Part III
Attachment III-E
Appendix III-E.1

REGIONAL GEOLOGY AND HYDROGEOLOGY

Pescadito Environmental Resource Center
MSW No. 2374
Webb County, Texas

PESCADITO
ENVIRONMENTAL RESOURCE CENTER

Initial Submittal March 2015
Revised September 2015

Prepared for:
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Laredo, TX 78041

Prepared by:

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Table 2 - Hydrogeologic Properties

Reg	Aquifer		Carrizo-Wilcox	Queen City-Bigford	El Pico	Laredo	Yegua Jackson
	Function		Aquifer west Webb	Local aquifer, west	Regional confining	Aquifer regional	TWDB minor aquifer
	Composition		coarse sands gas production site bookend confining	sands and clays bookend confining	clay, some sand upgrad	sand, clayey sand sandier near base	clay, claystone, more clay sand stringers, sandier near base
	formation w/in		Wilcox	Queen City-Bigford	El Pico	Laredo	Yegua and Jackson undifferentiated
	transmissivity	ft^2/day	115-350[1]	see (1)	↑ Confining [1]	85-2735(1),141-192[3]	J 225[1]
	SC	ft/day	6-33[1]	see (1)		4-711[1]	J 17[1]
	K		.3-1[7] map	.1-.3[7] map		631-809 md core[3]	upper Y .3-1ft/dayH[2,2.1.4] lower Y 1-3 ft/dayH[2,2.1.4]
	Recharge	inches	outcrop,	outcrop, .5-1[7]		5%*21=~1[1] 5%*20.4=~ 1[6]	<~1inch, see text
	Thickness site area, ft geophysical log		~1700'	~2000'	110	875	Y 440
	Thickness Laredo Sheet		not described	~650' outcrop	900-1150 **	620	Y 400
	Rainfall(mean)	in/year	outcrop 21.3[4]2014	21.3[4]2014		20.4[4]	20.4[4]
	Lake Evaporation (mean)	in/year	64.07[4]2014	64.07[4]2014		66.26[4]	66.26[4]
	water table/confined		confined by Reklaw	confined by El Pico		wt/confined downdip	wt/confined downdip
	recharge character		Carrizo outcrop	Bigford outcrop		Laredo outcrop	surface minor, Laredo major
	recharge w/in 5 miles		none, west edge cty	none, west county		none	surface minor
	depth groundwater, ft.		162-204[1]	125-268[1]		12-252[1]	94-292[1], ~200[6]
	elevation groundwater		few wells	few wells		few wells east of Laredo	few wells in region
	groundwater flow rate		isolated wells	isolated wells		isolated wells	~.5'/yr using dip gradient, seepage vel eqn*
	groundwater flow direction		east-southeast	east-southeast		downdip east-southeast	downdip east-southeast, south[1]
	formation dip direction		east	east	east-southeast	east-southeast	east-southeast
	formation dip	ft/mile	87'/mi[1]	66'/mile [5]	54[1]	72[1]	64[1]
	flow from wells	gpm	150-200[1]west	see (1)		5-170gpm[1], 60gpm av[3]	<15gpm[1]
	TDS range	mg/l	826-2220[1]west	1000-5000[7]		1226-2200[3] (east side Laredo)	3-4k(2,4-235, lower Y) 2.1k[6],4.47k[1]
	Chloride range	mg/l	120-630	see [1]		100-1030[1]	300-1k[2], 712[6], 1772[1]
	map ref gradient		isolated wells	isolated wells		isolated wells	Deeds, 2004
	water use		domestic, ranch	ranch		Laredo supply, Las Lomas(w/RO)	ranch (domestic, livestock), rig supply
	wells w/in 1 mile site		0	0		0	1
	wells w/in 5 miles		0	0	↓ Confining (1)	Las Lomas area	ANB, Weid, Hurd, Alarcon?

Note: While the Carrizo-Wilcox and the Bigford-Queen City are important regional aquifers in Webb County, in the site area both are greater than a thousand feet below and saline (1) and Winslow et al (1972)

References:

(1) Lambert, 2004, few Bigford Wells in Webb County, none sampled
(2) Deeds, 2003
(3) Ch2MHill, 1999
(4) TWDB rainfall and evaporation website, quad = 1008, 2015
(5) oil and gas geophysical log site area, geophysical log cross section
(6) this study
(7)Kelley, 2004

*A flow rate depends on interconnected sands for both Laredo(1) and Yegua(see text) seepage eqn estimate is likely inappropriate

** Includes sands below

Table 2 - Hydrogeologic Properties

Aquifer		El Pico	Laredo	Yegua Jackson
Function		Regional confining	Aquifer regional	TWDB minor aquifer
Composition		clay, some sand upgrad	sand, clayey sand sandier near base	clay, claystone, more clay sand stringers, sandier near base
Formation w/in		El Pico	Laredo	Yegua and Jackson undifferentiated
transmissivity	ft^2/day	Confining [1]	85-2735(1),141-192[3]	J 225[1]
SC	ft/day		4-711[1]	J 17[1]
K			631-809 md core[3]	upper Y .3-1ft/dayH[2,2.1.4] lower Y 1-3 ft/dayH[2,2.1.4]
Recharge	inches		5% *21=~1[1] 5% *20.4=~ 1[6]	<~1inch, see text
Thickness site area, fr geophysical log		110	875	Y 440
Thickness Laredo Sheet		900-1150 **	620	Y 400
Rainfall(mean)	in/year		20.4[4]	20.4[4]
Lake Evaporation (mean)	in/year		66.26[4]	66.26[4]
water table/confined			wt/confined downdip	wt/confined downdip
recharge character			Laredo outcrop	surface minor, Laredo major
recharge w/in 5 miles			none	surface minor
depth groundwater, ft.			12-252[1]	94-292[1], ~200[6]
elevation groundwater			few wells east of Laredo	few wells in region
groundwater flow rate			isolated wells	~.5'/yr using dip gradient, seepage vel eqn *
groundwater flow direction			downdip east-southeast	downdip east-southeast, south[1]
formation dip direction		east-southeast	east-southeast	east-southeast
formation dip	ft/mile	54[1]	72[1]	64[1]
flow from wells	gpm		5-170gpm[1], 60gpm av[3]	<15gpm[1]
TDS range	mg/l		1226-2200[3] (east side Laredo)	3-4k(2,4-235, lower Y) 2.1k[6],4.47k[1]
Chloride range	mg/l		100-1030[1]	300-1k[2], 712[6], 1772[1]
map ref gradient			isolated wells	Deeds, 2004
water use			Laredo supply, Las Lomas(w/RO)	ranch (domestic, livestock), rig supply
wells w/in 1 mile site			0	1
wells w/in 5 miles		Confining (1)	Las Lomas area	ANB, Weid, Hurd, Alarcon?

