstone bedrock units. The geomorphic surface and associated alluvial deposits at the site are used by Geomatrix to assess the timing and style of the most-recent slip on the West fault. They interpret that the most-recent rupture occurred after about 31,000 years ago, based on radiocarbon analysis of one charcoal sample taken from faulted deposits exposed in trench 4a. Also based on the exposure in trench 4a, Geomatrix interprets about 6 to 7 feet of down-on-the-southwest vertical separation of Alluvium 1, based on three displaced datums: (a) a charcoal horizon within Alluvium 1 in trench 4a, (b) the Alluvium 1-bedrock contact in trench 4b, and (c) a bedding contact in Alluvium 1 in trench 10c. In addition, Geomatrix interprets right-normal displacement on the basis of slickenside data collected in trench 4a. The following sections discuss these interpretations, which are critical to assessing the timing and style of deformation along the West fault, and thus along all of the mapped faults at the WCWTP.

4.5.1 Offset of Burn Horizon in Trench 4a

In the interpretation of trenches 4a and 4b, the burn horizon on the northeast side of the fault is correlated with the lowermost burn horizon on the southwest side of the fault (their Figure 3-2). The rationale for this correlation is not given. It seems likely that the burn horizon on the northeast correlates with the uppermost horizon on the southwest, based on the thickness and continuity of the horizons shown on plate A-8. This is important because the stratigraphic correlation of units across the fault interpreted by Geomatrix suggests oblique-normal

displacement on the West fault, and because the amount of vertical separation is used later in estimating a fault slip rate for the entire fault. An alternative interpretation is that the upper burn horizon on the southwest side correlates with the horizon on the northeast, and thus that the fault exhibits a component of northeast-vergent reverse slip. In this interpretation, there is 4 ft of vertical separation, rather than 7 ft, which would yield a lower slip rate for the fault. Geomatrix should provide the basis for correlating burn horizons across the fault shown on Figure 3-2.

Also shown on Figure 3-2, the northeasterly extent of the lowest exposed burn horizon is different than that on the original trench maps. On Figure 3-2, the burn horizon extends northeast to the main shear zone, whereas on the original map of the trench (Plate A-8), the lowest burn horizon extends to only about 4 feet from the shear zone. This is important because the lowest burn horizon on the southwest side of the fault is correlated with the only burn horizon on the northeast side of the fault. The schematic map of Figure 3-2 may not adequately represent the locations and thicknesses of the burn horizons, and thus may influence the interpretation of how the horizons correlate across the fault.

The log of trench 4a (Plate A-8) shows the presence of several other charcoal samples in the exposure, including samples near each of the three burn horizons southwest of the fault, and samples within and above the burn horizon northeast of the fault. Geomatrix should note whether other samples were collected and analyzed. If so, these data should be presented, because they may bear directly on the correlation of horizons across the fault. Considering that the correlation of burn horizons in trench 4a is the cornerstone for interpreting the sense and amount of slip on the West fault, additional basis for the correlation of units across the fault is warranted. Also, the reasoning for analyzing the charcoal from below the burn horizon is unclear. It seems that a date from the actual horizon would be better, assuming that the burn horizon contains *in situ* charcoal (which seems likely), and that charcoal from below the horizon may be reworked. Lastly, formal presentation of the data from radiocarbon analyses (i.e., lab number, analytical error) should be included in the report.

4.5.2 Offset of Alluvium 1 - Bedrock Contact in Trench 4b

Trench 4b, which is a road cut exposure located below and slightly to the northwest of trench 4a, exposed a structurally deeper level of the West fault than in trench 4a. The map of trench 4b (Plate A-8) shows unfaulted Alluvium 2 directly overlying sandstone bedrock. It is unclear why this map does not show Alluvium 1 beneath Alluvium 2. Perhaps at the location of trench 4b, the base of Alluvium 2 has completely eroded Alluvium 1. Nevertheless, the original mapping of this trench exposure does not support the interpretation that there is down-on-the-southwest displacement of the contact between Alluvium 1 and bedrock. Figure 3-2, which is a composite sketch map of trenches 4a and 4b, shows the interpretation that the base of Alluvium 1 is lower on the southwest side of the fault. It is unclear how this interpretation was formulated, and thus how the amount of down-to-the-southwest displacement of the basal contact of Alluvium 1 was estimated. In addition, Figure 3-2 shows the presence of sheared claystone on the southwest in

fault contact with sandstone on the northeast. Neither of the actual maps of trenches 4a or 4b (Plate A-8) depicts the presence of claystone in the exposure. Geomatrix should provide a basis for the interpretation of a fault contact between sandstone and claystone.

