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Date: June 20, 2003
Refer to: RRES-GPP-03-074

TA-36 (Pajarito Canyon, Hydrogeologic Workplan, Groundwater, H-54)

Mr. Mat Johansen
National Nuclear Security Administration
Department of Energy, MS A316
Los Alamos Site Operations
Los Alamos, NM 87545

SUBJECT: **CHARACTERIZATION WELL R-23 COMPLETION REPORTS**

Dear Mat:

Enclosed are two copies of the Characterization Well R-23 Completion Report. This report documents work completed under the Hydrological Work Plan.

If you have questions, please call me at (505) 665-4681.

Sincerely,

Charles Nylander, Program Manager
Groundwater Protection Program

CN/th

Enclosure: Characterization Well R-23 Completion Report (ER2003-0235/GPP-03-042)

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Remediation Program

RRES

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GPP-03-042

Characterization Well R-23 Completion Report

Los Alamos
NATIONAL LABORATORY
Los Alamos NM 87545

Produced by the Groundwater Protection Program, Risk Reduction & Environmental Stewardship Division

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List of Acronyms and Abbreviations

AITH	Array Induction Tool, Version H
ASTM	American Society for Testing and Materials
bgs	below ground surface
CMR	Combinable Magnetic Resonance
CNTG	Compensated Neutron Tool, Model G
DR	dual rotation
ECS	Elemental Capture Sonde
EES	Earth and Environmental Sciences
EPA	US Environmental Protection Agency
FMI	formation microimager
FMU	Facility Management Unit
FSF	Field Support Facility (part of Risk Reduction and Environmental Stewardship Division)
GPS	global positioning system
GR	gamma radiation
hp	horsepower
IC	ion chromatography

ICPES	inductively coupled plasma emission spectroscopy
ICPMS	inductively coupled plasma mass spectrometry
ID	inner diameter
LANL	Los Alamos National Laboratory
NGS	Natural Gamma Spectroscopy
NTU	nephelometric turbidity unit
OD	outer diameter
psi	pounds per square inch
PVC	polyvinyl chloride
RC	reverse circulation
RRES	Risk Reduction and Environmental Stewardship (Division)
SAP	Sampling and Analysis Plan
TA	technical area
TD	total depth
TLDM	triple detector lithodensity
UR-DTH	under-reaming down-the-hole (hammer bit)
VOC	volatile organic compound
WCSF	waste characterization strategy form
WGII	Washington Group International, Inc.

Metric to US Customary Unit Conversions

Multiply SI (Metric) Unit	by	To Obtain US Customary Unit
kilometers (km)	0.622	miles (mi)
kilometers (km)	3281	feet (ft)
meters (m)	3.281	feet (ft)
meters (m)	39.37	inches (in.)
centimeters (cm)	0.03281	feet (ft)
centimeters (cm)	0.394	inches (in.)
millimeters (mm)	0.0394	inches (in.)
micrometers or microns (µm)	0.0000394	inches (in.)
square kilometers (km^2)	0.3861	square miles (mi^2)
hectares (ha)	2.5	acres
square meters (m^2)	10.764	square feet (ft^2)
cubic meters (m^3)	35.31	cubic feet (ft^3)
kilograms (kg)	2.2046	pounds (lb)
grams (g)	0.0353	ounces (oz)
grams per cubic centimeter (g/cm^3)	62.422	pounds per cubic foot (lb/ft^3)
milligrams per kilogram (mg/kg)	1	parts per million (ppm)
micrograms per gram (µg/g)	1	parts per million (ppm)
liters (L)	0.26	gallons (gal.)
milligrams per liter (mg/L)	1	parts per million (ppm)
degrees Celsius (°C)	9/5 + 32	degrees Fahrenheit (°F)

CHARACTERIZATION WELL R-23 COMPLETION REPORT

ABSTRACT

Characterization well R-23 was installed by Los Alamos National Laboratory (the Laboratory) under implementation of its hydrogeologic work plan. Washington Group International, Inc., under a subcontract to the Laboratory, carried out drilling activities. The Laboratory's Risk Reduction and Environmental Stewardship (RRES) Division directed the R-23 project in accordance with the sampling and analysis plan for the drilling of characterization wells R-16, R-20, R-21, R-23, and R-32 in the vicinity of Technical Area (TA)-54. The well is located on the south side of Pajarito Road approximately 1000 ft west of the intersection of Pajarito Road and State Highway 4 in Pajarito Canyon. The primary purpose of this well is to provide hydrogeologic and water-quality data for regional groundwater near potential contaminant release sites at TA-54.

Hydrologic, geologic, geochemical, and geophysical information obtained during completion and subsequent sampling of well R-23 will provide data for the Laboratory's hydrologic and geologic conceptual models and contribute to implementing a Laboratory-wide groundwater monitoring system. Monitoring this network of wells supports the Laboratory's Groundwater Protection Management Program plan.

The R-23 borehole was drilled to a total depth of 935 ft below ground surface using a combination of conventional mud-rotary drilling, air-rotary drilling, and fluid-assisted dual rotary drilling with casing-advance methods. Geologic strata encountered during drilling operations included, in descending order, alluvium, Otowi ash flows and Guaje Pumice Bed of the Bandelier Tuff, Cerros del Rio lava flows and interbeds, sediments with basalt detritus of probable Cerros del Rio origin, and Santa Fe Group sediments. A possible perched zone was encountered at 470 ft below ground surface, and a sample was collected from this zone and submitted for analysis. A regional groundwater sample was collected during the final stages of well development and submitted for analysis. Based on the analytical results for the two samples, contamination from Laboratory discharges does not appear to be present in the groundwater at this well site.

The well was designed with one screen placed at the top of the regional aquifer. Following development, the completed well was equipped with a dedicated pump on January 8, 2003. The static water level was measured at a depth of 829 ft in the completed well.

1.0 INTRODUCTION

This completion report for characterization well R-23 summarizes preparation, drilling, well construction, well development, and site completion activities conducted from July 9, 2002, to March 13, 2003. Characterization well R-23 is located on the south side of Pajarito Road approximately 1000 ft west of the intersection with State Highway 4 in Pajarito Canyon (Figure 1.0-1). Well R-23 was installed as part of the "Hydrogeologic Workplan," in support of Los Alamos National Laboratory's (LANL or the Laboratory) "Groundwater Protection Management Program Plan" (LANL 1998, 59599; LANL 1996, 70215).

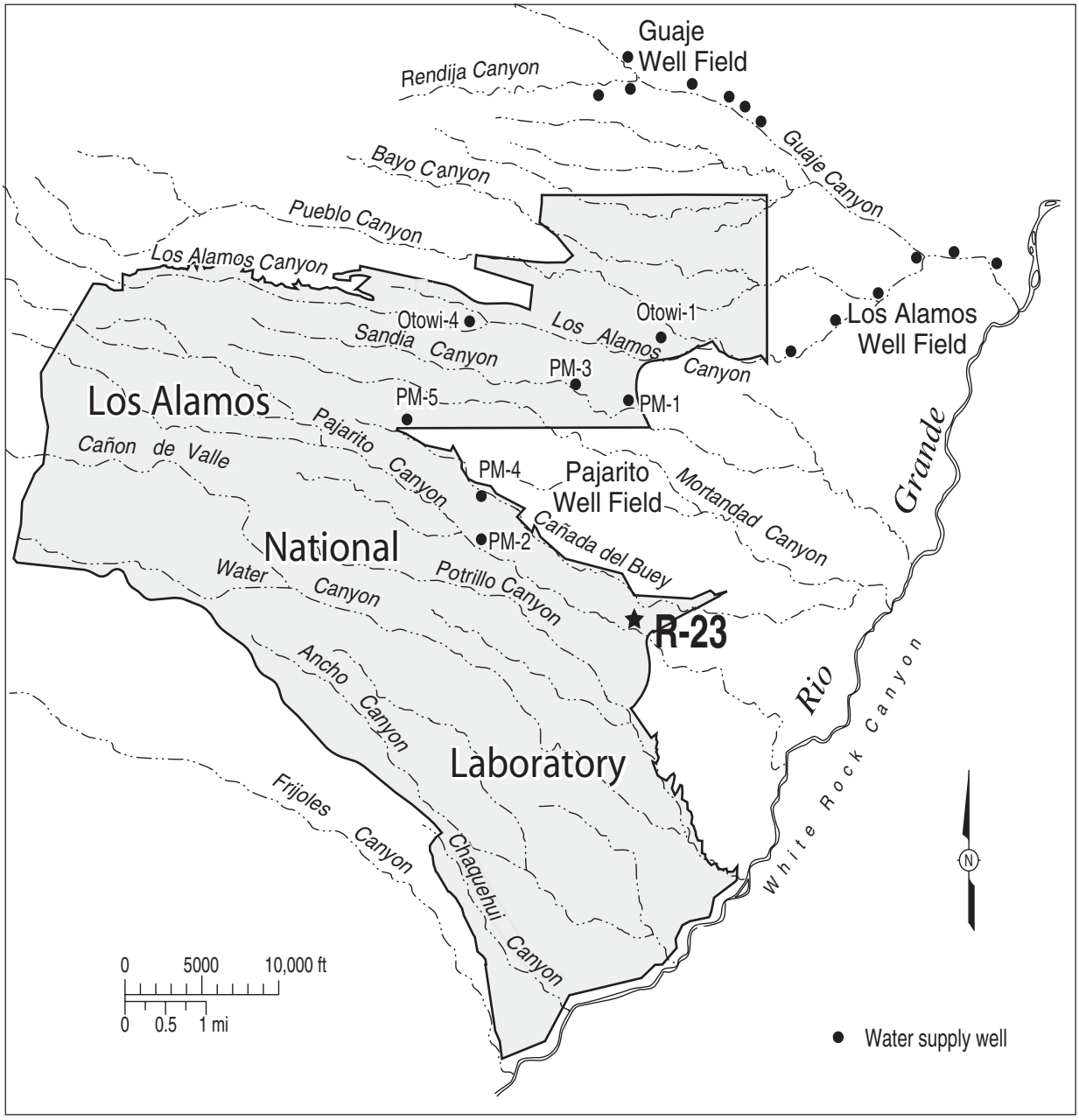


Figure 1.0-1. Location map, characterization well R-23

Characterization well R-23 was funded by the Nuclear Weapons Infrastructure, Facilities, and Construction Program and installed by the Laboratory's Risk Reduction and Environmental Stewardship (RRES) Division. Washington Group International, Inc. (WGII), under contract to the Laboratory, was responsible for executing the drilling activities.

The primary purpose of this characterization well is to provide water-quality, geochemical, hydrologic, and geologic information that would contribute to understanding regional subsurface characteristics and distribution of contaminants resulting from Laboratory releases from Technical Area (TA)-54. Additionally, data from R-23 will be used to update the sitewide hydrologic and geologic conceptual models for the Laboratory.

This report focuses on operational activities associated with the drilling, sampling, installation, and completion of well R-23. Detailed analysis and interpretation of geologic, geochemical, geophysical, and hydrologic data, included as part of previous well completion reports, will be discussed in separate documents to be prepared by the Laboratory.

2.0 PRELIMINARY ACTIVITIES

WGII received contractual authorization to start administrative preparation tasks on June 6, 2002. As part of this preparation, WGII developed a modification to existing site-specific health and safety plan No. 271 to include well R-23. WGII also prepared the R-23 waste characterization strategy form (WCSF). The Laboratory prepared the "Sampling and Analysis Plan (SAP) for the Drilling of Characterization Wells R-16, R-20, R-21, R-23, and R-32 in the Vicinity of TA-54" (LANL 2002, 73390), which included guidance for field personnel in the execution of R-23 field activities. Appendix A of this report compares activities planned in the sampling and analysis plan (SAP) with the work performed. The host facility, Facility Management Unit (FMU) 80, signed a Facility Tenant Agreement to provide access and security control for R-23 activities.

A readiness review meeting was held on July 9, 2002, to discuss all administrative agreements, documents, permits, and plans pertaining to the R-23 project. The Groundwater Investigations Focus Area project leader gave authorization on July 9, 2002, to begin site preparation. The readiness review checklist for drilling activities was signed on July 9, 2002.

K. R. Swerdfeger Construction, Inc., was subcontracted by WGII to conduct site preparation activities. Construction activities included clearing the site, constructing an access road and the drill pad, and constructing a lined cuttings-containment area. Site preparation was conducted from July 16 to 23, 2002.

The R-23 site initially was cleared of small trees and stumps. The construction of the drill pad involved leveling the designated 150-ft-long by 100-ft-wide area with a grader and compacting several layers of base-course gravel. An 80-ft-long by 25-ft-wide by 12-ft-deep cuttings-containment area was excavated along the southwest section of the drill pad and lined with a 6-mil polyethylene liner for storing drilling fluids and cuttings. A 3-ft-high berm was constructed around the containment area, and the entire excavation area was lined with a 6-mil polyethylene liner. A secondary containment area was graded and lined with 6-mil polyethylene to accommodate three 20,000-gal. tank trailers used for storing drilling fluids. Silt fences were constructed around the site, and safety barriers and signs were positioned around the cuttings-containment area and at the site entrance. In addition, the original fencing along Pajarito Road was modified and a new security barbed-wire fence was constructed on the southwest side of the site. Office and supply trailers, generators, and safety lighting equipment were moved to the site during subsequent mobilization of drilling equipment.

3.0 SUMMARY OF DRILLING ACTIVITIES

The drilling objectives for well R-23 were to collect groundwater samples for contaminant analysis, collect drill cuttings for geologic characterization, and provide a borehole for well installation into the regional aquifer. The borehole was drilled to a total depth (TD) of 935 ft below ground surface (bgs).

Dynatec Drilling Company, Inc. (Dynatec), performed all the drilling activities at the R-23 site during July, August, and September 2002. Dynatec provided an Ingersoll-Rand™ T-4 drill rig and a Foremost™ dual rotary (DR)-24 drill rig, along with reverse circulation (RC) drill rods and support equipment. Drill fluid mixing and circulation equipment included a mixing tank and pump assembly, a generator to power the mixing unit, a shaker unit to remove solids from the discharged drilling fluids, and an auxiliary pump. Equipment and fabrication support for drilling activities were provided by RRES Division's Field Support Facility (FSF).

Dynatec assembled its equipment to drill with either mud-rotary or fluid-assisted RC air-rotary drilling techniques to meet changing geologic and drilling conditions. Various additives were mixed with municipal water to minimize fluid loss, improve borehole stability, and facilitate cuttings removal from the borehole. Air-rotary drilling was assisted with a foam mixture that consisted of municipal water mixed with soda ash, QUICK-GEL® (bentonite), LIQUI-TROL® (polymer), and QUICK-FOAM® (surfactant). The fluid mixture used to assist mud-rotary drilling at R-23 typically consisted of municipal water mixed with QUICK-GEL® and LIQUI-TROL® (see Appendix B, on a CD attached to inside back cover). A Baroid mud engineer was on the site to provide expertise on drill fluid formulations. Table 3.0-1 shows the additives and fluids used.

Table 3.0-1
Fluid Additives Used, Characterization Well R-23

Additive	Amount	Unit of Measure
Interval Drilled (0–935 ft)		
Water	55,000	gal.
Bentonite	28,250	lb
LIQUI-TROL®	46	gal.
QUICK-FOAM®	550	gal.
Soda ash	41	lb
Pac-L	700	lb
N-Seal®	1830	lb
Magma Fiber®	2160	lb

Figure 3.0-1 summarizes the well data and depicts the groundwater and geologic conditions encountered. Figure 3.0-2 shows the drilling chronology and other on-site activities.

Location: In Pajarito Canyon, just west of the N.M. 4 and Pajarito Road intersection; on the south side of Pajarito Road.

Survey coordinates (brass marker in NW corner of R-23 cement pad):
x: 1647914 E y: 1755165 N (NAD 83)
z: 6527.8 ft asl (NGVD 29)

Drilling: air rotary drilling, casing advance.
R-23 Start date: 8/17/02
R-23 End date: 9/27/02

Borehole R-23 drilled to 935.0 ft. bgs. (T.D.).

Data collection:
Hydrologic properties: Field hydraulic test: Pump test
Cores/cuttings submitted for geochemical and contaminant characterization: (0)
Groundwater samples submitted for geochem and contaminant characterization: (1)
Geologic properties: (14)
Mineralogy, petrography, and chemistry
Borehole logs from R-23:
Lithologic: 0-935.0 ft.
Video (LANL tool): 0-599 ft. (cased) and 599-826.6 ft. (open hole).
Natural gamma (LANL tool): 0-599 ft. (cased) and 599-840 ft. (open hole).
Schlumberger Logs: 0-599 ft. (cased) and 599-828 ft. (open hole): Litho density, Thermal/Epithermal Neutron, Array Induction, Natural Gamma, Elemental Capture, and Combinable Magnetic Resonance.

Contaminants Detected in R-23 Water Sample: none

Well construction:
Drilling Completed: 09/27/02.
Contract Geophysics: 09/23-24/02.
Well Constructed : 09/27/02-10/02/02.
Well Developed : 10/08/02-02/20/03
Dedicated Pump: 01/06/03-01/08/03

Casing: 4.5-in. I.D. stainless steel with external couplings.

Number of Screens: 1
4.5-in. I.D. pipe based, s.s. wire-wrapped with 0.010-in slots.

Screen (perforated pipe interval):
Screen #1 - 816.0 - 873.2 ft. bgs.

Well development consisted of wire brushing, bailing, surging, and pumping.

Static water level measured on October 8, 2002, in completed and developed well.

Geologic contacts for R-23 were determined by examination of cuttings and interpretation of geophysical logs. Contacts may be refined by petrologic, geochemical, or mineralogic analysis of geologic samples.

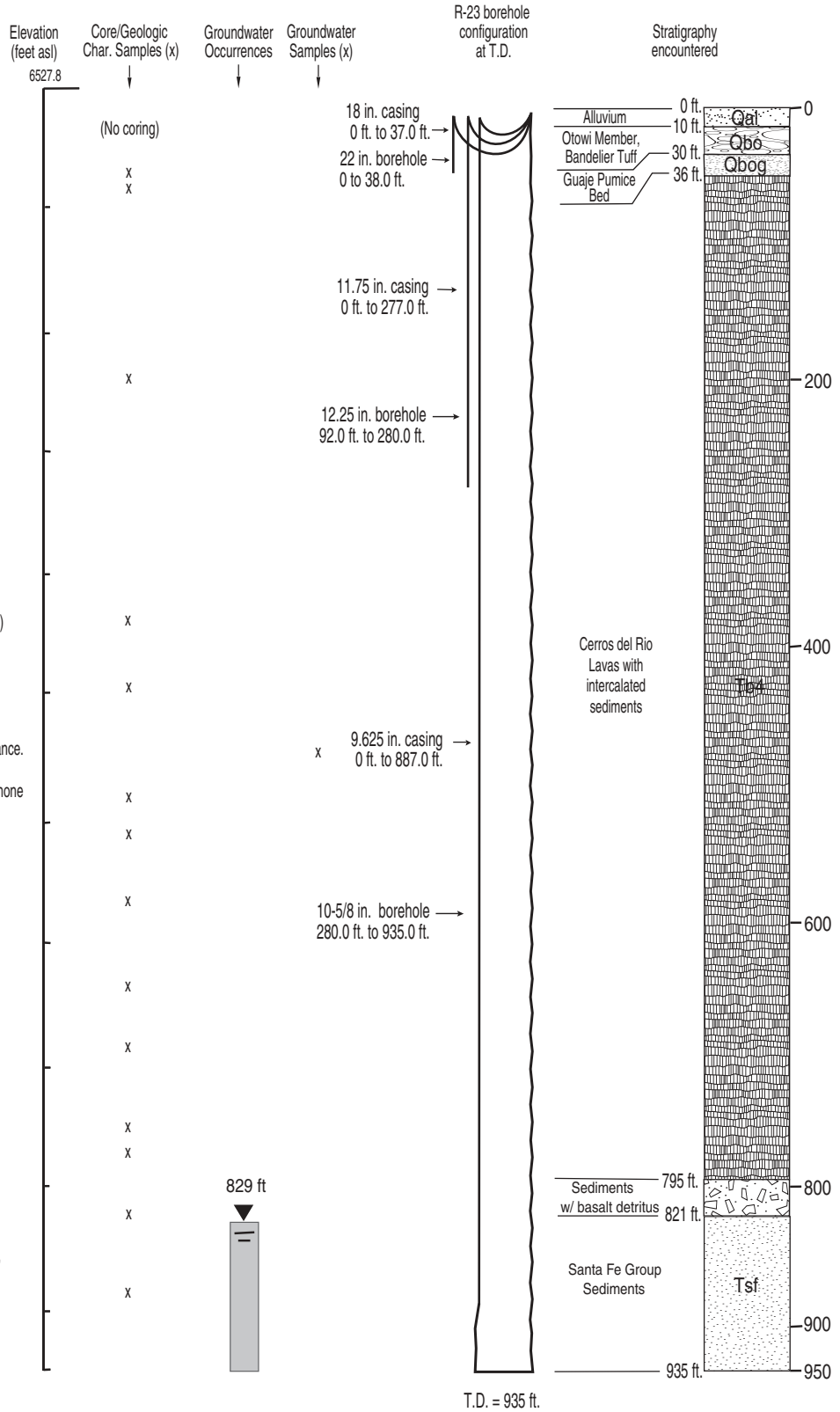


Figure 3.0-1. Well summary data sheet, characterization well R-23

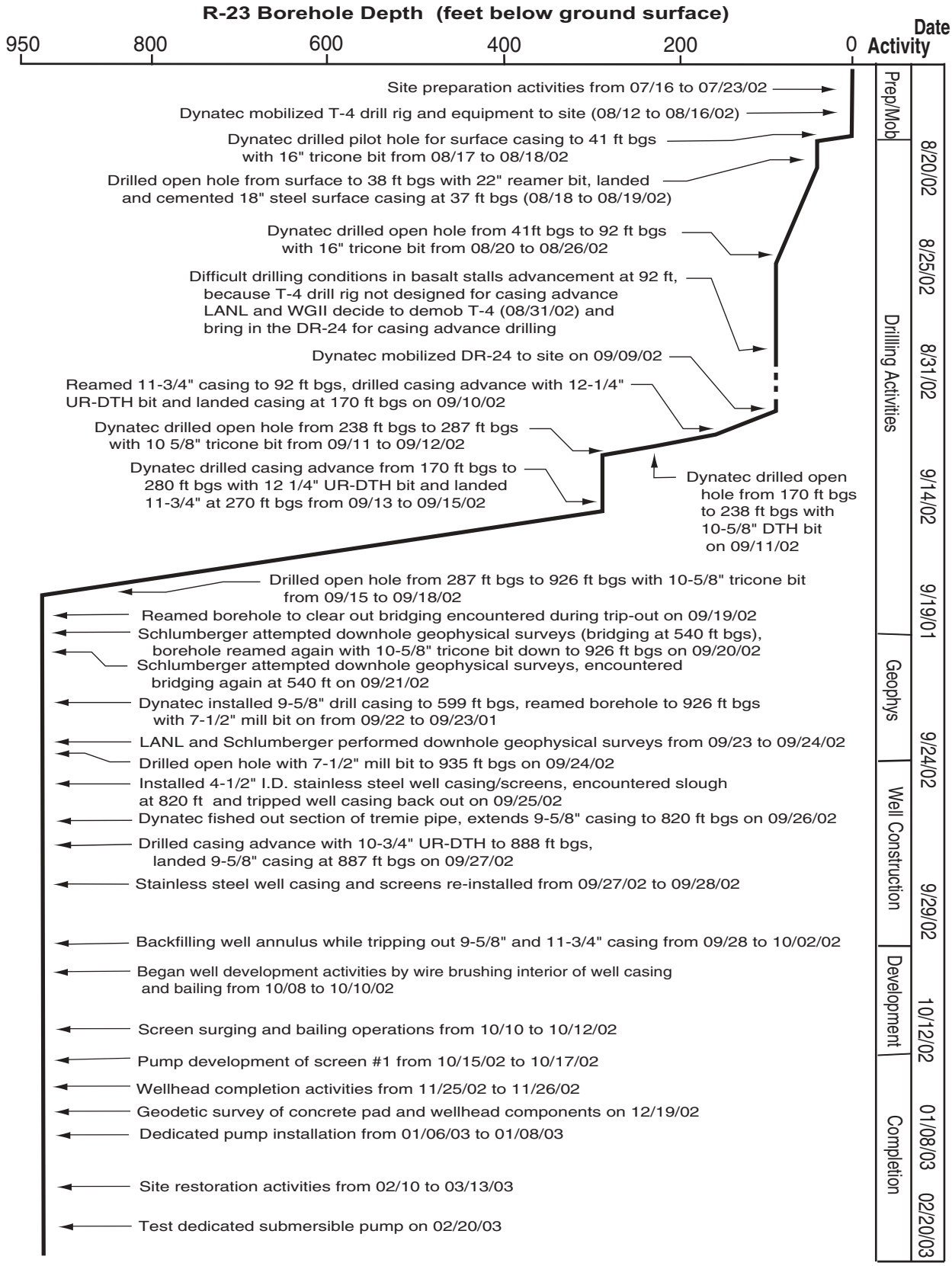


Figure 3.0-2. Operations chronology diagram, characterization well R-23

Drilling Activities

From August 12 through 16, 2002, Dynatec mobilized the Ingersoll-Rand™ T-4 drill rig and support equipment to the site. Dynatec began drilling on August 17, 2002, by advancing a 16-in. tricone drill bit to create a pilot hole for an 18-in. surface casing. On August 18, 2002, the borehole was advanced to 41 ft bgs, and Dynatec then switched to a 22-in. quadcone drill bit to ream a larger borehole from ground surface to 38 ft bgs. An 18-in. surface casing then was installed to 37 ft bgs and cemented in place. Dynatec continued advancing the borehole on August 21, 2002, with a 16-in. tricone drill bit from 41 to 92 ft bgs, where, on August 25, 2002, the drill-bit assembly became stuck in Cerros del Rio basalt. When the drill bit assembly was freed, several attempts were made over the next several days to ream and clear the borehole, without significant progress. Because the T-4 drill rig was not capable of casing-advance drilling, it was demobilized on August 31, 2002, and the Foremost™ DR-24 was used to complete the borehole when that rig finished drilling at well R-16. On September 9, 2002, the Foremost™ DR-24 drill rig was brought to the R-23 site and drilling in the basalt continued.

Drilling resumed on September 10, 2002, when Dynatec reamed an 11.75-in. drill casing through slough in the existing borehole. Dynatec continued drilling with a 12.25-in. under-reaming down-the-hole (UR-DTH) hammer bit, while advancing the 11.75-in. casing to 170 ft bgs where the casing was landed. From this depth, open-hole drilling continued in the basalt with a 10.625-in DTH hammer bit to 238 ft bgs, where Dynatec switched to a 10.65-in. tricone drill bit and continued open-hole drilling. At a depth of 287 ft bgs, Dynatec switched to casing-advance methods in an attempt to eliminate borehole instability and recurring problems with lost circulation of drilling fluids.

Beginning September 13, 2002, Dynatec advanced 11.75-in. drill casing with a 12.25-in. UR-DTH hammer bit from 170 to 280 ft bgs where the casing was landed at 270 ft bgs. Open-hole drilling continued with the 10.625-in. tricone drill bit from 287 ft through the Cerros del Rio basalt. On September 18, 2002, drilling was halted temporarily at 926 ft bgs in Santa Fe Group sediment to obtain a water-level measurement in the regional zone of saturation.

Dynatec resumed drilling operations after a water-level measurement had been taken but had difficulty establishing circulation. Subsequently, bridging was encountered while tripping out the 10.625-in. drill-bit assembly, and the borehole was reamed back down to 926 ft in an attempt to clear out the bridged materials. Drilling operations were terminated due to Laboratory concerns about borehole stability and because the primary data quality objectives had been accomplished (i.e., installing a single-screen well and determining Cerros del Rio basalt thickness).

On September 20, 2002, Schlumberger Inc. (Schlumberger) was unable to run geophysical logging tools through the entire length of the borehole due to an obstruction encountered at 540 ft bgs. Dynatec again reamed out the borehole with a 10.625-in. tricone bit to 926 ft bgs. The next day, Schlumberger again attempted to lower the first geophysical logging tool past 540 ft bgs but failed because of the obstruction. To ensure clear passage through the borehole for geophysical logging tools and subsequent well installation, Dynatec installed 9.625-in. drill casing to 599 ft bgs and then reamed the borehole again with a 7.5-in. mill-tooth bit to 926 ft bgs.

Geophysical logging was successfully conducted on September 23 and 24, 2002; however, slough had partially filled the bottom portion of the borehole from 812 to 926 ft bgs. Dynatec again reamed the borehole with a 7.5-in. mill-tooth bit to 926 ft bgs, and resumed open hole drilling to 935 ft bgs. On September 25, 2002, an attempt was made to install the 5-in. stainless steel well casing and screens, but the borehole had sloughed in to 820 ft. As a result of the sloughing, the well screens could not be set at the designed depths. The stainless steel casing was tripped out of the borehole and drilling operations resumed to advance the 9.625-in. drill casing to the depth required for well installation. Dynatec tripped in

a 10.75-in. UR-DTH hammer bit and advanced additional 9.625-in. drill casing from 599 to 887 ft bgs on September 26, 2002. Drilling operations then ceased, and the well was installed.

4.0 SAMPLING AND ANALYSIS OF DRILL CUTTINGS AND GROUNDWATER

Drill cuttings were collected at 5-ft intervals as specified in the SAP (LANL 2002, 73390). A portion of the cuttings was sieved (at >#10 and >#35 mesh) and placed in chip tray bins along with an unsieved portion. These samples were used to prepare lithologic logs (Appendix C). The remaining cuttings were placed in ziplock bags and set in core boxes for curation. Prior to curation, 14 sample splits were removed for use in mineralogy, petrography, and geochemical analyses.

One groundwater sample was collected from the open borehole during drilling in a perched zone and analyzed for low-level tritium. In addition, a groundwater sample from the regional aquifer was collected from a 9490-gal. aliquot representing the final 12 hr of well development; the sample was analyzed for select inorganic, radiological, and organic constituents. The results are reported below.

Geochemistry of Sampled Waters

Groundwater samples were analyzed to investigate the presence of constituents resulting from Laboratory activities. Major potential contaminants of concern at R-23 include perchlorate, nitrate, and tritium.

Perched groundwater from 470 ft bgs was collected by reverse circulation through the drill string. Groundwater samples were collected using a submersible pump with the intake at 860 ft bgs (screen interval from 816.0 to 873.2 ft bgs). Nonfiltered water was collected for metals, trace elements, major cations, major anion, organics, and radiochemical analyses. Samples were acidified as needed with the appropriate analytical-grade acid to a pH of 2.0 or less for metal, major cation, and volatile organic compound (VOC) analyses. All groundwater samples collected in the field were stored at 4°C until they were analyzed.

Groundwater samples were analyzed by fixed laboratories under contract to the Laboratory under the University of California Los Alamos National Laboratory statement of work for analytical laboratories (LANL 2000, 71233) and at the Earth and Environmental Science (EES)-6 laboratory using techniques specified in the US Environmental Protection Agency (EPA) SW-846 manual. Ion chromatography (IC) was the analytical method used for bromide, chloride, fluoride, nitrate, nitrite, oxalate, perchlorate, phosphate, and sulfate. Inductively coupled (argon) plasma emission spectroscopy (ICPES) was used for aluminum, arsenic, barium, chromium, cobalt, copper, iron, manganese, nickel, selenium, silver, calcium, magnesium, potassium, silica, sodium, and zinc. Antimony, beryllium, cadmium, lead, thallium, vanadium, and uranium, were analyzed by inductively coupled (argon) plasma mass spectrometry (ICPMS). Tritium activity in a groundwater sample was determined by electrolytic enrichment at the University of Miami. Americium-241 was analyzed according to HASL-300; cesium-137 was analyzed by generic gamma spectroscopy; plutonium-238 and plutonium-239 were analyzed by isotopic plutonium (HASL-300); strontium-90 was analyzed by beta counting; and uranium-234, uranium-235, and uranium-238 were analyzed by isotopic uranium (HASL-300). VOC analysis was performed by gas chromatography mass spectroscopy. The precision limits (analytical error) for major ions and trace elements generally were less than ±10% using ICPES and ICPMS.

Results of screening analyses for regional groundwater samples collected from the Cerros del Rio Basalt and Santa Fe Group in R-23 are provided in Table 4.1-1. Based on analytical results, contamination from Laboratory discharges does not appear to be present in the regional aquifer at this well site.

Table 4.1-1
Hydrochemistry of Perched and Regional Aquifer, Characterization Well R-23

Parameter and Analyte	Cerros del Rio Basalt (perched) (470 ft bgs) 09/19/02	Santa Fe Group (regional) 10/17/02 (816.0–873.2 ft bgs)
Parameter		
Alkalinity (lab; mg $CaCO_3$/L)	—	95.1
Conductivity (field; µS/cm)	—	107
pH (field)	—	7.28
Temperature (field; ^oC)	—	18.9
Turbidity (field; NTU)	—	1.37
Inorganic Analyte		
Al (mg/L)	—	0.013
Sb (mg/L	—	[0.001], U
As (mg/L)	—	0.001
Ba (mg/L)	—	0.047
Be (mg/L)	—	[0.001], U
B (mg/L)	—	0.029
Br (mg/L)	—	0.04
Cd (mg/L)	—	[0.001], U
Ca (mg/L)	—	25.1
Cl (mg/L)	—	3.72
ClO_4 (mg/L)	—	[0.004], U
ClO_3 (mg/L)	—	[0.02], U
Cr (mg/L)	—	0.0022
Co (mg/L)	—	0.0012
Cu (mg/L)	—	0.0014
F (mg/L)	—	0.29
Hg (mg/L)	—	[0.0002], U
Fe (mg/L)	—	0.21
Pb (mg/L)	—	[0.001], U
Mg (mg/L)	—	5.33
Mn (mg/L)	—	0.44
Mo (mg/L)	—	0.0031
Ni (mg/L)	—	0.0026
NO_3 (mg/L; as N)	—	0.47
NO_2 (mg/L; as N)	—	[0.006], U
C_2O_4 (mg/L) (oxalate)	—	[0.02], U

Table 4.1-1 (continued)

Parameter and Analyte	Cerros del Rio Basalt (perched) (470 ft bgs) 09/19/02	Santa Fe Group (regional) 10/17/02 (816.0–873.2 ft bgs)
P (mg/L)	—	[0.02], U
K (mg/L)	—	2.75
Se (mg/L)	—	[0.001], U
Ag (mg/L)	—	[0.001], U
Na (mg/L)	—	16.5
SiO_2 (mg/L)	—	66.8
SO_4 (mg/L)	—	11.2
Tl (mg/L)	—	[0.001]' U
U (mg/L)	—	0.0011
V (mg/L)	—	0.005
Zn (mg/L)	—	0.001
Organic Analyte		
Acetone (mg/L)	—	6.4
Bis-2-ethylhexylphthalate	—	2.2, J
Radiochemical Analyte		
Am^{241} (pCi/L)	—	[0.0044], U
Cs^{137} (pCi/L)	—	[0.495], U
^{3}H (pCi/L)	[25.6], U (< 3TPU)	—
Pu^{238} (pCi/L)	—	[0.0234], U
Pu^{239} (pCi/L)	—	[0.0117], U
Sr^{90} (pCi/L)	—	[0.108], U
U^{234} (pCi/L)	—	0.995
U^{235} (pCi/L)	—	[0.0109], U
U^{238} (pCi/L)	—	0.476

Notes: 1. U = not detected.
2. Dash = "not analyzed."
3. J = the analyte is classified as "detected" but the reported concentration value is expected to be more uncertain then usual.
4. All groundwater samples are nonfiltered.
5. < 3TUP = less than three times the propagated uncertainty.

5.0 BOREHOLE GEOPHYSICS

The Laboratory and Schlumberger provided geophysical logging services at well R-23; Table 5.0-1 lists borehole and well logging surveys performed.

Table 5.0-1
Borehole and Well Logging Surveys, Characterization Well R-23

Operator	Date	Method	Cased Footage	Open-Hole Interval (ft bgs)	Remarks
WGII/LANL	September 23, 2002	Video, natural gamma	0–599	599–826.6, 599–840	LANL borehole logging conducted in borehole prior to design and installation of the well casing.
Schlumberger	September 24, 2002	Logging suite[a,b]	0–599	599–828	Schlumberger borehole logging conducted in borehole prior to design and installation of the well casing.
WGII/LANL	November 21, 2002	Video, natural gamma	0–886	NA[c]	Video run to document and verify well screen interval and interior condition of the well. Natural gamma was run to verify backfill placement.

[a] Schlumberger's suite of borehole logging survey tools included array induction, combinable magnetic resonance, triple detector lithodensity, elemental capture, natural gamma ray spectroscopy, thermal\epithermal compensated neutron, and natural gamma.

[b] Array induction and combinable magnetic resonance logs were run only in the open portion of the borehole.

[c] NA = Not applicable; video and natural gamma logs were run inside the well casing.

