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To: MR. TOM OSTROM, CHIEF
OFFICE OF EARTHQUAKE ENGINEERING

Date: April 15, 2013

File: 11-IMP-98, PM 34.84
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Alamo River Bridge
Bridge No. 58-0136

From: DEPARTMENT OF TRANSPORTATION
DIVISION OF ENGINEERING SERVICES
Materials Engineering and Testing Services and Geotechnical Services
Office of Geotechnical Support – Geotechnical Instrumentation

Subject: Evaluation of Fault Rupture Potential, Alamo River Bridge, Imperial County, CA

SUMMARY

Alamo River Bridge No. 58-0136, is located 180 feet east of the Imperial fault, the nearest Caltrans-active fault. The fault is very well-located in this area, and there is a lack of off-fault deformation suggesting that lateral movement is confined to a narrow zone. **No rupture is expected at the bridge**, however the bridge will be subject to high levels of ground motion which may cause offset. No further work is recommended.

INTRODUCTION

This evaluation was prepared as part of the statewide evaluation of fault rupture potential at Caltrans bridges. Caltrans' policies regarding fault rupture at bridges are described in Memo to Designers (MTD) 20-10. Caltrans requires a fault rupture evaluation if a bridge is located within an Alquist-Priolo (AP) Earthquake Fault Zone (EFZ) or within 1,000 feet of an un-zoned fault 15,000 years or younger in age. Alamo River Bridge is situated within the EFZ established for the Imperial fault in 1974 and revised in 1990 in the Bonds Corner 7-1/2' Quadrangle; therefore a fault evaluation was required.

An initial estimate of potential offset was based on an analysis developed by Division of Research and Innovation in collaboration with Geotechnical Services, using methods presented in Abrahamson (2008) and Petersen et al (2011). Both a probabilistic (5% in 50 yr) fault displacement analysis (PFDHA) and a deterministic fault displacement analysis (DFDHA) were performed based on maximum magnitude earthquake, slip rate (for PFDHA), assumed mapping and base map errors, and likelihood of secondary fault traces. If the Imperial fault is located as shown on the 1990 EFZ map, the expected displacement at the bridge would be about 2 feet

(probabilistic; estimated deterministic displacement is a few inches). Mark Yashinsky and Fadel Alameddine reviewed the bridge plans and determined the bridge could not withstand 2 feet displacement without modification. Therefore additional work, documented herein, was undertaken to better define the fault location.

Alamo River Bridge was built prior to 1940 and replaced in 1977 with a wider and longer bridge. The new bridge extends approximately 12 feet farther to the west. The bridge is a continuous 7-span RC slab with RC open-end diaphragm abutments and 5 column bents, all supported on concrete piles. The bridge is 196 ft long and 43 feet wide.

FAULT RUPTURE EVALUATION

Existing data

The nearest Caltrans-active fault is the Imperial fault, a near-vertical right-lateral strike-slip fault that extends approximately 39 miles from south of the International border north to Brawley (Figure 1). The fault is part of the main boundary between the Pacific and North American plates, connecting to the San Andreas Fault in the north through the right-stepping Brawley Seismic Zone and through another right step to the Cerro Prieto and related faults farther south. The fault is located west of the bridge (Figure 2).

Caltrans air photos (1969, 1989, and 1996) failed to reveal the fault because of recent field planting although a faint northwest-trending broad lineament was observed both north and south of Route 98. No LiDAR imaging is currently available for this area. Rockwell and Klinger (2013) mapped displacement on the Imperial fault resulting from the 1940 M7.1 Imperial Valley Earthquake on high-resolution air photos taken around the year of the earthquake. That work is used here both for the fault trace location (Figure 3) and for estimating expected displacement (Figures 4a and 4b). Rockwell and Klinger (2013) noted the lack of off-fault deformation outside a 16-foot-wide band encompassing both the fault and secondary cracking, and pointed out that this was surprising given the depth of alluvium in the area. They also noted that the nearby Superstition Hills Earthquake appeared to have a narrow zone of faulting as well.

Landmark Consultants Inc. (2006) performed an AP fault evaluation study southwest of the bridge (Figure 5) that included trenching. Fault traces were found in Trenches 2 and 3 (Trench 1 encountered undocumented fill in the area the fault was mapped on the surface in 1940 and therefore was not visible in the trenches). Trench 2 (southernmost) encountered several fault traces in a 24-foot wide zone on trend with existing mapping. Trench 3 revealed two fault traces 24 feet apart, again on trend with existing mapping. No evidence of faulting farther east nearer the river and bridge was found in the trenches.

The M7.1 1940 Imperial Valley Earthquake resulted in fault rupture of the Imperial fault and is described as follows: "The most conspicuous area of surface rupture was on State Highway 98 eight miles east of Calexico… rows of trees in an orange grove south of the highway and west of the Alamo River Bridge were offset almost 10 feet. (Imperial County, 2007).

