Holloman 2

GROUNDWATER STUDY OF THE SACRAMENTO MOUNTAIN FRONT

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Prepared for:

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Holloman Air Force Base, NM

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INTRODUCTION

Holloman Air Force Base is located in the arid Tularosa Basin of southern New Mexico. Little fresh groundwater exists in the basin due to the large amounts of gypsum and other salts which constitute much of the sedimentary section. The primary sources of water for the base are the Sacramento Mountains and the alluvial fans along the mountain front (see Fig. 1). Continuing growth at the base requires additional water sources. The objective of this study is to determine the subsurface structural geology and stratigraphic controls on aquifers in the alluvial fans along the Sacramento Mountain front as well as to drill an exploratory well to obtain water samples. The geophysical methods used in this study include seismic, gravity and well logging techniques.

One of the assumptions at the start of this study as well as previous studies (e.g., Earth Technology Corp., 1987; Belzer, 1999), is that the alluvial fans seen on the surface near the Sacramento Mountain front extended into the subsurface a considerable distance beyond their extent on the surface. This assumption is further reinforced by the existence of two producing water wells, the Fish Tank well, Sec. 10, T19S, R10E; and the Langford well, Sec. 17, T19S, R10E. These wells produce what appears to be good quality water for livestock in this area. The approach of this study was to drill an exploratory well near, but not on the up thrown side of the main boundary fault forming the Sacramento Mountain front. The objective was to sample the stratigraphic sequence of sedimentary beds just off of the Paleozoic bedrock forming the Sacramento Mountains and obtain water samples from this sequence. The well was sited just north of the Ft. Bliss McGregor Range boundary, which is as far south as Holloman AFB controlled property extends. In addition, geophysical studies were used to extend information gathered from the exploratory well onto the Escondido alluvial fan to the north of the well.

Site selection was coordinated with and permitted by the New Mexico State Engineer's Office. In the initial stages of the study permitting problems with local landowners required the relocation of geophysical studies to the north on to Holloman AFB controlled property, rather than extending along an east-west line through the well site. The well site is in the SW1/4 of the SW1/4 of the NE1/4 of Sec. 2, T19S, R10E, N.M.P.M. The Environmental Management Office of Holloman AFB conducted environmental clearances at the drilling site and along the seismic lines. Desert flora and faunal habitat were flagged to indicate they should be avoided. Field personnel were given an environmental briefing on site prior to beginning work.

The University of Texas at El Paso was contracted to drill an exploratory well and conduct geophysical studies in October 2000 with the expectation that the drilling would commence in November 2000 and that geophysical surveys would be completed in January and February 2001. After the contract was let, the drilling company initially designated to drill the well declined the opportunity and a local drilling company was contracted. However, because of permitting difficulties drilling did not start until April 2001 and geophysical surveys were not completed until July 2001. Drilling was continually delayed by equipment failures, lost circulation zones, swelling clay and caving of the borehole. The drilling operation was not completed until December 2001. The well was electrically logged and water samples were taken at that time.

PREVIOUS STUDIES

Two previous studies have been conducted in the area. The first by the Earth Technology Corp. (ETC) in 1987 concentrated on the Grapevine Canyon alluvial fan. That study described the distal deposits of the Grapevine Canyon fan as extending nearly to U.S. Highway 54, making it much larger in areal extent than the alluvial fans farther north. Based on an electrical resistivity survey conducted by the U.S.G.S. (Orr and Myers, 1986), ETC drilled two exploratory wells on the Grapevine Canyon fan. The first was the GCOW-1 well drilled in NW1/4 of Sec. 27, T19S, R10E had a total depth of 645'. This well encountered mostly clays below 100' and found no significant fresh water. A second well, GCAO-1, was drilled in the NW1/4 of Sec. 25, T19S, R10E with a total depth of 418'. This well encountered more gravel with a zone of swelling clay, but reached bedrock at only 332'. Drilling was also hampered by several severe lost circulation zones and ultimately terminated when fluid loss could not be controlled.

In addition to the drilling program, ETC (1987) conducted a seismic refraction survey on the proximal portion of the Grapevine Canyon fan. This survey consisted of two profiles with a total of nine shots fired. These shots ranged from 1 to 100 lbs. in size and were drilled to a depth of approximately 20'. An interpretation by ETC, concluded "anticipated increased depth to bedrock on the downthrown side of the mid-fan fault was not present". Reinterpretation of these and other data by Belzer (1999) did show that a significant trough was possible in this area.

The second study of the groundwater potential in this area was conducted by the University of Texas at El Paso in 1997 and interpreted by Belzer (1999) and Belzer, et al., 2002). It involved the collection of gravity and seismic data on the Grapevine

Canyon fan and Negro Ed Canyon fan immediately to the north. Three gravity profiles were collected, one through the approximate centers of Sec. 21, 22, 23, and 24; a second through the approximate centers of Sec. 13, 14, 15, and 16; and a third through the approximate centers of Sec. 9, 10, 11, and 12, all in T19S, R10E (see Fig. 2). A short seismic reflection/refraction profile was also collected along the northernmost gravity profile, extending northeast from Fish Tank well (see Fig. 2). The gravity profiles identified a small graben bounded on the east by the main boundary fault of the Sacramento Mountains on the west by a smaller buried fault. The seismic profile detected no dipping interfaces indicating the Negro Ed fan does not extend under the seismic line.