5.1 Geophysical Logging Using Laboratory Tools

On September 23 and November 21, 2002, WGII ran natural gamma and video logs in borehole R-23 using down-hole tools provided by the Laboratory (Table 5.0-1). Natural gamma logs have proven successful in discriminating between geologic units that contain varying concentrations of uranium, thorium, and potassium. The first natural gamma log was run to provide lithologic and stratigraphic information that would complement data gathered from cuttings. The second natural gamma log was run to verify placement of annular fill materials after well R-23 was installed. The first gamma log was run with 18-in. surface casing in place from the surface to 37 ft bgs, 11.75-in. drill casing from the surface to 277 ft bgs, the 9.625-in. drill casing from ground surface to 599 ft bgs, and the open borehole from 599 to 840 ft bgs. The second gamma log was run inside the installed well casing, with the 18-in. surface casing in place from the surface to 37 ft bgs. Measurements of natural gamma activity were obtained every 0.1 ft as the logging tool was raised in the hole at a rate of about 15 ft/min.

The first video log was run to evaluate the stability of the borehole wall before the natural gamma tool was deployed and to record stratigraphic, geologic, and hydrologic features visible in the open portion of the borehole. The second video log was run as a quality control procedure to document well installation and inspect the condition of casing and screen after well development. The open-borehole video logs are included in this report as Appendix D (on CD attached to the inside back cover).

5.2 Schlumberger Geophysical Logging

Schlumberger conducted borehole geophysical logging on September 24, 2002, in the R-23 borehole (Table 5.0-1). A suite of logs was collected prior to well design and installation. The Schlumberger geophysical logging suite was collected with 18-in. surface casing in place from the surface to 37 ft bgs, 11.75-in. drill casing from ground surface to 277 ft bgs, and 9.625-in. drill casing from surface to 599 ft bgs. The borehole was open from 599 to 828 ft bgs.

Geophysical logging was conducted to characterize conditions in hydrogeologic units penetrated by the borehole, with an emphasis on determining moisture distribution in the vadose zone and saturated

porosity in the regional aquifer and obtaining lithologic/stratigraphic data, including evaluating borehole geometry and the amount of drilling-fluid invasion along the borehole wall.

The Schlumberger suite of geophysical logging tools included the following:

- Array Induction Tool, Version H (AITH™) measures formation electrical resistivity and borehole fluid resistivity, evaluates the drilling fluid invasion into the formation, and determines the presence of moist zones far from the borehole wall.
- Combinable Magnetic Resonance (CMR™) measures nuclear magnetic resonance response of the formation, for evaluating total and effective water-filled porosity of shallow formations and estimating pore size distribution and hydraulic conductivity of saturated intervals.
- Triple detector LithoDensity (TLD™) measures formation total porosity and bulk density, photoelectric effects, and borehole diameter and assists in characterizing lithology.
- Thermal/Epithermal Compensated Neutron Tool, Model G (CNTG™) measures volumetric water content beyond the casing to evaluate formation moisture content and porosity.
- Elemental Capture Sonde (ECS™) measures elemental weight concentrations of a variety of elements (Ca, Fe,) to aid in characterizing the formation mineralogy, lithology, and water content.

In addition, a calibrated natural-gamma logging tool was used to record gross natural gamma ray activity with every logging method to correlate depth runs between each survey.

The Schlumberger logging summary report and montage files for borehole R-23 are presented as Appendix E (on a CD attached to the back inside cover of this report).

6.0 LITHOLOGY AND HYDROGEOLOGY

A preliminary assessment of the hydrogeologic features encountered during drilling is presented below, including a description of the geologic formations and units identified during characterization of cuttings. Discussion of groundwater occurrence is based on evidence gathered during drilling, open-hole logging, and geophysical logging.

6.1 Stratigraphy and Lithologic Logging

Rock units and stratigraphic relationships, interpreted primarily from visual examination of drill cuttings samples and supporting geophysical data, are discussed in order of younger-to-older occurrence. Such interpretations may be refined upon further analysis of petrographic, geochemical, and mineralogical analyses as well as geophysical logging data. A field-generated lithologic log for R-23 is presented as Appendix C.

Alluvium (0 to 10 ft bgs)

Unconsolidated tuffaceous sands and gravels were noted in the interval from 0 to 10 ft bgs. Alluvial sediments consist primarily of detrital clasts of Bandelier Tuff and Tschicoma dacitic lavas, with mineral grains consisting predominantly of quartz and feldspar. The alluvium is part of the inactive stream channel of Pajarito Canyon.

Bandelier Tuff (10 to 36 ft bgs)

The Quaternary-age Bandelier Tuff was encountered in the interval from 10 to 36 ft bgs. Only the lower two subunits of the Bandelier tuff are locally represented: the Otowi Member and the Guaje Pumice Bed.

Otowi Member of the Bandelier Tuff (10 to 30 ft bgs)

The Otowi Member of the Bandelier Tuff is made up of rhyolitic ash-flow tuffs that contain ash, vitric pumice with quartz and sanidine phenocrysts, and volcanic lithics of intermediate composition (i.e., dacite and andesite). The Otowi ash-flow tuffs are nonwelded at the R-23 site.

Guaje Pumice Bed (30 to 36 ft bgs)

The Guaje Pumice Bed is a fall deposit composed of layered rhyolitic pumice and ash that regionally forms the basal unit of the Bandelier Tuff. Drill cuttings from this interval are composed of frothy-textured pumice; finer ash was washed out during drilling.

Cerros del Rio Basalt (36 to 795 ft bgs)

The Pliocene Cerros del Rio basalt is a sequence of mafic volcanic lavas, breccias, and pyroclastic strata (Dethier 1997, 49843). At R-23, borehole drilling penetrated 759 ft of lavas and interflow sedimentary deposits in the interval from 36 to 795 ft bgs.

Cuttings samples indicate that the upper half of the Cerros del Rio basalt section, from 36 to 411 ft bgs, is made up of a series of basaltic flows separated by layers of scoriaceous breccia. At least four separate lava flows are present in this interval. Flow units in the interval from 36 to 168 ft bgs are slightly porphyritic with sparse olivine and plagioclase phenocrysts in an aphanitic groundmass. Five- to ten-ft-thick layers of oxidized scoriaceous basalt mark the bases of some flows. At least two additional flows are evident in the interval from 168 to 411 ft bgs. These are massive, slightly porphyritic, olivine- and pyroxene-bearing basalts that are separated by intervals of basaltic scoria. Basalts of the upper lava flows have weak alteration in the form of iron oxidation and local clay development on fractures. Generally more intense rock alteration, characterized by calcite precipitation and groundmass alteration, is observed in cuttings of the lower flows.

The interval from 411 to 531 ft bgs represents a sequence of basaltic lavas and interflow sedimentary deposits. Chip samples from throughout this section typically contain slightly porphyritic, olivine-bearing basalt and locally abundant fragments of siltstone and claystone. A discrete basalt lava flow is indicated by a coherent 20-ft-thick interval at the base of this section.

The Cerros del Rio basalt is represented by lavas and volcaniclastic interflow sediments from 531 to 696 ft bgs, with underlying basalt lavas at the base of this interval from 696 to 795 ft bgs. Clayey sand and gravel deposits in the upper 165 ft (531 to 696 ft bgs) of this section are represented by abundant clastic sedimentary rock fragments, including basaltic sandstone, tuffaceous sandstone, siltstone, and claystone. A significant component of altered basalt chips is present throughout the interval. One or more strongly altered basalt flows make up the lowermost part of the Cerros del Rio basalt section from 696 to 795 ft bgs. The upper part of this interval is highly vesicular to scoriaceous, with vesicles that commonly are lined with silica and clay. The lower part consists of massive olivine- and pyroxene-bearing basalts with groundmass that is pervasively altered and bleached; probable fracture faces have pitted surfaces.

Unassigned Sediments with Basalt Detritus (795 to 821 ft bgs)

The interval from 795 to 821 ft bgs is interpreted as a sedimentary unit containing abundant basaltic detritus, probably derived from Cerros del Rio sources, plus sands that include microcline and quartz. This deposit may represent either a local Puye Formation subfacies or Santa Fe Group sediments reworked with early Cerros del Rio debris, but these sediments but are unassigned, pending further study and determination of the degree of cuttings intermixture during drilling.

Santa Fe Group Sediments (821 to 935 ft bgs)

Santa Fe Group sediments, composed of volcanic and quartzo-feldspathic sand and gravel deposits, were encountered from 821 ft bgs to the bottom of the borehole, at 935 ft bgs (TD). Chip samples of this unit are composed of basalt and minor dacite together with abundant detrital quartzite, feldspar (microcline), and granitic lithics derived from Precambrian sources. The relative abundance of Precambrian versus volcanic constituents increases downward in the interval, possibly as a result of lessening contamination of deeper sands by chips of overlying Cerros del Rio basalts that were carried down during drilling.

6.2 Groundwater Occurrence and Characteristics

It was anticipated that the regional water table would be encountered at approximately 892 ft bgs, in the Cerros del Rio basalt formation. Perched saturated zones were considered likely, although no specific depths were presented in the SAP (LANL 2002, 73390). Drilling throughout the entire depth of the borehole below 92 ft bgs used air-rotary casing-advance techniques with and without foam additives. This method substantially reduces the ability to detect and observe perched groundwater zones, if they were present. However, a sample of possible perched groundwater at approximately 470 ft bgs was collected and analyzed for anions, metals, and low-level tritium.

The first water level measurement for the regional zone of saturation was obtained on September 19, 2002, after the borehole was drilled to 926 ft bgs and had rested for approximately 4 hr. The regional water table was measured at 817.5 ft bgs, in basaltic sediment between the Cerros del Rio basalt and underlying Santa Fe Group sediment. Drill casing (11.75-in.) was in place to 277 ft bgs at that time. After well construction but before well development, the water level was measured at 828.3 ft bgs. At the end of well development, the water level in the well stabilized at 829 ft bgs.

7.0 WELL DESIGN AND CONSTRUCTION

Sections 7.1 and 7.2 describe the well R-23 design and construction, respectively.

7.1 Well Design

The design for well R-23 was completed jointly by the Laboratory and WGII, in consultation with the US Department of Energy and the New Mexico Environment Department (NMED). Information gathered from geophysical logs, video logs, borehole geologic samples, water-level data, field water-quality data, and drillers' observations was analyzed by the Groundwater Integration Team to plan the well design. The final design specified a single screen that straddled the water table (measured at 817.5 ft bgs on September 19, 2002) would be equipped with a dedicated pump. This well design permits monitoring water levels and sampling for potential contaminant concentrations in the regional aquifer downgradient of Laboratory operations. An intermediate perched zone at 470 ft may exist, but the SAP had called for installing a single screen in the regional aquifer. Planned and actual screen locations are given in Table 7.1-1.

Table 7.1-1
Summary of Well Screen Information, Characterization Well R-23

Screen	Planned Depth (ft)	Actual Depth (ft)	Geologic/Hydrologic Setting
1	816.9–873.9	816.0–873.2	Top of regional aquifer in basaltic sediments and in the Santa Fe Group sediments

7.2 Well Construction

Well R-23 casing and pipe-based screens were manufactured using 4.5-in. inner diameter (ID)/5.0-in. outer diameter (OD), type 304 stainless steel fabricated to American Society for Testing and Materials (ASTM) standard A554. External couplings were type 304 stainless steel, fabricated to ASTM standards A312 and A511, both of which exceed the tensile strength of the threaded casing ends. The pipe-based screens were modified from 10-ft sections of blank well casing by drilling 0.5-in.-diameter holes (168 holes/ft) and then welding a stainless steel wire-wrap (with 0.010-in. spacing) over the perforated interval. The final OD of the screened section was 5.56 in.

All stainless steel well components were cleaned at the well site using a high-pressure steam cleaner and scrub brushes. All annular fill materials were placed in the well casing/borehole annulus through a tremie pipe. Well-construction activities were completed from September 24 to October 2, 2002.

7.2.1 Well Steel Installation

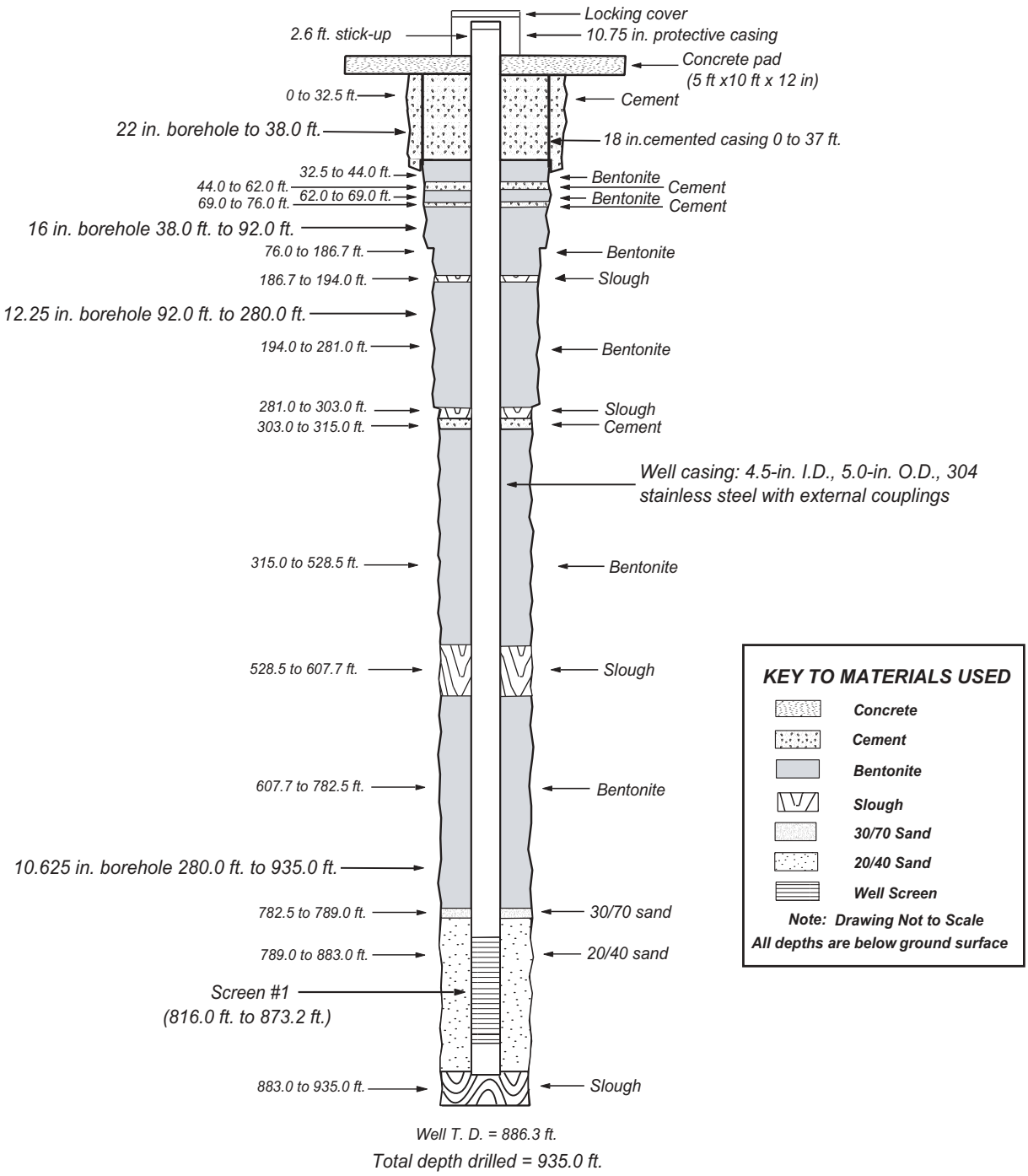
Well installation consisted of connecting joints of stainless steel well casing and screen sections using threaded couplings. Stainless steel centralizers were not installed because the 9.625-in. drill casing (temporarily left in the hole to ensure borehole stability during well installation) limited available space.

Dynatec initially installed approximately 830 ft of the R-23 well casing and screen on September 24, 2002. However, due to sloughed material in the well annulus, Dynatec could not advance the well casing to the planned designed depth of 887 ft. Tremie pipe was lowered in the annulus to a depth of 835 ft bgs, and a solution of water and EZ MUD® polymer was then pumped into the annulus in an attempt to clear the slough and lower the well casing to the desired depth. Air pressure also was applied at depth but the well casing still could not be advanced. The tremie pipe and well casing then were removed from the borehole.

Dynatec made a second attempt to install the well by advancing the 9.625-in. casing to 887 ft. The drill-bit assembly was tripped out and the tremie rod tripped in to begin well construction. On September 27 and 28, 2002, Dynatec installed the well casing and screen sections. The well casing was successfully lowered to a depth of 882.8 ft bgs. Dynatec advanced the well string an additional 2.5 ft, using a water and EZ MUD® polymer solution to wash slough material out of the bottom of the borehole. The bottom of the well casing was set at 886.3 ft bgs. Figure 7.2-1 shows the as-built well casing configuration and the depths of the various well components from ground surface.

7.2.2 Annular Fill Placement

A steel tremie pipe was used to deliver annular materials to the specified depths (Figure 7.2-1). The bottom of the borehole was measured at 883.0 ft bgs as placement of backfill materials began. The 11.75-in. and 9.625-in. drill casings were retracted as fill materials were placed in the annulus. Filter pack across the screened interval consisted of silica/sand materials mixed with municipal water and placed in the annulus. Bentonite materials were placed above the screened interval to seal the annular space and isolate the screened zone. Above the silica/sand fill, bentonite mixed with EZ-MUD® polymer and municipal water was delivered to the annulus. Portland® cement (mixed at a ratio of 5 gal. of water to each bag of cement) was used to provide a foundation for the annular fill above the regional aquifer and to protect the annular space around the wellhead in the upper 32.5 ft of the borehole. Approximately 9860 gal. of municipal water was used during placement of annular fill material.



Note:
1. The screen interval lists the footage of the pipe perforations, not the top and bottom of screen joints.
2. Pipe-based screen: 4.5-in. I.D., 5.563-in. O.D., 304 stainless steel with s.s. wire wrap; 0.010-in slot.
3. The upper intervals of slough consist of basaltic gravels; slough at the base of the borehole consists of Santa Fe Group sands.
4. Centralizers not placed due to use of 9-5/8" casing for borehole stability.
5. Dedicated pump location not shown.
6. Well sump interval: 873.2 to 886.3 ft.

Figure 7.2-1. As-built configuration diagram, characterization well R-23

Dynatec conducted annular fill activities from September 28 through October 2, 2002. Table 7.2-1 shows the annular fill materials installed. Figure 7.2-1 shows the final configuration of annular materials.

Table 7.2-1
Annular Fill Materials Used, Characterization Well R-23

Material	Use/Function	Amount	Unit*
20/40 sand (medium-grained)	To pack screened intervals	71	Bag
30/70 sand (fine grained)	To separate screen packs from bentonite or cement from bentonite	6	Bag
Benseal® bentonite (granular bentonite)	Produces slurry when mixed with water	125	Bag
Holeplug® (0.375-in. angular and unrefined bentonite chips)	To provide a borehole annular seal	356	Bag
Pelplug® bentonite pellets (0.25-in. by 0.375-in. refined elliptical pellets)	To provide borehole annular seal below water table	357	Bucket
Portland® cement (mixed with municipal water at ratio of 5 gal. water for each bag of cement)	To provide annular support and surface seal on upper 100 ft of borehole	57	Bag

*Sand bag = 50 lb ea; bentonite bag/bucket = 50 lb ea; cement bag = 94 lb ea.

8.0 WELL DEVELOPMENT AND HYDROLOGIC TESTING

Well development activities at well R-23 were conducted from October 8 to 17, 2002. Hydrologic tests were not conducted.

8.1 Well Development

Well development at R-23 was performed using a variety of methods: wire-brushing the well interior, surging to draw fine sediment from the constructed filter pack, and bailing to remove solid materials from the well. In addition, the well was pumped to remove remaining fines from the filter pack and adjacent formation.

Adequacy of well development was based on field water-quality parameters (turbidity, pH, specific conductance, and temperature). To monitor progress of each method of development, groundwater samples were collected approximately every hour and the parameters were measured. One goal of well development was to remove suspended sediment from the water until turbidity had stabilized to a value less than 5 nephelometric turbidity units (NTUs) for three consecutive samples. Similarly, other measured parameters were required to stabilize before well development could be terminated. The well was declared sufficiently developed when the above criteria were met or could not be improved with continued pumping. Table 8.1-1 presents pumping and water-quality parameter data measured at the beginning and end of each well-development method.

Preliminary bailing of the well sump and screen was performed on October 8, 2002. The casing and screen then were cleaned using a wire-brush system to remove any materials that may have been introduced to the well interior during construction. Surging techniques were used across the screen with a weighted surge block to induce rapid upward-downward strokes. The well screen was surged repeatedly; periods of bailing followed from October 10 to 12, 2002. During this development method, early water turbidity measurements exceeded 1000 NTU and declined to 522 NTU after an estimated 3800 gal. were bailed (Table 8.1-1).

Table 8.1-1
Development of Characterization Well R-23

Method	Water Produced (gal.)	Range of Parameters[a]			
		pH	Temperature (°C)	Specific Conductance (µS/cm)[b]	Turbidity (NTU)
Preliminary bailing/wire brushing/surging	3800	7.5–7.4	20.3–21.1	241–160	>1000–522
Pump	22,100	7.3–7.3	20.7–18.9	192–107	16–1.4
Install dedicated submersible pump	ND[c]	ND	ND	ND	ND
Test submersible/final pumping	5970	7.96–8.44	19.5–18.2	208–167	2.3–1.4
TOTAL	31,870				

[a] Parameters presented as value at beginning followed by value at end of development method.
[b] Specific conductance reported in microsiemens per centimeter (µS/cm).
[c] No data.

Pump development of R-23 was conducted from October 15 to 17, 2002. A 7.5-horsepower (hp) submersible pump was lowered to 860 ft bgs, near the bottom of the screen. On/off cyclic pumping was conducted with approximately 30-min periods of nonpumping to allow water levels in the well to recover. Field parameters were monitored in collected water samples. During pump development turbidity declined from an initial value of 16 to 1.4 NTU (Table 8.1-1) after an estimated 22,200 gal. were purged. Figure 8.1-1 shows the effects of pumping on measured field parameters. The graph shows that pH, specific conductance, and temperature were stable during the later stages of pumping and that turbidity declined consistently to a value less than 5 NTU when R-23 was declared fully developed.

8.2 Hydrologic Testing

No hydrologic tests were performed. The Laboratory plans to conduct hydrologic tests at a later date and to present the results in a separate report.

8.3 Dedicated Pump Installation

On January 6, 2003, a dedicated pump for groundwater sampling was installed in well R-23. The pump is a 4-in.-diameter Grundfos Model 10S50-48DS with a 5 hp, 460-V, three-phase motor. With the pump intake set at 871 ft bgs, the pump is capable of producing groundwater at a rate of 10 gal./min. The pump will be used to purge and collect groundwater samples for water-quality monitoring. The dedicated pump assembly, riser pipe, and other components were installed with a Smeal work-over rig provided and operated by Rio Grande Well Supply from Albuquerque, New Mexico.

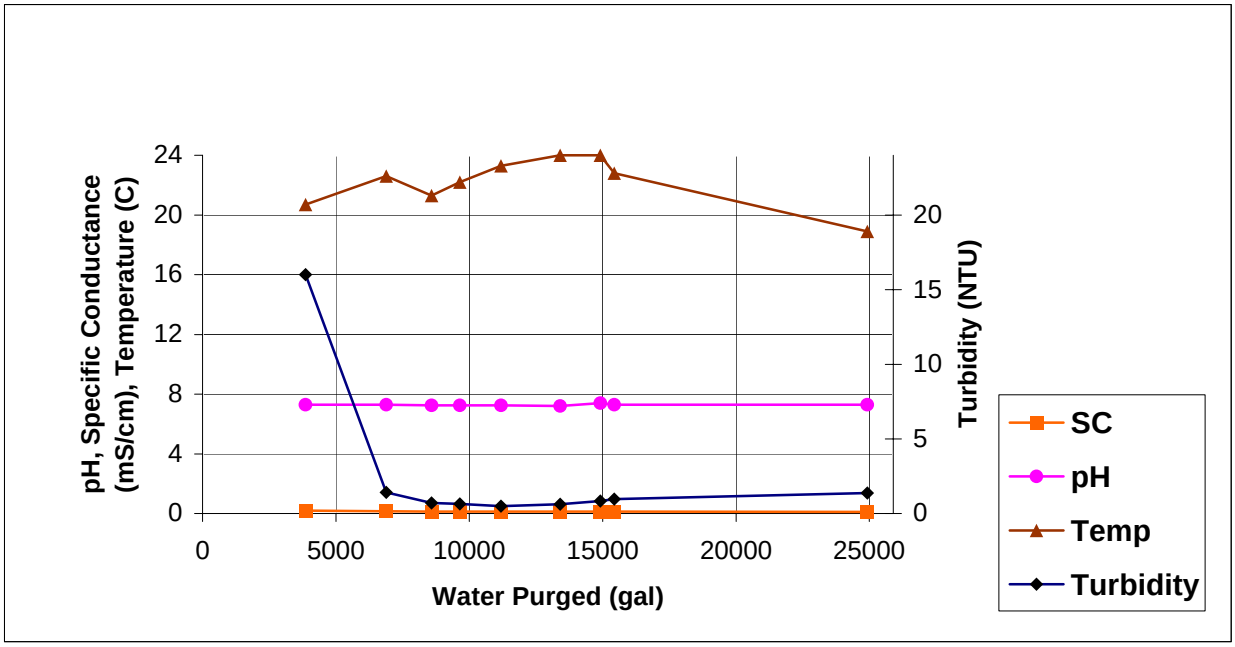


Figure 8.1-1. Effects of pump development on water quality parameters, characterization well R-23

The riser pipe consisted of 1.25-in., Schedule 40S, type 304/TP 304L stainless steel connected with 3000-lb test F304/F304L stainless steel couplers. The thread compound used was Loctite 567. A 1-in., Schedule 40, polyvinyl chloride (PVC) flush-thread transducer access pipe was set at the top of the pump to permit unobstructed access for water-level measurements. The pump control leads and PVC transducer pipe were secured to the riser pipe with a stainless steel band 5 ft above the pump and every 60 ft thereafter. In addition, the leads and PVC pipe were secured to the riser pipe every 10 ft with cold-weather vinyl cable and pipe tape that is both water- and corrosion-resistant. The length of the pump assembly, riser joints, and couplers were measured and assembled to ensure installation of the pump intake at 871 ft. bgs.

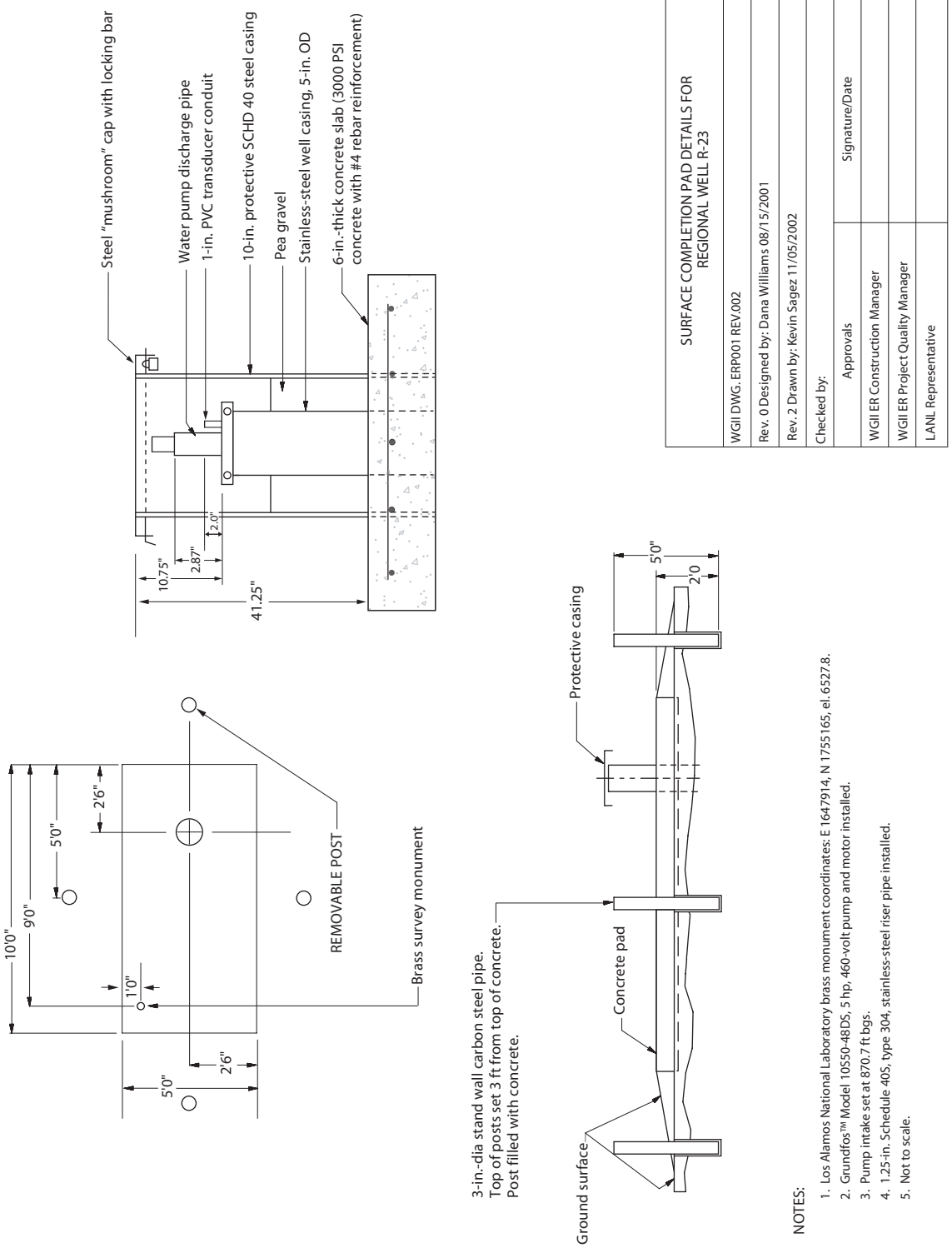
The pump installation was completed on January 8, 2003. The dedicated pump was tested on February 19 and 20, 2003. A total of 5970 gal. of groundwater were produced from the well during this test. Final turbidity readings were less than 2 NTU.

9.0 WELLHEAD COMPLETION AND SITE RESTORATION

After pump installation, finish work commenced on the wellhead area. Well components were surveyed, and the site underwent final cleanup and restoration.

9.1 Wellhead Completion

Surface completion for well R-23 involved constructing a reinforced (3000 pounds per square inch [psi]) concrete pad, 5-ft wide by 10-ft long by 6-in. thick, around the well casing to ensure long-term structural integrity (Figure 9.1-1). The concrete pad was poured on November 26, 2002. A brass survey cap was installed in the northwest corner of the concrete pad. A 10.75-in. steel casing with locking lid was installed to protect the well riser. The pad was designed to be slightly elevated, with base-course gravel graded around the pad to promote drainage. Four 4-in.-diameter cement-filled steel bollards were placed around the well pad, one on each side. One bollard is removable to allow access for sampling and maintenance.



NOTES:

1. Los Alamos National Laboratory brass monument coordinates: E 1647914, N 1755165, el. 6527.8.
2. Grundfos™ Model 10S50-48DS, 5 hp, 460-volt pump and motor installed.
3. Pump intake set at 870.7 ft bgs.
4. 1.25-in. Schedule 40S, type 304, stainless-steel riser pipe installed.
5. Not to scale.

Figure 9.1-1. Surface completion configuration diagram, characterization well R-23

9.2 Geodetic Survey

Southwest Mountain Surveys, Inc. (NMPLS #6998), conducted a geodetic survey of well R-23 on December 19, 2002, using a global positioning satellite (GPS) system. The GPS system utilizes National Geodetic Vertical Datum (NGVD99/96) for vertical computations; the datum for the horizontal control network is North American Datum 1983 (NAD 83). The survey located the brass monument in the northwest corner of the concrete pad and measured location and elevation at the top of the steel protective casing and the top of the stainless steel well casing (Table 9.2-1). The coordinates shown are in New Mexico State Plane coordinates, Central Zone (NAD 83) expressed in feet. To be consistent with current Laboratory standards, elevations are expressed in feet above mean sea level and referenced to the National Geodetic Vertical Datum of 1929 (NGVD29).

Table 9.2-1
Geodetic Data, Characterization Well R-23

Description	East	North	Elevation
Brass cap in R-23 pad	1647913.60	1755165.37	6527.75
Top of stainless steel well casing	1647918.78	1755161.40	6530.31
Top of protective steel surface casing	1647918.59	1755161.32	6530.70

9.3 Site Restoration

Site restoration activities at R-23 were conducted from February 10 to March 13, 2003 (Figure 3.0-2). Waste-management activities were conducted before and during restoration. Waste materials were removed from the site, as specified in the WCSF. Drilling-generated media, including drilling fluids, cuttings, and development water, were sampled for contaminant analysis. These data were reviewed by the Laboratory and NMED. The drill cuttings then were used to help backfill the cuttings-containment area; drilling fluids and development water were applied to land downgradient of the site and to the road, as specified in the provisions of the Notice of Intent. The waste streams from spill cleanup included petroleum-contaminated soils and absorbent materials that had been used to clean up minor spills. After the Laboratory approved the waste profile forms, the waste streams were disposed of as New Mexico Special Waste. The drill site area was regraded by K. R. Swerdfeger Construction, Inc. Before the area was regraded, the cuttings-containment area was excavated and the plastic lining was removed. The containment basin and water-tank storage areas then were backfilled with dirt that had been bermed during pad construction and the area was regraded. Base-course gravel was regraded and compacted across the site to form a smaller pad. In addition, a chipper was moved to the site to chip slash piles accumulated during tree removal procedures related to drill-pad construction. The slash-pile chips were used to mulch re-seeded areas of the site. The site was re-seeded with a blend of native grasses mixed with fertilizer to facilitate regrowth of ground cover.

10.0 DEVIATIONS FROM THE R-23 SAP

Appendix A compares the actual characterization activities performed at well R-23 with the activities planned in the hydrogeologic work plan and the R-23 sampling and analysis plan (LANL 1998, 59599; LANL 2002, 73390). Significant deviations are discussed below:

- *Planned depth.* Well R-23 was planned for a depth of 1392 ft (LANL 2002, 73390). This depth was based on the general characterization goals of the hydrogeologic work plan to investigate the hydrogeology in the upper 500 ft of the regional zone of saturation. Drilling operations were terminated at R-23 because hole stability problems raised concerns about loss of the borehole and because site-specific objectives for deep drilling had been accomplished. The goals for R-23 were attained by drilling to 935 ft, a depth at which the borehole was deep enough to install a single-screen well and penetrate the base of the Cerros del Rio basalt.
- *Amount of core.* Core was not collected at R-23 because the site finally chosen had only a thin cover above the Cerros del Rio lavas. The lavas would have provided poor samples for contaminant characterization because of the likelihood of focused fracture rather than dispersed matrix flow paths.
- *Number of water samples collected for contaminant analysis.* One sample was collected and analyzed from perched water at 470 ft bgs. One sample was collected from the regional aquifer at the end of well development and submitted for analysis.
- *Number of core/cuttings samples collected for contaminant analysis.* No core was collected for the reasons cited above. Cuttings were not selected for contaminant analysis because of the unlikely detection of contaminants from basalt matrix chips, when contaminant accumulation would most likely occur along fractures.
- *Core/cuttings sample analytes.* No core was collected; no analyses were performed on cuttings for the reasons cited above.

11.0 ACKNOWLEDGEMENTS

Dynatec Drilling Company provided rotary drilling services.

Tetra-Tech EM, Inc.; D. B. Stephens and Associates, Inc.; and S. M. Stoller provided support for well-site geology, sample collection, and hydrologic testing.

Southwest Mountain Surveys provided the final geodetic survey of finished well components (NMPLS #6998).

D. Thompson and C. Schultz of PMC Technologies (Exton, Pennsylvania); and P. Schuh, E. Tow, and R. Lawrence of Tetra-Tech EM, Inc. (Albuquerque, New Mexico), contributed to the preparation of this report.

R. Bohn and E. Louderbough of Los Alamos National Laboratory reviewed this report for classification and legal purposes, respectively.

D. Broxton, A. Groffman, S. Pearson, W. Stone, and D. Vaniman of Los Alamos National Laboratory prepared this report.

Schlumberger Integrated Water Solutions provided processing and interpretation of borehole geophysical data.

