Report of Findings: WRGS 13-010

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Eastern Kerr County/Western Kendall County Regional Water System Project - Geology Section

for:

Cow Creek Groundwater Conservation District
201 E. San Antonio Ave., Suite 100
Boerne, Texas 78006

Headwaters Groundwater Conservation District
125 Lehmann Dr., Suite 102
Kerrville, Texas 78028

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Kerr and Kendall Counties, Texas
December 2013

WRGS Project No. 055/072-003-13

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Section I: Executive Summary

The Texas Water Development Board has awarded a grant to develop a regional solution to water needs in Kerr and Kendall counties. As a part of the larger grant study, this report describes the geology of the study area which encompasses Eastern Kerr/Western Kendall counties. The goal of this study is to provide a preliminary review of the Lower Trinity Aquifer as a potential target for a regional Aquifer Storage and Recovery project as well as utilizing the Ellenburger Aquifer as an alternative source of water for the area.

The Eastern Kerr/Western Kendall area is located south of the Llano Uplift; an area marked by the uplift of Precambrian igneous granites and metamorphic rocks forming a gentle dome surrounded by Cretaceous aged limestone. The area is structurally complex with extensive faulting and contains three minor aquifers (The Hickory Sandstone, Ellenburger-San Saba and Marble Falls aquifers) and two major aquifers (Trinity and Edwards-Trinity aquifers). The Middle Trinity Aquifer has historically been the primary groundwater source for the area. To a lesser extent the Edwards-Trinity Aquifer and the Lower Trinity Aquifer have also provided water to domestic and stock wells. These aquifers make up a thick and regionally extensive aquifer system composed of Cretaceous aged carbonates that were deposited throughout central Texas.

Structurally, the area is dominated by the Llano Uplift, a structural dome of Precambrian igneous granitic pluton that was uplifted during the Ouachita Orogeny causing the surrounding Paleozoic aged rocks to fold and uplift. Another major structural feature that impacts the study area is the Fredericksburg High.

As part of this study the elevations to the top of the Upper Glen Rose, Lower Glen Rose, Hensell, Hosston (top and bottom) and the Ellenburger were determined based upon electric logs of wells drilled within the study area and outside of the study area within Bandera County. In addition, north-south, east-west and downdip (northwest-southeast) cross sections were developed.

Electric logs of water wells were provided by the Headwaters Groundwater Conservation District (HGCD), the Cow Creek Groundwater Conservation District (CCGCD) and GeoCam, Inc. The majority of the water well electric logs were of wells completed to the base of the Middle Trinity Aquifer and in some cases to the top of the Ellenburger Group. Gamma, spontaneous potential (SP), single point resistivity, 4-point resistivity, conductivity and caliper logs were included in electric logs conducted on the water wells. In addition, electric logs of oil and gas wells were obtained through the Railroad Commission of Texas (RRC) for wells completed to at least the top of the Ellenburger Group. The logs contained in most cases a resistivity and SP curve; in other logs gamma and density logs were included.

The elevation of the top of the Ellenburger Group ranges from a high of 1,272 feet MSL within the northern portion of the study area in Kerr County to a low of -3,173 feet MSL just southwest of the study area. Structural features such as Paleozoic faults and the Fredericksburg High affect the total depth to the Ellenburger Group. The Fredericksburg High, located approximately NE to SW along the eastern portion of the study area, has pushed up the Ellenburger Group causing it to be encountered at shallower elevations.

The need for additional water supply to the Eastern Kerr/Western Kendall area has been documented through the regional water planning process. To be able to meet projected water demand and to allow for diversification of the area's water resources, stakeholders have identified alternative groundwater sources such as the Ellenburger Aquifer and ASR using the Lower Trinity Aquifer. Based upon the electric logs, the depth to the top of the Ellenburger Group varies greatly from north to south going downdip and within the Fredericksburg High. The electric logs of three wells analyzed as part of this study (HGCD MW3, HGCD MW 14 and Q-17 (Kendall County) have encountered the Ellenburger Group at a shallower than expected depth potentially due to the Fredericksburg High. Test well locations updip within the northern 1/3 section of the study area and/or within the Fredericksburg High would provide the best opportunity for further study and evaluation.

The Lower Trinity is composed of the Hosston Sand and its thickness varies within the study area between 87 feet at well Q-7 (Kendall County) and 272 feet thick at well Q-2 (Kendall County). It is also nonexistent at wells Q-17 (Kendall), HGCD MW 3 and HGCD MW 14, possibly due to the Fredericksburg High. Within the Lower Trinity Aquifer further study should concentrate around areas where the Hosston Sand produces at larger production rates and thereby has higher transmissivities in addition to areas where the Hosston is thicker. Based upon the data collected in this study, the Hosston is thickest at wells further away from the Fredericksburg High and downdip within the aquifer near the southern boundary of the study area. This includes the area northwest of the City of Boerne, within the City of Kerrville and southeast of the City of Kerrville near the Bandera County line.

Section II: Introduction

The Texas Water Development Board (TWDB) awarded a grant to Kerr County, Kendall County, Upper Guadalupe River Authority (UGRA), Guadalupe-Blanco River Authority (GBRA), Headwaters Groundwater Conservation District (HGCD), Cow Creek Groundwater Conservation District (CCGCD) and the Kendall County Water Control and Improvement District (KCGWCID) #1 to develop a regional solution to water needs in Kerr and Kendall counties.

As a part of the larger grant study, this report details the geology of the Eastern Kerr/Western Kendall counties area and in particular, the Lower Trinity and the Ellenburger aquifers. This geologic investigation provides a preliminary review for the potential of using the Lower Trinity Aquifer for a regional Aquifer Storage and Recovery (ASR) project and the Ellenburger Aquifer as an alternative source of water for the area. Figure 1 provides a location map showing the study area.

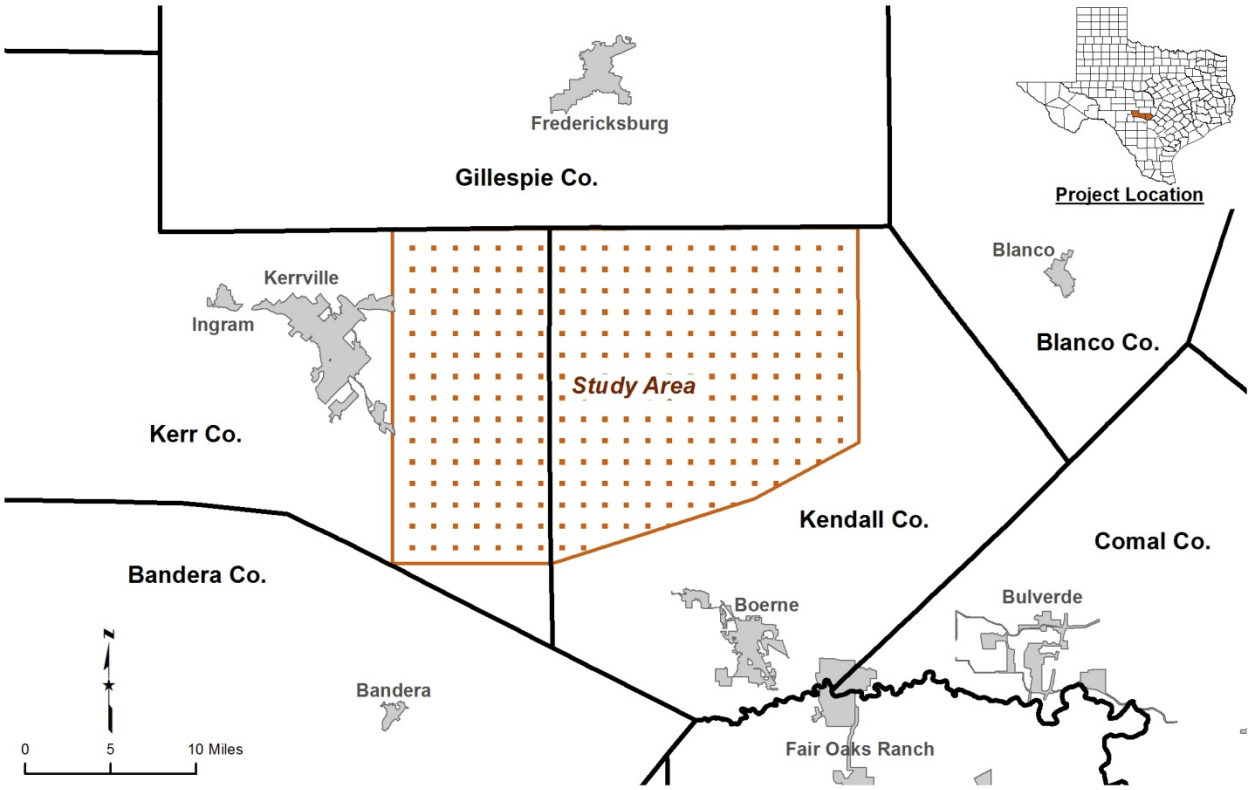

Figure 1: Location map of the study area

The objectives of this report are to:

1. Provide a regional geologic summary which describes the stratigraphic units and overall structure of the study area;

2. Analyze geophysical logs to delineate the following: Edwards Group (Segovia and Fort Terrett), Upper and Lower Glen Rose Limestone, Hensell Sand, Hammett Shale, Hosston, Pennsylvanian aged deposits and the Ellenburger Group;

3. Develop individual maps showing the elevation to the top of the various formations in the study area;

4. Develop a north-south, east-west and downdip (northwest-southeast) cross section of the study area; and

5. Provide a description of the methodology used to determine the formational elevations and based upon findings, recommend locations within the study area that warrant further investigation within the Ellenburger Aquifer and ASR within the Lower Trinity Aquifer.

Section III: Geology of the Study Area

III.1. Introduction

The Eastern Kerr/Western Kendall area is located south of the Llano Uplift; an area marked by the uplift of Precambrian igneous granites and metamorphic rocks forming a gentle dome surrounded by Cretaceous aged limestone. The area is structurally complex with extensive faulting and contains three minor aquifer (The Hickory Sandstone, Ellenburger-San Saba and Marble Falls aquifers) and two major aquifers (Trinity and Edwards-Trinity aquifers).

The Middle Trinity Aquifer has historically been the primary groundwater source for the area. To a lesser extent the Edwards-Trinity Aquifer and the Lower Trinity Aquifer have also provided water to domestic and stock wells. These aquifers make up a thick and regionally extensive aquifer system composed of Cretaceous aged carbonates that were deposited throughout central Texas.

III.2. Stratigraphic Units of the Eastern Kerr/Western Kendall Area

Figure 2 provides the geologic and hydrogeologic units found within the study area with the oldest units located at the bottom and progressively younger units moving upward.

III.2.1 Precambrian

Precambrian aged gneiss (Valley Spring Gneiss, Lost Creek Gneiss), schist (Packsaddle Schist) and granites (Town Mountain Granite) form the basement within the Llano Uplift area. The age of these Precambrian rocks is up to approximately 1.36 billion years old (Reese, et. al, 2000). Much of the metamorphosis including compression and folding of the rocks are known to occur as far back as 1.2 billion years ago (Roback et. al., 1999) with fracturing of the rock occurring in multiple orientations (Johnson, 2004). The surface of the Precambrian rocks was eroded and during the Cambrian with the Hickory Sandstone deposited on top under fluvial conditions. The thickness of the Hickory is dependent upon the erosional surface of the Precambrian basement rocks (Krause, 1996).

