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Date: August 22, 2014

ATL Job No: G14-202

Scientech Engineers, Inc.
701 Shepherd Drive, Suite 200
Houston, Texas 77077

Attention: Mr. David Sadeghpour, P.E.

Reference: Phase I Fault Investigation
Proposed Neighborhood Street Rehabilitation – Project 464
Springdale (Sec. 1&2) and Restridge (Sec. 1&5)
WBS No. N-000397-0001-3
File No. 4600011023
Houston, Texas

Dear Mr. Sadeghpour:

Per your request, Associated Testing Laboratories, Inc. (ATL) has conduct a Phase I Fault Investigation to identify the probable Long Point Fault crossing(s) along the Lynnview Drive project alignment between Long Point Road and Montridge Drive in Houston, Texas. A Site Vicinity Map is shown in Figure 1. The proposed Lynnview Drive project alignment is shown in Figure 2.

PROJECT INFORMATION

Neighborhood Streets Rehabilitation (NSR) Project 464 in the Springdale and Restridge Subdivision Areas project entails street reconstruction and installation of storm sewer and water

lines along the approximately 14,045 LF project alignments in the City of Houston, Texas. The project alignments traverse streets in the Key Map 451 N, P and S area. The approximate invert depths of the proposed water and storm sewer lines, based on information provided by Scientech Engineers, Inc., is up to 15 feet below existing grade.

A preliminary fault evaluation indicated that the possibility of the SW-NE trending Long Point Fault crosses near the southern end of the project alignments, most probably near the southern end of the Lynnview Drive alignment. A Phase I Fault Study recommended to identify the probable influence zone of Long Point Fault crossing the proposed Lynnview Drive project alignment was concurred by COH Geo-Environmental Branch.

GEOLOGICAL SETTING

The project alignment is underlain by the Lissie Formation. The Lissie Formation is of Pleistocene age and consists of sand, silt, clay, and minor amount of gravel. Iron oxide and iron-manganese nodules common in zone of weathering and contains locally calcareous material. The surface is fairly flat and featureless except for many shallow depressions and pimple mounds. The near surface materials are often weakened by the weathering process.

Among the geologic and geomorphological features in this region are sedimentary deposits broken by structure such as normal faults, salt domes, etc. The sedimentary deposits slope gently toward the Gulf of Mexico. They are broken by normal faults, most of which dip toward the Gulf and extend downward many thousands of feet. The earth movements that caused these faults took place within the last 50,000 years. In general, the regional faults in the Houston area trend parallel to the Gulf Coast. Only the local faults over the salt domes show a radial pattern associated with the upthrust of the salt mass. There are numerous faults and fault systems in the Greater Houston and surrounding area. The movements of many of these faults has been affected in recent history by area subsidence theorized to have been associated with the removal of oil and groundwater. As much as nine (9) feet of subsidence has occurred in the area east of Houston in the last 70 years. Conversion to surface water usage and the limiting of oil production has greatly reduced the subsidence rate in the area east of Houston.

GEOLOGICAL DATA REVIEW

ATL reviewed the following literatures and maps in the course of the Phase I fault study:

- Published Houston-Galveston area geological fault literatures.
- Available historical aerial photographs.
- Published m Houston-Harris County are maps including "Principal Active Faults of the Houston Area (after O'Neill and Van Siclen, May 1984", as shown in Figure 3.
- A geological faults of Houston mapped on Lidar Imagery by Engelkemeir (2008), shown in Figure 4.

Based on these maps, it appears that the Long Point Fault crosses near the southern portion of the project alignments, most probably near the southern end of the Lynnview Drive alignment. The Lidar imagery in Figure 4 also shows that the fault band crossing the Lynnview Drive project alignment widens as the fault splintered into three branches.

FIELD RECONNAISSANCE AND STUDY

ATL conducted a Phase I Fault Study following the preceding literature research that consist of a site reconnaissance to observe probable signs that may be associated with the Long Point Fault along the Lynnview Drive project alignment. ATL also conducted a simple elevation survey along the center line of Lynnview Drive using a survey level for a distance of approximately 600 feet from the Long Point Road/Lynnview Drive intersection.

