

July 1, 2009

L54(2380)
WHIS/General

Memorandum

To: Superintendent, Whiskeytown National Recreation Area

Through: William L. Jackson, Chief, Water Resources Division (WRD)
Gary Rosenlieb, Chief, Water Operations Branch (WOB)

From: Larry Martin, Hydrogeologist, Water Operations Branch, WRD

Subject: Trip Report to Whiskeytown National Recreation Area to identify locations for construction of test wells.

Summary

Water supplies for facilities at Oak Bottom and Brandy Creek are obtained by treating surface water from Whiskeytown Lake. The existing water treatment plants are aging (ca. 40 years) and in need of replacement. The park would prefer to construct wells to obtain water from a groundwater source, if feasible. A groundwater system would be less expensive to construct and would require less staff time to operate. Several sites for test drilling were identified during this trip. While there is no guarantee that test wells will produce the necessary quantity of water, selecting drilling sites based on geologic principles will increase the chances of success. Money for test drilling is expected to be available in FY-10.

Previous Investigations

Several shallow test wells were drilled at Whiskeytown in 1963. At that time, the thinking was that the bedrock underlying the area was generally impermeable. Groundwater would only be available in the shallow alluvium associated with streams, or by drilling into fracture zones near the reservoir, which would enable surface water from the reservoir to flow toward the well. Accordingly, eight of ten test wells constructed in 1963 were drilled to depths of 45-73 feet. Only two wells were drilled deeper than 100 feet; they were 106 and 125 feet deep.

The test wells in the Whiskey Creek area were able to provide sufficient water for the planned development. There is no camping at Whiskey Creek, so demand for water is less than at Brandy Creek and Oak Bottom. Water for facilities at Whiskey Creek is obtained from the low-yield wells that were constructed in 1963.

Shallow test wells constructed at Oak Bottom and Brandy Creek in 1963 did not produce enough water to meet the larger demands for water at these areas. Surface water treatment plants were constructed to treat water from the lake. These systems continue to be used, but are aging and in need of replacement. Wells that draw water from a true groundwater source (not groundwater under the direct influence of surface water) would be preferred to building new surface water treatment facilities.

In 1976, a 115-foot well was constructed east of the wastewater treatment plant to supply water to the plant. The well obtains water from several fracture zones at various depths and had an estimated yield of about 7 gpm.

In 2003, a 186-foot well was constructed to supply water for NPS residences west of Oak Bottom (Structures 318, 321, and 324). The well was test pumped at 50 gpm for 17 hours, resulting in 19 feet of drawdown. The well could probably have a sustained yield greater than 50 gpm, but additional testing with a larger pump would be required to determine the maximum sustained yield. The well is currently equipped with a pump that is rated to pump 10 gpm to the storage tank. Pumping water from the well to the storage tank requires a lift of about 400 feet. Alternative pumps are readily available that would pump 50-plus gpm to the storage tank.

Hydrogeology and site selection criteria

Groundwater at Whiskeytown occurs in alluvial sediments associated with streams and in fractures in the underlying bedrock formations.

Alluvial deposits along streams are only a few tens of feet thick. California regulations require public water-supply wells to have a surface seal to a depth of 50 feet, effectively eliminating alluvial sediments as a potential source of water for wells. Groundwater from a well in close proximity to a stream would likely be classified as being “under the direct influence of surface water” and would therefore require treatment as if it came from a surface water source. There would be no advantage to constructing a well under these conditions, rather than continuing to use surface water from the lake. Therefore, alluvium was not considered as a potential target aquifer for test drilling.

Bedrock underlying the Whiskeytown area is primarily Copley Greenstone and Balakala Rhyolite. Both formations are composed of metamorphosed volcanic rocks of Devonian age (originally deposited 350-415 million years ago). The formations are generally impermeable except where fractured. The key to obtaining adequate yield from a well drilled into these formations is intersecting enough water-bearing fractures and fracture zones. There is no guaranteed method to identify locations where a well will intercept water-bearing fractures several hundred feet below ground surface. However, topographic features sometimes provide clues about the presence of underlying fracture zones.

Fractured bedrock is more easily eroded than unfractured bedrock. Sometimes the occurrence of linear-trending valleys is associated with similar trending fracture zones in the underlying bedrock. Thus, we can increase the chances of intersecting fractures by locating test wells near linear-trending valleys. It's not necessary that a well be located in the center of such a valley as

it's likely that fractures occur across a wide band in a fracture zone. Some examples of linear-trending valleys are shown on Figures 1, 2, 3, and 4. Linear features are not as obvious on the two-dimensional maps in the figures, but become more pronounced when viewed in three dimensions such as GoogleEarth or the terrain view in GoogleMaps. The well constructed west of Oak Bottom in 2003 could be associated with a fracture zone associated with the north-south trending Bull Gulch.

In addition to locating test wells in areas that are likely to be underlain by fractured bedrock, well sites should also be some distance from the lakeshore to lessen the chance that the well will be interconnected with surface water in the lake. We want to increase the chances of constructing a well that will be classified as a "groundwater" source, rather than "groundwater under the direct influence of surface water".

Test wells should be drilled to at least 300 feet, and possibly 400-500 feet, unless adequate quantities of water are obtained at shallower depths. Hydrofracking might be used to increase the number and size of fractures to increase the yield of low-yield fracture zones.

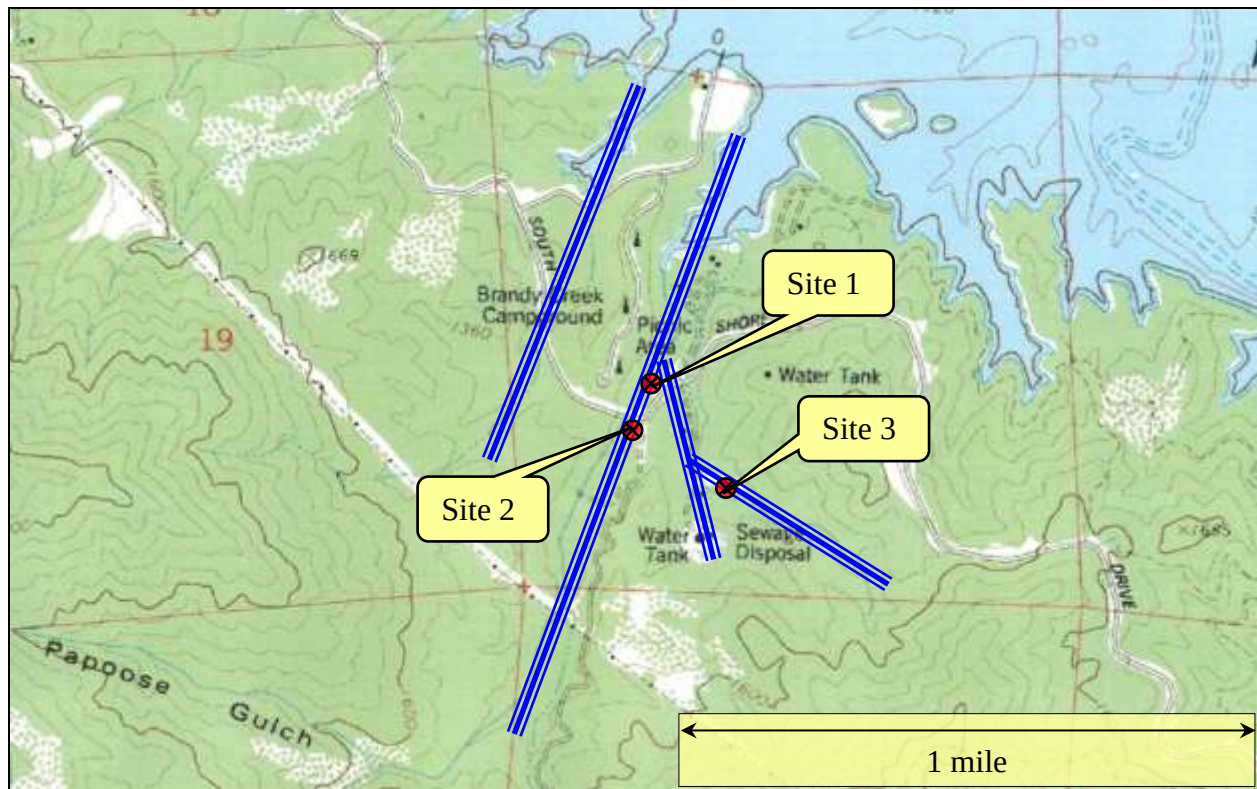
Brandy Creek

Linear-trending valleys in the vicinity of the Brandy Creek campground, picnic area, and marina are shown in Figure 1. Three sites were identified that meet the criteria of being some distance from the lake, within reasonable proximity of the existing water system, and in areas likely to be underlain by fractured rocks.

Site 1 is in the parking area at the entrance to the Brandy Creek picnic and swim beach area. It has the advantage of being in a flat area with good access and plenty of room for a drilling rig and associated equipment. A good location for a test well at Site 1 would be adjacent to the trees at the edge of the parking lot near the main road (South Shore Drive). However, the well site would be within 100 feet of a road and within an area that is heavily used by park visitors.