A M6.5 earthquake occurred October 15, 1979 on the Imperial fault. Surface rupture associated with this event did not extend as far south as the Alamo River Bridge, however the bridge was inspected after that event and the following observations were made:

- *The soffit of the superstructure at the tops of the pile columns at the easterly end is spalled. The spalls measure ½" deep and extend a maximum of 6" from the pile columns.*
- *The ground around the pile columns is displaced 4 inches from the lateral movement of the piles.*
- *The four wing walls and the concrete rail above have cracks measuring from hairline to 1/16" wide. The cracks in the wing wall face are hollow sounding when rapped with a hammer.*

(J.M.Borik, October 16, 1979).

The 1940 rupture with respect to the bridge is shown in figures 6-8. These photos along with the Rockwell and Klinger (2013) photo interpretation and the trenching indicate the fault ruptures in a narrow zone.

Field Reconnaissance

A field reconnaissance in the vicinity of the bridge was conducted on 4/9/2013 by Douglas Cook, CEG from the office of Geotechnical Design South - Branch 2, and Martha Merriam. We located a vault about sixty feet north of the Hwy 98 centerline and 300 feet west of the bridge (Figure 9) which is the easterly end of a 20 m long wire creep meter gauge ("Tuttle Ranch" instrument), operated in the 1970s but abandoned because of rust damage. Schulz (1989) notes about the trench excavated for the gauge that, "A vertical offset in the strata was encountered within about 1 meter of the trench mid-point." This observation suggests that the fault crosses roughly 10 m westerly of the vault.

We were unable to locate the fault on the ground surface because of agricultural activity and road repairs.

POTENTIAL FOR FAULT RUPTURE

I ran a second PFDHA and included measurements of displacement on the rupture that occurred within 1 km of the bridge (Hecker et al, 2013) during the 1940 Imperial Valley earthquake (Rockwell and Klinger, 2013; Figures 4a and 4b). I used the following parameters:

an "accurately located" and "simple" fault trace,
100% of offset on the main trace located 180 feet west of the bridge,
MMax = 7.1 (1940 earthquake magnitude, associated with measurements),
slip rate = 35mm/yr (Dawson and Weldon, 2012) (probabilistic),

aseismic slip factor (asf) = 0.1 (Dawson and Weldon, 2012),
N(number of measurements) = 57, and
Average measurement =4.1 m

Fault rupture at the bridge is estimated at one meter probabilistically or a few inches deterministically (Figure 9).

PFDHA is very useful in areas where uncertainties in trace location and base maps exist. Given that we have photos of the historic fault rupture and trenches indicating there are not likely to be any traces closer to the bridge, along with observations by others that the fault zone is narrow, I recommend we assume the rupture will occur where it has occurred previously (a basic tenet of paleoseismology) in a zone 15-30 feet wide (considered in the 180 feet estimate above).

No design for rupture is therefore required, and potential for rupture is low.

RECOMMENDATIONS FOR ADDITIONAL INVESTIGATION

No additional work is recommended at this time. If you have any questions, please contact Martha Merriam at (916) 227-7135.

Prepared by: Date: April 15, 2013

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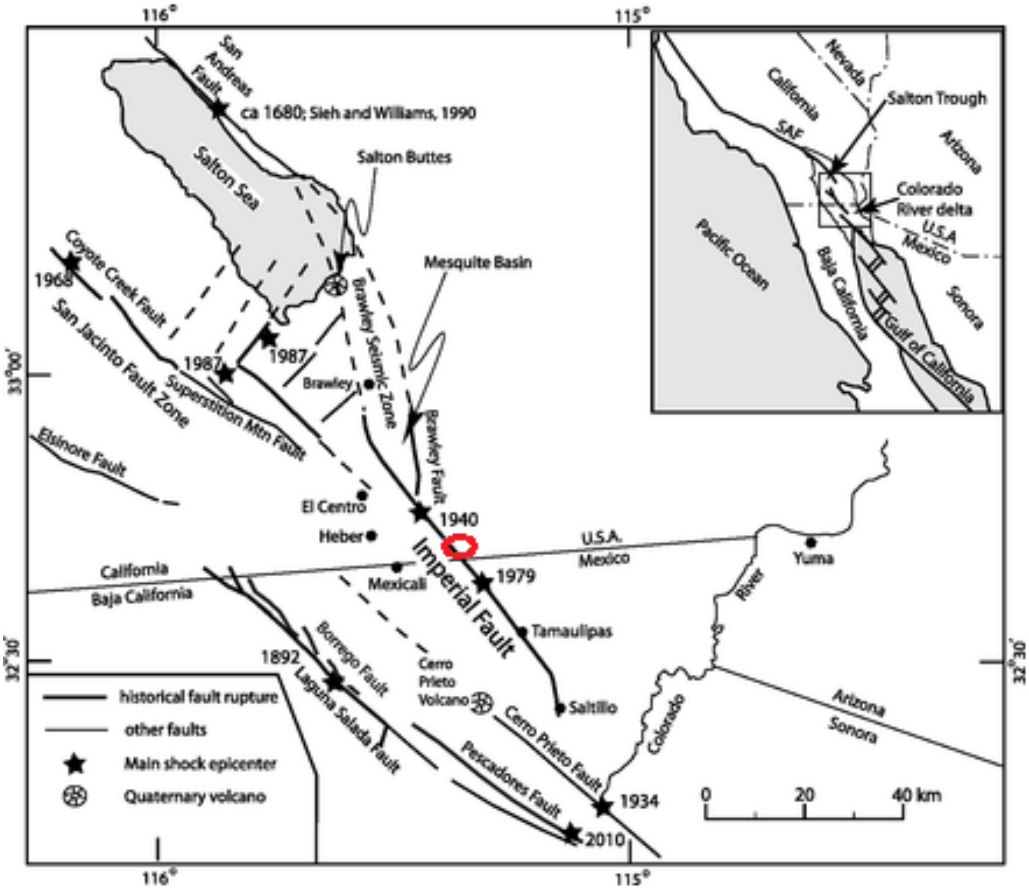


