EFFECTS
OF
KEYSTONE XL PIPELINE LEAK
INTO
CARRIZO-WILCOX AQUIFER

March 2011

LAWRENCE G. DUNBAR, P.E.
WATER RESOURCES & ENVIROMENTAL ENGINEER/CONSULTANT
6342 Dew Bridge Dr.
Sugar Land, Tx. 77479
281-980-2225 Phone 713-481-8201 Fax

TABLE OF CONTENTS

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by: Lawrence G. Dunbar, P.E.
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1. Introduction

The purpose of this report is to identify potential impacts of a leak or spill from the proposed Keystone XL Pipeline that is to be located in eastern Texas on the groundwater resources in the area. Of greatest concern is the potential impact on the Carrizo-Wilcox aquifer in northeastern Texas where portions of the pipeline will cross over the outcrop of this aquifer, where near-surface water is in direct communication with the remainder of the aquifer. This aquifer is one of the three largest and most significant aquifers in Texas, and is a major source of drinking water. A major oil spill from this proposed pipeline project could have disastrous impacts on the human and natural resources in the area.

Information in this report has primarily come from the Draft Environmental Impact Statement for the Keystone XL Pipeline Project and documents available from the Texas Water Development Board website.

2. Keystone XL Pipeline Project

The Keystone XL Pipeline project is part of a proposed pipeline project for transporting hazardous liquid material (e.g. tar sands crude oil) from Canada to the Gulf Coast in southeastern Texas. The proposed route of this pipeline across the United States is shown on the enclosed Exhibit 1. A more close-up view of this pipeline project as it is proposed to cross eastern Texas is shown on Exhibit 2.

The Draft Environmental Impact Statement (DEIS) for this project describes this pipeline project as follows (Section ES.2):

> "The Project would consist of approximately 1,380 miles of new 36-inch-diameter pipeline in the U.S. The proposed pipeline would cross the international border between Saskatchewan, Canada and the United States near Morgan, Montana. The Project initially would have the nominal transport capacity of 700,000 barrels per day (bpd) of crude oil, with up to 200,000 bpd delivered to an existing terminal in Cushing, Oklahoma and the remaining amount shipped to existing delivery points in Nederland (near Port Arthur), Texas, and Moore Junction (in Harris County), Texas. By increasing the pumping capacity in the future, the Project could ultimately transport up to 900,000 bpd of crude oil through the proposed pipeline. At that throughput, up to 200,000 bpd would be

delivered to the Cushing Oil Terminal and the remainder would be delivered to the existing terminals in Texas."

The following table, from the DEIS, lists the miles of new pipeline by state for the proposed Keystone XL Project:

According to the DEIS, the 36-inch-diameter pipeline will be buried underground with at least 4 feet of cover (Table 2.3.2-2), with the existing, natural soil at the location of the pipeline to generally be used for covering after excavation and placement of the pipeline in the ground (Section 2.3.2.5). Thus, any leak from the pipeline would release the transported liquid material directly into the existing soils surrounding the pipeline and the adjacent environment. Of particular concern for this report is the potential for release of the transported hazardous liquid material into the nearby water resources in Texas along the proposed pipeline route, especially the Carrizo-Wilcox Aquifer in northeastern Texas.

3. Tar Sands Crude Oil

The primary material to be transported through this proposed Keystone pipeline into Texas from Canada is tar sands crude oil, known as bitumen. Bitumen is one of the most complex molecules found in nature. According to the Canadian Encyclopedia, "Bitumen is the heaviest, thickest form of petroleum… unlike conventional crude oil, bitumen does not flow freely; it is heavier than water and more viscous than molasses… To deliver bitumen, it must first be diluted with natural gas condensate or similar material to make it pumpable."

Of particular concern for this report is the potential for release of this hazardous liquid material into the nearby water resources in Texas along the proposed pipeline route, especially the Carrizo-Wilcox Aquifer in northeastern Texas, and how it might affect this valuable water resource. The Government of Alberta, Canada acknowledges on its website that the release of bitumen into water can result in the bitumen-derived hydrocarbon compounds going into solution (the Athabasca River has always had measurable levels of oil sands-derived hydrocarbon compounds, including Polycyclic Aromatic Hydrocarbons, because of bitumen seeping into the river from exposed oil sands along the river banks). Sufficient release of bitumen into a water resource therefore can result in rendering the water resource not useable for drinking water.

4. Water Resources along Proposed Pipeline Route

This proposed Keystone XL pipeline will be crossing numerous surface water features throughout eastern Texas, as shown on Exhibit 3. In addition, this pipeline will cross over various groundwater resources, as shown on Exhibit 4.

One of the largest aquifers to be potentially affected by this pipeline project in Texas is the Carrizo-Wilcox Aquifer. A typical cross-section of this aquifer is shown on Exhibit 5. This aquifer has been modeled by the Texas Water Development Board (TWDB) in three segments (north, central and south) for estimating groundwater availability (see Exhibit 6). The Northern Carrizo-Wilcox Groundwater Availability Model (GAM) covers the area of this aquifer where

TABLE ES.2.1-1 Miles of Pipeline by State for the Proposed Project

MT		SD	NE	OK	TX	Total
Steele City Segment	282.5	314.1	254.1	0.0	0.0	850.7
Gulf Coast Segment	0.0	0.0	0.0	155.4	324.8	480.2
Houston Lateral	0.0	0.0	0.0	0.0	48.6	48.6
Project total	**282.5**	**314.1**	**254.1**	**155.4**	**373.4**	**1,379.5**

the proposed pipeline project will cross. This portion of the aquifer is also part of the aquifer system within the Groundwater Management Area #11, as shown on Exhibit 7.

The following are excerpts from the Final Report on the Northern Carrizo-Wilcox Aquifer GAM (2003) that provide some background information about this aquifer and its importance to this region:

> "The Carrizo-Wilcox Aquifer is classified as a major aquifer in Texas (Ashworth and Hopkins, 1995) ranking third in the state for water use (430,000 acre-feet per year [AFY]) in 1997 behind the Gulf Coast aquifer and the Ogallala aquifer (TWDB, 2002). The aquifer extends from the Rio Grande in South Texas to East Texas and continues into Louisiana and Arkansas. The Carrizo-Wilcox aquifer provides water to all or parts of 60 Texas counties with the greatest historical use being in and around the Tyler, Lufkin-Nacogdoches, and Bryan-College Station metropolitan centers and in the Wintergarden region of South Texas (Ashworth and Hopkins, 1995).
>
> The model area includes portions of the North East Texas Region (Region D) and the East Texas Region (Region I) (Figure 2.4), and all or parts of the following Groundwater Conservation Districts (Figure 2.5): (1) the Anderson County Underground Water Conservation District, (2) the Brazos Valley Groundwater Conservation District (3) the Neches and Trinity Valleys Groundwater Conservation District, (4) the Piney Woods Groundwater Conservation District, (5) the Bluebonnet Groundwater Conservation District, (6) the Lone Star Groundwater Conservation District, (7) the Mid-East Texas Groundwater Conservation District, and (8) the Lake Country Groundwater Conservation District.
>
> The East Texas Regional Water Planning Group (Region I) plans to meet 59% of their projected water needs by the year 2050 through the use of existing groundwater supplies. The North East Texas Regional Water Planning Group

(Region D) plans to meet 25% of their 2050 projected water needs through existing groundwater supplies and an additional 2% through new groundwater resources.

The model area intersects five major river basins from west to east: (1) the Brazos, (2) the Trinity, (3) the Neches, (4) the Sabine, and (5) the Red River basins (Figure 2.6). In the model area, the Red River Basin has been further subdivided into the Sulphur River Basin, the Cyprus Creek Basin, and the Red River Basin. The model domain also intersects the San Jacinto River Basin, but only in the downdip portion of the model where there is no direct interaction between streams and the model. Eight river authorities (Angelina-Neches River Authority, Brazos River Authority, the Lower Neches Valley Authority, the Red River Authority, the Sabine River Authority, the San Jacinto River Authority, the Sulphur River Basin Authority, and the Trinity River Authority) are present in the model area.