Elevation Study

Results of the simple elevation survey for a distance of approximately 600 feet along the center line of Lynnview Drive from the Long Point Road/Lynnview Drive intersection is presented in Figure 5. Also presented in Figure 5 is the elevation profile along the center line of the right-of-way (ROW) conducted by the project surveyor at larger spacing.

Site Reconnaissance

The following are observations that were noted during a site reconnaissance along the Lynnview Drive project alignment:

- The existing pavement along Lynnview Drive from Long Point Road to an approximate Sta. 12+85 consist of portland cement concrete (PCC) pavements, and with asphaltic concrete (AC) overlay thereafter to the end of the project alignment at the Montdrige Drive intersection.
- The existing PCC pavements appears to be relatively new, so do the majority of the buildings, sidewalks and the driveways along its sides. The existing pavements with AC overlay appears to be relatively older with surface shrinkage cracking.
- Differential settlements were observed on the surface of the roadway pavements from the Long Point Road/Lynnview Drive intersection to approximate Sta. 13+00, beyond that the differential movements on the roadway appears to be smaller in magnitude although shrinkage cracks can be observed on the AC surface.
- Cracks and differential settlements were observed on driveways and sidewalks along the entire Lynnview Drive project alignments (both the older pavements and newer pavements), possible causes are shrink/swell movements of the high plasticity clays at ground surface, and varying degrees of fault related movements (with larger magnitude of movements within primary fault influence zone).

It should be noted that individual features discussed above are not definitive markers of actual fault movements, other manmade or natural processes could also contribute to cause these features.

INTERPRETATION OF FINDINGS AND RECOMMENDATIONS

Interpreted Fault Influence Zones and Estimated Movements

Based on the findings from the elevation survey and the observation from the site reconnaissance, ATL recommends that the proposed Lynnview Drive project alignment between Sta. 0+00 and 6+00 be designated as the Primary Fault Influence Zone, and Sta. 6+00 and 13+00 be designated as the Secondary Fault Influence Zone, as shown in the elevation profile plot in Figure 5.

Long Point Fault is one of the longest documented growth faults in Houston area. It extends from the southwest on Westella Drive (near intersection with Westmead Drive) to approximately Hempstead Road just northeast of the Silber Road intersection. The fault typically downthrown towards the southeast. Near the Long Point Road/Lynnview Drive intersection, the Long Point Fault crosses the Long Point Road at an approximate angle of 33 degrees. The interpreted Primary and Secondary Fault Zone along Lynnview Drive site plan is shown in the plan in Figure 6.

The historical movements of the Long Point Fault average about 0.3 inches per year, but episodes of faster movements of 1 to 1.5 inches per year had been recorded. ATL recommends that the proposed storm sewers and water lines by designed for the following average fault movements over the design life:

Fault Influence Zone	Estimated Annual Fault Movement Rate, Inches/Year
Primary (Sta. 0+00 to 6+00)	0.3
Secondary (Sta. 6+00 to 13+00)	0.15

Considering the Houston area growth faults typically dip at an angle of about 74 degrees, the horizontal component of the fault movement is estimated to be about 1/3 of the vertical.

Fault Movements Mitigation Measures

The following are measures (but not limited to) that can be taken to mitigate the potential impact of fault movements on the proposed structures:

1. Protect pipes in durable casing.
2. Shorten pipe lengths and provide flexible joints.
3. Provide adequate manholes to allow for rehabilitation of segment of pipes within fault zone (when accumulated fault movements necessitate such rehabilitation) and allow for by-pass pumping.
4. Do not used rigid bedding and backfill such as cement-stabilized sand. Encase pipes in crushed stones wrapped in filter fabric, and sand backfill to one foot below the subgrade or base of pavement/structure.
5. Provide shorter joint spacing for jointed reinforced concrete pavements, and provide lime-stabilized subgrade.