Note: While the Carrizo-Wilcox and the Bigford-Queen City are important regional aquifers in Webb County, in the site area both are greater than a thousand feet below and saline (1) and Winslow et al (1972)

References:

(1) Lambert,
(2) Deeds,
(3) Ch2MHill,
(4) TWDB rainfall and evaporation website,
(5) oil and gas geophysical log site area,
(6) this study

*A flow rate depends on interconnected sands for both Laredo(1) and Yegua(see text) seepage eqn estimate is likely inappropriat

** Includes sands below

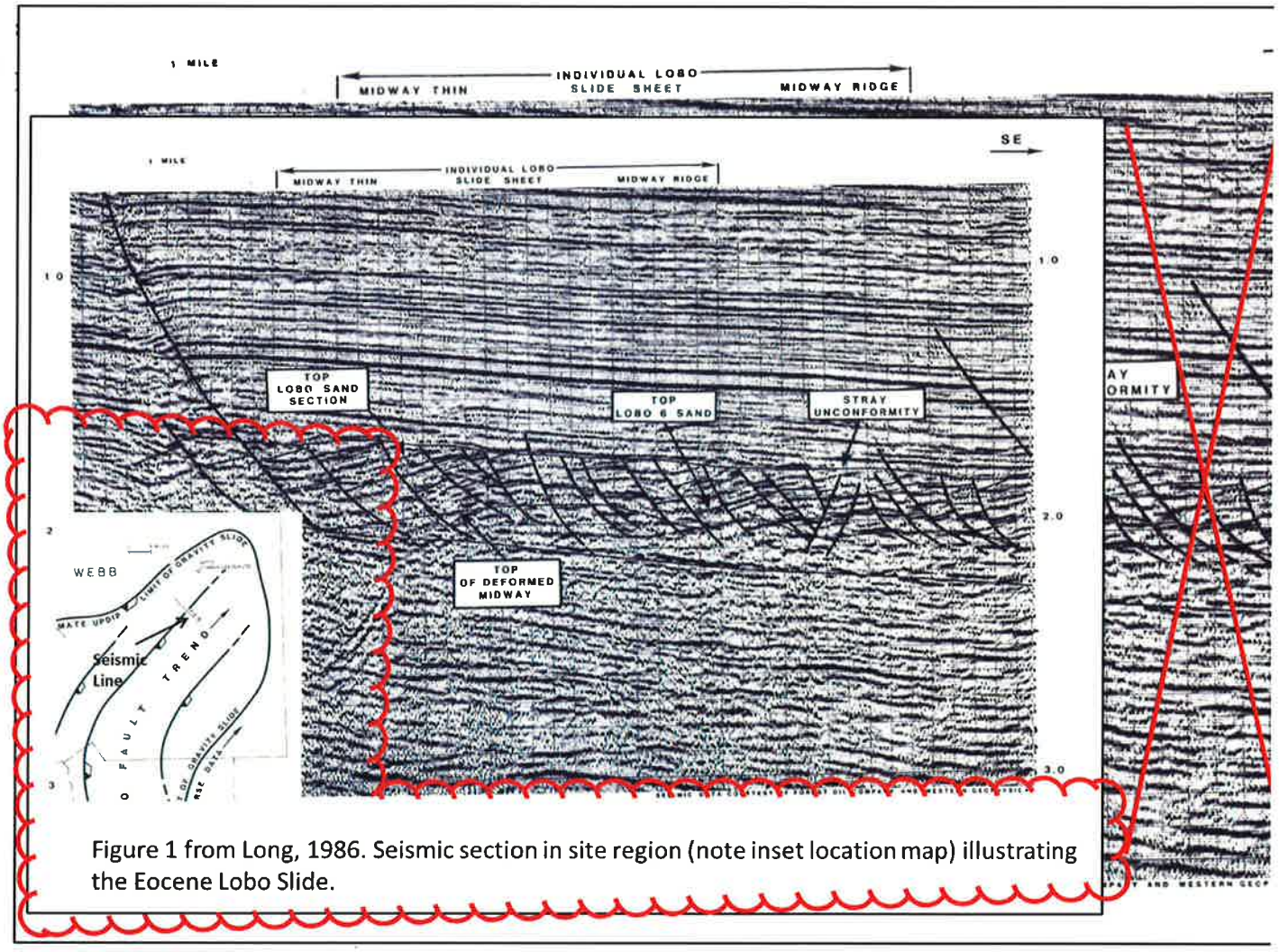


Figure 1 from Long, 1986. Seismic section in site region (note inset location map) illustrating the Eocene Lobo Slide.

This particular section is near the site and illustrates the Lobo slide "sandwich" as well as Wilcox regional listric faulting. Lobo production was discovered in the seventies, and these recent seismic sections tie together a picture of what must have been a difficult exploration task. Wells on the Yugo Ranch, the location of the proposed landfill, produce from these Lobo sands at depths of about 7000 to 10000 feet.

The remaining Wilcox deposition in the region is generally a combination of sands and muds of the Cotulla Barrier Bar system (Fisher and McGowen, 1967) and fine grained shelf system deposition in the landfill region. Overall, the Wilcox sands and clays are bound inland at the Cretaceous shelf edge, the Sligo and Stuart reef area, and the anticlinal Laramide structures to the south, and Wilcox deposition generally extended the continent by progradation accompanied by rapid subsidence.