III.2.2 Cambrian System (Moore Hollow Group)

Located above the Precambrian basement is the Riley and Wilberns formations of the Moore Hollow Group. The Riley Formation consists of from oldest to youngest, the Hickory, Cap Mountain and Lion Mountain Members.

The Hickory Sandstone is a white, yellow, or reddish brown cross-bedded quartz sandstone deposited predominately within shallow seas (Preston, et. al., 1996) on top of an irregular erosional surface of the Precambrian. The Hickory can be up to 530 feet at its thickest where the more erodible Precambrian Packsaddle Schist, Valley Spring Gneiss and granites formed lowland areas (Barnes and Bell, 1977) and encircles the Llano Uplift where it becomes thicker radially outward.

Barnes and Bell (1977) divided the Hickory into three sections; the basal section consists of thick massive beds with rounded to sub-rounded poorly sorted sand with some conglomerates near the base. The middle section consists of thin beds of sandstone with silty and micaceous layers interbedded.

ERA	System	Group	Formation	Member	Hydrologic Unit
Mesozoic	Cretaceous	Fredricksburg	Edwards	Segovia	Edwards Plateau Aquifer
				Fort Terrett	Confining Bed
		Trinity	Glen Rose	Upper Unit	Upper Trinity Aquifer
				Lower Unit	Middle Trinity Aquifer
			Travis Peak	Hensell / Bexar	
				Cow Creek	
				Hammett	Confining Bed
				Sligo / Hosston	Lower Trinity Aquifer
Paleozoic	Pennsylvanian	Canyon	undifferentiated	undifferentiated	Confining Bed
		Bend	Smithwick	undifferentiated	
			Marble Falls Limestone	Upper Unit	Marble Falls Aquifer
				Lower Unit	
	Devonian & Mississippian (undifferentiated) where present				Confining Bed
	Ordovician	Ellenburger	Honeycut	undifferentiated	Ellenburger-San Saba Aquifer
			Gorman	undifferentiated	
			Tanyard	Staendebach	
				Threadgill	
	Cambrian	Moore Hollow	Wilberns	San Saba	
				Point Peak	Confining Bed
				Morgan Creek	
				Welge	Mid-Cambrian Aquifer
			Riley	Lion Mountain	
				Camp Mountain	Confining Bed
				Hickory	Hickory Aquifer
Precambrian Base					

Sources: TWDB Numbered Report 339 (Bluntzer, 1992), TWDB Report: Llano Uplift Aquifers Structure and Stratigraphy (Standen & Ruggiero, 2007)

Figure 2: Geologic and hydrogeologic units within the Eastern Kerr/Western Kendall area

The upper section is a distinctive red, hematite cemented, medium to coarse grained sandstone with well rounded grains. The upper section of the Hickory contains large amounts of iron (hematite) owing to its reddish color and has a gradational contact with the overlying Cap Mountain limestone where it can contain some lime rich sandstone (Preston, et. al., 1996). The sandstone grains within the Hickory are typically well rounded especially at the upper section where the sandstone is coated in iron oxide (Barnes and Bell, 1977).

The Hickory Sandstone is considered a minor Aquifer by the Texas Water Development Board (TWDB). The TWDB defines a major aquifer as an aquifer that produces large amounts of water over large areas and a minor aquifers as an aquifer that produces minor amounts of water over large areas or large amounts of water over small areas. The Hickory Aquifer produces moderate to large amounts of water to areas within the Llano Uplift. The aquifer contains some minerals that were deposited with the quartz sandstone that are a source of elevated radium concentration in groundwater produces in some areas of the aquifer.

The Cap Mountain Limestone of the Riley Formation is located unconformably above the Hickory and consists of thinly bedded limestone with moderate amounts of sand in the basal section where the contact with the Hickory Sandstone is gradational. The Cap Mountain grades upward into thicker beds of siltstone, silty limestone and limestone (Preston et. al., 1996) and is thinnest near the Llano Uplift where it thickens radially up to 650 feet (Preston et. al., 1996). The Cap Mountain is considered an aquitard or confining unit.

The Lion Mountain Sandstone is the uppermost Member of the Riley Formation and is composed of thin beds of glaconitic quartz sandstone, quartzose greensand, sandy limestone, impure fossiliferous limestone, crossbeds of trilobite coquinite and minor amounts of shale and siltstone (Barnes and Bell, 1977). The Lion Mountain ranges in thickness up to 85 feet (Preston et. al., 1996) and forms an unconformable boundary with the Welge Member of the Wilberns Formation. Both the Welge and Lion Mountain are hydraulically connected and together form the Mid-Cambrian Aquifer. The Mid-Cambrian Aquifer is considered a minor aquifer by the TWDB.

Located above the Riley Formation is the Wilberns Formation of the Moore Hollow Group. The Wilberns Formation consists of from oldest to youngest, the Welge, Morgan Creek, Point Peak and San Saba Members.

The Welge Sandstone is the lowermost member of the Wilberns Formation and is composed of thick beds of non-glauconitic sandstone (Barnes and Bell, 1977). The non-glauconitic Welge is distinguishable from the green glauconitic sandstone of the Lion Mountain and can vary in thickness from 5 feet to over 30 feet (Preston et. al., 1996).

The Morgan Creek Limestone of the Wilberns Formation is composed of coarse grained clastic limestone which is sandy at the base of the member with silty beds near the top (Barnes and Bell, 1977) and forms a gradational boundary between both the Welge beneath and the Point Peak above. The Morgan Creek is fossiliferous and varies in color; thicknesses of the Morgan Creek range from 90 to 190 feet (Preston et. al., 1996).

The Point Peak Shale together with the Morgan Creek Limestone form a confining layer separating the Mid-Cambrian Aquifer from the Ellenburger-San Saba Aquifer. The Point Peak is a siltstone at the base and increases in limestone content near the top where it forms a gradational contact with the San Saba Member. Thickness of the Point Peak Shale can range up to 220 feet thick (Preston et. al., 1996).

The youngest member of the Wilberns Formation is the San Saba Limestone. The San Saba is the thickest of the Wilberns Formation making up half of its thickness (Barnes and Bell, 1977). Depending upon the location, it is composed of limestone or dolomite varying with thick and thin beds. The upper portion of the San Saba is thought to be Ordovician in age because of Ordovician trilobites found within the San Saba (Barnes and Bell, 1977). The contact with the above lying Threadgill Member of the Tanyard Formation is conformable and shows evidence of continuous deposition across the Cambrian – Ordovician time (Barnes and Bell, 1977). The San Saba varies in thickness from 250 feet to 850 feet (Preston et. al., 1996) and together with the Ellenburger Group forms the Ellenburger-San Saba Aquifer.

III.2.3 Ordovician System (Ellenburger Group)

Located above the Cambrian Moore Hollow Group is the Ordovician Ellenburger Group which consists of from oldest to youngest, the Tanyard, Gorman and Honeycut formations. Together these formations form the Ellenburger Aquifer.

The Tanyard Formation is the lower most formation of the Ellenburger Group and consists of the Threadgill and Staendebach members. The Tanyard ranges in thickness from 475 feet to 730 feet thinning westward (Preston et. al., 1996). The Threadgill Member is a limestone but also can be dolomitic and consists of thinly bedded to massive limestone and both coarse and fine grained dolomite (Barnes and Bell, 1977). Overlying the Threadgill is the Staendebach Member, which typically is near 300 feet in thickness but can range from 229 feet up to 456 feet (Barnes and Bell, 1977). The Staendebach is composed of both limestone and very fine grained dolomite and typically contains chert nodules within the limestone and dolomite beds (Barnes and Bell, 1977). Above the Tanyard Formation lies the Gorman and Honeycut formations which in total comprise the Ellenburger Group. Both the Gorman and Honeycut are limestone and dolomite in composition and are undifferentiated. The Ellenburger – San Saba Aquifer is considered a minor aquifer by the TWDB with a thickness that ranges up to 2,400 feet.

Figure 3 provides the elevation to the top of the Ellenburger Group taken from electric logs of wells within Eastern Kerr, Western Kendall and Northern Bandera counties. In addition, the location of Paleozoic faults taken from Standen and Ruggiero (2007) and Ewing (1991) are shown. Of the 30 electric logs obtained within the study area, 12 were logged to the top of the Ellenburger Group. The data are sparse, however Figure 3 provides elevations to the top of the Ellenburger Group in different portions of the study area. The elevation ranges from a high of 1,272 feet above Mean Sea Level (MSL) within the northern portion of the study area in Kerr County to a low of -3,173 feet MSL just southwest of the study area.

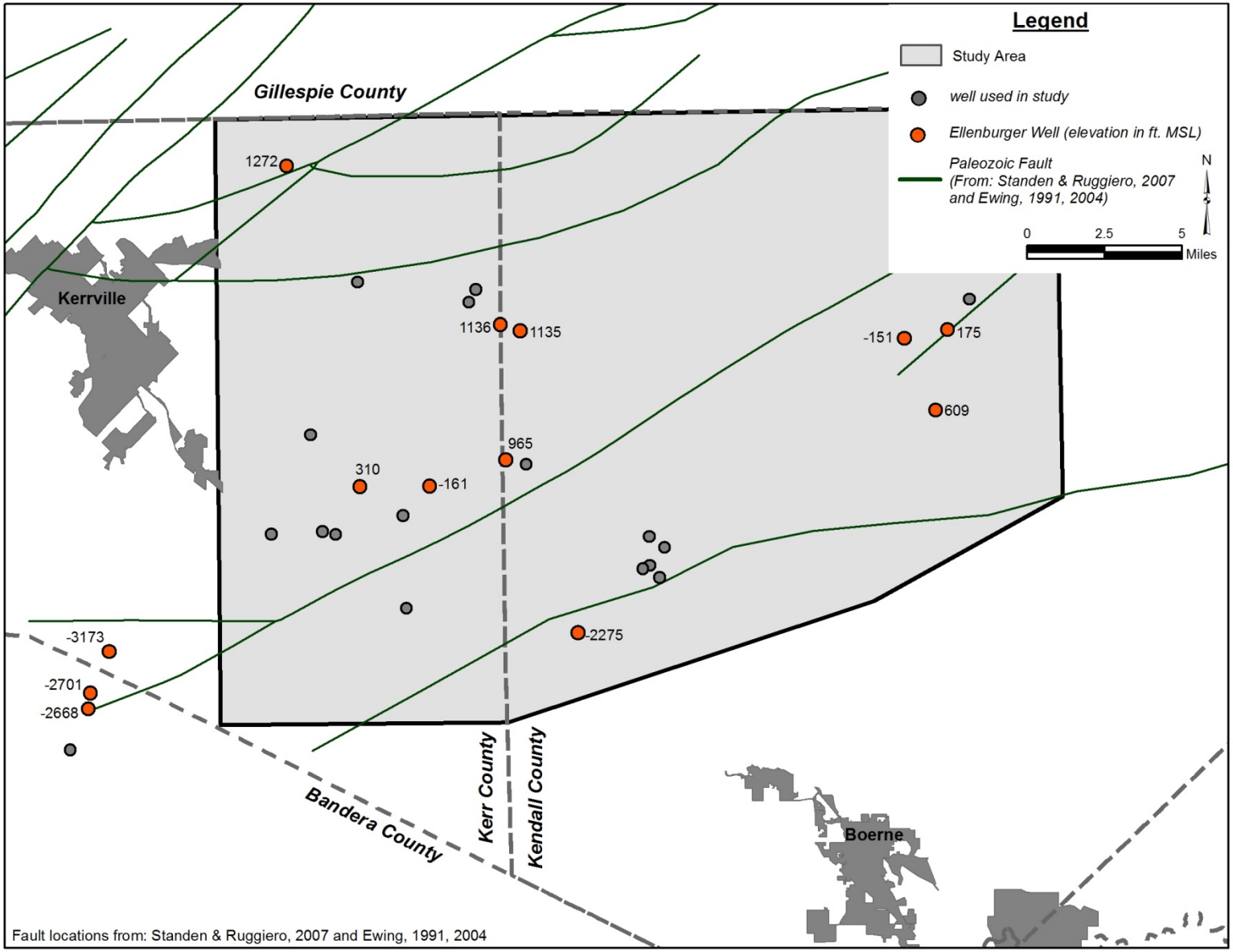

Figure 3: Elevation to the top of the Ellenburger Group

III.2.4 Devonian and Mississippian Systems

Devonian and Mississippian formations are generally thin, not deposited or have been eroded away (Standen and Ruggiero, 2007; Preston et. al., 1996) and are not discussed within this study. These formations where present act as a confining bed.

