State of California
DEPARTMENT OF TRANSPORTATION

Business, Transportation and Housing Agency

Memorandum

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To: MR. TOM OSTROM
Supervising Bridge Engineer
Office of Earthquake Engineering

Date: March 25, 2014

Attention: Mark Yashinsky

File: 01-MEN-101 PM 28.26
59-93034-N
EFIS# 0000001016-N
York Creek Bridge 10-0203L

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Subject: **PRELIMINARY EVALUATION OF FAULT RUPTURE POTENTIAL FOR YORK CREEK BRIDGE (LEFT) - BRIDGE 10-0203L ON HIGHWAY 101, MENDOCINO COUNTY**

SUMMARY

Caltrans bridge 10-0203L, York Creek Bridge (MEN-101-28.58; Figure 1) lies in Ukiah, Mendocino County. A secondary trace of the Maacama fault lies 50 meters northeast of the bridge, and the main (creeping) trace of the fault lies approximately 250 meters northeast of the left bridge.

The probabilistic potential offset within the left bridge footprint is 0.2 meters (7.9 inches). Vertical displacement of approximately 10% of the selected horizontal value, or up to 0.02 meters (0.8 inches), should be assumed to occur with the horizontal displacements.

INTRODUCTION

This evaluation was prepared as part of a statewide evaluation of fault rupture potential at Caltrans bridges. Caltrans policies regarding fault rupture at bridges are described in Memo to Designers 20-10. Caltrans requires a fault rupture evaluation if a bridge is located within an Alquist-Priolo Earthquake Fault Zone or within 300 meters of an un-zoned fault 15,000 years or younger in age.

The York Creek (left) bridge was built in 1962. It is a continuous 4-span cast-in-place/reinforced concrete T-girder on reinforced concrete pier walls. It has reinforced concrete diaphragm abutments. All are founded on driven precast concrete piles.

This evaluation consisted of literature, air photo, and LiDAR review, a site visit, and deterministic and probabilistic calculations of expected offset.

LITERATURE, AIR PHOTO, LiDAR, AND FIELD REVIEW

Hart and Bryant, 2001 (USGS Fault and Fold Database)

The northern Maacama fault extends from Mark West Creek in Sonoma County to Laytonville in Mendocino County. It has been interpreted as a right-stepping extension of the Rogers Creek fault. The Maacama fault is a right-lateral strike-slip fault.

California Division of Mines and Geology (CDMG) FER 111 (1981), Upp (1982)

The bridge lies west of the Maacama fault as mapped on the Alquist-Priolo EFZ map (Figure 2) and by Upp (1982). The Maacama fault has two active strands here, a creeping strand on the east, considered the main active strand, and a secondary strand to the west, closer to the York Creek Bridge. The York Creek Bridge (left) lies approximately 50 meters west of the secondary strand, and the main strand of the fault lies approximately 250 meters east of the bridge (Figure 2). The secondary strand was mapped by the CDMG (1981) and by Upp (1982) based on tonal lineaments and a scarp in Quaternary alluvium (Figure 3).

Historical Air Photos and LiDAR images

Air photos from 1955 confirm the location of the fault features mapped by both Upp (1982) and the CDMG (1981). The traces mapped by the State of California (1974; Figure 2) and CDMG (1981) are correctly located with respect to the York Creek Bridge and the site-to-source distance shown on the maps is accurate.

LiDAR images in the graded and developed area around the York Creek Bridge do not show fault expression immediately around the bridge. Some geomorphic features can be seen northwest of the bridge on the LiDAR image, such as a scarp in Quaternary alluvium (Figure 3).

Site Visit

I visited the site in March 2014. York Creek is very densely vegetated and the banks are very steep. The secondary fault trace is mapped crossing York Creek approximately 50 m east of the left bridge. There are no trails leading to the creek bottom, and the creek level was too high to wade through. No expression of this fault trace was visible from the top of the creek banks. To the northwest, the secondary strand was mapped in a private vineyard west of Highway 101, based on air photo lineaments. The expression of the fault there is subtle and not readily apparent

on the ground. I found no evidence of fault creep on the main fault strand at State Street near York Creek.