The aquifer is recharged with water from rainfall or from streams infiltrating the outcrop. The Northern region of the aquifer receives the majority of its water from the Brazos, Trinity, Neches, Sabine, and Red River basins. The drainage area of these river basins is nearly 115,000 square miles, and there are 48 major reservoirs. These rivers are perennial and gain flow from the underlying geology…"

The above-referenced Figures 2.4, 2.5 and 2.6 are shown herein as Exhibits 8, 9 and 10. Exhibit 10 shows that the proposed pipeline route would cross the Neches River, the Sabine River and the Cyprus Creek as the pipeline passes over the Carrizo-Wilcox Aquifer.

Additional excerpts are provided from a report on the Carrizo-Wilcox Aquifer in Texas by Scott Jones (2008) as follows:

"The Carrizo Sand, composed of homogenous fluvial sands, unconformably overlies the more heterogeneous Wilcox Group. The northeastern part of this portion of the aquifer is known as the Cypress Aquifer due to the lack of confining units between aquifers (Fryer et al., 2003)…

Groundwater in the aquifer exists under both water-table and artesian conditions. Water-table conditions usually occur in the outcrop areas, and artesian conditions occur where the aquifer is overlain by confining beds with lower hydraulic conductivity rates. Well yields are usually 500 gal/min, but some may reach 3,000 gal/min downdip where the aquifer is under artesian conditions (Thorkildsen and Price, 1991).

> The groundwater pumped from the Carrizo-Wilcox aquifer is used primarily for municipal public water supply, rural domestic use, and manufacturing in approximately 60 counties in Texas. Approximately 35 percent of the total groundwater removed from the aquifer is for municipal water supply; the largest public water supplies, Bryan-College Station, Lufkin-Nacogdoches, and Tyler, make up a large portion of that percentage as they receive all of their water from the Carrizo-Wilcox aquifer. These major municipalities include over 370,000 people, but the aquifer as a whole provides water to ten to twelve million people (National Wildlife Federation et al, 2006). The Southern region of the aquifer is usually pumped heavily for irrigation purposes, but irrigation pumping occurs throughout the aquifer accounting for nearly 51 percent of the total groundwater removed…
>
> The groundwater of the Carrizo-Wilcox Aquifer in Texas is one of the greatest assests of the East-Central region of Texas. It provides water for agriculture, industry, and human consumption and use."

As discussed above, the Carrizo-Wilcox Aquifer is a valuable water resource for East Texas, and as such, it must be protected from becoming contaminated from tar sands crude oil leaking out of an overlying pipeline. Not only would the groundwater in the aquifer become contaminated, but the surface waters in the area that are fed by this aquifer could also become contaminated.

5. <u>Potential Impacts from Leaks into Groundwater Resources</u>

If there were to be a leak or spill from this proposed pipeline in Texas, the potential for impacting the groundwater resources in the area of the release could be substantial, depending on a number of factors, including the spatial and temporal extent of the release, and exactly where the release takes place (especially if it occurs in the outcrop of the aquifer).

The DEIS acknowledges the potential impacts to groundwater quality resulting from a spill or leak associated with construction activities for this project, especially where the aquifer is near the surface, as is the case with the outcrop area of the Carrizo-Wilcox Aquifer. According to the Draft EIS for the Keystone XL Pipeline Project (Section ES.6.3.1):

> "Potential impacts to groundwater during construction activities could include: groundwater quality degradation during or after construction resulting from disposal of materials and equipment, or vehicle spills and leaks; … degradation of groundwater quality due to potential blasting; and groundwater withdrawal for hydrostatic testing… Many of the aquifers present in the subsurface beneath the proposed route are isolated by the presence of glacial till or other confining units, which characteristically inhibits downward migration of water and contaminants

> into these aquifers. However, shallow or near-surface aquifers are also present beneath the proposed route and may be impacted by construction activities."

Of greater concern is a potential spill or leak during operation of the pipeline as it is transporting the hazardous tar sands crude oil. Section ES.6.13.1 of the DEIS discusses the potential risk of such an oil spill, as follows:

> "Releases of crude oil from the Project and appurtenant facilities could occur. Spill frequency can be estimated using historic spill frequencies on other pipelines… Releases of oil or petroleum products would affect the environment to varying degrees, and would be of concern to all stakeholders… Spills from the proposed pipeline, associated pump stations, valves, or pigging facilities could occur during Project operation and have the potential to result in larger-volume spills… Although leak detection systems would be in place, some leaks might not be detected by the system."

Potential impacts to groundwater from an oil spill are discussed in Section 3.13.4 from the DEIS, and includes the following statements:

> "Substantial spills of refined products, especially diesel, and substantial to very large spills of crude oil may reach groundwater where the overlying soils are porous and not water saturated, and the water table is relatively near the surface. Areas near major wetlands and meandering streams or rivers are key examples where the water table may be close to the surface and the soils are wet to saturated, depending on rainfall and snowmelt conditions. In some of these areas, it may be difficult to distinguish between groundwater and surface water."

Furthermore, the DEIS notes in Table 3.13.4-2 that there would be a "substantial" impact to the groundwater if there were a large to very large spill from this pipeline.

The outcrop area of the Carrizo-Wilcox Aquifer, as the primary source of recharge for this aquifer (TWDB 2003), provides overlying soils that would be most susceptible to allowing a release of hazardous tar sands crude oil to enter into and contaminate the groundwater of this aquifer system.

The DEIS continues with the following statements:

> "Diesel fuel or gasoline has a low viscosity and likely would percolate toward the water table, where it would float on the water. It may move downgradient with the groundwater, although potentially at a lower rate than the groundwater. Some of the diesel may become dispersed in the groundwater, contaminating the groundwater for agricultural or domestic drinking supply uses. Some of the diesel

may become adsorbed or adhere to soil grains and remain there for years as it very slowly weathers or degrades. The oil-contaminated groundwater may contaminate surface waters (e.g., wetlands, ponds and lakes, streams and rivers) if the groundwater surfaces and discharges into these surface water areas.

Crude oil is more viscous than refined products and would percolate downward more slowly. Furthermore, a substantial portion of the crude oil may adhere to the soil particles, thereby reducing the amount that reaches groundwater. Once crude oil reaches the groundwater surface, most of it would float and may move downgradient with the groundwater, although probably more slowly. The oil also would undergo some biodegradation, adsorption to soil particles, and dispersion into water, causing a natural attenuation and remediation of the contamination. *Like diesel fuel, crude oil may reduce or eliminate agricultural or domestic use of the groundwater and may contaminate surface waterbodies if the contaminated groundwater discharges into these waters.* (emphasis added).

During the life of the Project, potential minor short to long-term groundwater quality degradation is possible from equipment and vehicle spills or leaks. Routine operation and maintenance is not expected to affect groundwater resources; *however, if a crude oil release occurred, crude oil could migrate into subsurface aquifers and into areas where these aquifers are used for water supplies."* (emphasis added).

The DEIS acknowledges that the hazardous tar sands crude oil could migrate into a subsurface aquifer (like the Carrizo-Wilcox Aquifer), may reduce or eliminate agricultural or domestic use of this groundwater, and may contaminate surface water resources if the contaminated groundwater discharges into these waters. The major rivers in this area are recognized as being perennial and gain flow from the underlying geology, such as the Carrizo-Wilcox Aquifer (TWDB 2003). Thus, a release of this tar sands crude oil into the water resources in the area could have disastrous results. And with this crude oil being heavier than water, having an API gravity of 7.7-9, (NRDC, 2010) the cleaning up of such an oil spill and removal of the contamination from the water resources in the area would be extremely difficult.

The DEIS concludes with the following:

"In summary… the low probability of large, catastrophic spill events and the routing of the proposed pipeline to avoid most sensitive areas suggest a low probability of impacts to human and natural resources. Nevertheless, the potential for construction and operation-related spills does exist." (p. ES-20)

The DEIS states that while the potential for spills would still exist with the transporting of the tar sands crude oil, it also notes that the routing of the proposed pipeline was done to avoid most sensitive areas in order to conclude that there was a low probability of impacts to natural resources. However, the routing of this pipeline is directly across numerous faults in southwestern Rusk County, as shown on Exhibit 11 herein, obtained from the DEIS. If these faults are "active", then there is an increased risk of pipeline failures/ruptures as the ground shifts, with subsequent releases of the hazardous tar sands oil into the surrounding soils and near-surface waters. With the outcrop area of the Carrizo-Wilcox Aquifer being located in the vicinity of where the pipeline would cross this fault zone (see Exhibit 7), it is important to know for sure that these faults are not "active".

