Geophysical Signature of Haby Crossing Fault and Its Implication on Edwards Recharge Zone, Medina County, Texas

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Introduction

Resistivity imaging, natural potential (NP), ground conductivity and magnetic surveys were conducted across the Haby Crossing fault, which is located in eastern Medina County of San Antonio (Figure 1). The study area is within the Balcones Fault Zone and is limited between CPS Energy's new proposed transmission line of pole locations 80 and 82 (Figure 2).

In general, it is known that most fault deformation in the Balcones Fault Zone increases permeability within and near faults in all stratigraphic horizons with the exception of clay or shale smear (Ferrill et al. 2008). This is borne out by the common occurrence of dissolution features associated with faults (Ferrill et al. 2003) and the importance of faults as recharge features (Clark, 2000). The goal of this study is to characterize the Haby Crossing fault in terms of its dissolution features, permeability, and mineralization content and as well as its faulting signature.
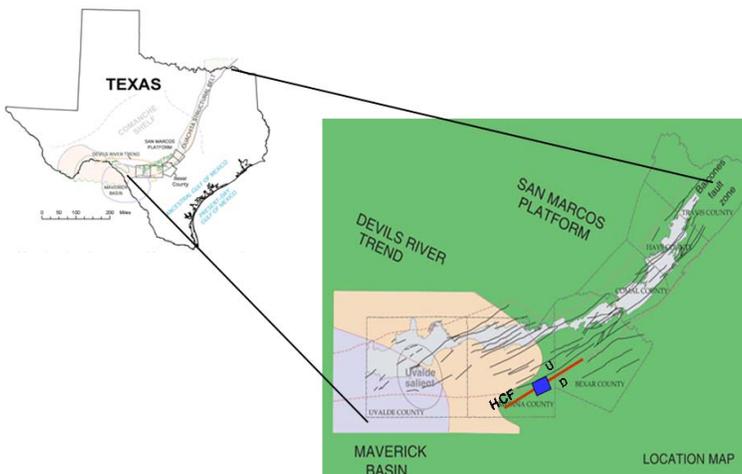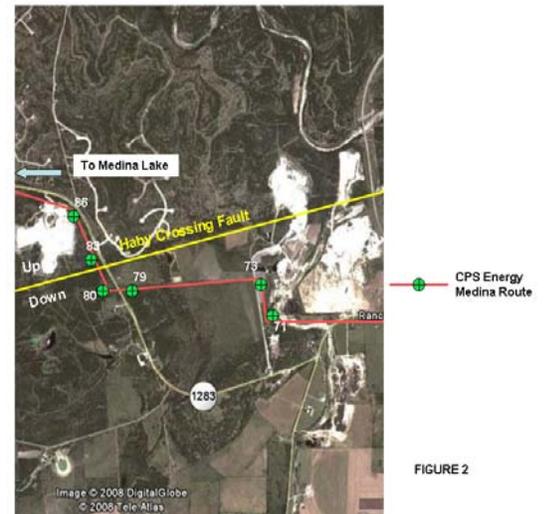

FIGURE 1

FIGURE 2

Objective

The purpose of the geophysical study is to characterize the subsurface geology down to 100 feet or more, and to determine locations of karst anomalies (caves, subsidence, conduits, faults/fractures) on either side (up and downthrown) of the Haby Crossing fault.

Geophysical surveys (resistivity imaging, natural potential, conductivity and magnetic) were performed along a profile across the Haby Crossing fault, which is located in south south-east of Medina County, Texas. The fault is located within a new transmission route that CPS Energy is

currently constructing (Figure 2). We should mention that we performed geophysical surveys, prior to this work, along the transmission line to determine locations and depth of voids beneath the proposed pole locations. In this way, pole locations can be relocated if necessary to reduce the potential for the construction to impact threatened or endangered species and to locate more competent limestone to seat the pole footings.

Site Geology

   The geology along the CPS Energy's proposed route consists of Upper and Lower Cretaceous-age limestone formations that are structurally influenced by numerous en echelon normal (extensive) faults located within the Balcones Fault Zone. This fault zone is a 25- to 30-km –wide en echelon system of mostly south-dipping normal faults that formed during the middle to late Tertiary. The Balcones Fault Zone includes the Edwards and Trinity Aquifers, which both are primary sources of water for south-central Texas communities, including the city of San Antonio (Ferrill et.al, 2008). The Trinity Aquifer underlies the Edwards Aquifer through the Balcones Fault Zone.