4.5.3 Offset of Alluvium 1 - Bedding Contact in Trench 10c

Trench 10c exposed faulted beds within Alluvium 1 (Plate A-15), and Geomatrix interprets about 0.4 ft of down-to-the-southwest displacement of the top of a gravelly sand within this alluvium. This displacement is measured across one strand of the fault at about station 21, which has an overall cross-trench orientation of N36W and a vertical dip (Plate A-15). The overall width of the fault zone in this trench is about 6 ft. The amount of displacement of the gravelly sand contact measured from this exposure may not represent the entire amount of displacement across the fault zone. The northeasterly dip of the contact suggests that the overall sense of separation across the fault zone may be down-on-the-northeast, which is opposite to that interpreted by Geomatrix. Although the fractures shown on Plate A-15 may not displace beds above the gravelly sand, the trench log shown does not demonstrate that the gravelly sand contact is undisplaced across the entire zone of deformation. In addition, the fault at station 21 has a vertical orientation, and likely has had some component of strike slip. Considering the "indistinct" nature of the bedding contact northeast of the fault and the likelihood of lateral juxtaposition of irregular bodies of gravelly sand, the interpretation of down-to-the-southwest displacement on the West fault from this exposure is unconvincing. The possibility of overall down-to-the-northeast vertical separation across the fault zone cannot be precluded with the available data.

In summary, none of these interpreted down-to-the-southwest displacements is convincing. An interpretation of right-oblique (reverse) displacement along the West fault either is better supported by the trench data or is at least a reasonable alternative.

4.6 Results of Trenching Studies – Central Fault (section 3.5.2)

Analysis of aerial photography and trenching conducted by Geomatrix appears to provide the best information to date on the location of the Central fault. The fault location is constrained by trench 11 in the southeastern part of the WCWTP, and by the absence of faulting in trenches 2a through 2f in the northwestern part of the site. Geomatrix notes that there is no disruption of a remnant of the late Pleistocene geomorphic surface by the Central fault, although now the surface is overlain by fill. Unfortunately, the location of this buried surface remnant is unclear from Plates 1, 2, and 3, which show no areas underlain by fill north of the settling basin. However, the Central fault as mapped projects along a valley between two Qt surface remnants that appear to be at comparable elevations across the fault trace. Uncertainty concerning the origin of these remnants and their associated deposits (see above) is somewhat problematic for precluding the possibility of rupture along this fault strand.

4.7 Results of Trenching Studies – East Faults (section 3.5.3)

Geomatrix does not provide definitive information concerning the activity of the East faults. The faults lie within primarily bedrock terrane, and thus there are few surficial deposits that can be used to assess fault activity. North of the site, the mapped traces of the faults merge with the main trace of the Franklin fault, which separates two remnants of the Qt map unit (Plate 3). As with the Central fault, detailed mapping and correlation of these remnants and their associated deposits, if possible, may provide information on the activity of the main trace of the Franklin fault, but would not provide information on the activity of the East faults. Trench 6, which was excavated to expose the East fault traces, encountered bedrock overlain by Holocene colluvium. Notably, trench 6 exposed a well-developed breccia zone at its northeastern end that is at least 2 feet wide. As noted by Geomatrix, bedrock on the northeastern side of this shear zone was not exposed in the trench. This is important because the primary criteria for locating the main trace of the Franklin fault is the presence of Eocene bedrock units (primarily claystone) on the northeast and Miocene bedrock (mostly sandstone) on the southwest. In our opinion, the shear zone exposed at the northeastern end of trench 6 may be the primary Franklin fault. Several lines of data support this interpretation: (a) the width of the zone is consistent with a major fault, (b) the measured strike of the breccia zone projects southeastward directly into the concealed trace of the Franklin fault shown on Plate 1, (c) the southwestward dip is consistent with regional geologic relations (of the Southhampton fault), and (d) the location of the main trace of the Franklin fault is poorly constrained based on previous work. This is important because the fault is shown as a strand of the East fault on all the plates; if this strand of the East fault is actually the Franklin fault, then the Franklin fault traverses a larger portion of the northeastern corner of the property. However, this possibility does not impact the existing facilities or the proposed expansion facilities.

4.8 Results of Trenching Studies – Other Faults

Because of the evidence of recent activity along the West fault, which lies beneath the proposed clearwell expansion, geologic data in the vicinity of proposed expansion alternatives also are relevant. Trenches 5 and 10c provide subsurface information southeast of the two 9-million-gallon steel tanks that are an alternative to the proposed clearwell expansion (Plate 1). The map of trench 5 shows the presence of a 10-ft-wide, steeply northeast-dipping shear zone developed between sandstone bedrock on the southwest and mudstone / siltstone on the northeast (Plate A-10). As mapped by Geomatrix (Plate 1), the sandstone and mudstone units are both part of the upper Briones Formation. The northwesterly strikes of planes within the shear zone exposed in trench 5 project toward the locations of the proposed steel tanks. Minor shearing within colluvium coincides with the bedrock shear zone and large bedrock fractures within the shear zone (Plate A-10). It is unclear whether this shearing in colluvium is interpreted as a result of faulting or some other non-tectonic process (e.g., hillslope creep); in fact, this trench exposure is not described in the text of the report. Trench 8 lies across the southeastern projection of the shear zone exposed in trench 5, and extends across the West fault as mapped on Plate 1. The log