III.2.5 Pennsylvanian System (Bend and Canyon Groups)

The Pennsylvanian System contains from oldest to youngest, the Bend Group consisting of the Marble Falls and Smithwick formations and the undifferentiated Canyon Group.

The Marble Falls Limestone is separated into a lower unit and upper unit with a total thickness that ranges up to 460 feet (Preston et. al., 1996). The lower unit consists of a massive very fine grained limestone reef with thin shale beds in the lower section of the lower unit. The lower unit lies unconformably above the Ellenburger Group and where present Devonian and Mississippian formations (Preston et. al., 1996). The upper unit contains very fine grained limestone with varying bed thickness and fossiliferous chert nodules (Preston et. al., 1996). The Marble Falls Limestone forms the Marble Falls Aquifer which is considered a minor aquifer. The aquifer occurs in separated sections north of the Llano Uplift and east within Burnet and Blanco counties.

The Smithwick Shale lies unconformably above the Marble Falls Limestone and can range in thickness from 300 to 500 feet (Preston et. al., 1996). The Smithwick is comprised of claystone, siltstone and some sandstone (Preston et. al., 1996) and together with the Bend Group acts as an aquitard or confining bed separating the Marble Falls Aquifer from the Lower Trinity Aquifer. When drilling an open borehole using air rotary drilling through the Smithwick the formation will tend to slough into the borehole making it difficult to keep open.

The Canyon Group of the Pennsylvanian System ranges in thickness up to 1,500 feet and is mostly comprised of interbedded limestone with shale and fine grained sandstone (Preston et. al., 1996).

III.2.6 Cretaceous System (Trinity and Fredericksburg Groups)

A major unconformity separates the Pennsylvanian System from the much younger Cretaceous System. During the Cretaceous, shallow seas advanced and retreated over the region depositing the Trinity and Fredericksburg groups. From oldest to youngest, the Trinity Group is comprised of the Travis Peak Formation overlain by the Glen Rose Formation.

The Travis Peak Formation from oldest to youngest is divided into the Hosston/Sligo, Hammet, Cow Creek and Hensell/Bexar members. The Hosston consists of a conglomerate of gravel, sand and clay cemented by both calcite and quartz. The Hosston also contains sections of sandstone, siltstone, claystone, dolomite, limestone and shale. Within the study area, the Sligo Limestone is not present; the Hosston varies in color from red and white to gray.

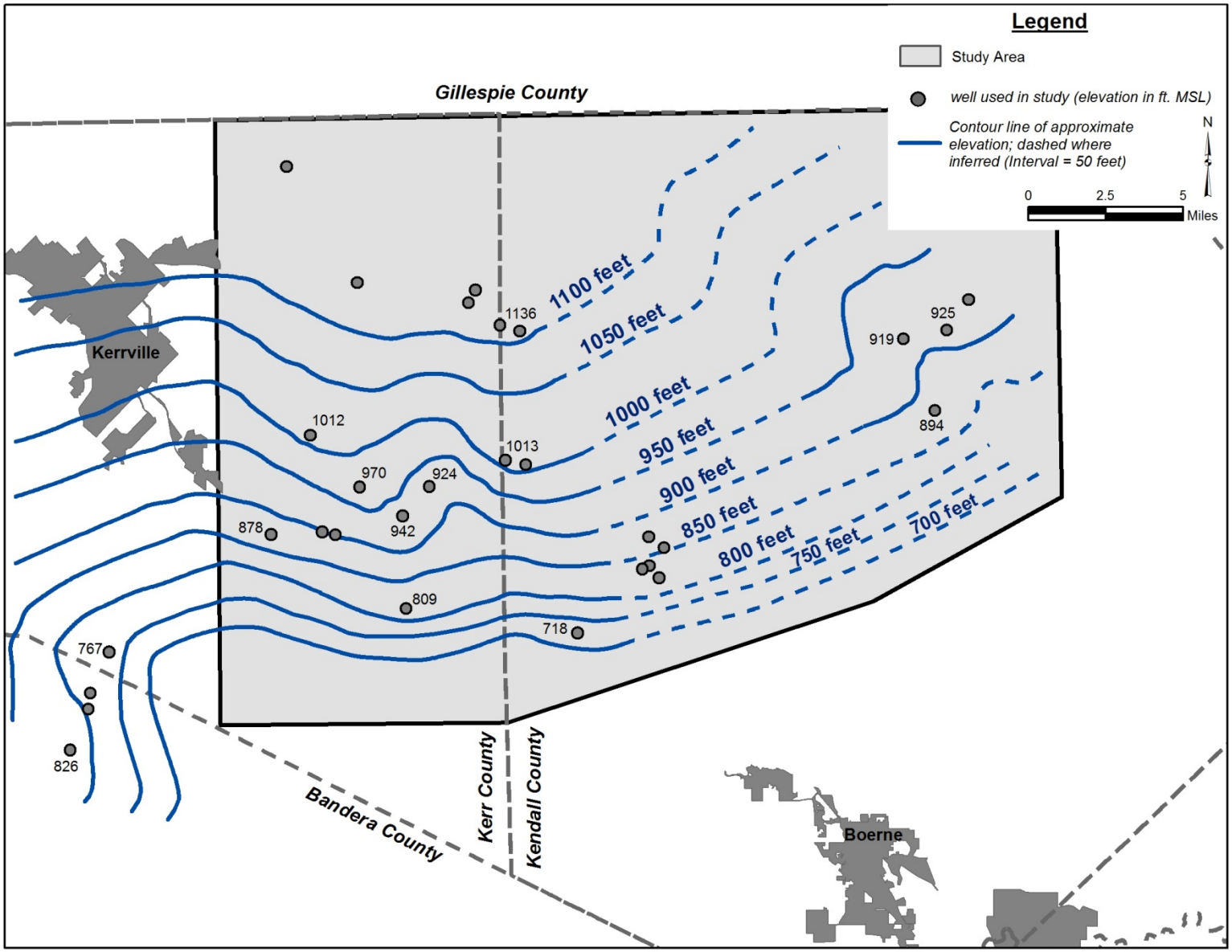

Figure 4: Elevation to the base of the Hosston Member

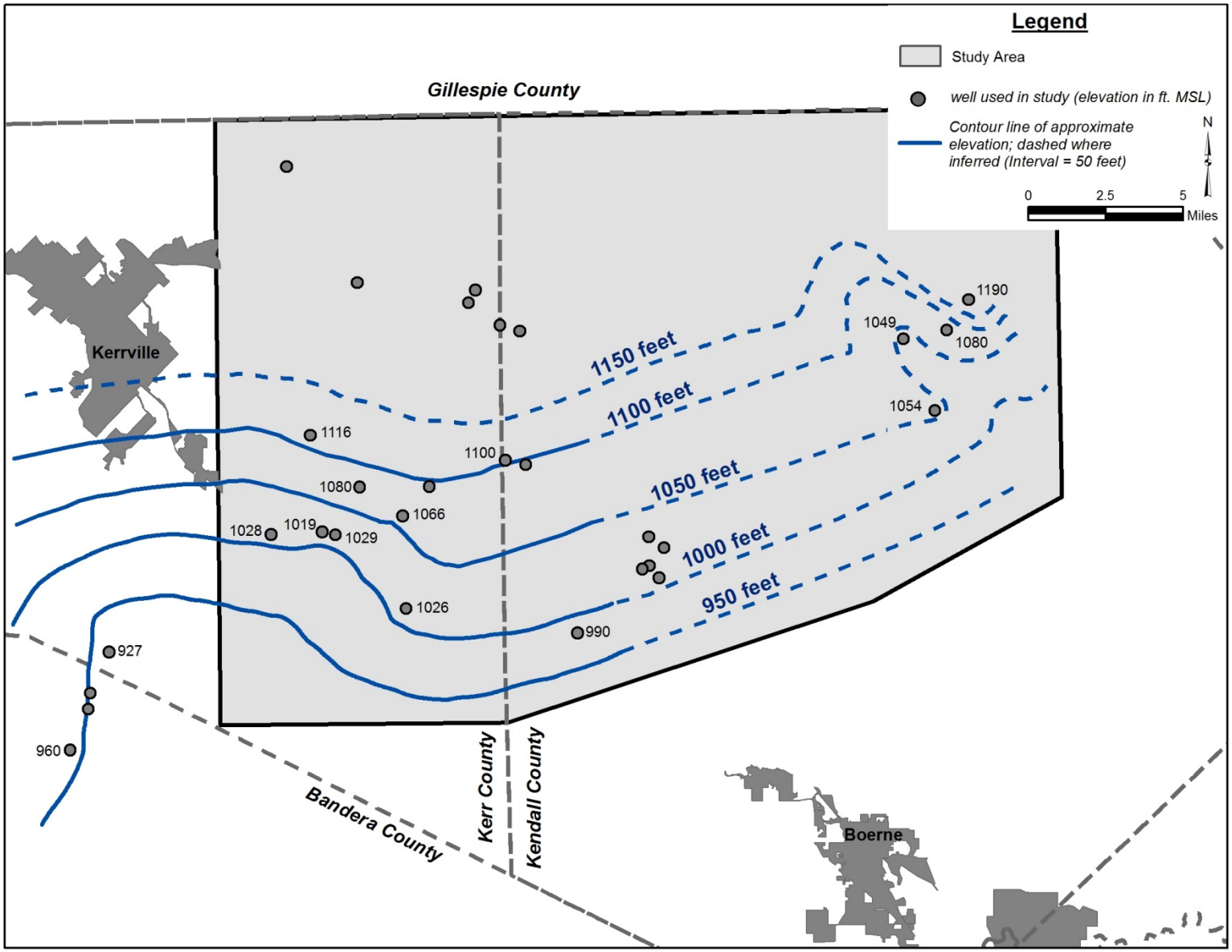

Figure 5: Elevation to the top of the Hosston Member

Figure 4 and Figure 5 provide a contour map of the elevations to the base and top of the Hosston Member which forms the Lower Trinity Aquifer within the study area. As the name suggests, the Trinity Aquifer is a grouping of three aquifers, the Upper, Middle and Lower Trinity. The Lower Trinity Aquifer within the study area is relatively less produced than the more prolific Middle Trinity Aquifer. Located at greater depths, a well completed within the Lower Trinity Aquifer involves greater cost due to the necessity of sealing off the Hammett Clay via casing and cement. The Hammett Clay is located above the Lower Trinity Aquifer and is a heavily sloughing formation which causes difficulty in keeping the well bore open. Within the study area, well yields within the Lower Trinity Aquifer are generally less than 50 gpm however, there are localized areas within the City of Kerrville where Lower Trinity Wells produce in excess of 500 gpm.

