Beulah Highlands Residential Ranch Hydrology Report

Assessment of Antelope Butte LLC Exempt Wells

Prepared For

Felt, Monson & Culichia

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HYDROKINETICS INC.

13975 W. 24th St.
Golden, (Applewood) Colorado 80401
(303) 237-6026
Fax 237-8026

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1.0 Introduction

Antelope Butte LLC has requested 10 exempt well permits sited on lots in the NW1/4 of Section 10, T23S, R68W of the 6th PM, in Pueblo County, Colorado. These wells are located in the "Glendale Subdivision", a legal subdivision dating to the early part of the 19th century. The State Engineer's Office (SEO) , a division of the Colorado Division of Water Resources, has evaluated these applications and has issued permits for these wells pursuant to CRS 37-92-602(3)(b)(II)(A). The permits are numbered 270467 through 270476. The permits limit water use to ordinary household purposes inside a single family dwelling. No irrigation usage is allowed. Additionally, the homes shall be required to employ individual, non-evaporative waste water disposal systems to maximize return flows. These permits were issued September 14, 2006 and expire September 14, 2008.

Subsequent to issuance of the permit, several objections were filed by Beulah area residents contending these wells will cause material injury to existing area water rights. The Beulah Water District and Pine Drive Water District provide water service to most of the area residents, but neither has filed an objection to the permits. The Beulah Water District draws water from a surface diversion on Middle Creek in the NE 1/4 of Section 4, T23S, R68W of the 6th PM. (Figure 1) . The point of diversion for the Pine Drive Water District lies on St. Charles Creek, over a mile away from the Antelope Butte property, in the SE1/4 of Section 2, T23S, R68W. This report assesses the potential for pumping of the Antelope Butte LLC exempt wells to injure the Beulah Water District, the Pine Drive Water District , or other local water users.

2.0 Site Stratigraphy

The areas east of the Town of Beulah, and along most of the stream drainages, are

covered with alluvium and colluvium of relatively recent origins. These geologic units are composed of unconsolidated silts, sands, and clays deposited in or adjacent to stream systems. Where saturated, this alluvial material is generally capable of supplying small to moderate quantities of water to individual domestic wells. Locally, where these sediments are thick, the aquifer may sustain better yields and be capable of supplying municipal or small irrigation systems.

Underlying the alluvial materials are a sequence of early Paleozoic sediments. These Paleozoic rocks are approximately 30,000,000 years older than the overlying alluvial materials. The Antelope Butte LLC property lies in outcrop area of the uppermost of the Paleozoic formations. More specifically, the 10-lot property lies in the outcrop area of the Fountain Formation, a geologic unit of Pennsylvanian age. This is a geologic unit composed of red to tan colored siltstones, sandstones, conglomerates, mudstones, and claystones. The Fountain may approach 2000 feet in total thickness, though only a portion of this formation remains beneath the Antelope Butte property. Where saturated, the Fountain Formation can generally yield adequate quantities of water to supply individual domestic wells. Where fractured, the brittle sandstones and conglomerates can provide moderate quantities of water to both individual domestic and municipal wells.

Underlying the Fountain Formation is a sequence of rocks of Ordovician to Missippian age. The uppermost portion of this sequence of rocks consist of the Beulah, Hardscrabble, Williams Canyon, and Fremont Limestones. This limestone sequence contains both limestones, marlstones, and a few interbedded sandstones. In total, this sequence of rocks range from 50 to 200 feet in thickness. In some locales, the Beulah limestone has experienced some metamorphism and is known locally as the Beulah Marble.

Beneath the limestone sequence is a hard, well cemented sandstone unit known as the Harding Formation. This sandstone ranges from 0 to 70 feet in thickness, and composes the lower portion of the Mississippian-Ordovician sequence. The combined geologic units deposited in the Missippian to Ordovician periods (Beulah through Harding Formations) generally have relatively low interstitial porosity and permeability. Where fractured or jointed, they can often produce adequate water to supply individual domestic wells. Where solution

mechanisms have operated in the limestones, there may be significant karst related permeability and greater yields may be expected. On the Geologic Map, Figure 1, these units have been grouped together and are identified as "MO", for Mississippian-Ordovician sediments.