Figure 1. Location of faults in southern California near the International Border (Rockwell and Klinger, 2013). Alamo River Bridge location is shown by red oval.

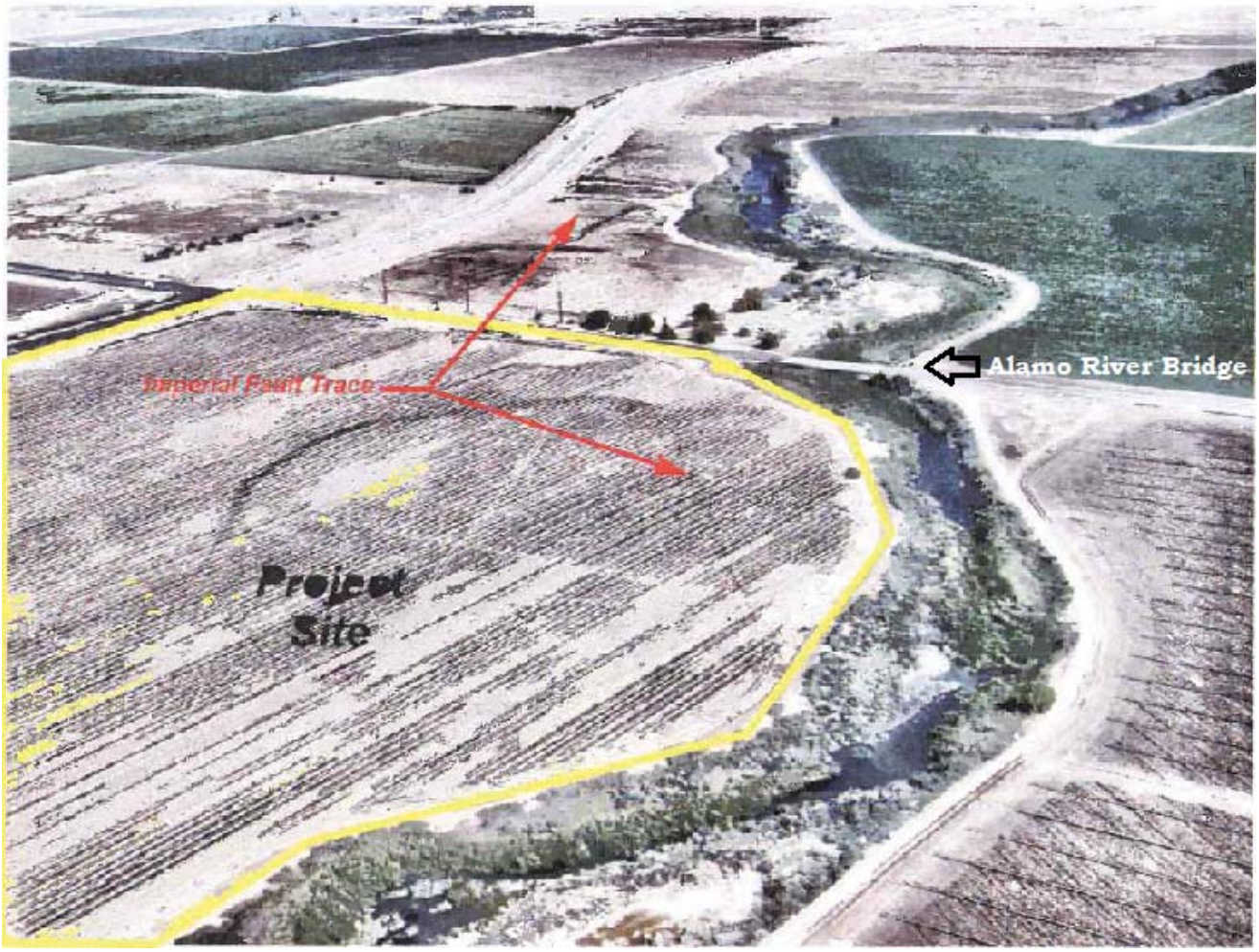


Figure 2. Oblique view of bridge and Imperial fault. Landmark, 2006 (photo from 2003). North is towards the top of the photo.