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Appendix A

Activities Planned for R-23 Compared with Work Performed

Activity	"Hydrogeologic Workplan" (LANL 1998, 59599)	R-23 Sampling and Analysis Plan (LANL 2002, 73390)	R-23 Actual Work
Planned Depth	100 to 500 ft into the regional aquifer	Estimated depth of 1392 ft below ground surface (bgs)	Total drill depth 935 ft bgs
Drilling Method	Methods may include, but are not limited to hollow stem auger (HSA), air-rotary/Odex/Stratex, air-rotary/Barber rig, and mud-rotary drilling	Drilling methods not specified in SAP.	Fluid-assist air rotary and fluid-assist air rotary with casing advance
Amount of Core	10% of the borehole	Continuous core from surface to estimated depth of 94 ft bgs, but no deeper than 100 ft bgs	No core collected
Lithologic Log	Log to be prepared from core, cuttings, and drilling performance data	Log to be prepared from core, cuttings, geophysical logs and drilling performance data	Log prepared from core, cuttings, geophysical logs and drilling performance data
Number of Water Samples Collected for Contaminant Analysis	A water sample may be collected from each saturated zone, five zones assumed. The number of sampling events after well completion is not specified	If perched water is encountered within the unsaturated zone, one groundwater-screening sample each will be collected within up to three perched zones. Groundwater-screening samples will be collected within the regional aquifer at the regional water table and at the total depth (TD) of the borehole.	One water sample from 470 ft bgs obtained during drilling. Regional aquifer to be sampled in the completed well.
Water Sample Analysis	Initial sampling: radiochemistry I, II, and III, tritium, general inorganics, stable isotopes, volatile organic compounds (VOCs), and metals. Saturated zones: radionuclides (tritium, ^{90}Sr, ^{137}Cs, ^{241}Am, plutonium isotopes, uranium isotopes, gamma spectrometry, and gross alpha, beta, and gamma), stable isotopes (hydrogen, oxygen, and in special cases nitrogen), major ions (cations and anions), trace metals, and trace elements.	Metals (dissolved), Anions (dissolved), VOCs, ^{99}Tc, gamma spec, ^{241}Am, ^{137}Cs, ^{238}Pu, ^{239,240}Pu, ^{234}U, ^{235}U, ^{238}U, ^{90}Sr, stable isotopes (^{18}O/^{16}O, D/H, ^{15}N/^{14}N), tritium (low level or direct counting), RV (Rad Van) gross-alpha, beta, gamma	A possible perched zone was encountered at 470 ft bgs and one groundwater sample was analyzed for metals (including uranium), anions, and low level tritium.
Water Sample Field Measurements	Alkalinity, pH, specific conductance, temperature, turbidity	Alkalinity, pH, specific conductance, temperature, turbidity	pH, specific conductance, temperature, turbidity

Activity	"Hydrogeologic Workplan" (LANL 1998, 59599)	R-23 Sampling and Analysis Plan (LANL 2002, 73390)	R-23 Actual Work
Number of Core/Cuttings Samples Collected for Contaminant Analysis	Twenty samples of core or cuttings to be analyzed for potential contaminant identification in each borehole.	If possible, at least two core/cuttings samples will be collected for geochemical and contaminant characterization within water-bearing zones encountered during drilling.	No cuttings samples submitted for analysis
Core/Cuttings Sample Analytes	Uppermost core or cuttings sample to be analyzed for a full range of compounds: deeper samples will be analyzed for the presence of radiochemistry I, II, and III analytes, tritium (low and high detection levels), and metals. Four samples to be analyzed for VOCs.	Analytical suite for cuttings samples includes anions, stable isotopes, VOCs, tritium profiles, perchlorate, ^{241}Am, ^{238}Pu, ^{239,240}Pu, ^{234}U, ^{235}U, ^{238}U, ^{90}Sr, gamma spectroscopy, radiological screening (gross alpha, beta, and gamma), radionuclides, and metals.	No analyses were performed
Laboratory Hydraulic-Property Tests	Physical properties analyses will be conducted on 5 core samples and will typically include moisture content, porosity, particle density, bulk density, saturated hydraulic conductivity, and water retention characteristics.	Physical properties analyses will be conducted on core samples for moisture content.	No core collected
Geology	Ten samples of core or cuttings will be collected for petrographic, x-ray fluorescence (XRF) and x-ray diffraction (XRD) analyses.	Analytical testing of samples may include mineralogy by XRD, petrography by modal analysis of thin sections, by electron microprobe, and/or by scanning electron microscope, and geochemistry by XRF.	14 samples were selected for potential mineralogy, petrography, and rock chemistry analyses.

Activity	"Hydrogeologic Workplan" (LANL 1998, 59599)	R-23 Sampling and Analysis Plan (LANL 2002, 73390)	R-23 Actual Work
Geophysics	In general, open-hole geophysics includes caliper, electromagnetic induction, natural gamma, magnetic susceptibility, borehole color videotape (axial and side scan), fluid temperature (saturated), fluid resistivity (saturated), single-point resistivity (saturated), and spontaneous potential (saturated). In general, cased-hole geophysics includes: gamma-gamma density, natural gamma, and thermal neutron.	The number and types of logs will vary as function of borehole condition and the presence or absence of drill or well casing. In general, open-hole geophysics includes: caliper, array induction, triple litho density, combinable magnetic resonance, natural gamma, natural gamma ray spectrometry, epithermal compensated neutron, mechanical sidewall coring tool, fullbore formation microimager, and borehole color videotape (axial and side scan). In general, cased-hole geophysics includes: triple litho density, natural gamma ray spectrometry, natural gamma, and epithermal compensated neutron.	LANL tools: 0–599 ft bgs (cased), 599–840 ft bgs (open hole): Natural Gamma; 0–599 ft bgs (cased), 599-840 ft bgs (open hole): video; 0–826.6 ft bgs. Well: video, natural gamma 0–886. Schlumberger geophysics: 0–599 ft bgs (cased), 599-828 ft bgs (open hole): array induction, combinable magnetic resonance, triple litho density, natural gamma, elemental capture, and thermal-epithermal neutron.
Water-Level Measurements	Procedures and methods not specified in hydrogeologic work plan.	Water levels will be determined for each saturated zone by water-level meter or by pressure transducer.	Water level for the regional water table determined by water-level meter.
Field Hydraulic-Property Tests	Tests to be conducted not specified in hydrogeologic work plan.	Straddle-packer/injection tests will be performed in all screens completed below the regional water table.	Hydrologic testing was not conducted.
Surface Casing	Approximately 20-in. outer diameter (OD), extends from land surface to 10-ft depth in underlying competent layer and grouted in place.	Install 18-in. or 20-in. OD steel casing to approximately 60 ft.	18-in. OD steel casing set at 37 ft bgs, cemented in place
Conductor Casing	Unless other technical methods are applied, a temporary steel casing, up to 14-in. OD, will be advanced to total depth (TD) of borehole.	Install 11.75-in. OD steel casing from 0 to ~700 to 800 ft bgs, or approximately 100 ft above anticipated regional water level, or set thin-wall casing over problem zone(s) and seal off casing using whatever is required regulatorily.	11.75-in. OD drill casing from 0 to 729 ft bgs 9.625-in. OD drill casing from 0 to 887 ft bgs
Minimum Well Casing Size	6 5/8-in. OD	5-in. OD	5-in. OD x 4.5-in. inner diameter (ID) stainless steel casing w/ external couplings

Activity	"Hydrogeologic Workplan" (LANL 1998, 59599)	R-23 Sampling and Analysis Plan (LANL 2002, 73390)	R-23 Actual Work
Well Screen	Machine-slotted (0.01-in.), stainless steel screens with flush-jointed threads; number and length of screens to be determined on a site-specific basis and proposed to NMED.	Well screen shall be constructed with multiple sections of 5.5-in. OD stainless steel pipe with wire wrap (0.010-in. slot opening).	Screened intervals constructed of 5.56-in. OD (4.5-in. ID) pipe based, stainless steel, wire- wrapped, 0.010-in. slotted screen
Filter Material	>90% silica sand, properly sized for the 0.010-in. slot size of the well screen; extends 2 ft above and below the well screen.	Filter pack shall extend at least 5 ft and no more than 10 ft above and below each well screen. No differentiation made between primary and secondary filter packs.	Primary filter pack consisted of 20/40 silica sand placed in a layer 9.8 ft below and 27 ft above well screen. Secondary filter pack consisted of 30/70 silica sand placed in a layer 6.5-ft-thick above primary filter pack.
Annular Material (exclusive of filter materials)	Uncontaminated drill cuttings below sump and bentonite above sump.	Bentonite and cement in borehole or well annulus.	Slough in borehole and annulus below and around sump from TD to 3.3 ft above bottom of sump Bentonite seal and slough above screen and cement plug Cement plug from 303 to 315 ft bgs Inter-layered cement-bentonite grout and bentonite chips from surface to 76 ft bgs
Sump	Stainless steel casing with an end cap	Not specified	5-in. diameter stainless steel casing, 13.1-ft long, with an end cap
Bottom Seal	Bentonite	Bentonite	None

Appendix B

Drill-Additive Product Specifications
(CD attached to inside back cover)

QUIK-GEL®

Viscosifier

Description

QUIK-GEL is an easy-to-mix, finely ground (200-mesh), premium-grade, high-yielding Wyoming sodium bentonite. QUIK-GEL imparts viscosity, fluid loss control and gelling characteristics to freshwater-based drilling fluids.

Applications/Functions

- Mix with fresh water to form a low-solids drilling flluid for general drilling applications
- Viscosify water-based drilling fluids
- Reduce filtration by forming a thin filter cake with low permeability
- Improve hole-cleaning capability of drilling fluids
- Mix with foaming agents to make "gel/foam" drilling fluids for air/foam drilling applications

Advantages

- ANSI/NSF Standard 60 certified
- Single-sack product and cost effective
- Provides lubricity for drilling fluids
- Mixes easily and quickly reaches maximum viscosity
- Yields more than twice as much mud of the same viscosity as an equal weight of API oilfield grades of bentonite

Typical Properties

Appearance	Grey to tan powder
Bulk density, lb/ft^3	68 to 72 (compacted)
pH (3% solution)	8.9

Recommended Treatment

Mix slowly through a jet mixer or sift slowly into the vortex of a high-speed stirrer.

Approximate Amounts of QUIK-GEL Added to Freshwater			
Application/Desired Result	**lb/100 gal**	**lb/bbl**	**kg/m^3**
Normal Drilling Conditions	15-25	6-10	18-30
Unconsolidated Formations	35-50	15-21	42-60
Make-Up For Gel/Foam Systems	12-15	5-7	14-18

- 1 bbl = 42 U.S. gallons

Additional Information

***Note*:**

- For optimum yield, pre-treat make-up water with 1-2 pounds of soda ash per 100 gallons of water (1.2-2.4 kg/m^3).

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Packaging QUIK-GEL® is packaged in 50-lb (22.7-kg) multiwall paper bags.

Availability QUIK-GEL can be purchased through any Baroid Industrial Drilling Products Distributor. To locate the Baroid IDP distributor nearest you contact the Customer Service Department in Houston or your area IDP Sales Representative.

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Houston, TX 77032

Customer Service	(800) 735-6075 Toll Free	(281) 871-4612
Technical Service	(877) 379-7412 Toll Free	(281) 871-4613

QUIK-FOAM®

High Performance Foaming Agent

Description

QUIK-FOAM, a proprietary blend of alcohol ethoxy sulfates (AES) which are biodegradable, is an effective foaming agent. QUIK-FOAM can be added to fresh, brine, or brackish water for air/foam, air/gel-foam, or mist drilling applications.

Applications/Functions

- Enhance the rate of cuttings removal
- Increase the ability of lifting large volumes of water
- Improve hole-cleaning capability of the airstream
- Reduce the sticking tendencies of wet clays, thereby eliminating mud rings and wall packing
- Reduce erosion of poorly consolidated formations
- Provide a technique for drilling in zones with lost circulation
- Increase borehole stability
- Reduce air-volume requirement
- Suppress dust during air drilling operation

Advantages

- ANSI/NSF Standard 60 Certified
- High quality, high expansion foam with a consistency similar to shaving foam
- High stability with excellent retention time
- Versatile and compatible with various types of make-up water
- Readily undergoes primary and ultimate (>99%) biodegradation
- Proven product for multi-discipline application

Typical Properties

Appearance	Light yellow, transparent liquid
Specific gravity	1.03
pH (0.5% solution)	7.1
Flash point, PMCC °F, °C	82, (28)
Pour point, °F, °C	0, (-18)

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Recommended Treatment

Approximate Amounts of QUIK-FOAM® Added to Injection Water			
Application	**Amount/100 gal**	**Amount/bbl**	**Liters/m^3**
Dry-air drilling (as a dust suppressant)	0.5 - 1 pints	0.2 - 0.5 pints	0.5 - 1.5
Mud-mist drilling in sticky clays	1 - 2 quarts	1 - 2 pints	2.5 - 5
Foam and gel-foam drilling	0.5 - 2 gallons	1.5 - 7 pints	5 - 20
As a slug to clean the annulus	1 pint*	0.5 pints*	0.5**

* in drill pipe, followed by 3 to 5 gallons of water; ** followed by 20 liters of water

Note:

Close product container immediately after use to avoid gelation of remaining QUIK-FOAM.

Product Make-ups for Air Drilling Injection Slurries				
Main Ingredient of Injection Slurry	**Water (gallons)**	**QUIK-GEL® viscosifier (pounds)**	**QUIK-TROL® polymer (pounds)**	**QUIK-FOAM foaming agent (% by volume)**
Foam Drilling System	100	…	…	0.02 - 3.0
Mixing/Injection Procedure Add QUIK-FOAM to injection water. Inject into the air stream at a rate necessary to maintain hole stability and penetration rate. Increase amount of QUIK-FOAM as required to compensate for downhole water dilution				
Firm-Foam Drilling System	100	…	0.5 - 1	0.1 - 2.0
Mixing/Injection Procedure Mix polymer with water before adding QUIK-FOAM. 1-2 pints of EZ MUD® may be used as a substitute for QUIK-TROL. Inject into the air stream at a rate necessary to maintain hole stability and penetration rate.				
Mud-Mist Drilling System	100	25	…	0.3 - 1.0
Mixing/Injection Procedure Mix viscosifier with water before adding QUIK-FOAM. Inject into the air stream at a rate necessary to maintain hole stability and penetration rate. Resulting viscosity is 32-40 sec/qt as measured by Marsh Funnel.				
Gel-Foam Drilling System	100	12 - 15	1	0.3 - 1.0
Mixing/Injection Procedure Mix viscosifier and polymer with water before adding QUIK-FOAM. Inject into the air stream at a rate necessary to maintain hole stability and penetration rate. Resulting viscosity is 32-40 sec/qt as measured by Marsh Funnel.				

Note:

In some states, it is illegal to discharge any foreign substance into the water shed due to potential contamination of ground water. After use, the foam mixture must be localized in an earthen pit or some type of containment and allowed to biodegrade naturally.

Packaging QUIK-FOAM® is packaged in 5-gal (19-liter) plastic containers or in 55-gal (208 liter) drums.

Availability QUIK-FOAM can be purchased through any Baroid Industrial Drilling Products Distributor. To locate the Baroid IDP distributor nearest you contact the Customer Service Department in Houston or your area IDP Sales Representative.

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PAC™-L

Modified Natural Cellulosic Polymer

Description

PAC-L, modified natural cellulosic polymer, provides filtration control in most water-based drilling fluids without substantially increasing viscosity. PAC-L, when added to a QUIK-GEL® or BORE-GEL™ slurry, yields a drilling mud system suitable for drilling in sandy formation. PAC-L can be added to vegetable or mineral oil to provide an oil-based fluid suspension, which can be poured into drill string directly.

Applications/Functions

- Provide filtration control in fresh or brackish water-based drilling fluids
- Reduce fluid loss without significantly increasing fluid viscosity
- Encapsulate shale to prevent swelling and disintegration
- Promote borehole stability in water sensitive formations
- Minimize rod chatter, rotational torque and circulating pressure
- Improve hole cleaning and core recovery

Advantages

- Effective in fresh water, salt water and brackish water-based drilling fluids
- Effective in small quantities for filtration control
- Non-fermenting
- Compatible with other Baroid drilling fluid additives
- Resistant to harsh environments and contaminants

Typical Properties

Appearance	White, free-flowing powder
pH (1% aqueous solution)	7.75

Recommended Treatment

- Using a Venturi Mixer, or into vortex of a high-speed stirrer, add slowly and uniformly to the entire circulating system.

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Recommended Treatment

Approximate Amounts of PAC™-L Added to Water Based Fluids		
Desired Condition/Result		
Added to fresh or salt water	**lb/100 gal**	**kg/m^3**
Ÿ To stabilize water sensitive formation	3 – 7	4 – 8.5
Ÿ To reduce torque and lower circulating pressure	0.5 - 2	0.6 – 2.4
Added to QUIK-GEL® slurry (25 lb/100 gallons) or (30 kilograms per m^3)	**lb/100 gal**	**kg/m^3**
Ÿ To reduce filtration rate and improve borehole stability	0.5 - 2.0	0.6 – 2.4
Added to BORE-GEL™ slurry (35 lb/100 gallons) or (42 kilograms per m^3)	**lb/100 gal**	**kg/m^3**
Ÿ To reduce filtration rate and improve borehole stability	0.5 – 2.0	0.6 – 2.4

Note:
Very salty waters may require twice as much PAC-L as fresh water. Preferably, PAC-L should be mixed in fresh water before it is added to very salty water.

Packaging

PAC-L is packaged in 50-lb (22.7 kg) bags.

Availability

PAC-L can be purchased through any Baroid Industrial Drilling Products Distributor. To locate the Baroid IDP distributor nearest you contact the Customer Service Department in Houston or your area IDP Sales Representative.

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N-SEAL™

Lost Circulation Material

Description

N-SEAL, acid soluble lost circulation material, is specially formulated extrusion spun mineral fiber. Due to its solubility in weak acids, N-SEAL is easily removed from production zones.

Applications/Functions

N-SEAL can be used in concentrations of up to 70 lb/100 gallons (86 kg/m^3) in slug treatments or as additive to entire system.

Advantages

- Acid soluble
- Easily-wetted
- Inorganic and non-fermenting

Typical Properties

Appearance	Gray white fiber
Specific gravity	2.6

Recommended Treatment

N-SEAL can be added directly through the hopper.

- For normal treatment to the active system, add 5-20 lb/100 gallons drilling fluid (6-24 kg/m^3)
- As a pill, add 20-70 lb/100 gallons of drilling fluid (24-86 kg/m^3)

N-SEAL is 95% acid soluble. To dissolve 1 lb of N-SEAL, treat with either

- 1-2 lb AQUA-CLEAR™ MGA (1-2 kg/kg)

  or
- 0.5-1 gal of 10% HCl/5% Acetic acid blend (1-2 liters/kg)

Packaging

N-SEAL is packaged in 30-lb (13.6 kg) multiwall paper bags.

Availability

N-SEAL can be purchased through any Baroid Industrial Drilling Products Distributor. To locate the Baroid IDP distributor nearest you contact the Customer Service Department in Houston or your area IDP Sales Representative.

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LIQUI-TROL™

Modified Cellulosic Polymer Suspension

Description

LIQUI-TROL is a free-flowing, liquid suspension of a modified natural cellulosic polymer, in an ultra-clean oil. LIQUI-TROL, when added to a QUIK-GEL® or BORE-GEL™ slurry, yields a drilling mud system suitable for drilling in water sensitive formations.

Applications/Functions

- Provide filtration control in fresh or brackish water-based drilling fluids
- Promote borehole stability in water sensitive formations
- Pour a slug of concentrate into drill string directly to sweep the hole
- Minimize rotational torque and circulating pressure
- Improve hole cleaning and core recovery
- Stiffen the foam to improve cuttings transport in air/gel-foam drilling
- Reduce air requirements, uphole velocity and borehole annulus pressure

Advantages

- Effective in fresh water, salt water and brackish water-based drilling fluids
- Effective in small quantities for filtration control
- Non-fermenting
- Compatible with other Baroid drilling fluid additives
- Resistant to harsh environments and contaminants

Typical Properties

Appearance	Off-white, free-flowing, viscous fluid
Specific gravity	0.98
pH (0.3% solution)	9.0
Flash point, PMCC °F (°C)	185, (85)
Pour point, °F (°C)	35, (1.7)
Freeze point, °F (°C)	-40, (-40)

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Recommended Treatment

- Using Venturi Mixer, or into vortex of a high-speed stirrer, add slowly and uniformly to entire circulating system.
- Used to slug down the rods to produce a high viscosity hole-cleaning sweep.

Approximate Amounts of LIQUI-TROL™ Added to Water-Based Fluids		
Desired Condition/Result		
Added to fresh or salt water	**qt/100 gal**	**liters/m^3**
• To stabilize water sensitive formation	4-6	10-15
• To reduce torque and lower circulating pressure	2-4	5-10
Added to QUIK-GEL® slurry (25 pounds per 100 gallons) (30 kilograms per m^3)	**qt/100 gal**	**liters/m^3**
• To enhance drilling mud fluid properties	1-2	2.5-5
• To improve drilling mud suspension and stabilization capabilities	2-4	5-10
Added to injection liquid in air/foam drilling	**qt/100 gal**	**liters/m^3**
• To improve foam performance and hole cleaning	1-4	2.5-10

Note:

Salt water may require twice as much LIQUI-TROL as fresh water. Preferably, LIQUI-TROL should be mixed in freshwater before it is added to salty water.

Packaging

LIQUI-TROL is packaged in 5-gal (19-liter) metal pails with an integrated, resealable pour spout.

Availability

LIQUI-TROL can be purchased through any Baroid Industrial Drilling Products Distributor. To locate the Baroid IDP distributor nearest you contact the Customer Service Department in Houston or your area IDP Sales Representative.

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HOLEPLUG®

Graded Sodium Bentonite

Description

HOLEPLUG is a naturally occurring Wyoming sodium bentonite clay that is a sized and graded chip material used to seal and plug earthen boreholes.

HOLEPLUG is available in two particle size grades:

- HOLEPLUG 3/4" (100% of particles pass through 3/4" screen; all particles retained on 3/8" screen)
- HOLEPLUG 3/8" (100% of particles pass through 3/8" screen; all particles retained on 1/4" screen)

Applications/Functions

- Highly recommended for use in grouting annulus in all types of wells, particularly environmental monitoring well applications
- Seal above gravel packs
- Plug decommissioned boreholes
- Stemming shotholes
- Seal around conductor pipe
- Seal lost circulation zones
- Shut off artesian flow

Advantages

- Prevents entry of surface water into boreholes
- High swelling potential
- In situ swelling to provide a superior seal with excellent casing stabilization
- Easier to apply than pellets
- Cost effective
- Simple to apply, mixing not required
- Prevents vertical movement of fluids in the hole between porous zones
- Forms a permanent, flexible downhole seal
- Allows hole re-entry
- Rehydratable
- ANSI/NSF Standard 60 certified

Typical Properties

Volume of 50-lb (22.7 kg) sack	
HOLEPLUG 3/4"	0.73 ft^3 or 0.027 yd^3 or 0.021 m^3
HOLEPLUG 3/8"	0.70 ft^3 or 0.026 yd^3 or 0.020 m^3
Permeability	1.5×10^{-9} cm/sec (in fresh water)
Appearance	Beige to tan chips

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Recommended Treatment

Plugging and Stemming Drill Holes

Due to shipping and handling, a small amount of fine bentonite particles may be present. For optimum results, HOLEPLUG® should be poured over a mesh or screen with ¼" (6.4 mm) openings to "sift out" the smaller particles. The screen should be large enough (approx.1 yd^2 or $1m^2$) to be folded into a "V" shape to allow sifting while the product is being poured into the hole. Also, HOLEPLUG should be poured slowly. Allow approximately two minutes to pour a 50-lb (22.7 kg) bag.

1. Position the screen with the lower end placed over the borehole
2. Slowly pour HOLEPLUG down the "V" so that fine particles fall through the screen before the larger particles fall into the borehole
3. Fill hole as required (above static water level or to ground level)
4. Observe all regulatory specifications

Stopping loss of circulation and stabilizing unconsolidated formations

1. Pull drill pipe out of hole
2. Pour HOLEPLUG into hole to fill above problem zone
3. Drill ahead slowly with reduced pump pressure

Plugging flowing wells

Pour HOLEPLUG into hole until water flow subsides or hole is filled to surface.

Treatment Considerations

§ Adequate annular space should be present to allow for the placement of HOLEPLUG into the area of concern without bridging. It is recommended that a minimum annular space of two inches on either side of the outside dimension of the casing be present. This will facilitate the placement of tremie lines and reduce the potential of the HOLEPLUG bridging during pouring operations. The use of this product should always correspond with applicable federal, state and local well construction guidelines.

Application Amounts

Amounts of HOLEPLUG® Required for Plugging Applications				
Hole Diameter (inches)	Hole Volume (ft^3/ft)	Pounds HOLEPLUG Needed to Fill One Foot	Feet Filled by One Bag HOLEPLUG	Bags HOLEPLUG Needed to Fill 100 ft
2	0.022	1.6	32.6	3.2
2.5	0.034	2.4	20.5	5.0
3	0.049	3.5	14.3	7.0
3.5	0.067	4.8	10.4	9.6
4	0.087	6.3	7.9	12.6
4.5	0.110	7.9	6.3	15.8
5	0.136	9.8	5.1	19.6
5.5	0.165	11.9	4.2	23.8
6	0.196	14.1	3.5	28.2
6.5	0.230	16.6	3.0	33.2
7	0.267	19.2	2.6	38.4
7.5	0.307	22.1	2.3	44.2
8	0.349	25.1	2.0	50.2
8.5	0.394	28.4	1.8	56.8
9	0.442	31.8	1.6	63.6
9.5	0.492	35.4	1.4	70.8
10	0.545	39.2	1.3	78.4
11	0.660	47.5	1.1	95.0
12	0.785	56.5	0.89	113.0
15	1.227	88.3	0.57	176.6
18	1.767	127.2	0.39	254.4
20	2.182	157.1	0.32	314.2
25	3.409	245.4	0.20	490.8
30	4.909	353.4	0.14	706.8

Application Amounts (metric equivalents)

Amounts of HOLEPLUG® Required for Plugging Applications				
Hole Diameter (mm)	Hole Volume (m^3/m)	Kilograms HOLEPLUG Needed to Fill One Meter	Meters Filled by One Bag HOLEPLUG	Bags HOLEPLUG Needed to Fill 10 meters
51	0.002	2.3	9.87	1.0
64	0.003	3.6	6.31	1.6
76	0.005	5.2	4.38	2.3
89	0.006	7.0	3.22	3.1
102	0.008	9.2	2.47	4.1
114	0.010	11.6	1.95	5.1
127	0.013	14.4	1.58	6.3
140	0.015	17.4	1.30	7.7
152	0.018	20.7	1.10	9.1
165	0.021	24.3	0.93	10.7
178	0.025	28.2	0.81	12.4
191	0.029	32.4	0.70	14.3
203	0.032	36.8	0.62	16.2
216	0.037	41.6	0.55	18.2
229	0.041	46.6	0.49	20.5
241	0.046	51.9	0.44	22.9
254	0.051	57.5	0.39	25.3
279	0.061	69.6	0.33	30.7
305	0.073	82.8	0.27	36.5
381	0.114	129.4	0.18	57.0
457	0.164	186.4	0.12	82.1
508	0.203	230.1	0.10	101.4
635	0.317	359.5	0.06	158.4
762	0.456	517.7	0.04	228.1

Packaging

HOLEPLUG graded bentonite is packaged in 50-lb (22.7 kg) multiwall paper bags.

Availability

HOLEPLUG can be purchased through any Baroid Industrial Drilling Products Distributor. To locate the Baroid IDP distributor nearest you contact the Customer Service Department in Houston or your area IDP Sales Representative.

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EZ-MUD®

Polymer Emulsion

Description

EZ-MUD, a liquid polymer emulsion containing partially hydrolyzed polyacrylamide/polyacrylate (PHPA) copolymer, is used primarily as a borehole stabilizer to prevent reactive shale and clay from swelling and sloughing. EZ-MUD is also added to low-solids drilling fluids to increase lubricity, fluid viscosity, and to improve carrying capacity of air/foam injection fluids.

Applications/Functions

- Stabilize reactive shale and clay formations
- Improve borehole stability
- Enhance slurry rheological properties
- Alleviate mud rings, bit balling and booting-off in clay formations
- Reduce drill pipe torque and pumping pressure
- Minimize rod chatter in diamond core drilling
- Create "stiff-foam" and maintain foam integrity
- Flocculate non-reactive solids in reserve pit at low concentrations

Advantages

- Mixes easily with minimum shear in fresh water
- Provides effective clay and shale stabilization with lower viscosity
- Imparts high degree of lubricity
- Non-fermenting
- Breaks down chemically with bleach (sodium hypochlorite)
- ANSI/NSF Standard 60 Certified

Typical Properties

Appearance	Thick, opaque white liquid
Density	8.5 lb/gal (1.02 g/cm^3)
pH (1 quart per 100 gallons water)	8.5
Flash point, PMCC °F, °C	>200 (>93.3)
Thermal stability, °F, °C	250 (121)

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Recommended Treatment

Approximate Amounts of EZ-MUD® Added to Drilling Fluid System			
Drilling Application/Desired Property	**Quarts/ 100 gal**	**Pints/bbl**	**Liters/m^3**
Added to fresh water (To formulate a clay-free drilling fluid)			
• To stabilize reactive clay and shale	0.5 - 2.0	0.5 - 1.75	1.25 - 5.0
• To retard rod vibration, reduce torque and pumping pressure	1.0 - 2.0	1.0 - 1.75	2.5 - 5.0
Added to QUIK-GEL® or BORE-GEL™ Drilling Fluids			
• To retard reactive shale and clay and enhance lubricity	0.5 - 1.0	0.5 - 1.0	1.25 - 2.5
Added to injection liquid in air/foam drilling applications			
• To improve foam performance and hole conditions	0.5 - 1.0	0.5 - 1.0	1.25 - 2.5

Notes:

- Make-up water used to mix EZ-MUD should meet the following quality:
  total chloride less than 1500 ppm (mg/L)
  total hardness less than 150 ppm as calcium
  total chlorine less than 50 ppm
  water pH between 8.5-9.5
- Reduce total hardness of make-up water by adding soda ash (sodium carbonate) at 0.5 to 1 pound per 100 gallons (0.6 - 1.2 kg/m^3) of make-up water.
- EZ-MUD can be chemically broken down with liquid bleach in regular household concentration (5% sodium hypochlorite). Use one gallon of liquid bleach per 100 gallons (10 liters/m^3) of fluid formulated with EZ-MUD. Do not use perfumed liquid bleach or solid calcium hypochlorite.

Packaging

EZ-MUD is packaged in 5-gal (19-liter) and 1-gal (3.8-liter) plastic containers.

Availability

EZ-MUD can be purchased through any Baroid Industrial Drilling Products Distributor. To locate the Baroid IDP distributor nearest you contact the Customer Service Department in Houston or your area IDP Sales Representative.

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BENSEAL®

Sealing and Plugging Agent

Description

BENSEAL is a granular (8-mesh), natural Wyoming sodium bentonite for use in sealing and grouting well casings and earthen structures. BENSEAL is not recommended for use as a drilling mud.

Applications/Functions

- Seal or grout plastic or steel casings in monitor and water well construction
- Seal or plug abandoned boreholes
- Seal leaking ponds, ditches and dams
- Soil stabilization
- Prepare BENSEAL/EZ-MUD® grouting system
- Aid in controlling loss of circulation

Advantages

- High swelling capacity
- Uniform particle size
- No heat of hydration
- Prevents commingling of aquifers and contamination from surface
- Forms a flexible seal to protect casing from corrosive contaminants
- Allows for hole re-entry
- ANSI/NSF Standard 60 certified

Typical Properties

Appearance	Bluish to gray granules
Dry screen analysis	85% of 8 mesh
Volume, ft^3/sack	0.7 (as packaged)
Specific gravity	2.6
Permeability	less than 1×10^{-8} cm/sec (in fresh water)

Recommended Treatment

As a casing drill and drive operation:

1. Dig a cone-shaped depression around casing. Depression should be 6 - 8 inches (152-203 mm) larger than the outside diameter of the casing and 2 - 3 feet (60-75 cm) deep.
2. Keep cone-shaped depression filled with dry BENSEAL while driving the casing.

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Recommended Treatment (continued)

Note:

When drilling and driving a 4" (102mm) pipe, expect to use 2.5 pounds of BENSEAL® per foot of hole or 3.7 kilograms of BENSEAL per meter of hole.

Sealing ponds or earthen structures:

Depending on the native soil, disc in or mix 3 to 5 pounds of BENSEAL per square foot (14-24 kg/m^2) uniformly over the area to be sealed so that a 6-inch (~152 mm) blanket of soil and BENSEAL is formed. Do not neglect the edges of the dam or the sides/walls of the pond. This sealing blanket should then be compacted in place and as a further protection to the sealing blanket, 2 to 4 inches (51-102 mm) of local soil or sand should cover the sealing blanket and be compacted.
If the leaking area can be identified and isolated, an attempt can be made to broadcast BENSEAL uniformly at 4 to 6 pounds of BENSEAL per square foot (20-30 kg/m^2) of surface area into the water over the area of concern.
Note*:* Bentonite is more effective as a sealing agent when confined. Therefore, every effort should be made to cover the BENSEAL after it is broadcast with a 2-3 inch (51-76 mm) layer of sand. This will reduce the potential for dispersion into the water and un-yielded bentonite particles interfering with the gill action of fish.

Lost returns (moderate):

1. Begin with the pit full of mud.
2. Raise the pump suction off bottom and place a shovel next to it and slightly under suction.
3. Pour dry BENSEAL slowly into the space between shovel and suction and pump it down the hole.

Packaging

BENSEAL is packaged in 50-lb (22.7 kg) multiwall paper bags, containing 0.7 ft^3 (0.02 m^3).

Availability

BENSEAL can be purchased through any Baroid Industrial Drilling Products Distributor. To locate the Baroid IDP distributor nearest you contact the Customer Service Department in Houston or your area IDP Sales Representative.

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AQUA-CLEAR™ PFD

Phosphate-Free Dispersant

Description

AQUA-CLEAR PFD is a concentrated liquid polymer dispersant that provides superior mud and sediment removal from the producing formation and gravel pack. This product is also a highly effective mud thinner. AQUA-CLEAR PFD contains no phosphates.

Applications/Functions

- Disperse mud, sediment and clay from the producing formation and gravel pack in the screened interval.
- Reduce viscosity and gel strength of drilling fluids

Advantages

- ANSI/NSF Standard 60 certified
- Reduces development time
- Increases well yield and capacity
- Safe to use on most plastics, rubber and metals
- Non-fermenting
- Reduces pumping costs

Typical Properties

Appearance	straw colored liquid
Specific gravity	1.2 to 1.4
pH (neat)	6.5 to 7.5

Recommended Treatment

As a Well Development Aid

- Determine volume of water in screen area and double the calculated volume to account for water in gravel pack and formation interface ***or*** determine the static volume of water and add 50% excess.
- Once the water volume is determined, calculate the required treatment volume of AQUA-CLEAR PFD by the following formula:

  AQUA-CLEAR PFD (gal or L) = 0.002 x Water Volume (gal or L)

This equates to one gallon of AQUA-CLEAR PFD for every 500 gallons of water (0.2% by volume) or 2.0 liters of AQUA-CLEAR PFD for every cubic meter of water.

- Mix thoroughly before introducing into well.
- The preferable application method utilizes a tremie line with the product applied into the screened area.
- If necessary, the AQUA-CLEAR PFD/water solution may be poured into the well.
- Mixture should be thoroughly blended in well, then agitated using a surge

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Recommended Treatment (continued)

and swab, jetting, or other developmental technique repeatedly every two hours for a period of up to 24 hours.

- Pump to waste until turbidity clears up and then connect well to distribution system.

As a Mud Thinner

- Start by adding one pint of AQUA-CLEAR™ PFD to 500 gallons of mud. Increase concentration until desired viscosity is achieved.

Well Capacity Chart (Gallons per Foot)					
Well Diameter (Inches)	**Well Capacity in Gallons/ft**	**Well Diameter (Inches)**	**Well Capacity in Gallons/ft**	**Well Diameter (Inches)**	**Well Capacity in Gallons/ft**
2	0.2	12	5.9	24	23.5
4	0.7	14	8.0	26	27.6
6	1.5	18	13.2	30	36.7
8	2.6	20	16.3	36	52.9
10	4.1	22	19.7	48	94.0

Well Capacity Chart (Liters per Meter)					
Well Diameter (millimeters)	**Well Capacity Liters/meter**	**Well Diameter (millimeters)**	**Well Capacity Liters/meter**	**Well Diameter (millimeters)**	**Well Capacity Liters/meter**
51	2.0	305	73.0	610	292.0
102	8.1	356	99.3	660	342.6
152	18.3	457	164.2	762	456.1
203	32.4	508	202.7	914	656.8
254	50.7	559	245.3	1219	1167.7

Note: The volumes in these tables show only the volume of water in a 1 foot or 1 meter section of a given size of screen. Excess volume must be included to account for water present in the formation interface and gravel pack.

Packaging

AQUA-CLEAR PFD is packaged in a 5-gal (19-liters) plastic pail or 1-gal (3.8-liter) plastic container.