At the base of the Harding Sandstone is an unconformity, or break in the geologic time sequence. The Harding Sandstone lies directly upon the much older Precambrian Gneiss. This gneiss is composed of biotite micas, quartz, and plagioclase feldspars and has relatively low natural porosity. However, where fractured or jointed by tectonic activity, this unit is generally capable of yielding small to moderate quantities of water to domestic wells. Though technically classified as a "gneiss", this often is simply referred to as "granite" by local drillers.

3.0 Structural Geology

The sediments described above have been bent and broken by tectonic activity over time. The sedimentary units (Pennsylvanian through Ordovician units) have been thrust upward on the west so they now generally dip from 7 degrees to over 45 degrees toward the east. The up-thrusting that has resulted in the eastward dipping sediments has also caused some significant faulting in the area. As identified on the Geologic Map, Figure 1, there is a significant high angle fault that runs in a southwest to northeast direction just northwest of the Antelope Butte property. As the fault trace moves northward, the track of the fault also bends northward, runs through the Town of Beulah, then north westward to intersect with another east-west trending fault north of the Town. This as an ancient, inactive fault system, similar to many hundreds of other such faults running up and down the front range. The main fault is up-thrust on the west side and down-thrust on the east side. Consequently, at a given elevation across the fault, rocks on the east side will be younger and will lie higher in the geologic sequence than rocks west of the fault. The exact "throw" or displacement along the fault is not known, though from the configuration of contacts east and west of the fault, it appears to have a throw at least equal to ½ the combined thickness of the Missippian and Ordovician sediments. It is clear that a well drilled at any elevation east of the fault will see a significantly greater thickness of Fountain formation than a well drilled at a similar elevation west of the fault.

The fault will create a peripheral zone of more highly fractured rocks both east and west of it's trace. These areas will be more conductive to water flow than undisturbed areas of these formations, and will produce more water to wells if the formation is saturated. However, the core of the fault itself is likely to be significantly less permeable due to the development of fault gouge materials (low permeability, clay rich materials formed from the crushing action between the two fault plates).

4.0 Well Drilling

There has only been one relatively deep water supply well drilled in the vicinity of the Antelope Butte property. This well was constructed under permit no. 267372, and is located west of the fault approximately 350 feet northwest of the southeast corner of Section 4. (See Figure 1) This well passed through the remnants of the Fountain formation, through the full Mississippian-Ordovician sequence, and penetrated the underlying Precambrian materials. According to the drillers log, Figure 2, the Precambrian materials were encountered at approximately 249 feet. Most of the water being yielded by this well appears to be coming from the Precambrian materials.

Test pumping of this well indicated it sustained a flow rate of 2 g.p.m. with a drawdown of 335 feet. This results in a specific capacity of approximately .006 g.p.m./foot of drawdown. From this, we can estimate the transmissivity and hydraulic conductivity of the aquifer. Generally, the transmissivity is found to be around 2000 times the specific capacity for artesian aquifers and 1500 times the specific capacity for unconfined aquifers. Multiplying these factors by the specific capacity gives us a transmissivity of 9-12 g.p.d./ft. Recognizing there may be some leaky artesian effects at this site, a transmissivity of around 10 g.p.d./ft is reasonable. This equates to a hydraulic conductivity for the penetrated gneiss of around .044 g.p.d./sqft. This is a reasonable hydraulic conductivity for a low permeability metamorphic material, or even for minimally jointed or fractured limestones and cemented sandstones.