of trench 8 shows numerous fractures in bedrock throughout the exposure (Plate A-13). Plate 1 indicates that some of these fractures are strands of the West fault, although the differentiation between major and minor fault strands is not apparent from the trench log. The report should justify the interpretation that faults and fractures exposed in the southwestern end of trench 8 do not continue northwestward to intersect trenches 5 or 10c. Trench 10c lies across the northwestern projection of the shear zone exposed in trench 5, although Plate 1 does not indicate the presence of faulting in trench 10c. The trench log (Plate A-15), in contrast, shows the presence of numerous northwest- and northeast-striking fractures throughout the entire trench. These features dip south, southeast and southwest, and thus generally dip in the opposite direction than the shear zone exposed in trench 5. The report should address the presence of a well-developed shear zone in trench 5, but the lack of a similar zone in trench 10c. In our opinion, these trenches raise the possibility of a large shear zone west of the West fault, and appear to contradict the statement that "no evidence was found that [geologic structures] extend beyond the limits of the zone" of deformation between the West and Franklin fault (p. 42).

4.9 Origin of Observed Deformation (section 3.6)

Geomatrix notes that the "regional tectonic context of how the West, Central, and East faults interact with the main Franklin fault at depth is not completely understood at present" (p. 42). Given this perspective, it is understandable that the report does not contain a geologic cross section through the WCWTP vicinity. Nevertheless, such a cross section may help constrain the range in possible interpretations of site geology and structure. In our opinion, the report should include a local geologic cross section. As an example, we prepared a simple cross section through the WCWTP site (Figure 2) based on geologic data contained in Plate 3 from the Phase II report.

Geomatrix provides four kinematic models to help explain uncertainties in the local geologic structure and to provide a framework for estimating amounts of coseismic fault displacement. They judge that folding and faulting conditions at the WCWTP are best explained as "secondary contractual [sic] and extensional deformation associated with the right-reverse movement on a vertical Franklin fault located east of the plant site or similar slip on the northern Calaveras fault" (p. 43). They favor this model, in part, because of the interpretation that the site is located northwest of a large releasing double-bend in the Franklin-Calaveras fault system, which would provide a mechanism to produce right-normal displacement on the West fault. Two concepts place this interpretation into question. First, as explained above, there are several lines of evidence suggesting right-reverse displacement on the West fault, rather than right-normal displacement. These include:

- a left-stepover in the mapped trace of the main, right-lateral or right-reverse Franklin fault (Plate 3),
- parallelism between folds and faults in the WCWTP vicinity (Plate 3),
- geomorphic and stratigraphic evidence of down-to-the-northeast separation of late Quaternary deposits at the WCWTP (Plate 1),