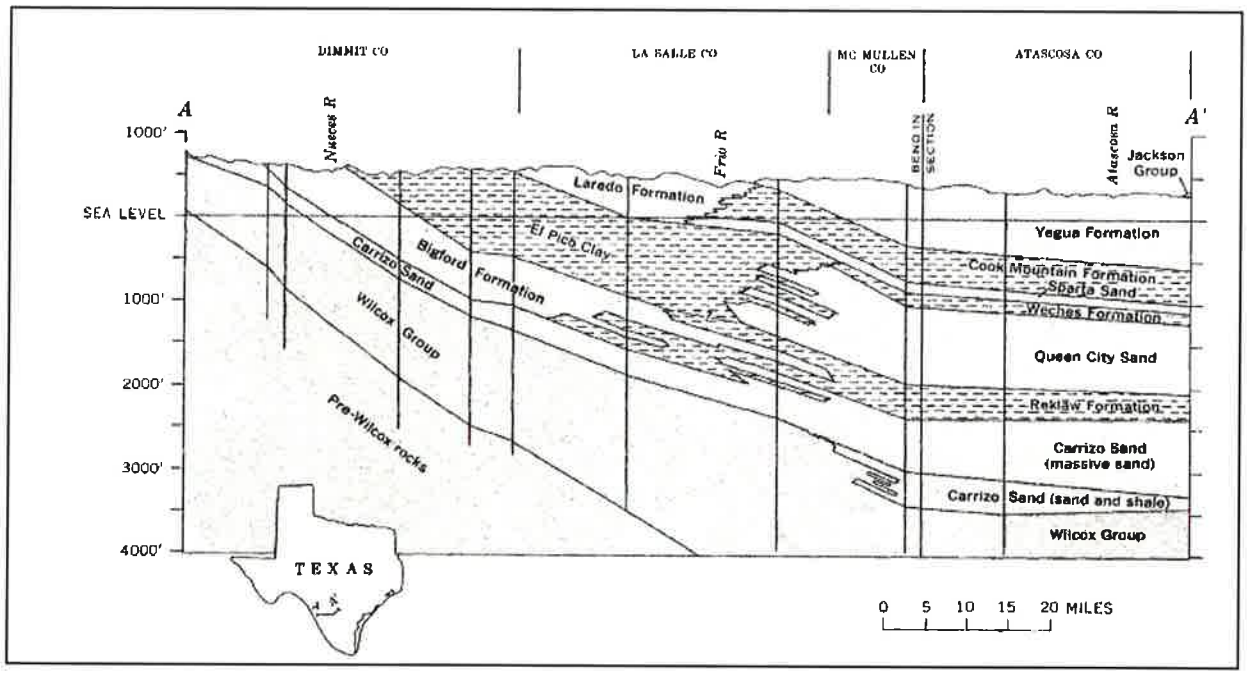
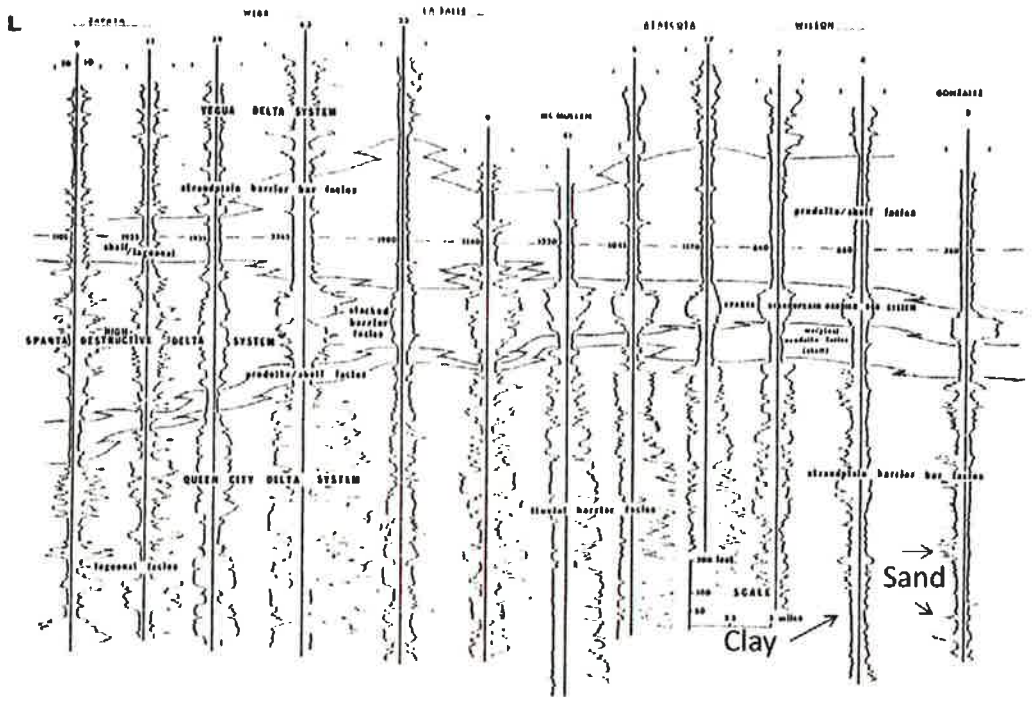


Figure 2 — Stratigraphic Dip Section Showing Equivalence of Formations Across the Region, Eargle, 1968

Here, dip and strike cross sections from the Ricoy study intersect near the landfill site, and while his study focused on the Sparta (think Laredo kind of equivalent), the sections are instructive in that they include the Queen City below and the Yegua above, together with depositional framework interpretations of each. Across Webb County and through the site region, the Queen City changes from lagoonal muds to a delta system (Ricoy, 1976) with stacked sand sequences. The Ricoy dip section and the strike section as well, show a continuous clay above the Queen City and below the sands above; this then is the Weches Formation, or the equivalent of the upper part of the El Pico Clay (Eargle, 1968). This clay is shown on the geophysical log section at the site as a continuous, uniform clay, about 110 feet thick and serves as the ultimate confining layer beneath the site.

Lonsdale (1937) found groundwater resources in the El Pico (then the Post-Bigford) to be "scanty and of poor quality" and that assessment holds true today (Lambert, 2004). The Queen City fares little better, the limited sands updip produce little water and the quality is marginal (Lambert, 2004), and while sands are plentiful downdip, they are also saline. (See Figures 3 and 4, Ricoy, 1976).



From Ricoy, 1976, Geophysical log strike section illustrating relationship of South to Central Texas facies.