Creep

The Sanford Ranch Road creep site lies approximately 8 km southeast of the site. Fault creep of 4.2 mm/year on average has been recorded there for two decades (McFarland et al., 2009). Fault creep has also been recorded on fault segments north of the site in Willits. There is no evidence of creep on the secondary fault segment near the York Creek Bridge. Bridge inspection reports from 2013 and before record no evidence of possible fault creep affecting the bridge.

Paleoseismic Studies

Sickler and others (2005) excavated a trench approximately 1.6 km southeast of the York Creek Bridge. They found a laterally offset terrace riser and were able to constrain the date of the most recent surface rupture on this segment of the fault (1400 to 1600 AD). They did not measure the offset in past earthquakes.

Caltrans Logs of Test Borings

The Logs of Test Borings drilled for these bridges do not show fault gouge or high groundwater, which might indicate the presence of a fault.

Literature Review and Site Visits - Conclusions

The Maacama fault has two parallel traces near the York Creek Bridges – the main (creeping) segment, which lies approximately 250 meters east of the bridges, and the secondary trace within 50 meters of the left bridge. These faults are accurately located on published maps.

The Maacama fault is mapped as multiple traces throughout much of its length. Near the York Creek bridges, there is strong continuity on the main trace (approximately 250 m east of the York Creek bridges) to the northwest and southeast. The secondary trace closest to the left York Creek bridge is a short (approximately 3 km) segment parallel to the main fault, mapped based on air photo lineaments.

CALCULATIONS OF EXPECTED OFFSET

To quantify potential fault offset, I used a spreadsheet developed by the Division of Research and Innovation in collaboration with Geotechnical Services, based upon methods presented in Petersen, et al. (2011), and Abrahamson (2008). Both a deterministic fault displacement analysis and a probabilistic fault displacement analysis were performed. The input parameters included

distribution of rupture across multiple strands, maximum magnitude, slip rate, mapping and base map errors, and aseismicity factor.

Distributed Rupture

The methodology of Peterson et al. (2011) allows multiple strands to be weighted to account for rupture distribution. Peterson et al. (2011) discuss the assessment of distributed ruptures for fault rupture hazard along strike-slip faults (electronic supplement, Section 2).

> "In contrast to principal fault rupture, we define the term *distributed faulting* as surface rupture that occurs along faults off of the principal fault trace and in response to an earthquake along the principal fault. Distributed ruptures . . . can occur on a variety of structures either related to the principal fault that ruptures during an earthquake, or along separate structures with no direct connection to the principal fault either at the surface or at depth."

In most surface fault rupture hazard displacement analyses, multiple fault strands lie close enough to each other and close enough to the structure that distributing slip among the strands results in a calculated offset at the bridge site that is influenced by each strand, and close to the total offset possible on or near the fault. At the York Creek bridge, the main trace of the Maacama fault lies far away enough from the bridge that it does not contribute to the calculated potential offset at the bridge. <u>Thus, the calculated potential offset at the bridge is a direct function of the weight given to the secondary fault trace closest to the bridge.</u>

Very little information is available to assess the relative proportion of Holocene activity on the secondary trace of the fault. The weight assigned to this strand is highly subjective and could be revised in the future. A weight of 85% was assigned to the main trace while 15% was assigned to the short secondary trace near the left bridge.

Mmax

The $\mathbf{M}_{max}$ of 7.4 is cited in the Caltrans fault database[1], which references Dawson and Weldon (2012). This is consistent with values of Mw 7.0 to 7.6 calculated by Sickler, et al. (2005).

Slip Rate

Sickler, et al. (2005) gives the slip rate of 8.7-13.4 mm/year. In this report we use the slip rate from Dawson and Weldon (2012) of 9 mm/year, also cited by Hart and Bryant (2001).