Availability

AQUA-CLEAR PFD can be purchased through any Baroid Industrial Drilling Products Distributor. To locate the Baroid IDP distributor nearest you, contact the Customer Service Department in Houston or your area IDP Sales Representative.

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AQUA-CLEAR™ MGA

Modified Granular Acid

Description

AQUA-CLEAR MGA is a dry blend of granular acid and additives used in the removal of iron, manganese and carbonate scale. It retains strength longer than most liquid acids, which increases its cleaning capability.

Applications/Functions

- Disperse scale and incrustation
- Remove scale and incrustation from the water well screen, casing, gravel pack and pumping equipment
- Restore well production
- AQUA-CLEAR MGA can be used in combination with AQUA-CLEAR AE to remove more difficult scale and incrustation

Advantages

- ANSI/NSF Standard 60 certified
- Safe to use on all plastics, rubber and metals
- No harmful vapors
- Improves water quality (color, taste and appearance)
- Reduces equipment and piping failures due to scale build-up and corrosion
- Reduces pumping costs

Typical Properties

Appearance	Free-flowing, off-white granules
Specific gravity	2.00
pH (10% solution)	0.9
Solubility in water	Complete with slight to hazy turbidity

Recommended Treatment

- Record initial well water pH
- The preferred application method is to apply a solution of AQUA-CLEAR MGA into the screened interval through a tremie pipe.

Recommended Treatment (continued)

- Mix AQUA-CLEAR™ MGA with water at ½ - 1 pound per gallon of water or 0.06 - 0.12 kilograms per liter of water and apply directly into screened interval with a tremie pipe. When utilizing this method, calculate the volume of water in the screened area and double the calculated volume to account for the water in the gravel pack and formation interface.

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Note: The previous concentration of* AQUA-CLEAR™ MGA *is recommended for a complete reconditioning of an existing well.

- Calculation for volume in well:
- Gallons per foot = (diameter, inches)^2 x 0.042
- Liter per meter = (diameter, millimeters)^2 x 0.0008
- Displace solution into the well screen and formation, then surge, swab, agitate or jet well through screen and gravel pack for 20-30 minutes.
- Allow to stand in well for up to two hours and then repeat activity approximately every two hours for a period of 24 hours.
- Pump well to waste until well water pH is within 0.5 of original well pH.

  Note: Wastewater can be neutralized by adding soda ash or lime

- Chlorinate well and reconnect to water distribution system.

  Caution: Never mix chlorine and* AQUA-CLEAR MGA *in well.

- If necessary, AQUA-CLEAR MGA may be poured directly into well as per treatment table, but results will not be as good as if applied in a dissolved form via a tremie pipe. The undissolved form will require more mechanical agitation.

Note:

- ***In heavily encrusted wells, it is desirable to brush or scrape the casing and screen, then pump or airlift the debris to waste prior to treating with acid.***

The following charts recommend a concentration of* AQUA-CLEAR MGA *that is suitable for a typical maintenance treatment of an existing well.

AQUA-CLEAR MGA Application Amounts per 10 Feet of Standing Water					
Well Diameter (Inches)	**Pounds of Product**	**Well Diameter (Inches)**	**Pounds of Product**	**Well Diameter (Inches)**	**Pounds of Product**
2	0.35	12	12.73	24	50.94
4	1.41	14	17.33	26	59.78
5	2.21	16	22.64	28	69.33
6	3.18	18	28.65	30	79.60
8	5.66	20	35.37	36	114.61
10	8.84	22	42.80	48	203.75

Recommended Treatment (continued)

AQUA-CLEAR™ MGA Application Amounts per 10 Meters of Standing Water					
Well Diameter (millimeters)	**Kilograms of Product**	**Well Diameter (millimeters)**	**Kilograms of Product**	**Well Diameter (millimeters)**	**Kilograms of Product**
51	0.53	305	18.97	610	75.90
102	2.11	356	25.83	660	89.10
127	3.29	406	33.73	711	103.31
152	4.74	457	42.69	762	118.60
203	8.43	508	52.71	914	170.77
254	13.18	559	63.78	1219	303.60

Note: The concentrations of* AQUA-CLEAR MGA *shown in the previous tables do not take into account the 100% excess volume required to compensate for the water present in the formation interface and gravel pack. The previous tables only account for the product concentration required for the volume of water occupying a 10 foot or 10 meter section of a given size of screen.

For other diameters:

- Gallons per foot = (diameter, inches)^2 x 0.042
- Liter per meter = (diameter, millimeters)^2 x 0.0008
- Pounds of AQUA-CLEAR MGA = (gallons per foot x 8.34) x 0.026
- Kilograms of AQUA-CLEAR MGA = (liters per meter) x 0.026
- Double the calculated volume in order to take into account the water present in the gravel pack and formation interface.
- AQUA-CLEAR AE can be used with AQUA-CLEAR MGA for iron bacteria treatment. When used together, utilize one gallon of AQUA-CLEAR AE for every 10 pounds of AQUA-CLEAR MGA or 0.84 liters of AQUA-CLEAR AE for every kilogram of AQUA-CLEAR MGA.

Safety

- AQUA-CLEAR MGA is safe to handle when in dry form, but when mixed with water it should be handled in accordance with recognized standard practices for handling corrosive and acidic materials (refer to Material Safety Data Sheet).
- Avoid skin and eye contact – flush with water
- Do not ingest and avoid prolonged inhalation
- When disposing of waste fluid make sure to comply with all federal, state and local regulations as applicable.

Packaging

AQUA-CLEAR™ MGA is packaged in 5-gal (19-liter) pails containing 50 pounds (22.7 kg) and in 1-gallon (3.8-liter) plastic jars containing 10 pounds (4.5 kg).

Shipping

The following are required for commercial transport:

- Insurance policy must include an endorsement for transporting hazardous cargo.
- Vehicle driver must have a Hazmat endorsement on his/her Commercial Drivers License.
- Hazardous Materials Certificate of Registration issued by the U.S. Department of Transportation (renewable annually) is required.
- Consult the state in which operating for any additional requirements that may exist.
- No hazardous materials placard is required for shipments less than 1000 pounds.

Availability

AQUA-CLEAR MGA can be purchased through any Baroid Industrial Drilling Products Distributor. To locate the Baroid IDP distributor nearest you contact the Customer Service Department in Houston or your area IDP Sales Representative.

Baroid Industrial Drilling Products,

A Product and Service Line of Halliburton Energy Services, Inc.

3000 N. Sam Houston Pkwy E.

Houston, TX 77032

Customer Service	(800) 735-6075 Toll Free	(281) 871-4612
Technical Service	(877) 379-7412 Toll Free	(281) 871-4613

AQUA-CLEAR™ AE

Acid Enhancer/Antifoulant

Description

AQUA-CLEAR AE is a liquid blend of acids and acid enhancers formulated to control bacterial slime contamination due to the presence of iron-related and sulphate-reducing bacteria.

Applications/Functions

- Remove the bio-mass matrix caused by bacterial fouling
- Reduce sulphur taste and odor in water
- Clean up well screens, pumps and distribution system
- Restore well productivity and reduce power and maintenance costs
- AQUA-CLEAR AE can be used in combination with AQUA-CLEAR MGA and other acids such as, hydrochloric (muriatic), phosphoric and sulfamic to enhance their effectiveness and to remove more difficult scale and incrustation

Advantages

- ANSI/NSF Standard 60 certified
- Safe to use on all plastics, rubber and metals
- Cost effective, efficient extended life treatment
- Improves water quality and renews well production rate
- Mitigates corrosion and equipment failure
- Reduces pumping costs

Typical Properties

Appearance	Light amber colored liquid
Specific gravity	1.08
pH of solution	1.1

Recommended Treatment

To treat bacteria fouling

- Record initial well water pH
- The preferred application method is to apply a solution of AQUA-CLEAR AE into the screened interval through a tremie pipe.

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Recommended Treatment (continued)

- Mix AQUA-CLEAR™ AE with water at 6 - 12 ounces per gallon of water or 47 - 94 ml per liter of water and apply directly into screened interval with a tremie pipe. When utilizing this method, calculate the volume of water in the screened area and double the calculated volume to account for the water in the gravel pack and formation interface.

Note: The above concentration of* AQUA-CLEAR AE *is recommended for a complete reconditioning of an existing well.

- Calculation for volume in well:
- Gallons per foot = (diameter, inches)^2 x 0.042
- Liter per meter = (diameter, millimeters)^2 x 0.0008
- Displace solution into the well screen and formation, then surge, swab, agitate or jet well through screen and gravel pack for 20-30 minutes.
- Allow to stand in well for up to two hours and then repeat activity approximately every two hours for a period of 24 hours.
- Pump well to waste until at least 23 well volumes have been removed and well water pH is within 0.5 of original well pH.

Note: Wastewater can be neutralized by adding soda ash or lime.

- Chlorinate well and reconnect to water distribution system.

Caution: Never mix chlorine and* AQUA-CLEAR AE *in well.

- If necessary, AQUA-CLEAR AE may be poured directly into well as per treatment table, but results will not be as good as if applied via a tremie pipe.

Notes:

- ***In heavily encrusted wells, it is desirable to brush or scrape the casing and screen, then pump or airlift the debris to waste prior to treating with acid.***
- ***The following charts recommend a concentration of* AQUA-CLEAR AE *that is suitable for a typical maintenance treatment of an existing well.***

AQUA-CLEAR AE Application Amounts per 10 Feet of Standing Water					
Well Diameter (Inches)	**Gallons of Product**	**Well Diameter (Inches)**	**Gallons of Product**	**Well Diameter (Inches)**	**Gallons of Product**
2	0.04	12	1.27	24	5.10
4	0.14	14	1.73	26	6.00
5	0.22	16	2.26	28	6.93
6	0.32	18	2.87	30	7.96
8	0.57	20	3.54	36	11.46
10	0.88	22	4.28	48	20.40

AQUA-CLEAR™ AE Application Amounts per 10 Meters of Standing Water					
Well Diameter (millimeters)	**Liters of Product**	**Well Diameter (millimeters)**	**Liters of Product**	**Well Diameter (millimeters)**	**Liters of Product**
51	0.49	305	17.60	610	70.35
102	1.95	356	23.94	660	82.57
127	3.05	406	31.27	711	95.76
152	4.40	457	39.57	762	109.93
203	7.82	508	48.86	914	158.29
254	12.21	559	59.12	1219	281.41

Recommended Treatment (continued)

Note: The concentrations of* AQUA-CLEAR AE *shown in the previous tables do not take into account the 100% excess volume required to compensate for the water present in the formation interface and gravel pack. The previous tables only account for the product concentration required for the volume of water occupying a 10 foot or 10 meter section of a given size of screen.

For other diameters:

- Gallons per foot = (diameter, inches)^2 x 0.042
- Liter per meter = (diameter, millimeters)^2 x 0.0008
- Gallons of AQUA-CLEAR AE = (gallons per foot x 8.34) x 0.0026
- Liters of AQUA-CLEAR AE = (liters per meter) x 0.0241
- Double the calculated volume in order to take into account the water present in the gravel pack and formation interface.

Treating Severe bio-fouling and scaling

- AQUA-CLEAR AE is used as an enhancer when mixed in the well with AQUA-CLEAR MGA
- One gallon of AQUA-CLEAR AE to every 10 pounds of AQUA-CLEAR MGA
- 3.8 liters of AQUA-CLEAR AE to every 4.5 kilograms of AQUA-CLEAR MGA

Safety

- Use recognized standard practices for handling corrosive and acidic materials (refer to Material Safety Data Sheet)
- Avoid skin and eye contact – flush with water
- Do not ingest and avoid prolonged inhalation
- When disposing of waste fluid make sure to comply with all federal, state and local regulations as applicable.

Packaging

AQUA-CLEAR™ AE is packaged in 1-gallon (3.8-liter) and 5-gallon (19-liter) plastic containers.

Shipping

- The following are required for commercial transport:
- Insurance policy must include an endorsement for transporting hazardous cargo.
- Vehicle driver must have a Hazmat endorsement on his/her Commercial Drivers License.
- Hazardous Materials Certificate of Registration issued by the U.S. Department of Transportation (renewable annually) is required.
- Consult the state in which operating for any additional requirements that may exist.
- No hazardous materials placard is required for shipments less than 1000 pounds.

Availability

AQUA-CLEAR AE can be purchased through any Baroid Industrial Drilling Products Distributor. To locate the Baroid IDP distributor nearest you, contact the Customer Service Department in Houston or your area IDP Sales Representative.

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Appendix C

Lithology Log

Geologic Unit	Lithologic Description	Sample Interval (ft bgs)	Elevation Range (ft above msl)
Qal, Alluvium	Unconsolidated sediments, moderate yellowish-brown (10YR 5/4), clayey gravel (GC) with sand +10F (i.e., plus No. 10 size sieved sample fraction): mostly subangular intermediate volcanic clasts (up to 1.0 cm). +35F (i.e., plus No. 35 size sieved sample fraction): 60% quartz and sanidine grains; 40% volcanic lithic fragments.	0–5	6527.8–6522.8
	Unconsolidated sediments, moderate brown (5YR 4/4), sand (SP), medium-grained, most grains broken, 80% intermediate volcanic clasts, 20% quartz and sanidine grains. Note: None of the sample was retained by the No. 10 sieve; Qal/Qbo contact estimated at 10 ft bgs.	5–10	6522.8–6517.8
Qbo, Otowi Member, Bandelier Tuff	Rhyolitic tuff, mottled, moderate brown (5YR 4/4) to pale yellowish-gray (5YR 8/1). WR (i.e., unsieved whole rock) sample contains 20% pumice; 10% quartz and sanidine phenocrysts; 70% lithic fragments. +10F: 90% subrounded vitric pumice (up to 1.0 cm) with single 1.5 cm andesite lithic fragment.	10–15	6517.8–6512.8
	Rhyolite tuff, pale yellowish-brown (10YR 6/2). WR sample contains 50% pumice; 10% phenocrysts; 40% lithic fragments. +10F: 90%–95% subrounded, white frothy pumice (up to 1.0 cm); 5%–10% volcanic lithic fragments (up to 5 mm), mostly dacite with some andesite. +35F: 45%–50% pumice; 45%–50% lithic fragments; 3%–5% quartz and sanidine phenocrysts.	15–25	6512.8–6502.8
	No cuttings recovered in this interval. Note: Qbo/Qbog contact estimated at 30 ft bgs.	25–30	6502.8–6497.8
Qbog, Guaje Pumice Bed	Tephra deposit, very pale orange-tan (10YR 8/2), pumiceous. WR sample contains 100% pumice. +10F: 100% subrounded to rounded frothy pumice (up to 1.2 cm).	30–35	6497.8–6492.8
	Tephra deposit, pale yellowish-brown (10YR 6/2), pumiceous. WR sample contains 70%–80% pumice; 5%–10% phenocrysts; 20%–30% lithic fragments. +10F: 80%–90% white subrounded vitric pumice (up to 5 mm); 10% dacite and andesite lithic fragments (up to 1.5 cm), minor basalt. Note: Qbog/Tb4 contact estimated at 36 ft bgs based on first basalt returns.	35–40	6492.8–6487.8
Tb4, Cerros del Rio basalt	Basalt, medium-dark gray (N4) with some volcaniclastic sediments. WR/+10F: 70%–80% vesicular porphyritic basalt with aphanitic groundmass; 20%–30% volcanic lithic fragments of intermediate composition and quartz and sanidine phenocrysts. Note: Tb4 begins at approximately 36 ft bgs.	40–45	6487.8–6482.8
	Basalt, brownish-gray (5YR 4/1), +10F: vesicular porphyritic basalt with aphanitic groundmass, 5%–7% phenocrysts of olivine and plagioclase, thin iron oxide coating on fractured surfaces, minor amounts of white clay coating vesicle surfaces.	45–50	6482.8–6477.8
	Basalt, medium-dark gray (N4), porphyritic with aphanitic groundmass, vesicular. +10F: 5%–7% phenocrysts of plagioclase and unaltered pale green olivine; trace of white clay lining vesicles from 60–65 ft.	50–65	6477.8–6462.8

Geologic Unit	Lithologic Description	Sample Interval (ft bgs)	Elevation Range (ft above msl)
Tb4, Cerros del Rio basalt	Basalt, medium-dark gray (N4), sparsely porphyritic with aphanitic groundmass, variable vesicularity. +10F: 3%–5% phenocrysts of plagioclase and slightly oxidized brown olivine; partial iron oxide coating on fractures and lining vesicles; locally white calcite coats fractures and chips.	65–80	6462.8–6447.8
	Basalt, medium-dark gray (N4), sparsely porphyritic with aphanitic groundmass, vesicular. +10F: phenocrysts of plagioclase and dark colored olivine (up to 1 mm), olivine is oxidized or replaced; trace of light tan clay lining vesicles.	80–90	6447.8–6437.8
	Basalt, medium-dark gray (N4), sparsely porphyritic with phenocrysts of plagioclase and olivine (up to 2 mm); groundmass probably altered.	90–92	6437.8–6435.8
	No cuttings recovered in this interval.	92–97	6435.8–6430.8
	Basalt, brownish-gray (5YR-4/1) to medium-dark gray (N4), vesicular, porphyritic with phenocrysts of olivine (up to 2 mm) and mostly lath-shaped plagioclase (up to 2 mm), some olivine oxidized and iron-stained, some blocky plagioclase crystals; groundmass microcrystalline to aphanitic; some vesicles filled with alteration products or have iron-stained surfaces.	97–103	6430.8–6424.8
	Basalt, medium-dark gray (N4), vesicular to massive, porphyritic with phenocrysts of olivine (up to 2 mm) and lath-shaped plagioclase (up to 2 mm), some olivine oxidized and iron-stained; some vesicles have iron-stained surfaces or are infilled with material. +35F: 2%–3% quartz crystals (up to 3 mm).	103–113	6424.8–6414.8
	Basalt, medium gray (N5), mostly vesicular, porphyritic with phenocrysts of olivine (up to 2 mm) and lath-shaped plagioclase (up to 1 mm long); some coating and iron staining of vesicles; some rounded clayey sandstone clasts in +35F.	113–118	6414.8–6409.8
	Basalt, medium gray (N5), mostly massive, porphyritic with phenocrysts of olivine and lath-shaped plagioclase; minor amounts of quartz crystals and one quartz pebble.	118–123	6409.8–6404.8
	Basalt, medium-dark gray (N4) to grayish-red purple (5RP 4/2), abundant vesicles to scoriaceous, porphyritic with phenocrysts of olivine (up to 3 mm) and lath-shaped plagioclase (up to 2 mm long); iron staining common; vesicles filled with clay; quartz crystals comprise 5%–10% of the +35F.	123–128	6404.8–6399.8
	Basalt, medium-dark gray (N4), some vesicles, porphyritic with phenocrysts of olivine (up to 2 mm) and blocky to lath-shaped plagioclase (up to 2 mm long); groundmass microcrystalline to aphanitic; some vesicles filled with clay; minor iron staining; quartz crystals comprise 5% of +35F.	128–133	6399.8–6394.8
	Basalt, medium-dark gray (N4), sparse vesicles, mostly massive, porphyritic with phenocrysts of olivine (up to 2 mm) and lath-shaped to blocky plagioclase (up to 2 mm); very little iron staining or filling of vesicles.	133–148	6394.8–6379.8

Geologic Unit	Lithologic Description	Sample Interval (ft bgs)	Elevation Range (ft above msl)
Tb4 Cerros del Rio basalt	Basalt, medium gray (N5), very few vesicles, mostly massive, porphyritic with phenocrysts of olivine (up to 2 mm) and lath-shaped to blocky plagioclase (up to 2 mm); groundmass microcrystalline; iron staining absent.	148–158	6379.8–6369.8
	Basalt, medium gray (N5) to grayish-red purple (5RP 4/2), abundant vesicles to scoriaceous, porphyritic with generally unaltered phenocrysts of olivine (up to 2 mm) and lath-shaped plagioclase (up to 1 mm long). Secondary alteration of groundmass; vesicles lined with secondary alteration minerals, possibly including silica; iron staining common and some calcite evident.	158–168	6369.8–6359.8
	Basalt, grayish-red purple (5RP 4/2), vesicular, porphyritic with phenocrysts of olivine (up to 2 mm) and lath-shaped plagioclase (up to 1 mm long); secondary alteration of groundmass.	168–181	6359.8–6346.8
	Basalt, brownish-gray (5YR 4/1), vesicular, porphyritic with phenocrysts of olivine (up to 2 mm) and lath-shaped plagioclase (up to 1 mm long); secondary alteration of groundmass, blocky calcite crystals evident.	181–191	6346.8–6336.8
	Basalt, brownish-gray (5YR 4/1), sparse vesicles, porphyritic with phenocrysts of olivine (up to 2 mm) and blocky to lath-shaped plagioclase (up to 2 mm); secondary alteration of groundmass.	191–196	6336.8–6331.8
	Basalt, grayish-red purple (5RP 4/2), vesicular, porphyritic with phenocrysts of olivine (up to 3 mm) and both blocky and lath-shaped plagioclase (up to 2 mm); secondary alteration of groundmass; shape of vesicles not well defined.	196–206	6331.8–6321.8
	Basalt, medium gray (N5), massive, nonvesicular, porphyritic with phenocrysts of olivine (up to 2 mm) with abundant small (>0.5 mm) scattered olivine in groundmass, lath-shaped plagioclase (up to 2 mm long); secondary calcite crystals common (up to 1 mm); altered microcrystalline groundmass.	206–216	6321.8–6311.8
	Basalt, medium gray (N5), massive, porphyritic with phenocrysts of olivine (up to 2 mm) and abundant small (>0.5 mm) scattered olivine crystals and opaque pyroxene, both blocky and lath-shaped plagioclase (up to 2 mm). Slightly altered microcrystalline groundmass. Alteration less pronounced than basalts above.	216–236	6311.8–6291.8
	No cuttings recovered in this interval.	236–287	6291.8–6240.8
	Basalt, grayish black (N2) to grayish-red purple (5RP 4/2), abundant vesicles to scoriaceous, porphyritic with phenocrysts of olivine (up to 2 mm), no visible plagioclase; microcrystalline groundmass; small, secondary blocky calcite crystals, some silicification evident.	287–297	6240.8–6230.8
	Basalt, grayish black (N2) to grayish-red purple (5RP 4/2), vesicular to scoriaceous, porphyritic with phenocrysts of olivine (up to 2 mm); microcrystalline groundmass, silicification evident; some clay coating on chips.	297–302	6230.8–6225.8
	No cuttings recovered in this interval.	302–342	6225.8–6185.8

Geologic Unit	Lithologic Description	Sample Interval (ft bgs)	Elevation Range (ft above msl)
Tb4 Cerros del Rio basalt	Basalt, medium-dark gray (N4) scoriaceous, porphyritic with phenocrysts of olivine (up to 2 mm) and lath-shaped plagioclase (up to 2 mm); some silicification evident; few chips of clay and but clay lines some vesicles; some basalt chips are rounded, indicating probable sedimentary transport.	342–346	6185.8–6181.8
	Basalt, medium light gray (N6) scoriaceous, porphyritic with phenocrysts of olivine (up to 2 mm) and lath-shaped plagioclase (up to 2 mm); some calcite crystals; most chips and vesicles have clay coatings; rare chips of pinkish gray clay.	346–356	6181.8–6171.8
	Basalt, medium gray (N5) vesicular to massive, porphyritic with phenocrysts of olivine (up to 1 mm) and lath-shaped plagioclase (up to 2 mm); some secondary calcite crystals; most vesicles have clay coatings; altered microcrystalline groundmass.	356–361	6171.8–6166.8
	Basalt, light gray (N7), mostly massive with rarely vesicular, porphyritic with phenocrysts of olivine (up to 2 mm) and lath-shaped plagioclase (up to 2 mm long); abundant small crystals (<0.5 mm) of olivine, and sparse pyroxene.	361–371	6166.8–6156.8
	Basalt, light gray (N7), mostly massive with minor amount of vesicles, porphyritic with phenocrysts of olivine (up to 2 mm) and blocky to lath-shaped plagioclase (up to 1 mm); abundant small crystals (<0.5 mm) of olivine, sparse pyroxene.	371–386	6156.8–6141.8
	Basalt, medium light gray (N6), massive with rare vesicles. +10F: porphyritic with phenocrysts of olivine (up to 2 mm), blocky to lath-shaped plagioclase (up to 1 mm); abundant small crystals (<0.5 mm) of olivine, sparse pyroxene.	386–411	6141.8–6116.8
	Basaltic sediments, sand (SW) with silt, brownish-gray (5YR 4/1), silt to medium-grained sand, poorly sorted, subangular grains; sand grains are mostly lithic fragments of basalt with some quartz and cemented clay. +10F: basalt, similar to above unit. +35F: basalt and silicified basalt (similar to interval from 287–302 ft bgs); rare chips of pinkish-gray silica-cemented clay.	411–416	6116.8–6111.8
	Basalt, brownish-gray (5YR 4/1). WR sample contains some sand. +10F: basalt chips, mostly massive with rare vesicles, porphyritic with phenocrysts of olivine (up to 1 mm) and plagioclase laths (up to 2 mm long), abundant small crystals (<0.5 mm) of olivine, sparse pyroxene.	416–421	6111.8–6106.8
	Basalt, medium light gray (N6). WR sample contains some sand, +10F: massive basalt, porphyritic with phenocrysts of olivine (up to 1 mm), some very light in color, plagioclase laths (up to 2 mm long); rare pinkish-gray cemented clay chips; groundmass mostly microcrystalline. +35F: contains abundant grayish-brown basalt chips and some cemented clay chips.	421–431	6106.8–6096.8
	Basalt, medium light gray (N6). +10F: massive with some brownish-gray basalt, porphyritic with phenocrysts of olivine (up to 2 mm), with majority very light in color, visible plagioclase crystals are rare; groundmass mostly bleached to white in color; some chips coated with calcite.	431–451	6096.8–6076.8

Geologic Unit	Lithologic Description	Sample Interval (ft bgs)	Elevation Range (ft above msl)
Tb4 Cerros del Rio basalt	Basalt, medium gray (N5). +10F: massive, porphyritic with phenocrysts of olivine (up to 2 mm), some bleached; rare blocky plagioclase crystals, most very small to microcrystalline, abundant small (<0.5 mm) olivine, and some pyroxene; altered microcrystalline groundmass.	451–471	6076.8–6056.8
	Basalt with cemented clay chips, medium gray (N5), poor cuttings returned. +10F: porphyritic basalt with phenocrysts of olivine (up to 2 mm), many bleached; rare, small plagioclase crystals; groundmass microcrystalline. +35F: contains several cemented clay chips.	471–476	6056.8–6051.8
	Basalt and silty sand (SM) (possible interbed), pale yellowish-brown (10YR 6/2). WR sample contains 80% medium gray basalt; 20% sand, very fine to fine-grained, poorly sorted, angular grains, mostly quartz grains with some lithic fragments. +10F: basalt chips with few cemented clay chips. +35F: 80% basalt; 10% brown siltstone; 10% pale-orange cemented clay chips.	476–486	6051.8–6041.8
	Basalt and sandy siltstone (possible interbed), medium light gray (N6). WR sample contains mostly basalt with 10% sandy silt. +10F: 97% medium-dark gray basalt, mostly massive with few vesicles, aphanitic to microcrystalline, rare olivine phenocrysts (up to 1 mm), some plagioclase; 3% grayish-orange sandy siltstone. +35F: mostly basalt; 5% sandy siltstone; 2% cemented clay chips.	486–491	6041.8–6036.8
	Basalt and silty sandstone (possible interbed), medium light gray (N6). WR sample contains 95% basalt; 5% silty sand. +10F: mostly massive porphyritic basalt, rare vesicles, olivine phenocrysts (up to 1 mm); minor plagioclase (up to 0.5 mm); groundmass mostly microcrystalline; 1% silty sandstone; one euhedral quartz crystal. +35F: 97% basalt; 3% very fine-grained, silty, sandstone chips.	491–496	6036.8–6031.8
	Basalt and silty sandstone (possible interbed), medium light gray (N6). +10F: mostly massive porphyritic basalt, rare vesicles, olivine phenocrysts (up to 1 mm), plagioclase laths (up to 1 mm); 5% silty sandstone and sandy siltstone; few cemented clay chips and basalt chips with clay coating.	496–506	6031.8–6021.8
	Basalt with siltstone, medium light gray (N6). +10F: mostly massive basalt, sparse olivine and plagioclase phenocrysts (up to 1 mm), groundmass microcrystalline; 3% orange-pink siltstone with very fine-grained sand; rare basalt chips with cemented clay coatings.	506–511	6021.8–6016.8
	Basalt, medium gray (N5). +10F: mostly massive porphyritic basalt with rare vesicles, olivine phenocrysts are nearly clear (bleached), rare plagioclase phenocrysts, groundmass microcrystalline; 2%–3% pink tuffaceous siltstone; some basalt chips have white clay coatings.	511–521	6016.8–6006.8
	Basalt, medium gray (N5), porphyritic with aphanitic groundmass, WR: some clay. +10F: 85%–90% porphyritic basalt, olivine phenocrysts, both unaltered pale green, and completely replaced by limonite, groundmass mostly unaltered but with 10%–15% altered groundmass evident; trace of pink siltstone.	521–526	6006.8–6001.8

Geologic Unit	Lithologic Description	Sample Interval (ft bgs)	Elevation Range (ft above msl)
Tb4 Cerros del Rio basalt	Basalt, light brownish-gray, porphyritic with aphanitic groundmass, WR sample contains abundant clay chips. +10F: 93%–95% unaltered to strongly altered basalt; 5%–7% white very fine-grained clayey sandstone and siltstone; trace of basalt-rich sandstone. Probable contact between basalt and sediments at 530 ft. bgs.	526–531	6001.8–5996.8
Tb4, Cerros del Rio basalt, Interflow Sediments	Basalt/clastic sediments, sandy clay (SC) and basalt, grayish-orange pink (5YR 7/2). WR sample contains 85% sandy clay with 15% basalt chips; highly plastic clay contains some very fine-grained sand and silt. +10 F: mostly basalt, massive, aphanitic, few olivine phenocrysts and some plagioclase; 10% clayey sandstone chips. +35F: mostly basalt with 35% clayey sandstone chips.	531–536	5996.8–5991.8
	Basalt/clastic sediments, sandy silt (SM) and basalt, grayish-orange pink (5YR 7/2). WR sample contains mostly sandy silt with 30% basalt chips; sandy silt contains 20% very fine to fine-grained sand and has some clay content. +10F: 60% silty sand and sandy siltstone; 40% basalt, aphanitic, few olivine and plagioclase phenocrysts. +35F: 50% basalt; 50% sandy siltstone and silty sandstone; few cemented clay chips.	536–541	5991.8–5986.8
	Basalt/clastic sediments, sandy clay (SC), grayish-orange pink (5YR 7/2). WR sample contains 70%–75% clay; 20%–25% sand; 5%–7% basalt chips. +10F: 50% pinkish fine-grained sand and siltstone, sand grains of glassy basalt, feldspar, and possibly olivine; 50% angular, clay-coated basalt chips. +35F: 50% sandy clay; 50% basalt.	541–546	5986.8–5981.8
	Basalt/clastic sediments, sandy clay (SC) and basalt, grayish-orange pink (5YR 7/2). WR sample contains 30%–40% clay; 25%–35% sand; 15%–20% basalt chips. +10F: 35%–40% pink tuffaceous siltstone and claystone; 15%–20% fine-grained sand, grains of mafic crystals and feldspar, partially iron-stained; 35%–40% basalt chips.	546–551	5981.8–5976.8
	Basalt/clastic sediments, clayey gravel (GC) with sand, pale yellow-brown (10YR 6/2), basalt-rich. WR sample contains 70%–90% gravel; 10%–15% sand; 15%–30% fines. +10F: 60%–65% angular basalt chips; 7%–10% basaltic sandstone, grains of basalt, feldspar, and olivine, iron-stained; 30%–35% pinkish siltstone and claystone chips.	551–561	5976.8–5966.8
	Basalt/clastic sediments, clayey gravel (GC) with sand, pale yellowish-brown (10YR 7/2), basalt-rich. WR sample contains 70% gravel; 20% sand; 10%–15% fines. +10F: 70%–75% unaltered to altered basalt chips; 20%–25% fine-grained basaltic sandstone and pinkish claystone and siltstone; trace of calcite. +35F: 95% altered basalt; 5% sandstone and siltstone.	561–566	5966.8–5961.8
	Basalt/clastic sediments, clayey gravel (GC), pale yellowish-brown (10YR 7/2), basalt-rich. WR sample contains 75%–80% gravel; 5%–10% sand; 20%–30% fines. +10F: 80%–90% massive to vesicular basalt, aphanitic (lacks olivine), strongly altered, with brown staining; 10%–20% volcaniclastic sandstone and pinkish claystone and siltstone. +35F: abundant flakes of clay-altered basalt.	566–576	5961.8–5951.8

Geologic Unit	Lithologic Description	Sample Interval (ft bgs)	Elevation Range (ft above msl)
Tb4, Cerros del Rio basalt, Interflow Sediments	Basalt/clastic sediments, clayey gravel (GC), pale yellowish-brown (10YR 7/2), basalt-rich. WR sample contains 75%–80% gravel; 5%–10% sand; 20%–30% fines. +10F: 8%5–90% altered basalt or basaltic andesite, aphanitic, abundant flakes of clay-altered basalt; 10%–15% volcaniclastic sandstone and siltstone.	576–586	5951.8–5941.8
	Basalt/clastic sediments, siltstone and basaltic sandstone (SW), grayish-orange pink (5YR 7/2) coarse chips (up to 2.5 cm). WR/+10F: 75% pinkish claystone, siltstone and fine-grained sandstone, grains of basalt, feldspar, and mafic crystals; 20%–25% coarse subangular, aphyric chips (up to 2.0 cm) of basalt and basaltic andesite.	586–591	5941.8–5936.8
	Basalt/clastic sediments, clay (CH) to clayey sand (SC), grayish-orange pink (5YR 7/2). WR sample contains 10%–20% gravel; 40%–50% sand; 30%–40% fines. +10F: 40%–50% altered basalt and basaltic andesite, clayey with flakes of clay common; 40%–50% pinkish claystone, siltstone and tuffaceous sandstone; trace of crystalline calcite.	591–601	5936.8–5926.8
	Basalt/clastic sediments, gravel (GW) with clay and sand, pale yellowish-brown (10YR 6/2). WR sample contains 55%-65% gravel; 20%–30% sand; 10%–15% fines. +10F: 50%–55% broken and subangular chips of basalt, partially sericitized; 40%–45% pinkish, very fine-grained tuffaceous sandstone and siltstone, minor amounts of orange claystone, sandstone locally contains basalt lithic fragments.	601–611	5926.8–5916.8
	Basalt/clastic sediments, gravel (GW) with clay and sand, pale yellowish-brown (10YR 6/2). WR sample contains 40–50% gravel; 25%–35% sand; 10–15% fines. +10F: 80%–85% broken and subangular basalt chips, partially altered; 15%–20% pinkish-tan tuffaceous siltstone and claystone; 5%–7% basalt–rich volcaniclastic sandstone.	611–621	5916.8–5906.8
	Basalt/clastic sediments, clayey sand (SC), pale brown (5YR 5/2). WR sample contains 5%–15% gravel; 60%–70% sand; 20%–25% fines. +10F: only small amount retained; 45%–60% broken basalt chips, aphyric and porphyritic with phenocrysts of olivine, groundmass aphanitic, partially altered; 40%–55% pinkish tan, very fine-grained tuffaceous sandstone and siltstone.	621–631	5906.8–5896.8
	No cuttings returned in this interval.	631–636	5896.8–5891.8
	Basalt/clastic sediments, clayey sand (SC) to sand (SW) with clay, pale yellowish-brown (10YR 6/2). WR sample contains 5%–10% gravel; 55%–65% sand; 15%–25% fines. +10F: only small amount retained; 5%–10% broken basalt chips; 90%–95% pinkish very fine-grained sandstone, siltstone, and claystone. +35F: 20%–25% basalt; 75%–80% siltstone.	636–646	5891.8–5881.8
	Basalt/clastic sediments, clayey sand (SC) to sand (SW) with clay, pale yellowish-brown (10YR 6/2). WR sample contains 5%–7% gravel; 65%–70% sand; 15%–25% fines. +10F: 25%–35% broken basalt chips, partially altered; 65%–75% pinkish tuffaceous siltstone and claystone. +35F: Similar percentages and composition.	646–661	5881.8–5866.8