Located stratigraphically above the Hosston Sand is the Hammett Clay Member or also known by some as the Pine Island Shale. The Hammett Clay ranges in thickness up to approximately 60 feet within the study area; it is clay rich with some thin limestone beds that form a gradational contact with the Hosston. Color can be dark gray to black, blue, greenish gray and gray. The Hammett is a confining bed separating the Lower Trinity Aquifer from the Middle Trinity Aquifer.

The Cow Creek Limestone Member of the Travis Peak Formation is a massive, fossiliferous limestone and dolomite which contains some interbeds of sand, clay, and evaporite minerals such as gypsum and anhydrite (Preston et. al., 1996). The Cow Creek Limestone can range in thickness up to approximately 80 feet and is typically yellow to gray in color. Based upon drill cuttings from wells completed to the top of the Hammett Clay and from driller's logs within the study area, the Cow Creek Limestone appears to pinch out and is not observed within the study area. The Cow Creek Limestone forms part of the Middle Trinity Aquifer along with the Hensell Sand/Bexar Shale, and the Lower Glen Rose Limestone. It is heavily fractured in some locations and provides large well yields where encountered. The gypsum and anhydrite layers found within some areas of the Cow Creek can be a source of elevated sulfate concentration in wells.

The Hensell Sand Member of the Travis Peak Formation is composed of sand, silt, clay, sandstone conglomerate and thin beds of limestone (Preston et. al., 1996); within the study area, the Hensell Sand is predominately a fine to medium quartz sand. Further south of the study area, the Hensell grades into the Bexar Shale Member which is composed of thin beds of shaley limestone, dolomite and calcareous shale. Within the study area the Hensell Sand is found beneath the Lower Glen Rose and above the Hammett Clay. The Hensell, along with the Lower Glen Rose forms the Middle Trinity Aquifer. Much of the larger yielding Middle Trinity wells produce the majority of their water through the Hensell Sand. Figure 6 provides a contour map of the elevation of the top of the Hensell Sand Member of the Travis Peak Formation within the study area determined from electric logs.

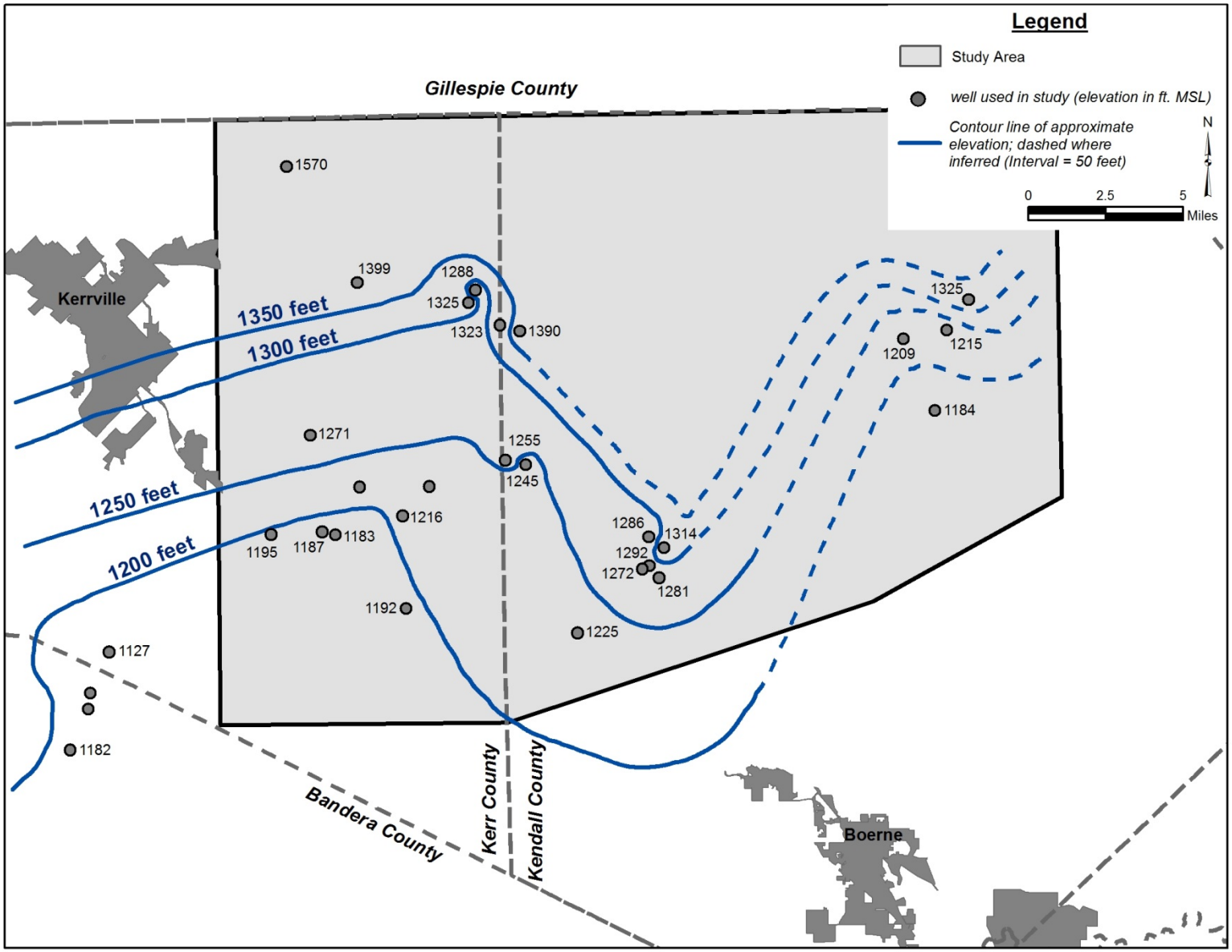

Figure 6: Elevation to the top of the Hensell Sand Member

The Glen Rose Limestone is divided into a Lower and Upper Member; the separation between the two units is marked by the presence of a fossil marker bed called the Corbula Bed. The Corbula bed is a heavily fossiliferous layer that contains the small fossil clam called *Corbula martinae*. The separation between the two units is also distinguishable on electric logs where two distinct evaporite zones are found within the Upper Glen Rose; one midway through the Upper Glen Rose and another near the base shown by resistivity spikes on the electric log. The basal section of the Lower Glen Rose contains massive limestone beds with various degree of fracturing grading up into thinner beds of alternating marly, limestone and dolomite. Near the top of the Lower Glen Rose in some locations is a reef deposit which can range up to 40 feet in thickness that is cavernous and heavily fractured. Where the reef deposit is encountered, the Lower Glen Rose provides high yielding wells with rates exceeding 1,000 gpm. Figure 7 provides a contour map of the elevation of the top of the Lower Glen Rose based upon an analyses of electric logs.

The Cow Creek, Hensell/Bexar Shale and the Lower Glen Rose Members form the Middle Trinity Aquifer. The Middle Trinity Aquifer provides the primary source of groundwater to the study area with some well yields near 1,000 gpm.

The Upper Member of the Glen Rose Formation consists of alternating beds of limestone and dolomite with marly sections forming the characteristic stair step topography of the Upper Glen Rose. The Upper Glen Rose contains thinner beds of limestone and contains two distinct evaporite beds of gypsum or anhydrite which are the source of elevated sulfate concentrations in groundwater. The Upper Glen Rose Limestone forms the Upper Trinity Aquifer, which in some locations provides the primary source of water to stock and domestic wells. Figure 8 provides a contour map of the elevation to the top of the Upper Glen Rose based upon an analyses of electric logs.

Located above the Trinity Group is the Fredericksburg Group which consist of the Fort Terrett and Segovia Members. The Fort Terrett Member contains three sections with the bottom section comprised of a nodular limestone and marly clay (Preston et. al., 1996) which provides a confining bed separating the Upper Trinity Aquifer from the Edwards Plateau Aquifer. The middle section contains chert filled, fossiliferous limestone and dolomite (Preston et. al., 1996) and the upper section contains limestone with collapsed breccia and chert (Preston et. al., 1996).

Above the Fort Terrett stratigraphically lies the Segovia Member of the Fredericksburg Group. The Segovia is divided into a lower section which contains fossiliferous limestone and marly sections, a middle section containing vuggy chert filled dolomite with collapsed breccia and an upper section containing chert filled fossiliferous limestone (Preston et. al., 1996). The Segovia Member together with the middle and upper section of the Fort Terrett forms the Edwards Plateau Aquifer. Within the study area the Edwards Plateau provides groundwater to domestic and stock wells.