LIMITATIONS

The Phase I fault investigation findings provided in this report is limited to our interpretation of the available information from published literature, maps, aerial photographs, topographic maps and field observations during our site reconnaissance, and our engineering judgment. Other faults beyond those described in this report may exist in the project site or surrounding area due to the following reasons: not observed during the reconnaissance due to limitations of the scope of work; the presence of obscuring vegetation and cultural/environmental features; modification of the land surface by human activities; and, possible presence of yet undocumented fault(s) which do not currently have surface expressions.

CLOSING

It has been a pleasure working with you on this project. Should you have any questions concerning this project work, please call us at (713) 748-3717.

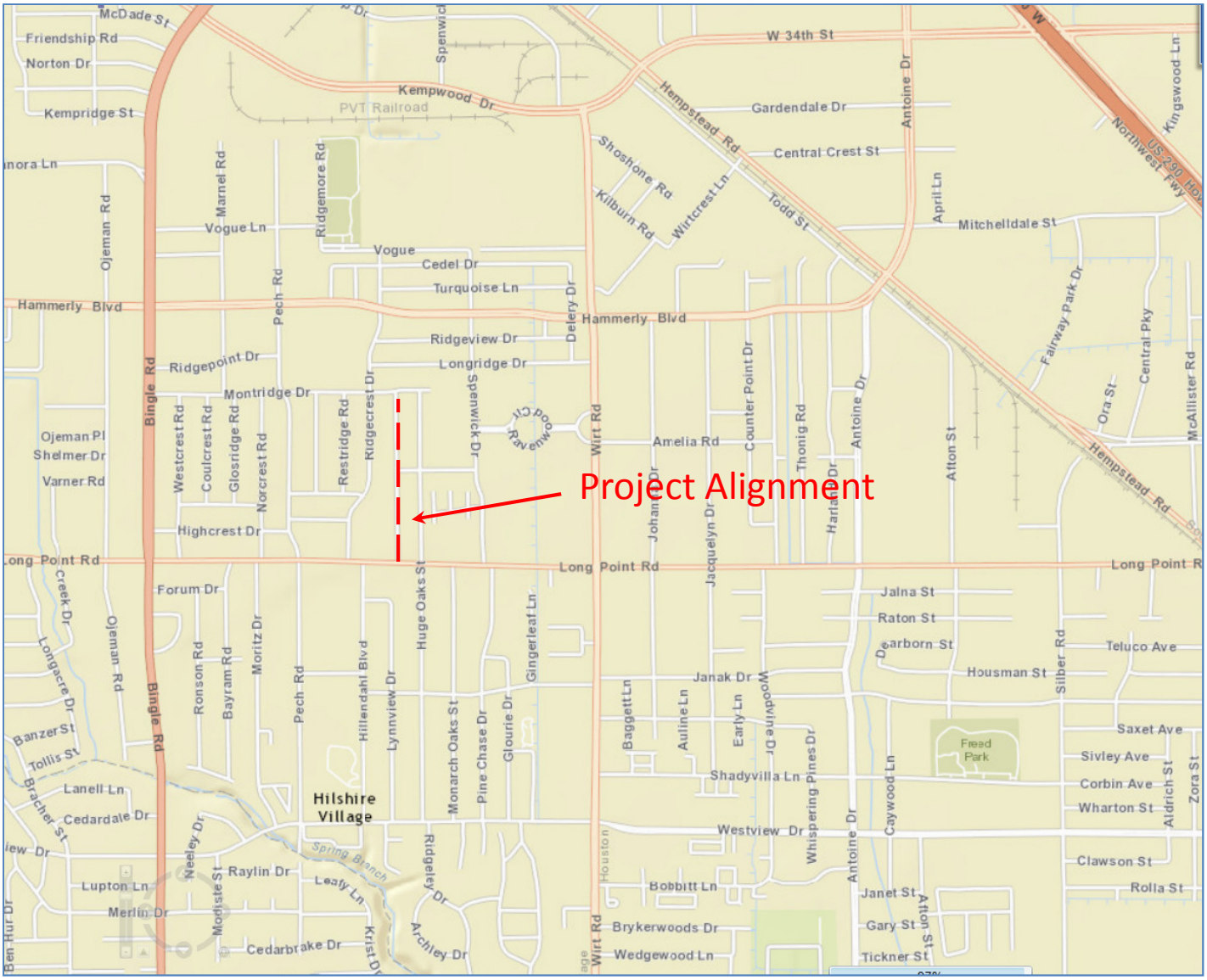
Sincerely,

ASSOCIATED TESTING LABORATORIES, INC.

Peng Sia Tang, P.E.

Manager, Geotechnical Services

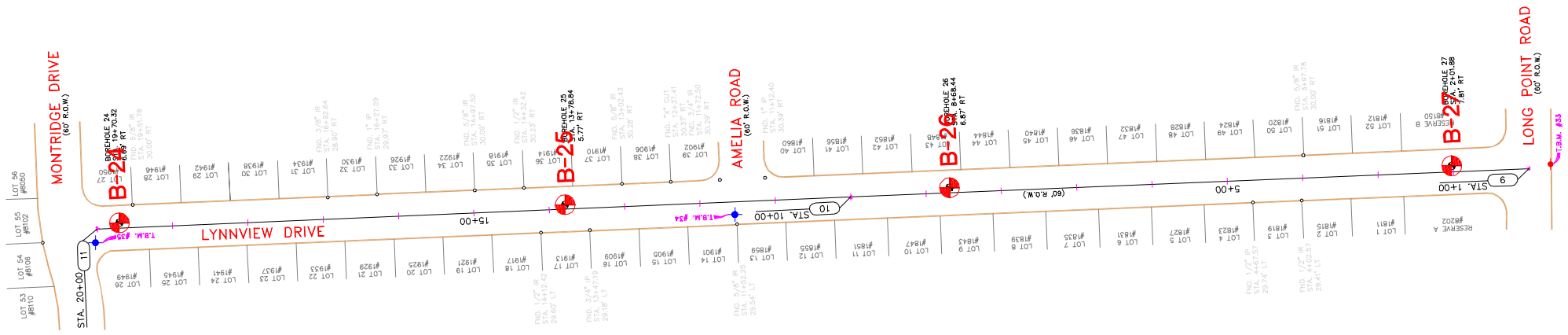
Attachment: Figure 1: Site Vicinity Map
Figure 2: Project Alignment Map
Figure 3: Principal Active Faults in Houston Area
Figure 4: Lidar Imagery of Lidar Hillshaded Image of Several Branches of the Long Point Fault
Figure 5: Elevation Profile Along Proposed Lynnview Drive Alignment
Figure 6: Interpreted Primary and Secondary Fault Zone along Lynnview Drive