Site 2 is at the edge of the parking area for the Brandy Creek Trail. This is an already disturbed area with good access for a drilling rig and associated equipment. A test well might be located between the edge of the parking area and the Shasta Bally Road. A well at this site would be within 100 feet of a road and within an area that is heavily used by park visitors. There is limited space for parking at the trailhead and a well site might further reduce the size of the parking area.

Site 3 is in the boneyard area. This area is already disturbed and has adequate road access for a drilling rig and associated equipment. It has the advantage of being away from the public use areas and in close proximity to the existing water storage tank. Site 3 is associated with a smaller linear-trending valley and the chance of encountering a significant fracture system is less than at Sites 1 and 2. However, the advantages of having a well site outside of the main visitor use areas might offset the risk of lower yield. Hydrofracking could be used to increase the yield from a low-yield well at Site 3.



Base map from USGS Igo 7.5' Quad

Figure 1. Linear-trending valleys in the vicinity of Brandy Creek.

Oak Bottom

Linear-trending valleys in the vicinity of the Oak Bottom campground, picnic area and marina are shown in Figure 2. Two sites were identified that meet the criteria of being some distance from the lake, within reasonable proximity of the existing water system, and in areas likely to be underlain by fractured rocks. A well constructed in 2003 near the mouth of Bull Gulch provides evidence of potential large yields from wells that intersect fractures in the underlying bedrock.

Additionally, there is the option of extending service from the 2003 well to the Oak Bottom area. The well that was drilled in 2003 to supply water to Structures 318, 321, and 324 is capable of a sustained yield of 50 gpm, possibly more. A 50 gpm well pumped for 8 hours/per day would yield 24,000 gallons. There should be more than enough capacity from the 2003 well to supply the needs of all facilities in the Oak Bottom area. The cost of re-engineering the existing water system from the 2003 well and extending service to Oak Bottom should be compared to the cost and risk of constructing a new test well at Oak Bottom.

Site 1 at Oak Bottom is on the south side of the access road to the water storage tank, in an open area before the road begins to climb steeply. The area is clear, open, and relatively flat. Access for a drilling rig and associated equipment is good. The site is not closely associated with a linear-trending valley, but the proximity to the existing water system and storage tank makes it attractive. This is probably the only feasible site for a test well on the south side of the highway.

Site 2 is on the north side of the highway, in the valley of Grizzly Gulch. The exact location of a well site is not of great importance with respect to intersecting fractures in the bedrock several hundred feet below ground surface. If the location and trend of a valley is the result of some underlying fracture zone or pattern, then the fractures likely occur for some distance on either side of the centerline of the valley. It is more important to locate the well site where there is reasonable all-weather access and within reasonable proximity to power and the existing water system. Construction of a well at Site 2 would require trenching under Highway 299 to construct a water line to the storage tank.

A well was constructed a few hundred feet north of Site 2 to supply feedwater for operations at the wastewater treatment plant in 1976. The well is 115 feet deep and reportedly produces 7 gpm. The accuracy of this estimate and the potential sustained yield from the well are unknown. The existence of the well provides some indication that there is a good potential to obtain an adequate groundwater supply in this area, particularly if a deeper well was drilled.

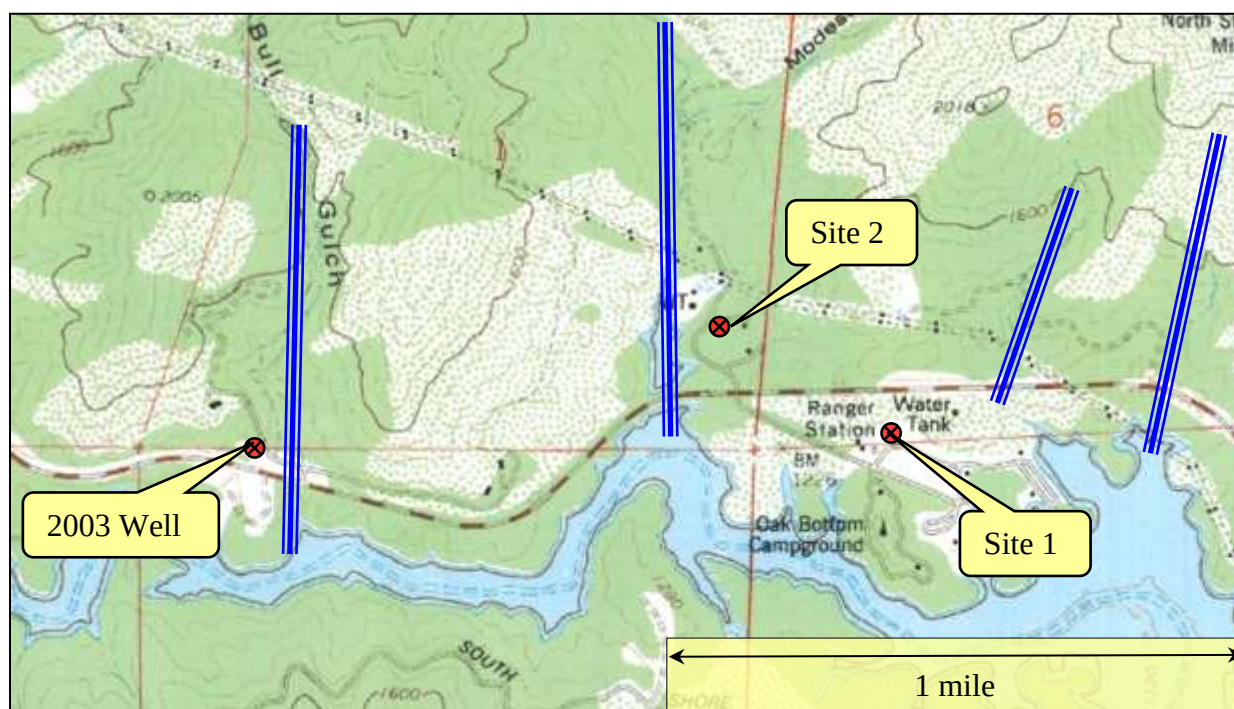


Figure 2. Linear-trending valleys in the vicinity of Oak Bottom.

Tower House Historic District

Figure 3 shows linear-trending valleys in the vicinity of the Tower House Historic District. Drill rig access to most areas in the historic district is difficult due to narrow roads, tight turns, narrow fence openings, and load-restricted bridges. It appears that the only reasonable site for well drilling in the area is at the picnic area on the northeast side of Clear Creek. There is a large parking lot at the picnic area that would provide access for a drill rig and associated equipment.



Base map from USGS French Gulch 7.5' Quad

Figure 3. Linear-trending valleys in the vicinity of the Tower House Historic District.

Dry Creek

Linear-trending valleys in the vicinity of the Dry Creek group campground are shown in Figure 4. One site was identified that meets the criteria of being some distance from the lake, within reasonable proximity of the existing water system, and in areas likely to be underlain by fractured rocks. The site is at the southeast side of the parking area; placing the well site upgradient from runoff and other potential contaminants in the parking lot.



Base map from USGS Igo 7.5' Quad

Figure 4. Linear-trending valleys in the vicinity of the Dry Creek group campground.

Park Headquarters

The area surrounding park headquarters is entirely underlain by granitic rocks of the Mule Mountain Stock, rather than metamorphosed volcanic rocks like the other areas discussed in this report. We have no information regarding the potential for fractures in these granitic rocks. There are no linear topographic features in the vicinity of park headquarters that might indicate the presence of fracture zones. Any drilling in the headquarters area really would be exploratory. There are no apparent geologic advantages or disadvantages to any particular site at park headquarters. If a test well is desired, the location should be picked based on access for drilling equipment and protection from potential contaminant sources.

Well Construction

Construction of the 2003 well for Structures 318, 321, and 324 provides a good model for construction of test wells in other areas of the park. The basic steps include;

1. Drill a pilot hole (minimum 6-inch diameter) to the target depth.
2. Test the potential yield of the well and water quality. Decide whether to complete the hole as a well or proceed with plugging and abandonment.
3. Plug and abandonment – Fill the borehole with cement, grout, or bentonite to comply with California regulations.
4. If the decision is to convert the test hole to a well;

- a. Ream the hole to a diameter at least 4 inches greater than the outside diameter of the permanent surface casing. The hole should be reamed to a depth of 55 feet.
- b. Install surface casing, centered in the hole with casing centralizers.
- c. Install the sanitary surface seal (cement, grout, bentonite, etc) in the annular space between the borehole and surface casing per California regulations.
- d. Allow the surface seal to cure.
- e. Redrill the well through the inside of the surface casing to remove any debris that may have fallen into the well during reaming for the surface seal and deepen the well to the final depth.
- f. Install a 4-inch PVC liner to protect the submersible pump from loose rocks that might fall from above the final pump setting and create a wedge that would prevent removal of the pump. Several sections of the PVC liner (at the bottom of the well) should be factory-slotted to allow water to enter the well.

If there are any questions regarding this trip report, please call me at (970)-225-3515.