The DEIS states that "the proposed route would not cross any known active faults…" (Section ES.6.1.4). Furthermore, the DEIS notes in Section 3.1.4.1 that "in Texas, surface faults have been mapped in the project area. There is little evidence of ground movement along these faults, and as such, they pose very minimal risk to the pipeline" (Crone and Wheeler 2000). Review of the report by Crone and Wheeler (USGS Open-File Report 00-260) dated 2000 revealed that this report is only a preliminary report and was simply a systematic evaluation of published information on 69 features in Central and Eastern U.S. for classification purposes and to compile a national database regarding potentially significant earthquake areas. The report even states that "it is very likely that the inventory presented in this report is incomplete." This USGS report that was cited by the DEIS as the source of the information used to conclude that these faults "pose very minimal risk to the pipeline" is <u>not</u> a reliable source for determining whether there are active faults along the proposed pipeline route in Texas. This USGS report was not intended to be a complete compilation of active faults in Central and Eastern U.S., rather it was intended to be an initial start to a compilation of potential areas for significant earthquakes, a source of reference material for seismicity. As such, it should <u>not</u> have been used to conclude that the faults in southwestern Rusk County are not "active" and therefore would not pose any risk to the proposed pipeline.

In fact, there is documentation evidencing that this area does contain active faults. For example, a Bureau of Economic Geology report (Geologic Circular 84-3) by Pennington and Carlson dated 1984 states that several recent earthquakes "occurred near the Mount Enterprise Fault System along a 90-km segment and may represent activity along that fault system, along nearby secondary faults, or both." The Mount Enterprise Fault System is shown on Exhibit 12 and includes the faults in southwestern Rusk County where the proposed pipeline will be located. Furthermore, an October 2010 DEIS from the Corps of Engineers regarding a proposal for a lignite mining project in Rusk County states:

> "Northeast Texas is not a seismically active area (USGS 2009b). A search of the USGS earthquake database found two earthquakes events within 60 miles of the study area from 1973 to the present (National Earthquake Information Center 2009). Historically, strong earthquakes have been felt in the area. In 1891, there was a strong earthquake in the vicinity of Rusk, Texas, approximately 60 miles

> southwest of the study area. Reports indicated that the intensity of the earthquake may have been equivalent to a 5.0 to 5.9 magnitude earthquake (USGS 2009c). This earthquake is thought to have originated from the Mount Enterprise Fault Zone (Davis et al. 1989). There is some evidence of historical movement on the fault zone, which would indicate that it is active (Ferguson 1984). The cause of the movement is not certain; however, it may be related to movement of the Louann Salt that comprises the "basement" of the East Texas Basin."

This information about fault activity in the Mount Enterprise Fault Zone raises serious questions about the potential for an increased risk of failure of the proposed pipeline that is to be routed through this fault zone area in the immediate vicinity of the outcrop area of the Carrizo-Wilcox Aquifer.

6. Conclusion

Contrary to the above claims made in the DEIS suggesting a low probability of impacts to human and natural resources, the route of the proposed pipeline does not avoid the most sensitive areas when it comes to the Carrizo-Wilcox aquifer, since the pipeline will cross the outcrop portions of the aquifer, where a near-surface oil spill of tar sands crude oil would be able to enter into the aquifer system, degrading its water quality. In addition, the fact that the proposed route of this pipeline will be directly through the Mount Enterprise Fault Zone will only increase the probability of a spill.

The DEIS acknowledges that the spilling of the hazardous tar sands crude oil could migrate into a subsurface aquifer (like the Carrizo-Wilcox Aquifer), may reduce or eliminate agricultural or domestic use of this groundwater, and may contaminate surface water resources if the contaminated groundwater discharges into these waters. The major rivers in this area are recognized as being perennial and gain flow from the underlying geology, such as the Carrizo-Wilcox Aquifer. Thus, a release of this tar sands crude oil into the water resources in the area could have disastrous results. And with this crude oil being heavier than water, the cleaning up of such an oil spill and removal of the contamination from the water resources in the area would be extremely difficult.

Thus, special precautions need to be taken to minimize the likelihood that any of this hazardous liquid material could escape and enter into the water resources in the area in the event of a spill. The consequences of such a spill migrating into the groundwater and/or surface water are significant enough to necessitate a design that can assure the users of these water resources that their source of water is not at risk of being contaminated by tar sands crude oil.

7. <u>REFERENCES</u>

1. *USGS Open-File Report 00-260,* Crone and Wheeler. (2000).

2. Draft Environmental Impact Statement for the Proposed Keystone XL Pipeline Project.

3. Final Report on the Northern Carrizo-Wilcox Aquifer GAM Texas Water Development Board (2003).

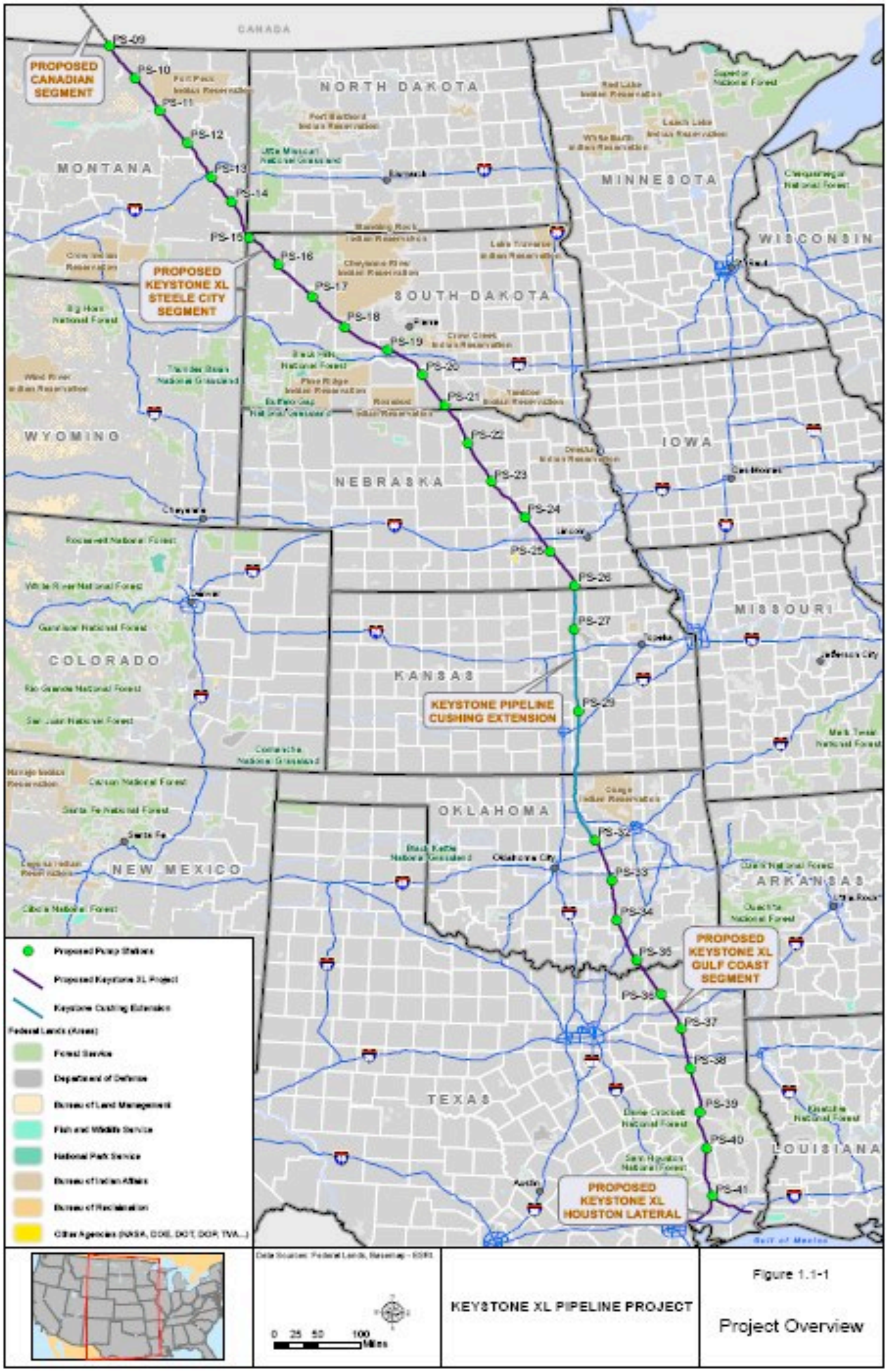
4. Natural Resources Defense Council, *Tar Sands Pipeline Safety Backgrounder*, Dec. 2010.