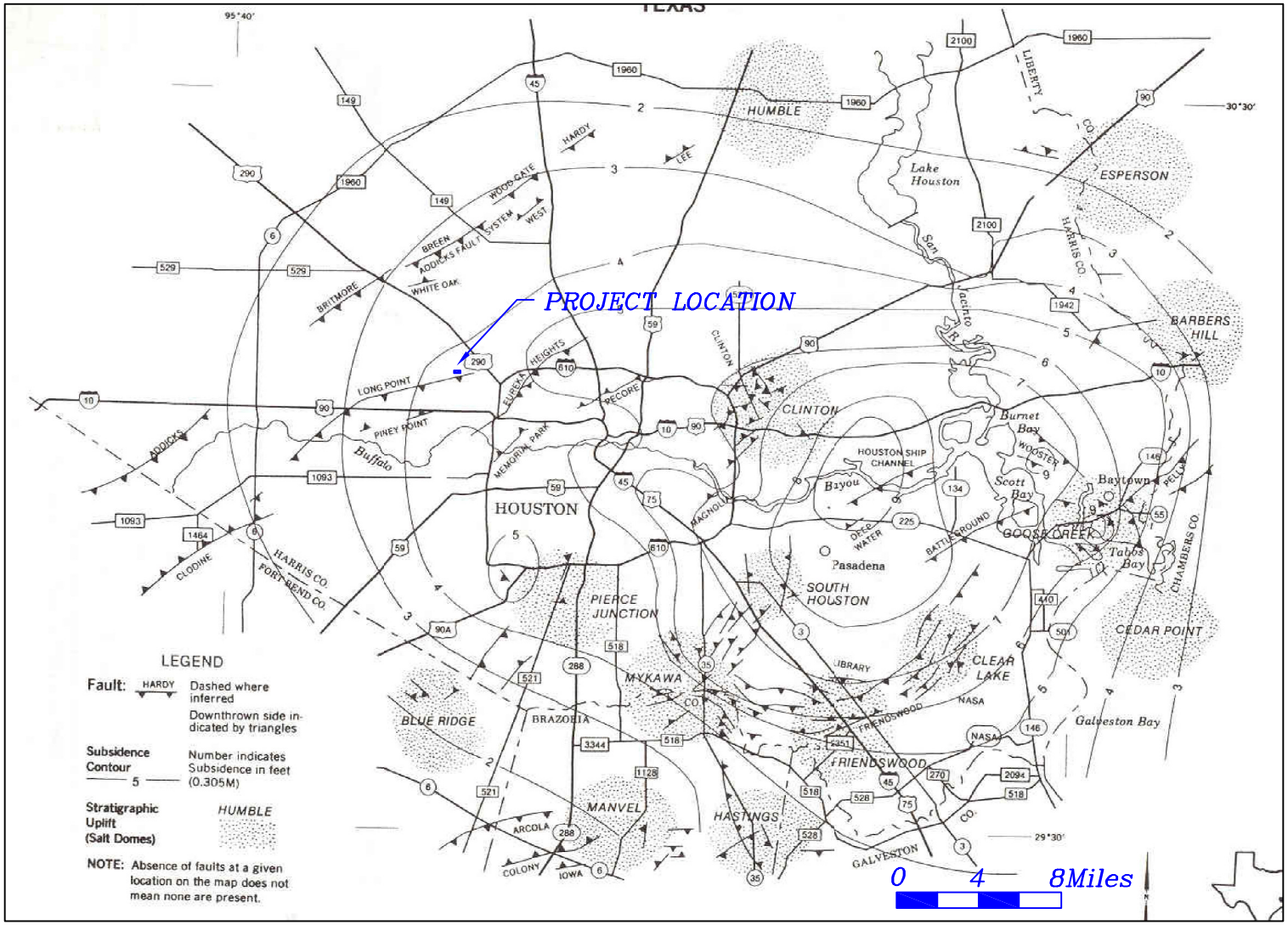
Note: Base map is from COH GIMS

SITE VICINITY MAP	ASSOICATED TESTING LABAORATORIES, INC. 3143 YELLOWSTONE BLVD., HOUSTON, TEXAS TEL: (713) 748-3717 Fax: (713) 748-3748
PROPOSED NSR – PROJECT 464 SPRINGDALE (SEC. 1&2) AND RESTRIDGE (SEC. 1&5)	WBS No. N-000397-0001-3
	PROJECT NO. : G14-202 / FIGURE 1