Figure 3 ~~From Ricoy, 1976~~

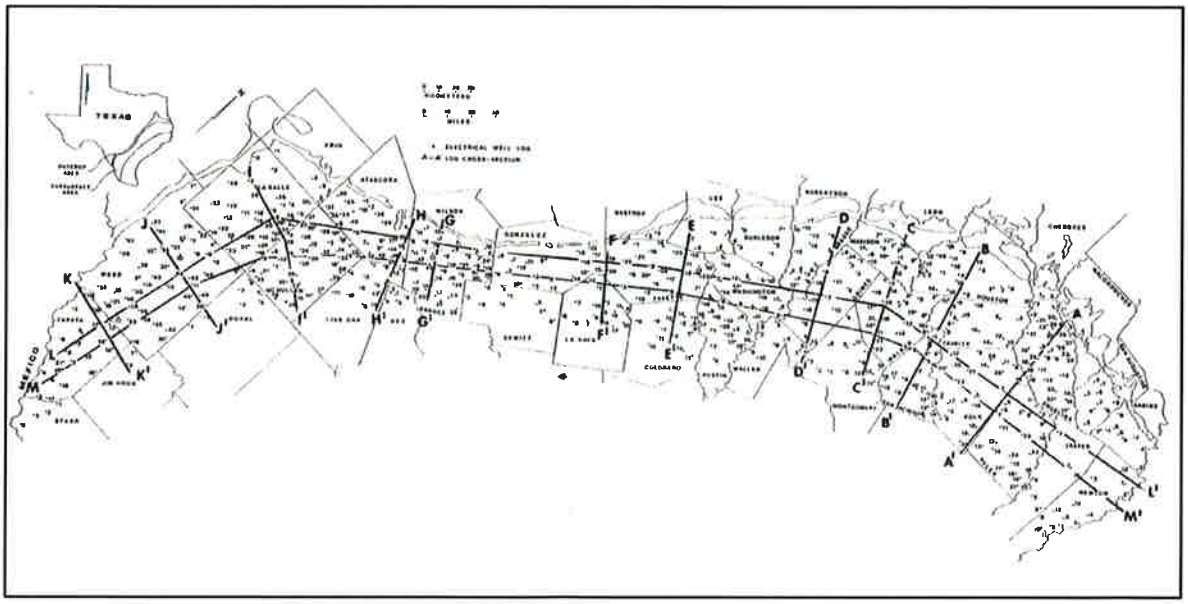


Figure 3a - Location Map for Section J-J' and L-L' – From Ricoy 1976

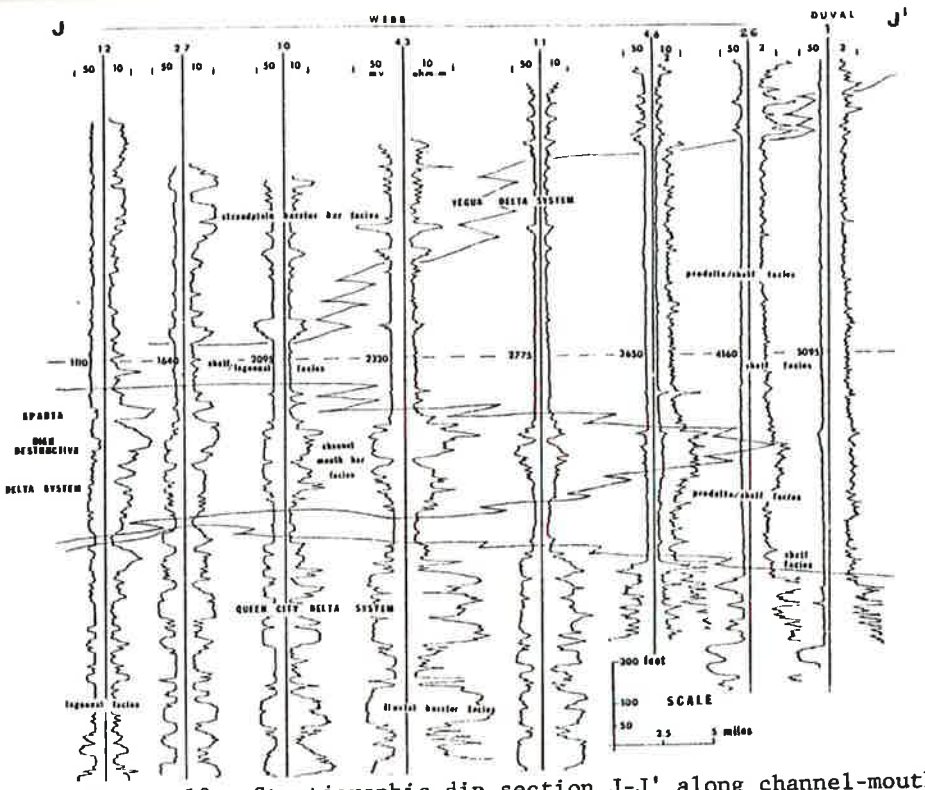


Figure 12. Stratigraphic dip section J-J' along channel-mouth bar facies, Sparta high-destructive delta system, south Texas.

51

Figure 4 ~~— From Ricoy, 1976~~ – Stratigraphic Dip Section J-J' – From Ricoy, 1976

1.3.7 Laredo (elsewhere Sparta and Cook Mountain) with meaning for water

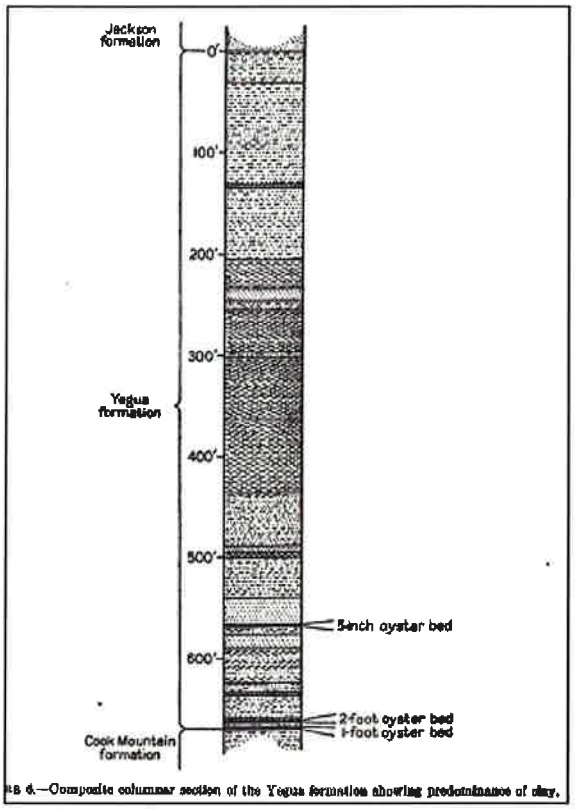
The Laredo Formation overlies the El Pico Clay (Weches) in the site region. It outcrops as sands and clays in the Laredo area (Plates 1 and 2), with cemented sands forming prominent ridges parallel to the strike. Its light color and dominant fine sands distinguish it from the El Pico Clay below and Yegua above. It was mapped and described in section by Trowbridge (Trowbridge, 1932) as part of a geologic reconnaissance along the Rio Grande, then by Lonsdale and Day (Lonsdale, 1937) looking more at groundwater resources in Webb County. Both

1.3.8~~7~~ Yegua Formation (last of the Claiborne) and Jackson Group

Where light colored, fine and thick sands characterize the Laredo around and several miles east of the city, the Yegua is far more clay-rich with red, brown and purple muds along with sandy clays dominating the outcrop. The Jackson appears much the same as the Yegua, but includes more volcanic ash (Trowbridge, 1932; Lonsdale, 1937; Eargle, 1968; Barnes, 1976), though this is not immediately obvious in the outcrop, cores, or geophysical logs (Geocam gamma logs of soil borings, this study). This similarity between Yegua and Jackson makes it difficult to distinguish the contact between them. The Laredo-Yegua boundary at the base of the pair, as well as where the Jackson meets the Frio above are readily identifiable in the field and on geophysical logs; so the package of the two is bound and the pair is considered together as a designated minor aquifer, it's the boundary between that is elusive.