References

Bergman, Bill, and Traver E. Metcalf, 2003, *Memorandum of findings, proposed well locations, Oak Bottom area, Whiskeytown National Recreation Area*, memo from Kleinfelder Inc. to Mr. Rob Dennis, Richard P Arber Associates, 4 pp.

Dale, R.H., 1963, *Proposed well sites at Whiskeytown Reservoir, Shasta County, California*, U.S. Geological Survey Memorandum Report, 12 pp.

Kinkel, A. R., Jr.; Hall, W. E.; Albers, J. P., 1956, *Geology and base-metal deposits of West Shasta copper-zinc district, Shasta County, California*, U.S. Geological Survey Professional Paper 285, 156 pp.

Page, R.W., 1969, *Water-resources reconnaissance of Whiskeytown National Recreation Area, California*, U.S. Geological Survey Administrative Report, 28 pp.

cc:

WHIS – David Larabee

PWRO – Cynthia Hunter, Stephen Bosiljevac, Mietek Kolipinski

WRD – Chuck Pettee, Mark Flora, Jeff Cross

Test wells were constructed at Oak Bottom and Brandy Creek in July 2010.

Two test holes were constructed at Brandy Creek. A well near the entrance to the picnic area was drilled to 305 feet. The estimated yield from this well by air-lift testing was less than 2 gpm. The second well was drilled about 800 feet south of the highway, in the vicinity of the water storage tank. It was drilled to 401 feet and produced an estimated 6 gpm by air-lift testing. Both wells were plugged and abandoned. There are plans to conduct additional hydrogeologic investigations of the area to identify locations for future test wells.

The well at Oak Bottom was drilled to 286 feet. It was estimated to produce 50 gpm during air-lift testing. The well was completed to California standards for a public water-supply well. The report of construction and testing is attached.



July 14, 2010

File: 1344

Mr. Matt Hirschbeck
Richard P. Arber Associates
198 Union Boulevard, Suite 200
Lakewood, Colorado 80228



**Subject: TEST BORINGS AT BRANDY CREEK CAMPGROUND
WHISKEYTOWN NATIONAL RECREATION AREA, CALIFORNIA**

Dear Mr. Hirschbeck:

This report documents the drilling operations for two test borings drilled at Brandy Creek Campground at Whiskeytown National Recreation Area in Shasta County, California. This work was conducted in accordance with our agreement dated May 2, 2010 and Amendment No. 1 dated July 6, 2010. The locations of the Brandy Creek test borings, designated Brandy #1 and Brandy #2 are presented in Plate 1.

TEST BORINGS BRANDY #1 AND BRANDY #2

On March 24, 2010, GEOPlus attended a site walk meeting held by Richard P. Arber Associates (RPAA) and National Park Service (NPS) staff. Attendees visited three prospective drilling locations proposed in an internal memorandum prepared by NPS geologist Larry Martin dated July 1, 2009. Brandy #1 and Brandy #2 were identified in the site walk as the best locations with respect to surface geology, access, and presence of infrastructure.

Between June 1 and June 10, 2010 our drilling subcontractor advanced two 6-1/8-inch diameter test borings by air rotary methods using an Ingersoll-Rand TH-60 rig with down-hole percussion bit. Brandy #1 was drilled to total depth of 305 feet on June 1 and was abandoned on June 2, 2010. Brandy #2 was drilled to a depth of 401 feet on June 9 and was abandoned on June 10, 2010.

Materials Encountered:

GEOPlus's geologist collected samples of the drill cuttings at approximately 20-foot intervals to describe the geologic materials encountered. Near the surface the material encountered consisted of highly weathered light brown greenstone which extended to a depth of approximately 19 feet

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July 14, 2010

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in Brandy #1 and 6 feet in Brandy #2. The primary rock type encountered in both borings was a Devonian-age andesitic volcanic rock that has been metamorphosed to dark green, fine-grained amphibolite and hornfels known as the Copley Greenstone. Thin layers of metamorphosed gray rhyolite containing quartz inclusions known as the Balaklala Rhyolite were also encountered in both borings below depths of 200 feet.

Water Encountered:

While injecting air through the drill stem to the bottom of the pilot hole to remove the rock cuttings from the hole ("airlifting"), the driller estimated a discharge rate of approximately 1-3/4 gallons per minute (gpm) in Brandy #1 and 6 gpm in Brandy #2. The depths to water in the borings measured several hours after airlifting stopped were 202 feet in Brandy #1 and 4 feet in Brandy #2.

Abandonment

Because neither test boring produced water in sufficient quantities to meet the project goal of 20 gpm, the holes were abandoned by backfilling with drill cuttings to a depth of approximately 20 feet, followed by bentonite chips from 20 feet to the surface according to Shasta County Environmental Health Division requirements.

CONCLUSIONS AND RECOMMENDATIONS

Based on the information provided by the NPS and our field observations, GEOPlus presents the following conclusion and recommendation.

1. There is no geologic evidence that sufficient quantities of water would be encountered by drilling deeper at either Brandy #1 or Brandy #2.
2. We do not recommend drilling additional sites for Brandy Creek without first performing an additional Preliminary Groundwater Resource Assessment, expanding on the NPS Geologist's memorandum.

LIMITATIONS

The services provided under this contract, as described in this report, include professional opinions and judgments based on the data collected and analyzed. We performed these services

according to currently accepted hydrogeologic practices for water resources engineering in Northern California. We base this report on information derived from the following:

- Review of a NPS internal memorandum dated July 1, 2009;
- Field observations and measurements; and,
- Driller's field records.

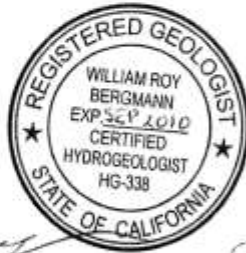
The conclusions and recommendations presented in this report were developed for the purpose of recording baseline hydrogeologic conditions. The horizontal and vertical extent of the water bearing geologic materials can never be fully ascertained due to incomplete knowledge of subsurface conditions. Therefore, GEOPlus makes no warranty or guarantee regarding the long term yield of any well or the variable subsurface conditions which may exist. If the client wishes to reduce the uncertainty beyond the level associated with this study, GEOPlus should be notified for additional consultation.

CLOSING REMARKS

We enjoyed assisting the Richard P. Arber Associates with this challenging project. If you have any questions or need additional information, please contact Bill Bergmann at (530) 222-7203.

Sincerely,

GEOPLUS, INC.




William R. Bergmann, R.G., C.H.G.
Principal Hydrogeologist


Traver E. "Corky" Metcalf, Jr., P.E., GE.
Principal Geotechnical Engineer

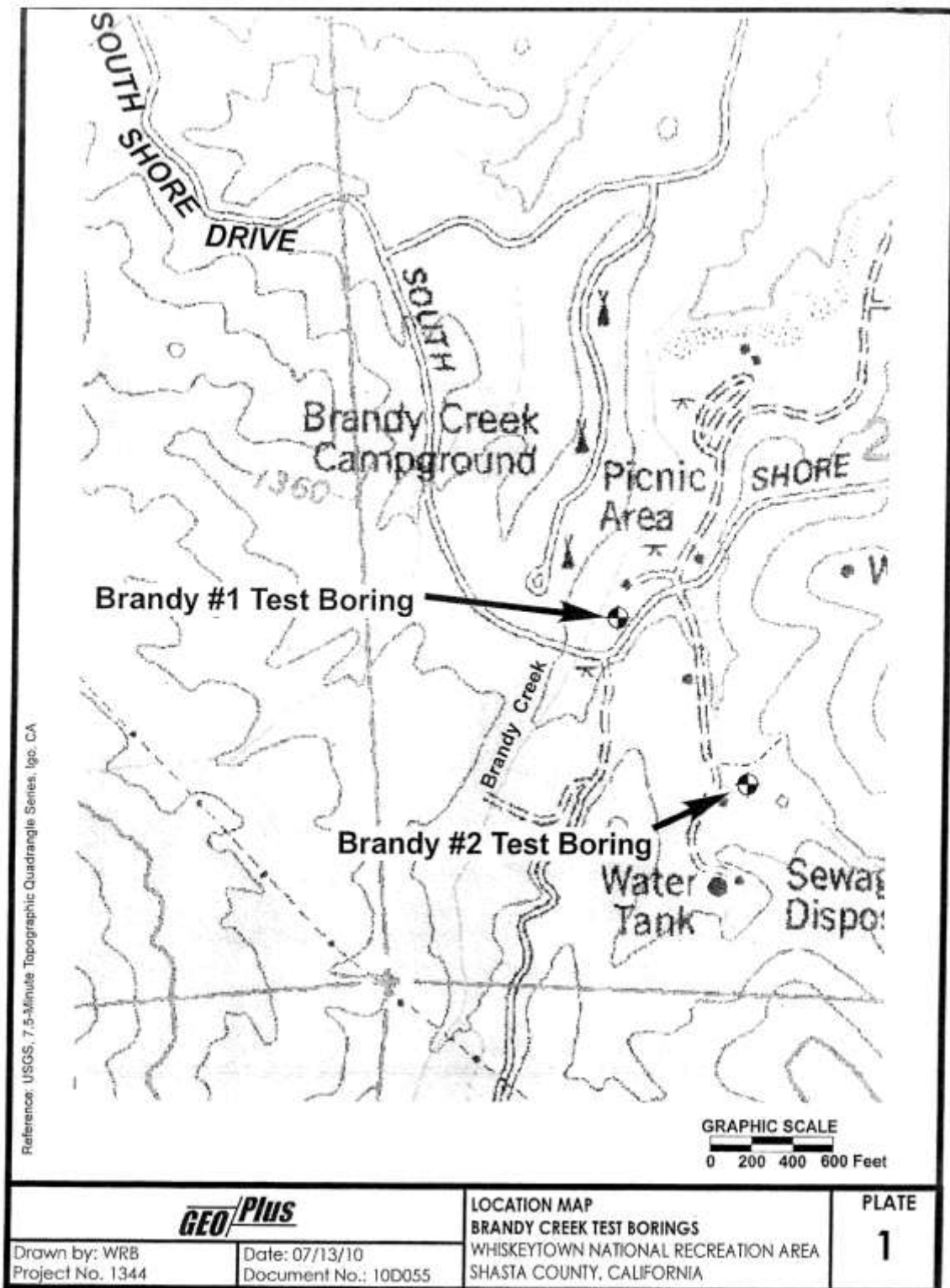
Attachments: Plate 1: Test Borings Location Map
DWR Well Drillers Reports: Well WW-1, #0950479
Well WW-2, #0950480
Shasta County Environmental Health Division Well Permit