5. Jones, Scott. (2008). *Carrizo-Wilcox Aquifer in Texas.*

6. Geologic Circular 84-3, *Bureau of Economic Geology report,* Pennington and Carlson. (1984).

7. DEIS for the Rusk Lignite Mining Project, USACE-SWF, Oct. 2010.

<u>EXHIBIT 1:</u> Proposed Pipeline Route across the United States (from DEIS for Keystone XL Project)



<u>EXHIBIT 2:</u> Proposed Pipeline Route across the State of Texas (from DEIS for Keystone XL Project)

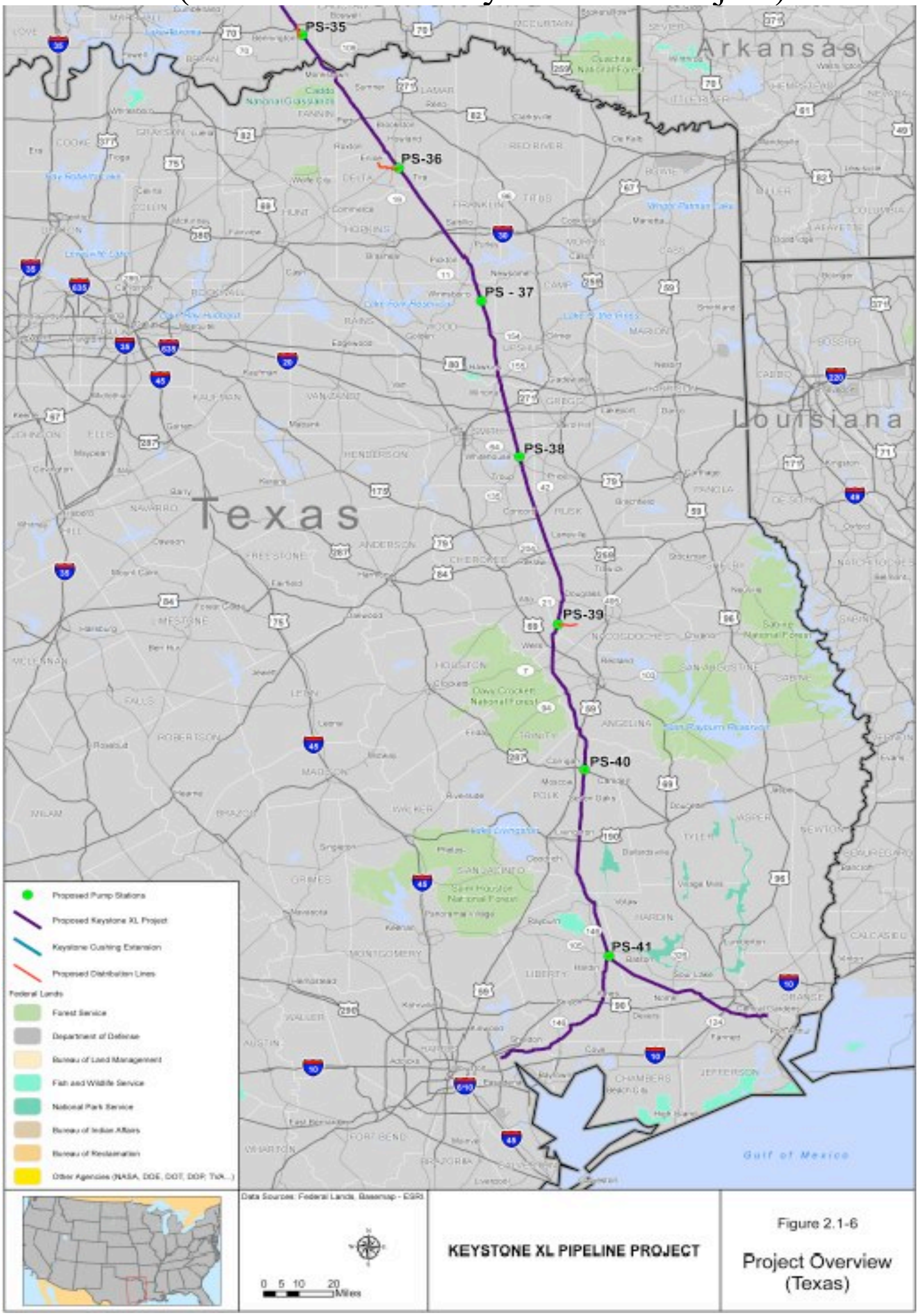


EXHIBIT 3: Proposed Pipeline Route across the Major Surface Waters of Texas (from TWDB)

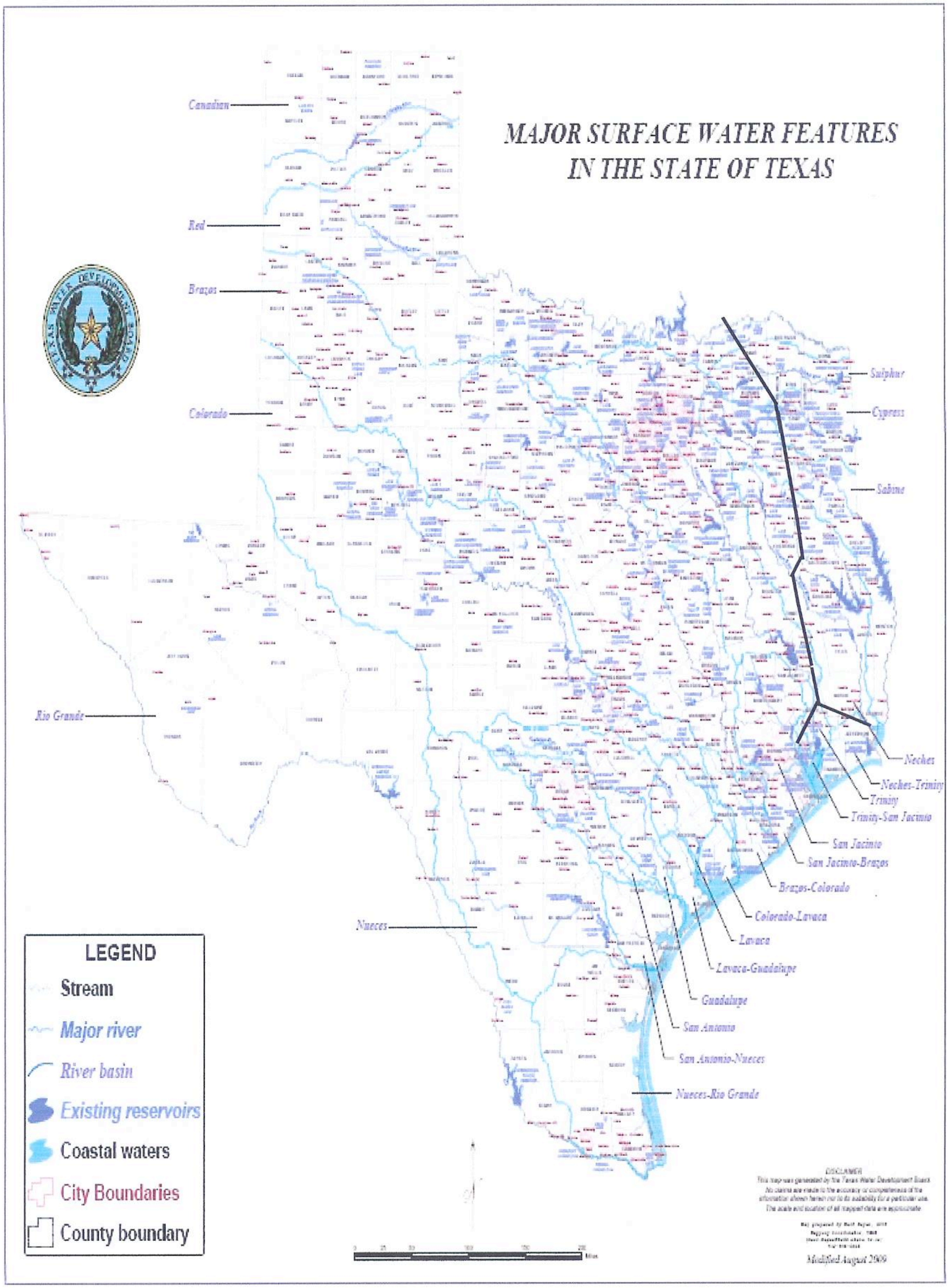


EXHIBIT 4: Proposed Pipeline Route across the Major Aquifers of Texas (from the TWDB)