The Yegua begins slightly below a two foot thick prominent oyster bed that is found even today a few miles east of Laredo (Trowbridge, 1932, Lonsdale, 1937, Gardner, 1938), in a roadcut on US59 (and its predecessor roads). Like the Laredo, the Yegua includes resistant portions that parallel the regional strike forming gentle cuestas, evidence of the role that the shoreline orientation played in its development. This is a transition from much of the rest of the Yegua deposition, where sand bodies are found to be oriented normal to the shoreline, still in the form of the original fluvial and deltaic framework (Payne, 1970, Ricoy and Brown, 1977). The presence in the outcrop of the oyster beds, thin sandstones and occasional thicker sands indicate that the Yegua here was deposited close to, if not at the shoreline, in a bay or nearshore environment, often tidally controlled. The influx of muds, silts and sands from, or influenced by, the Laramide structures just to the south in Mexico created a high energy depositional environment, and this interpretation is supported by the character of the rock found in the test pits and in the outcrop of this study. This is affirmed by the Yegua geophysical log signatures and interpretation shown on the Ricoy (1976) sections. Lonsdale (1937) measured the Yegua in section in the vicinity of the present day US59 about 7.5 miles east of downtown Laredo, illustrated in his drawing where the Yegua totals about 670 feet thick. (See Figure 5) The thick oyster beds at the base are found today on US59, and the section in roadcuts shows the transition to dark brown, purple, greenish and yellow clays, thin sands and sandy clays he described.

Trowbridge (1932) covered much of the same area and at the time, though recognizing the use of the term Yegua, continued an earlier designation, Cockfield, for these sediments.

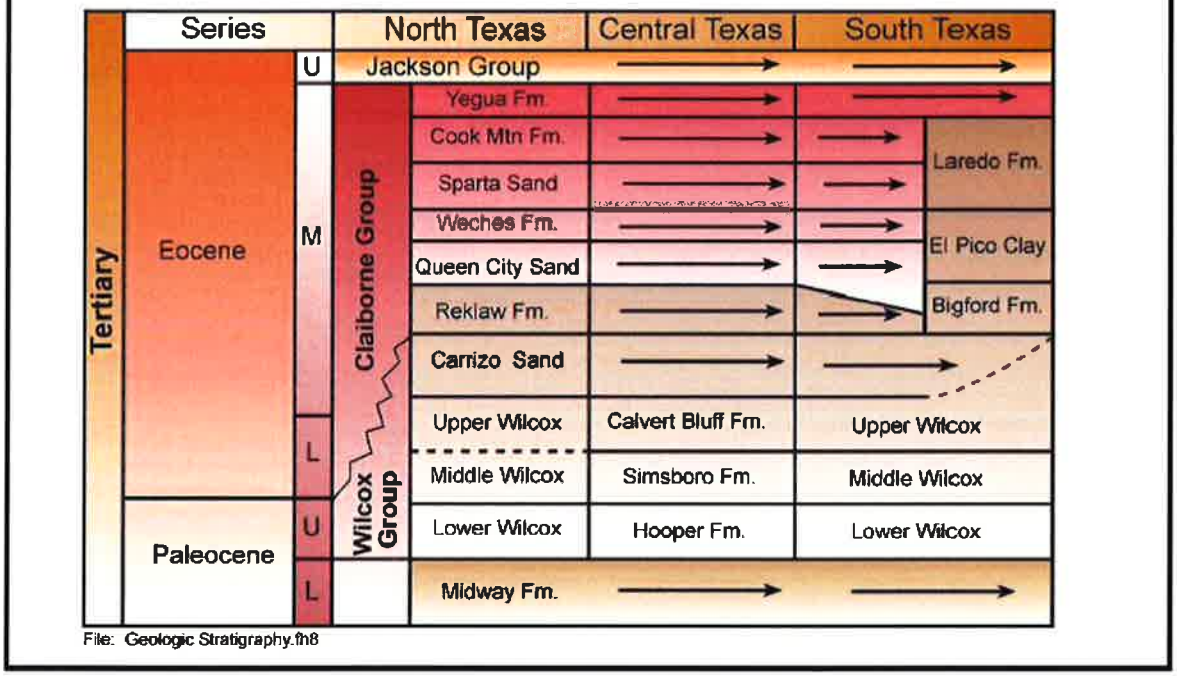


ns 6.—Composite columnar section of the Yegua formation showing predominance of clay.

Figure 5 - Lonsdale, 1937 – Yegua Stratigraphic Section along US 59

Lonsdale (1937) found water production to be minimal and of poor quality, and thought better development in the area could be obtained by drilling through to the underlying Cook Mountain (now Laredo). A drilling log for a water well near the landfill site, the completion of the ranch well next to the site and a deep boring on the site indicate that more sand is found in the lower part of the Yegua here, and that is the source of water production. The thin, interbedded sands found in the Yegua at shallow depths may contain moisture and may be ultimately interconnected and serve as a sensor for groundwater monitoring purposes.

The base of the Jackson is frustratingly similar to what is found in Yegua outcrops, making its contact with the underlying Yegua difficult to distinguish in the surface and subsurface. Lonsdale (1937) marked the contact in measured section where he examined the sediments and found volcanic ash. There is a whitish sandstone that outcrops on US59 just east of the ranch entry road that may involve ash, but the evidence for that or any volcanic material nearby does not stand out. The Jackson (Lonsdale, 1937) includes clays, sandy clays and some sands that at least in part are arkosic and derived from volcanic activity to the west. Further north along strike, the Jackson includes extensive lignite (Ewing, 1999). Lonsdale estimated that the Jackson here is about 1500 feet thick and dips at about 80 feet per mile. He held the same view of water possibilities for the Jackson as the Yegua, few wells producing salty water, and where even in the outcrop, better water was available from roof catchment and surface ponds.



Generalized stratigraphic section for the Wilcox and Claiborne groups in Texas (after Ayers and Lewis, 1985; Hamlin, 1988; Kaiser, 1978; Ricoy and Brown, 1977; Guevara and Garcia, 1972; and Payne, 1968).

Figure 6 - From Kelley, et al, 2004 – Generalized Stratigraphic Section for the Wilcox and Claiborne Groups

Each of these aquifers reflects the effects of being at the southern end of basin-wide depositional systems, that is, the composition of the aquifer is not always the same as typical in the rest of Texas, and the semi-arid situation here has minimized the development of extensive groundwater resources in this area. The regional hydrogeology is discussed here, along with notes about differences from the broad regional systems designated as major and minor aquifers by the TWDB and included in the Groundwater Availability Models (GAMs).