   A detailed geological study by Small and Clark, 2000 shows that the study area for the geophysical work includes the geological units of Eagle Ford Group of Upper Cretaceous and Dolomitic Member of Kainer Formation of Lower Cretaceous (Figure 3). The Lower Cretaceous unit of Kainer Formation of the Edwards Group is known to be karstified, faulted limestone (Stein and Ozuna, 1996).

EXPLANATION

Upper Cretaceaus of Eagle Ford Group

Lower Cretaceous of Kainer Formation

Location of Geophysical Profile

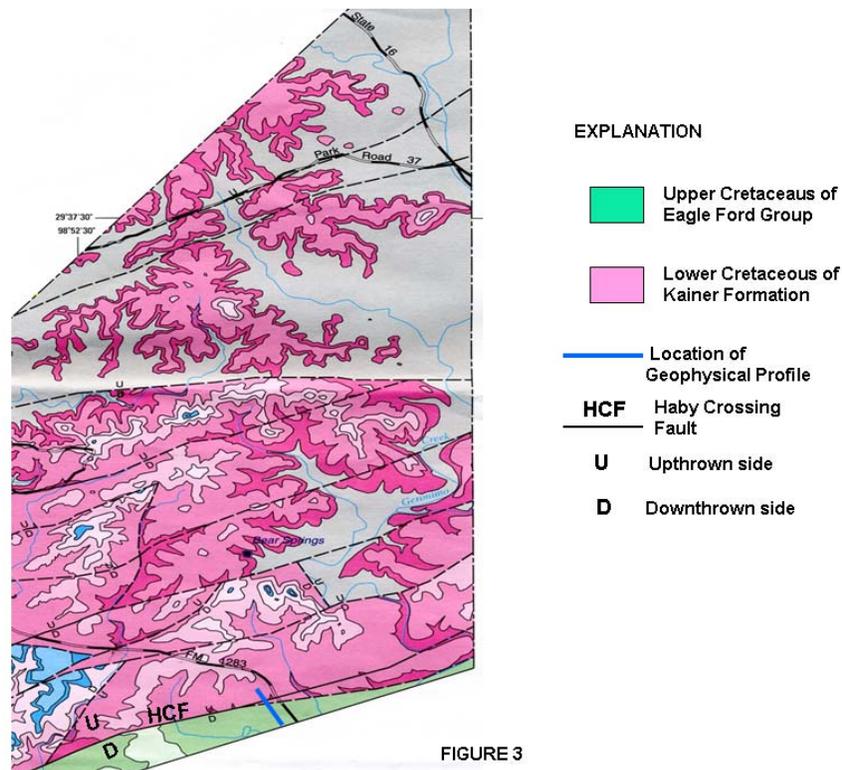HCF Haby Crossing Fault

U Upthrown side

D Downthrown side

FIGURE 3

The Haby Crossing fault, which is located within the proposed route of the CPS Energy power line, has more than 300+ feet displacement along its entire length (Small and Clark, 2000). As a result, the Trinity Aquifer is juxtaposed with the Edwards Aquifer along the fault. The location of geophysical profile is shown in Figure 3. Two field pictures of the study area are shown in Figures 4 and 5.

FIGURE 4

FIGURE 5

Geophysical Methods
Resistivity Imaging (AGI's Sting/Swift System)

Electrical resistivity imaging is a subsurface imaging technique, which aims to build up a picture of the electrical properties of the subsurface by passing an electrical current along electrodes and measuring the associated voltages. This technique has been used widely in determining karst features, such as voids, caves, and faults/fractures, etc.

In this study, we used an AGI's Super Sting/Swift system and employed a dipole-dipole resistivity technique with 28 electrodes, which is more sensitive to horizontal changes in the subsurface, and provides a 2-D electrical image of the near-surface geology.

Natural Polarization (NP)

Natural electrical (NP) currents occur everywhere in the subsurface. In karst investigations we are concerned with the unchanging or slowly varying direct currents (d.c.) that give rise to a surface distribution of natural potentials due to the flow of groundwater within permeable materials. Differences of potential are most commonly in the millivolts range and can be detected using a pair of non-polarizing electrodes and a sensitive measuring device (i.e. a voltmeter). It should be noted that water movement should be present within a cave in order to determine a void or cave location. A cave without the water seepage can not be detected by the NP method. Positive and negative NP values are attributed to changes in geometry of voids as well as variations in flow conditions. The source of NP anomalies can be also due to changes in topography, changing soil and rock conditions.