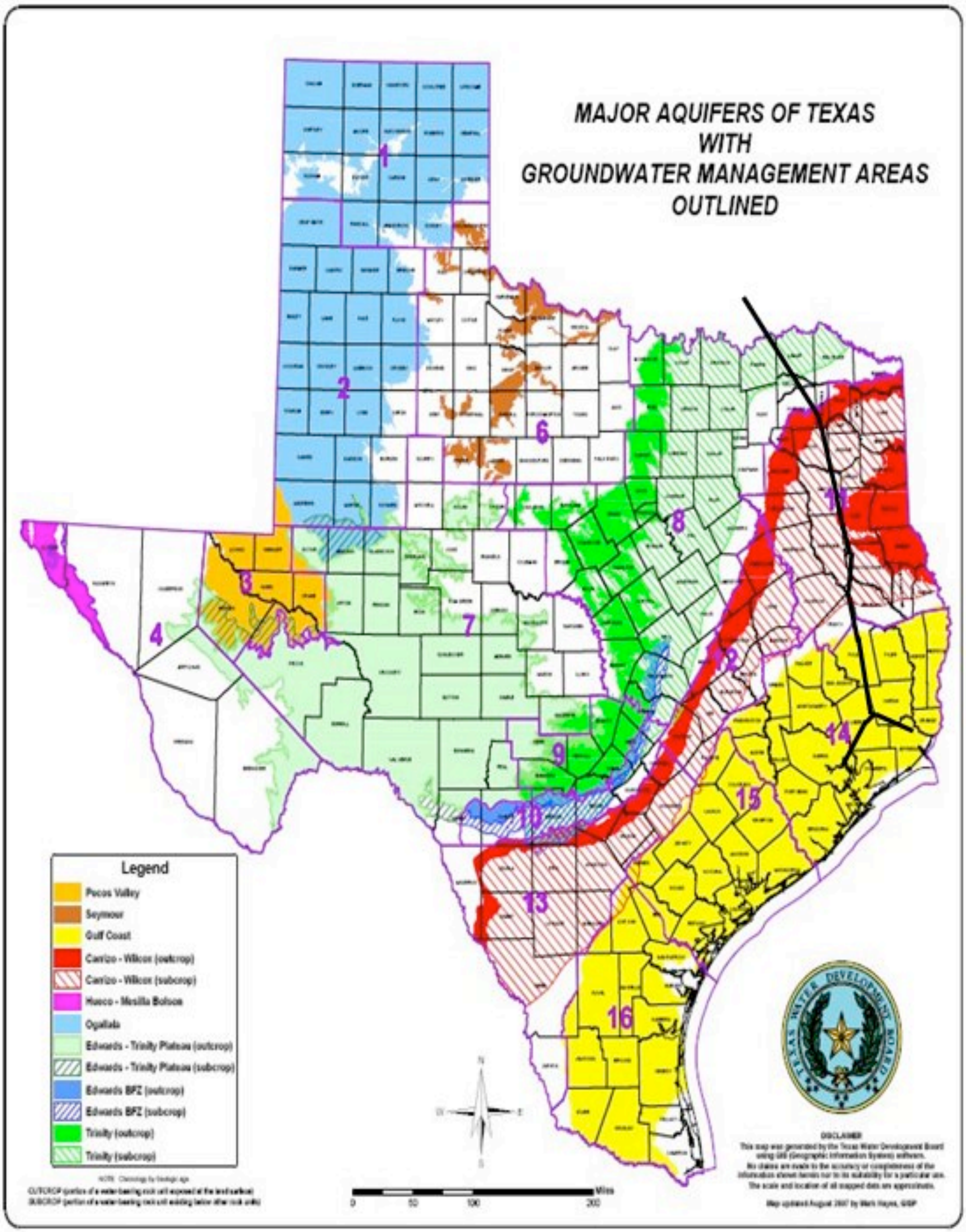
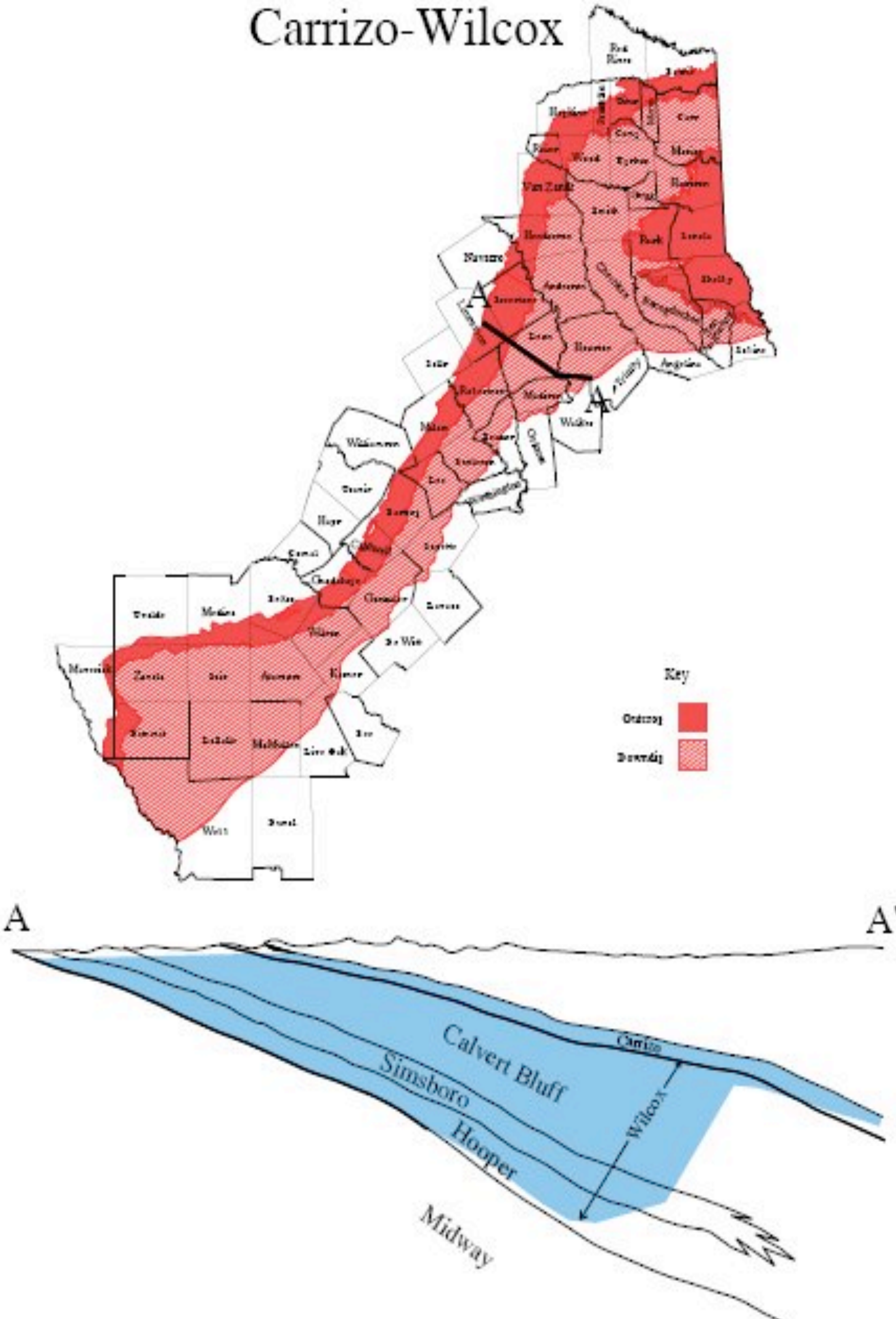
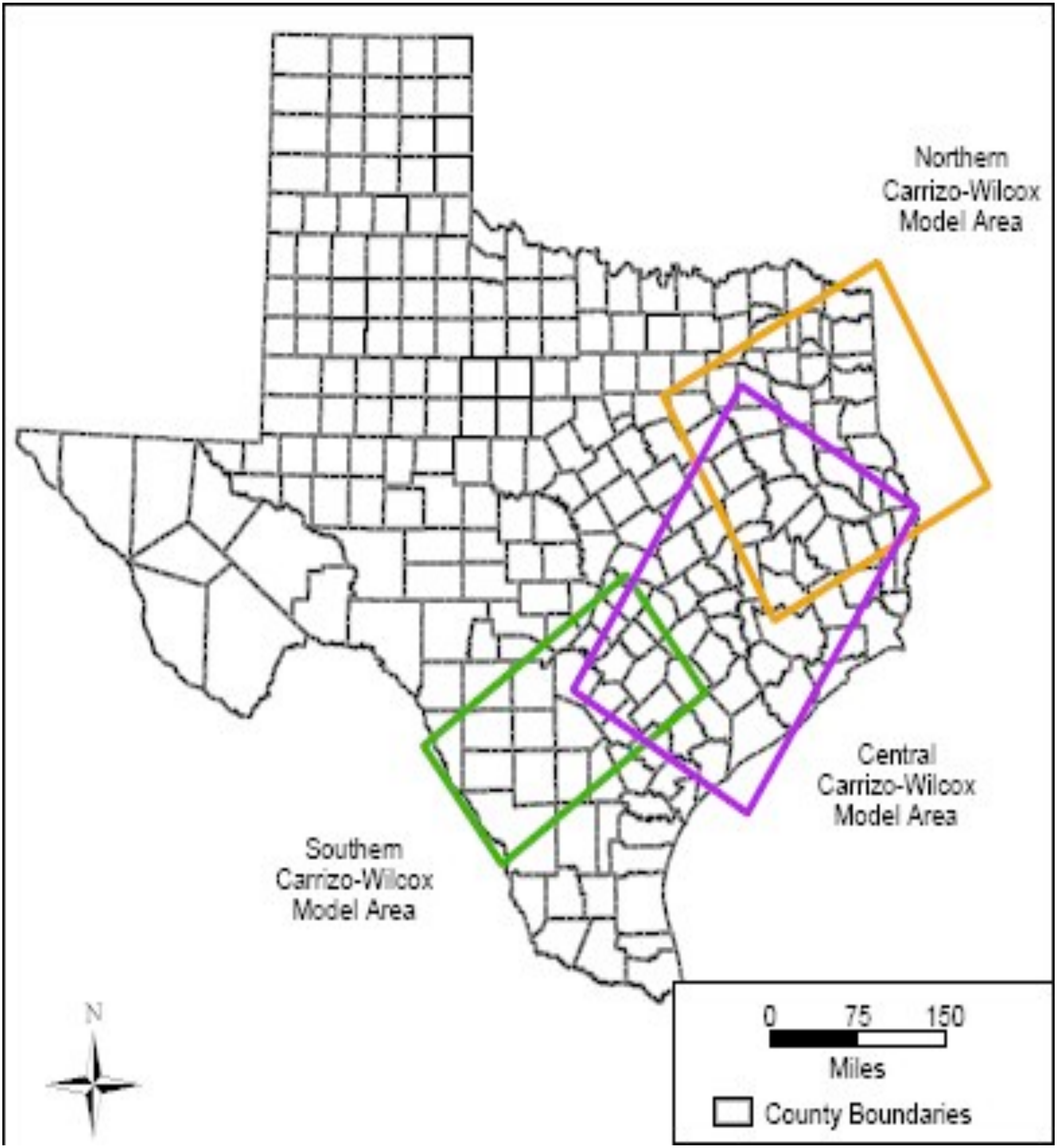