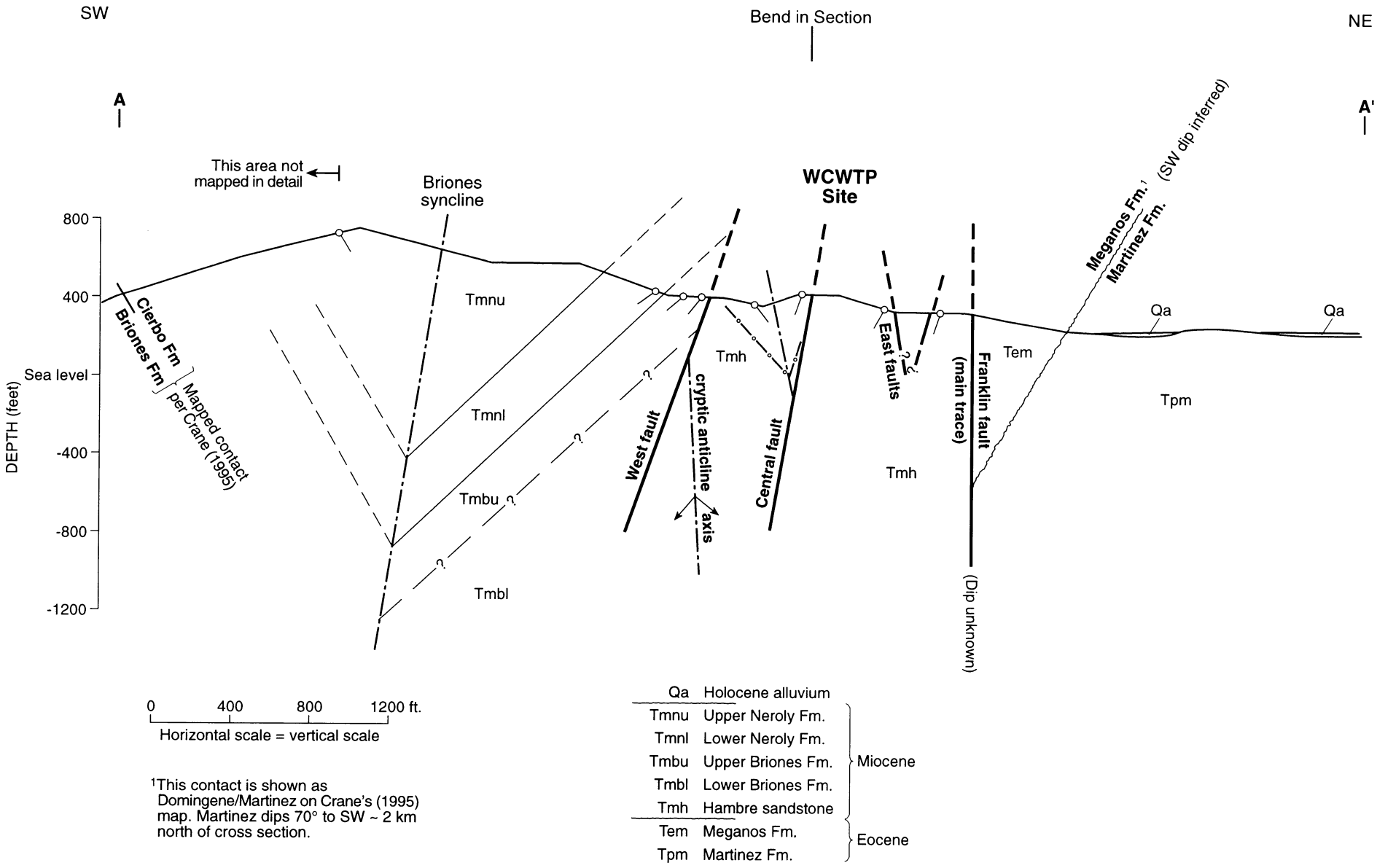


Figure 2. Cross-section through the WCWTP site. Geologic data from Plate 3, Phase II Report (Geomatrix, 1998; see enclosed copy of Plate 3 for location of section line A-A').

- reverse displacement suggested by offset burn horizons across the West fault, as exposed in trench 4a, and
- kinematic analysis of slickensides measured in trench 4a.

Second, the interpretation that the site is located within a large releasing double-bend in the Franklin-Calaveras fault system is one of many possible interpretations. However, we believe that the site-specific data from the WCWTP developed in this and previous studies can be used to better assess the local fault geometry, and, thus, to improve on regional tectonic models. Thus, the evidence for right-reverse displacement along the West fault provides weight to the interpretation of a local left-step in the Franklin fault near the WCWTP (as shown on Plate 3). These relations eliminate the need for an interpretation of a large double-bend in the Franklin-Calaveras fault system (to explain right-normal displacement on a secondary fault), as well as the need to physically connect the Franklin and Calaveras faults. All of these data are consistent with the regional tectonic setting of the northern East Bay Hills, overall right-reverse displacement on the Franklin fault, and the lack of evidence of late Quaternary displacement on the northern Calaveras fault north of San Ramon (Simpson et al., 1992).

5.0 REVIEW OF SECTION "4.0 ASSESSMENT OF SURFACE FAULT-RUPTURE HAZARD"

5.1 Methodology and Assumptions

As noted by Geomatrix, there are few data available on the Franklin fault or other faults at the WCWTP for determining the amount of displacement expected during a surface-rupturing earthquake. We concur with Geomatrix that about 50% of the displacement may occur on any of the secondary fault traces during a rupture event. However, we believe that this is a conservative (and perhaps overly conservative) estimate, because it is more likely that during any individual earthquake, the amount of rupture not occurring on the primary fault trace will be distributed on several of the fault strands. The Geomatrix model suggests that during any given rupture, 50% of slip may occur on the primary strand, and that the remaining 50% may occur on just one of the secondary strands. While this scenario cannot be precluded, we believe this to be conservative. Unfortunately, the available data are insufficient to preclude any of the three or four secondary faults from being the one that accommodates this 50% of the total slip. Thus, engineering designs should provide for a maximum of 50% of the total fault slip along any of the secondary fault strands, as recommended by Geomatrix.