2.3.1 Carrizo Aquifer

The aquifer with the greatest potential for future production in Webb County is the Carrizo; in this region, the sand-rich component of the Carrizo-Wilcox, a designated major aquifer in Texas. The Carrizo sands are the most lithologically uniform of all the Claiborne

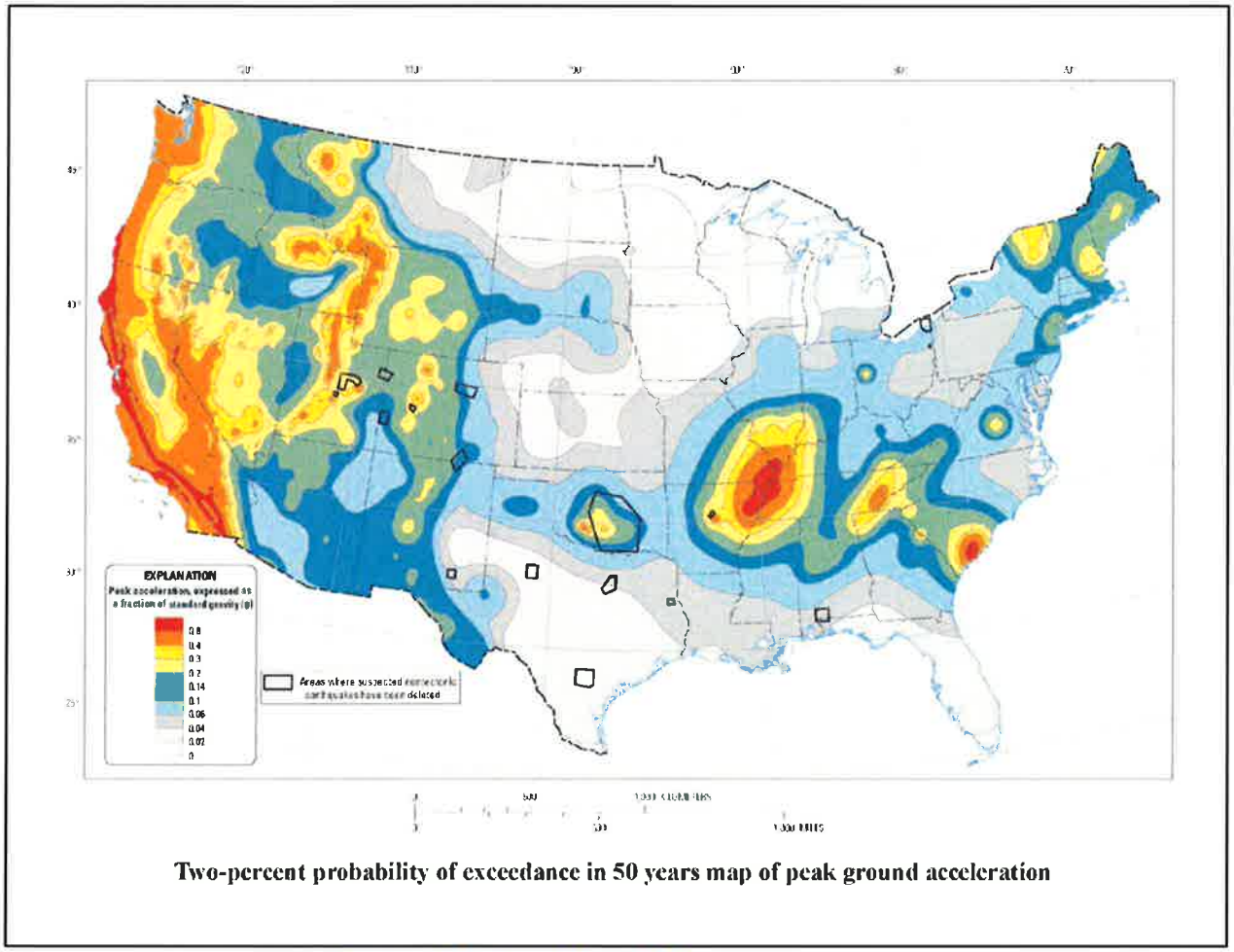


Figure 8. (USGS, 2014) – National Seismic Hazard Map

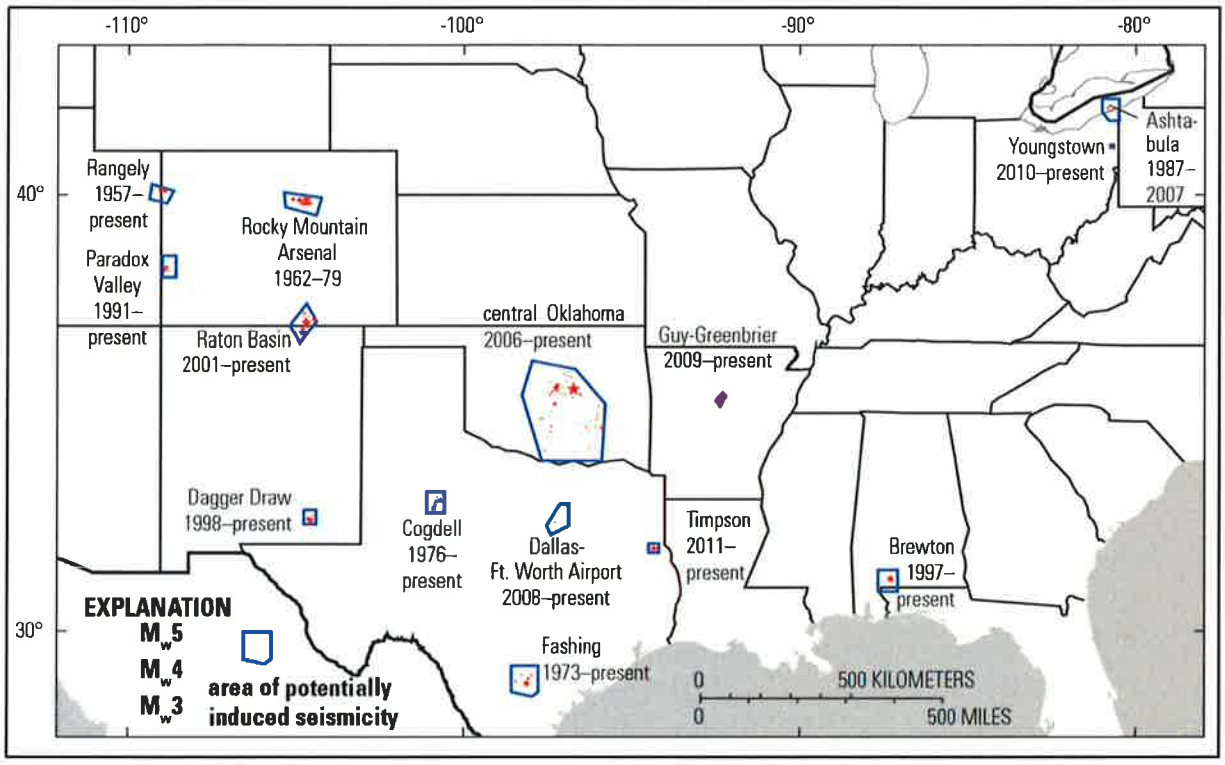


Figure 9 - Map showing areas of potentially induced seismicity in the Central and Eastern United States, USGS 2014

The gas field in the site area is a mature development and production from source rock is distant. There are no salt water disposal wells in the immediate area.