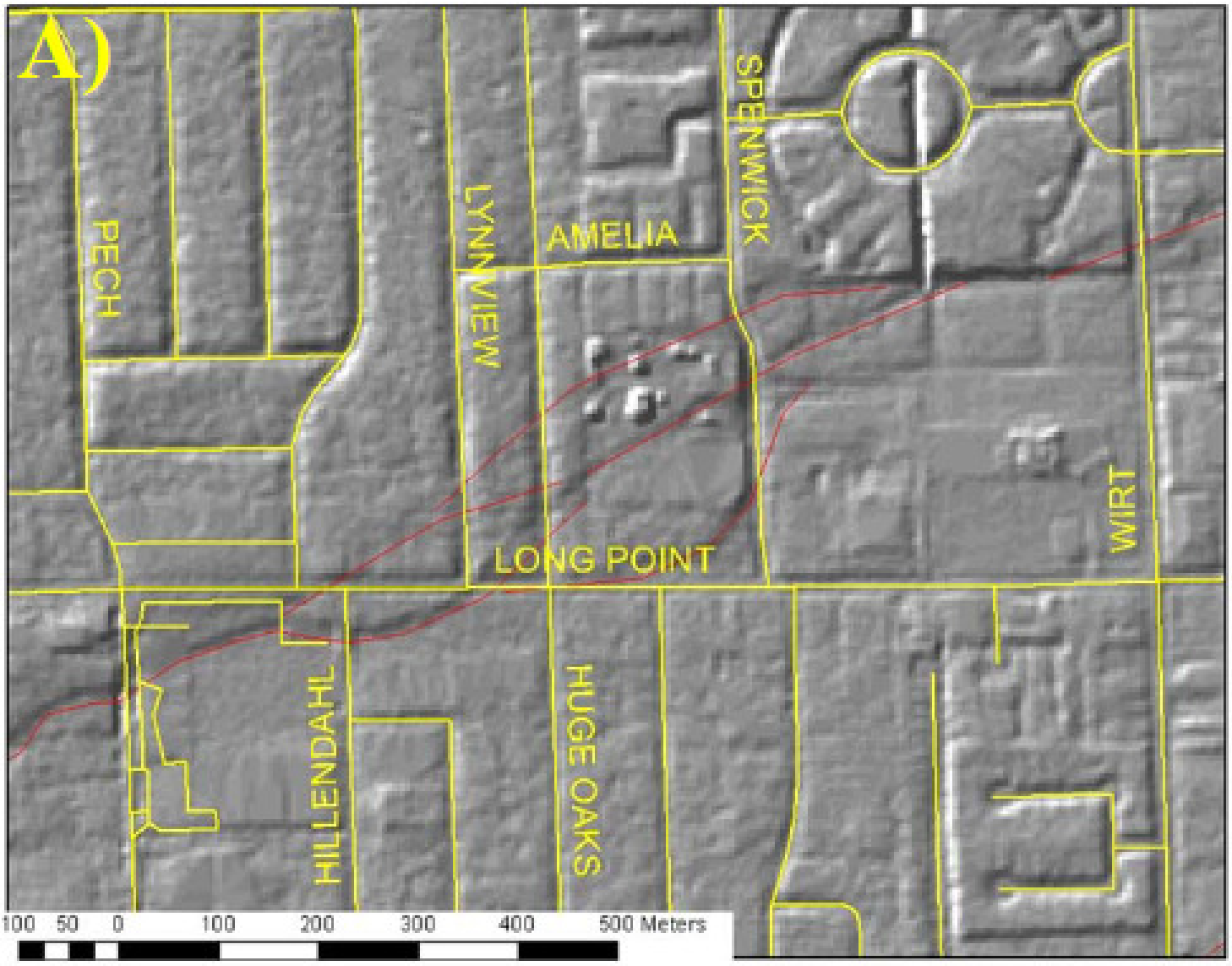
PST 8/28/12



PROJECT ALIGNMENT MAP	Associated Testing Laboratories, Inc. 3143 Yellowstone Blvd. Houston, Texas Tel: (713) 748-3717 Fax: (713) 748-3748	
PROPOSED NSR – PROJECT 464 SPRINGDALE (SEC. 1&2) AND RESTIDGE (SEC. 1& 5)	WBS No.: N-000397-0001-3	SCALE: 1"=200'
	PROJECT NO. G14-202	FIGURE. 2