Geologic Unit	Lithologic Description	Sample Interval (ft bgs)	Elevation Range (ft above msl)
Tb4, Cerros del Rio basalt, Interflow Sediments	Basalt/clastic sediments, sand (SW) with clay and gravel, grayish orange-pink (5YR 7/2). WR sample contains 10%–20% gravel; 65%–75% sand; 10%–15% fines. +10F: 35%–45% broken basalt chips, aphyric, partly scoriaceous, and sericitized or silicified; 55%–65% pinkish fine-grained tuffaceous sandstone and siltstone.	661–671	5866.8–5856.8
	Basalt/clastic sediments, gravel (GW) with clay and sand, grayish-orange pink (5YR 7/2). +10F: 55%–60% broken basalt chips, massive and scoriaceous, partially clay altered, replacement by opaline silica evident; 40%–45% pink to orange very fine-grained tuffaceous sandstone and siltstone.	671–681	5856.8–5846.8
	Basalt/clastic sediments, gravel (GW) with clay and sand, light brown-gray (5YR 6/1). +10F: 65%–70% broken basalt chips, both massive and scoriaceous, frequently sericitized and bleached and/or replaced by opaline silica; 30%–35% pinkish siltstone and claystone.	681–691	5846.8–5836.8
	Basalt/clastic sediments, gravel (GW) with clay and sand, light brown-gray (5YR 6/1), contact with underlying basalt at approximately 692 ft. bgs. WR sample contains 60%–70% gravel; 25%–30% sand; 10%–15% fines. +10F: 80%–85% broken basalt chips, scoriaceous, moderately to strongly altered, majority replaced with opaline silica; 15%–20% pinkish very fine-grained tuffaceous sandstone and siltstone.	691–696	5836.8–5831.8
Tb4, Cerros del Rio basalt	Basalt, light olive-gray (5Y 6/1), aphyric, scoriaceous, clayey matrix binding chips. +10F: 90% broken basalt chips, dominantly scoria, pervasive silicification; 10% very fine-grained tuffaceous sandstone and siltstone.	696–701	5831.8–5826.8
	Basalt, light olive-gray (5Y 6/1), sparsely porphyritic with aphanitic groundmass, partly scoriaceous. +10F: 92%–95% broken and altered scoriaceous basalt chips, partly replaced by silica, with clay-lined vesicles; 5%–7% pinkish very fine-grained sandstone and white siltstone.	701–706	5826.8–5821.8
	Basalt, light olive-gray (5Y 6/1), sparsely porphyritic with aphanitic groundmass, alteration evident. +10F: 97%–98% broken basalt chips, less altered than interval above, chips are pitted and lined with mostly silica and some clay; 2%–3% pinkish very fine-grained sandstone and siltstone.	706–716	5821.8–5811.8
	Basalt, medium-light gray (N6), scoriaceous, sparsely porphyritic with aphanitic groundmass, alteration evident. +10F: 97%–99% broken scoriaceous basalt chips, small vesicles (< 0.5 mm), moderate to massive alteration by silica, clay lining vesicles and vugs, groundmass replaced by silica, minor unaltered olivine and plagioclase phenocrysts (up to 1 mm); 1%–3% pinkish very fine-grained sandstone and white siltstone.	716–731	5811.8–5796.8
	Basalt, medium-light gray (N6), scoriaceous, sparsely porphyritic with aphanitic groundmass, alteration evident. +10F: 97%–99% broken scoriaceous basalt chips, distinctive alteration, pitted, original glassy groundmass spotted with silica and clay, vesicles and vugs lined with drusy quartz crystals and clay, pervasive silicification between 741–746 ft. bgs; 1%–3% pinkish siltstone.	731–746	5796.8–5781.8

Geologic Unit	Lithologic Description	Sample Interval (ft bgs)	Elevation Range (ft above msl)
Tb4, Cerros del Rio basalt	Basalt, medium-light gray (N6), sparsely porphyritic with aphanitic groundmass, alteration evident. +10F: 96%–98% broken basalt chips, 1%–2% phenocrysts of olivine, pyroxene, and plagioclase, pyroxene is dark brown; phenocrysts generally unaltered; groundmass is mostly bleached, clay altered, and/or silicified; 2%–4% pinkish fine-grained sandstone and siltstone.	746–761	5781.8–5766.8
	Basalt, medium-light gray (N6), massive to vesicular and scoriaeous, porphyritic with aphanitic groundmass, alteration evident. +10F: 98%–99% broken basalt chips, 2%–3% phenocrysts of olivine, pyroxene, and plagioclase, pyroxene is dark brown to black; groundmass commonly bleached and altered, white clay has replaced plagioclase; 2%–3% pinkish fine-grained sandstone and siltstone.	761–771	5766.8–5756.8
	Basalt, medium-light gray (N6), massive to vesicular, porphyritic with aphanitic groundmass. +10F: 99% porphyritic basalt, 1%–3% phenocrysts of pyroxene, olivine, and plagioclase (up to 1 mm), generally unaltered, cumulophyric clusters of olivine; groundmass partially to totally bleached and altered.	771–781	5756.8–5746.8
	Basalt, medium-light gray (N6), porphyritic with aphanitic groundmass, partially altered. +10F: 97%–99% pyroxene bearing basalt, 1%–2% phenocrysts of black pyroxene, plagioclase, and olivine (up to 1.0 mm), generally unaltered; groundmass spotted or bleached and altered; 1%–3% very fine-grained sandstone and siltstone.	781–791	5746.8–5736.8
Tb4, Cerros del Rio basalt (791–795 ft bgs) Basaltic Sediments Unassigned Section (795–821 ft bgs)	Basalt, medium-light gray (N6), massive, porphyritic with aphanitic groundmass, partially altered. +10F: 98% basalt, 1%-2% phenocrysts of black pyroxene, plagioclase, and olivine (up to 1.0 mm), some in cumulophyric clusters, generally unaltered, groundmass spotted with clots of clay-altered feldspars, some totally bleached and altered; 2% very fine-grained sandstone and siltstone. Note: basal contact between Cerros del Rio basalt and underlying sediments containing basalt detritus is estimated at 795 ft bgs.	791–801	5736.8–5726.8
Basaltic Sediments (unassigned)	Clastic sediments/basalt, medium-light gray (N6), massive, porphyritic with aphanitic groundmass, partially altered. +10F: 99% broken basalt chips, 1%–2% phenocrysts of black pyroxene, plagioclase, and olivine (up to 1.0 mm), some in cumulophyric clusters, generally unaltered; groundmass spotted with clots of clay-altered feldspars, some totally bleached and altered 1% sandstone and siltstone; trace of subrounded quartzite granules; trace of calcite.	801–811	5726.8–5716.8

Geologic Unit	Lithologic Description	Sample Interval (ft bgs)	Elevation Range (ft above msl)
Basaltic Sediments (unassigned)	Clastic sediments/basalt, medium-light gray (N6), massive, porphyritic with aphanitic groundmass, moderately altered. +10F: 96%–98% broken basalt chips, 1%–2% phenocrysts of black pyroxene, plagioclase, and olivine (up to 1.0 mm), some in cumulophyric clusters, generally unaltered; groundmass spotted with clots of clay-altered feldspars, some totally bleached and altered. 2%–4% very fine-grained sandstone and siltstone; trace of quartzite granules. +35F: 1%-3% quartzite and pink to orange potassium feldspar grains.	811–821	5716.8–5706.8
Tsf, Santa Fe Group Sediments	Basalt and clastic sediments, light brownish-gray (5YR 6/1). WR: clayey matrix; 1%–3% quartzite clasts. +10F: 96%–98% broken to subangular basalt chips, altered; 2%–4% very fine-grained sandstone and siltstone. +35F: 8%5–90% basalt; 5%–8% quartzite and potassium feldspar (microcline); 3%–5% pale tan very fine-grained sandstone and siltstone.	821–826	5706.8–5701.8
	Basalt and clastic sediments, light brownish-gray (5YR 6/1), gravel (GW) with clay and sand. WR sample has a clayey matrix; 60% basalt; 40% quartzite, quartz and feldspars. +10F: 95%–96% altered basalt chips; 1%–2% quartzite and potassium feldspar (microcline) grains; 1%–2% very fine-grained sandstone and siltstone. +35F: 40% basalt; 50%–60% quartzite, quartz and feldspar; 3% sandstone.	826–831	5701.8–5696.8
	Clastic sediments, gravel (GW) with sand, light brownish-gray (5YR 6/1). +10F: 95%–97% broken chips of altered basalt; 2%–4% quartzite, quartz, and pink to orange potassium feldspars; 1%–2% siltstone. +35F: 30%–35% basalt; 65%–70% quartz, milky white quartzite, and potassium feldspar; 1%–2% siltstone.	831–841	5696.8–5686.8
	Clastic sediments, gravel (GW) with sand, light brownish-gray (5YR 6/1). WR sample contains 80%–85% quartzite, quartz, and feldspar clasts; 15%–20% subangular basalt clasts. +10F: 75%–80% broken chips of altered basalt; 15%–20% siltstone; 2%–4% quartz and quartzite grains. +35F: 15%–25% altered basalt and other volcanic lithic fragments (dacite); 75%–80% subangular grains of quartzite, quartz, and orange to pink potassium feldspar; 1%–3% sandstone.	841–856	5686.8–5671.8
	Clastic sediments, gravel (GW) with clay and sand, light brownish-gray (5YR 6/1). WR sample contains 80%–90% non-volcanic clasts (mostly quartzite and granitoids); 10%–20% volcanic clasts (mostly basalt). +10F: 75%–80% broken chips of mostly altered basalt, some subrounded dacite; 10%–15% quartzite, potassium feldspar, and other granitoid clasts; 5%-10% very fine-grained sandstone and siltstone. +35F: 20%-30% basalt and other volcanic lithic fragments; 70%–80% quartzite and granitoid clasts; 1%–2% sandstone.	856–866	5671.8–5661.8

Geologic Unit	Lithologic Description	Sample Interval (ft bgs)	Elevation Range (ft above msl)
Tsf, Santa Fe Group Sediments	Clastic sediments, sand (SW) with clay and gravel, light brownish-gray (5YR 6/1). WR sample contains 85%–90% non-volcanic, mostly quartzite and granitoid clasts; 10%–15% mostly basalt clasts; clayey matrix. +10F: 65%–75% broken basalt chips; 25%–35% quartzite, orange to pink potassium feldspar, and other granitoid clasts; 2%–3% siltstone; trace of calcite. +35F: 15%–20% volcanic lithic fragments, mostly basalt with some dacite; 80%–85% quartzite, quartz, and orange to pink potassium feldspar; 1%–2% sandstone. Note: +10F over-emphasizes basalt fraction in this interval.	866–881	5661.8–5646.8
	Clastic sediments, sand (SW) with clay, light brownish-gray (5YR 6/1). WR sample contains 85%–95% nonvolcanic clasts (mostly quartzite and granitoid clasts); 5%–15% volcanic clasts (mostly basalt). +10F: 55%–65% broken chips of mostly basalt with some dacite; 35%–45% quartzite, potassium feldspar, and other granitoid clasts; 2%–4% very fine grained sandstone and siltstone. +35F: 15%–20% volcanic clasts, mostly basalt; 80%-85% quartzite and granitoid grains; 1%–2% sandstone.	881–896	5646.8–5631.8
	Clastic sediments, sand (SW) with clay, light brownish-gray (5YR 6/1). WR sample contains 93%–95% non-volcanic clasts (mostly quartzite and granitoid clasts); 5%–7% volcanic clasts (mostly basalt). +10F: 30%–35% broken chips of mostly basalt with some dacite; 65%–70% quartzite, orange to pink potassium feldspar, and chert clasts; 2%–3% sandstone. +35F: 10%–15% volcanic clasts, mostly basalt; 85%–90% quartzite and granitoid grains; 1%–2% sandstone.	896–911	5631.8–5616.8
	Clastic sediments, sand (SW) with clay, light brownish-gray (5YR 6/1). WR sample contains 90% nonvolcanic clasts, mostly quartzite and granitoid clasts; 10% volcanic clasts (mostly basalt); clay matrix. +10F: 20%–30% broken chips of mostly basalt with some gray dacite; 75%–80% quartzite, potassium feldspar, chert clasts; 2%–3% very fine-grained sandstone and siltstone. +35F: 15% volcanic clasts, mostly basalt; 85% quartzite and granitoid grains; 1%–2% sandstone; trace of garnet crystals.	911–926	5616.8–5601.8
	Clastic sediments, clay (CH) with sand, grayish-orange pink (5YR 7/1). WR sample contains 40%–50% clay. +10F: 15%–20% subangular basalt clasts; 40%–45% quartzite, potassium feldspar, chert, and granitoid clasts; 30%–40% siltstone.	926–935	5601.8–5592.8
	R-23 BOREHOLE COMPLETED AT 935 FT BGS TOTAL DEPTH (TD).		

Notes:

1. American Society for Testing Materials (ASTM) standards (D 2488-90: Standard Practice and Identification of Soils [Visual-Manual Procedure]) were used to describe the texture of drill chip samples for sedimentary rocks such as alluvium and the Puye Formation. ASTM method D 2488-90 incorporates the Unified Soil Classification System (USCS) as a standard for field examination and description of soils. The following standard USCS symbols were used in the R-23 lithologic log:

SW = Well-graded sand	SM = Silty gravel	SC = Clayey sand
GW = Well-graded gravel	GM = Silty gravel	CH = Clay, high plasticity
GP = Poorly graded gravel	GC = Clayey gravel	

2. Cuttings at R-23 were collected at nominal 5-ft intervals and divided into three sample splits: (1) unsieved, or whole rock (WR) sample; (2) +10F sieved fraction (No. 10 sieve equivalent to 2.0 mm); and (3) +35F sieved fraction (No. 35 sieve equivalent to 0.50 mm).
3. The term *percent,* as used in the above descriptions, refers to percent by volume for a given sample component.
4. Color designations such as hue, value, and chroma (e.g., 5YR 5/2) are from the Geological Society of America's Rock Color Chart.

Appendix D

LANL Borehole Video Logs
(CD attached to inside back cover)

TO VIEW THE VIDEO THAT ACCOMPANIES THIS DOCUMENT, PLEASE CALL THE HAZARDOUS WASTE BUREAU AT 505-476-6000 TO MAKE AN APPOINTMENT

Appendix E

Schlumberger Geophysical Report/Montage
(CD attached to inside back cover)

Geophysical Logging Report

Schlumberger Water Services
February 2003

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1.0 ABSTRACT

This report describes the borehole geophysical logging measurements acquired in characterization well R-23 by Schlumberger, logged in September 2002 just prior to well completion. It also presents the final processed results from these measurements and discusses the interpretation of these results. The logs were acquired from 16 ft to 832 ft below ground surface, when the borehole was open (uncased) below 559 ft, drilled with 10.625 in diameter bit size, and contained 9.625 in diameter free-standing steel casing above 599 ft (as measured by the logs). The primary purpose of the geophysical logging was to characterize the geologic/hydrogeologic section intersected by the well with emphasis on determining moisture content, perched groundwater zones, capacity for flow, and the stratigraphy/mineralogy of geologic units. A secondary purpose of the geophysical logging was to evaluate the borehole conditions such as borehole diameter versus depth and degree of drilling fluid invasion. These objectives were accomplished by measuring, nearly continuously, along the length of the well: (1) total and effective water-filled porosity and pore size distribution, from which an estimate of hydraulic conductivity is made, (2) bulk density (sensitive to total water- plus air-filled porosity) and photoelectric effect (sensitive to lithology), (3) bulk electrical resistivity at multiple depths of investigation, (4) bulk concentrations of a number of elements, (5) spectral natural gamma ray, including potassium, thorium, and uranium concentrations, and (6) borehole diameter.

Preliminary results of these measurements were generated in the logging truck at the time the geophysical services were performed and are documented in field logs provided on-site. However, the measurements presented in the field results are not corrected for borehole casing and fluid conditions and are provided as separate, individual logs. The field results were reprocessed by Schlumberger to (1) correct/improve the measurements, as best as possible, for borehole/formation environmental conditions, (2) perform an integrated analysis of the log measurements so that they are all coherent, and (3) combine the logs in a single presentation, enabling integrated interpretation. The reprocessed log results provide better quantitative property estimates that are consistent for all applicable measurements, as well as estimates of properties that otherwise could not be reliably estimated from the single measurements alone (e.g. total porosity inclusive of all water and air present, water saturation, mineralogy).

Most of the geophysical log measurements from Well R-23 provide good quality results that are consistent with each other through much of the borehole, although the quality of some measurements was degraded in certain sections where the borehole contains large washouts behind the free-standing casing. The measurements most affected by the adverse borehole conditions were ones that have a shallow depth of investigation and require close contact to the borehole wall—the bulk density and porosity measurements (particularly neutron and density porosity); instead of measuring formation properties they partially measure borehole fluid properties. Through the integrated analysis and interpretation of all the logs, the individual shortcomings of the specific measurements are reduced. Thus, the integrated log analysis results (e.g. the optimized water-filled porosity log) are the most robust single representation of the geophysical log results—providing a wealth of valuable high resolution information on the geologic and hydrogeologic environment of the R-23 locale.

Important results from the processed geophysical logs in R-23 include the following.

1. The estimated water saturation (fraction of pore space filled with water) remains below 75% through most of the bottom of the logged section (the open hole section from 599–824 ft) with no significant fully saturated intervals. The highest estimated water saturations of the entire log

interval occur in the bottom 150 ft of the cased hole section and extending slightly into the open hole section (450–620 ft), including 100% water saturation in some zones. However, these moist zones likely correspond to water-filled washouts behind the casing, as evidenced by very high measured porosity, and thus do not represent natural formation conditions. These results, interpreted independent of other data sources, suggest that the regional aquifer groundwater level lies somewhere below the bottom of the log interval (824 ft) and that there are no significant perched water zones within the logged section.

2. The measured near wellbore water-filled porosity is less than 20% of total formation volume through most of the logged section, ranging from a low of 5% to a high of about 30%, except artificially higher in cased hole zones where there is water-filled annulus behind the casing. The highest water-filled porosities wherein the measurement is not suspect occur in the zones 404–408 ft (maximum 32%), 624–680 ft (maximum 22%), and 760–800 ft (maximum 20%).

3. Effective water-filled porosity (moveable water) is less than 4% through all of the logged open hole section (599–824 ft), ranging from a low of 0% to a high of 4%. (The measurement cannot be made in cased hole.) Correspondingly, the estimated hydraulic conductivity is generally very low. The highest effective water-filled porosity and hydraulic conductivity occurs in the interval 676–732 ft, with a peak of 4% of total volume at 711 ft. Overall there is little indication of moveable water (water that can flow) in the open hole section.

4. The integrated log analysis shows a very iron rich, mafic-mineral rich zone from 46–550 ft that likely corresponds to a basalt lava flow sequence. The analysis indicates the zone 599–626 ft contains lesser amounts of heavy mafic minerals and only minor amounts (if any) of quartz/silica glass—still likely basalt lava flow material. The interval 626–794 ft also contains minor amounts of heavy mafic minerals, but also a significant amount of quartz/silica glass (20-60% dry weight fraction), and could be a dacitic volcanic deposit. Washed out, higher porosity zones could correspond to fractured and altered lava flow zones that contain small amounts of clay.

5. The integrated log analysis predicts variable amounts of clay/montmorillonite below 474 ft (0–30% by volume) and negligible amounts above. The highest clay amounts occur in the zones 526–544 ft and 589–597 ft. High water content occurs above these zones, suggesting the clay may act to inhibit downward flow of water. Higher clay content also occurs in the zones 597–690 ft and 732–824 ft, which also contain washouts and higher total and water-filled porosity; these zones could correspond to fractured and altered lava flow zones.

6. The borehole was enlarged and/or washed out throughout the open hole log interval (599–824 ft), but the washouts were generally minor (maximum diameter 14.3 in) and caused minimal impact on geophysical log quality. However, washouts were likely present in a number of zones within the cased hole log interval (17–599 ft), causing the log measurements to be heavily influenced by the annular space between the casing and formation.

2.0 INTRODUCTION

Geophysical logging services were performed in characterization well R-23 by Schlumberger in September 2002, prior to initial well completion. The purpose of these services was to acquire in situ measurements that help characterize the borehole, near-borehole, and abutting geologic formation environment. The primary objective of the geophysical logging was to provide in situ evaluation of formation properties (hydrogeology and geology) intersected by the well. This information was (and is) used by scientists, engineers, and project managers in the Los Alamos Characterization and Monitoring Well Project to design the well completion, better understand subsurface site conditions, and assist in overall decision-making.

The primary geophysical logging services performed by Schlumberger in well R-23 were the

- Combinable Magnetic Resonance (CMR*) tool to measure the nuclear magnetic resonance response of the formation, which is used to evaluate total and effective water-filled porosity of the shallow formation and to estimate pore size distribution and in situ hydraulic conductivity;
- Compensated Neutron Tool, model G (CNTG[*]) to measure volumetric water content of the formation, which is used to evaluate moist/porous zones;
- Triple detector Litho-Density (TLD*) tool to measure formation bulk density , which is used to estimate total porosity;
- Array Induction Tool, version H, (AITH*) to measure formation electrical resistivity at five depths of investigation, which is used to evaluate drilling fluid invasion into the formation, presence of moist zones far from the borehole wall, and presence of clay-rich zones;
- Natural Gamma Spectroscopy (NGS) tool to measure gross natural gamma and spectral natural gamma ray activity, including potassium, thorium, and uranium concentrations, which is used to evaluate geology/lithology, particularly the amount of clay and potassium-bearing minerals;
- Elemental Capture Spectroscopy (ECS*) tool to measure elemental weight percent concentrations of a number of elements – used to characterize mineralogy and lithology of the formation.

In addition, calibrated gross gamma ray (GR) was recorded with every service except the NGS, for the purpose of depth matching the logging runs to each other. Table 2.1 summarizes the geophysical logging runs performed in R-23.

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Table 2.1
Geophysical logging services, their combined tool runs and intervals logged, as performed by Schlumberger in borehole R-23

Date of Logging	Borehole Status	Run #	Tool 1	Tool 2	Tool 3	Depth Interval (ft)
24-Sept-2002	Open hole below 599 ft Bit size of 10.625 in. Surface casing above 599 ft Casing OD of 9.625 in.	1	CNTG	TLD	GR	16–822 ft (CNTG) 24–824 ft (CNTG)
Same	Same	2	AITH	NGS		19–814 ft (NGS) 620–832 ft (AITH)
Same	Same	3	CMR	ECS	GR	46–832 ft (ECS) 599–823 ft (CMR)

2.1 Technology Description

Geophysical logging represents mature, yet constantly evolving, technologies employed as the principal methods of borehole analysis in subsurface characterization. Geophysical logs have a long history of use in the groundwater industry for aquifer delineation and basic characterization. More recently, advanced logging technologies, developed for the petroleum industry, are being applied for characterizing a wide range of groundwater-related physical properties.

Wireline geophysical logging systems consist of three components (Figure 2.1):

1. downhole instrument (or sonde) introduced into a borehole that measures one or more physical properties of the formation (a logging “tool” is usually defined as the sonde plus required accompanying electronic cartridges;
2. cable that connects the sonde to the surface, conducting power downhole and transmitting data uphole; and
3. logging truck that controls sonde location, provides power and houses a computer that controls sonde operation, as well as processes and displays data in real time. The resulting data are shown on a continuous strip chart commonly called a log.

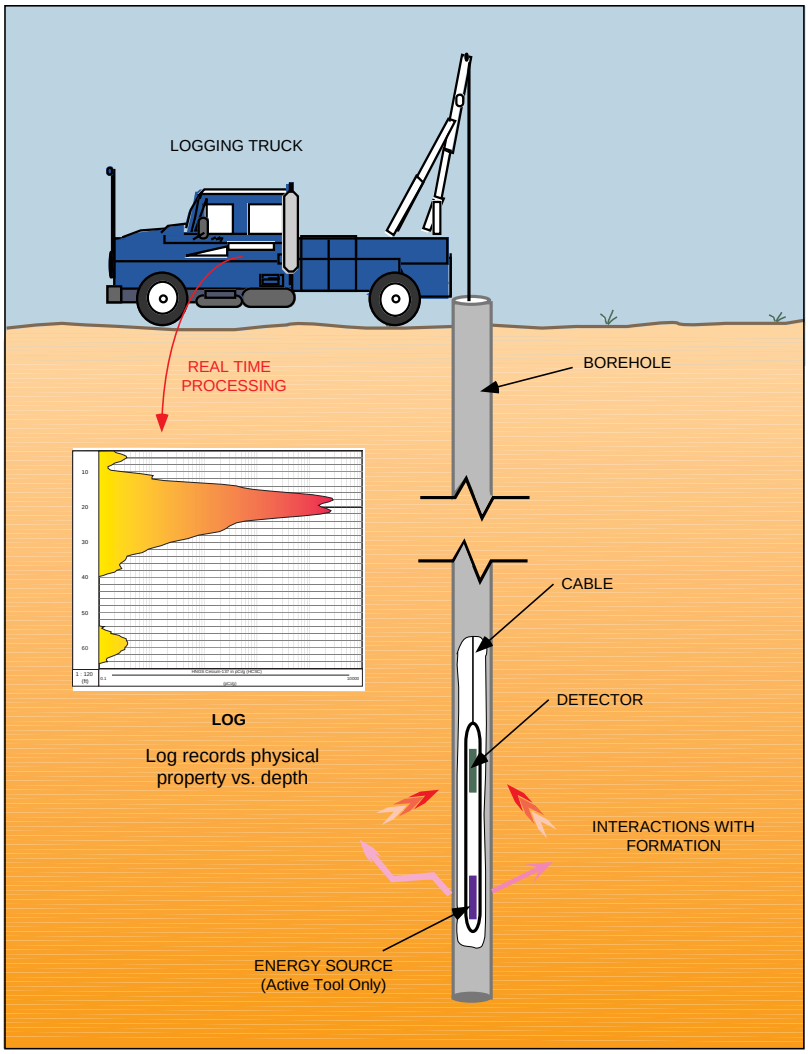

Figure 2.1: Schematic diagram of a wireline logging system in operation.

Geophysical logging systems are designed to give an accurate and precise in situ measurement of formation properties. Formation parameters commonly measured include porosity, moisture content, bulk geochemistry, hydraulic conductivity, orientation of bedding and fractures, identification and quantification of specific radionuclides and other elements, and many others. Similarly, logging systems provide accurate and precise measurements of completed well parameters, such as casing geometry, casing thickness, cement bond, and annular fill composition. Logging systems can also be used for downhole sampling and testing.

The integration of multiple logging technologies plus other data types (e.g., geologist's log, core analyses, surface geophysics, hydrologic test analyses) can lead to a fairly comprehensive picture of the subsurface. The precision of the measurements, in concert with the potential to measure the same volume repeatedly (i.e., re-enter the same borehole), enhances the use of logging systems for monitoring.

2.1.1 Compensated Neutron Tool, Model G (CNTG)

The CNTG tool measures the hydrogen index (HI), which is usually closely related to hydrogen concentration and water volume and can be employed in either open or cased, water or air filled boreholes. The HI measurement is made by emitting high-energy neutrons from a 16-Ci Americium-Beryllium neutron source, which collide with atoms in the volume surrounding the tool and are slowed to epithermal and thermal energy levels. The number of slowed neutrons returning to a set of detectors is then measured. The CNTG contains two He-3 thermal detectors, spaced 37.8 cm (15 in.) and 62 cm (24.7 in.) above the neutron source, as well as two He-3 epithermal neutron detectors spaced 11.6 in. and 20.5 in. below the source. This model of the CNT makes an HI measurement from epithermal neutrons in addition to one from thermal neutrons. The detectors count the neutrons that have been reduced to thermal/epithermal energy level. Measured count rates from the detectors are used to compute a ratio that varies primarily with the hydrogen concentration, or HI, of the media, and is related to formation water-filled porosity. Environmental effects are reduced using the ratio of the two count rates from the two detectors, which are affected in a similar manner by the environment. Residual environmental effects can be corrected with offsite processing. While the HI measurement is calibrated to provide a volumetric water content estimate, it is affected by lithology; it measures all hydrogen in clays, including that in hydroxyl molecules, as well as other oddball neutron absorbers, typically resulting in an elevated porosity in clays.

The CNTG provides two different porosity measurements, thermal and epithermal. The advantage of the epithermal measurement is that it provides a measurement in air-filled boreholes (not possible with the thermal measurement) and is relatively insensitive to thermal neutron absorbers (such as chlorine in salt water and the rare earth elements in shale). However, because of less efficient detection and of the relatively brief time spent by the neutrons in the epithermal energy band, epithermal count rates are lower than thermal count rates, under identical conditions in water-filled boreholes, by a factor of ten.

The measurements are calibrated in open and cased boreholes, albeit the measurement will be affected by the annular fill between the casing and the formation. The median depth of investigation is approximately 7 in. and vertical resolution approximately 18 in., although the thermal measurement can be resolution-enhanced to 8 in.

Basic measurement specifications for the CNTG are shown below.

Range of Measurement (water content):	0 to 60 %
Repeatability (Precision) (1 standard deviation or σ):	0– 20% = <1% porosity 20 to 30% = ± 2% porosity above 45% = ± 5% porosity

2.1.2 Combinable Magnetic Resonance (CMR)

The CMR makes pulse-echo nuclear magnetic resonance (NMR) measurements that are sensitive to the hydrogen nuclei (protons) contained in the pore space of the formation. These measurements contain information relating to both pore water volume and pore size. The pore size information can be used to partition the formation porosity into bound and free fluid volumes. This information can, in turn, be used to estimate formation hydraulic conductivity and water producibility. The pore size information also can be used to extrapolate relative grain size. The pore size information is unique to NMR logging devices.

The CMR log uses a compact magnet and antenna sensor package mounted in a pad-like skid that is pressed against the borehole wall. The tool has a vertical resolution of 6 in. (15 cm) and a median depth

of investigation of 1.5 in. (4 cm). Since the CMR makes a shallow measurement that requires good borehole wall-to-pad contact, disruption of contact between the skid and the wall because of borehole washout or hole rugosity affects data quality, resulting in erroneously high/low total and free water content in water/air-filled hole. The measurement also can be significantly affected by a sizeable presence of iron-bearing minerals, such as magnetite.

Basic measurement specifications for the CMR and a schematic diagram of the tool and sensor section are shown below and in Figure 2.2, respectively. The measurement specifications assume good logging conditions, good contact between the CMR pad and the borehole wall, and the absence of large amounts of magnetic material in the borehole environment.

Repeatability (σ):	Total water-filled porosity	1%
	Effective water-filled porosity:	0.5%
Total margin of error:	2%	

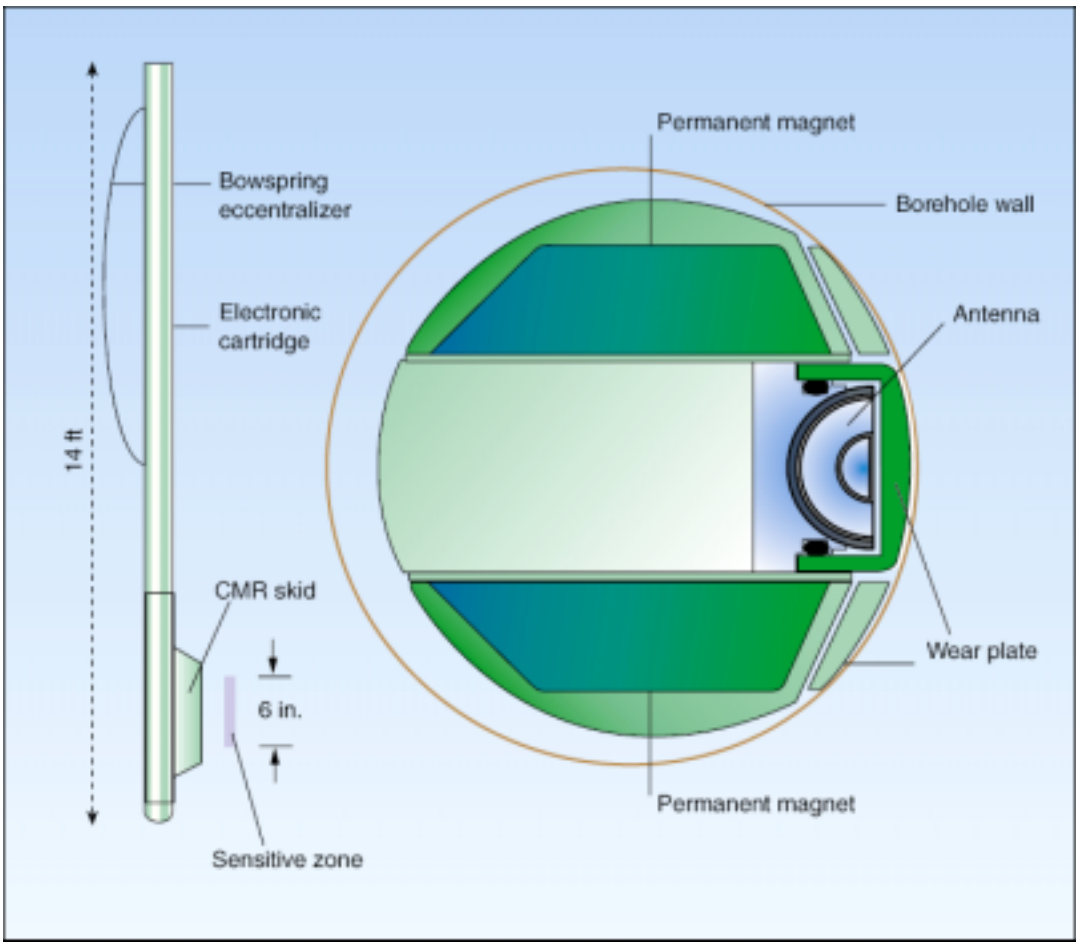

Figure 2.2. Schematic diagram of CMR tool with an enlarged cross-section of the sensor section

2.1.3 Triple Detector Litho-Density Tool (TLD)

The TLD tool is a triple-detector gamma-gamma (gamma ray source and gamma ray detectors) system for measuring compensated bulk density and formation photoelectric factor (P_e). Formation bulk density is

a function of porosity, rock matrix density, and pore fluid density, and P_e is a measure of the average atomic number of the formation that corresponds to formation chemistry and lithology. The tool uses a focused gamma source (1.5-curie ^{137}Cs) to emit a large flux of gamma rays into the formation and measures the resulting gamma intensity in dual near and far detectors. From these spectral measurements, a robust, environmentally corrected calculation of bulk density is made. True matrix porosity can be calculated based on bulk density, an estimation of matrix grain density (aided by the P_e measurement) and fluid densities. This porosity is unaffected by bound hydrogen in clays, as is porosity from neutron devices. The detectors, like the source, are highly focused because of their small size and heavy shielding and thus produce a high-resolution measurement.

The TLD also employs a third backscatter detector that improves the environmental correction for borehole washouts and rugosity, improves the dynamic range of the P_e, and has higher count rates and, thus, better measurement statistics, in hard rocks.

The TLD tool has a vertical resolution as high as 1.2 in. (3 cm) and a depth of investigation of 4 in. (10 cm). The tool is sensitive to changes in bulk density down to 0.01 g/cm3 and can be run in open hole and certain types of cased hole completions, and in both saturated and unsaturated formations.

The TLD uses a pad-like skid that is pressed against the borehole wall. Because the tool has a relatively shallow depth of investigation, it can be severely affected by borehole washouts and rugosity.

A schematic diagram of a TLD-type sensor system is shown in Figure 2.3.

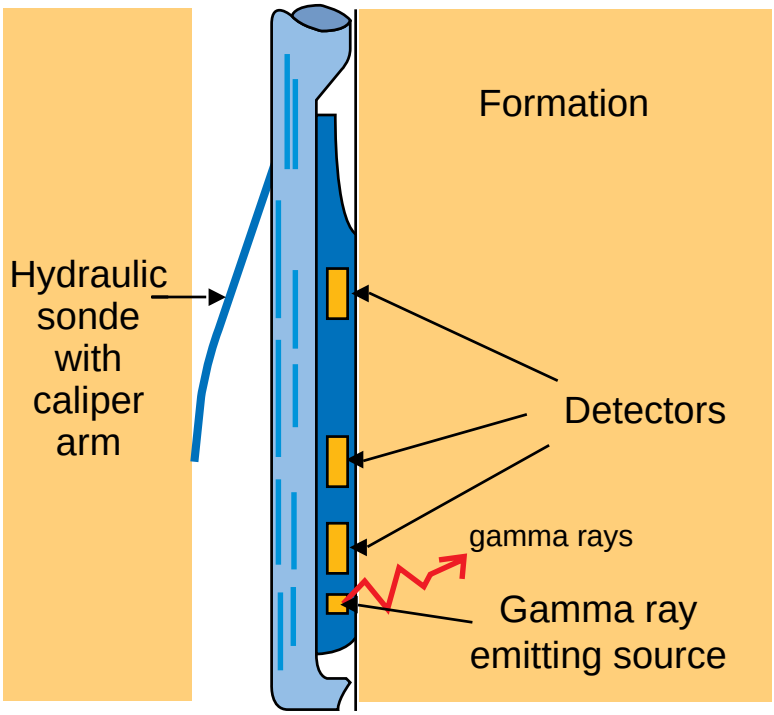

Figure 2.3. Schematic diagram of TLD-type density logging system.