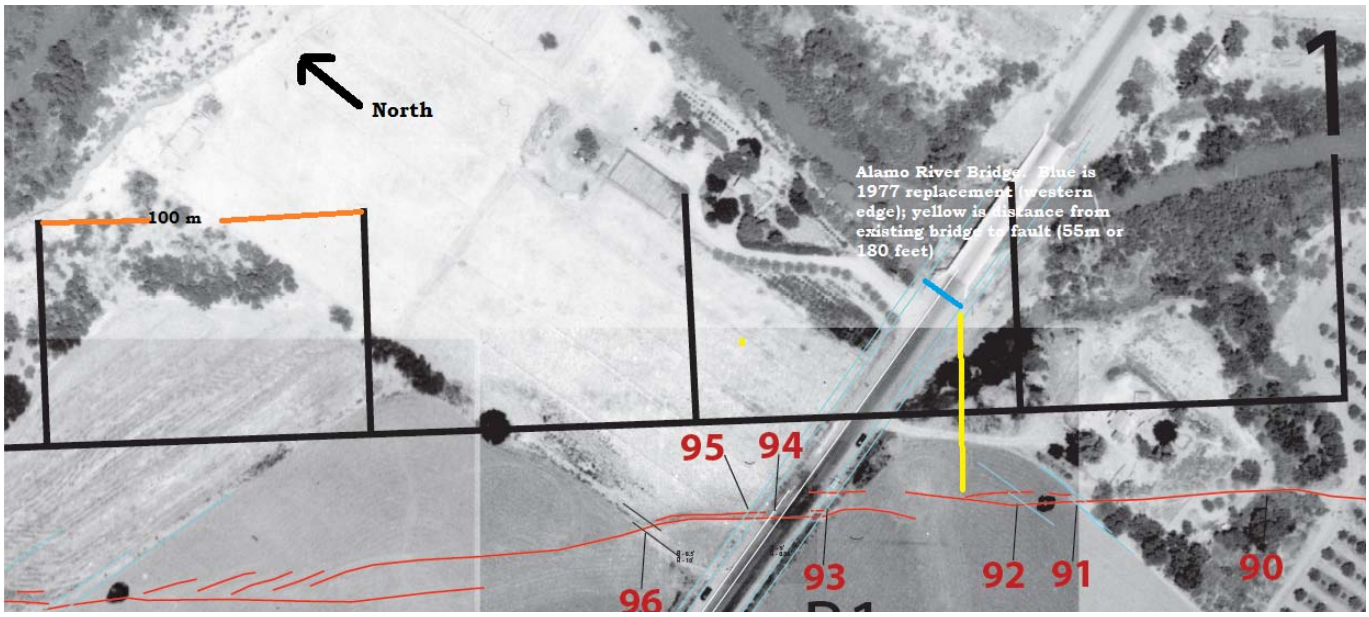
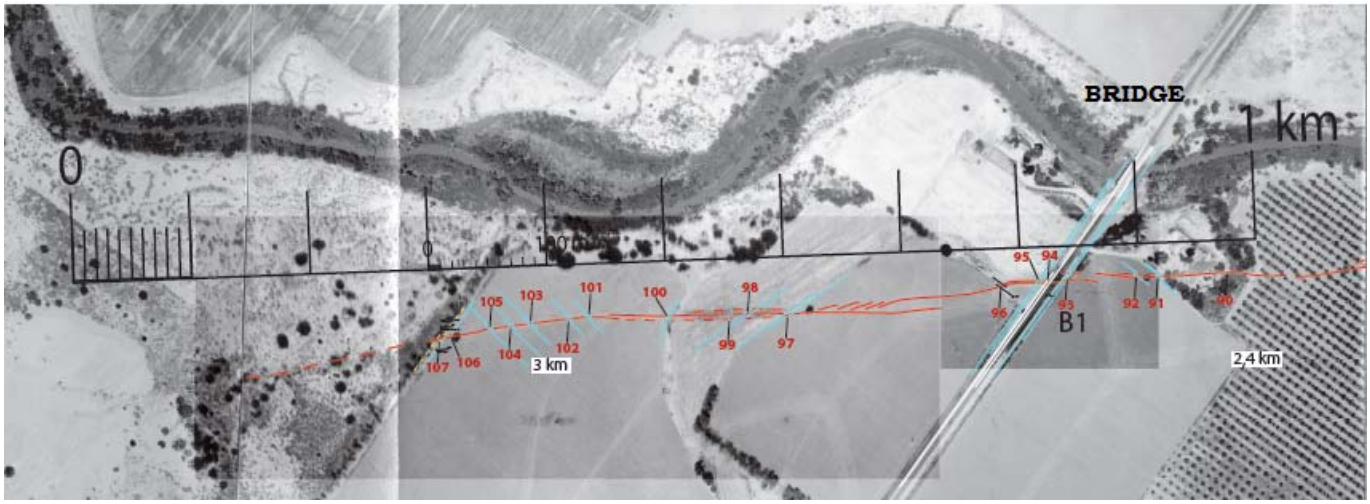
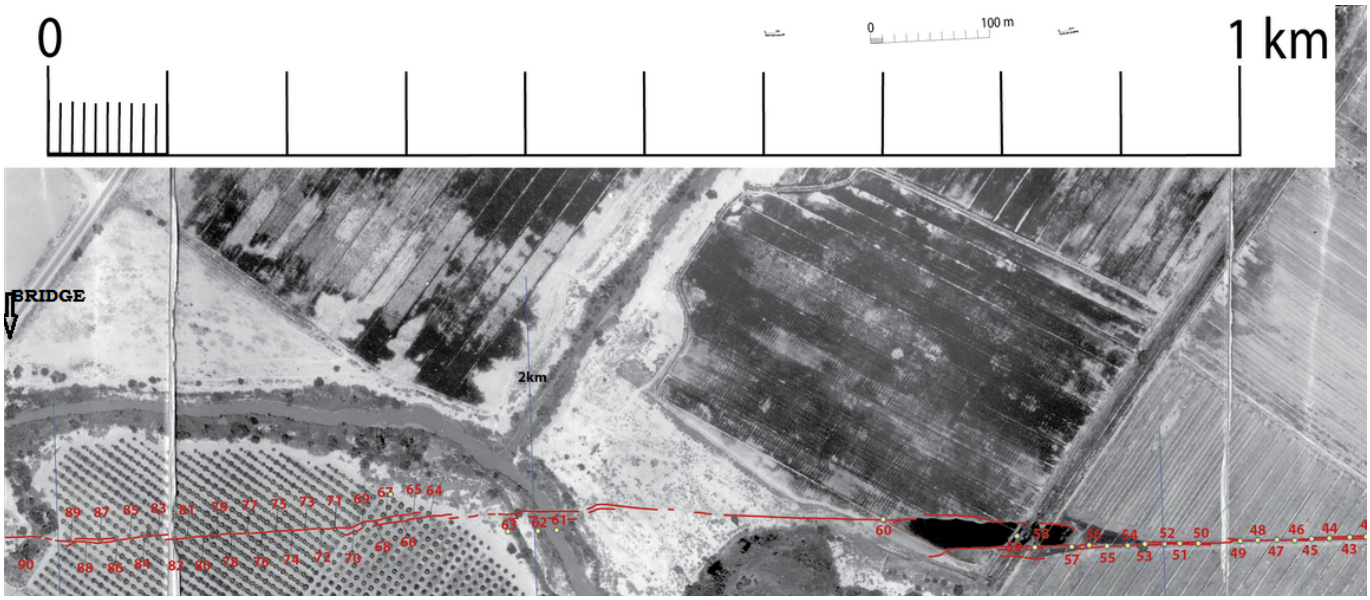