[1] CT fault database: http://dap3.dot.ca.gov/shake_stable/v2/technical.php

Average Block Model Moment Reduction (Aseismicity Factor)

Average slip on the fault as a whole should be reduced by aseismic slip. We apply an aseismicity factor of 0.25 from UCERF 3 (Weldon, et al., 2012). This has the effect of reducing the predicted offset to account for the reduction in moment created by ongoing slip on a portion of the fault plane. In this calculation, the Average Block Model Moment Reduction applies to both the main strand and the secondary strand.

Empirical Slip Measurements

Numerous paleoseismic trenches in the area failed to define a slip measurement for the most recent event on the Maacama fault. Empirical slip measurement is complicated by creep on the fault. In this analysis, no empirical slip measurements were used.

Site-to-Source Distance

I used the closest measured distance from the northeast corner of the left bridge to the fault mapped in the EFZ maps in Google Earth and on paper maps (State of California, 1974). The EFZ maps can be inaccurate by up to several tens of meters in some places, so the mapped traces were confirmed with 1955 air photos and mapping by Upp (1982). The EFZ mapped traces coincide with air photo lineaments and features visible on LiDAR images. The main trace lies 250 m from the York Creek (left) Bridge, and the secondary trace lies 50 m from the bridge.

Type of Slip

The Maacama fault is a right-lateral strike-slip fault.

Calculated Potential Offset at the Bridge

Fault Offset within the Bridge Footprint

The deterministic offset (0.1 m or 3.9 inches) within the left bridge footprint is shown on Figure 4. The probabilistic offset (0.2 m or 7.9 inches) within the left bridge footprint is shown on Figure 5.

Vertical Displacement

Vertical displacements of approximately 10% of the horizontal offset should be assumed to occur temporally with horizontal displacements in the bridge footprint. This corresponds to approximately 0.02 meters (0.8 inch) for the larger probabilistic case and 0.01 m (0.4 inch) for the deterministic offset.

Table 1 - Results of Offset Calculations for Left Bridge

Scenario	**M_{max}**[2]	**Slip Rate**[3]	**Site-to-source distance**	**Deterministic offset**	**Probabilistic offset, 975 yr return**
Main Trace 85% Secondary Trace 15%	7.4	9 mm/year	250 m (Main) 50 m (Secondary)	0.1 m (3.9 inches)	0.2 m (7.9 inches)

RECOMMENDATIONS

No further geologic work is recommended at this time. If you have any questions, please contact Anna Sojourner at (510) 622-8839.

c: TPokrywka, CRisden, Daily File
ASojourner/mm
Attachments: Figures 1 - 5

[2] CT fault database: http://dap3.dot.ca.gov/shake_stable/v2/technical.php
[3] Dawson and Weldon (2012)