There is no commercially available NP device in the geophysical market. For this reason, we fabricated a NP system to use in this study. The NP unit consists of a voltmeter, copper-sulfide

electrodes, and 3000 feet of wire on a reel.

Ground Conductivity Meter (EM-31)

Ground conductivity surveys were conducted using a Geonics model EM-31 instrument. The EM-31 unit is a one-man unit with an intercoil spacing of 12 feet, which has an effective depth exploration of up to 20 feet, depending on the conductivity of the subsurface soil and/or rocks. It measures conductivity contrast of the subsurface geology and its unit is milliSiemen/meter (mS/m).

Magnetometer (G-858)

Instrumentation used for the magnetic survey was a G-858 cesium magnetometer. It measures earth's magnetic field, and thus can detect ores, faults, fractures, caves containing ferrous minerals, etc., in the subsurface. Its unit is nanoTesla (nT). Its sensitivity is about 0.1 nT.

Field Work and Survey Design

We performed resistivity imaging, NP, conductivity, and magnetic surveys across the Haby Crossing fault. The length of the profiles varied between 1550 to 1650 feet.

First we collected ground conductivity and magnetic data as reconnaissance surveys for the study area. We collected continuous conductivity and magnetic data along the profile. We established a magnetic base station in the middle of the site where there were no ferrous sources affecting the magnetometer. We occupied the base station before and after the magnetic survey, in order to correct for the earth's magnetic field diurnal variations. The magnetic survey lasted 16 minutes; however, we did not observe any magnetic drift, thus no correction was applied to the data.

We collected roll-along resistivity data across the Haby Crossing fault. We used 2 resistivity cables, each cable having 14 electrodes with 20-feet electrode spacing. After the initial section of resistivity data was collected, the first cable of 14 electrodes was moved ahead of the survey line. This process was continued until all data along the desired length were collected. The data from the roll along can be combined into a single apparent-resistivity data set during processing. Appropriate quality assurance/quality control procedures such as testing contact resistance before data collection, was performed for each segment of each profile. Contact resistance measures the resistance to current flow at electrodes caused by imperfect electrical contact with the earth. Poor data quality or anomalous data can result from high or highly variable electrode contact resistance along a profile. To decrease the effect of contact resistance along each profile, we added a saltwater solution to each electrode before the contact resistance test was performed.

This resistivity survey design penetrated down to 125 feet depth along the profile. However, the depth of exploration was reduced on either side of the pole location due to reasons inherent in the resistivity imaging.

We utilized the "short-line" NP method, in which differences of electrical potential are measured between a base electrodes planted in the soil and a roving electrode sampling along the entire resistivity profile, which included the locations of CPS Energy's proposed poles 80, 81 and 81. Readings were made in shallow holes in soil at stations separated by 20 feet by utilizing standard copper/copper sulfate 3-inch-diameter non-polarizing electrodes with a Fluke Model

high-impedance multimeter connected through a reel of 14-gauge wire. Three readings in each hole were averaged to characterize voltage at each station. In addition, three holes within 2 feet of the base electrode were sampled repeatedly at the beginning and end of the profile in order to measure the voltage drift in the ground and in the electrodes caused by solar heating and cooling during the day.

Data Preparation and Processing

Resistivity imaging data are presented as a colored 2-D electrical image of subsurface (i.e. a vertical cross section of the distribution of subsurface resistivity). Such a display section indicates low, medium, and high resistivity areas and the structural configuration of the subsurface geology. A topographic correction was applied to the resistivity data entire profile. It should be mentioned that the resolution of resistivity data obtained in this study is such that only voids of 10 feet or larger can be identified.

Resistivity data were processed and inverted using the AGI 2D Earth Imager software. The following color code for 2D resistivity sections was used: high resistivity (low conductivity) is displayed in red color whereas low resistivity (high conductivity) is represented by blue color.

The NP data were processed using a software program that was written by EGA. Drift corrections were applied to raw NP field data before generating the NP profiles. NP profiles were constructed as horizontal distance versus milliVolt values. Geosoft Mapping Software was used to process and interpret the ground conductivity and magnetic data. Both data sets were filtered using a low-pass filter to eliminate the high frequency (noisy) data. The presentation of the magnetic and conductivity data is given in profile format to show the background and anomalous locations.