Ej

Jackson Group

Sandstone and clay; mostly sandstone, fine to coarse grained, friable to quartzitic, commonly laminated and crossbedded, white, gray, greenish brown, light brownish yellow, fossiliferous; clay, sandy, calcareous, greenish gray, pink, red, silicified wood abundant; some beds of white volcanic ash; large, dark limestone concretions composed of calcite crystals common; thickness about 360 feet

Ey

Yegua Formation

and sandstone; mostly clay, lignitic, sandy, bentonitic, silty, mostly well laminated, chocolate brown to reddish brown, lighter colored upward, produces dark-gray soil; sandstone, mostly quartz, some chert, fine grained, indurated to friable, calcareous, glauconitic, massive, laminated, crossbedded, weathers to loose, ferruginous, yellow-orange and reddish-brown soil; some fossil wood; thickness about 400 feet

El

Laredo Formation

Sandstone and clay; thick sandstone members in upper and lower part, very fine to fine grained, in part glauconitic, micaceous, ferruginous, crossbedded, dominantly red and brown; clay in middle, weathers orange-yellow; dark-gray limestone concretions common, some fossiliferous; marine megafossils abundant; thickness about 620 feet

Eep

El Pico Clay

Clay, sandstone, and coal; mostly clay, in part gypsiferous, medium gray to brown; sandstone, mostly fine grained, some medium to coarse, argillaceous, silty, in part glauconitic, gray to brown, thin bedded to massive, friable to indurated; aphanitic septarian concretions common; thickness 900-1,150 feet

Plate 1 to Appendix III-E.1
Geologic Map of Region

N

2 1 0 2 4 6 8 Miles

Scale 1:150,000

Source: Geologic Atlas of Texas, Laredo Sheet (1976)

Approximate Site Location

CONTOUR INTERVAL 50 FEET
WITH SUPPLEMENTARY CONTOURS AT 25 FOOT INTERVALS
TRANSVERSE MERCATOR PROJECTION
1976 MAGNETIC DECLINATION FOR CENTER OF THIS SHEET
WAS 9° 30' EAST, ANNUAL CHANGE IS 8' WESTERLY

GEOLOGIC ATLAS OF TEXAS, LAREDO SHEET

JULIA GARDNER MEMORIAL EDITION

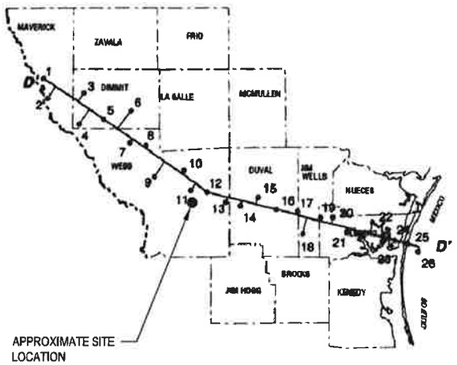
1976

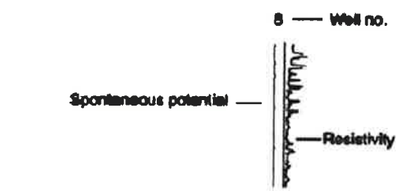
Revised 9/2015

PLATE 2 TO APPENDIX III-E.1
HYDROSTRATIGRAPHIC SECTION ACROSS WEB COUNTY

GEOLOGIC SECTION D-D'

BY E.T. BAKER, JR (1995)





EXPLANATION

INTERNAL CONTAINING WATER WITH LESS THAN 3,000 MILLIGRAMS PER LITER DISSOLVED-SOLIDS CONCENTRATION – Estimated from electric logs

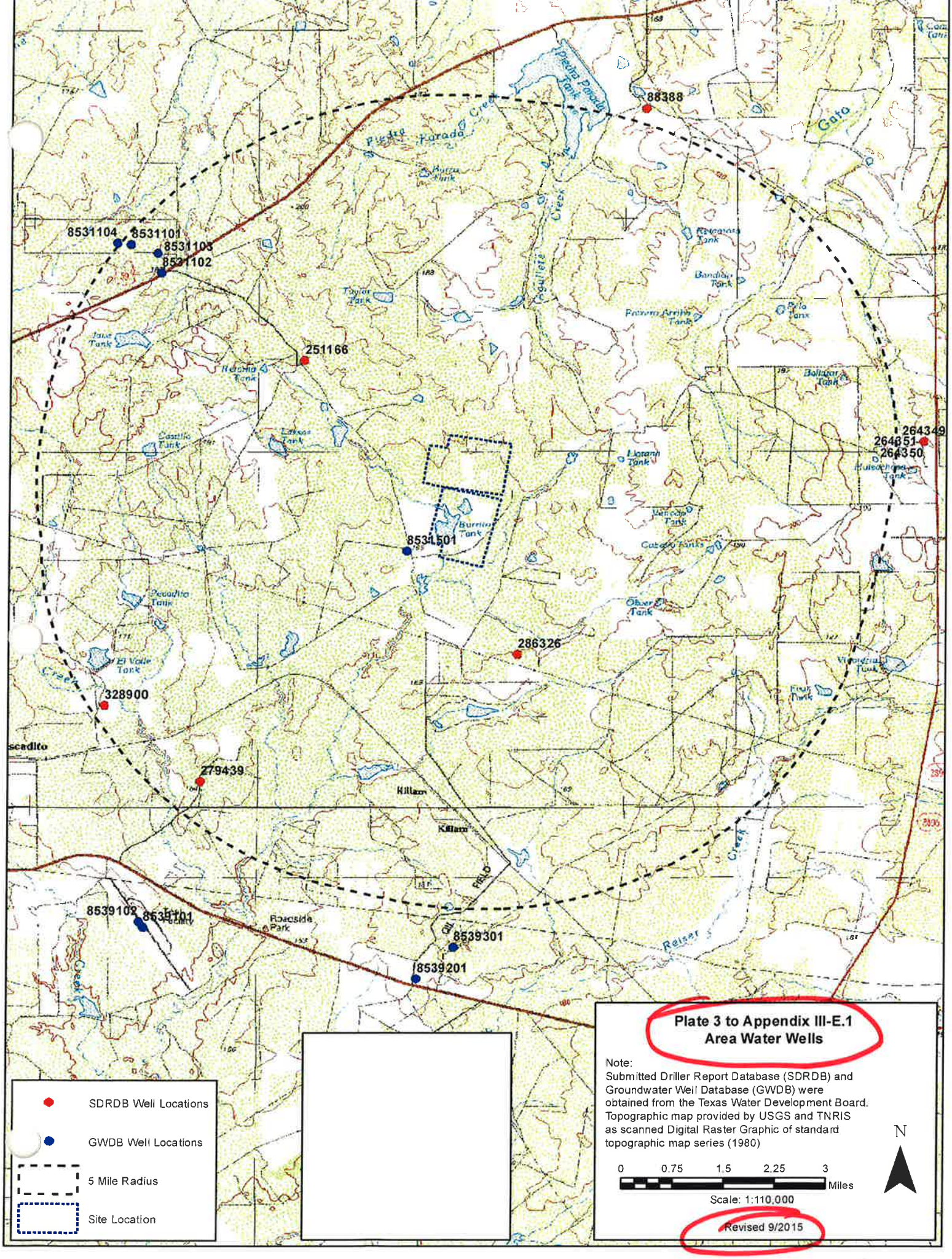
DIAGNOSTIC MICROFOSSIL – Discorbis nomada