5.0 Water Demands from Antelope Butte Wells

If we assume an average residential density of 3.5 people per home, and an average daily in-house use of 80 g.p.d./person, we can estimate the average household use to be 280 gal/day. This is equivalent to a sustained yield from a well of 0.194 gallons per minute (g.p.m.), which we can round up to 0.20 g.p.m. The 10 permitted wells would then require a sustained yield of 2 g.p.m. at buildout. The required leach fields will return 80-90% of the pumped water to the groundwater regime. If we assume conservatively that only 80% will be returned, the consumptive use of the homes will be approximately 20% of that pumped, or .04 g.p.m. per site (0.4 g.p.m. for the 10- well project).

6.0 Impacts of Pumping on Beulah Water District Rights

The Beulah Water District point of diversion is located on Middle Creek. (See Figure 1). This diversion lies in the Precambrian gneiss streambed approximately 5500 feet northwest of the Antelope Butte wells.

6.1 Distance Drawdown Calculations

There are many reasons why pumping of the Antelope Butte wells will not impact the Beulah Water District Diversion. The quantities of water pumped from the Antelope Butte wells are very small, return flows from the septic systems will mitigate much of the depletive effects of pumping, and there is a significant fault system lying between the Beulah diversion point and the Antelope Butte wells. In order for the pumping of the Antelope Butte wells to detrimentally impact the stream at the Beulah Water District point of diversion, the Antelope Butte wells would need to propagate a cone of depression (a depression in the water table created by pumping of the wells) which would reach up gradient to the west 5500 feet, across an intervening stream branch, to the diversion point on Middle Creek. This cone of depression would also have to transect the intervening fault system, a structure that by itself provides a significant physical

barrier to propagation of a cone of depression to the northwest from the Antelope Butte wells.

Rather than trying to evaluate all of the mechanisms that prevent impacts from the Antelope Butte wells from impacting the Beulah Water District diversion, we can demonstrate the lack of impacts by making a number of overly simplistic assumptions about groundwater flow in the area, and evaluate the simplified model. The assumptions we are making all favor the opportunity for the Antelope Butte wells to impact the diversion point. First, we will assume the aquifer and water table are flat. Secondly, we will ignore the existence of the large fault system and assume it doesn't have any impact on the ground water flow. We will assume the aquifer has contiguous and uniform permeability from the location of the wells to the Beulah diversion point. We will also assume that the Antelope Butte wells will draw water directly and solely out of the Precambrian materials (which is the geologic material in the streambed at the point of the Beulah diversion). Additionally, we will fully ignore any return flows from septic leach systems and stress the aquifer with the full amount of pumping from the wells. Finally, we will assume the stream is in perfect hydraulic connection with the Precambrian bedrock, there is no recharge reaching the aquifer from surface precipitation, and no recharge from other surface streams. Implementing all of these simplifying assumptions, we can utilize the transmissivity calculated from the well test and build a Theis model to describe the size and geometry of the cone of depression that would result from pumping the Antelope Butte wells for various periods of time.

A Distance-Drawdown solution for the Theis equation utilizing the aquifer and pumping conditions described above is presented on Figure 3. This was prepared using a transmissivity of 10 g.p.d./ft and a specific yield for the aquifer of 0.02. The four lines on the graph depict the drawdown at various distances from a well that would result from pumping at the rate of 0.2 g.p.m. for 1, 10, 50, and 100 years. The distance drawdown graphs demonstrate that after 1 year of pumping at the rate of 0.2 g.p.m.(the average sustained rate required to produce just over 280 gpd) , the drawdown impacts from a single well will be concentrated in an annulus around the well about 500 feet in radius. After 10 years of sustained pumping, the radius of the cone of depression expands to about 1200 feet. In 50 years, this radius expands to 5000 feet, and creates a drawdown at this point of approximately 0.002 feet. After 100 years of pumping, the drawdown at 5000 feet (the approximate distance to the Beulah Diversion Point) is around 0.05

feet. If all 10 wells were pumping, drawdown impacts would increase by one order of magnitude, or after 100 years of pumping the drawdown at 5000 feet would be 0.5 feet.