Interpretation of Geophysical Data

Interpretation of resistivity, ground conductivity, magnetic and natural potential data are discussed below. CPS Energy's proposed pole locations 80, 81 and 82 are shown on the geophysical profiles (Figures 6 through 9). Fault locations and geological information along the profiles are also displayed for reference purposes.
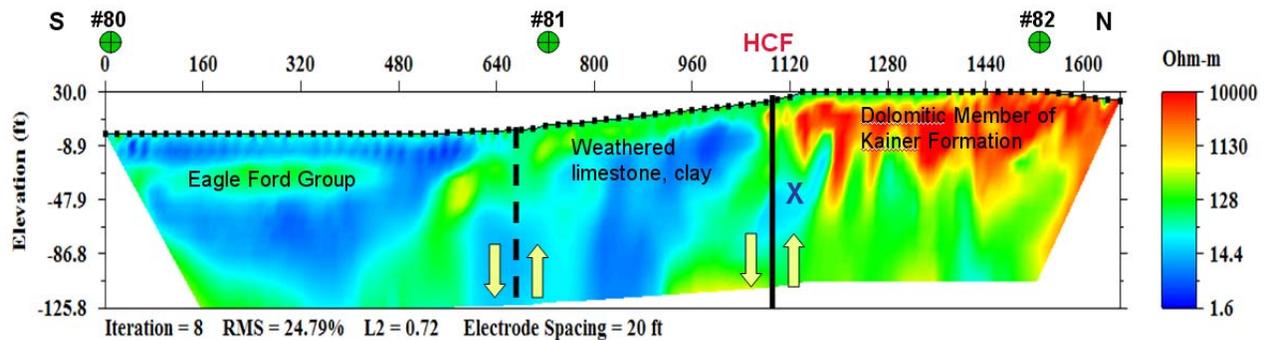

FIGURE 6

Resistivity Imaging Data

In our interpretation, we used resistivity imaging data to identify areas of subsidence or depression where lower-resistivity materials breaches into the bedrock. These areas appear to be associated with the fracturing and weathering process, and thus, may indicate the presence of potential dissolution features. The limestone bedrock is assumed to have resistivities higher than 1000 Ohm-meter. Fractured, weathered and soil-filled limestone is considered to have resistivities of 50 and less than 50 Ohm-meter. The ground resistivity is related to various geologic parameters such as the mineral and fluid content, porosity, degree of fracturing, and faulting.

Figure 6 shows the resistivity imaging data taken across the Haby Crossing Fault. Based on the geological information provided by Small and Clark, (2000), we identified the geological units present in the field and labeled them on the resistivity data.

The resistivity values of geological units along the profile vary between 2 and 10,000 Ohm-m. The depth of exploration of resistivity data varies between 100 and 125 feet. The resistivity data indicates two faults locations at 680 and 1080 feet, respectively. Location of the first fault along the resistivity profile corresponds to where the Eagle Ford Group rocks are present. The resistivity values of these rocks vary from 2 to 150 Ohm-m, which corresponds to clay and weathered limestone. The second fault, which is the Haby Crossing fault, juxtaposes the Eagle Ford Group with the Dolomitic member of Kainer Formation. The Dolomitic Member appears to consist of two types of limestone as far as their resistivity values are concerned:

1) Resistivity values with 500 to 10,000 Ohm-m, which are displayed with yellow and red colors on the resistivity imaging profile; 2) resistivity values with 50 to 500 Ohm-m, which are shown with the green color. It should be noted that the contact surface between the high and low resistivity limestone layers of Kainer Formation have a very irregular geometry, which may be caused by the tectonic and/or weathering activity.

There is a very low-resistivity anomaly (i.e., 2 to 10 Ohm.m) to the north of the Haby Crossing fault breaching into the higher resistivity limestone layers. This low-resistivity anomaly, which is shown with a letter "X," may be caused by a clay-filled void or cave.