2.1.4 Natural Gamma Ray Spectroscopy (NGS) Tool

The NGS tool is a passive gamma ray measuring sonde that can be used in either open or cased boreholes. The tool measures the natural gamma activity energy spectrum with two sodium-iodide crystal

detectors and uses a spectral weighted-least squares processing algorithm to resolve the three most common components of naturally occurring radiation—potassium, thorium, and uranium. The tool is designed for continuous logging and provides a depth/time averaged continuous log of the three elemental components in relative wt%. In addition, the standard gamma ray and gamma ray minus uranium are computed. The spectral gamma measurements are useful for evaluating clay content and clay type, especially when integrated with other types of log measurements.

Basic specifications for the NGS and a schematic diagram of the measurement sensor are shown below and in Figure 2.4, respectively.

Range of measurement:	GR	0 to >750 API units;
	K	0 to ~50%;
	Th	0 to ~10,000 ppm;
	U	0 to ~10,000 ppm
Statistical precision (σ):	Th–1.5 ppm; U–0.9 ppm; K–0.25%	
Min./Max. hole size:	4.5 in. / 24 in.	
Depth of Investigation:	9.5 in (24 cm)	

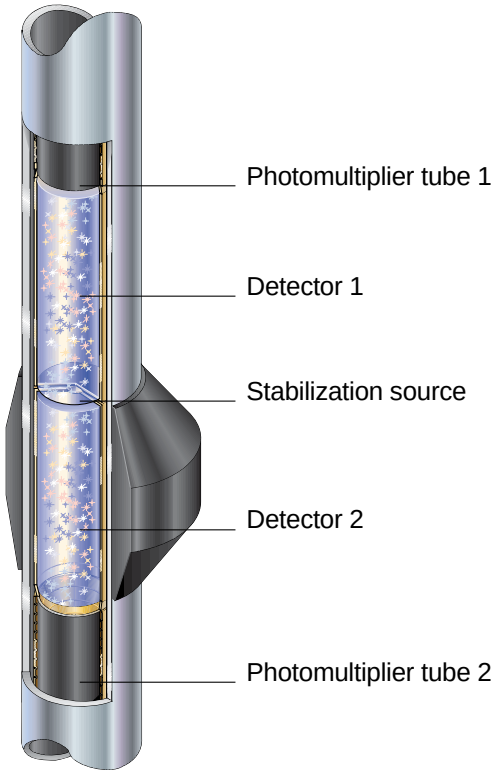

Figure 2.4. Schematic diagram of NGS sensor

2.1.5 Elemental Capture Spectrometer (ECS)

The ECS geophysical logging tool provides accurate measurements of the relative weight % concentrations of specific elements in the formation (such as Si, Ca, Fe, S, Ti, and Gd). The measurements have sensitivities as low as 1% dry weight concentration or less (dependent on which element and the logging speed).

The ECS actively emits a large flux of neutrons into the region surrounding the probe using a 16-Ci Americium-Beryllium chemical neutron source. The neutrons collide and interact with atomic nuclei, prompting the release of gamma rays having characteristic energies, depending on the specific element and type of interaction. These induced gamma rays are measured by the tool's scintillation gamma ray detector, resulting in a total gamma energy spectrum measurement when the sum of gamma rays generated from all neutron-element interactions is considered. A weighted least squares algorithm is used to decompose the gamma ray contributions from specific elements based on a known detector

spectral response, or standard, for each important constituent. The relative spectral contribution of the elements, or relative elemental yields, are converted to relative elemental dry weight % based on measurement characteristics of the tool type and an assumed mineralogical assemblage (oxide closure model).

The ECS employs a large shielded BGO spectral gamma ray detector that has very good measurement statistics. Because of the large detector, the ECS has a 5 in (127 mm) diameter.

The ECS works in either open or cased hole, and is relatively insensitive to borehole conditions, since the measurement is a dry matrix measurement (fluid contributions to the measurement are removed in the standard processing) and the radius of investigation is about 1 ft (30 cm). Thus, the ECS provides robust direct concentration measurements of important mineral-forming elements and provides robust mineralogical/lithologic control, very useful for developing a continuous mineralogy model along the borehole section when integrated with other wireline logs and core analysis results.

The statistical precision of the ECS measurement, for the standard suite of elements it measures, is shown in Table 2.2.

Table 2.2
ECS elemental weight % statistical precision at 100 ft/hr (30 m/hr) logging speed and 1.5 ft (0.46 m) depth average

Element	Weight % Precision (1 σ)
Si	0.63
Fe	0.07
S	0.27
Ca	0.57
Ti	0.03
Gd (ppm)	0.65
H	0.12

2.1.6 Array Induction Tool, Version H (AITH)

The AITH is a focused electrical induction probe that measures electrical conductivity/resistivity at multiple depths of investigation and vertical resolutions. The measurement is made by emitting an electromagnetic field that induces a current in the formation, subsequently creating a secondary electromagnetic field that is measured by the tool. The tool measures R- and X-signals from eight arrays, six of which operate at two frequencies simultaneously. The surface acquisition unit processes these raw measurements into five resistivity logs in real-time, each with matched vertical resolution and with median depths of investigation ranging from 10 to 90 in (25–230 cm). These depths of investigation change minimally over the entire range of formation conductivities. Each set of five logs is available in vertical resolution widths of 4, 2, and 1 ft (120, 60 and 30.5 cm).

From these measurements the AITH provides quantitative estimates of the following.

- True bulk formation resistivity–Formation resistivity is a function of water content, water salinity, and clay content.
- Drilling fluid invasion–In instances where the borehole fluid and formation fluid possess contrasting conductivity values, the depth of invasion of filtrate can be mapped and the zones with higher permeability can be identified.

The results are also useful for stratigraphic correlation. Vertical resolutions down to 1 ft (30.5 cm) show laminations and other formation structures with minimal environmental effects.

Since a current is not directly emitted into the formation, the measurement does not require water in the borehole and is accurate in the sub-saturated zone above the water table.

The AITH is largely insensitive to borehole environmental conditions since it has a deep depth of investigation.

Basic measurement specifications for the AITH are shown below and a schematic diagram of the basic tool setup in Figure 2.5.

Range of measurement:	0.2–2000 Ohm.m
Total measurement error:	2% of measurement
Min/Max. hole size:	4.75 in./20 in.
Vertical Resolution:	1 ft (30.5 cm), 2 ft (61 cm), 4 ft (122 cm)
Depth of Investigation:	10, 20, 30, 60 and 90 in. (median response) (25, 51, 76, 153, and 229 cm)

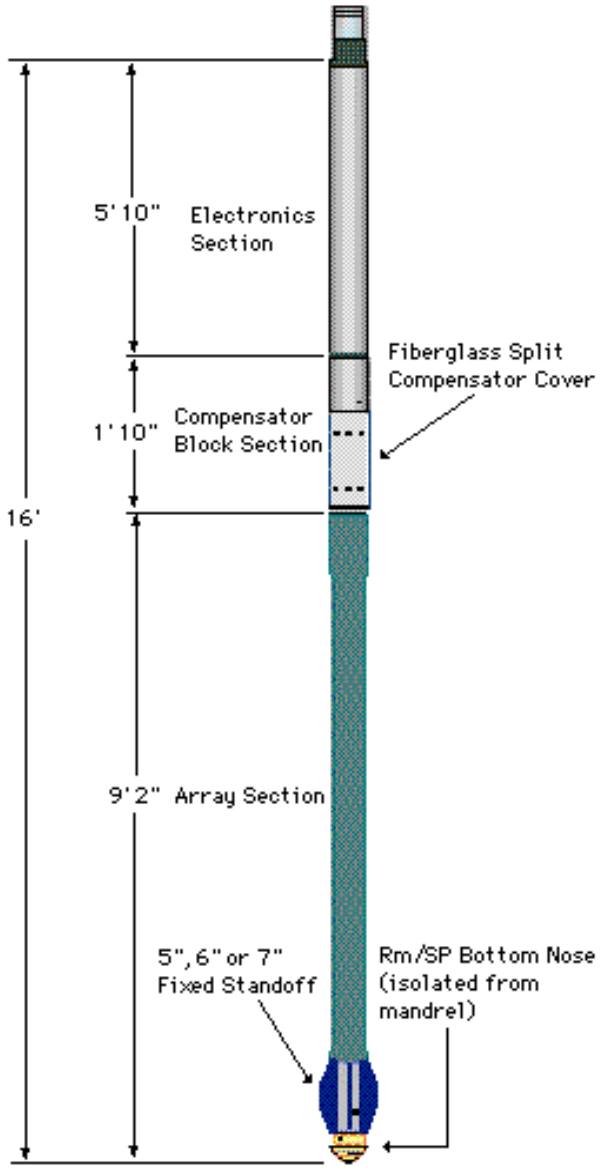

Figure 2.5. Schematic diagram of AIT tool, showing component lengths and standard logging setup.

3.0 METHODOLOGY

This section describes the methods employed by Schlumberger for performed geophysical logging services in Well R-23, including the following stages/tasks:

- Measurement acquisition at the well site
- Quality assessment of logs

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- Reprocessing of field data

3.1 Acquisition procedure

Once the well drilling project team notified Schlumberger that each well was ready for geophysical well logging, the Schlumberger district in Farmington, NM, mobilized a wireline logging truck, the appropriate wireline logging tools and associated equipment, and crew to the job site. Upon arriving at the LANL site, the crew completed site entry paperwork and received site-specific safety training.

After arriving at the well site, the crew proceeded to rig up the wireline logging system, including

1. parking and stabilizing the logging truck in a position relative to the borehole that is best for performing the surveys;
2. performing any required environmental protection procedures (e.g., covering the ground with plastic liner, where the tools will be assembled, and around the well) as specified in the work order;
3. setting up a lower and an upper sheave wheel (the latter attached to, and hanging above, the borehole from the drilling rig/mast truck);
4. threading the wireline cable through the sheaves; and
5. attaching the appropriate sonde(s) for the first run to the end of the cable.

Next, pre-logging checks and any required calibrations were performed on the logging sondes and the tool string was lowered into the borehole. If any of the tools required active radioactive sources (in this case a neutron and gamma source for the CNTG/ECS and TLD, respectively) just prior to lowering the tool string, the sources were taken out of their carrying shields and placed in the appropriate tool source-holding locations using special source handling tools. The tool string was lowered to the bottom of the borehole and brought up at the appropriate logging speed as measurements were made. At least two logging runs (one main and one repeat) were made with each tool string.

Upon reaching the surface any radioactive sources were removed from the tools and returned to their appropriate storage shields, thus eliminating any radiation hazards. The tool string was cleaned as it was pulled out of the hole.

The second tool string was attached to the cable for another suite of logging runs.

After completion of the surveys, any post-logging measurement checks were performed. Before departure, the engineer printed the field logs (including calibration summaries) for on site distribution and sent the data via satellite to the Schlumberger data archiving center in Sedalia, CO. The Schlumberger data processing center was alerted that the data were ready for initial post-acquisition processing.

3.2 Log Quality Control and Assessment

Schlumberger has a thorough set of procedures and protocols for ensuring that the geophysical logging measurements are of very high quality. This includes careful calibration of tools when they are first built, regular recalibrations and tool measurement/maintenance checks, and real-time monitoring of log quality as measurements are made. Indeed, one of the primary responsibilities of the logging engineer is to ensure, before and during acquisition, that the log measurements meet prescribed quality criteria.

CNTG

The calibration and verification methodology for the CNTG consists of an initial base calibration and verification, monthly shop verification, and a wellsite before and after verification. The initial base calibration constitutes the development of a measurement to moisture content algorithm for a certain set of environmental conditions. The calibration is based on Monte Carlo computer modeling and measurements in the Schlumberger EECF calibration models in Houston, TX. This initial base calibration only has to be performed once for a certain set of conditions.

Schlumberger also performs what is called a “master calibration,” which is actually a verification of water-filled borehole conditions where the CNTG measurements are checked in a water tank with known saturated porosity. In addition, detector and neutron generator electronics are checked, and detector plateau voltages are set.

Detector electronics verifications are also performed before and after every logging run of the CNTG, constituting the well site before and after verifications.

NGS

The Schlumberger calibration and verification methodology for the NGS, similar to the CNTG, consists of an initial base calibration and verification, routine shop verification, and a wellsite before and after verification. The initial base calibration constitutes the development of measurement to gross gamma activity and spectral gamma activity algorithms, accounting for environmental conditions that influence the measurements. The initial base calibration only has to be performed once for a certain set of conditions.

The NGS gross gamma measurement in API units is made by taking a linear combination of U, Th, and K gamma activity yields to determine total count rates and then converting total count rates to API units. The coefficients of the linear combination and the API conversion are determined from the NGS response in the API test pits at the University of Houston (the API calibration standard) and calibration facilities at the Schlumberger Environmental Effects Calibration Facility (EECF) in Houston, which are tied to the API test pits.

In order to calibrate the spectral gamma activity measurements the response function of the NGS to each radioactive isotope of interest must be determined. The response function is the spectrum that would be observed by the tool for a given detector resolution and gain if just the one element were present and evenly distributed in the formation in a certain concentration. Such a spectrum is called a spectral standard. For natural gamma ray logging Th, U and K standards are used. Test formations with known concentrations of radionuclides at the API test pits and EECF are used to determine the NGS spectral standards.

The routine shop verification, referred to as a “master calibration” by Schlumberger, consists of measuring the NGS response to a thorium blanket with known Th activity and a background check. During the background check the detector response to an internal 22Na stabilization source is measured. In addition, detector electronics checks are performed. The primary task of the shop verification is to set the electronic gain ratios properly so that the Th and 22Na gamma peaks occur at the correct energy levels.

NGS response to the stabilization source and detector electronics verifications are also performed before and after every logging run of the NGS, constituting the wellsite before and after verifications.

ECS

The Schlumberger calibration and verification methodology for the ECS, similar to the NGS, consists of an initial base calibration and verification, routine shop verification, and a well site before and after verification. The initial base calibration constitutes the development of gamma ray energy elemental spectral standards for each of the elements the tool measures, accounting for environmental and tool design-specific conditions that influence the measurements. The initial base calibration only has to be performed once for all ECS tools produced to develop a tool response catalog for individual elements that the ECS is sensitive to.

The routine shop verification consists of taking measurements in a specially designed water tank to verify correct identification of the spectral hydrogen peak and performing detector electronic gain checks using the small cesium internal check source.

Well site before and after checks consist of background internal electronic checks.

TLD

Similar to the CNTG and NGS, the calibration and verification methodology for the TLD consists of an initial base calibration and verification, monthly shop verification, and a well site before and after verification. The initial base calibration constitutes the development of a measurement to bulk density algorithm for a certain set of environmental conditions. The calibration is based on Monte Carlo computer modeling and measurements in the Schlumberger EECF calibration models. This initial base calibration only has to be performed once for a certain set of conditions.

The routine shop verification consists of checking the TLD bulk density measurement for uncased borehole conditions by making the measurement in materials with known densities. In addition, a background check with the gamma source removed from the tool is performed to verify that the system response to the 622 keV ^{137}Cs stabilization source located on each of the two detectors is accurate.

The background check is also performed before and after every logging run of the TLD, constituting the well site before and after verifications.

AITH

The Schlumberger calibration and verification methodology for the AITH consists of an initial base calibration and verification, routine shop verification, and a well site before and after electronics verification. The initial base calibration constitutes the determination of electronic gains and offsets and hardware adjustments for each individual tool so that the tool electrical induction response can be used to generate accurate electrical resistivity measurements. The initial base calibration has to be performed only once for all AITH tools produced to develop a tool specific response catalog for electronic gains and offsets.

The routine shop verification consists of taking measurements with specially designed calibration sleeves to verify correct measurement response as well as internal electronic gain checks.

Well site before and after checks consist of internal electronic checks.

CMR

After an initial base calibration and intensive measurement and electronic system checks performed at the time of tool production, the CMR calibration and verification methodology consists of a routine shop (or master) calibration and well site before and after survey calibration/verification.

The shop calibration consists of a one-point calibration in which the signal amplitude at 100% water-filled porosity is found by placing a calibration jig filled with water in front of the tool sensor section. In addition, an electronic calibration of system gain is performed using an internal test loop located on the tool's antenna. The measured amplitude and electronic gain are saved as a lookup table in the internal memory of the individual CMR tool to be used when logging in the field for the calculation of CMR porosities.

The well site before survey calibration covers two procedures for tuning the sensor antenna to the magnetic resonance frequency of water (known as the Larmor Frequency), performed at the surface and downhole in the vicinity of the logging interval. This tuning procedure compensates the sensor response for the well specific effects of pressure, temperature, and metallic debris in the hole. In addition, a check of system noise is made.

At the completion of the CMR logging, one of the tuning procedures is repeated: the system search for the Larmor Frequency to verify that the log was run "in tune." This procedure constitutes the well site after survey verification.

3.3 Processing Procedure

After the geophysical logging job was completed in the field and the data archived, the data were downloaded to the Schlumberger processing center. There the data were processed, in the stated order to (1) correct the measurements for near-wellbore environmental conditions and redo the raw measurement field processing for certain tools using better processing algorithms, (2) depth match and merge the log curves from different logging runs, and (3) model the near-wellbore substrate lithology/mineralogy and pore fluids through integrated log analysis. Afterwards an integrated log montage was built to combine and compile all the processed log results.

Environmental Corrections and Raw Measurement Reprocessing

If required, the field log measurements were processed to correct for conditions in the well, including fluid type (water or air), presence of steel casing, and (to a much lesser extent) pressure and temperature. Basically these environmental corrections entail subtracting from the measurement response the known influences of the set of prescribed borehole conditions. In R-23 the log measurements requiring these corrections are the CNTG porosity, TLD density, ECS elemental concentrations, and NGS spectral gamma ray logs.

The CNTG epithermal neutron moisture content measurement in air-filled hole is derived using an entirely different processing algorithm than applied in water-filled hole; this processing is performed in the field. In R-23 the CNTG thermal neutron porosity could not be used since it requires water in the well.

The standard open hole processing algorithm used for the TLD density measurement is influenced by the steel density in cased hole. A cased hole density algorithm was applied to the raw TLD field measurements to try to eliminate the casing response. While the algorithm can account for the casing per

say, it cannot account for air- or water-filled gaps in the annulus between the casing and the formation—that cause erroneously low bulk density readings.

The raw ECS elemental yield measurements include the contribution of iron from steel casing and hydrogen from fluid in the borehole. The processing consists of subtracting these unwanted contributions from the raw normalized yields, then performing the normal elemental yields-to-weight fraction processing. The contribution to subtract is a constant baseline amount (or zoned constant values if there are bit/casing size changes), usually determined by comparing the normalized raw yields in zones directly below/above the borehole fluid/casing change. In R-23 there was no water in the borehole so no hydrogen correction was required. The iron baseline subtraction was determined by comparing the zoned after-subtraction processed iron weight fraction from above the bottom casing depth (599 ft) with the no-subtraction processed iron fraction below, adjusting the subtraction and reprocessing until a reasonable match is obtained. The validity of this procedure is dependent on the assumption that the formation iron content is constant directly above and below the bottom of the casing and that casing material is consistent throughout the cased section (e.g. there is not second string of casing behind the first further up the hole). The primary consequence of uncertainty in this baseline subtraction is possible errors in the mineralogy result of the integrated log analysis, particularly in regards to the presence and amount of iron-bearing minerals.

The NGS spectral gamma ray are affected by the material (fluid, air, casing) in the borehole because different types and amounts of these materials have different gamma ray shielding properties; the NGS measures incoming gamma rays emitted by radioactive elements in the formation surrounding the borehole. The processing algorithms try to correct for the damping influence (or lack thereof) of the borehole material.

The measurements cannot be corrected for borehole washouts, rugosity, and the annulus material (if any) between casing and the formation since the specific characteristics of these features (e.g., geometry) are unknown and their effects on the measurements too complex to account for. Thus, the compromising effects of these conditions on the measurements should be accounted for in the interpretation of the log results.

Depth-Matching

Once the logs were environmentally corrected for the conditions in the wellbore and the raw measurement reprocessing was completed, the logs from different logging runs were depth-matched to each other using the AIT tool run as the base reference. Gamma ray was used as the common correlation log measurement for depth-matching the different runs.

Integrated Log Analysis

This analysis was performed using the Elemental Log Analysis (ELAN*) program. ELAN is a petrophysical interpretation program (Mayer and Sibbit, 1980; Quieren et al, 1986) designed for quantitative formation evaluation of cased and open-hole logs level by level. Evaluation is done by optimizing simultaneous equations described by one or more interpretation models.

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The primary purpose of ELAN is solving the inverse problem in which log measurements, or tools, and response parameters are used together in response equations to compute volumetric results for formation components. This relationship is often presented in the triangular diagram below (Figure 3.1).

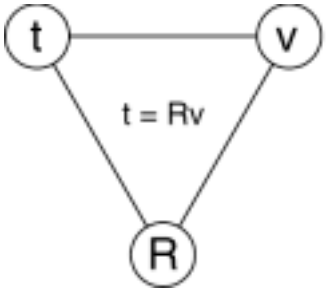

Figure 3.1. Schematic diagram of ELAN mathematical model

In this figure, t represents the tool vector—all logging instrument data and synthetic curves. The v is the volume vector, the volumes of formation components. R is the response matrix, containing the parameter values for what each tool would read, given 100% of each formation component. Given the data represented by any two corners of the triangle, ELAN can determine the third.

Additionally, ELAN includes methods by which individual models can be mixed and spliced to provide a combined model for more complex environments and large borehole extents. Each individual model is specified in a separate “Solve” process. The final result is produced by mixing and splicing the results from individual models in a “Combine” process.

The quality of the ELAN results can be assessed by reconstructing the individual geophysical logging curves from the solution and comparing them to the original data. However, a “good” fit does not necessarily mean the correct ELAN, as the answer is non-unique. The degree of match between input and output curves is summarized as an error curve.

ELAN requires an a priori specification of the volume components present within the formation—fluids, minerals, and rocks. For each component, the relevant parameters for each tool are also required. For example, if one assumes that quartz is a volume component and the bulk density tool is used, then the bulk density parameter for this mineral is usually assumed to be 2.65 g/cc.

A key point in properly using ELAN is the input of the most representative parameter values possible. For certain minerals (e.g., quartz) most parameter values are fairly constant and easy to select; other mineral (e.g., clays) present the potential for wide variability in many parameters due to compaction (sonic slowness, bulk density) and minor changes in chemistry (Th, K, Fe, Al, H). Estimation of parameters, or their changes with depth, can be a major limitation to ELAN. Geochemical logs (acquired in R-23) are particularly helpful measurements for ELAN since they provide abundances of a number of important mineral forming elements.

ELAN simultaneously solves for multiple volume components using different tools. Some tools are highly influenced by parameters other than mineralogy and pore fluid (e.g., sonic), including geomechanical properties and borehole environmental conditions that cannot be corrected for in pre-processing. The dependency of the tool measurements on these conditions depends on the specific tool type and measurement. Including log measurements that are being highly influenced by these properties in the ELAN can significantly affect the solution, since variations in the logs are not only due to changes in mineralogy or pore fluid—what ELAN is trying to estimate. For example, if some of the logs are sensitive

to washouts ELAN will try to match the log response in washed out zones by increasing the amount of porosity in the model, possibly at the expense of matching other log measurements used in the analysis that are not as sensitive to washouts (although the latter can be rectified by assigning more weight to the better logs). If some of the logs are affected by borehole conditions, or other properties not explicitly accounted for in the model (e.g. formation water salinity), while the others are not, often there is a poor match between modeled and actual log measurements in intervals where there are variations in these unaccounted for properties. Sometimes the solution can also become unstable—the model results change significantly due to only minor variations in log responses. In such cases it may be better to not include such measurements in the ELAN. In short, ELAN results are only as accurate at depicting true formation mineralogy and fluid content as the input logs are sensitive to the formation components included in the model—and insensitive to components/properties not included.

The tool measurements, volume components and parameters used in the ELAN analysis for R-23 are provided in Table 3.1. To make best use of all the measurement data and to perform the analysis across as much of the well interval as possible (19–832 ft), as many as possible of the processed logs were included in the analysis, with less weighting applied to less robust logs. Not all the tool measurements shown in these tables are used for the entire interval analyzed, as not all the measurements are available, or of good quality, across certain sections of the borehole. For example, in the cased hole section CMR porosity, AITH resistivity, and TLD volumetric photoelectric effect have to be removed from the analysis since they are invalid in casing. To accommodate fewer tool measurements certain model constituents are removed from the analysis in some intervals. Most notably, only a few minerals are retained in the model above 46 ft, where there is no ECS geochemical measurements.

The ELAN analysis was performed with as few constraints or prior assumptions as possible. A considerable effort was made to choose a set of minerals or mineral types for the model that is representative of Los Alamos area's geology and it's volcanic origins. No prior assumption is made about water saturation—where the boundary between saturated (if any) and unsaturated zones lies (e.g. the depth to the top of the regional aquifer or perched zones). Thus, the presence and amount of air in the pore space is unconstrained. Total porosity and water-filled porosity are also left unconstrained throughout the analysis interval. There are zones within the cased hole section where bulk density is very low and/or neutron porosity is very high—likely due to air- and/or water-filled voids behind the casing—resulting in high, physically unlikely, air- and/or water-filled porosity in the ELAN solution. (The bulk density and neutron porosity drive the ELAN total porosity and water-filled porosity, respectively, since bulk density is the only measurement directly sensitive to total porosity, while neutron porosity is the most sensitive measurement to water-filled porosity.) It was felt that the ELAN analysis should be performed with as few constraints as possible—even though the resulting model shows the effects of washouts, drilling foam invasion, and annular voids behind the casing (as elevated porosity and water content)—in order to guard against presumptions that the results are conclusive when in fact they may not be. Thus, interpretations should be made from the ELAN results with the understanding that the mineral-fluid model represents a mathematically optimized solution that is not necessarily a physically accurate representation of the native geologic formation. Within this context, the ELAN model is a robust estimate of the bulk mineral-fluid composition that accounts for the combined response from all the geophysical measurements.

Table 3.1
Tool measurements, volumes, and respective parameters used in the R-23 ELAN analysis .

Volume / Tool Measurement	Air	Capillary Bound Water	Water	Hornblende	Hypersthene	Labradorite	Silica Glass	Heavy Mafic Minerals	Augite	Montmorillinite	Pyrite	Orthoclase	Quartz
Bulk density (g/cc)	–0.19	1.00	1.00	3.11	3.55	2.65	2.2	4.0	3.08	2.02	4.99	2.58	2.64
Epithermal neutron porosity (ft^3/ ft^3)	-0.02	1.00	1.00	0.05	0.01	-0.01	0.0	0.02	-0.01	0.6	0.17	-0.01	0.0
Volumetric photoelectric effect	0	0	0.40	12	20.2	7	4.2	65.00	23.8	4.4	82.1	7.3	4.8
Total CMR water-filled porosity (ft^3/ ft^3)	0	1.0	1.0	0	0	0	0	0	0	0.425	0	0	0
CMR free fluid volume (ft^3/ ft^3)	0	0	1.0	0	0	0	0	0	0	0	0	0	0
Resistivity (ohm-m)	Very high	30	30	Very high	Very high	Very high	Very high	Very high	Very high	1.04	Very high	Very high	Very high
Dry weight silicon (lbf / lbf)	0.0	0.0	0.0	0.21	0.24	0.24	0.47	0.18	0.23	0.26	0	0.3	0.47
Dry weight calcium (lbf / lbf)	0.0	0.0	0.0	0.09	0.0	0.09	0.0	0.0	0.10	0.01	0.0	0.0	0.0
Dry weight iron (lbf / lbf)	0.0	0.0	0.0	0.07	0.20	0.0	0.0	0.22	0.11	0.02	0.47	0.0	0.0
Dry weight sulfur (lbf / lbf)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.53	0.0	0.0
Dry weight titanium (lbf / lbf)	0.0	0.0	0.0	0.005	0.01	0.0	0.0	0.0	0.048	0.0	0.0	0.0	0.0
Wet weight potassium (lbf / lbf)	0.0	0.0	0.0	0.01	0.0	0.0	0.0	0.0	0.003	0.005	0.0	0.102	0.0
Weight water (lbf / lbf)	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.18	0.0	0.0	0.0
Wet weight thorium (ppm)	0.0	0.0	0.0	50	25	3	2	4	20	24	0	5.5	2
Clay bound water volume (ft^3/ ft^3)	0	0	0	0	0	0	0	0	0	0.425	0	0	0

4.0 RESULTS

This section describes the final log results from the borehole geophysical logging performed by Schlumberger in R-23. These results have been processed, if required, to correct for the well environment and depth-match the logs from different tool runs in the well. Also, some of the results are not directly measured logs but are instead logs generated from integrated analysis of measured logs. In the following description of the results, an attempt is made to organize the discussion based on the evaluation needs addressed by the logs instead of describing each log independently.

The log results are presented as continuous curves of the processed measurement versus depth and are displayed as (1) summary log displays for selected directly related sets of measurements and (2) an integrated log montage that contains all the final log curves, on depth and side by side. The summary log displays address specific characterization needs, such as moisture content. The purpose of the integrated log montage is to present, side by side, all the most salient reprocessed logs and log-derived models, depth-matched to each other, so that correlations and relationships between the logs can be identified.

First the R-23 final processed log results are presented as a number of useful summary logs and described according to specific evaluation needs addressed by the geophysical logs. Next, the integrated log montage is described track by track.

4.1 Water-Filled Porosity

One of the primary objectives of the geophysical logging was to evaluate volumetric water content (water-filled porosity) to identify wet and porous water-producing zones. The CNTG neutron porosity, which measures water content in both open and cased hole above and below the borehole water level, was the primary service run for this purpose. The CMR was run to measure the water-filled pore size distribution and, most importantly, the amount of moveable water (effective water-filled porosity), which, in turn, provides valuable information on formation flow capacity (hydraulic conductivity). The TLD bulk density measurement provides useful information about total porosity—the sum of water-filled and air-filled porosity. The ECS geochemical measurement provides secondary information on water content through non-standard processing to obtain hydrogen weight fraction.

In Well R-23 the CNTG neutron porosity and the ECS hydrogen weight fraction are adversely impacted by fluid-filled voids behind the free-standing casing that was present above 599 ft at the time of logging—yielding unrealistically high water content values across many intervals. The ECS hydrogen weight fraction appears to be somewhat less impacted by the casing annulus than the CNTG; the ECS-derived water content estimate is considerably lower with fewer abrupt peaks above 400 ft, although it mimics the CNTG below. The better formation water content results of the ECS is possibly due to a deeper depth of investigation and less sensitivity to drilling fluid additives, such as bentonite mud, possibly present in the annulus. In the open hole section (below 599 ft) the CNTG neutron porosity and ECS hydrogen weight fraction measure higher water-filled porosity than the CMR, although the trends are generally the same. It is possible that the very shallow-reading CMR measurement is being affected by the desiccation of the near wellbore formation from invasion of drilling air/foam; conversely, it is possible the CNTG and ECS measurements are affected by moist drilling foam filling the borehole (if present) that cannot be corrected for. While standing water in the borehole has a large affect on the CNTG and ECS measurements, it is easily corrected for. The problem with the drilling foam is that it varies somewhere between air and water with regards to how the measurements respond and, thus, cannot be quantitatively corrected for. The CMR and TLD measurements are much less impacted by the foam filling the borehole because they are

pad type tools that are pushed against the formation; however, they are shallow reading measurements and could be affected by invasion of the foam—whether it acts to wet or dry the near wellbore formation.

The measurements cannot be corrected for the effects of enlarged casing-to-formation annulus resulting from borehole washouts and rugosity (causing an increased borehole fluid response), since the specific characteristics of the annular voids (e.g., geometry) are unknown and their effects on the measurements too complex to account for. Thus, it should be understood that the porosity measurements are highly influenced by borehole diameter variations, especially when there are large washouts behind the casing that are filled with drilling mud or water.

The best estimate of true water content is obtained from the ELAN integrated log analysis, since none of these measurements actually directly measures volumetric water content. This analysis accounts for the individual measurement response to each matrix and pore volume constituent, as well as the relative uncertainty in the measurements, in solving for a single matrix-pore volume model at each depth that best accounts for the processed measurements results.

The ELAN water-filled porosity results for R-23 are shown as part of the summary logs in Figure 4.1 (solid dark blue curve and blue shading in the second track from the right), and in expanded form, as part of the integrated log montage provided in Appendix E of the LANL R-23 Well Completion Report (compressed form shown in Figure 4.4). The summary log also displays

- ELAN moveable water volume fraction, or “effective porosity” (solid cyan curve and cyan shading in second track from right);
- ELAN bound water volume fraction (dotted blue shading in second track from right);
- ELAN total (water- and air-filled) porosity (red hashed curve in second track from right);
- Air-filled porosity (dotted red shading in second track from right);
- ELAN water saturation (dotted light blue curve in second track from right);
- CMR estimated tapered Timur-Coates equation hydraulic conductivity (solid blue curve and blue shading in first track from right);
- Gross gamma ray (solid brown curve in first track from left); and
- Caliper with measured washouts (dashed black curve with washouts shown by pink shading).

There was no standing water in R-23 at the time of the November 2001 geophysical logging. There is significant uncertainty in defining where true 100% saturation of the virgin geologic formation occurs from the geophysical logs (corresponding to conditions within the regional aquifer or in perched zones above, where the entire pore space is filled with water)—due to the unknown effects of the drilling foam and introduced water on the formation directly adjacent to the borehole and, ultimately, on the log measurements. In addition, the borehole has some significant washouts and hole rugosity, which can adversely affect the log measurements by elevating their response to the fluid/air filling the washouts. In particular, the measurements are detrimentally affected by the existence of an annulus and voids between the free-standing casing and borehole wall (resulting in elevated water content and water saturation if the annulus is filled with water or drilling fluid, and lowered water content/saturation if filled with air). Even without such borehole conditions, the water saturation estimate from the geophysical logs is very sensitive to the matrix grain density.

Despite these measurement and water saturation processing difficulties, the ELAN integrated log analysis results do not show indications of full saturation in the bottom, open hole section of the log interval (599–824 ft), with estimated water saturation values mostly below 75% and no substantial zones containing

100% saturation. The highest estimated water saturations of the entire log interval occur in the bottom 150 ft of the cased hole section and extending slightly into the open hole section (450–620 ft), including 100% water saturation in the zones 468–502 ft, 524–552 ft, 586–606 ft, and 617–620 ft. This interval is characterized by highly variable total porosity, ranging from 8% at 620 ft to 90% at 474 ft; the higher porosity zones likely correspond to water-filled washouts behind the casing—probably where total porosity is greater than 30%. There is an extremely tight zone from 589–620 ft, containing mafic materials and clay (from the ELAN results) that may act as a barrier to downward flow, allowing water or drilling fluid to accumulate above.

Other significant features of the R-23 porosity summary log are as follows:

- Zones with estimated water content of 30% or greater by volume:
  - 19–40 ft and 45–47 ft with a peak of 60%, located at the top of the logged interval, likely corresponding to introduced bentonite annular fill and/or drilling fluid behind the casing
  - 55–71 ft with a peak of 57% and estimated water saturation reaching 100%, possibly corresponding to introduced bentonite material and/or drilling fluid behind the casing
  - 404–408 ft with a peak of 32%, coincident with an increase in estimated water saturation to 85%
  - 467–494 ft with a peak of 90% and estimated water saturation reaching 100%, assuredly associated with a large water-filled washout behind the casing
  - 523–552 ft with a peak of 55% and estimated water saturation reaching 100%, likely associated with water-filled washout behind the casing
- Below the casing bottom (599 ft), where the log measurements are likely representative of true formation conditions throughout, the highest estimated water content occurs in the zones 624–680 ft (maximum of 22%) and 760–800 ft (maximum of 20%). The remainder of the open hole interval (bottom depth 824 ft) contains generally less than 12% water content.
- The highest measured moveable water content (only measurable in open hole below 599 ft) and, thus, estimated hydraulic conductivity, occurs in the interval 676–732 ft, with a peak of 4% of total volume at 711 ft. Overall there is little indication of moveable water (water that can flow) in the open hole section.