Another way of addressing the impacts of pumping the Antelope Butte wells on the Beulah diversion point is to utilize the "AWAS" (Aquifer Water Accounting System) software written by the State Engineer and Colorado State University. If we make all the same assumptions about mitigating influences that we did for the Theis analysis above, we can estimate the magnitude of depletions in terms of flow using the Glover methodology contained in AWAS. The Theis analysis demonstrates that, under the prescribed assumptions, a cone of depression will reach the Beulah Diversion point within 100 years. This will result in some depletion to the stream. To quantify this predicted depletion, we can run AWAS for 100 years at the 0.2 g.p.m. sustained well flow rate. Running this analysis yields a stream depletion rate, after 100 years of pumping, of 0.0025 g.p.m. For the 10 well package, the predicted stream depletion would be 0.025 g.p.m. In other words, using all the simplifying assumptions, pumping of all 10 of the Antelope Butte wells for a period of 100 years would result in a stream depletion of approximately 25 thousandths of a gallon per minute at the Beulah Water District point of diversion.

6.2 Actual Stream Depletions

The drawdowns described on Figure 3, and the depletions predicted with the AWAS software, are not intended to demonstrate what actual drawdowns and depletions will be, but rather demonstrate how small the impacts would be even if all the other mitigating factors were ignored. This is intended to provide some numeric perspective on how long it would take, under ideal conditions, for a cone of depression to migrate to the Beulah Diversion point, how small the drawdown on the margins of this cone would be, and how restricted the depletive effects would be even after 100 years of pumping. In reality, however, there are numerous hydrologic factors which will constrain the cone of depression, and protect the Beulah diversion from even the minimal depletions described by the modeling. These mitigating factors were introduced in Section 6.1 , and are described in more detail below:

1. In the above simplified model, we have assumed no precipitation recharge reaches the Precambrian aquifer. In fact, considerable precipitation recharge will reach the aquifer and this recharge will reduce the size and rate of expansion of any cone of depression.

2. We have assumed in the model that the Antelope Butte wells will penetrate the Precambrian aquifer where they have the greatest opportunity to impact the Beulah diversion. These wells may reach the Precambrian, but since they are on a down-thrown fault block, the depth to the Precambrian may be greater than at the test well site and sufficient saturated materials may be identified in the Fountain, or lower Paleozoic sediments to supply the wells. In this event, no cone of depression would be propagated in the Precambrian materials and no impacts felt at the Beulah Diversion.

3. We have assumed the Precambrian aquifer is in full hydraulic connection with the stream throughout Middle Creek. This may be an inaccurate assumption. If the stream is not in hydraulic connection to the aquifer, then no impacts will be transmitted to the stream.

4. We have ignored the significance of the large intervening fault system. In reality, however, this fault will prevent or significantly retard the westward migration of a cone of depression in any of the geologic materials. This fault is a very important feature of the groundwater regime, and will have a significant impact on groundwater movement in the region.

5. We have assumed the water table is flat. In fact, the water table will have a significant gradient to the east. The cone of depression imposed on the sloping water table will be attenuated in the up-gradient direction and will not reach as far west as it would if the water table were flat.

6. We have assumed that <u>all</u> of the water pumped is fully consumed, and that the combined sustained flows of the 10 wells will be 2 g.p.m. This is an especially conservative assumption since each well is evaluated independently for injury, not cumulatively. As described in Section

5, 80% or more of the water pumped will return to the aquifer systems and the actual consumptive use of the 10 well development will actually be around 0.4 g.p.m. rather than the 2 g.p.m. modeled. If we re-run the Theis and AWAS modeling using the 0.4 g.p.m. value, we find the drawdowns and depletions reduced by 80%.

Incorporating all of the above considerations, the Antelope Butte wells will not impact the Beulah Water District diversion even to the degree of the de-minimis depletions predicted by the Theis and AWAS modeling, and will likely have no measurable effect whatsoever on the diversion.