Figure 3. Imperial fault (1940 rupture) shown in red. Existing bridge extends 12 feet further to the west (extension is represented by blue line). Red numbers denote where measurements were obtained from air photo. Yellow line indicates distance between the existing bridge and the fault trace, namely 55m or 180 feet).
(1940 air photo, Figure S2 in Rockwell and Klinger, 2013).





Figures 4a and 4b. Locations of measurements obtained by Rockwell and Klinger (2013). A total of 57 points are within 1 km of the bridge with an average value of 4.1 m of lateral offset (235.4 m / 57 points).

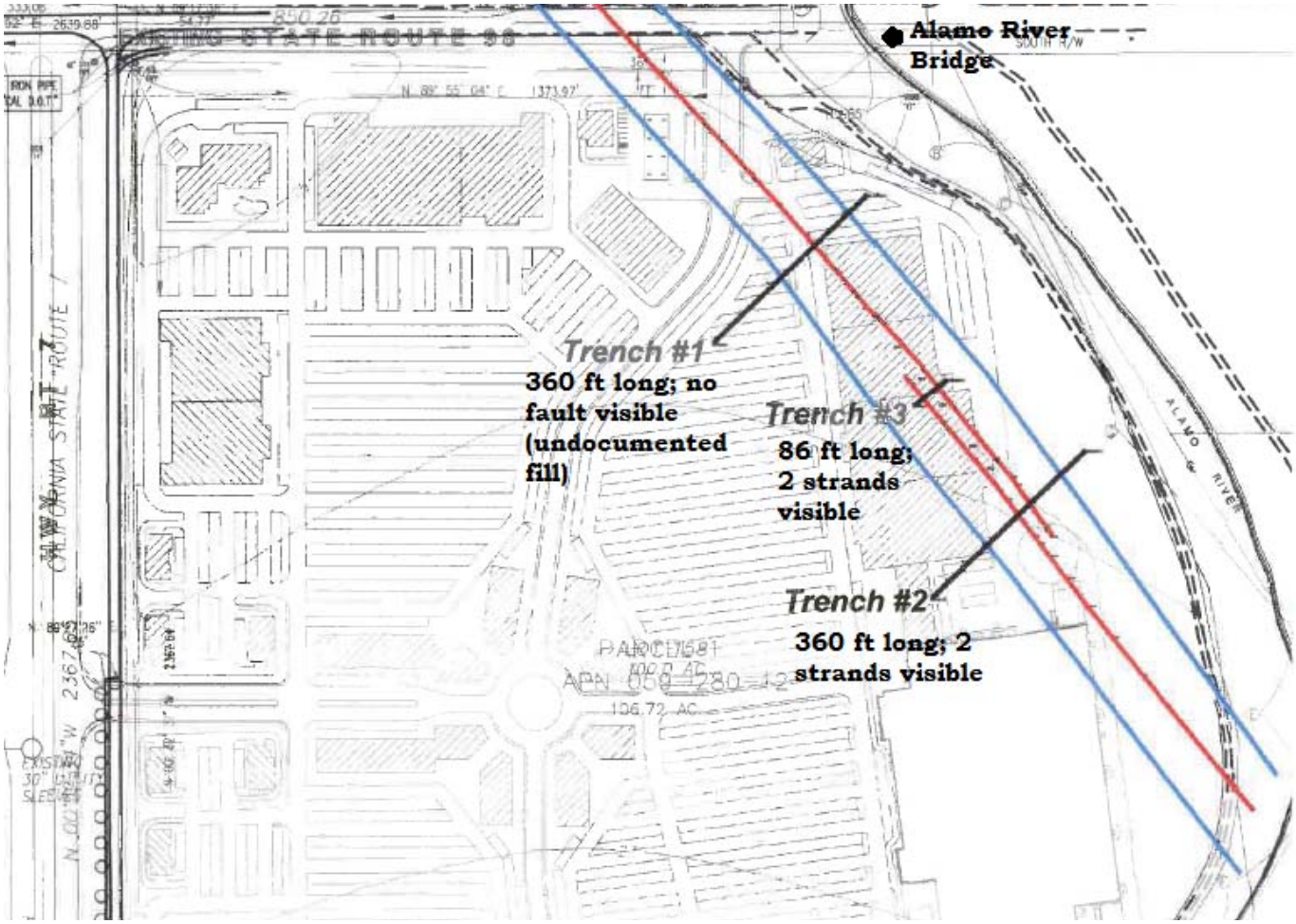


Figure 5. Trenches excavated for AP fault study (Landmark Consultants Inc., 2006). North is at top of figure.