WRB/TEM/wb

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July 14, 2010



ORIGINAL
File with DWR

COPY

STATE OF CALIFORNIA
WELL COMPLETION REPORT

Refer to Instruction Pamphlet

No. 0950479

Page 1 of 1

Owner's Well No. HW-1

Date Work Began 6/1/10, Ended 6/2/10

Local Permit Agency Shasta County Environmental Health

Permit No. WTR#10-069 Permit Date 5/24/10

DWR USE ONLY - DO NOT FILL IN

STATE WELL NO./STATION NO.	
LATITUDE	LONGITUDE
APN/PROBOTHER	

ORIENTATION (±)			DEPTH FROM SURFACE FL to FL	DESCRIPTION
VERTICAL	HORIZONTAL	ANGLE (SPECIFY)		
☒	☐			
DRILLING METHOD Air-Rotary FLUID				
Describe material, grain size, color, etc.				
			0 - 8'	Light tan silt w/boulders
			8 - 19'	Very Weathered Greenstone
			19 - 305'	Greenstone w/some fractures

Well did not produce enough water for campgrounds needs. Destroyed by backfilling w/dry cuttings to 21 feet. Then placing bentonite from 21 feet to surface.

WELL OWNER
Name National Park Service
Mailing Address P.O. Box 188
Whiskeytown, CA 96033
WELL LOCATION
Address Whiskeytown Brandy Creek Campground
City Whiskeytown French Gulch
County Shasta
APN Book 011 Page 390 Parcel 002
Township 10 Range Section
Lat Long

LOCATION SKETCH

SEE ATTACHED MAP

ACTIVITY (±)

☒ NEW WELL

MODIFICATION/REPAIR

☐ Deepen

☐ Other (Specify)

☒ DESTROY (Describe Procedure and Materials Under "GEOLOGIC LOG")

USES (±)

WATER SUPPLY

☐ Domestic ☐ Public

☐ Irrigation ☐ Industrial

MONITORING

TEST WELL

CATHODIC PROTECTION

HEAT EXCHANGE

DIRECT PUSH

INJECTION

VAPOR EXTRACTION

SPARGING

REMEDIATION

OTHER (SPECIFY)

TOTAL DEPTH OF BORING 305 (Feet)
TOTAL DEPTH OF COMPLETED WELL 305 (Feet)

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER 17' (FL) BELOW SURFACE

DEPTH OF STATIC WATER LEVEL N/A (FL) & DATE MEASURED

ESTIMATED YIELD N/A (GPM) & TEST TYPE

TEST LENGTH (hrs) TOTAL DRAWDOWN (FL)

* May not be representative of a well's long-term yield.

DEPTH FROM SURFACE			BORE-HOLE DIA. (Inches)	CASING (S)						DEPTH FROM SURFACE			ANNULAR MATERIAL				
				TYPE (±)				MATERIAL / GRADE	INTERNAL DIAMETER (Inches)				GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)	TYPE		
FL	to	FL	BLANK	BENTONITE	CEMENT	INCHES	FEET			PER	CEMENT (±)	BENTONITE (±)			FILL (±)	FILTER PACK (TYPE/SIZE)	

ATTACHMENTS (±)

☐ Geologic Log

☐ Well Construction Diagram

☐ Geophysical Log(s)

☐ Soil/Water Chemical Analysis

☒ Other See Map

ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME Diamond Core Drilling, Inc.

ADDRESS P.O. Box 491925 Redding, CA 96049

DATE 6/15/10

DATE SIGNED 512406

C-37 LICENSED WATER WELL CONSTRUCTOR

DWS 180 3/07, 05-05

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

OSP 03 7/06/05

15



July 20, 2010

File: 1344

Mr. Matt Hirschbeck
Richard P. Arber Associates
198 Union Boulevard, Suite 200
Lakewood, Colorado 80228

**Subject: OAK BOTTOM SUPPLY WELL COMPLETION REPORT
OAK BOTTOM CAMPGROUND
WHISKEYTOWN NATIONAL RECREATION AREA, CALIFORNIA**

Dear Mr. Hirschbeck:

GEOPlus, Inc. is pleased to present this completion report for a new supply well at the Oak Bottom area, Whiskeytown National Recreation Area, in Shasta County, California. This report summarizes the construction, development, and water quality testing of the well. This work was conducted in accordance with our agreement dated May 2, 2010 and Amendment No. 1 dated July 6, 2010. The location of the Oak Bottom well site is presented in Plate 1.

FINDINGS

GEOPlus installed a 286-foot deep well with a 4-inch diameter PVC liner between the dates of June 3 and June 7, 2010. The static water level in the completed well was approximately 15 feet below top of the steel casing (TOC). In a 9-day constant-discharge rate pumping test, the well produced 50 gallons per minute (gpm) at a final pumping level of approximately 102 feet TOC. The water produced from the well meets the regulatory requirements for drinking water for bacteria, general minerals, general physical parameters, inorganic compounds, volatile organic compounds, gross alpha radioactivity, cyanide, and asbestos.

BACKGROUND

Richard P. Arber Associates retained GEOPlus's services to assist the National Park Service (NPS) in developing a water supply well to provide potable use and fire flow needs for the Oak Bottom Campground. A water line will be constructed to convey water from the well to two 35,000-gallon storage tanks located atop the hill east of the Oak Bottom Firehouse.

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July 20, 2010

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Groundwater in the Oak Bottom vicinity occurs within bedrock fractures of Devonian age metavolcanic rocks of the Eastern Klamath terrane of the Klamath Mountains¹.

Existing Water Sources:

Oak Bottom has historically been served by a surface water treatment plant which draws water from the lake. Treatment at the plant consists of direct filtration with vertical pressure filters followed by disinfection with sodium hypochlorite. The 40-year-old plant currently has difficulty consistently producing water that is in compliance with current treatment standards. For this reason, the Park identified the need to replace the current system with a new potable water well. NPS has indicated that a supply well with 20 gpm peak day 24-hour capacity will meet the campground's minimum demand.

The nearest well to the site is the water supply well for the NPS wastewater treatment plant located in Grizzly Gulch, approximately 1/4-mile north of the project site. Because the capacity of the treatment plant well does not meet the campground's minimum demand, NPS decided to construct the subject well. The location for the well was based on recommendations prepared by NPS geologist Larry Martin in a memorandum dated July 1, 2009.

OAK BOTTOM WELL CONSTRUCTION

Prior to drilling the well GEOPlus acquired a well permit from the Shasta County Environmental Health Division (SCEHD) (see Appendix A). The permit specified a minimum 50-foot deep sanitary well seal as required for a public supply well. An as-built well construction diagram is presented in Plate 2. A copy of the driller's Well Completion Report (DWR form 188) is presented in Appendix B.

Pilot Boring:

On June 3, 2010 GEOPlus's drilling subcontractor, Diamond Core Drilling, Inc., advanced a 6-1/8-inch diameter pilot boring to a total depth of 285 feet using air rotary equipment (Ingersoll-Rand TH-60 rig with down-hole percussion bit). GEOPlus's geologist collected samples of the drill cuttings at approximately 20-foot intervals to describe the geologic materials encountered.