7.0 Impacts on other Water Rights

The Beulah Water District Diversion was a primary focus of our investigation because it is the principal central water supplier to the area residents. However, there are a few other water rights, and a number of other shallow wells without adjudicated rights which are in the area. The largest water right is held by the Pine Drive Water District (PDWD) , which has a point of diversion located in the SE1/4 of section 2, T23S, R68W of the 6th PM. This diversion point lies approximately 8500 feet northeast of the Antelope Butte wells on St. Charles Creek. Middle Creek, and the south fork of Middle Creek are tributaries of St. Charles creek up gradient of the District diversion.

The south fork of Middle Creek lies about 3000 feet northwest of the Antelope Butte wells. If, as we did in the Beulah Water District analysis, we greatly simplify the situation and ignore the fault, we can estimate the depletions that would occur to the South Fork of Middle Creek and could be transmitted downstream to the PDWD point of diversion. Running AWAS, we find that the depletion to the South Fork of Middle Creek would be 0.035 g.p.m. per well (or .35 g.p.m. for the 10-well package) after 100 years of pumping. This assumes the South Fork of Middle Creek is perennial, which based on the field observations seems unlikely. This also assumes we ignore all 6 of the mitigating features described in Section 6.2. Here again, potential stream depletions are de-minimus and unlikely to be even measurable.

There were no deep aquifer wells located within the immediate vicinity of the proposed Antelope Butte wells. However, there are a number of shallow wells in the area particularly along Squirrel Creek to the south of the Antelope Butte property. Most of these wells penetrate the shallow alluvium of Squirrel Creek, or the shallow bedrock near the creek and are less than 100 feet in depth. Squirrel Creek in this area lies east of the fault as does the Antelope Butte project. If the Antelope Butte wells penetrate the Precambrian aquifer, or the deeper Mississippian and Ordovician sediments, they will not impact the quantities of water available in Squirrel Creek as this creek overlies the Fountain formation and doesn't intersect outcrops of these deeper units for some considerable distance (nearly a mile) upstream. If the Antelope Butte wells encountered and produced water at a relatively shallow depth from the Fountain Formation, and the Fountain Formation was in hydraulic connection with the creek directly south of the Antelope Butte property, these wells could have some impact on Squirrel Creek or it's alluvium. However, we believe this impact is de-minimus. To assess this scenario, we have again used the AWAS procedure, and assumed the aquifer parameters in the Fountain are similar to those in the Precambrian. The assumption that there is no intervening fault, and that the Antelope Butte wells would be relatively shallow means that some impacts could be transmitted to the Squirrel Creek Alluvium if the hydraulic connection exists. However, given these constraints, the return flows from the homes will also play a significant part in reducing depletions in the shallow materials. Running AWAS again for 100 years, and using an individual well consumptive use rate of 0.04 gpm as described in Section 5, the depletion rate in Squirrel Creek after 100 years of pumping is found to be 0.00006 CFS, or 0.027 g.p.m. Though the analysis needs to be examined on an individual well basis, if we look at the cumulative impacts , we also find them to be so small as to be physically unmeasurable relative to the flow in the creek If all 10 of the wells were installed and pumped for 100 years at the combined 10-well consumptive use rate of 0.4 g.p.m. as described in Section 5, and utilizing all of the enabling assumptions, after 100 years of pumping the Antelope Butte wells would diminish flows in Squirrel Creek by about 1/4 of a g.p.m. This is not a significant enough change in flow to cause declines in water levels in wells penetrating the alluvium, or to prevent water users (whether they own adjudicated rights or not) from fully utilizing their wells.

8.0 Conclusions

Hydrokinetics, Inc. has conducted a study of the geology and hydrology in the vicinity of the Antelope Butte LLC wells in Section 10, T23S, R68W of the 6th PM. This analysis is based upon field mapping, review of State Engineer records, review of geologic mapping by the U.S. Geological Survey and others, and analysis of hydrogeologic conditions using both Theis and the AWAS analytic groundwater models. Based on this analysis, we believe that any impacts to existing water rights, or even un-adjudicated permitted wells, will be de-minimus. We believe the issuance of the exempt well permits by the State Engineer is proper.