Ground Conductivity Data

A ground conductivity profile across the Haby Crossing fault is shown in Figure 7. There are
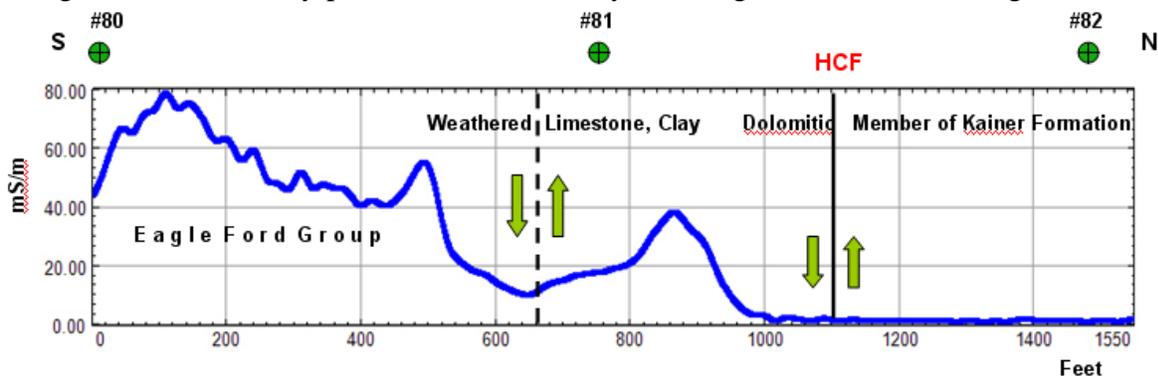

FIGURE 7

conductivity highs (up to 80 mS/m) and lows (down to 15 mS/m) between stations 0 and 1000 feet, which correspond to locations of the Eagle Ford Group and weathered and fractured limestone and clay and/or shale. The conductivity values are near to zero between the stations

1000 and 1550 feet. This conductivity low is caused by the resistive Dolomitic Member of the Kainer Formation.
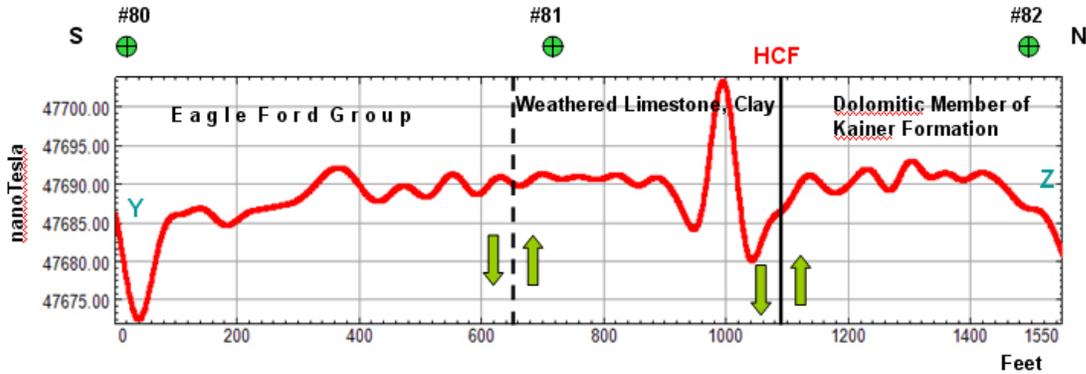
Ground Magnetic Data

FIGURE 8

A magnetic profile across the Haby Crossing fault is given in Figure 8. There are two significant magnetic anomalies along the profile. The first anomaly is between stations 900 and 1150 feet, which approximately corresponds to the area between the two faults where weathered limestone and clay-filled limestone are present.

The source for the magnetic anomaly could be due to the susceptibility contrast between the Eagle Ford Group and Dolomitic Member of Kainer Formation and/or localized ferrous mineralization along the fault plane. There are two additional anomalies along the profile which are located at the beginning and end of the profile, respectively; and are shown with letters "Y" and "Z." Sources of these anomalies are probably due to faults. In fact, the Small and Clark, (2000) study indicates a fault at the approximate location of where the Y anomaly is present.

Natural Potential Data (NP)

NP data across the Haby Crossing fault are given in Figure 9. The NP data indicate significant karst anomalies (voids, conduits, caves, etc.) within the faults and neighboring areas
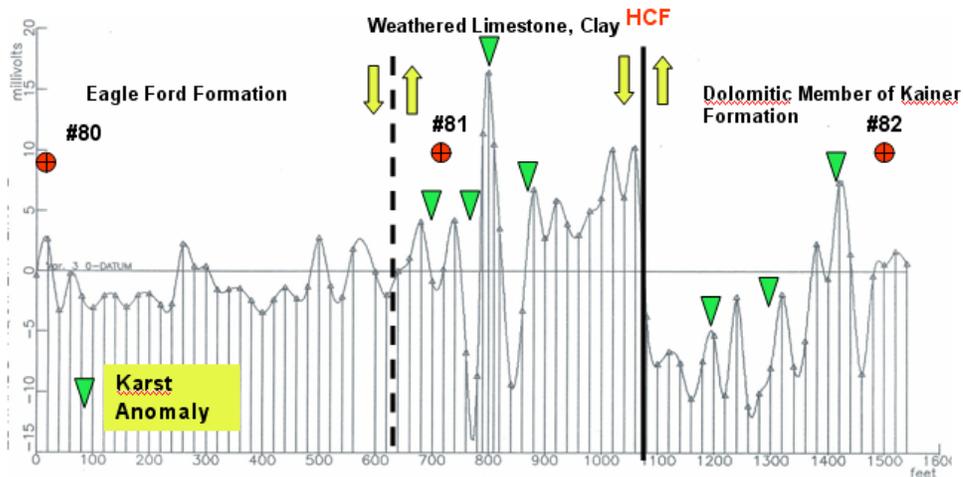