The rock type encountered throughout the boring was a Devonian-age andesitic volcanic rock that has been metamorphosed to dark green, fine-grained amphibolite and hornfels known as the Copley Greenstone. Near the surface the material encountered consisted of highly weathered

¹ Fraticelli, Luis A., John P. Albers, William P. Irwin, and Milton C. Blake, Jr. et al, 1987. Geologic Map of the Redding 1 x 2 Degree Quadrangle, Shasta, Tehama, Humboldt, and Trinity Counties, California, 1:250,000, 1987. 10R326 File: 1344
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light brown greenstone which extended to a depth of approximately 37 feet below existing grade. The rock's degree of weathering decreased with depth, becoming moderately weathered at approximately 37 feet, and fresh at approximately 60 feet depth. Fracture zones bearing increasing amounts of water were encountered at 105 to 125 feet, 150 to 270 feet, and 280 to 285 feet. While injecting air through the drill stem to the bottom of the pilot boring (286 feet depth) to remove the rock cuttings from the hole ("airlifting"), the driller estimated a discharge rate of approximately 50 gpm. GEOPlus collected a water sample (sample designation "Oak B. Well") from the cuttings discharge cyclone during airlifting from a total depth of 285 feet. The water level rose overnight to approximately 13 feet below ground surface.

Sanitary Seal Placement:

On June 7, 2010 the driller constructed the sanitary seal by reaming the hole to a final diameter of 10 inches to a depth of 56 feet, driving a 6-5/8-inch outer-diameter steel conductor casing to a depth of 58 feet, and placing the seal material into the annular space between the conductor casing and 10-inch hole. The seal material consisted of hydrated bentonite chips from 56 feet to 46 feet and 30 percent solids hydrated bentonite slurry from 46 feet depth to the surface. The bentonite slurry was pumped from the bottom upwards using a Chem-Grout® injection system and tremie pipe. The product information sheet for the bentonite slurry material is presented in Appendix C. SCEHD's environmental health specialist, Mr. Rob Demarr, witnessed the placement of the seal.

Hole Re-Drilling, Air-Lift Development, and Well Construction:

On June 7, 2010 the driller re-drilled the 6-1/8-inch diameter hole to a final depth of 286 feet.

After reaching the final depth the driller continued airlifting from the bottom of the hole for approximately 1 hour to develop the well. The purpose of development is to improve production capacity and reduce sand-pumping and turbidity by removing drill cuttings and fine sediment from the supply well borehole and adjacent formation. The driller visually estimated the airlifted discharge rate to be between 47 and 50 gpm.

A liner consisting of 4-inch diameter Class 200 PVC pipe was placed in the well from a depth of 6 feet to 186 feet to protect the well and future pump installation against caving. The PVC liner was terminated at a depth of 6 feet below grade to accommodate future installation of pitless-adaptor supply connection equipment. The bottom 40 feet of the liner consists of 0.032-inch factory-slotted Class 200 well screen to allow entry of water.

Well Disinfection:

After setting the PVC liner, the driller disinfected the well by introducing Well Sanitizer tablets (manufactured by Osmonics Autotrol of Emmetsburg, Iowa) in accordance with manufacturer specifications. This product contains 72 percent calcium hypochlorite.

DISCHARGE PERMITTING AND MONITORING

Natural runoff in the vicinity of the well site flows westward in a ditch bordering the north edge of the parking lot pavement to a drop inlet and culvert outfall which discharges to an inlet of Whiskeytown Lake approximately 550 feet west of the well. Water produced from the well was discharged to the ditch in accordance with a Notice of Applicability dated May 26, 2010 issued by the Sacramento Regional Water Quality Control Board (RWQCB) under General Order No. R5-2008-0081-069, NPDES No. CAG995001 -- Waste Discharge Requirements for Dewatering and Other Low Threat Discharges to Surface Waters (see Appendix D).

The discharge water produced by air lifting during drilling and development was controlled with a straw-bale containment cell and several rows of wattles to prevent sediment from entering the lake. Pump effluent from the completed well was piped under the firehouse driveway to the ditch. The water quality of the effluent and receiving water in the lake were monitored in accordance with the permit. Sampling of an "upstream" receiving water location was not possible because the effluent was discharge to the point of the inlet, and there was no ambient flow in the drainage leading to the culvert. Monitoring performed in accordance with the permit did not reveal degradation of the lake. Mr. Kevin Kratzke of the RWQCB inspected the discharge on June 8, 2010 during the step drawdown pumping test and had no objections to the discharge conditions. GEOPlus is preparing a complete monitoring report in accordance with the General Order to be submitted to the RWQCB under separate cover.

PUMPING TESTS

Pursuant to Section 64554 of the California Waterworks Standards pumping tests were performed to demonstrate the well's capacity to meet the system's maximum day demand. The standards restrict the capacity of public water systems to 50 percent of the continuous 10-day sustainable well capacity if the well is completed in fractured rock. Therefore, a pumping rate of 40 to 50 gpm was desired for the test to meet the operational design 20 to 25 gpm demand.

Test Pumping Equipment Installation:

A temporary 2 horsepower electrical submersible pump (Grundfos Model 40S20-7) was installed at an intake level of 140 feet below TOC. The pump was fitted with a check valve to achieve representative water levels during the recovery period after shut-off. The pump was connected to 230-volt single-phase line power by NPS staff. The drilling contractor operated and maintained the pump equipment and controls during the test. The discharge rate was controlled by throttling the discharge with a ball valve. Water discharge rates were estimated using an 18-gallon barrel and stopwatch at frequent intervals. As a backup, an in-line pitot tube flow meter was installed. GEOPlus measured the depth to water level in the well at regular time intervals using a pressure transducer/datalogger placed 5 feet above the pump intake. As a backup, water levels were also measured by hand using an electrical water level sounding tape.

Step Drawdown Test:

On June 8, 2010 a step drawdown test was performed to select the target rate for the constant rate test. The well was pumped at stepped discharge rates of 30 gpm, 40 gpm, and 50 gpm for a minimum duration of one hour each. A hydrograph (time versus water level plot) of the test is presented in Plate 3. Tabular transducer readings and hand measurements for the step drawdown test are presented in Appendix E.

The drawdown at the end of the 50 gpm step was 77 feet (92 ft pumping level minus 15 feet static water level). The hydrograph curve exhibits progressive stabilization without shifts that would suggest aquifer dewatering or low-flow boundary effects. On the basis of the step test, a 50 gpm rate was selected for the constant discharge rate test.

Constant Discharge Rate Test:

GEOPlus observed the performance of combined well development and a 12,960-minute (9-day) constant-rate pumping test starting at 10:46 AM June 9 and ending at 10:46 AM on June 18, 2010.

The water level dropped from its static level of 15 feet TOC to a final pumping level of 102 feet TOC after 9 days of pumping at 50 gpm. The rate of water decline had nearly stabilized at the end of the test, falling only 0.33 feet in the final 20 hours of pumping. The water level recovered to within approximately 95 percent of the static level within 10 days after pumping ceased. Graphical semi-log and arithmetic plots of time versus water level drawdown for the pumping and recovery periods are presented in Plate 4. Tabular transducer readings and hand

measurements for the constant rate test are presented in Appendix F. The results of the pumping test are summarized in Table 1.

TABLE 1.

SUMMARY OF WELL PUMPING TEST PERFORMED JUNE 9 - 18, 2010

Static Depth to Water	15.31 feet , referenced to top of casing (TOC) (approximately 13.7 feet below ground surface)
Casing Stick-up above ground surface	1.6 feet
Test Pump Intake Depth	140 feet TOC
Test Pump Used	2 HP electric submersible with check valve. Grundfos Model 40S 20-7 (3.9-inch O.D.)
Duration of Pumping	12,960 minutes (9 Days)
Total gallons pumped	648,000 gallons (more than 9 times the 70,000 gallon capacity of the storage tanks)
Average Discharge Rate	50 gpm (constant)
Final Drawdown in Feet	86.88 feet (pumping water level was 102.19 ft TOC when pumping stopped)
Final Discharge Temperature	17.5° C (63.5° F)
Turbidity (field measurement)	0.28 NTU, measured 6/11/10
Electrical Conductivity (field measurement)	176.8 umhos/cm, measured 6/11/10
pH (field measurement)	6.51 pH units, measured 6/11/10
Estimated Specific Capacity *	(50 gpm)/(86.88 ft drawdown) = 0.58 gpm per foot drawdown
* The specific capacity of a well is its yield per unit of drawdown after a given elapsed time – 9 days in this case.	

Water Sampling and Chemical Testing

GEOPlus collected water samples during development on June 3, 2010 and during the pumping test on June 11, and June 18, 2010. The testing schedule for each sample is summarized in Table 2.

TABLE 2.**SUMMARY OF ANALYTICAL TESTING PERFORMED**

Sample Name "Oak B. Well" Sampled June 3, 2010	Sample Name "Oak B 6-11-10" Sampled June 11, 2010	Sample Name "Oak B. Effluent" Sampled June 18, 2010
"Grab Sample" Preliminary test for Selected Dissolved Metals: • Manganese (Mn); • Iron (Fe); and, • Arsenic.	Discharge Permit Testing • Biological Oxygen Demand (BOD) • Total Residual Chlorine; • Electrical Conductivity; • pH • Settleable Solids; and, • Total Suspended Solids. Drinking Water Permit Testing • General Minerals • General Physical • Asbestos • Cyanide • Volatile Organic Compounds; • Gross Alpha Radioactivity • Inorganic Chemicals (total metals); and, • Total and Fecal Coliform Bacteria.	Discharge Permit Testing • Biological Oxygen Demand (BOD) • Total Residual Chlorine; • Electrical Conductivity; • pH; • Settleable Solids; and, • Total Suspended Solids.