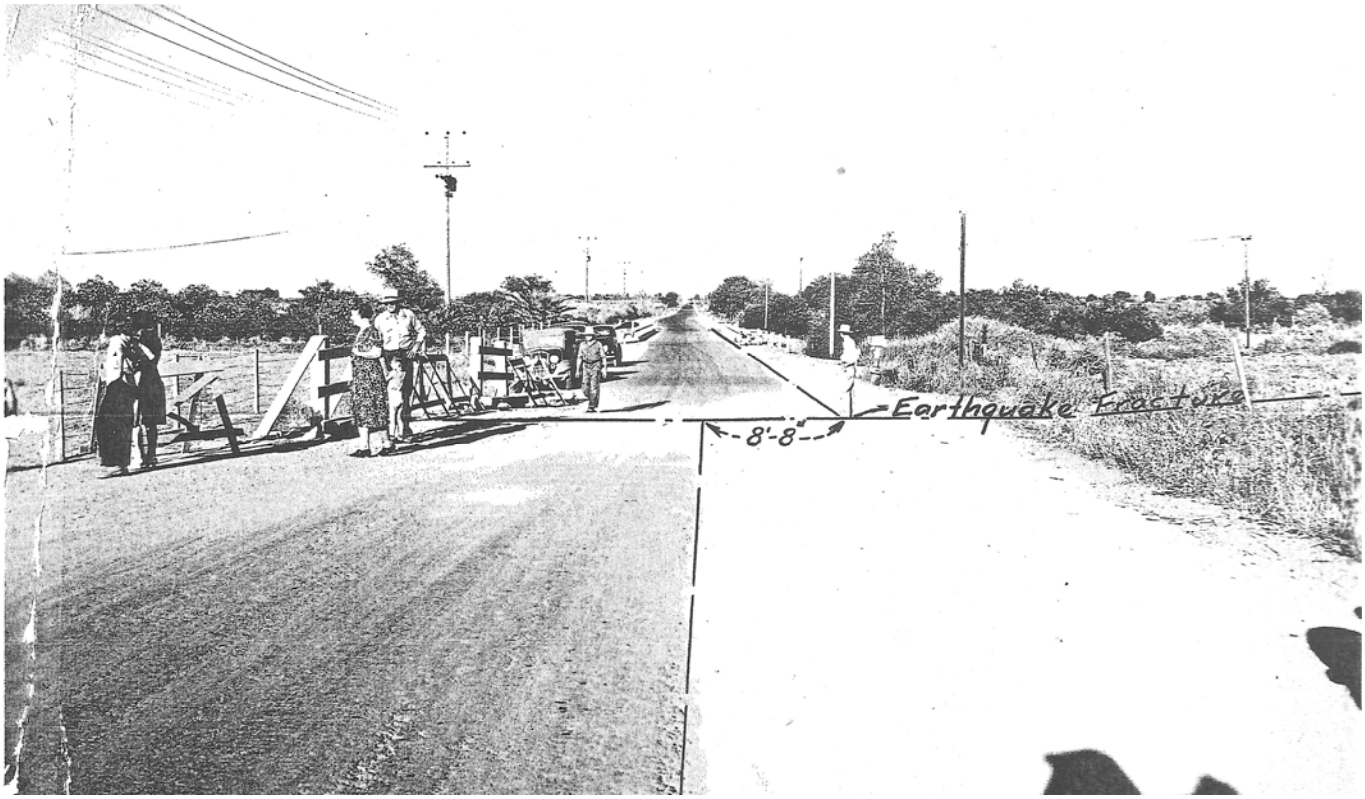
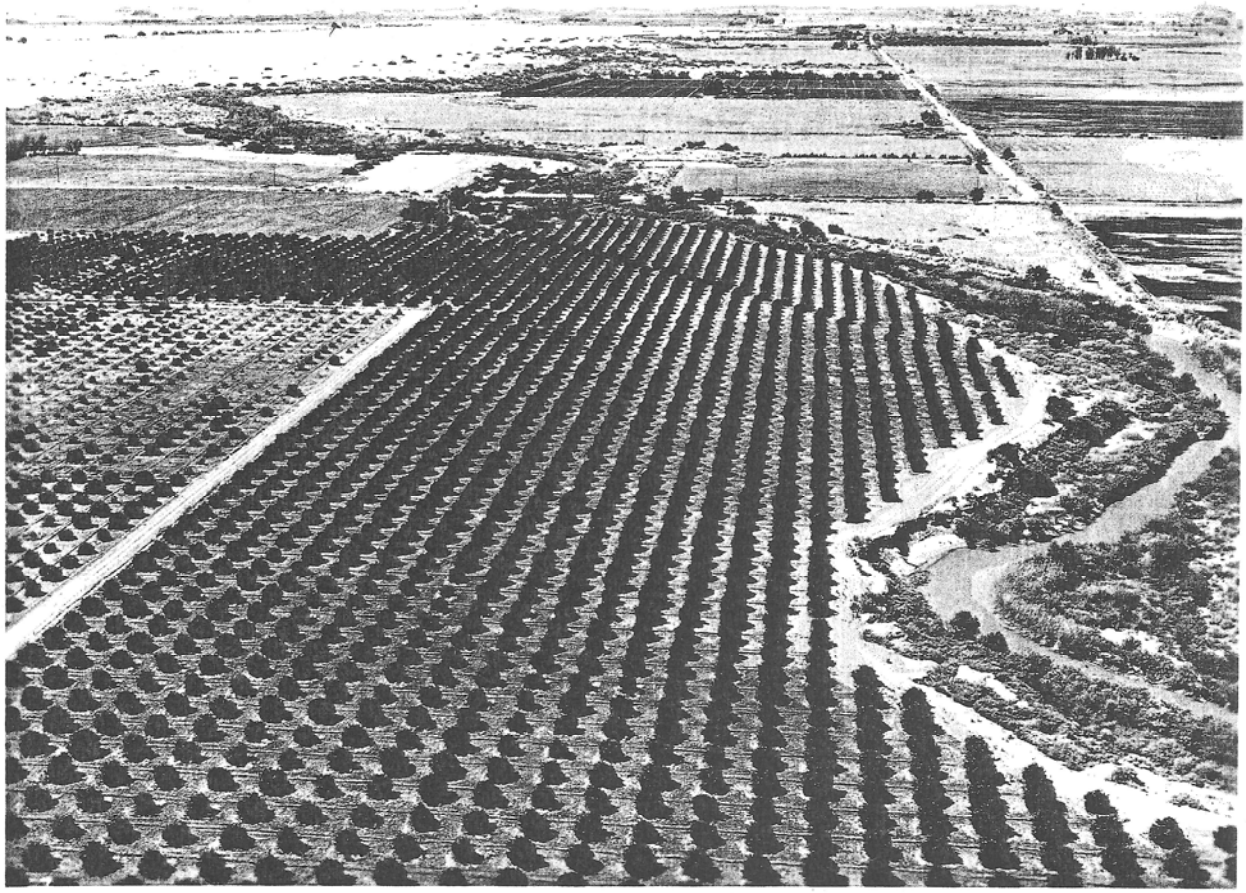


Figure 6. Looking east along Route 98 across the 1940 Imperial fault offset. Alamo River Bridge is in the background. The bridge was replaced in 1977 and is now 12 feet farther west. Photo taken May 23, 1940, by C.A.McDougall, in Clark, 1940.

Figure 7 (next page). Aerial view looking north at offset citrus grove tree rows. Bridge is at top of photo. Same fault location as shown in Figure 5. Photo taken by US Army, in Clark, 1940.

Figure 8 (next page). Aerial view looking east with Imperial fault in the foreground and Alamo River Bridge in the background. Photo taken by US Army, in Clark, 1940.