In our opinion, the map pattern of the Franklin fault in the WCWTP vicinity suggests the presence of a left-stepover in the fault trace. "Stepovers" are a common phenomenon along oblique slip faults and produce localized areas of distributed deformation within the stepover. The stepover at the WCWTP is bounded on the east by the main trace of the Franklin fault and on the west by the "West" fault. The "Central" fault and "East" faults occur within the

stepover. In this model, a large rupture propagating along the Franklin fault (from either direction) would encounter the stepover, transfer across the stepover via the secondary faults, and then continue along the main Franklin beyond the stepover. For example, in a northwest-propagating rupture, the total amount of displacement along the Franklin fault southeast of the site would encounter the intersection of the Franklin and secondary faults about 1800 feet southeast of the site. At this intersection, some of the slip would transfer onto the West, Central, and East faults, and some slip would continue along the main Franklin strand. Further to the northwest, slip would progressively transfer to the West fault, such that the main trace of the Franklin fault at the northeast corner of the site may have only a small percent of the total slip. Slip on the West, Central, and/or East faults would progressively increase from southeast to northwest, with perhaps most of the slip being accommodated along the West fault at the northern property boundary. It is our opinion, however, that it is valid to assume that 50% of the total slip may occur on any of the fault strands at the WCWTP.

5.2 Modes of Coseismic Ground Rupture

Geomatrix interprets that there are three modes of coseismic ground rupture during a surface-faulting event at the WCWTP: (1) primary fault rupture and subsidiary faulting associated with the main trace of the Franklin fault; (2) secondary right-normal oblique faulting along secondary, northwest-trending branch faults like the West, Central, and East faults; and (3) distributed secondary faulting and/ground warping and block rotation in the area between the Franklin and West faults. We generally concur with these three likely modes of ground rupture at the site, with a few minor exceptions (outlined below).

We concur that primary fault rupture may occur along the Franklin fault northeast of the site. Because of the possibility that the northeastern end of trench 6 actually exposed the main trace, we suggest that the location of this rupture may not occur at the location mapped by Geomatrix as the main fault trace (Plate 1). Considering the possibility that the site lies within a left-stepover of the Franklin fault, rupture of the main trace likely will transfer across the site along the secondary faults, as outlined above. This essentially is the second mode of deformation noted by Geomatrix. However, we believe that this deformation along the secondary faults will have a right-reverse sense of slip, rather than right-normal as suggested by Geomatrix.

5.3 Intensity and Location of Ground Rupture

Geomatrix uses empirical relations given by Wells and Coppersmith (1994) to estimate the amount of displacement expected during coseismic slip on the Franklin and other faults at the WCWTP. They present various estimated values of maximum and average displacements using a maximum credible earthquake of M_W 6.75 in these regressions, as well as maximum and average displacement using fault surface rupture length. This section would be improved significantly by the use of a simple table giving the values used in the calculations and the associated results. Also, the note about earthquake recurrence in this section (p. 50) is unrelated to the presentation

of the displacement data. Based on this approach, Geomatrix estimates a range in coseismic displacement for the Franklin fault of 2.3 to 4.3 ft. Geomatrix assumes that 30 to 50% of the total slip could occur on any of the secondary faults (see above comments), and on this basis provide a range in slip for the West, Central, and East faults of 1.3 to 2.1 ft. Using the same approach, we calculate a range in possible surface-rupture displacement along the secondary faults of 0.7 to 2.1 ft.

The amount of uncertainty in the estimated values of coseismic displacement should be acknowledged. Geomatrix should provide a treatment of uncertainty in the magnitude regressions. Table 1 (below) provides the mean values, and range in values, for coseismic displacement calculated using the regressions and standard deviations published by Wells and Coppersmith (1994). This table shows that the range (two standard deviations) in calculated coseismic displacement is larger (0.0 to 3.4 ft) than the range given by Geomatrix (1.3 to 2.1 ft).

As noted above, we consider it most likely that the Franklin fault (or Franklin/Southhampton fault) is about 22 km long, rather than 29 km. This length represents the distance along the fault trace from the Carquinez Straight to an intersection with the Mt. Diablo fault, near Interstate 680 at Ygnacio Valley Road. In addition, it is our opinion that the maximum credible earthquake for the Franklin fault is M_W 6.5. Based on a surface rupture length of 22 km, the regressions by Wells and Coppersmith (1994) yield displacement values ranging from 0.6 to 5.8 ft (see Table 2, below). Based on an estimated maximum credible earthquake of M_W 6.5, the regressions yield displacements ranging from 0.0 to 5.0 ft (Table 2). Again using the assumption that 30 to 50% of the total slip could occur on any of the secondary faults (see above comments), we estimate a range in slip for the West, Central, and East faults of 0.0 to 2.5 ft (Table 2). Although the maximum amount of displacement within this range is only slightly higher than the maximum value given by Geomatrix, we believe that the incorporation of uncertainty in the estimation makes the range of 0.0 to 2.5 ft more robust and defensible.