The analytical laboratory results for all three sets of water samples are presented in Appendix G.

None of the tested parameters were detected at concentrations near or exceeding either California or US EPA Maximum Contaminant Level (MCL) drinking water standards.

DISCUSSION OF SPECIFIC CAPACITY AND DRAWDOWN

The specific capacity of a well is its yield per unit of drawdown after a given elapsed time. The specific capacity can be used to predict drawdown at various pumping rates. Using the specific capacity of 0.58 gpm/ft obtained from the 50 gpm test, a drawdown of approximately 40 to 45 feet is estimated for the 25 gpm system design discharge rate.

It should be understood that drawdown increases with pumping duration and does not truly "stabilize" in a pumping well. This is particularly evident in the semi-log plot (attached). Therefore, specific capacity will continue to decrease slightly with pumping duration, and as such specific capacity should be used within the tested limits. Accordingly, the drawdown estimate stated above should be conservatively high if the system is not be operated at full capacity for durations longer than nine days.

CONCLUSIONS AND RECOMMENDATIONS

On the basis of our observations and laboratory test results, GEOPlus presents the following conclusions.

1. The intended 10-day constant rate pumping test was inadvertently terminated after 9 days elapsed pumping time. It is our professional opinion that the test is valid for the purposes of establishing the wells sustained capacity as described in the California Waterworks Standards for the following reasons.
 - The attached hydrograph for the test exhibits a generally steady slope after approximately 1,000 minutes (less than 1 day) which continued until the end of the test.
 - Available drawdown in the well (height of static water level above the top of perforations is 233 feet ($246' - 13' = 233'$ available drawdown), which is more than double the drawdown observed (87 feet observed drawdown). The available drawdown at the 50 percent rate would afford an even greater degree of conservation.
 - The water level at the end of the test (100 feet below ground surface) was 60 feet above the top of the uppermost water-bearing zone (the 160 -169-foot fracture zone shown in Plate 2). We therefore do not expect dewatering effects that would significantly increase the slope of the line (increase the rate of drawdown increase) within an additional day of pumping.
 - The water level after the pump was shut off recovered steadily to 95 percent of the final drawdown, which is a general indication that recharge to the aquifer system is occurring at a rate greater than the extraction rate.
2. Based on the hydrograph for the continuous rate pumping test, we conclude that the well can be pumped continuously for several weeks at a rate of 50 gpm. The water level in the

well recovered steadily to within 95 percent of its static level within 10 days after pumping ceased.

3. A drawdown of 40 to 45 feet is estimated during operation of the system based on the well's specific capacity of 0.58 gpm/ft drawdown and a design discharge rate of 25 gpm.
4. Total coliforms and fecal coliforms were not detected in the sample from the well collected on June 11, 2010.
5. Total manganese (Mn) was detected at a concentration of 225 micrograms per liter (ug/L) in the June 11, 2010 sample. This Mn concentration exceeds the 50 ug/L Mn California *secondary* aesthetics-based MCL. According to our discussions with RPAA, upon chlorination of the water, the manganese will precipitate and settle inside the storage tanks, lowering the Mn concentration in the delivered supply to negligible levels.
6. The 11 ug/L iron reported in the airlifted "grab" water sample (sampled 6/03/10) is attributable to turbidity and aeration by the air lifting process. Iron was not detected in the final sample obtained from the discharge of the stainless-steel electrical submersible pump (sampled 6/11/10), which met the regulatory drinking water requirements of all the parameters tested.
7. Dichloromethane (a.k.a. methylene chloride) was reported at a concentration of 0.86 ug/L, much less than the 5 ug/L MCL standard. Dichloromethane is a common laboratory artifact; therefore, this trace concentration does not represent groundwater conditions. No other volatile organic compounds (VOCs) were detected.
8. Asbestos, Cyanide, and Gross Alpha Radioactivity were below detectable levels.
9. Concentrations of all constituents tested for discharge monitoring were low and do not represent an environmental concern to Whiskeytown Reservoir.

On the basis of the information above, GEOPlus presents the following recommendations.

1. In accordance with the 50 percent rule of the California Water Works Standards, the well's pumping system should be designed for 25 gpm peak 24-hour demand.
2. We estimate that a 2-horsepower electric submersible pump should achieve 25 gpm at a total hydraulic head of 200 feet (rough estimate of lift from pumping water level to the storage tanks). Several pumps are manufactured to this specification designed to fit the 4-inch nominal diameter of the liner.

3. The pump's intake should be set at a depth of approximately 200 feet (46-feet above the top of liner perforations).
4. The well should be re-disinfected with calcium hypochlorite at the time the permanent pump is installed.

LIMITATIONS

The services provided under this contract, as described in this report, include professional opinions and judgments based on the data collected and analyzed. We performed these services according to currently accepted hydrogeologic practices for water resources engineering in Northern California. We base this report on information derived from the following:

- Well construction data for existing wells provided to GEOPlus by others;
- Field observations and measurements; and,
- Driller's field records.

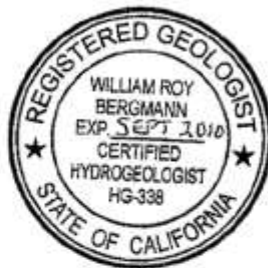
The conclusions and recommendations presented in this report were developed for the purpose of recording baseline hydrogeologic conditions, and to provide design information which may assist the project engineer with pump selection, depth setting, and design of water delivery system components. Interpretation of information available from groundwater pumping tests is limited by the duration of pumping, inherent variability of pumping rates, and incomplete knowledge of subsurface conditions. The horizontal and vertical extent of the water bearing geologic materials can never be fully ascertained. Therefore, GEOPlus makes no warranty or guarantee regarding the long term yield of any well or the variable subsurface conditions which may exist. If the client wishes to reduce the uncertainty beyond the level associated with this study, GEOPlus should be notified for additional consultation.

CLOSING REMARKS

GEOPlus enjoyed assisting the Richard P. Arber Associates with this project. If you have any questions or need additional information, please contact Bill Bergmann or Corky Metcalf at (530) 365-8088.

Sincerely,

GEOPLUS, INC.



William R. Bergmann *Traver E. Metcalf, Jr.*

William R. Bergmann, P.G., C.H.G.
Principal Hydrogeologist

Traver E. "Corky" Metcalf, Jr., P.E., GE.
Principal Geotechnical Engineer

Plates:

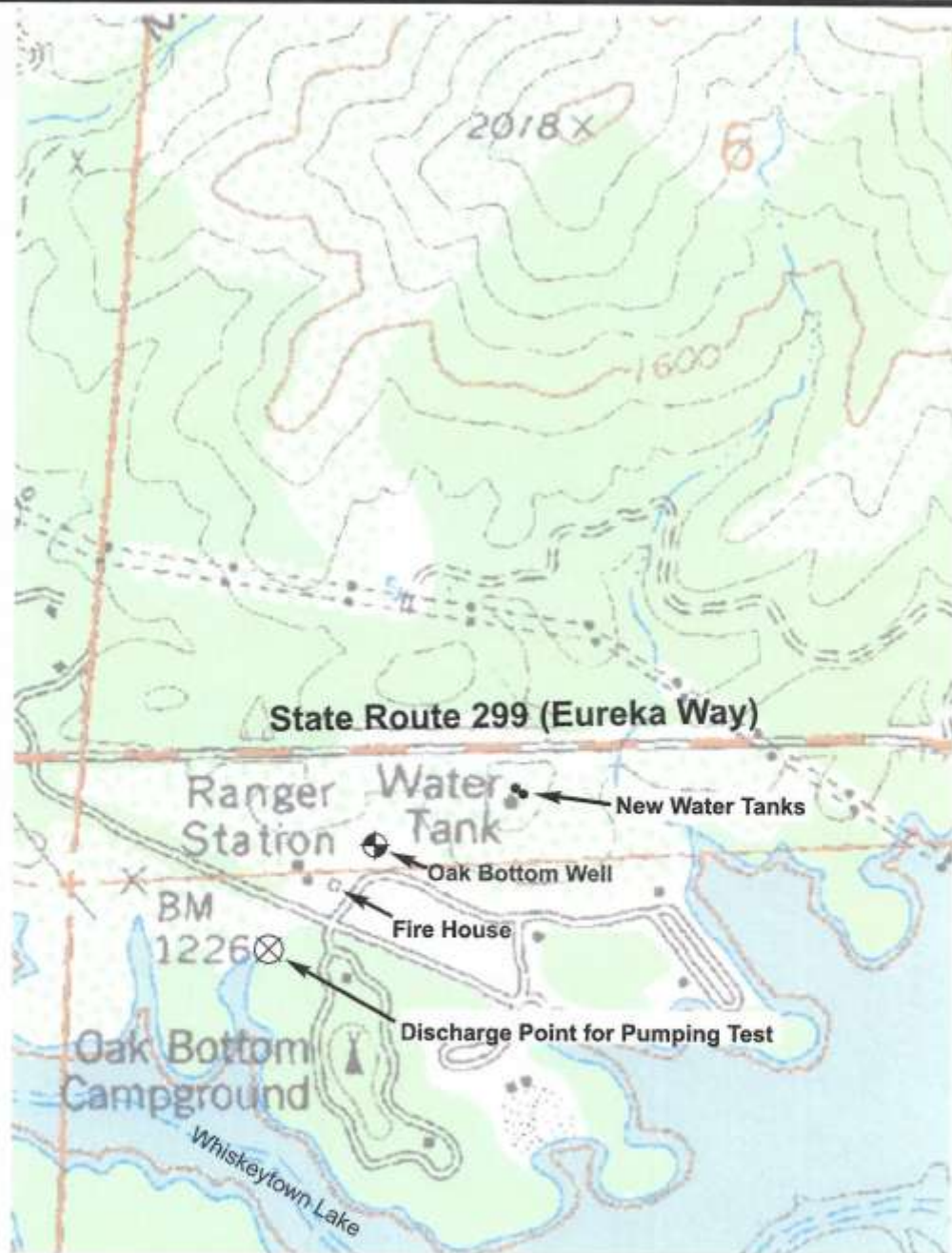
- Plate 1: Site Location Map
- Plate 2: As-Built Well Construction Diagram
- Plate 3: Step Drawdown Test Hydrograph
- Plate 4a: Constant Rate Test Pumping and Recovery Hydrograph– Arithmetic Plot
- Plate 4b: Constant Rate Test Pumping Hydrograph – Semilog Plot