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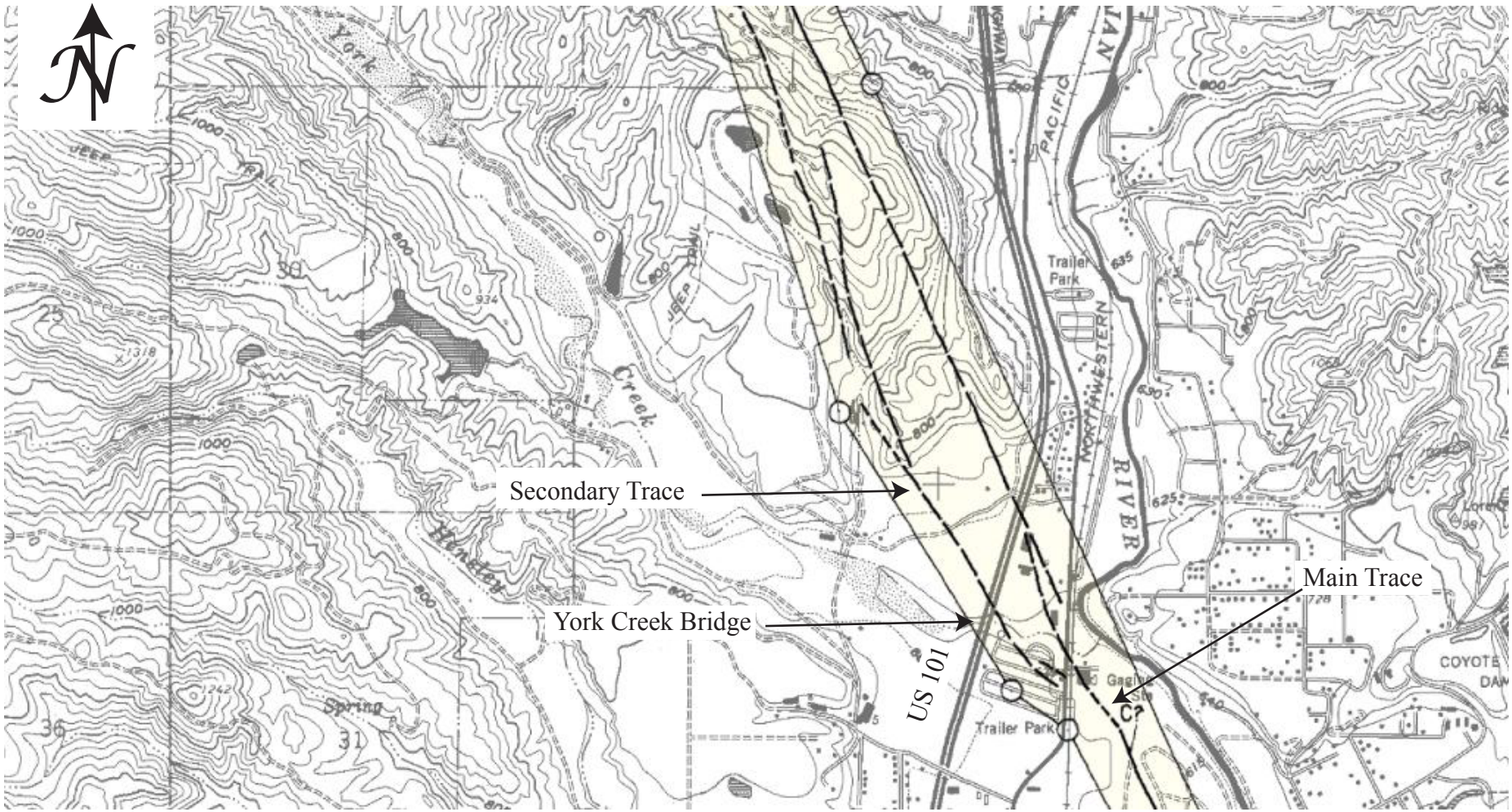
No Scale