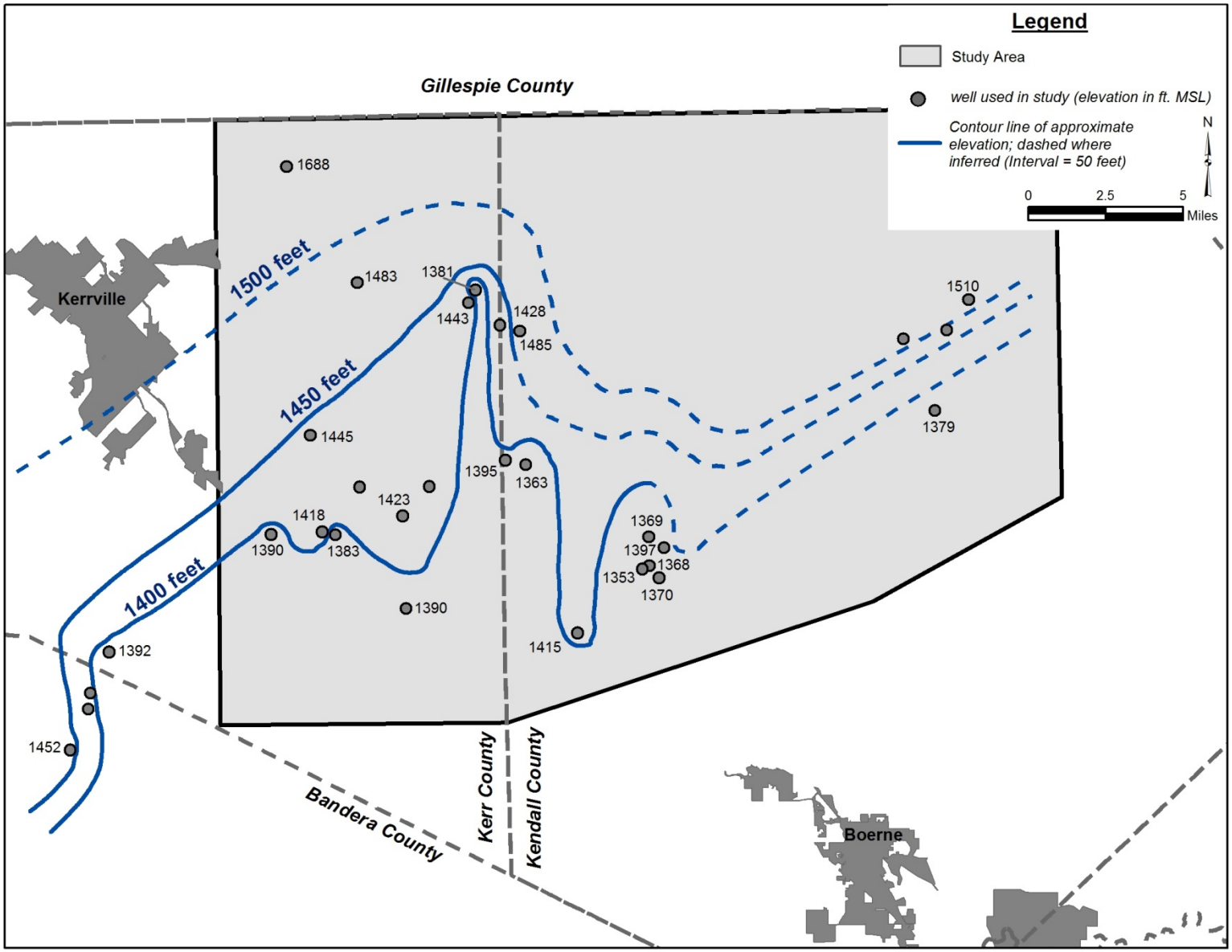

Figure 7: Elevation to the top of the Lower Glen Rose

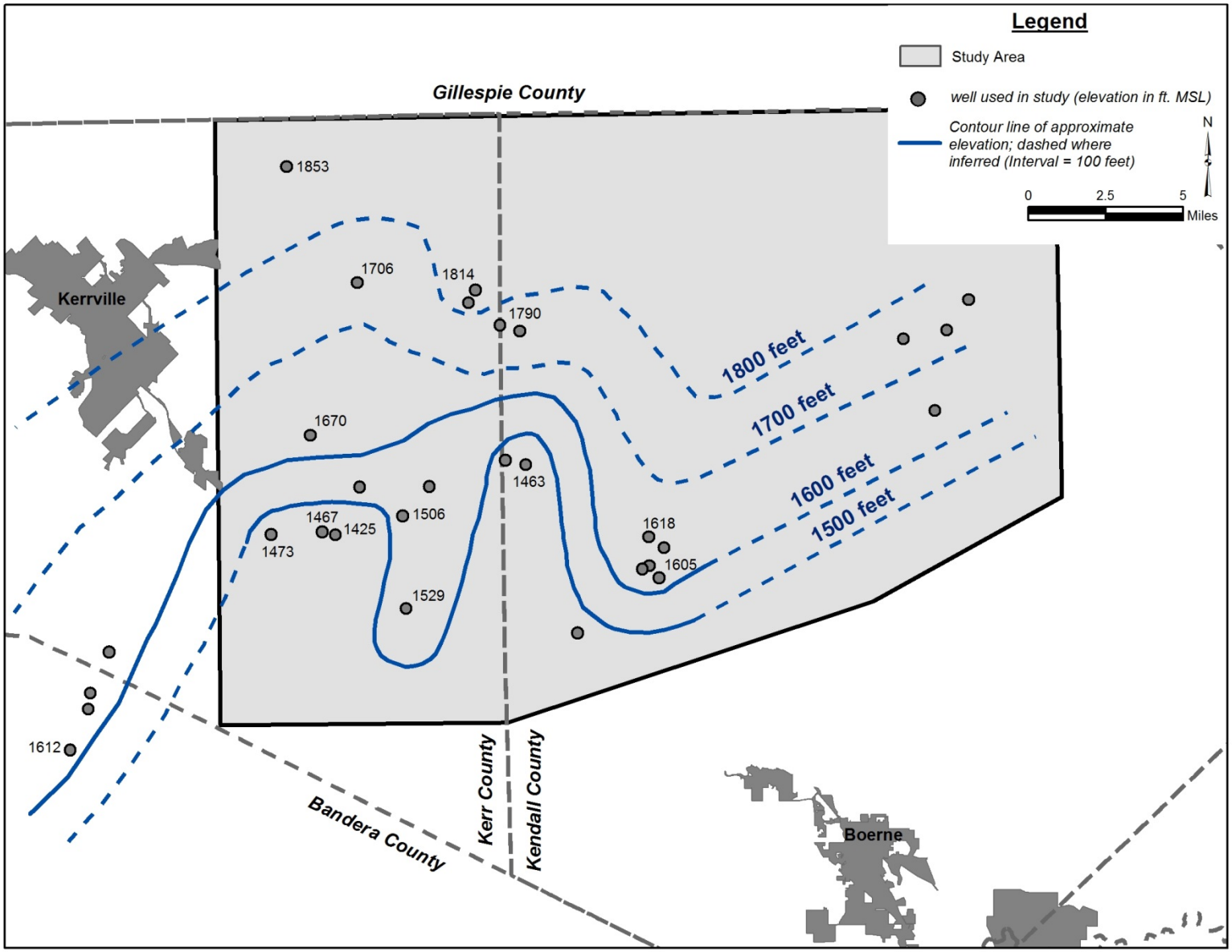

Figure 8: Elevation to the top of the Upper Glen Rose

III.3. Structure

Structurally, the area is dominated by the Llano Uplift, a structural dome of Precambrian igneous granitic pluton that was uplifted during the Ouachita Orogeny causing the surrounding Paleozoic aged rocks to fold and uplift. The uplift, weathering, erosion and subsequent deposition of the igneous and metamorphic sediments from the Llano formed part of the Cretaceous sediments. Figure 9 provides a geologic map of the study area, the Llano Uplift area is shown by the pinkish colored formations shown in Llano and Mason counties. Figure 10 shows the location of three cross sections constructed based upon analyses of electric logs in and near the study area. Figures 11, 12 and 13 include cross sections across the study area.

Another major structural feature that impacts the study area is the Fredericksburg High. The Fredericksburg High is a narrow subsurface ridge of structurally high Precambrian and Paleozoic rocks (Bluntzer, 1992) underlying the Cretaceous Trinity Group that extends southwest from the Llano Uplift through Gillespie County and Eastern Kerr County into Bandera County. This structural features causes the Paleozoic aged rocks to be encountered at lower elevations; a good example is seen in electric logs of wells completed in the Eastern Kerr/Western Kendall County line specifically HGCD MW 3, HGCD MW 14, and Kendall County well Q-17 (Figure 10, 12 and 13). At these locations, the Pennsylvanian System has been eroded away leaving the Cretaceous formations to be deposited on top of the Ellenburger Group.

The overlying Cretaceous rocks exhibit gently dipping beds at approximately 100 feet per mile towards the southeast; below the Paleozoic rocks dip at significantly greater angles also towards the southeast between 400 and 900 feet per mile (Bluntzer, 1992). During the Late Paleozoic to Early Mesozoic faults occurred within the Paleozoic and Precambrian rocks which were subsequently covered by the Cretaceous rocks of the Trinity and Fredericksburg Groups (Bluntzer, 1992). Figure 9 shows the location of the Paleozoic faults taken from Standen and Ruggiero (2007) and Ewing (1991, 2004). The location of these faults by Standen and Ruggiero (2007) and Ewing (1991, 2004) were determined by interpretation of electric logs and other published and unpublished sources (Standen and Ruggiero, 2007). The majority of the Paleozoic faults are normal faults that are steeply dipping and strike northeast-southwest with displacement of formations on either side of the fault (Bluntzer, 1992). Fracture traces commonly mimic the orientation of the faults.

Further to the southeast of the study area the Balcones Fault Zone is seen in Figure 9 running across Hays, Comal, Bexar and Medina counties. The Balcones Fault Zone is a series of normal en echelon faults that trend in a general northeast-to-southwest direction. Faulting in the area associated with the Balcones Fault Zone has caused some rock units to be upthrown against others, creating both barriers to flow and conduits for water to pass through.