5.4 Locations of Future Displacements at WCWTP

The assumption that future ruptures will occur where they have occurred in the past is commonly made, and in our opinion is reasonable. Thus, surface faulting may occur along the Franklin fault, along the West, Central, and East faults, and to a lesser degree, along minor faults identified by Geomatrix elsewhere at the WCWTP. Regarding rupture along the Franklin fault, it is our opinion that the fault exposed at the northeastern end of trench 6 may be a major strand of the Franklin fault (see comments above). Thus, primary rupture along the Franklin fault may instead occur along the eastern trace of the East fault as shown on Plates 1, 2, and 3.

We concur that rupture along the West fault may extend through the footprint of the proposed clearwell expansion, as shown on Plate 1. Geomatrix should explain why larger displacement along this fault "cannot be ruled out" (p. 52). In particular, information leading to this interpretation should be presented in the previous section (4.3.1 Estimated Amount of

Table 1. Calculated values of coseismic displacement based on regressions and standard deviations given by Wells and Coppersmith (1994), using input parameters given by Geomatrix.

	Mean value	1 standard deviation	2 standard deviations
Surface Rupture Length = 29 km			
Maximum Displacement	4.3 ft	3.0 to 5.6 ft	1.7 to 6.9 ft
Average Displacement	2.3 ft	1.1 to 3.5 ft	0.0 to 4.7 ft
Earthquake Magnitude = M_W 6 3/4			
Maximum Displacement	3.9 ft	2.6 to 5.2 ft	1.3 to 6.6 ft
Average Displacement	2.3 ft	1.1 to 3.5 ft	0.0 to 4.7 ft
Overall Range for Franklin Fault	2.3 to 4.3 ft	1.1 to 5.6 ft	0.0 to 6.9 ft
Overall Range for Secondary Faults (30 to 50%)	(1.3 to 2.1 ft, Geomatrix) 0.7 to 2.1 ft	0.3 to 2.8 ft	0.0 to 3.4 ft

Table 2. Calculated values of coseismic displacement based on regressions and standard deviations given by Wells and Coppersmith (1994), using input parameters estimated herein.

	Mean value	1 standard deviation	2 standard deviations
Surface Rupture Length = 22 km			
Maximum Displacement	3.2 ft	1.9 to 4.5 ft	0.6 to 5.8 ft
Average Displacement	1.8 ft	0.6 to 3.0 ft	0.0 to 4.2 ft
Earthquake Magnitude = M_W 6 1/2			
Maximum Displacement	2.4 ft	1.1 to 3.7 ft	0.0 to 5.0 ft
Average Displacement	1.6 ft	0.3 to 2.9 ft	0.0 to 4.2 ft
Overall Range for Franklin Fault	1.6 to 2.4 ft	0.3 to 4.5 ft	0.0 to 5.8 ft
Overall Range for Secondary Faults (30 to 50%)	0.5 to 1.2 ft	0.2 to 1.8 ft	0.0 to 2.5 ft

Displacement). Also, considering our comments about a possible substantial fault zone exposed in trench 5 west of the West fault, Geomatrix should address the possibility of fault rupture through the proposed locations of the 9-million-gallon water storage tanks. We concur with the conclusion by Geomatrix that these tanks are located in the hanging-wall block of the fault and may be subjected to distributed faulting, and we note that this is possible whether or not the fault has right-reverse or right-normal displacement. We agree with Geomatrix that displacement along the Central fault may adversely affect structures at the WCWTP, and agree that displacements as large as those expected on the West fault cannot be precluded. Because the mapped traces of the East faults do not traverse existing or proposed facilities, we concur with Geomatrix that rupture along these traces is unlikely to extend through site facilities. Geomatrix judges that the rupture hazard from the "cross faults" at the WCWTP is very low, and we concur. Lastly, we concur that displacement along minor faults distributed throughout the site will likely be less than one foot, but we note that the interpretation concerning the origin of these features should be presented earlier in the report.

6.0 REVIEW OF SECTION "5.0 SUMMARY AND CONCLUSIONS"

1. We concur with the conclusion by Geomatrix that the WCWTP is located within a zone of late Quaternary deformation characterized by secondary faulting, folding, and fracturing associated with the Franklin fault. We agree that secondary faults at the site may pose a rupture hazard to existing and proposed facilities. We also note that the "West" fault may, in fact, be better represented as a primary trace of the "Franklin" fault rather than a secondary trace.

2. Geomatrix judges that surface rupture along "the Franklin fault is very unlikely during the useful lifetime of the facilities" (p. 55). Although we concur that it is unlikely for a rupture to occur in the near future, the basis upon which this judgment is should be made more explicit. The likelihood of future rupture to occur is highly dependent on fault slip rate, which currently is very poorly constrained along the Franklin fault. As described earlier, Geomatrix concludes that the fault slip rate is 0.2 to <1.0 mm/yr. In our opinion, slip rate on the fault may range from a few tenths of a millimeter per year to 1-2 mm/yr.