Based on these past studies, the effort in this study was concentrated much closer the main boundary fault of the Sacramento Mountains. Past studies indicate beyond the topographic expression of these alluvial fans (i.e., area where the conical shape of the fan is seen on the surface and on topographic maps) sediments are dominated by lacustrine clays with little permeability. While water wells exist beyond the alluvial fans, they generally produce less water than is needed by Holloman AFB.

GROUNDWATER EXPLORATION PROGRAM

The groundwater exploration program was divided into two parts; a program to drill a deep test well and a geophysical program to extend information derived from the test well over a broader area. The test well was drilled within 1500' of the main boundary fault of the Sacramento Mountains much closer to the fault than any previous well in this area. The primary purpose of the test well was a stratigraphic test and to obtain samples for water quality tests. The geophysical program was aimed at extending information from previous geophysical surveys, and the test well, closer to the Sacramento boundary fault and the course alluvial fans associated with it. The geophysical program used two methods seismic refraction/reflection and gravity.

The Well Drilling Program

The selection of the site for test well was based on three criteria. First, based on previous drilling and geophysical studies, it was thought that more course-grained sediments would be encountered closer to the fault than farther from it. Second, the test well was restricted to property controlled by Holloman AFB and wells have been drilled farther north on this property. Third, the site had to be accessible to the drilling equipment without extensive road building, limiting it to places with existing roads. The site selected was between the Escondido fan to the north and the Negro Ed fan to south. It was less than 1500' from the main boundary fault and less than 1000' from the southern edge of the Holloman controlled property. The well was spudded in lacustrine clays at the base of these two alluvial fans where it was anticipated that the well would intersect the alluvial fans at a shallow depth.

The test well borehole was spudded in April 2001. The drilling fluid used was air with foam entrained. Drilling was plagued by mechanical problems throughout the project. The borehole reached a depth of 880' by November 2001. A boring log of the drill cuttings is located in Appendix A. Clay with varied amounts of silt make up the majority of the material encountered in this boring. Sand and gravel were encountered in the boring to a much lesser extent. Water was encountered at 373' and was artesian, rising to a depth of approximately 210'. The water was encountered in highly permeable zones resulting in poor circulation and caving. Caving caused the hole to close when the drill stem was removed. This added to the drilling time as cave-ins had to be drilled out each time the hole was reentered. An attempt to use drilling mud to hold the hole open failed when mud circulation could not be established because of the highly permeable zones.

After drilling was stopped in November 2001, the test well was cased to 370'. This depth was the top of the first high permeability zone where caving began. The casing was 4" PVC perforated throughout its length to allow electric well logs to be run inside the casing. The annulus between the well casing and boring walls was then filled with gravel to the surface. A bentonite seal was established extending from the surface to several feet below grade to act as a seal to prevent contamination of the aquifer from the surface. The well was capped with a removable cap to allow sounding of the well. The area was then graded to its original level.

After the well was cased water samples were taken and analyzed for Holloman AFB. It was also logged with a suite of electrical logs, including temperature, fluid conductivity, natural gamma, induction susceptibility, and caliper. A bend in the case at a depth of 200' did not permit logging with longer tools below this depth. The well logs, and a report summarizing the logging results, is included in Appendix B.

The Geophysical Program

The geophysical program consisted primarily of two seismic refraction/reflection lines, one running northeast-southwest and lying north of the test well (Line 1), the other running approximately north-south through the well site (Line 2) (see Fig. 1). Secondary, gravity measurements were made along the seismic lines. The seismic refraction method is sensitive to seismic velocity changes in the subsurface, such as the velocity increase associated with the water table and the further velocity increase associated with the bedrock surface. The seismic reflection method images smooth near horizontal surfaces with the earth. These are caused by changes in acoustic impedance, which correspond to interfaces between different rock types. Together these methods produce more information than either method alone, therefore the seismic lines were designed to record both refractions and reflections.

The design of the seismic refraction/reflection line was a receiver every 25' and a shot every 50'. Line 1 contained 281 receivers. Line 2 contained 200 receivers. The sources are shots of 1 lb. of pentolite buried 5' to 10' below the surface. At this depth the 1 lb. charge is entirely contained in the ground with no surface disturbance when the shot is fired. As drilling became more difficult shot spacing was increased to 100' or farther and on Line1 discontinued altogether when access because to difficult. With this combination of a large number of closely spaced receivers and numerous shots both refractions and reflections can be seen in the data. The refractions can be seen in the large source-receiver offsets and the reflections, in the closely spaced traces. Appendix C contains the 119 record sections recorded during this project. Inspection of the record sections shows both refracted and reflected arrivals.