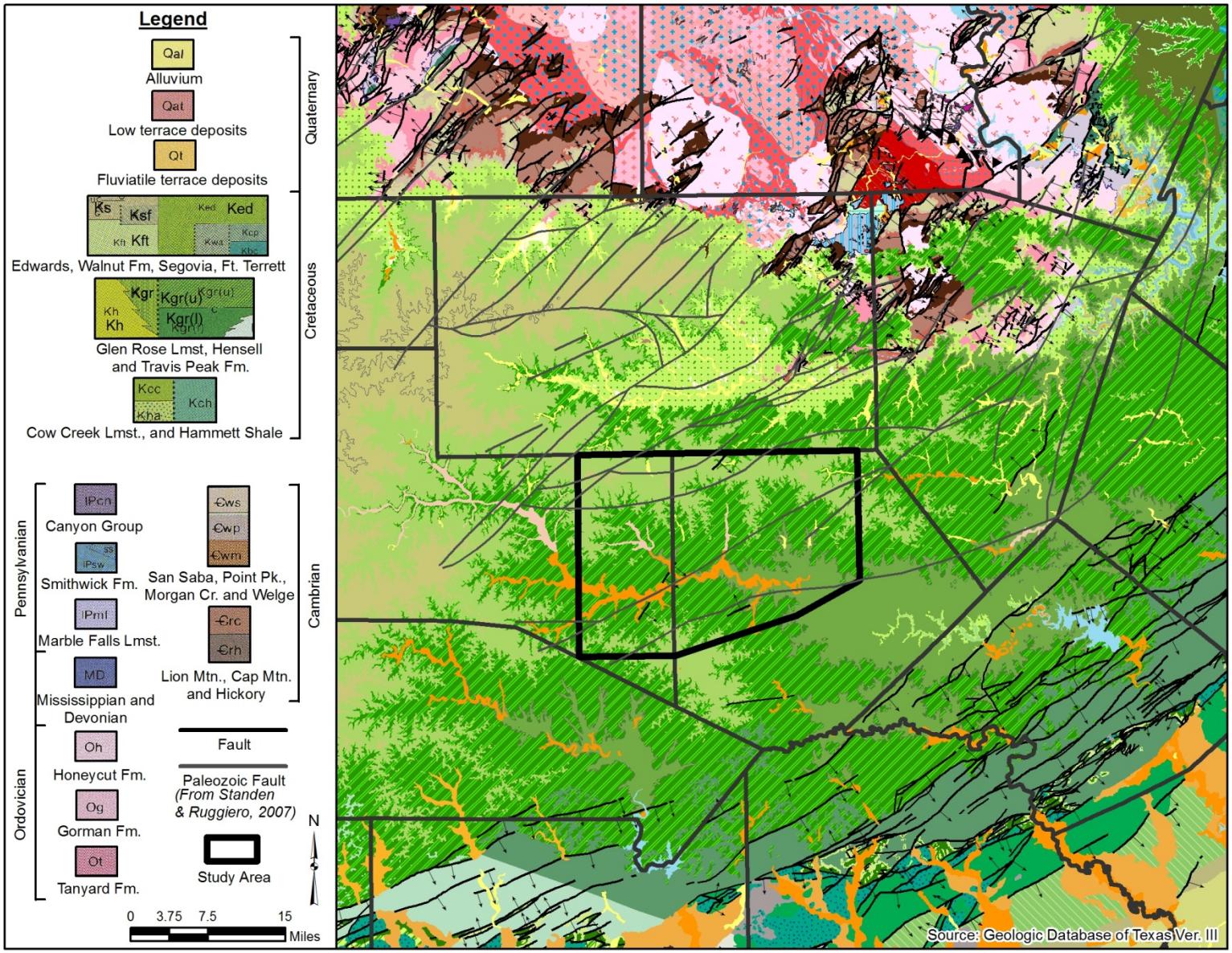

Figure 9: Geologic map of study area

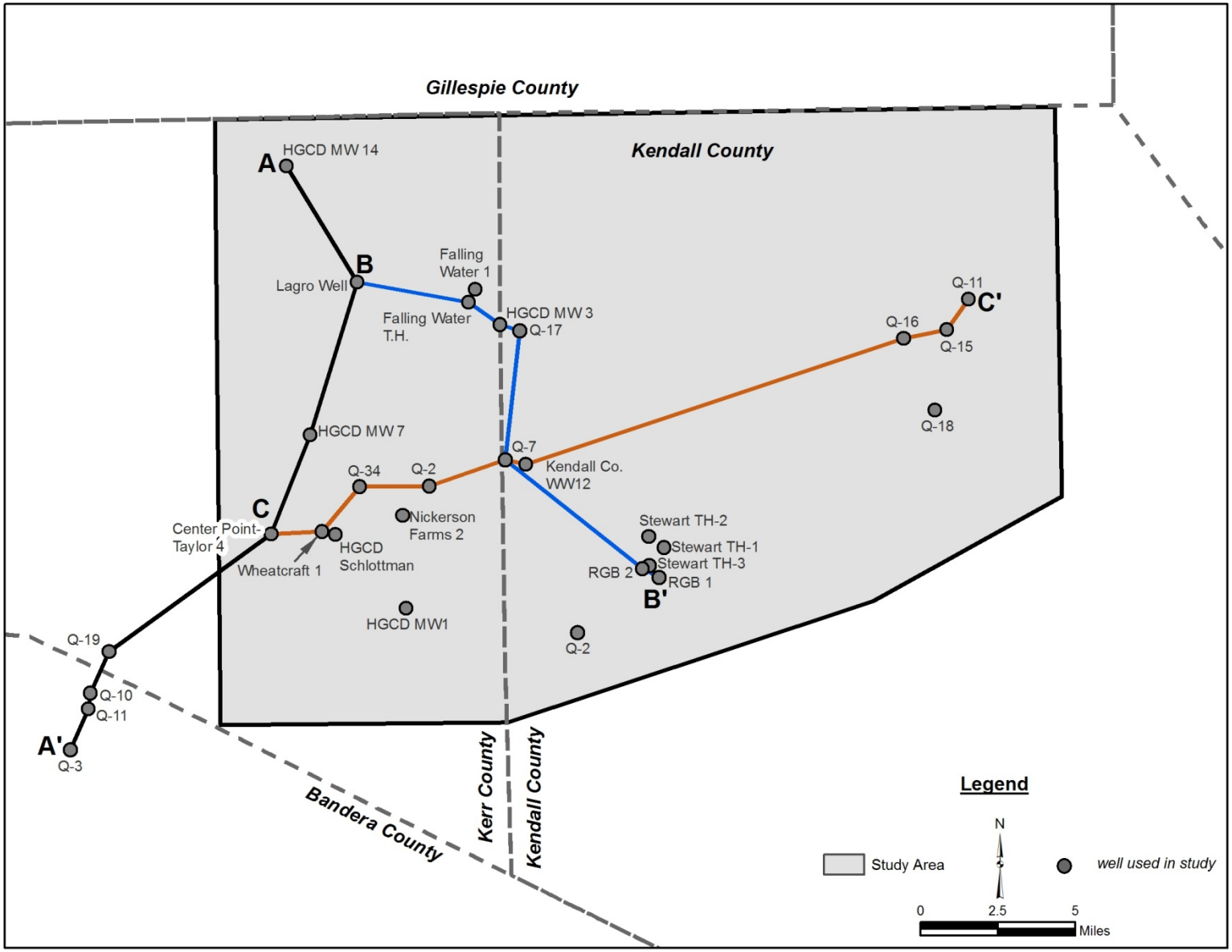

Figure 10: Cross section location map

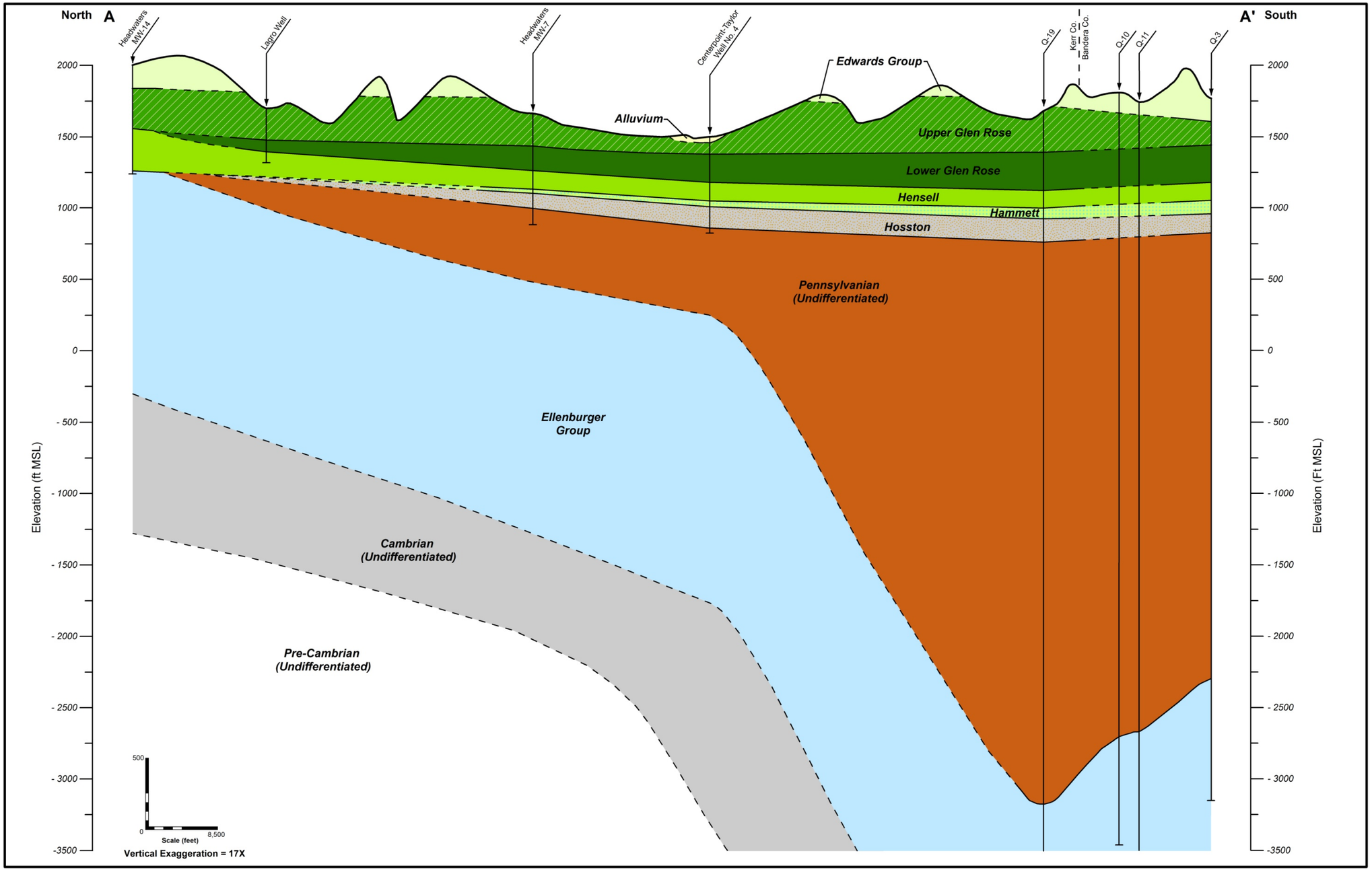

Figure 11: Cross section A – A'

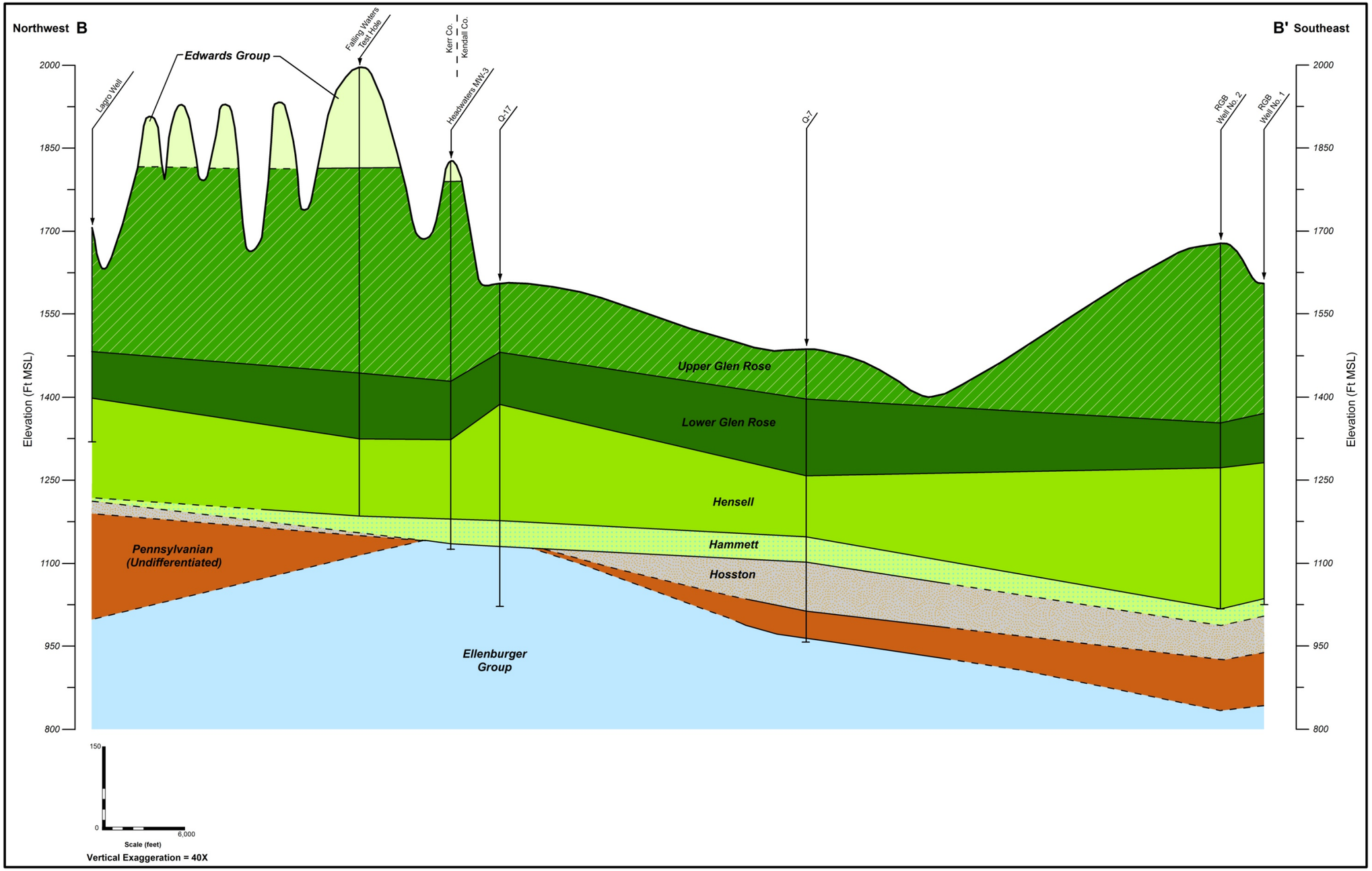

Figure 12: Cross section B – B'