Appendices:

- A -- Shasta County Environmental Health Division Well Permit
- B --DWR Well Drillers Report #0950481
- C -- Product information sheet for Hydro Grout 30 High Solids Bentonite Grout
- D -- RWQCB Notice of Applicability (discharge permit)
- E -- Step Discharge Test Automated Pressure Transducer Data and Field Data Sheets
- F -- Constant Rate Test Automated Pressure Transducer Data and Field Data Sheets
- G -- Analytical Laboratory Reports and Sample Custody Records

WRB/TEM

Reference: USGS, 7.5-Minute Topographic Quadrangle Series, Whiskeytown, CA



GRAPHIC SCALE
0 200 400 600 Feet

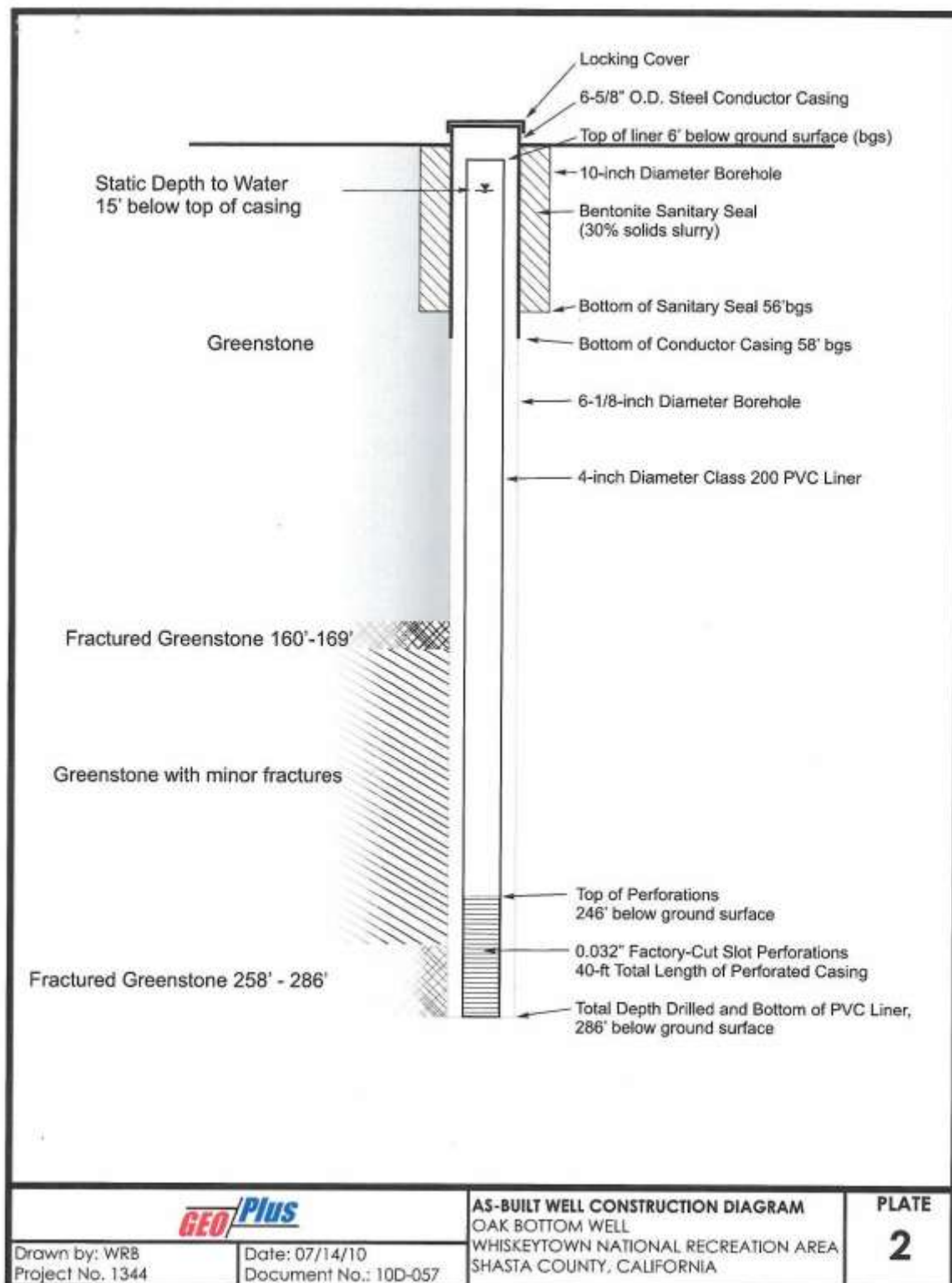
GEO/Plus

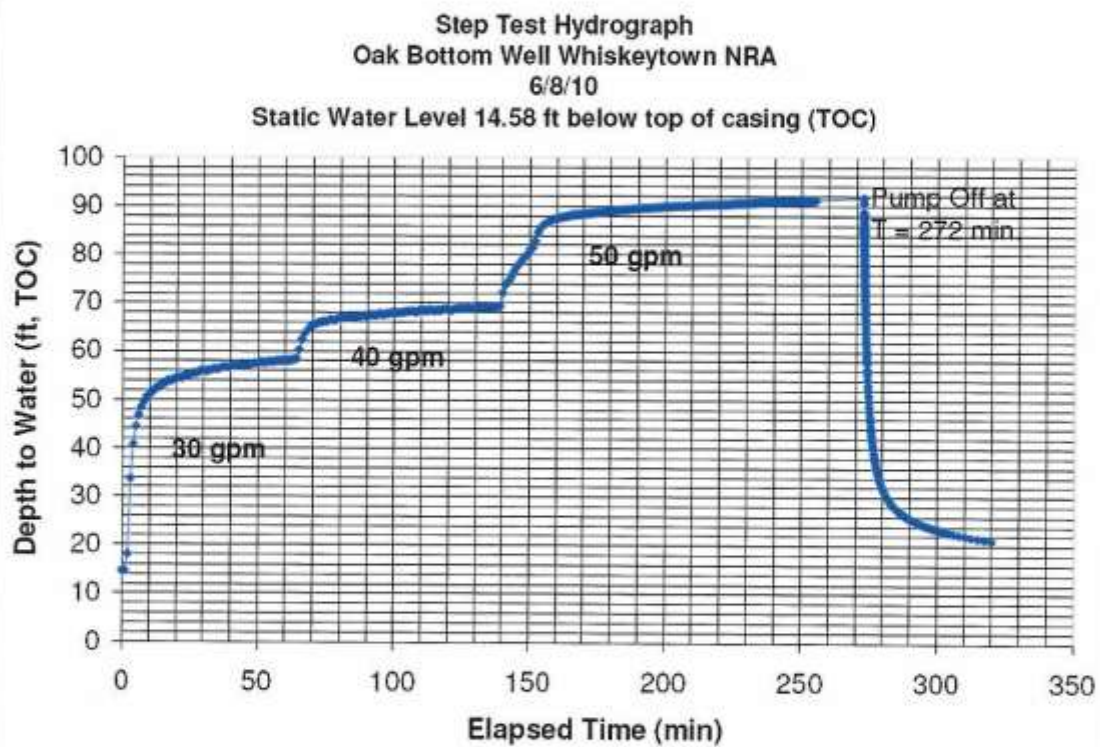
Drawn by: WRB
Project No. 1344

Date: 07/14/10
Document No.: 10D056

WELL LOCATION MAP
OAK BOTTOM CAMPGROUND
WHISKEYTOWN NATIONAL RECREATION AREA
SHASTA COUNTY, CALIFORNIA

PLATE
1

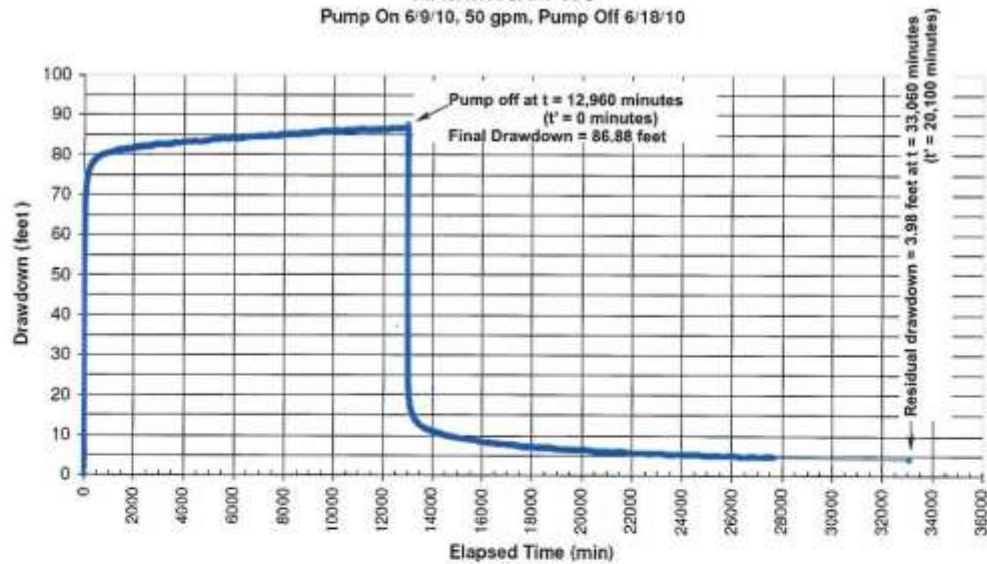




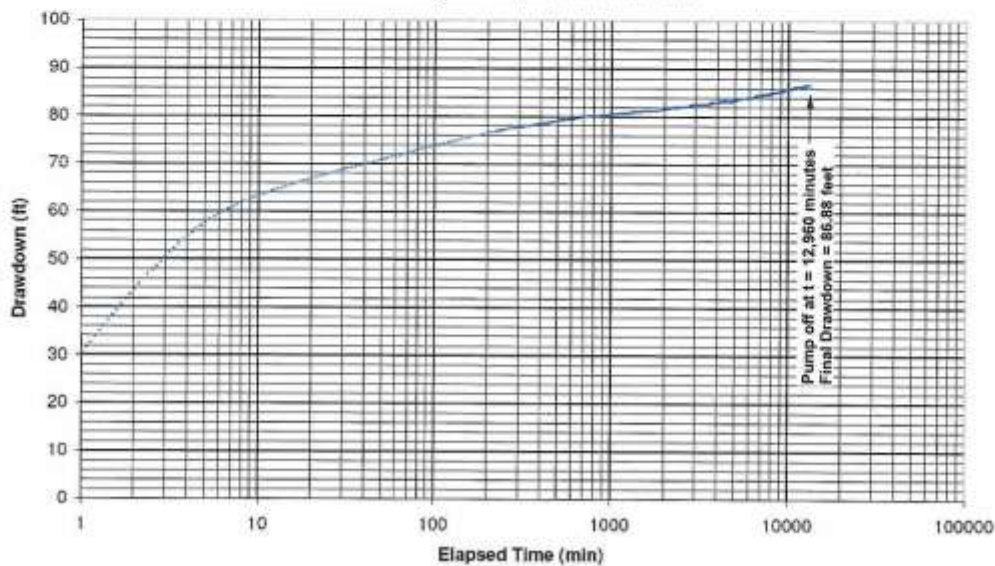
		STEP DRAWDOWN PUMPING TEST DATA OAK BOTTOM CAMPGROUND WHISKEYTOWN NATIONAL RECREATION AREA SHASTA COUNTY, CALIFORNIA	PLATE 3
Drawn by: WRB Project No. 1344	Date: 07/16/10 Document No.: 10D059		

Oak Bottom Well Pumping and Recovery Data
Whiskeytown NRA
Arithmetic Plot

Pump On 6/9/10, 50 gpm, Pump Off 6/18/10



Oak Bottom Well Pumping Data
Oak Bottom Well, Whiskeytown NRA
 Constant Q=50gpm Pump Started 10:46 6/9/10



GEO/Plus

Drawn by: WRB
 Project No. 1344

Date: 07/16/10
 Document No.: 10D059

CONSTANT RATE PUMPING TEST DATA
 OAK BOTTOM CAMPGROUND
 WHISKEYTOWN NATIONAL RECREATION AREA
 SHASTA COUNTY, CALIFORNIA

PLATE
4

ORIGINAL
File with DWR

COPY

STATE OF CALIFORNIA
WELL COMPLETION REPORT

Refer to Instruction Pamphlet

No. 0950481

Page 1 of 1

Owner's Well No. WW-1

Date Work Began 6/3/10, Ended 6/7/10

Local Permit Agency Shasta County Environmental Health

Permit No. WTR# 10-068 Permit Date 5/24/10

DWR USE ONLY - DO NOT FILL IN

STATE WELL NO./STATION NO.	
LATITUDE	LONGITUDE
APN/OTHER	

GEOLOGIC LOG				WELL OWNER	
ORIENTATION (°) ☒ VERTICAL ☐ HORIZONTAL ☐ ANGLE (SPECIFY)				Name National Park Services	
DRILLING METHOD Air-Rotary FLUID				Mailing Address P.O. Box 188	
DESCRIPTION				City Whiskeytown, CA 96033	
Describe material, grain size, color, etc.				STATE ZIP	
DEPTH FROM SURFACE	FL	TO	FL	WELL LOCATION	