This report was conducted to specifically address the potential for the Antelope Butte wells to injure other water users. It was not conducted to assess the availability of water from any particular source, and is not designed to predict the depth or yield of wells at any specific location on or off of the Antelope Butte tract.

If you have any questions on this material, please feel free to contact our office.

Respectfully Submitted:

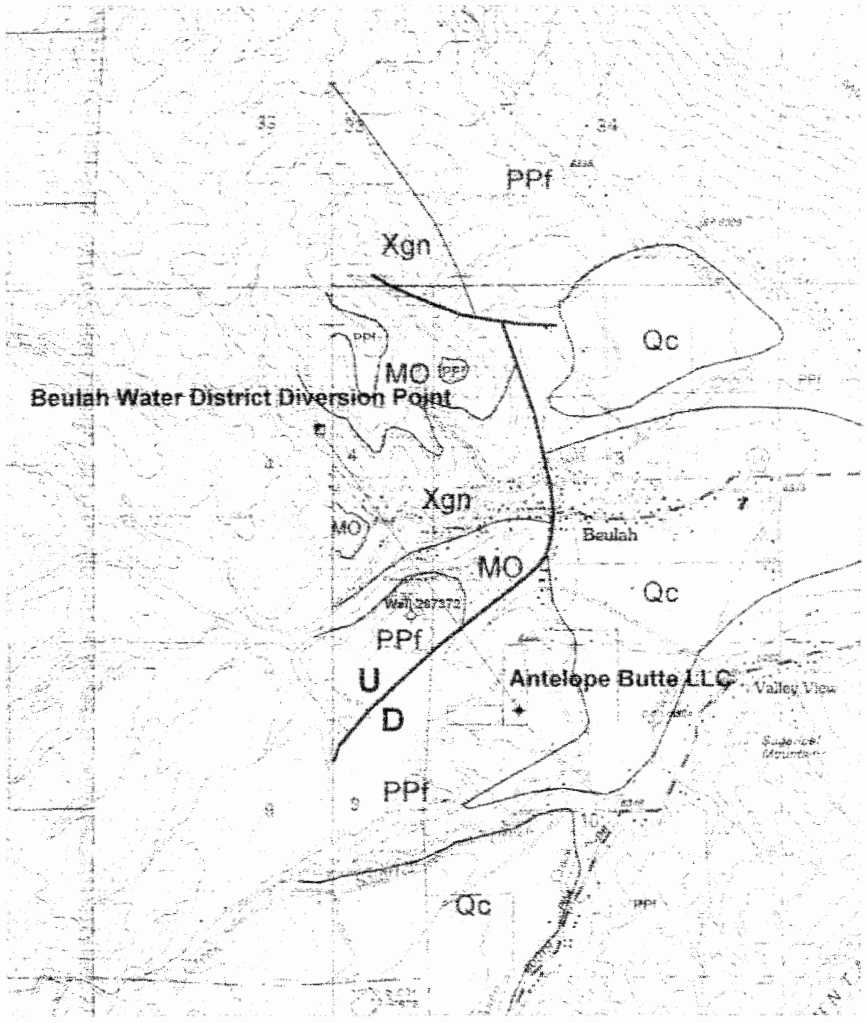
Scott G. Mefford
C.P.G. 5021

References

Malek-Aslani, M.K., Geology of the Beulah Area, Pueblo County, Colorado, Colorado School of Mines Dsc Dissertation, 1951

Scott, Glenn and Taylor, Richard, Reconnaissance Geologic Map of the Beulah Quadrangle, Pueblo County, Colorado, USGS Map MF-551, 1973