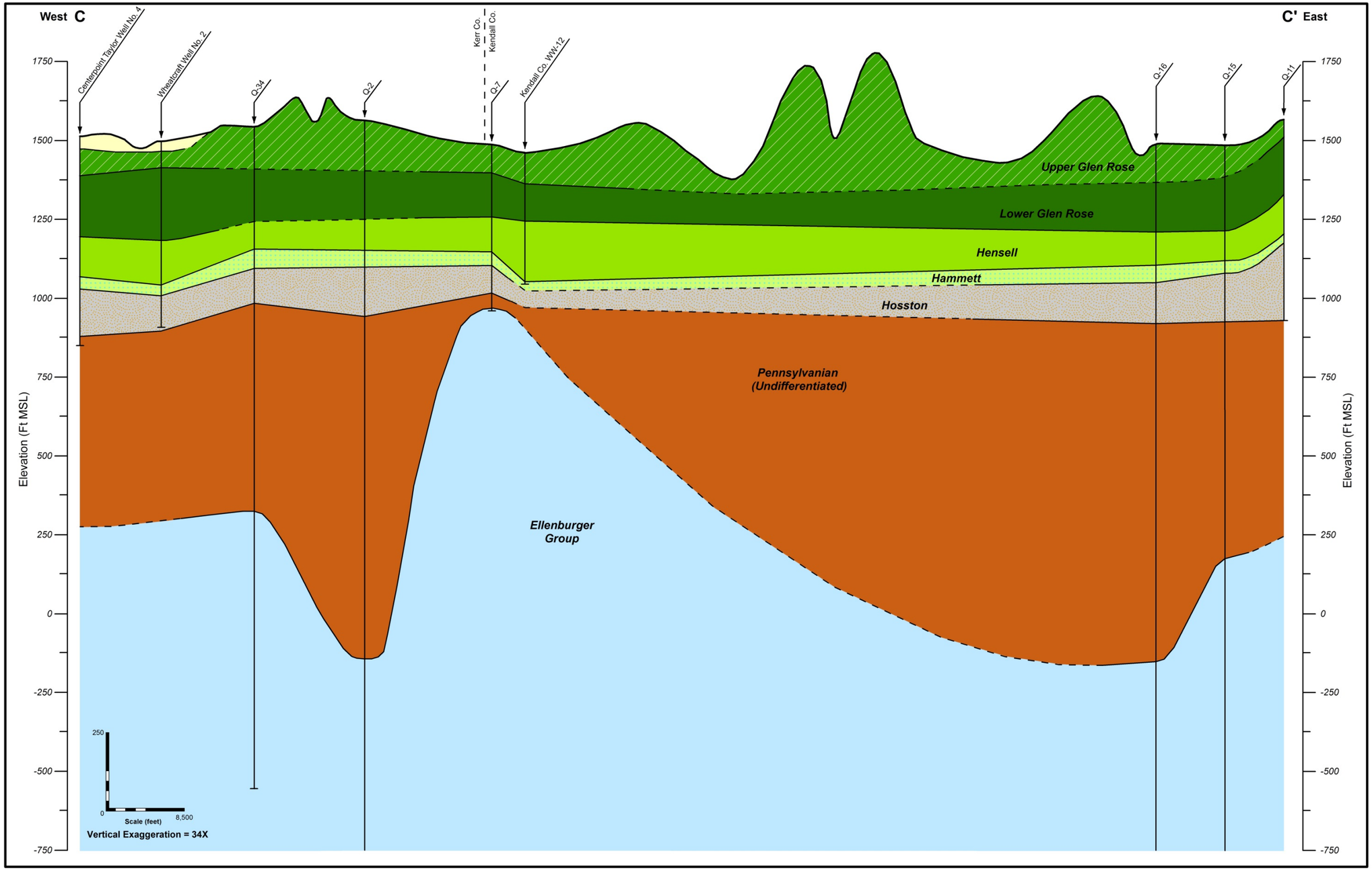

Figure 13: Cross section C – C'

Section IV: Methodology

The elevations to the top of the Upper Glen Rose, Lower Glen Rose, Hensell, Hosston (top and bottom) and the Ellenburger were determined based upon electric logs of wells drilled within the study area and outside of the study area within Bandera County. Electric logs of water wells were provided by the Headwaters Groundwater Conservation District (HGCD), the Cow Creek Groundwater Conservation District (CCGCD) and GeoCam, Inc. The majority of the water well electric logs were of wells completed to the base of the Middle Trinity Aquifer and in some cases to the top of the Ellenburger Group. Gamma, spontaneous potential (SP), single point resistivity, 4-point resistivity, conductivity and caliper logs were included in electric logs conducted on the water wells.

In addition, electric logs of oil and gas wells were obtained through the Railroad Commission of Texas (RRC) for wells completed to at least the top of the Ellenburger Group. In most cases the logs contained a resistivity and SP curve and in other logs gamma and density logs were included.

Each of the electric logs were analyzed and formational tops and bottoms were chosen. The formation tops and bottoms were chosen based upon the following criteria:

- Base of the Edwards Group/Top of the Upper Glen Rose Limestone – The base of the Edwards Group/Top of the Upper Glen Rose includes the basal nodular member of the Fort Terrett Member of the Edwards Group. This is shown within the gamma log by a characteristic grouping of humps with spikes within the gamma log;

- Top of the Lower Glen Rose Limestone – The top of the Lower Glen Rose is characterized by the presence of the Corbula bed and an evaporite bed which shows an elevated resistivity spike coupled with a decrease in the gamma count;

- Top of the Hensell Sand – The Hensell Sand forms a gradational contact with the base of the Lower Glen Rose Limestone and is observed from drillers logs and cuttings by the presence of sand to sandy limestone. It is observed on the gamma and resistivity logs by a decrease in the gamma count coupled with an increase in the resistivity;

- Top of the Hammett Clay – The Hammett Clay is a good stratigraphic correlation surface seen easily in drill cuttings and the electric log. The Hammett Clay forms a gradational contact with the Hensell Sand within the study area. It is observed in drill cuttings by the presence of a gummy clay to clay and within the gamma log and resistivity log by a sharp increase in gamma coupled with a sharp decrease in resistivity;

- Top of the Hosston Sand – The top of the Hosston Sand is distinguished within the gamma and resistivity log by an decrease in gamma count coupled by an increase in resistivity;

- Bottom of the Hosston Sand – The base of the Hosston Sand within the study area is commonly marked by the top of the Pennsylvanian System which contains a hard shale surface. This is seen on electric logs by a sharp increase in gamma count coupled by a sharp decrease in resistivity. Where the Pennsylvanian is not present, the Ellenburger Group is observed at the base of the Hosston Sand in Eastern Kerr County; and

- Top of the Ellenburger Group – The top of the Ellenburger Group is found within the study area beneath either the Hosston Sand due to the Fredericksburg High, the Marble Falls Limestone where the Mississippian and Devonian System is not present or beneath the Mississippian and Devonian System. The top of the Ellenburger is characterized in electric logs by a decrease in the gamma count and a sharp increase in resistivity.

Section V: Alternative Water Source within Study Area

V.1. Introduction

The need for additional water supply to the Eastern Kerr/Western Kendall area has been documented through the regional water planning process. Studies conducted for this region have recognized the variability of water available from the Guadalupe River and long term reliability of water from the Middle Trinity Aquifer to meet future growth in the area. To be able to meet projected water demand and to allow for diversification of the area's water resources, stakeholders have identified four potential water resources for further evaluation. These include: 1) the availability of water rights held by the Upper Guadalupe River Authority (UGRA) and Kerr County; 2) alternative groundwater sources such as the Ellenburger Aquifer; 3) groundwater desalination; and 4) ASR.

This section will review two of the options in the context of the geology of the area; Ellenburger Aquifer as an alternate groundwater resource and the Lower Trinity Aquifer targeted as an option for ASR.

V.2. Ellenburger – San Saba Aquifer

The Ellenburger – San Saba Aquifer is considered a minor aquifer by the TWDB with a thickness that ranges up to 2,400 feet. The formations which comprise the aquifer were deposited around the Llano Uplift and dip radially in all directions. Groundwater is produced in wells which transect fractures within the Ellenburger – San Saba Aquifer and well yields are variable depending upon fracture connectivity and faulting with well yields up to 1,000 gpm observed in some counties. Regional faults have compartmentalized the aquifer which restrict groundwater flow in some areas and increased production in other portions of the aquifer.

Based upon the electric logs analyzed in this study, the depth to the top of the Ellenburger Group (Figure 3) varies greatly from north to south going downdip and within the Fredericksburg High (Figures 11, 12, 13 and 14). Figure 14 provides a location map of the aquifers within the study area from the TWDB, in addition to the inferred location of the Fredericksburg High by Bluntzer (1992). The exact location of the Fredericksburg High is uncertain however electric logs from the HGCD MW 3, HGCD MW 14 and Q-17 (Kendall County) indicate that these wells encountered the Ellenburger Group at a shallower than expected depths potentially due to the Fredericksburg High.

Criteria for test well locations to evaluate the Ellenburger – San Saba Aquifer as a potential alternative water source should include the following:

- Areas where fresh water is most likely to be encountered;
- Areas where higher yielding wells would be encountered; and
- Areas where the Ellenburger Group is located at shallower depths to limit construction costs.