3. Geomatrix interprets that the West fault is a tectonic fault that traverses the WCWTP property and has had right-normal displacement. We believe that the weight of the evidence supports the interpretation that the fault has had right-reverse displacement. We concur with Geomatrix that the West fault is an active fault based on DSOD criteria, but may or may not be deemed active according to CDMG criteria. Based on the field studies conducted by Geomatrix, we agree that the fault does not cross the existing clearwell but does extend through the location of the proposed clearwell expansion, across existing pipelines, and across the Mokelumne aqueduct. Because the WCWTP lies within a left-stepover of the Franklin

fault, we suggest that the West fault be viewed as an integral part of the Franklin fault, and therefore that the width of the fault crossing for the Mokelumne aqueduct is about 1000 feet.

4. Geomatrix identifies the Central and East faults through the WCWTP site, and acknowledges that the timing of the most-recent surface rupture along these strands is unknown. We agree that late Pleistocene activity on these faults cannot be precluded, and they should be considered "conditionally active" based on DSOD criteria.

5. Geomatrix interprets that the West, Central, and East faults at the WCWTP are secondary to the Franklin fault, that there is a very low likelihood of rupture along the Franklin fault, and thus that surface faulting on the "secondary" faults also is very low. Available data on the likelihood of rupture along the Franklin fault is poor, but we agree that the likelihood of rupture along the Franklin fault probably is lower than that along demonstrably active high slip rate faults in the eastern San Francisco Bay area (i.e., Hayward, Calaveras, Concord). However, considering the possibility that the West fault may form the western boundary of a left stepover in the Franklin fault at the WCWTP site, Geomatrix should address whether the likelihood of rupture along the West fault is lower (or the same) as that along the Franklin fault.

6. Although we agree with Geomatrix that the regional context of the Franklin fault and associated faults in the WCWTP vicinity has not been fully established, we believe that a reasonable model for the structural context of the fault can be made based on available data. We believe that activity on secondary faults at the site may be a result of deformation within a local, 1400-ft-wide restraining stepover in the Franklin fault, rather than within a regional releasing double-bend between the Franklin and Calaveras faults or within the hanging-wall block of a right-reverse Franklin fault. Geomatrix should address this possibility, and comment on how this possibility might influence the interpretation of the West fault as a minor, low slip rate feature. Nevertheless, we agree that the West fault has had late Pleistocene activity, and should be considered an active fault according to DSOD criteria.

7. Lastly, we concur with Geomatrix that rupture on the Franklin fault likely will be accompanied by movement along the West fault and perhaps the Central and East faults. However, Geomatrix should address the possibility that the amount of displacement on the West fault may be comparable to that along the Franklin fault, because it too may border a left stepover in the fault system. We agree with Geomatrix that the Franklin fault may generate 4 feet of surface rupture during the maximum earthquake, but note that uncertainties in the regressions used to make this estimate need to be acknowledged. Our analysis using a lower maximum credible earthquake and a shorter fault length suggest a mean value of coseismic displacement of 1.6 to 2.4 ft. Acknowledging two standard deviations of uncertainty, we suggest a maximum displacement of 5 ft along the Franklin fault. Based on these relations, we agree with Geomatrix that the mean value of displacement on secondary

faults is expected to be on the order of 1 foot, but acknowledge that displacements could be as much as 2.5 ft. Given the possibility that the West fault is a major strand of the Franklin fault, rather than a secondary strand, we believe that the relatively low estimated displacements for the West fault are too low and may be non-conservative.