Figure 1 York Creek Bridge Location Map

Bridge #10-0203 01-MEN-101 PM 28.26

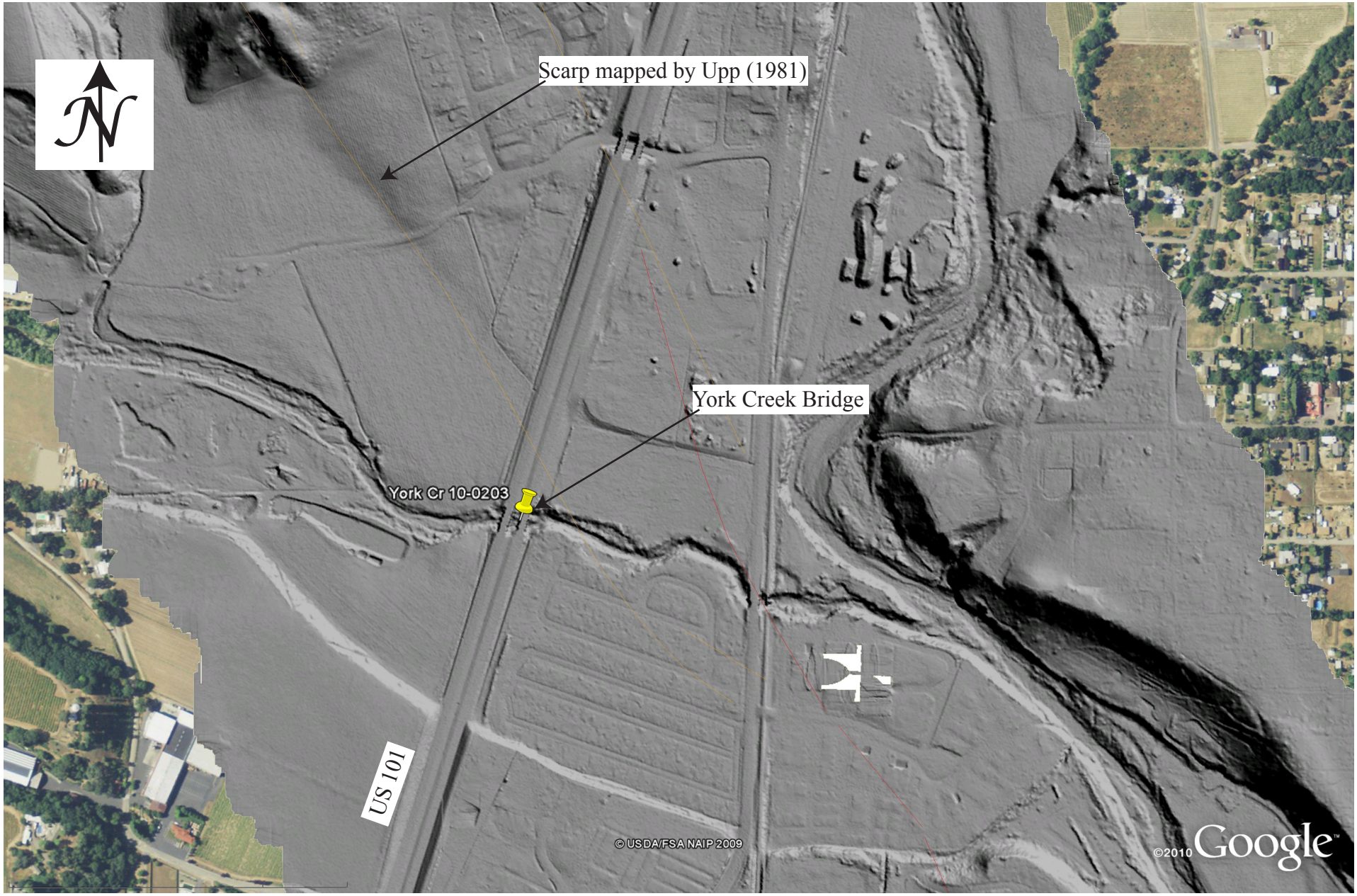
EFIS 0000001016-N March 2014



SCALE 1:24,000

Source: State of California, 1974,
State of California Special Studies
Zones, Ukiah Quadrangle, Official Map

Figure 2	**York Creek EFZ Map**
Bridge # 10-0203	01-MEN-101 PM 28.26
EFIS 0000001016-N	March 2014