EXHIBIT 5: Typical Cross-Section of the Carrizo-Wilcox Aquifer (from TWDB)

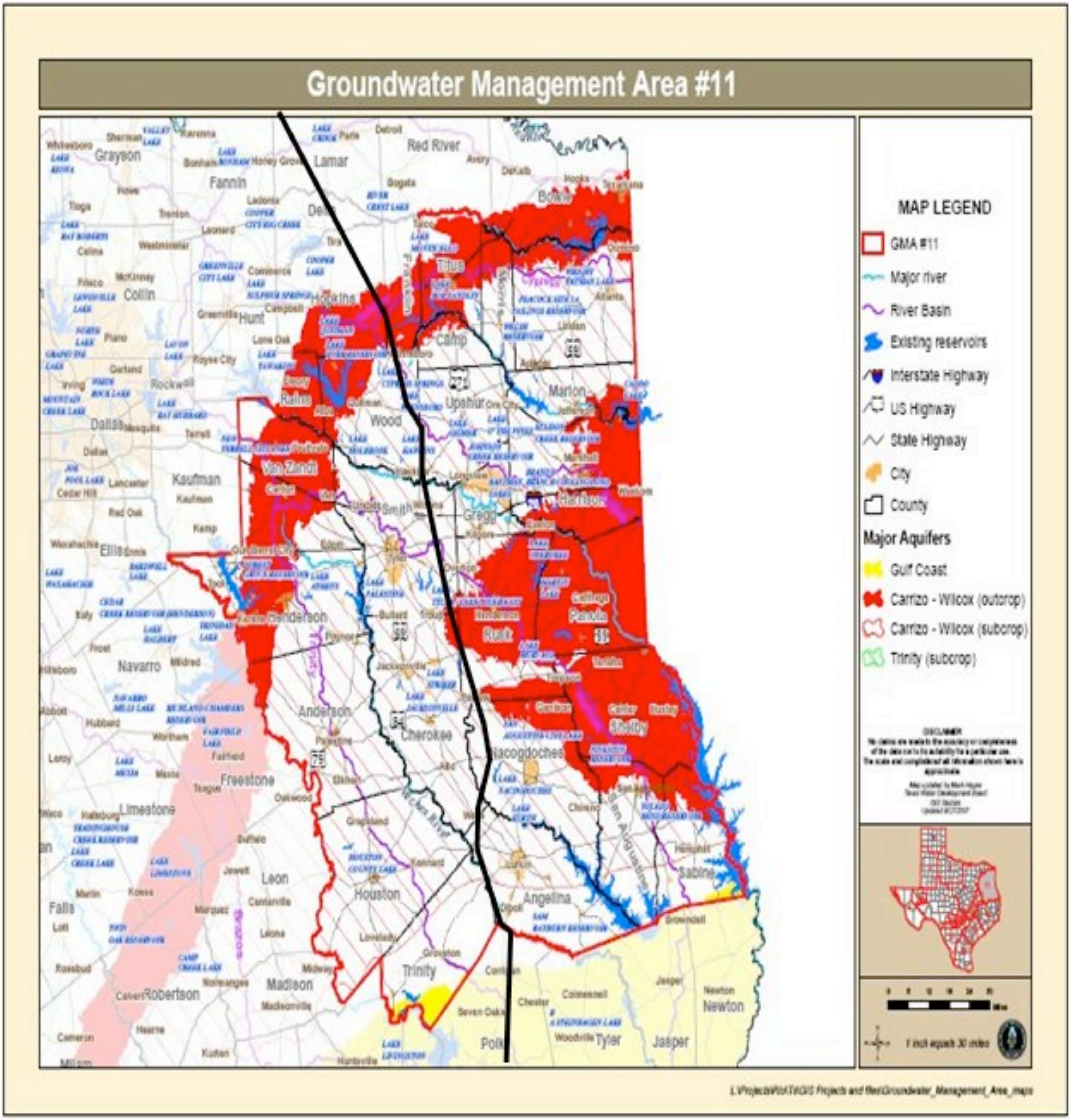


Modified from Thorkildsen and Price, 1991

EXHIBIT 6: Location of 3 Carrizo-Wilcox GAMs (from TWDB)