0	52			Address Whiskeytown NRA, Oak Bottom Camp	
52	57			City Whiskeytown? French Gulch ground	
57	160			County Shasta	
160	169			APN Book 011 Page 240 Parcel 068	
169	258			Township Range Section	
258	286			Lat Long	
Very fractured greenstone w/ reddish brown color				LOCATION SKETCH	
				NORTH	
				EAST	
				WEST	
				SOUTH	
				Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.	
				ACTIVITY (°)	
				☒ NEW WELL	
				☐ MODIFICATION/REPAIR	
				☐ Deepen	
				☐ Other (Specify)	
				☐ DESTROY (Describe Procedure and Materials Under "GEOLOGIC LOG")	
				USES (°)	
				☒ WATER SUPPLY	
				☒ Domestic ☐ Public	
				☐ Irrigation ☐ Industrial	
				☐ MONITORING	
				☐ TEST WELL	
				☐ CATHODIC PROTECTION	
				☐ HEAT EXCHANGE	
				☐ DIRECT PUSH	
				☐ INJECTION	
				☐ VAPOR EXTRACTION	
				☐ SPARGING	
				☐ REMEDIATION	
				☐ OTHER (SPECIFY)	
				WATER LEVEL & YIELD OF COMPLETED WELL	
				DEPTH TO FIRST WATER 46' (FL) BELOW SURFACE	
				DEPTH OF STATIC WATER LEVEL 13' (FL) & DATE MEASURED 6/7/10	
				ESTIMATED YIELD 50 (GPM) & TEST TYPE Air-Lift	
				TEST LENGTH 2 (Min.) TOTAL DRAWDOWN (FL)	
				* May not be representative of a well's long-term yield.	
TOTAL DEPTH OF BORING 286 (Feet)					
TOTAL DEPTH OF COMPLETED WELL 286 (Feet)					

DEPTH FROM SURFACE	BORE-HOLE DIA. (inches)	CASING (S)					DEPTH FROM SURFACE	ANNULAR MATERIAL			
		TYPE (°)	MATERIAL / GRADE	INTERNAL DIAMETER (inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (inches)		CE-MENT (°)	BEN-TONITE (°)	FILL (°)	FILTER PACK (TYPE/SIZE)
0	56	10" X	Steel	6 5/8	.188		0	56	X		Bentonite
56	58	7 1/2" X	Steel	6 5/8	.188						
58	286	6 1/8"	OPEN HOLE								
6	246	X	PVC	4"	CL 200						
246	286	X	PVC	4"	CL 200	.032					

ATTACHMENTS (°)		CERTIFICATION STATEMENT	
☐ Geologic Log		I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.	
☐ Well Construction Diagram		NAME Diamond Core Drilling, Inc.	
☐ Geophysical Log(s)		(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)	
☐ Soil/Water Chemical Analysis		P.O. Box 491925 Redding, CA 96049	
☒ Other See Map		ADDRESS	
ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.		Signed <i>[Signature]</i> 6/17/10 DATE SIGNED	
		C-57 LICENSED WATER WELL CONTRACTOR 512406 C-57 LICENSE NUMBER	

DWR 188 REV. 05-03

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

OSP 03 78836