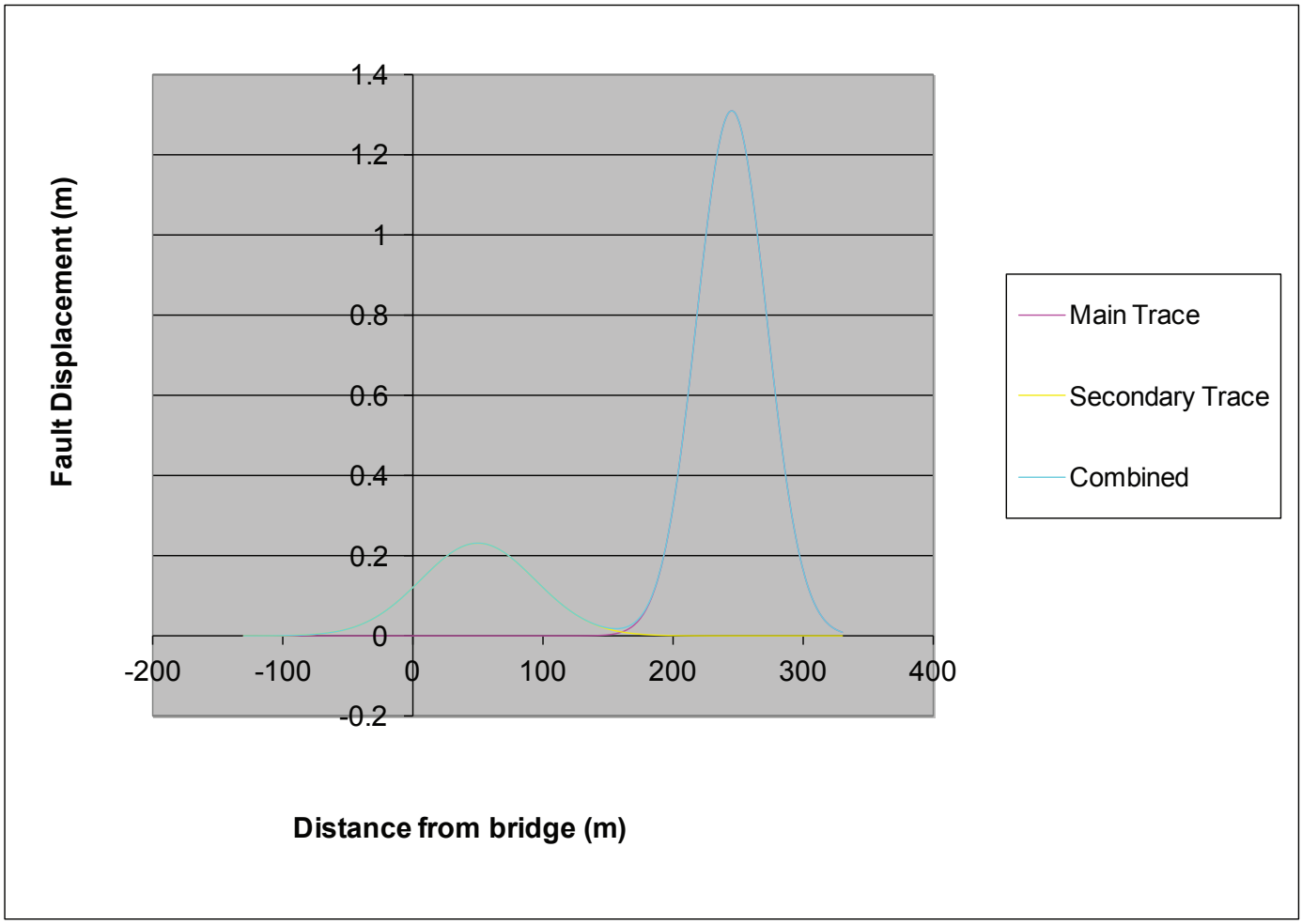


No scale

Figure 3 **York Creek Bridge LiDAR Image**

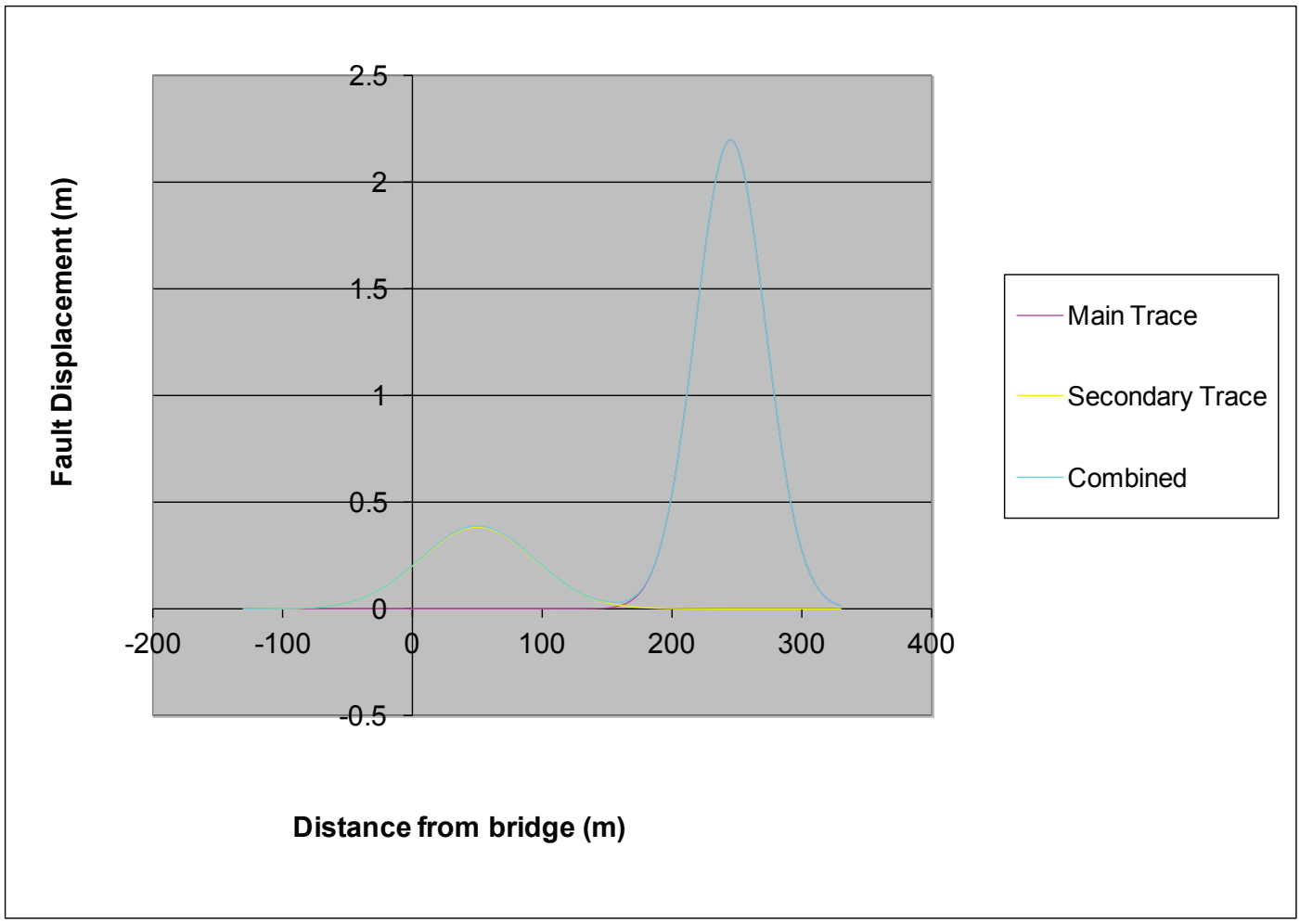
Bridge # 10-0203 01-MEN-101 PM 28.26

EFIS 0000001016-N March 2014



Graph showing deterministic offset on the Maacama fault within the left bridge footprint. Offset at the bridge (distance = 0) could be 0.1 meters.

Figure 4	**Deterministic Offset - Left Bridge**
Bridge #10-0203L	01-MEN-101 PM 28.26
EFIS 04-0000001016-N	March 2014



Graph showing probabilistic offset on the Maacama fault within the left bridge footprint. Offset at the bridge (distance = 0) could be up to 0.2 meters.

	Figure 5	**Probabilistic Offset - Left Bridge**
	Bridge # 10-0203L	01-MEN-101 PM 28.26
	EFIS 04-0000001016-N	March 2014