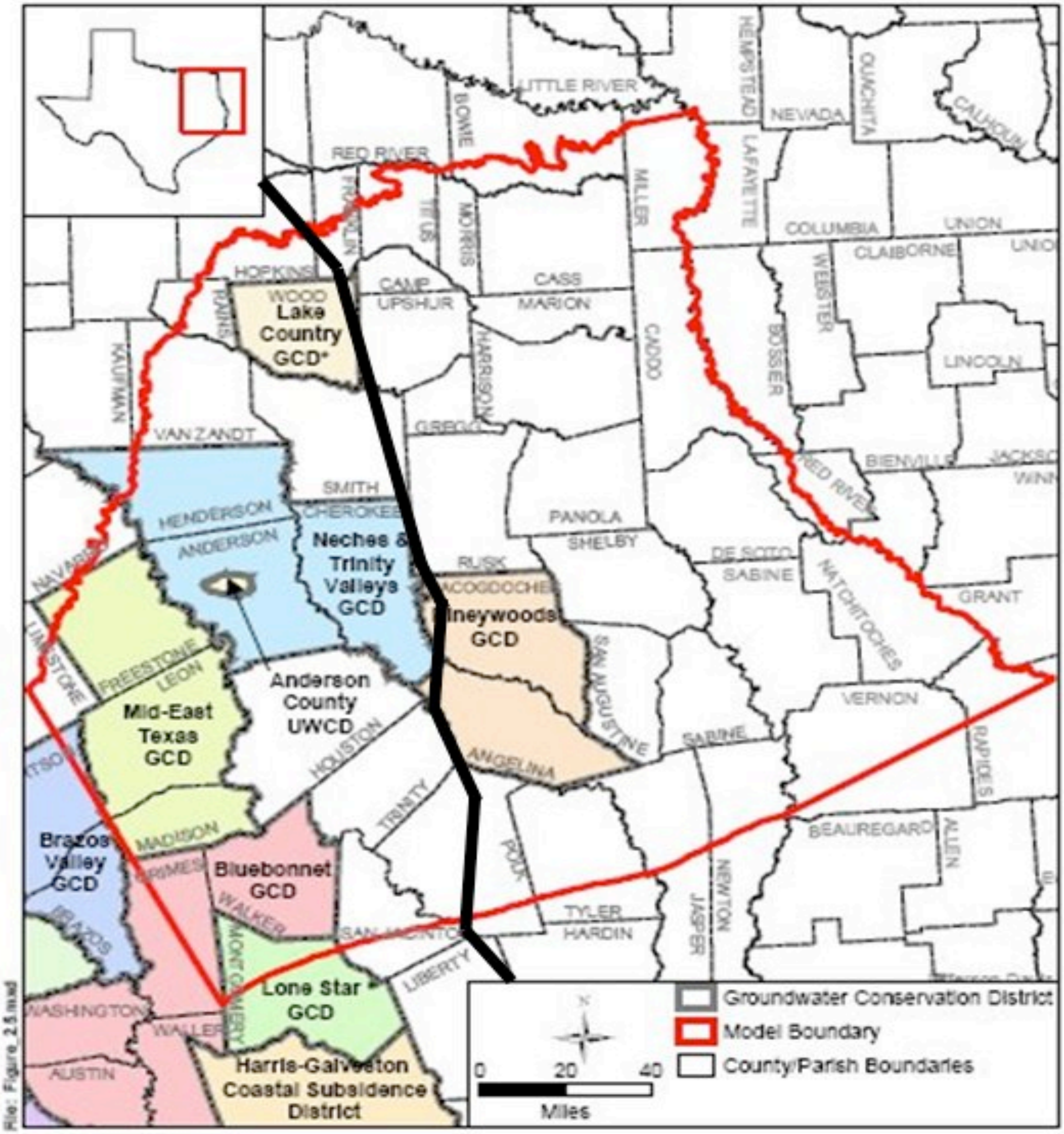
<u>EXHIBIT 7:</u> Proposed Pipeline Route across the Carrizo-Wilcox Aquifer Within GMA#11 (from the TWDB)



<u>EXHIBIT 8:</u> Proposed Pipeline Route across the Regional Planning Areas (from the TWDB)

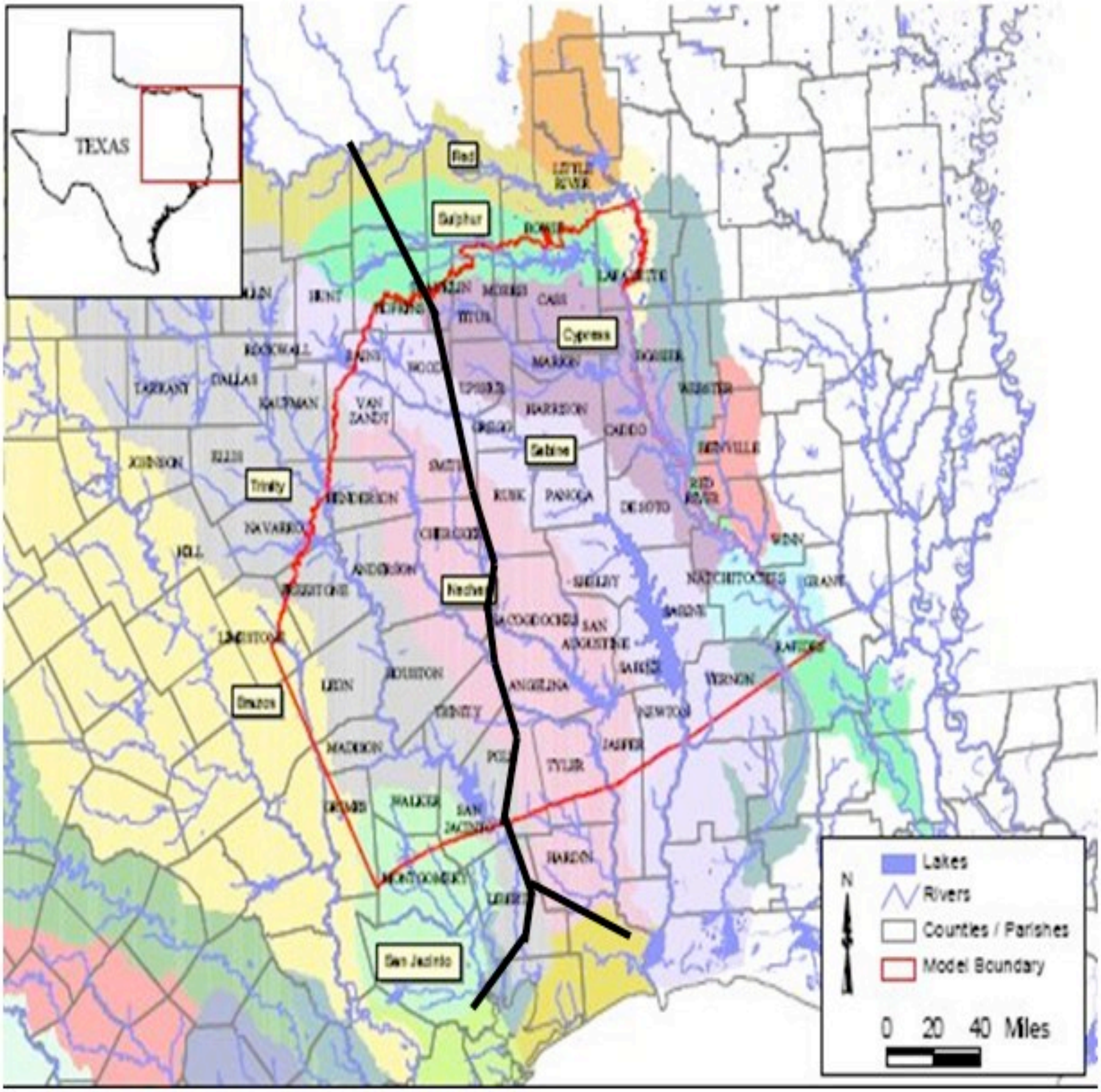
Source: Online: Texas Water Development Board, September 2002

<u>EXHIBIT 9:</u> Proposed Pipeline Route across the Groundwater Conservation Districts (from the TWDB)