PRINCIPAL ACTIVE FAULTS IN HOUSTON AREA	*Associated Testing Laboratories, Inc.* *3143 Yellowstone Blvd. Houston, Texas* *Tel: (713) 748-3717 Fax: (713) 748-3748*
PROPOSED NSR – PROJECT 464 *SPRINGDALE (SEC.1&2) ANDRESTRIDGE (SEC.1&5)*	*WBS No.: N-000397-0001-3*
	PROJECT NO. G14-202 / *FIGURE. 3*



Lidar Hillshaded Image of Several Branches of the Long Point Fault
(Engelkemeir and Khan, 2018)

FIGURE 4

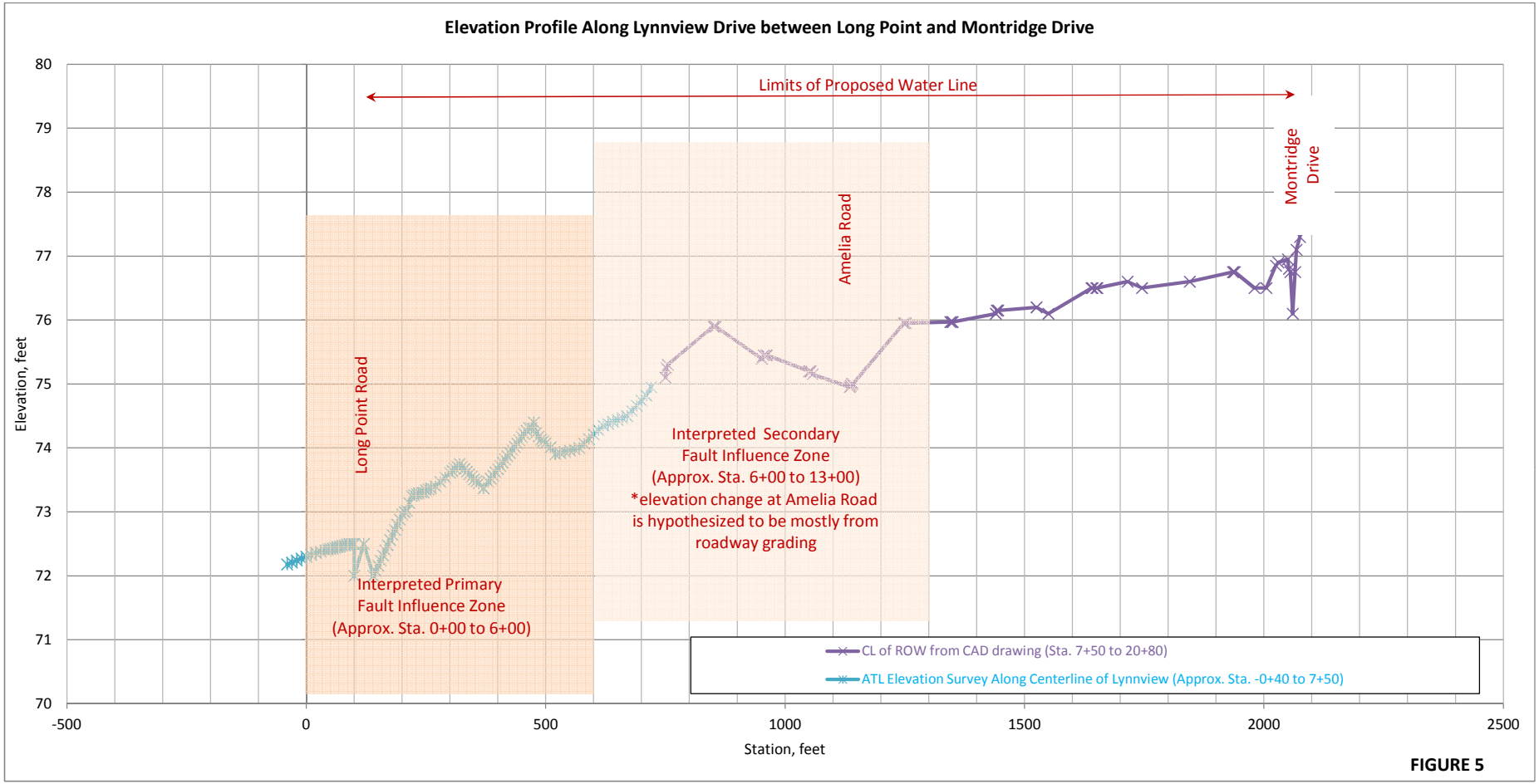
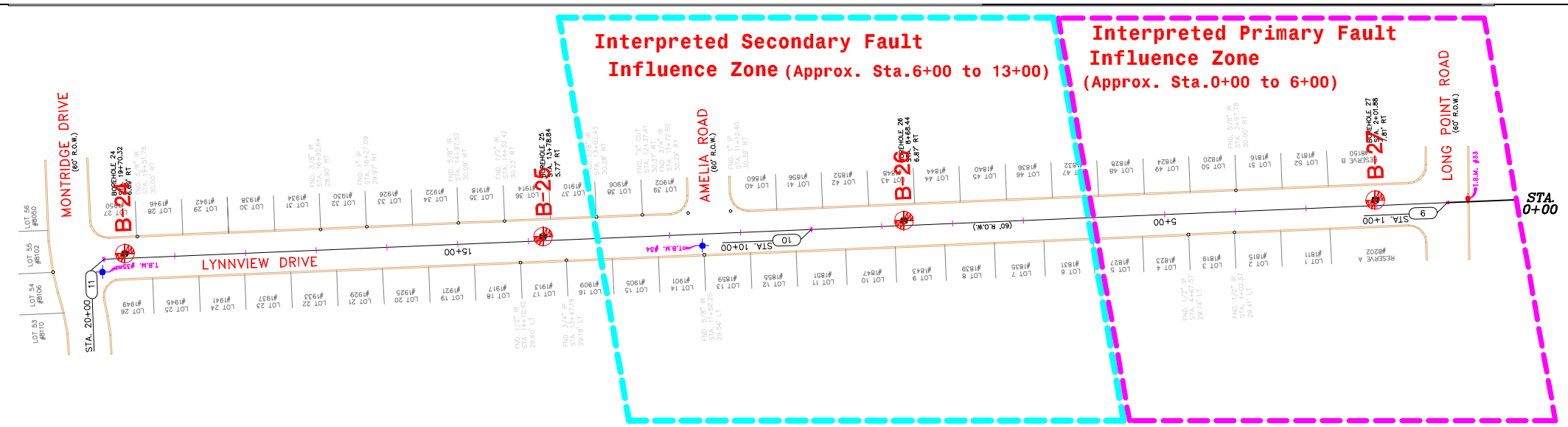