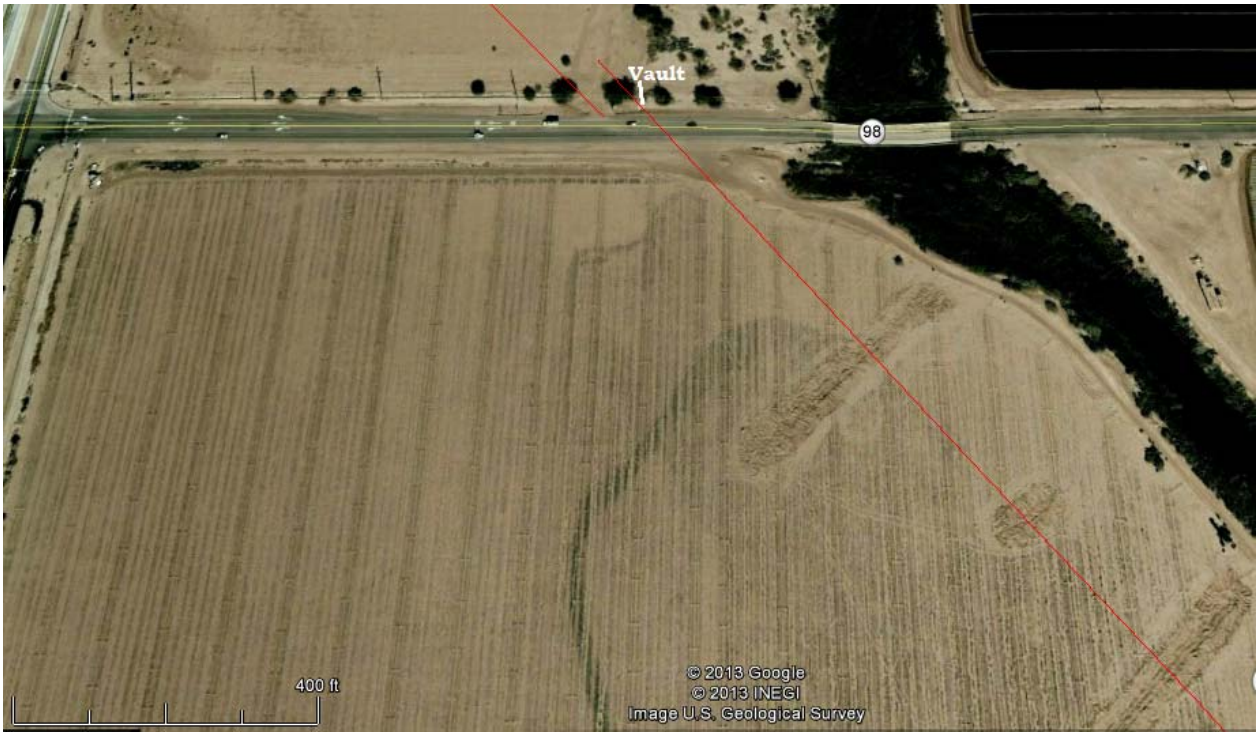


Figure 9. Location of eastern creep meter vault. Note "shadows" of 2006 Landmark trenches 1-3. (USGS, 2012; Google Earth 2008).

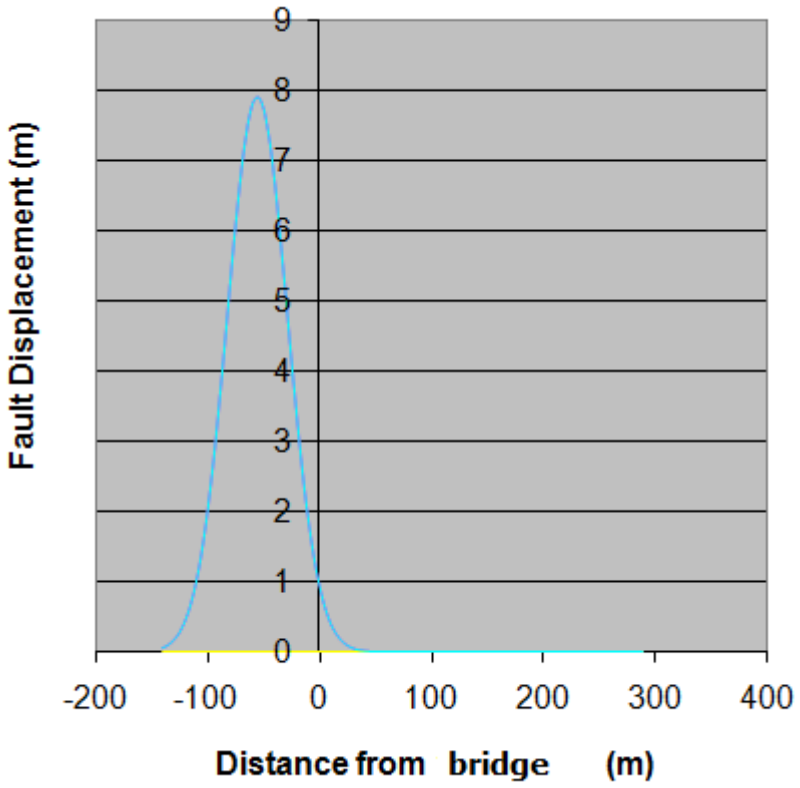


Figure 10. One meter (3.3 ft) = estimated displacement (probabilistic) at Alamo River Bridge (assumed 100% on main trace) based on an accurate fault trace location, MMax =7.1; slip rate =35 mm/yr, aseismic factor = 0.1, number of site-specific measurements [see Figure 3] =57; average value of site-specific measurements = 4.1 m, distance from bridge to fault is 55 m. Deterministic value is much less. **I recommend using a value of 0 because of the accuracy of the fault trace location (within a few m).**