*=Pending Confirmation
UWCD=Underground Water Conservation District
GCD=Groundwater Conservation District
Source: Online: Texas Water Development Board, December 2002

EXHIBIT 10: Proposed Pipeline Route across the Major River Basins (from the TWDB)



<u>EXHIBIT 11:</u> Proposed Pipeline Route across various Faults In Northeastern Texas (from DEIS for Keystone XL Project)

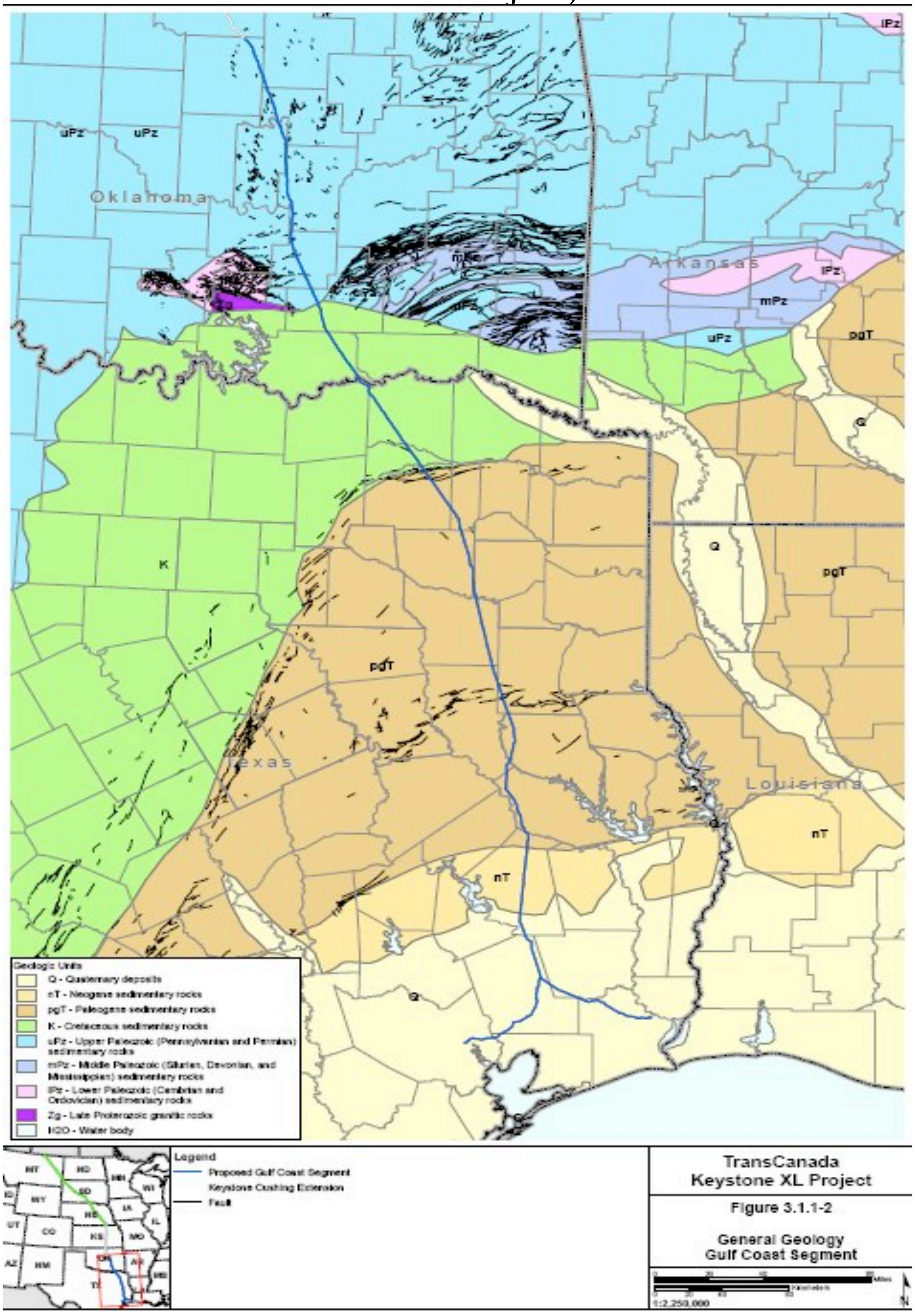
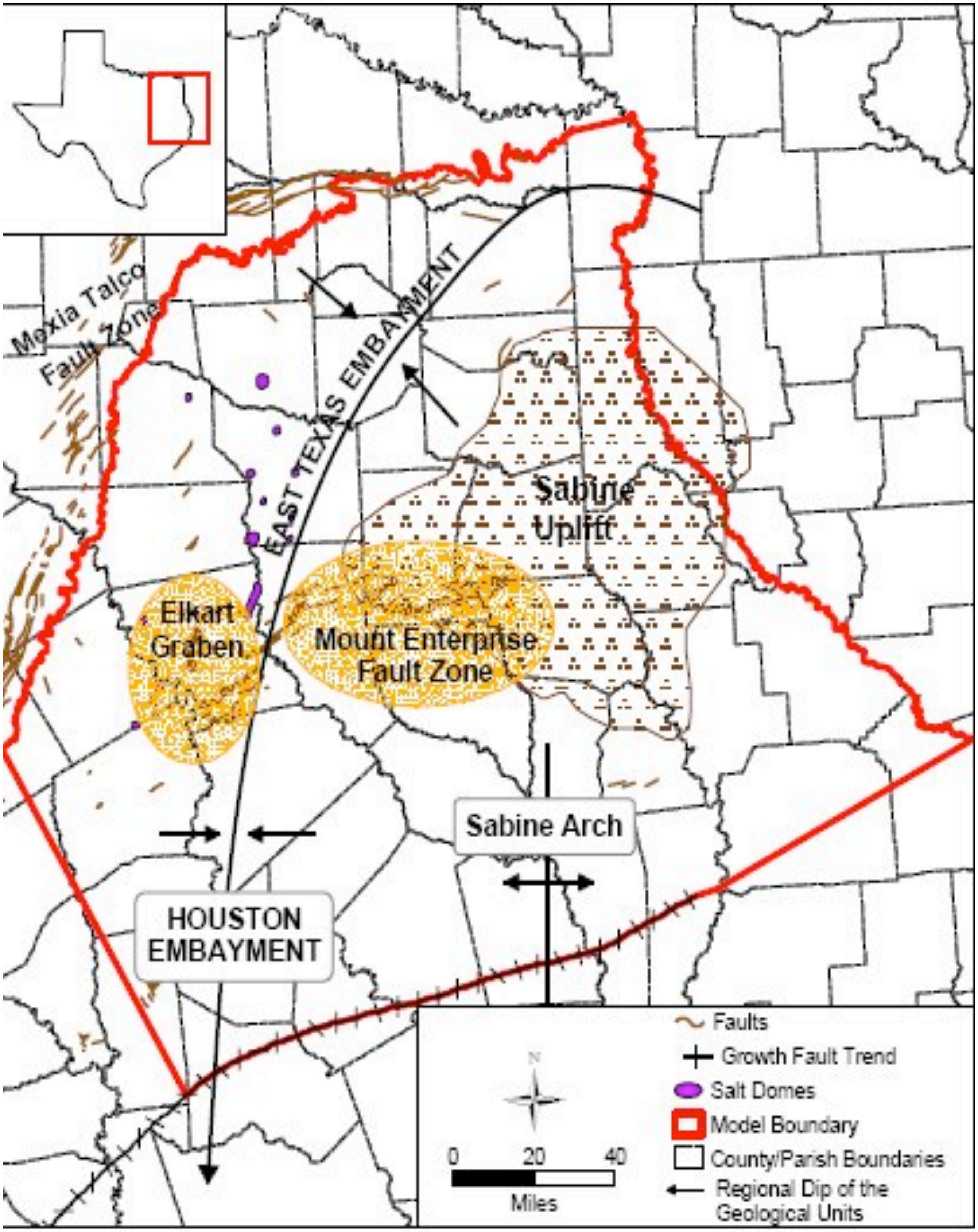


EXHIBIT 12: Various Fault Zones In Northeastern Texas (from TWDB)



Source: W.R. Kaiser (1990)