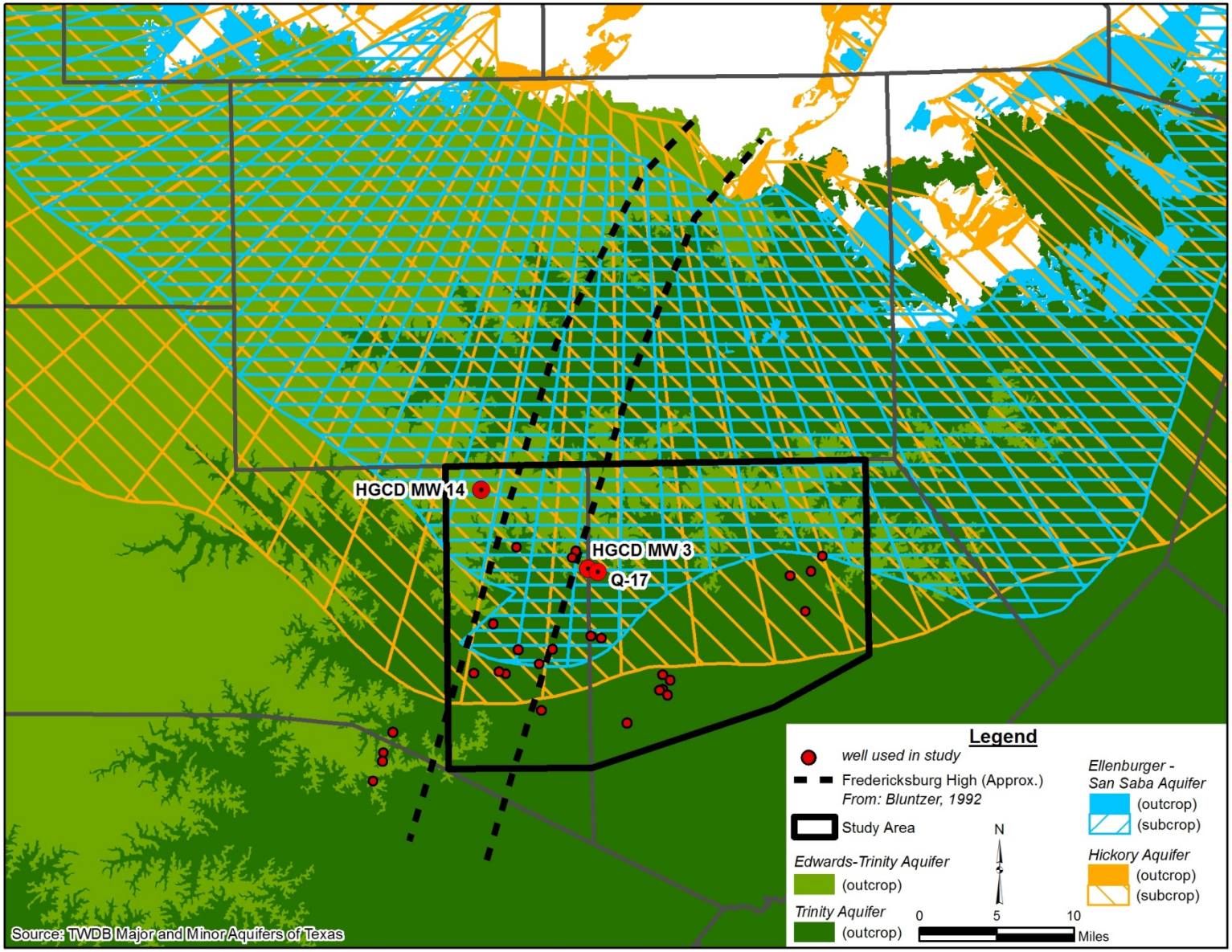

Figure 14: Alternative water sources within the study area

Based upon the criteria, test well locations updip within the northern 1/3 section of the study area and/or within the Fredericksburg High would provide the best opportunity for further study and evaluation.

V.3. ASR - Lower Trinity Aquifer

ASR is the storage of either surface water or groundwater into an aquifer during times of excess water for recovery through a well during times of need or drought. ASR has been utilized in the City of Kerrville since the 1990s with excess surface water from the Guadalupe River being pumped into wells completed within the Lower Trinity Aquifer.

The Lower Trinity Aquifer has been identified as a potential aquifer for use in ASR for the Eastern Kerr/Western Kendall area. The Middle Trinity Aquifer provides the majority of groundwater for the study area with relatively little production within the Lower Trinity Aquifer. The Lower Trinity is composed of the Hosston Sand and its thickness varies within the study area between 87 feet at well Q-7 (Kendall County) and 272 feet thick at well Q-2 (Kendall County). It is also nonexistent at wells Q-17 (Kendall County), HGCD MW 3 and HGCD MW 14, possibly due to the Fredericksburg High. Figure 15 provides a contour map of the thickness of the Lower Trinity Aquifer.

The Lower Trinity is separated from the Middle Trinity Aquifer by the Hammett Clay. The Hammett Clay is present throughout the study area but thins out north of the City of Kerrville where there can be some hydraulic communication between the Middle Trinity and the Lower Trinity. In the City of Kerrville, the ASR wells completed within the Lower Trinity Aquifer produce at rates in excess of 500 gpm up to near 1,000 gpm. Elsewhere, within Kerr and Kendall Counties, Lower Trinity wells have lower transmissivities and generally produce at rates less than 50 gpm.

A good candidate for a target aquifer used in ASR would include a formation(s) that can both produce the required quantity of water necessary for the project as well as accept the required injection rates of stored water. This storage of injected water will produce a cone of inversion for use at a later point in time when additional water is required for the project.

Within the Lower Trinity Aquifer further study should concentrate around areas where the Hosston Sand produces at larger production rates and thereby has higher transmissivities in addition to areas where the Hosston is thicker. Based upon the data collected in this study, the Hosston is thickest at wells further away from the Fredericksburg High and downdip within the aquifer near the southern boundary of the study area. This includes the area northwest of the City of Boerne, within the City of Kerrville and southeast of the City of Kerrville near the Bandera County line. There is limited data in the north-central and southeast section of the study area which limits the ability to identify thicknesses of the Hosston.

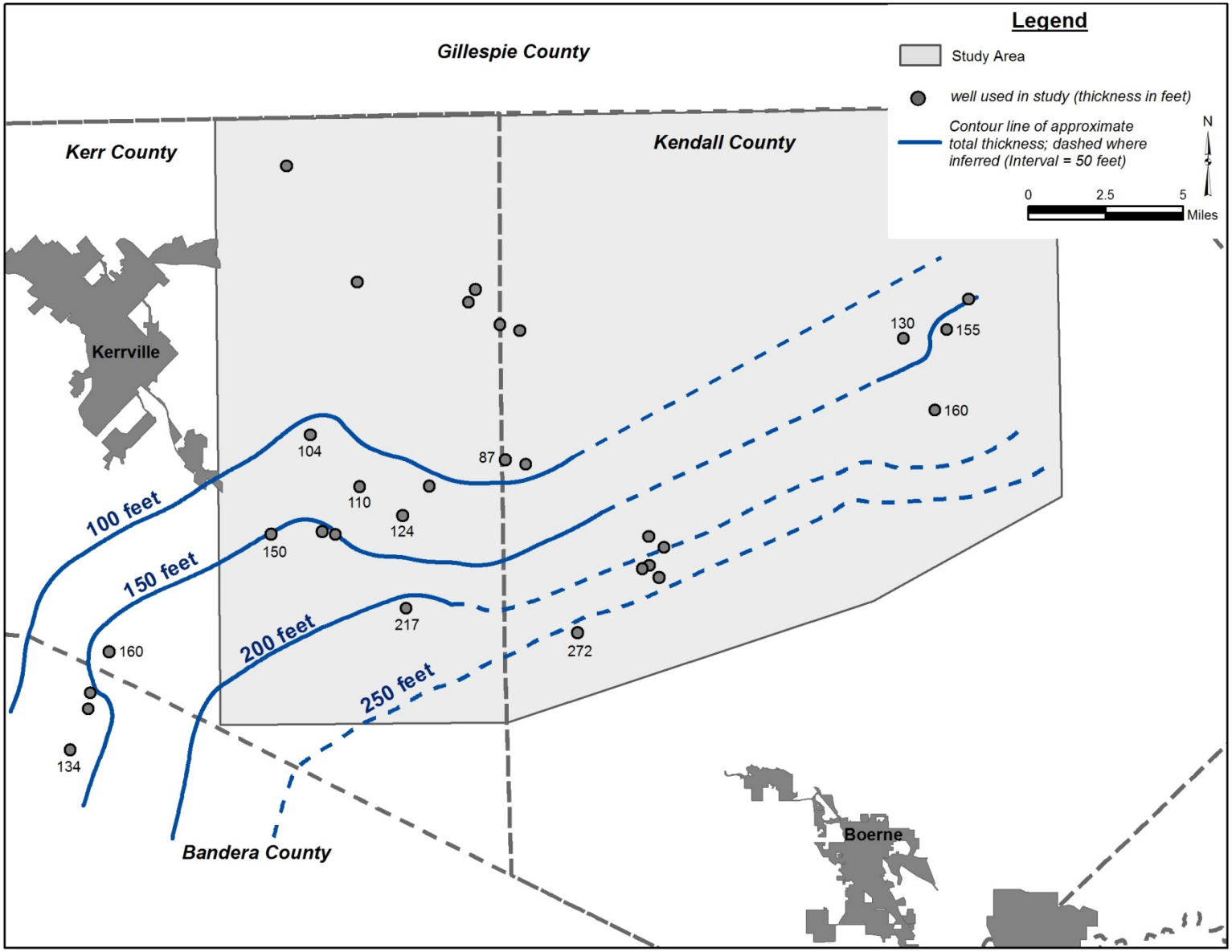

Figure 15: Total thickness of the Lower Trinity Aquifer

Section VI: Conclusions

The Texas Water Development Board has awarded a grant to develop a regional solution to water needs in Kerr and Kendall counties. As a part of the larger grant study, this report describes the geology of the study area which encompasses Eastern Kerr/Western Kendall counties. The goal of this study is to provide a preliminary review of the Lower Trinity Aquifer as a potential target for a regional Aquifer Storage and Recovery project as well as utilizing the Ellenburger Aquifer as an alternative source of water for the area.

The objectives of this study were to analyze geophysical logs to delineate the Edwards Group (Segovia and Fort Terrett), Upper and Lower Glen Rose Limestone, Hensell Sand, Hammett Shale, Hosston, Pennsylvanian aged deposits and the Ellenburger Group and to develop maps showing the elevation to the tops of the these formations. In addition, cross sections were developed detailing the geology of the region.

The conclusions from this study are:

- Structurally, the area is dominated by the Llano Uplift, a structural dome of Precambrian igneous granitic pluton that was uplifted during the Ouachita Orogeny causing the surrounding Paleozoic aged rocks to fold and uplift. Another major structural feature that impacts the study area is the Fredericksburg High. The Fredericksburg High is a narrow subsurface ridge of structurally high Precambrian and Paleozoic rocks underlying the Cretaceous Trinity Group that extends southwest from the Llano Uplift through Gillespie County and Eastern Kerr County into Bandera County;

- The elevation of the top of the Ellenburger Group ranges from a high of 1,272 feet MSL within the northern portion of the study area in Kerr County to a low of -3,173 feet MSL just southwest of the study area. Structural features such as Paleozoic faults and the Fredericksburg High affect the total depth to the Ellenburger Group. The Fredericksburg High, located approximately NE to SW along the eastern portion of the study area, has pushed up the Ellenburger Group causing it to be encountered at shallower elevations;

- The need for additional water supply to the Eastern Kerr/Western Kendall area has been documented through the regional water planning process. To be able to meet projected water demand and to allow for diversification of the area's water resources, stakeholders have identified alternative groundwater sources such as the Ellenburger Aquifer and ASR using the Lower Trinity Aquifer;

- Based upon the electric logs analyzed in this study, the depth to the top of the Ellenburger Group varies greatly from north to south going downdip and within the Fredericksburg High. The electric logs of three wells analyzed as part of this study (HGCD MW3, HGCD MW 14 and Q-17 (Kendall County) have encountered the Ellenburger Group at a shallower than expected depth potentially due to the Fredericksburg High. Test well locations updip within the northern 1/3 section of the study area and/or within the Fredericksburg High would provide the best opportunity for further study and evaluation; and

- The Lower Trinity is composed of the Hosston Sand and its thickness varies within the study area between 87 feet at well Q-7 (Kendall County) and 272 feet thick at well Q-2 (Kendall County). It is also nonexistent at wells Q-17 (Kendall), HGCD MW 3 and HGCD MW 14, possibly due to the Fredericksburg High. Within the Lower Trinity Aquifer further study should concentrate around areas where the Hosston Sand produces at larger production rates and thereby has higher transmissivities in addition to areas where the Hosston is thicker. Based upon the data collected in this study, the Hosston is thickest at wells further away from the Fredericksburg High and downdip within the aquifer near the southern boundary of the study area. This includes the area northwest of the City of Boerne, within the City of Kerrville and southeast of the City of Kerrville near the Bandera County line.

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