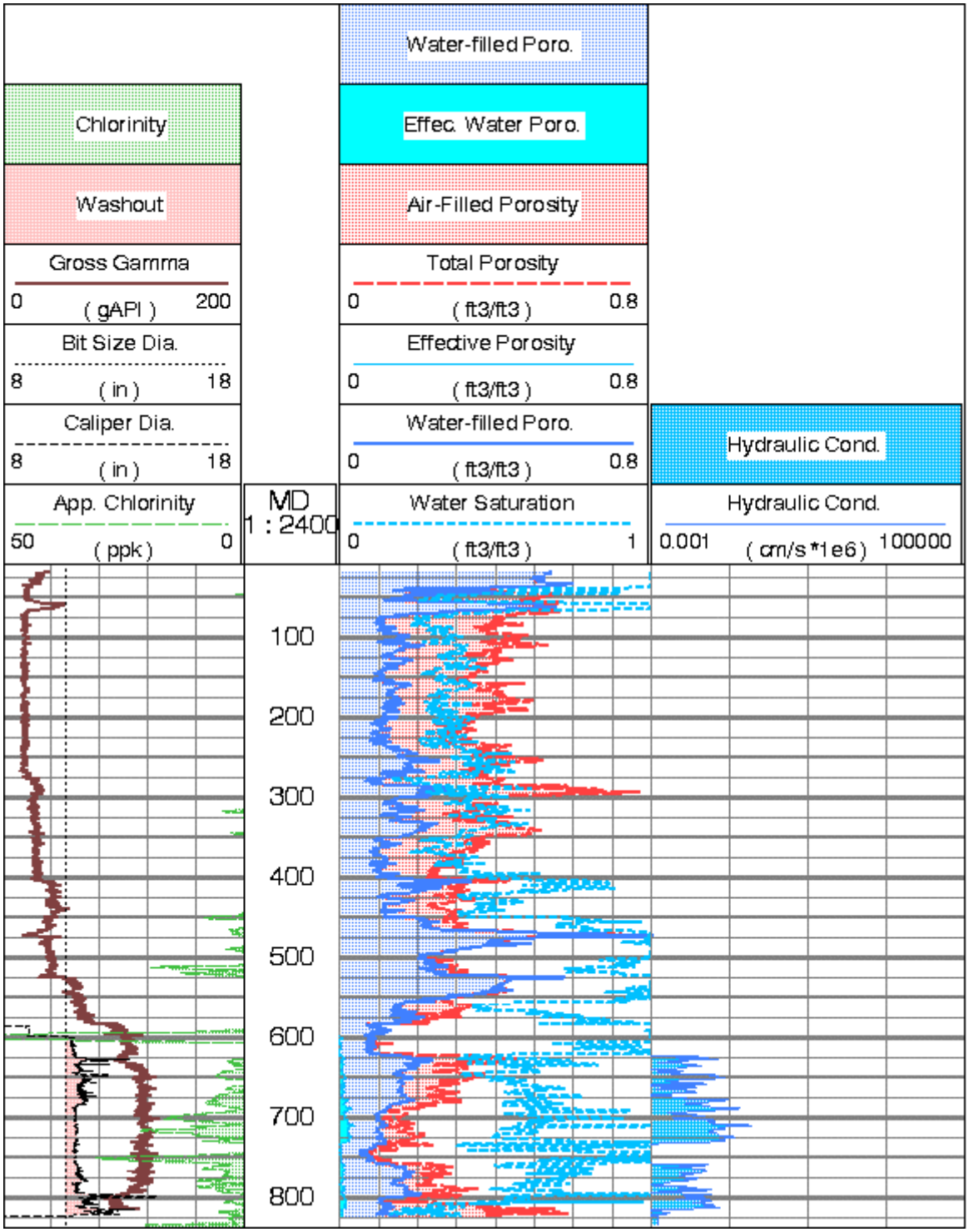

Figure 4.1. Summary porosity logs in R-23 borehole from processed geophysical logs, interval 19–824 ft, with caliper, gross gamma, apparent chlorinity, and water saturation logs. Porosity and water saturation logs are derived from the ELAN integrated log analysis.

4.2 Density

Bulk density and P_e log measurements, obtained from the TLD geophysical tool in R-23, provide information about the formation total porosity (water plus air) and lithology, respectively. The TLD measurements are typically only valid in open borehole, but there is a cased hole bulk density algorithm that has been adapted and implemented at Los Alamos. This algorithm was used in R-23 since the log interval above 599 ft contained free-standing casing at the time of logging. There is no way to rectify the P_e measurement in casing; thus, P_e could not be utilized in the cased hole section of R-23. The bulk density is the only measurement in the suite of logs run in R-23 (and most geophysical log measurements) that is directly sensitive to all formation components: air-filled porosity, water-filled porosity, and rock matrix. Total air plus water-filled porosity in the vadose zone can be estimated from density porosity when it is computed in conjunction with a water content measurement (e.g., neutron porosity, CMR total water-filled porosity) and an independent measurement/assumption of grain density. The processed bulk density curve, as well as the apparent grain density derived from the ELAN analysis, is displayed as part of the summary logs (third track from left) for R-23 in Figure 4.2. Another applicable curve in this summary log is gross gamma ray (for stratigraphic correlation), shown in the farthest left track.

The bulk density and P_e measurements have a shallow depth of investigation and, thus, the measurements can be severely affected by borehole washouts and standoff from the formation, that is, measuring borehole fluid/air density and P_e instead of the formation. The bulk density measurement is made using a focused gamma ray source and three detectors in a sensor pad that is pushed against the borehole wall with a strong caliper arm. However, with casing in the well, the pad can only be pushed as far as the inner wall of the casing and, thus, cannot mechanically compensate for any annulus between the casing and formation. In addition to employing this mechanical technique, the tool tries to compensate for differences in the near and far detector response—usually caused by pad standoff—by performing an internal processing correction, which is shown on logs as a density correction curve, flagged when it goes above/below quality cutoff thresholds. This flag is used as an indication when the TLD measurement quality may be compromised, but not necessarily if the large measurement correction properly accounts for the standoff. However, the density correction cannot be computed for cased hole. In the R-23 open hole section (599–824 ft) the density correction is flagged in only a few isolated places, generally correlating with washouts or rugose hole. The only zones where the bulk density and P_e measurements are clearly affected by washout are 626–628 ft, 632–634 ft, 798–800 ft, and 815–821 ft; in other zones the processing correction seems to be properly compensating for the borehole conditions.

The cased hole bulk density measurement in R-23 is much less robust than if the logs were run in open hole, since the casing in place at the time of logging was emplaced as freestanding pipe to support the borehole while drilling progressed. If the formation did not collapse around the casing water, drilling fluid, or air filled annulus would remain between the casing and the formation. In such a scenario the bulk density measurement, which is very sensitive to standoff from the borehole wall, would be heavily influenced by the water/air in the annulus—biasing the measurement towards the density of water (1 g/cc) or air (close to 0 g/cc). Unfortunately, there is no automatic internal processing flag to indicate when the casing-to-formation standoff is problematic to the measurement. However, there are zones in the R-23 log interval were the bulk density and total porosity (derived from bulk density) are unreasonably low and high, respectively, for natural geologic formations—indicating the likelihood of problematic standoff. Intervals where density porosity is above 60% and/or bulk density is below 1.5 g/cc are 286–299 ft and 472–476 ft. The bulk density measurement may compromised in other cased hole zones as well, but there is no way to clearly determine this.

Total porosity was computed from the ELAN integrated analysis of all the log measurements, including bulk density as a crucial input, as displayed in the first track from the right on the summary log (Figure 4.2) and the second track from the right on the integrated log montage (inclusive of the depth track). In this analysis no constraints were placed on air or water-filled porosity through the entire depth section. As can be seen on the summary logs, the ELAN total porosity mimics bulk density since bulk density is the primary measurement providing information on air-filled porosity. As mentioned above, where the bulk density measurement is of questionable quality, due to possible voids behind the casing or washouts, so is the total porosity estimate. Overall, the total porosity appears to be valid throughout much of the depth section.

The P_e measurement is a good indicator of lithologic changes. In this geologic setting, an increase in P_e above 3 is a good indicator of the presence of heavy, probably mafic, minerals; an increase to 5 is an indicator of a very heavy mineral-rich bed ("heavy" most likely corresponding to iron interval), such as a massive basalt lava flow. P_e is consistently above 3 from 626–794 ft. and close to 4 from 599–626 ft. The optimized ELAN mineral model results (see the integrated log montage, fourth track from the right) indicate that most of this section contains at least small amounts of heavy, iron-rich mafic minerals (such as magnetite and olivine), with significantly higher concentrations in the upper interval (8-10% dry weight fraction, matrix grain density of 2.8-2.9 g/cc) and less consistent, lower concentrations in the lower interval (0-8% dry weight fraction, matrix grain density of 2.6–2.75 g/cc). The dense upper section, which also contains a lot less quartz/silica glass, is probably basalt lava flow material. The lower interval contains a significant amount of quartz/silica glass (20-60% dry weight fraction) and could be a dacitic volcanic deposit. The washed out, higher porosity zones in both intervals could correspond to fractured, broken-up, and altered lava flow zones that contain small amounts of clay. The P_e measurement is not valid in the section of borehole that contained casing at the time of logging (above 599 ft).

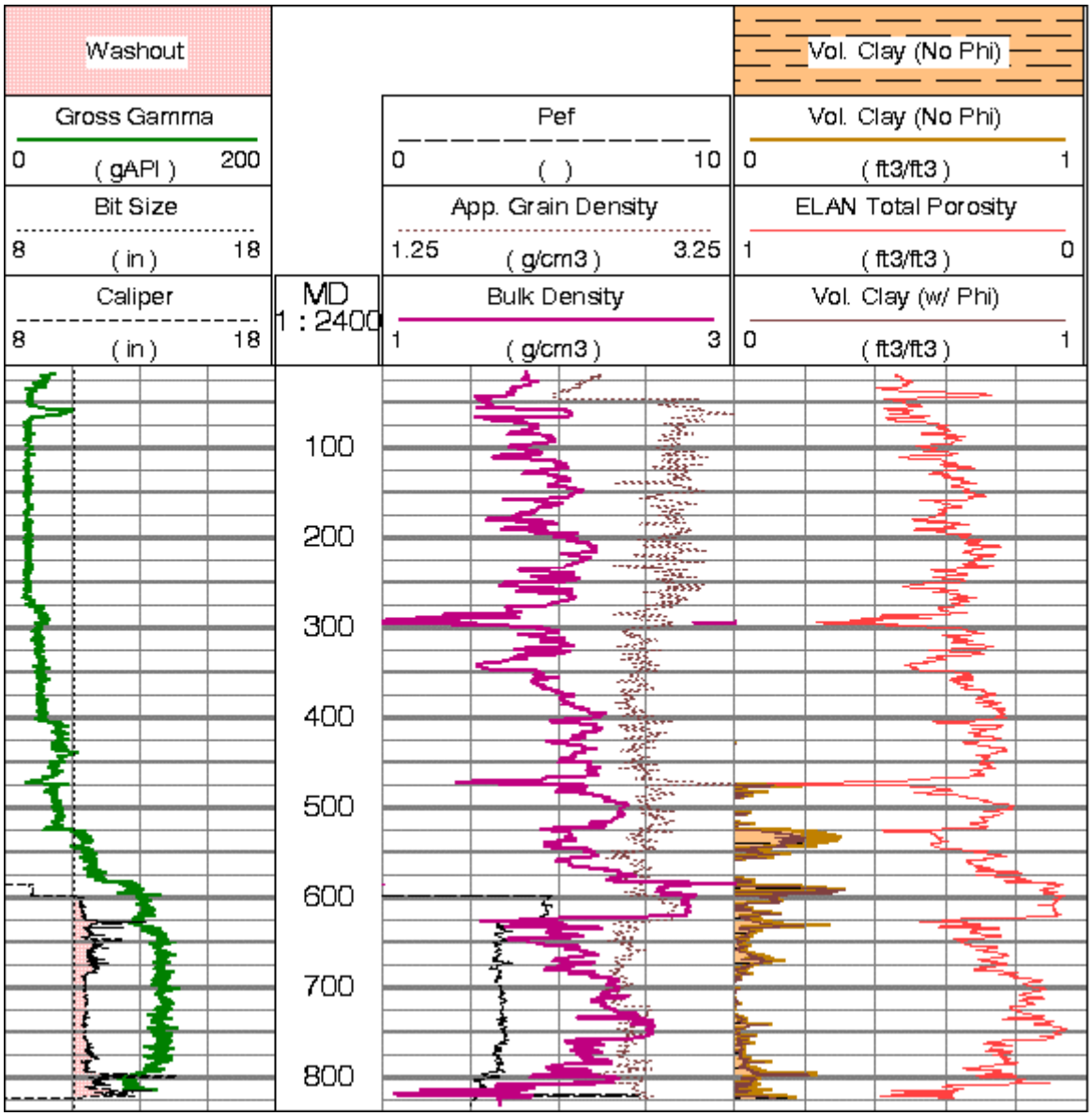

Figure 4.2. Summary bulk density and volume clay logs in R-23 borehole from processed geophysical logs, interval 22–824 ft. Also shown– caliper, gross gamma, apparent grain density, and total porosity logs.

4.3 Volume of Clay

Volume of clay is of interest particularly because clay can have a large influence on hydraulic conductivity as well as the groundwater geochemistry. Unfortunately, there is no way to directly measure volume of clay from geophysical logging. It can only be derived indirectly from other log measurements, preferably a combination of measurements. Of the logging services run in R-23, the one that provides the most

information about clay content is the NGS spectral gamma ray, since thorium and potassium are often associated with clays. However, because of the complex geologic history of the Los Alamos area, including many periods of volcanic activity, the geologic section contains numerous minerals other than clays that produce similar spectral gamma (and gross gamma) responses. This fact greatly complicates the estimate of clay volume directly from gamma ray measurements. The ECS provides important information about the collection of all minerals present since it measures the concentration of a number of important mineral-forming elements. Unfortunately, it cannot directly measure aluminum—the most important clay-forming element—although an indirect geochemical-derived estimate of aluminum can be made that is valid in siliciclastic rocks. The P_e measurement from the TLD provides additional information about bulk mineralogy, since it is sensitive to changes in the atomic number of mineral-forming elements, but it doesn't provide any specific information about clay minerals. The AIT resistivity measurement is sensitive to clay since clay has a low bulk resistivity; however, the measurement is also sensitive to pore water salinity and porosity. In addition, the CMR measures clay-bound water, which can be considered an indirect indicator of clay.

Considering the above-mentioned circumstances, the most robust way to estimate clay volume from the geophysical logs is to use all the logs together to solve for the full mineral and fluid volumetric composition of the formation. This type of analysis constitutes an inverse problem and can be performed using the ELAN program. Clay volume, along with the remaining matrix and fluid volumes, was estimated using the ELAN integrated log analysis approach with a fairly comprehensive mineral/fluid model containing montmorillonite, silica glass/quartz, orthoclase (representative of alkali feldspars), labradorite (representative of plagioclase feldspars), hypersthene, hornblende, augite, an analog representative of heavy mafic minerals (such as magnetite and olivine), water, and air. This set of volume constituents was chosen to provide a representative cross-section of possible major minerals in the R-23 geologic environment. However, montmorillonite, the one clay mineral, had to be eliminated from the mineral assemblage above 690 ft in the ELAN analysis in order for the model to be constrained. This requirement was precipitated by the need to eliminate the neutron porosity measurement from the analysis above this depth due to unrealistically high values (see discussion above).

The ELAN volume model result, as well as the dry wt% model result, is also shown as part of the integrated log montage, provided in Appendix E of the LANL R-23 Well Completion Report (and in Figure 4.4 in compressed form). The volume of clay derived from these ELAN results for R-23, presented both as (1) fraction of the total (matrix plus pore space) volume and (2) fraction of just the matrix volume (pore space subtracted out), are shown as part of the summary logs (farthest track to the right) in Figure 4.2.

The ELAN analysis predicts variable amounts of clay/montmorillonite below 474 ft (0–30% by volume) and negligible amounts above. The highest clay amounts occur in the zones 526–544 ft (maximum 30% of dry rock matrix volume) and 589–597 ft (maximum 30% of matrix/total volume). High water content occurs above both these zones, suggesting the clay may act to inhibit downward flow of water. Higher clay content occurs in the zones 597–690 ft (maximum 28% of dry matrix volume) and 732–824 ft (maximum 22% of dry matrix volume), which also contain washouts and higher total and water-filled porosity. Based on the ELAN analysis results, these zones could correspond to fractured and altered lava flow zones.

4.4 Spectral Natural Gamma Ray

Natural gamma ray spectroscopy logs were acquired in R-23 for the purpose of

- identifying geologic/lithologic layer boundaries,
- correlating geologic/lithologic units with other wells, and
- helping in the evaluation of mineralogy, including clay content.

The processed spectral gamma log results are shown as summary logs in Figure 4.3 and in expanded form as part of the integrated log montage in Appendix E of the LANL R-23 Well Completion Report (shown compressed in Figure 4.4). On the summary log, gross gamma and gross gamma minus the uranium contribution are displayed in the first track (from left), useful radioisotope ratios are displayed in the third track, and the individual radioisotope concentrations–potassium (K), thorium (Th), and uranium (U)–are displayed in the fourth track.

The NGS spectral gamma measurements are of good quality throughout the log interval, valid for the purpose of interpretation. The raw field measurements were preprocessed to correct for borehole environmental conditions–mainly the change from open hole in the bottom of the borehole (below 599 ft) to cased hole in the top. There is some uncertainty in the casing correction, particularly the precise amount of amplification to apply to the recorded gamma ray signal in order to account for the suppressing effect of the thick steel casing. Also the unknown size and presence of material (e.g. bentonite drilling mud) in the annulus cannot be corrected for; thus the processed measurements include any gamma ray contribution/suppression from annular material. Nonetheless, the K and Th spectral components were used as valuable input to the ELAN analysis in R-23. If possible, it is not recommended to use U as an input to the ELAN model, because it can vary significantly for a particular mineral component due to independent processes (e.g. water flow, geochemical conditions); U was not used in the R-23 ELAN.

The R-23 spectral gamma ray logs have a number of distinct characteristics, which are described below:

- Overall across the logged interval K, Th, and U trend together, resulting in relatively constant baseline ratios of these measured elements. The concentrations of the three elements are highest in the bottom section of the logged interval (586–824 ft) and decreases uphole, first steadily (475–586 ft) then slowly (260–475 ft), above which the concentrations trend constant.
- Major exceptions to this average trend are:
    - A large Th peak from 54–67 ft, inferred as a mineralogy change (the presence of hypersthene) in the ELAN model.
    - A decrease in Th and K from 472–475 ft that is coincident with, and likely the result of, a large washout behind the casing.
    - A sharp downhole increase in Th at 583 ft.
    - The highest K concentrations in the logged interval occur from 750–786 ft, with a peak of 4% dry weight fraction.

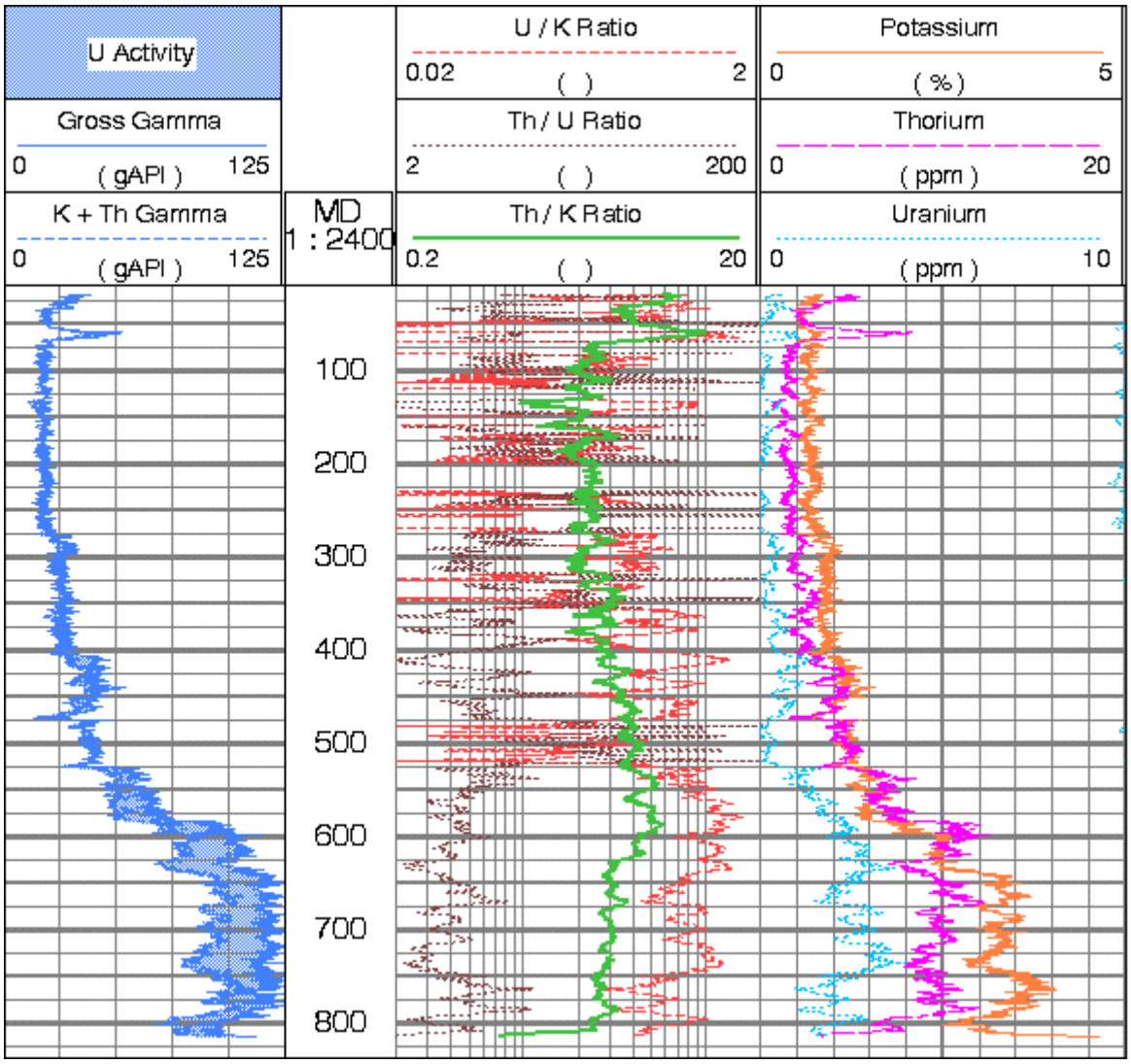

Figure 4.3. Summary spectral natural gamma ray logs from R-23 borehole, interval 19-814 ft

4.5 Integrated Log Montage

This section describes the integrated geophysical log montage for R-23: It includes a discussion of (1) what each log curve represents and how it was derived and (2) what are some of the most notable features in the displayed logs. The montage is provided in Appendix E of the LANL R-23 Well Completion Report and is shown compressed in Figure 4.4. A description of each log curve in the montage follows—organized under the heading of each track, starting from track 1 on the left-hand side of the montage. Note that the descriptions in this section focus on what the curves are and how they are displayed; the specific characteristics and interpretations of the R-23 geophysical logs are provided in the previous section.

Track 1–Depth

The first track on the left contains the depth below ground surface in units of feet, as measured by the geophysical logging system during the AITH logging run. All the geophysical logs are depth-matched to the gross gamma measurement run with the AITH.

Track 2–Basic Logs

The second track on the left (inclusive of the depth track) presents basic curves:

- gamma ray (thick black), recorded in API units and displayed on a scale of 0 to 150 API units;
- caliper (thin solid black) with bit size as a reference (dashed black) to show washout (pink shading, but none exist because the well was cased), recorded in inches and displayed on a scale of 8 to 18 in.;
- bulk chlorinity (dashed green with green shading), recorded in parts per thousand (ppk) and displayed on a scale of 50 to 0 ppk (left to right).

Two gamma ray curves from the NGS are presented:

- total gross gamma (thick solid black curve) and
- gross gamma minus the contribution of uranium (dashed black).

Gross gamma measurements are sensitive to radioactive elements in the near wellbore environment, which are potassium, thorium, and uranium—assuming the gamma activity is from naturally occurring sources. The response of the gross gamma curves is the result of the formation chemical makeup, including lithology/mineralogy. The gross gamma curve from the NGS is depth-matched to the gamma ray measurement from the AITH tool run.

The caliper curve is from the TLD tool, the single arm that is used to press the tool sensor against the borehole wall. It has been depth-matched to the AITH tool run using gross gamma ray as a reference. The caliper was retracted when the tool was in the casing (above 599 ft). The caliper shows some degree of borehole enlargement and washout throughout the open hole section, but nothing significant, especially compared to other Los Alamos wells. The largest measured borehole diameter was 14.3 in at 800 ft. The washouts generally are not abrupt and sharp (i.e. the hole is washed out, but not especially rugose). Hole rugosity has the greatest negative impact on shallow-reading tools since it prevents the sensor section of the tool from contacting the borehole wall; “smooth” washouts do not cause this problem. Consequently, the overall impact of the washouts on log quality in the open hole section is minor. However, washouts could have been present behind the casing and likely were, as evidenced by very low bulk density and high porosity measurements. Washouts behind casing are problematic to the log measurements because the casing forces tool standoff from the formation.

The bulk chlorinity log is estimated from the ECS and is considered an experimental measurement of average water chlorine content seen by the tool—assuming all the chlorine is dissolved in water.

Track 3–Resistivity

The third track displays the resistivity measurements from the AITH, spanning most of the open hole section. All the resistivity logs are recorded in units of ohmmeters and displayed on a logarithmic scale of 2 to 2000 ohm-m.

Five electrical resistivity logs from the AITH are displayed:

- Bulk electrical resistivity at five median depths of investigation–10 in. (black solid), 20 in. (long-dashed blue), 30 in. (short-dashed red), 60 in. (dashed-dotted green), and 90 in. (solid purple)–each having a two-foot vertical resolution.

The area between the 10 in. and 90 in. resistivity curves, representing radial variations in bulk resistivity (potentially from invasion of drilling fluids), is shaded:

- blue when the 10 in. resistivity is greater than the 90 in. resistivity (labeled “resistive invasive”) and
- yellow when the 90 in. resistivity is greater than the 10 in. resistivity (labeled “conductive invasive”).

The resistivity logs vary across the full-scale range from 2 and 2000 ohm-m (the upper limit of the AITH), but mostly from 12 to 2000 ohm-m, exhibiting a lot of character up and down the borehole. Zones where all the resistivity logs shift left significantly, corresponding to relative low resistivity readings, are likely associated with intervals where clay is present in the formation; in general, the lower resistivity values correlate quite well with increases in the CMR clay-bound moisture measurement. Conversely, zones where the resistivity logs shift right significantly, corresponding to relative high resistivity readings, are likely associated with intervals where clay is not present in significant amounts and the average pore size is larger or there is not much moisture present in the pore space.

Track 4–Porosity

The fourth track displays the primary porosity log results. All the porosity logs are recorded in units of volumetric fraction and displayed on a linear scale of 0.75 (left side) to negative 0.1 (right side). Specifically, these logs consist of

- CNTG water-filled epithermal neutron porosity (dashed sky blue curve)–epithermal neutron porosity processed for air-filled hole, which is probably the best estimate of this property in R-23;
- Geochemical estimated water-filled porosity derived from the ECS hydrogen weight % measurement (dotted purple);
- CMR total water-filled porosity (solid black);
- CMR effective water-filled porosity (dashed green);
- CMR bound water porosity (light blue area shading)–representing by the area between the CMR total and effective water-filled porosities;
- Total porosity derived from bulk density and neutron porosity using 2.65 g/cc grain density (thick long dashed red), 2.25 g/cc (thin dashed red), and 3.05 g/cc (thin dotted red)–with red shading between the 2.25 g/cc and 3.05 g/cc curves; and
- ELAN total water and air-filled porosity (dashed-dotted cyan)–derived from the ELAN integrated analysis of all log curves to estimate optimized matrix and pore volume constituents.

The CNTG log is environmentally corrected for borehole conditions–particularly casing and borehole fluid (air)–as is the ECS porosity and bulk density (used for density porosity), the latter only requiring casing

correction. The ELAN results are based on fully corrected logs. All the porosity logs are depth matched to the AITH log using the gross gamma ray measurement obtained in every logging run.

Track 5–Density

The fifth track displays the:

- bulk density (thick solid maroon curve) on a scale of 1 to 3 grams per cubic centimeter (g/cc);
- P_e (long-dashed black curve) on a scale of 0 to 10 non-dimensional units;
- density correction (dashed orange curve) on a scale of -0.75 to 0.25 g/cc; and
- apparent grain density (dashed-dotted brown curve), derived from the ELAN analysis, on a scale of 2.25 to 3.25 g/cc.

Grey area shading is shown where the P_e increases above 3 (indicating the presence of heavy, possibly mafic, minerals) and orange shading is shown where the density correction is greater than the absolute value of 0.25 (indicating the density processing algorithm had to perform a major correction to the bulk density calculation). The bulk density log is environmentally corrected for casing, but cannot be corrected for any annulus behind the casing. Both these logs have been depth matched to the NGS. These logs have been depth matched to the AITH using gross gamma ray.

Track 6–NGS Spectral Gamma

The sixth track from the left displays the spectral components of the NGS measurement results as wet weight concentrations:

- potassium (solid green curve) in units of percent and on a scale of -10 to 10 percent;
- thorium (dashed brown) in units of parts per million (ppm) and on a scale of 25 to -25 ppm; and
- uranium (dotted blue) in units of parts per million (ppm) and on a scale of 10 to 0 ppm.

The log results are environmentally corrected for borehole conditions (particularly borehole size and fluid properties). Potassium and thorium are presented in such a way that they increase to the right and the left from the center of the track, respectively, with gray shading between the two curves to qualitatively show changes in both concentration values. Uranium is plotted increasing to the left from the right side of the track.

Track 7–CMR Porosity

Track 7 displays various CMR water-filled porosities along with measurement quality flags–valid only in the open hole section (below 599 ft). The porosity and measurement quality logs are presented on a scale of 0.5 to zero volume fraction and discrete blocks originating from the left side, respectively. Specifically, the CMR logs shown in this track are

- Total water-filled porosity (solid black curve)–representing the total water volume fraction measured by the CMR;
- Three millisecond (ms) porosity (short-dashed brown)–representing the water volume fraction corresponding to the portion of the CMR measured T2 distribution that is above 3 ms, a cutoff

that is considered to be representative of the break between clay-bound water (less than 3 ms) and all other types of water (greater than 3 ms);

- Effective water-filled, or free fluid, porosity (solid pink)–representing the water volume fraction that is moveable (can flow), based on a 33 ms T2 distribution cutoff that is considered representative of the break between bound water (less than 33 ms) and moveable water (greater than 33 ms) in clastic rocks;
- Clay-bound water (brown area shading between total and 3 ms porosity logs)–representing the water volume fraction that is bound within clays;
- Capillary-bound water (pink area shading between 3 ms and effective porosity logs)–representing the water volume fraction that is bound within matrix pores by capillary forces;
- CMR wait-time flag (red area shading)–activates when there is significant measurement response at late T2 times, corresponding to large amounts of completely free ("bathtub") water and often associated with washouts or very large pores;
- CMR measurement noise flag (yellow and orange area shading)–activates when there is potentially detrimental amounts of measurement noise detected by the tool, at moderate (yellow) and high (orange) levels.

All these CMR logs have been reprocessed from the field measurements to ensure proper and consistent processing algorithms are applied. The reprocessed logs are depth matched to the AITH tool run using gross gamma.

The CMR logs exhibit a moderate degree of variability throughout the measured interval, indicating hydrogeologic heterogeneity (variability in pore-size distribution), although overall the logs indicate low moisture content and moveable water.

Track 8 –Pore Size Distribution

Track 8 displays the water-filled pore size distribution as determined by the CMR–shown as binned water-filled porosities and valid only in the open hole section (below 599 ft). The binned porosity logs are presented on a scale of 0.5 to zero volume fraction with colored area shading corresponding to the different bins:

- Clay-bound water–brown area shading;
- Micro pore and small pore water (the sum comprising capillary-bound water)–gray and blue area shading, respectively;
- Medium pore, large pore, and late decay (the sum comprising effective water-filled porosity)–yellow, red, and green area shading, respectively.

Track 9–CMR T2 Distribution (Waveforms)

The CMR T2 distribution is displayed in Track 9 as green waveform traces at discrete depths. While the T2 distribution is displayed in the cased hole section (above 599 ft), it is not valid in steel casing; there was no convenient way to cut off the display. The horizontal axis, corresponding to relaxation time in milliseconds, is on a logarithmic scale from 0.3 to 3000 ms. Also plotted are the:

- T2 logarithmic mean (solid blue curve) and

- T2 cutoff time used for differentiating between bound and free water (solid red line)–a constant 33 ms in this case.

Track 10–CMR T2 Distribution (Heated Amplitude)

Track 10 displays the T2 distribution in another way–on a heated color scale where progressively “hotter” color (green to yellow to red) corresponds to increasing T2 amplitude. The remaining aspects of the display are the same as in Track 9, except that the T2 logarithmic mean is shown as a solid white curve and the T2 cutoff is not displayed. As in Track 9, the T2 distribution is displayed in the casing only because of display requirements; it is not valid in steel casing.

Track 11–CMR Hydraulic Conductivity

Track 11 displays several estimates of hydraulic conductivity (K) from the CMR measurements, valid only in the open hole section (below 599 ft), as well as one derived from the ELAN analysis, presented on a logarithmic scale of 10^{-3} to 10^{7} centimeters per second (cm/s) multiplied by 10^{6}:

- A K versus depth estimate derived from using the SDR permeability equation, converted to hydraulic conductivity (dashed purple curve);
- A K versus depth estimate derived from using the Timur-Coates permeability equation applied to a tapered T2 cutoff, converted to hydraulic conductivity (solid blue curve); and
- An intrinsic K versus depth estimate (assuming full saturation) derived from the ELAN analysis, converted to hydraulic conductivity (dotted pink).

The hydraulic conductivity values have been multiplied by 10^{6} to reduce the number of significant figures, since in cm/s the values are very small. Thus, when using these hydraulic conductivity estimates for quantitative analysis, the values should be divided by10^{6} or converted to other units.

Area color shading has been applied from the left side of the track up to the Timur-Coates equation K estimate, with different colors corresponding to ranges of K with representative clastic grain sizes:

- Grey–Clay K range (10^{-9} to 10^{-7} cm/s)
- Brown–silt K range (10^{-7} to 10^{-5} cm/s)
- Orange–silty-sand K range (10^{-5} to 10^{-3} cm/s)
- Yellow–clean sand K range (10^{-3} to 10^{-1} cm/s)
- Blue–gravel K range (10^{-1} to 10 cm/s)

Tracks 12 to 16– Geochemical Elemental Measurements

The narrow tracks 12 to 16 present the geochemical measurements iron (Fe) and silicon (Si), sulfur (S) and calcium (Ca), potassium (K) and estimated aluminum (Al), titanium (Ti) and gadolinium (Gd), and hydrogen (H) and bulk chlorinity (Cl) —from left to right respectively, in units of dry matrix weight fraction (except H and K in wet weight fraction, Cl in ppk). All these measurements were obtained from the ECS except K, which is from the NGS. All these measurements are depth matched to the AITH.

Track 17–ELAN Mineralogy Model Results (Dry Weight Fraction)

Track 17 displays the results from the ELAN integrated log analysis (the matrix portion)–presented as dry weight fraction of mineral types chosen in the model:

- Montmorillonite clay (brown/tan)
- Quartz (yellow with small black dots)
- Silica glass (orange)
- Orthoclase or other potassium feldspar (lavender)
- Labradorite or other plagioclase feldspar (pink)
- Hypersthene (purple)
- Hornblende (forest green)
- Augite (maroon)
- Heavy mafic/ultramafic minerals, such as magnetite or olivine (dark green)
- Pyrite (cross-hatched red).

Track 18–ELAN Mineralogy-Pore Space Model Results (Wet Volume Fraction)

Track 18 displays the results from the ELAN integrated log analysis–presented as wet mineral and pore fluid volume fractions:

- Montmorillonite clay (brown/tan)
- Clay-bound water (checkered gray-black)
- Quartz (yellow with small black dots)
- Silica glass (yellow with large black dots)
- Orthoclase or other potassium feldspar (lavender)
- Labradorite or other plagioclase feldspar (pink)
- Pyrite (tan with large black squares).
- Hypersthene (purple)
- Hornblende (forest green)
- Augite (maroon)
- Heavy mafic minerals, such as magnetite (dark army green)
- Air (red)
- Moveable water (white)
- Capillary-bound water (light blue).

Track 19–Summary Logs

Track 19, the second track from the right, displays several summary logs that describe the fluid and air-filled volume measured by the geophysical tools, including water saturation:

- Optimized estimate of total volume fraction water from the ELAN analysis (solid dark blue curve and area shading);
- Optimized estimate of total volume fraction of air-filled porosity from the ELAN analysis (solid red curve and dotted red area shading);
- Optimized estimate of water saturation (percentage of pore space filled with water) from the ELAN analysis (dashed-dotted purple curve);
- Water saturation as calculated directly from the bulk density and geochemical estimated porosity using a grain density of 3.05 g/cc (dotted light blue curve), 2.65 g/cc (long-dashed light blue curve), and 2.25 g/cc (dashed light blue curve)–with light blue shading between the 2.25 and 3.05 g/cc saturation curves to show the range;
- Potential for water flow indicator from the CMR log (block green cross-hatched shading coming from the right-hand side of the track).

The porosity curves scale from 0 to 1 volume fraction, left to right; the water saturation scales from 0 to 1 volume fraction of pore space, from left to right. The flow indicator is a binary-valued flag that rises to halfway through the first division from the right on the x-axis when the CMR measurement indicates a potential for flow.

Track 20–Depth

The final track on the right, same as the first track on the left, displays the depth below ground surface in units of feet, as measured by the geophysical logging system during the AITH logging run.