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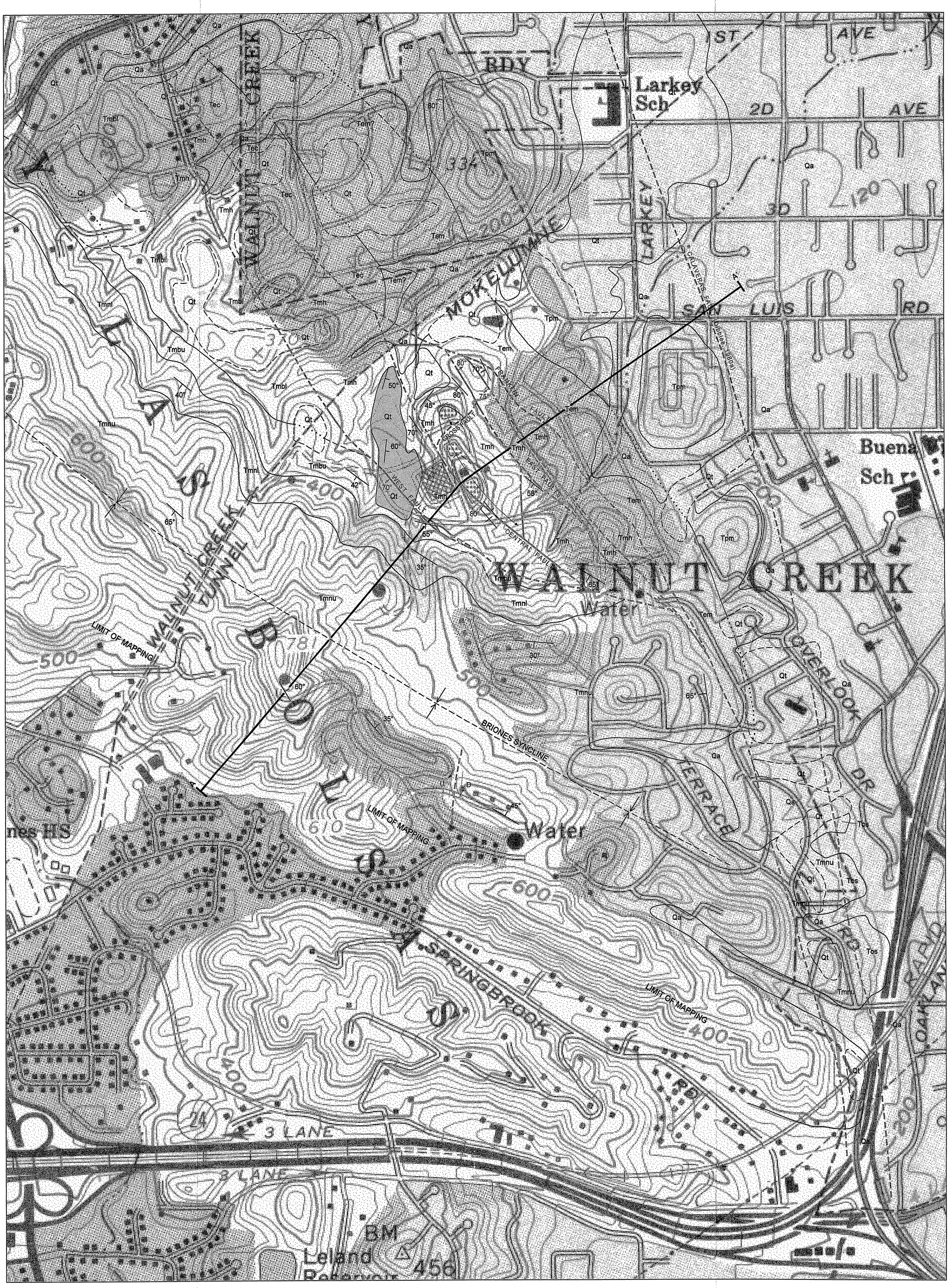
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EXPLANATION

GEOLOGIC UNITS

Qa	ALLUVIUM (HOLOCENE TO HISTORICAL), SANDY CLAY, SAND, AND SANDY GRAVEL
Qt	ALLUVIUAL GEOMORPHIC SURFACE (LATE PLEISTOCENE)
Tmnu	UPPER NEROLY FORMATION (UPPER MIOCENE), SANDSTONE
Tmnl	LOWER NEROLY FORMATION (UPPER MIOCENE), SANDSTONE AND SHALE
Tmbu	UPPER BRIONES FORMATION (UPPER MIOCENE), SHALE MEMBER
Tmbl	LOWER BRIONES FORMATION (UPPER MIOCENE), SANDSTONE MEMBER
Tmh	HAMBRE SANDSTONE (MIDDLE MIOCENE), FINE-GRAINED SANDSTONE
Tos	SAN RAMON FORMATION (LOWER OLIGOCENE), SANDSTONE
Tec	UNNAMED CLAYSTONE (LOWER EOCENE), CLAYSTONE, MINOR SANDSTONE
Tem	MEGANOS FORMATION (LOWER EOCENE), CLAYSTONE
Tpm	MARTINEZ FORMATION (UPPER PALEOCENE), SANDSTONE AND CLAYSTONE

SYMBOLS

- 70° U / D — FAULT, DASHED WHERE APPROXIMATELY LOCATED, QUERIED WHERE INFERRED; FULL ARROW INDICATES DIP OF FAULT HALF ARROWS INDICATE RELATIVE SENSE OF SLIP; U=UP; D=DOWN
- CONTACT, DASHED WHERE APPROXIMATELY LOCATED, DOTTED WHERE CONCEALED, QUERIED WHERE INFERRED
- AXIS OF SYNCLINE
- 44 — STRIKE AND DIP OF BEDDING
- STRIKE AND DIP OF VERTICAL BEDDING
- A — A' — LOCATION OF GEOLOGIC CROSS SECTION (FIGURE 2) IN THE PEER REVIEW

N

400 0 400

SCALE IN FEET

REGIONAL GEOLOGIC MAP
Walnut Creek Water Treatment Plant Expansion
Seismic Study-Phase II
East Bay Municipal Utility District
Walnut Creek, California

GEOMATRIX	October 1998	Project No. 3970	Plate 3