FIGURE 9

along the profile. The NP anomaly across the Haby Crossing fault is quite distinct where NP values fall from 20 to -5 mV. There is no significant karst anomaly observed within the Eagle Ford Group.

Discussion

Resistivity, ground conductivity, magnetics and natural potential surveys identified significant anomalies across the Haby Crossing fault. The resistivity data show the location of Haby Crossing fault which juxtaposes the Eagle Ford Group of Upper Cretaceous with the Dolomitic Member of Kainer Formation of Lower Cretaceous. There is another apparent fault identified by the resistivity survey within the Eagle Ford Group. Low-resistivity materials appear to breach into higher-resistivity materials, which may be indicative of presence of the voids, conduits, or caves. The geometry of the stratigraphic horizons between the faults and neighboring areas is quite irregular due to the tectonic and weathering activity.

The conductivity data show the location of the Haby Crossing fault quite distinctly. The conductivity values of 40 mS/m drop down to almost 0 mS/m over the fault. There are significant conductivity variations from 80 to 40 mS/m across the Eagle Ford Group. This variation is probably related to changes in the water content of the clay and mineral chemistry of the rocks. However, the conductivity values drop to 20 mS/m between stations 500 and 800 feet. This is probably caused by the presence of weathered limestones in the near-surface. In fact, we did observe some limestone outcrops in that area.

The magnetic data show the location of the Haby Crossing fault with a quite distinct high anomaly. This anomaly is probably caused by the presence of ferrous mineralization and/or karstic features, such as caves containing ferrous materials, along the fault zone. There are two other similar anomalies at the beginning and end of the magnetic profile. There is no additional magnetic information on these anomalies to speculate on their origin.

The NP data indicate significant karst anomalies (voids, conduits, caves, etc.) within the faults and neighboring areas along the profile. The NP anomaly across the Haby Crossing fault is quite distinct where NP values fall from 20 to -5 mV. There is no significant karst anomaly observed within the Eagle Ford Group.

Conclusions

Geophysical results (resistivity, conductivity, magnetics and natural potential) reported here characterized the Haby Crossing fault in the Balcones Fault Zone. The fault location is detected by each geophysical technique used in this study. In addition, the resistivity data indicated another fault to the south of the Haby Crossing fault. Presence of two faults appears to define a fault zone, which covers the area between the two faults and neighboring areas. The width of the fault zone is about 600 feet. The natural potential data indicate significant karst anomalies (voids, caves, conduits, fissures, etc.) within this fault zone.

These results show that the fault zone includes voids, fractures, weathered limestones, and clay layers, which all-except clay-help increase vertical and horizontal permeability of the fault zone. With the presence of karstic features, the Haby Crossing Fault Zone can have recharge of rain water directly from the surface and can act as a source of groundwater flow.

REFERENCES

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FIGURE CAPTIONS
Figure 1. Location of Haby Crossing fault and study area. HCF denotes Haby Crossing fault; the blue box indicates the study area.

Figure 2. Site map showing partial location of Medina-CPS Transmission Line.

Figure 3. Geological map of the study area. The geological map is taken and modified from Small and Clark, 2000.

Figure 4. Photograph of a fault within Eagle Ford Group. View is to the north. The location of this fault is approximately mapped by Small and Clark, 2000.

Figure 5. Photograph of the Haby Crossing fault. View is to the north.

Figure 6. Resistivity imaging profile across the Haby Crossing fault. HCF denotes Haby Crossing fault. Dashed vertical line corresponds to a known fault determined by Small and Clark, 2000.

Figure 7. Conductivity data across the Haby Crossing fault.

Figure 8. Magnetic data across the Haby Crossing fault.

Figure 9. Natural potential data across the Haby Crossing fault.