While both refractions and reflections occur in the same record section the processing and interpretation of these arrivals is very different. Refractions arrivals, usually first arrivals, are picked and travel-times are inverted for earth models while reflections are extensively processed to produce an image of the subsurface. The first arrival picks for Line 1 are shown in Fig. 2 and for Line 2 in Fig. 3. A simple refraction interpretation is show for Line 1 in Fig. 4 and for Line2 in Fig. 5. The first layer below the surface along both these lines are the unsaturated sediments with seismic velocities between 3500'/s and 3700'/s, less than the velocity of water, 4400'/s. The second layer below the surface along both these lines are the saturated sediments with seismic velocities between 8000'/s and 9200'/s, hence the water table is the interface between layers 1 and 2. Both the first and second layers are composed of clay and courser grained alluvium and cannot be distinguished from seismic refraction alone. On Line 1, the first layer appears pinch out toward the northeast end of the line. This is due to the fact that no seismic shots were placed at the northeast end of Line 1 because it was inaccessible to the small drill used to drill the shot holes. Because there are no short source-receiver combinations at this end of the line there is no shallow information in the interpretation and the first layer may indeed not pinch out in this area. The third layer, although very poorly constrained, is interpreted to be the sedimentary bedrock underlying this area.

GEOLOGICAL AND HYDROLOGICAL EVALUATION

Perhaps the most surprising part of this project is that the test well encountered mostly lacustrine facies sediments to its total depth. This indicates that in the past, even close to the main boundary fault of the Sacramento Mountains, sedimentation was dominated by the playas that are seen there today. Because the lacustrine facies are dominantly clay, with little or no permeability, they can produce little water and act as aquitards in the hydrologic environment. The fact that they are aquitards can be seen in the artesian rise in the test well where 373' of sediment were drilled before water was encountered, but where the current depth to water is only 210'. It can also be seen in sloping interfaces between the first and second layers in the refraction velocity models. Normally, the watertable is nearly level sloping only slightly in response to regional gradients. Here the watertable follows the bottom of an impermeable layer, an aquitard, because it cannot flow into the clay and there is no outlet in the down dip direction. The clay layer that forms the aquitard may be repeated below in several intervals. However it appears that these clay layers become thinner higher up on the alluvial fans and may pinch out altogether near the top of the fans. If the clay layers do pinch out at the top of the fans, then there is the possibility of local aquifer recharge in these areas.

RECOMMENDATIONS

Because we now know that a lacustrine environment dominated the geological history of these alluvial fans, exploring for water off the topographic expression of the fan makes little sense. Further exploration should be concentrated on as high on the alluvial fans as practical, but staying on the downthrown side of the boundary fault. These are the areas that will have the most course-grained sediments with the highest permeability and will produce the largest volumes of water. These areas are also where the most drilling difficulties will be encountered.

The geologic history of both the Escondido and Negro Ed fans appears to be similar. Both fans have relatively steep surface gradients and have sediments derived from the same source. The Grapevine Canyon fan appears to be somewhat different due to a lower surface gradient and what appears to be a larger volume of sediment. The lower gradient indicates a lower energy and therefore finer-grained sediments will be found in the Grapevine Canyon fan. Hence, exploring high on this fan may not be as productive as the Escondido and Negro Ed fans.

04-012 HOLLO2   readme file

This directory structure relates to data that wass collected by UTEP for Holloman Air Force Base in New Mexico. The objective of this study was to locate areas to drill a production water well to meet the needs of the increasing size on the Base personnel. The German Air Force has moved of its training to Holloman, New Mexico. The site is located at the base of the Sarcamento Mountains in an alluvial fan.

The .sgy files do not have geometry loaded into the headers. The geometry data can be found in the /Geometry directory of this dataset. The data in the file holloman.xyz is in the following format   "Station#   Northing   Easting   Elevation (meter)"

All shots were located at specific stations. The file "shot.txt" contains information on the station the shot was at and the time the shot was fired. The shot depth ranged between 4 - 10 feet below the ground surface.

There is a Site map in the /Docs directory that shows the location of the test well and the location of the 2 seismic lines. There are 2 sitemap files (.cdr - correl draw & .jpg - jpeg).
The file /Geometry/holloman.utm has coordinates in correct format to be used with 7.5'quad (Horizontal Datum = UTM, NAD27, zone=13, Horizontal units=meters, Vertical Datum = NGVD29, Vertical units = meters).

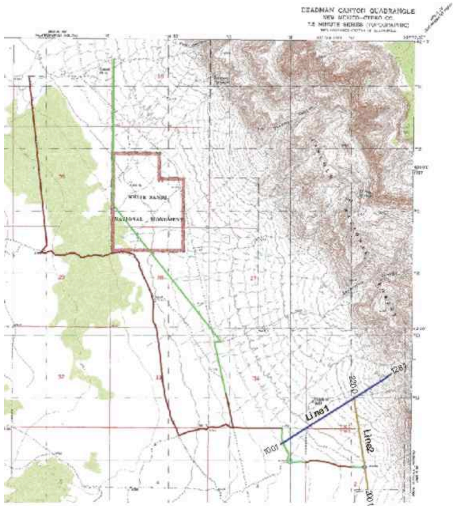

Figure 1. Location map showing Seismic Lines 1 and 2 (blue and brown, respectively).
The green line represents access route across government controlled property.
The red line represents access route across private property (Righ-of Entry).