Geologic Map
Antelope Butte LLC Properties



0 ¼ ½ Mile

0 1000 2000 Feet

0 0.5 Kilometer

Antelope Butte LLC Water Wells

LEGEND

Qc - Quaternary Colluvium and Alluvium
PPf - Fountain Formation
MO - Beulah, Hardscrabble, Fremont, and Harding Formations
Xgn - Precambrian Biotite Gneiss

—— Fault

Figure 1

form no. GWS - 31 11/90

"WELL CONSTRUCTION AND TEST REPORT"
STATE OF COLORADO, OFFICE OF THE STATE ENGINEER

for office use only
RECEIVED
MAY 30 2006
WATER RESOURCES STATE ENGINEER COLO.

1. **WELL PERMIT NUMBER** 267372

2. **OWNER NAME(S):** BARTLEY THOMAS D
Mailing Address: 125 DECKERS DRIVE
City, St. Zip: PENROSE, CO. 81240
Phone : 719-276-6847

3. **WELL LOCATION AS DRILLED :** SE 1/4 SE 1/4, Sec.: 4 Twp.: 23S Range: 68W
DISTANCES FROM SEC.LINES 354 ft.from SOUTH (south or north) Sec. line, and 316 ft. from EAST (east or west) Sec. Line OR
SUBDIVISION: LOT : BLOCK : FILING (UNIT) :
STREET ADDRESS AT WELLLOCATION: EASTING: 500331 NORTHING: 4213620

4. GROUND SURFACE ELEVATION: ft. DRILLING METHOD AIR PERCUSSION
DATE COMPLETED: 3/1/2006 TOTAL DEPTH: 475 ft. DEPTH COMPLETED: 475 ft.

5. **GEOLOGIC LOG :**

Depth	Description of Material (Type, Size, Color, Water location)
0-3	BROWN TOPSOIL
3-148	LOOSE SANDSTONE
148-249	TAN & GRAY SNDSTONE
249-475	TAN & GRAY GRANITE

REMARKS: WATER 443'

6. **HOLE DIAM. (in.)**

HOLE DIAM. (in.)	From (ft)	To (ft)
8 3/4	0	152
6.00	152	475

7. **PLAIN CASING**

OD (in)	Kind	Wall Size	From (ft)	To (ft)
6 5/8	STEEL	188	1+	152
4.5	PVC	214	15	415
4.5	PVC	214	455	475

PERF. CASING Screen Slot Size 3/32"

4 1/2	PVC	0.214	415	455

8. **FILTER PACK**
Material :
Size:
Interval :

9. **PACKER PLACMENT**
Type : FORMATION
Depth : 39'

10. **GROUTING RECORD :**

Material	Amount	Density	Interval	Placement
CEMENT	6 SACKS	15.3	9'-39'	Poured
				Vibrated

11. **DISINFECTION,** Type CHLORINE Amt. Used : 1 GALLON, WATER INJ., 18 HRS

12. **WELL TEST DATA** ☐ Check box if test data is submitted on supplemental form
TESTING METHOD : AIR LIFT
Static Level : 140 ft. Date/Time Measured : 3/01/06 5:00 Production Rate 2 gpm.
Pumping Level : 475 ft. Date/Time Measured : 3/01/06 6:00 Test Length (hrs) 1.00
Remarks :

13. I have read the statements made herein and know the contents thereof, and that they are true to my knowledge. (pursuant to section 24-4-104 (13)(a) C.R.S., the making of false statements herein constitutes perjury in the second degree and is punishable as a class 1 misdemeanor.

CONTRACTOR : ARKANSAS VALLEY DRILLING PHONE: 719-276-6847 Lic. No. : 1305
Mailing Address : 125 DECKERS DRIVE PENROSE, CO 81240

Name/Title (please type or print)	Signature	Date
TODD A. MOORE		5/25/06

Figure 2.