ABBREVIATION OF LITHOSTRATIGRAPHIC UNITS -- Gr., Group; Sd., Sand; Fm., Formation

OUTCROP GEOLOGY – From Brown and others (1975, 1976); modified from Brewton and others (1976)

NOTE: Although faulting is common regionally and is complex in some areas, all faults have been omitted from this geologic section to maintain unbroken continuity of the formation boundaries

REVISED 9/2015


88388
8531104
8531101
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8531102
251166
264349
264351
264350
8531501
286326
328900
279439
8539102
8539101
8539301
8539201
Killam
Roadside Park
SDRDB Well Locations
GWDB Well Locations
5 Mile Radius
Site Location
Plate 3 to Appendix III-E.1
Area Water Wells
Note:
Submitted Driller Report Database (SDRDB) and Groundwater Well Database (GWDB) were obtained from the Texas Water Development Board. Topographic map provided by USGS and TNRIS as scanned Digital Raster Graphic of standard topographic map series (1980)
N
0 0.75 1.5 2.25 3
Miles
Scale: 1:110,000
Revised 9/2015

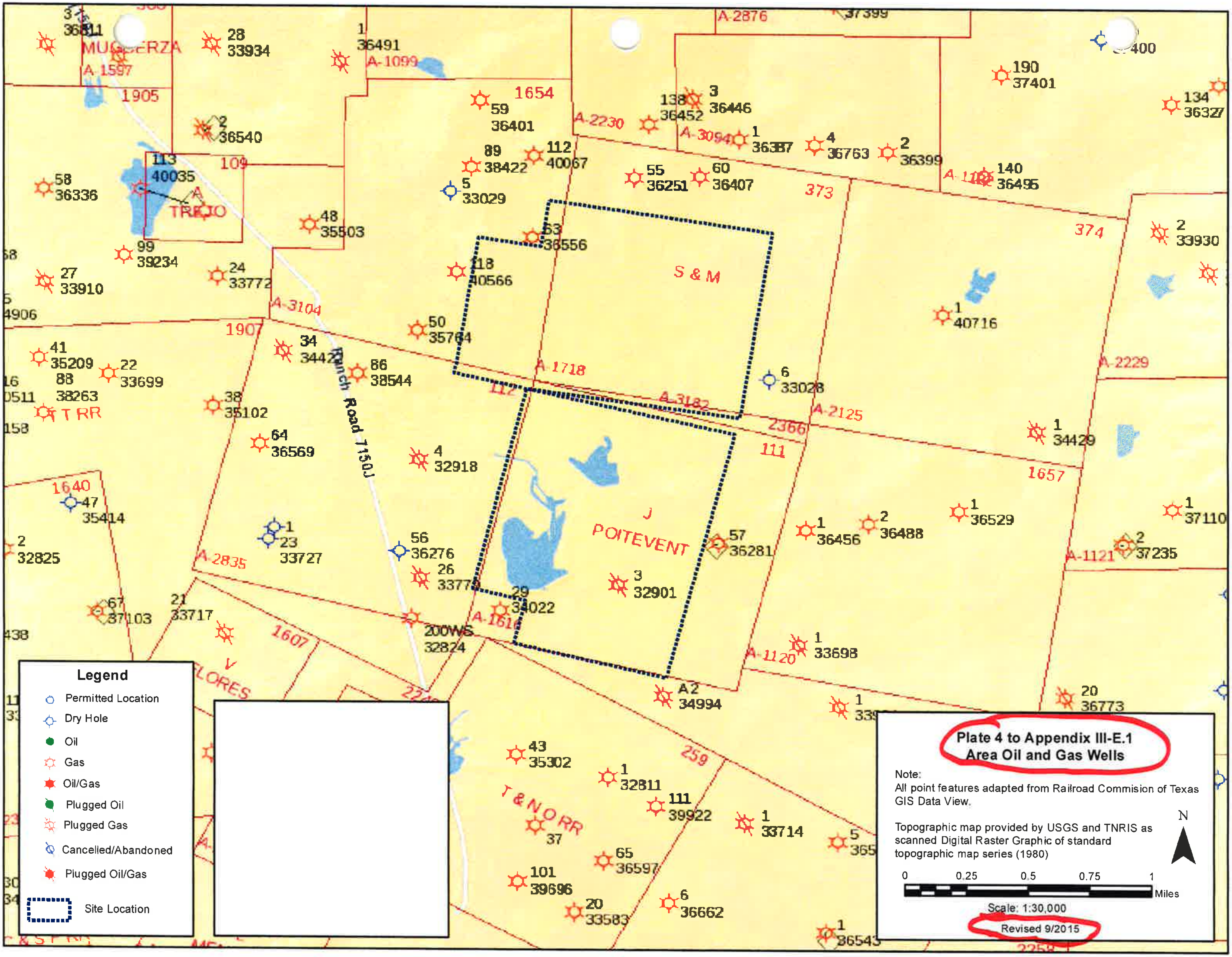

Plate 4 to Appendix III-E.1
Area Oil and Gas Wells
Note:
All point features adapted from Railroad Commision of Texas GIS Data View.
Topographic map provided by USGS and TNRIS as scanned Digital Raster Graphic of standard topographic map series (1980)
N
0 0.25 0.5 0.75 1 Miles
Scale: 1:30,000
Revised 9/2015
Legend
Permitted Location
Dry Hole
Oil
Gas
Oil/Gas
Plugged Oil
Plugged Gas
Cancelled/Abandoned
Plugged Oil/Gas
Site Location
Ranch Road 7150J
S & M
J POITEVENT
T & NO RR
T RR
TREJO
V LORES