Elevation Profile Along Lynnview Drive between Long Point and Montridge Drive
Limits of Proposed Water Line
Montridge Drive
Amelia Road
Long Point Road
Interpreted Secondary Fault Influence Zone (Approx. Sta. 6+00 to 13+00) *elevation change at Amelia Road is hypothesized to be mostly from roadway grading
Interpreted Primary Fault Influence Zone (Approx. Sta. 0+00 to 6+00)
CL of ROW from CAD drawing (Sta. 7+50 to 20+80)
ATL Elevation Survey Along Centerline of Lynnview (Approx. Sta. -0+40 to 7+50)
Elevation, feet
Station, feet
80
79
78
77
76
75
74
73
72
71
70
-500
0
500
1000
1500
2000
2500

FIGURE 5



INTERPRETED PRIMARY AND SECONDARY FAULT ZONE ALONG LYNNVIEW DRIVE	*Associated Testing Laboratories, Inc.* *3143 Yellowstone Blvd. Houston, Texas* *Tel: (713) 748-3717 Fax: (713) 748-3748*	
PROPOSED NSR – PROJECT 464 *SPRINGDALE (SEC. 1&2) AND RESTRIDGE (SEC.1&5)*	*WBS No.: N-000397-0001-3*	*SCALE: 1"=200'*
	PROJECT NO. G14-202	*FIGURE. 6*