Antelope Butte LLC Wells
Distance-Drawdown Plots
1 Well Pumping 0.2 gpm

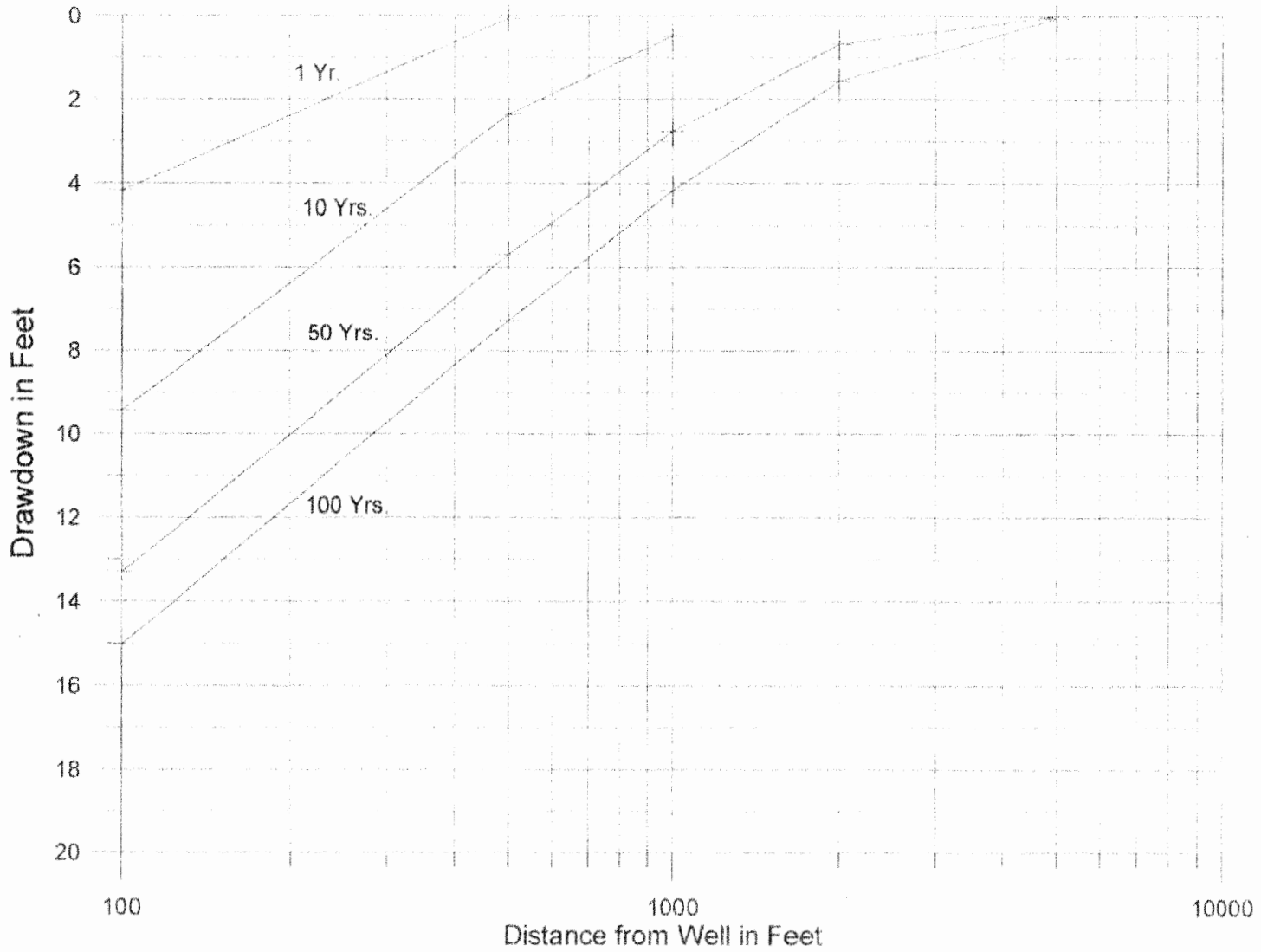


Figure 3