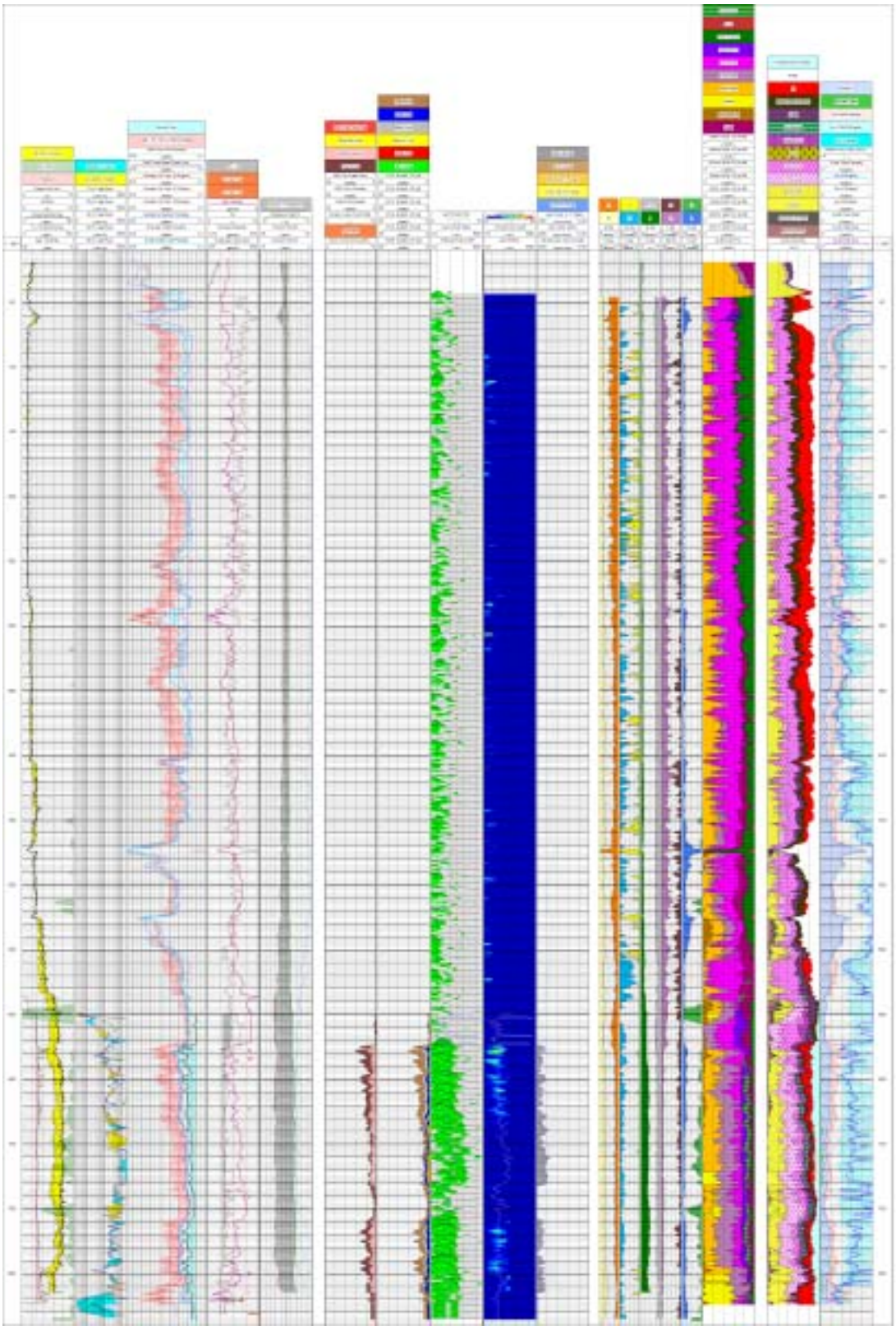

Figure 4.4. Geophysical log montage showing a compressed composite of all processed logs, including ELAN models, from borehole R-23.

5.0 REFERENCES

Kenyon, B., R. Kleinberg, C. Straley, G. Gubelin, and C. Morris: 1995. “Nuclear Magnetic Resonance Imaging— Technology for the 21st Century.” Oilfield Review, v. 7, n. 3, p. 19–33.

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Schlumberger

GEOFRAME PROCESSED INTERPRETATION

Integrated Log Well Montage

Processed Wireline Geophysics Data

* A Mark of Schlumberger

Using the following logs: CMR*, CNTG*, AIT*, TLD*, NGT, ECS*

COMPANY:	Washington Group / LANL
WELL:	R-23
FIELD:	Los Alamos Monitoring Well Network
COUNTY:	Los Alamos
STATE:	New Mexico
COUNTRY:	U.S.
Date Logged:	24-Sep-2002 Date Processed: 11-Feb-2003
Well Location:	Los Alamos National Laboratories
Elevations:	KB: DF: GL:
API Number:	Job Number:

FOLD HERE The well name, location, borehole reference data were furnished by the customer.

All interpretations, are opinions based on inferences from electrical or other measurements, and we cannot, and do not guarantee the accuracy or correctness of any interpretation, and we shall not, except in the case of gross or willful negligence on our part, be liable or responsible for any loss, damage or expense incurred or sustained by anyone resulting from any interpretation made by any of our officers, agents or employees. These interpretations are also subject to Clause 4 of our General Terms and Conditions as set out in our current Price Schedule.

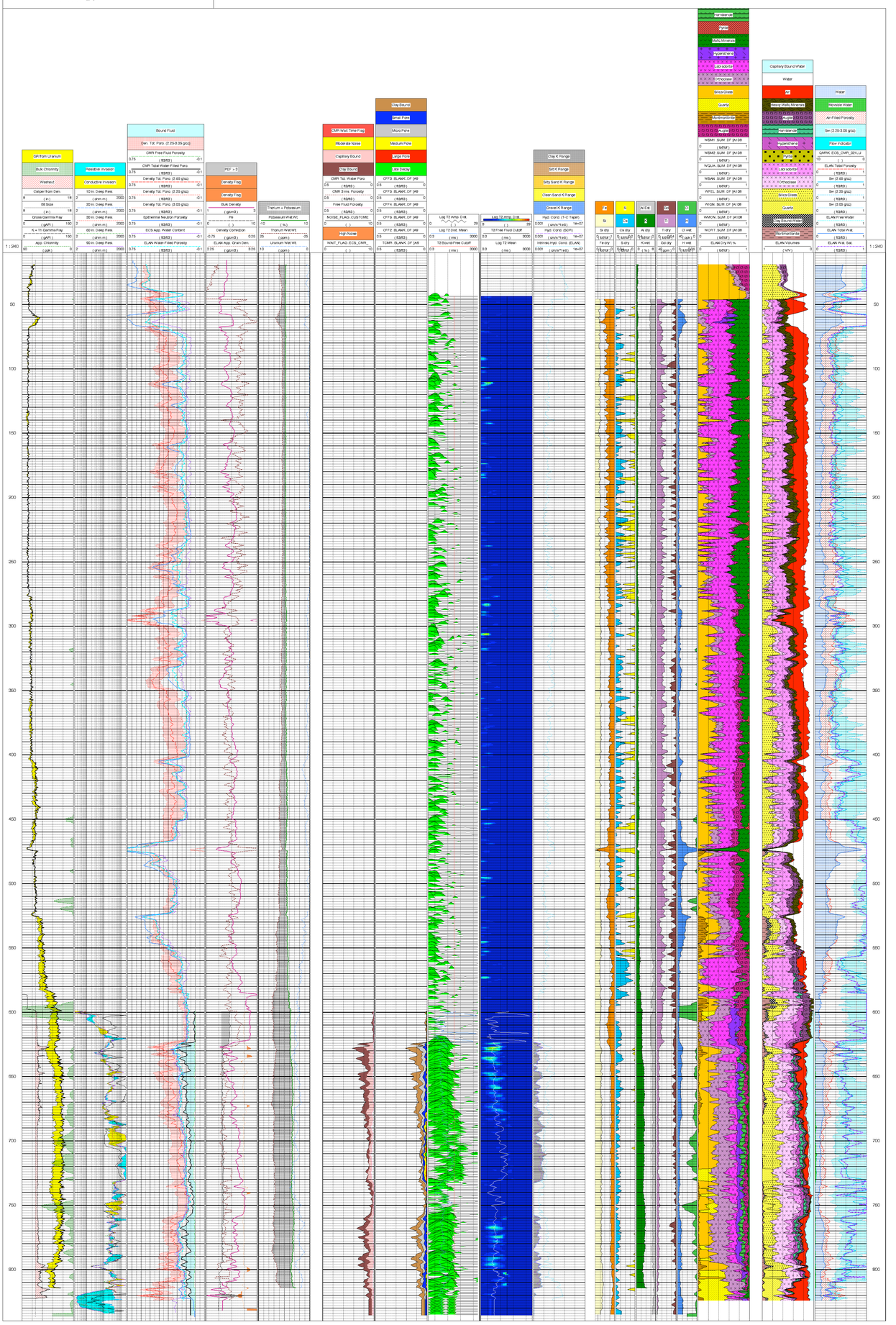
Field Recording:	Location:	Farmington	Software Version:	10C0-006	Engineer: Tom Hansen / Meg
Office Recording:	ICS Center:	SKS Sacramento	Baseline:	GF3.8.1	Log Analyst: Ned Clayton

Mud and Borehole Measurements:

Rm @ Measured temperature:	@	BHT:		Bitsize:	10.6 in
Rmf @ Measured temperature:	@	Type Fluid in Hole		AV / Drilling Foam	
Rmc @ Measured temperature:	@	Mud Density:			

Remarks:

AT NGT tool run used as primary depth reference
Neutron and density logs adversely affected by water/air/mud-filled annulus between casing and formation.
ELAN analysis performed with no porosity or water saturation constraints
Logs are corrected for borehole environment
Borehole filled with air/foam at time of logging



Appendix F

Waste Characterization Data

Los Alamos
NATIONAL LABORATORY

Risk Reduction & Environmental Stewardship Division
Water Quality & Hydrology Group (RRES-WQH)
PO Box 1663, MS K497
Los Alamos, New Mexico 87545
(505) 667-7969/Fax: (505) 665-9344

Date: November 7, 2002
Refer to: RRES-WQH: 02-415

Mr. John Young
Hazardous Materials Bureau
New Mexico Environment Department
P.O. Box 26110
Santa Fe, New Mexico 87502

Mr. Curt Frischkorn
Ground Water Quality Bureau
New Mexico Environment Department
P.O. Box 26110
Santa Fe, New Mexico 87502

SUBJECT: NOTICE OF INTENT TO DISCHARGE, HYDROGEOLOGIC WORKPLAN WELL R-23

Dear Mr. Young and Mr. Frischkorn:

On November 1, 2002, your agency concurred with Los Alamos National Laboratory's proposal to land apply approximately 65,000 gallons of ground water produced during the development of Hydrogeologic Workplan Well R-23 (personal communication, Mr. Bob Beers, Los Alamos National Laboratory, and Mr. John Young, New Mexico Environment Department). The Laboratory's proposal to discharge development water from Workplan Well R-23 was made in accordance with the requirements of the Hydrogeologic Workplan Notice of Intent (NOI) submitted to your agency on August 2, 2001, and subsequently revised on July 16, 2002. Under the Hydrogeologic Workplan NOI, when development water produced from a Hydrogeologic Workplan Well exceeds a New Mexico Water Quality Control Commission (NM WQCC) Regulation 3103 ground water standard or a RCRA regulatory limit the Laboratory will coordinate disposal with the NMED. Since the development water produced from Workplan Well R-23 exceeds the NM WQCC Regulation 3103 ground water standard for manganese (Mn), your agency's concurrence was requested.

The Laboratory has containerized approximately 65,000 gallons of ground water produced during the development of Workplan Well R-23. Workplan Well R-23 is located on Pajarito Road near the intersection with State Road 4. Development water from Workplan Well R-23 will be land applied to the drill site (depth to groundwater is 827 ft.) or to the dirt road leading to Mortandad Canyon from Technical Area (TA)-52 (depth to groundwater is 1260 ft.). The preferred land application site is the R-23 drillsite, but wetland, habitat, and access issues may preclude use of this site. As required by the Workplan NOI, no ponding, pooling, or run-off of the discharged water will be permitted. Information regarding the quality of the development water is provided below.

Water Quality Data

Attachment 1.0 contains analytical reports (metals, general chemistry, perchlorate, nitrate, tritium, and high explosives) from the sampling of containerized development water from Workplan Well R-23.

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Mr. Young and Mr. Frischkorn - 2 - November 7, 2002
RRES-WQH:02-415

All samples were filtered prior to analysis. Sample results were compliant with all NM WQCC Regulation 3103 ground water standards with the exception of the following contaminant:

Contaminant	Screening Result (mg/L)	NM WQCC ground water standard (mg/L)
Mn	0.44	0.2

No perchlorate, tritium, or high explosives (HE) were detected in the Workplan Well R-23 development water at concentrations greater than the analytical laboratory's Method Detection Limits (MDLs).

Please call me at (505) 667-6969 or Roy Bohn of the Laboratory's Environmental Restoration Project (RRES-R) at (505) 665-5138 if additional information is required.

Sincerely,

Bob Beers
Water Quality & Hydrology Group

BB/tml

Enclosures: a/s

Cy: M. Leavitt, NMED/GWQB, Santa Fe, NM, w/enc.
J. Davis, NMED/SWQB, Santa Fe, NM, w/enc.
J. Bearzi, NMED/HWB, Santa Fe, NM, w/enc.
J. Vozella, DOE/OLASO, w/o enc., MS A316
G. Turner, DOE/OLASO, w/enc., MS A316
M. Johansen, DOE/OLASO, w/enc., MS A316
B. Ramsey, RRES-DO, w/o enc., MS J591
K. Hargis, RRES-DO, w/o enc., MS J591
D. Stavert, RRES-EP, w/enc., MS J591
C. Nylander, RRES-GP, w/o enc., MS M992
S. Rae, RRES-WQH, w/enc., MS K497
D. Rogers, RRES-WQH, w/o enc., MS K497
M. Saladen, RRES-WQH, w/o enc., MS K497
J. McCann, RRES-WQH, w/o enc., MS M992
R. Bohn, RRES-R, w/enc., MS M992
D. Volkman, FWO-UI, w/o enc., MS K718
RRES-WQH File, w/enc., MS K497
IM-5, w/enc., MS A150

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ATTACHMENT 1.0

HYDROGEOLOGIC WORKPLAN
WELL R-23

CONTAINERIZED DEVELOPMENT WATER

ANALYTICAL REPORTS:

- GENERAL CHEMISTRY
- METALS
- PERCHLORATE
- NITRATE/NITRITE
- HE
- TRITIUM

SAMPLE DATE:

October 17, 2002

Certificate of Analysis

Company : Los Alamos National Lab
Address : PO Box 1663
TA-3, Bldg. 271, Drop Pt. 01U
Los Alamos, New Mexico 87545
Contact: Keith Greene
Project: Groundwater Project

Report Date: October 25, 2002

Page 1 of 1

Client Sample ID:	GW23-02-49608 1/3	Project:	LANL00401
Sample ID:	69084001	Client ID:	LANL004
Matrix:	Ground Water		
Collect Date:	17-OCT-02		
Receive Date:	19-OCT-02		
Collector:	Client		

Parameter	Qualifier	Result	DL	TPU	RL	Units	DF	Analyst	Date	Time	Batch	Mtd.
Rad Liquid Scint												
LSC, Tritium Dist, Liquid												
Tritium		ND	140	44.1	250	pCi/L		JS1	10/23/02	1125	209717	1

The following Analytical Methods were performed

Method	Description
1	EPA 906.0

Notes:
TPU is calculated at the 67% confidence level (1-sigma).
The Qualifiers in this report are defined as follows :

< Actual result is less than amount reported
> Actual result is greater than amount reported
B Analyte found in the sample as well as the associated blank.
BD Flag for results below the MDC or a flag for low tracer recovery.
E Concentration exceeds instrument calibration range
H Holding time exceeded
J Indicates an estimated value. The result was greater than the detection limit, but less than the reporting limit.
P The response between the confirmation column and the primary column is >40%D
U Indicates the compound was analyzed for but not detected above the detection limit
UI Uncertain identification for gamma spectroscopy.
X Lab-specific qualifier - must be fully described in case narrative and data summary package
Y QC Samples were not spiked with this compound.

The above sample is reported on an "as received" basis.

This data report has been prepared and reviewed in accordance with General Engineering Laboratories, Inc. standard operating procedures. Please direct any questions to your Project Manager, Stacy Griffin.

Reviewed by

R-23 Development Water
Screening Results

ER

ER WATER SAMPLES

SAMPLE ID	DESCRIPTION	DATE MM/DD/YY	ER Req#	Ag ppm	Al ppm	Std.D. +/-	Alk(Lab) ppm CaCO3	As ppm	Std.D. +/-	B ppm	Std.D. +/-
GW23-02-49608	R-23 development water	10/17/02	13285	<0.001	0.013	0.001	95.1	0.0010	0.0001	0.029	0.001

Page 1

R-23 Development Water
Screening Results

ER

SAMPLE ID	Ba ppm	Std.D. +/-	Be ppm	Br ppm	C TIC ppm	C TOC ppm	Ca ppm	Std.D. +/-	Cd ppm	Cl ppm	ClO3 ppm	ClO4 ppm	Co ppm
GW23-02-49608	0.047	0.001	<0.001	0.04	21.5	26.5	25.1	0.1	<0.001	3.72	<0.02	<0.004	0.0012

Page 2

R-23 Development Water
Screening Results

ER

SAMPLE ID	Std.D. +/-	CO3 ppm	Cr ppm	Std.D. +/-	Ca ppm	Cu ppm	Std.D. +/-	F ppm	Fe ppm	Std.D. +/-	Hardness CaCO3 ppm	HCO3 ppm	Hg ppm	Std.D. +/-
GW23-02-49608	0.0001	0	0.0022	0.0001	<0.001	0.0014	0.0001	0.29	0.21	0.01	84.6	116	<0.0002	

Page 3

R-23 Development Water
Screening Results

ER

SAMPLE ID	K ppm	Std.D. +/-	Li ppm	Std.D. +/-	Mg ppm	Std.D. +/-	Mn ppm	Std.D. +/-	Mo ppm	Std.D. +/-	Na ppm	Std.D. +/-	Ni ppm	Std.D. +/-	NO2 ppm
GW23-02-49608	2.75	0.03	0.029	0.001	5.33	0.05	0.44	0.01	0.0031	0.0001	16.5	0.3	0.0026	0.0001	<0.02

Page 4

R-23 Development Water
Screening Results

ER

SAMPLE ID	NO3 ppm	N total ppm	Oxalate ppm	Pb ppm	pH Lab	PO4 ppm	Rb ppm	Std.D. +/-	Sb ppm	Se ppm	Si ppm	Std.D. +/-	SiO2 ppm calc
GW23-02-49608	2.07	0.47	<0.02	<0.001	7.34	<0.05	0.006	0.001	<0.001	<0.001	31.2	0.4	66.8

Page 5

R-23 Development Water
Screening Results

ER

SAMPLE ID	SO4 ppm	Sn ppm	Sr ppm	Std.D. +/-	Th ppm	Ti ppm	Tl ppm	U ppm	Std.D. +/-	V ppm	std.D. +/-	Zn ppm	Std.D. +/-	HMX ppm
GW23-02-49608	11.2	<0.001	0.11	0.01	<0.001	<0.001	<0.001	0.0011	0.0001	0.005	0.001	0.001	0.001	<0.01

Page 6

R-23 Development Water
Screening Results

ER

SAMPLE ID	RDX ppm	1,3,5-TNB ppm	1,3-DNB ppm	TNT ppm	NB ppm	2a-4,6-DNT ppm	2,4-DNT ppm	Acetate ppm	Formate ppm
GW23-02-49608	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	+	+

Page 7

HYDROGEOLOGIC WORKPLAN
WELL R-23

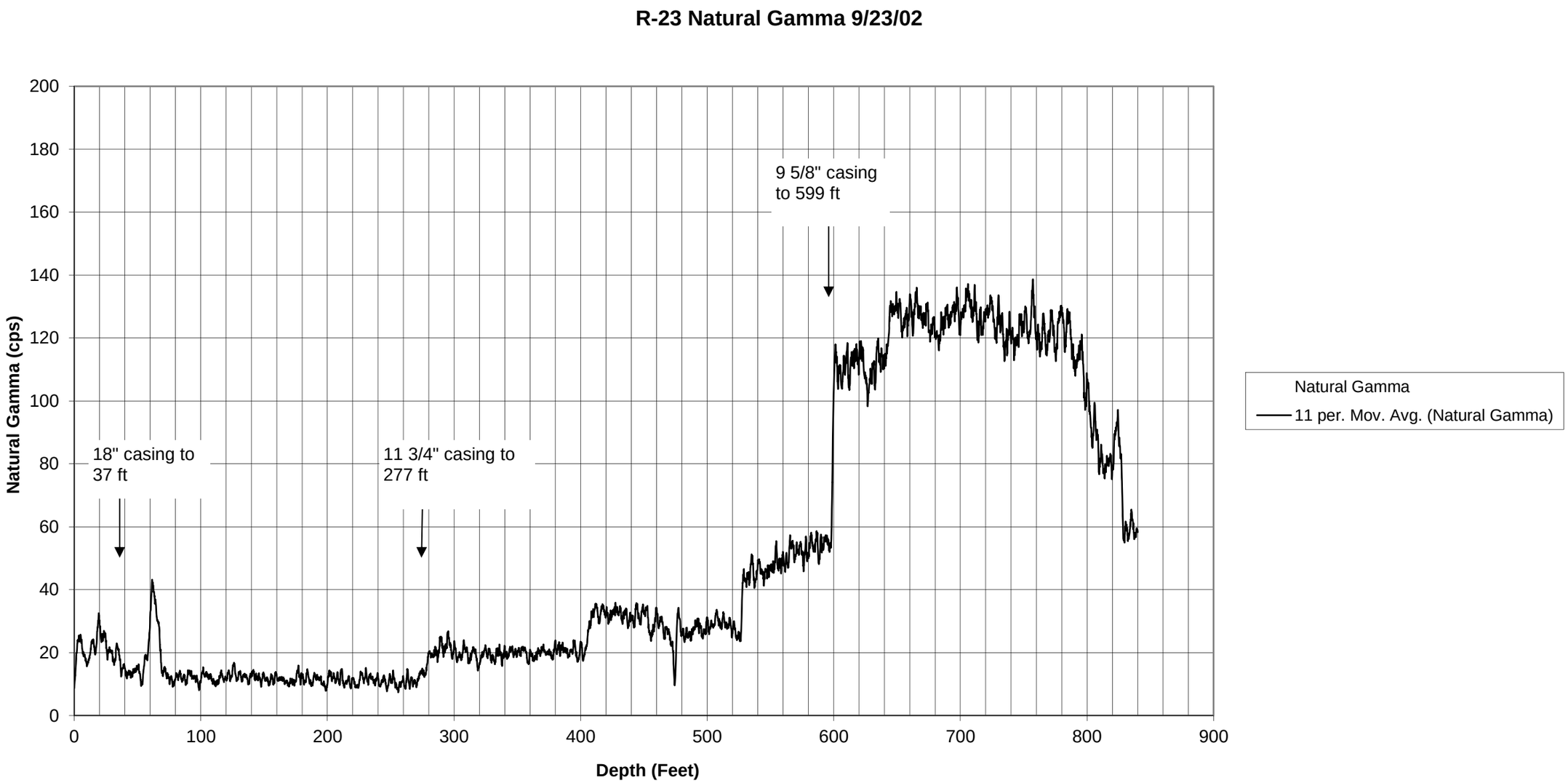
CONTAINERIZED DEVELOPMENT WATER

ANALYTICAL REPORTS

- GENERAL CHEMISTRY
- METALS
- PERCHLORATE
- NITRATE/NITRITE
- HE
- TRITIUM

SAMPLE DATE:

October 17, 2002


R-23 Natural Gamma 9/23/02
Natural Gamma (cps)
Depth (Feet)
0
20
40
60
80
100
120
140
160
180
200
0
100
200
300
400
500
600
700
800
900
18" casing to
37 ft
11 3/4" casing to
277 ft
9 5/8" casing
to 599 ft
Natural Gamma
11 per. Mov. Avg. (Natural Gamma)

```
~VERSION INFORMATION
VERS                    .2.0                          :CWLS LOG ASCII STANDARD-VERSION 2.0
WRAP                    .NO                           :ONE LINE PER DEPTH STEP
~WELL INFORMATION
STRT                    .FT                   2.59184 :START DEPTH
STOP                    .FT                  -2.49341 :STOP DEPTH
STEP                    .FT                         0 :STEP
NULL                    .                      -999.25 :NULL VALUE
COMP                    .         N/A                 :COMPANY
WELL                    .         N/A                 :WELL
FLD                     .         N/A                 :FIELD
LOC                     .         N/A                 :LOCATION
PROV                    .         N/A                 :PROVINCE
SRVC                    .         N/A                 :SERVICE COMPANY
DATE                    .         N/A                 :LOG DATE
UWI                     .         N/A                 :UNIQUE WELL ID
~CURVE INFORMATION
DEPT                    .FT                           :DEPTH
GAMM                    .CPS                          :Gamma
~PARAMETER INFORMATION
Dept                    .                             :Depth Logger
BH F                    .         827 ft              :BH Fluid
COMP                    .         WGI/PMC             :COMPANY:
Dept                    .         926 ft              :Depth Driller
File                    .         R23Gamma9-23-02     :File Name
Witn                    .         Paula Schuh         :Witness:
Loca                    .         Pajarito Canyon     :Location:
Casi                    .         598.75 ft           :Casing
Well                    .         R-23                :Well
Date                    .                  9/23/2002  :Date
Logg                    .         Andy Crowder        :Logged by:
~OTHER
~A
                  2.59184  24.3428
                  2.59184  15.4907
                  2.59184  28.7363
                  2.59184  21.0225
                  2.59184  17.7031
                  2.59184  18.8096
                  2.59184  22.1299
                  2.59184       21
                  2.59184  16.5967
                  2.75588  22.9902
                  2.91992  20.7607
                  3.08396  18.3887
                    3.248  30.3818
                  3.41204  18.3633
                  3.57608  30.1592
                  3.74012  21.3203
                  3.90416  22.0488
                   4.0682  33.3008
                  4.23224  22.2383
                  4.39628  18.7295
                  4.56032  22.5469
                  4.72436  14.9717
                   4.8884  22.4775
                  5.05244  29.8037
                  5.21648  22.4189
                  5.38052  22.4688
                  5.54456  40.7988
                   5.7086  22.0615
                  5.87265  15.2915
                  6.03669  33.7324
                  6.20073  17.5225
                  6.36477  36.0605
                  6.52881   13.082
                  6.69285  13.1323
                  6.85689  21.9082
                  7.02093  17.4912
                  7.18497  13.1128
                  7.34901  8.84521
                  7.51305  13.3677
                  7.67709   8.9292
                  7.84113  26.7607
                  8.00517  17.7441
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                  8.33325   22.125
                  8.49729  17.6484
                  8.66133   18.041
                  8.82537  36.2676
                  8.98941  12.7871
                  9.15345  21.1807
                  9.31749  29.5586
                  9.48153  17.2061
                  9.64557  9.35449
                  9.80961  25.1621
                  9.97365  30.8457
                  10.1377  32.2285
                  10.3017  16.5049
                  10.4658  16.5039
                  10.6298  5.54395
                  10.7939  5.64307
                  10.9579        0
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                   11.286  21.7383
                    11.45  31.3555
                  11.6141  20.4395
                  11.7781  20.6113
                  11.9421  10.3247
                  12.1062  25.8135
                  12.2702  31.2832
                  12.4343   10.582
                  12.5983  5.30493
                  12.7623  21.1738
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13.2545	15.96
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13.9106	16.1875
14.0747	16.2031
14.2387	27.1592
14.4027	32.5645
14.5668	43.0957
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14.8949	15.8784
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15.387	26.7744
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15.7151	16.0635
15.8791	47.7871
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16.6993	26.4941
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17.0274	53.1777
17.1914	21.2197
17.3555	15.9409
17.5195	10.7324
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17.8476	21.2695
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18.1757	16.0908
18.3397	27.0215
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18.6678	16.1396
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21.7846	26.6572
21.9486	16.1367
22.1126	32.0957
22.2767	15.98
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23.2609	21.6494
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24.2452	32.2461
24.4092	47.5957
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25.7215	37.1602
25.8856	26.3848
26.0496	15.96
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102.656	10.7993
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102.985	5.44312
103.149	5.4458
103.313	5.38525
103.477	15.9565
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103.805	10.5342
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105.609	15.7568
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116.436	0
116.6	26.458
116.764	10.6206
116.928	15.8496
117.092	31.3389
117.256	10.3032
117.42	10.249
117.584	20.4248
117.748	10.2021
117.912	0
118.076	5.09302
118.24	15.4404
118.404	10.2993
118.568	20.4668
118.732	10.2534
118.896	10.2163
119.06	5.06763
119.225	10.2324
119.389	10.0889
119.553	5.02588
119.717	15.2295
119.881	5.12036
120.045	5.19019
120.209	10.5054
120.373	10.5986
120.537	5.3501
120.701	5.29834
120.865	15.8057
121.029	10.5645
121.193	5.26196
121.357	5.27979
121.521	5.26318
121.685	10.3403
121.849	25.6836
122.013	15.3911
122.177	10.2544
122.341	20.6006
122.505	5.12231
122.669	5.12573
122.833	10.2295
122.997	10.2529
123.162	15.3433
123.326	10.3169
123.49	15.4185
123.654	20.5547
123.818	5.16406
123.982	10.3027
124.146	15.5127
124.31	0
124.474	31.2051
124.638	31.498
124.802	10.5547
124.966	0
125.13	5.34692
125.294	15.8867
125.458	0
125.622	5.28101
125.786	0
125.95	21.1641
126.114	0
126.278	15.563
126.442	10.3838
126.606	0
126.77	10.2847
126.934	25.5527
127.098	0
127.263	5.12842
127.427	5.12109
127.591	5.13574
127.755	15.3301
127.919	10.2886
128.083	15.4736
128.247	5.1377
128.411	5.14478
128.575	10.2949
128.739	10.3154
128.903	15.6528
129.067	10.4126
129.231	5.22778
129.395	26.4502
129.559	0
129.723	10.7012
129.887	5.25659
130.051	15.8013
130.215	15.897
130.379	10.5562
130.543	15.7139
130.707	5.19727
130.871	15.5361
131.035	20.7041
131.199	15.561
131.364	15.3516
131.528	0
131.692	15.3408
131.856	15.4097
132.02	15.3887
132.184	5.13403

132.348	15.4185
132.512	0
132.676	15.4214
132.84	15.52
133.004	5.13745
133.168	10.3159
133.332	10.4458
133.496	10.394
133.66	10.3984
133.824	26.2637
133.988	0
134.152	10.6221
134.316	15.8208
134.48	5.23706
134.644	21.2871
134.808	31.6113
134.972	15.7847
135.136	0
135.3	15.6675
135.465	5.19507
135.629	20.7773
135.793	15.5024
135.957	5.12085
136.121	20.4746
136.285	15.2983
136.449	5.09766
136.613	10.269
136.777	15.3237
136.941	5.14014
137.105	5.11084
137.269	10.2788
137.433	5.17505
137.597	5.16528
137.761	0
137.925	25.9893
138.089	15.5806
138.253	0
138.417	15.8208
138.581	0
138.745	5.3418
138.909	5.2749
139.073	10.5483
139.237	10.6196
139.402	10.6445
139.566	26.416
139.73	26.1445
139.894	25.7979
140.058	5.16187
140.222	0
140.386	15.6636
140.55	30.7363
140.714	15.1992
140.878	5.10718
141.042	25.4951
141.206	20.4248
141.37	15.3125
141.534	10.1548
141.698	20.4121
141.862	15.3657
142.026	20.5234
142.19	10.3486
142.354	5.14868
142.518	5.19751
142.682	25.7744
142.846	5.2251
143.01	10.4404
143.174	10.4067
143.338	15.4375
143.503	5.1272
143.667	5.12476
143.831	10.3564
143.995	5.22974
144.159	10.4185
144.323	10.3682
144.487	5.1687
144.651	0
144.815	36.2656
144.979	5.229
145.143	10.3921
145.307	15.5786
145.471	10.1973
145.635	10.209
145.799	26.9141
145.963	5.15552
146.127	15.2461
146.291	15.2822
146.455	10.2876
146.619	10.3076
146.783	5.13403
146.947	26.0088
147.111	15.501
147.275	0
147.439	10.5
147.604	0
147.768	26.3594
147.932	10.542
148.096	15.7036
148.26	15.8989
148.424	15.8916
148.588	31.6045
148.752	10.4033
148.916	0
149.08	10.2817
149.244	5.16553

149.408	10.3853
149.572	10.3931
149.736	10.394
149.9	15.3662
150.064	5.09033
150.228	5.07959
150.392	5.12378
150.556	30.9795
150.72	5.19238
150.884	10.4639
151.048	5.24854
151.212	31.2998
151.376	5.19702
151.54	10.5176
151.705	10.2949
151.869	10.519
152.033	5.25269
152.197	10.5347
152.361	5.25659
152.525	10.5791
152.689	21.0879
152.853	5.29395
153.017	42.4688
153.181	0
153.345	5.21851
153.509	36.2734
153.673	15.5186
153.837	15.481
154.001	10.4351
154.165	0
154.329	5.14185
154.493	35.8496
154.657	15.4033
154.821	20.5693
154.985	15.5444
155.149	0
155.313	20.9717
155.477	5.20313
155.641	25.918
155.806	15.5479
155.97	10.2803
156.134	15.4365
156.298	26.0947
156.462	15.7637
156.626	0
156.79	5.25342
156.954	15.7212
157.118	0
157.282	15.9663
157.446	10.6016
157.61	15.8286
157.774	15.6504
157.938	0
158.102	0
158.266	20.6045
158.43	5.19824
158.594	10.334
158.758	10.2773
158.922	10.355
159.086	5.11841
159.25	10.2661
159.414	10.3247
159.578	20.7783
159.743	10.395
159.907	15.6343
160.071	10.3745
160.235	0
160.399	15.561
160.563	25.8955
160.727	5.16895
160.891	10.4727
161.055	5.22046
161.219	10.52
161.383	15.7852
161.547	21.1201
161.711	21.2861
161.875	21.1387
162.039	5.32959
162.203	5.25415
162.367	31.0186
162.531	10.3408
162.695	15.4541
162.859	10.3721
163.023	10.3389
163.187	20.7266
163.351	10.3804
163.515	10.3003
163.679	15.3252
163.844	25.8584
164.008	15.5117
164.172	0
164.336	20.6816
164.5	10.3364
164.664	10.373
164.828	15.606
164.992	15.4941
165.156	20.7393
165.32	20.7119
165.484	15.6162
165.648	10.5508
165.812	31.5889
165.976	10.5674
166.14	5.29688
166.304	26.4355

166.468	21.0928
166.632	10.5786
166.796	20.8281
166.96	15.4907
167.124	5.16919
167.288	5.16016
167.452	25.8525
167.616	5.18945
167.78	20.6963
167.945	15.4883
168.109	10.2681
168.273	31.1113
168.437	31.1777
168.601	15.4917
168.765	10.3472
168.929	5.1958
169.093	10.4082
169.257	5.19409
169.421	10.4482
169.585	0
169.749	20.7168
169.913	0
170.077	10.5303
170.241	10.5947
170.405	15.8784
170.569	21.2148
170.733	0
170.897	5.28589
171.061	21.2363
171.225	20.9365
171.389	0
171.553	10.395
171.717	15.4248
171.881	10.2939
172.046	10.3599
172.21	15.6465
172.374	25.8877
172.538	25.8525
172.702	0
172.866	15.52
173.03	5.16919
173.194	31.0117
173.358	15.5703
173.522	20.7979
173.686	15.5479
173.85	5.18481
174.014	20.79
174.178	20.666
174.342	10.3359
174.506	21.0508
174.67	5.24585
174.834	21.1729
174.998	5.27026
175.162	5.27271
175.326	10.6162
175.49	0
175.654	5.2688
175.818	15.6538
175.982	5.19336
176.147	20.6807
176.311	5.13867
176.475	10.332
176.639	0
176.803	10.394
176.967	31.3848
177.131	10.3203
177.295	10.2974
177.459	25.7041
177.623	15.5557
177.787	10.3359
177.951	15.584
178.115	20.7979
178.279	5.18848
178.443	20.874
178.607	10.3311
178.771	0
178.935	5.20361
179.099	15.6797
179.263	26.3418
179.427	10.5234
179.591	26.2783
179.755	21.2061
179.919	21.1123
180.084	15.7295
180.248	21.0605
180.412	0
180.576	5.18701
180.74	0
180.904	10.3101
181.068	20.6953
181.232	0
181.396	15.5581
181.56	15.4292
181.724	31.0859
181.888	10.2646
182.052	25.8887
182.216	0
182.38	10.3804
182.544	15.5786
182.708	20.7412
182.872	20.6953
183.036	0
183.2	10.3706
183.364	5.16089

183.528	20.9268
183.692	0
183.856	21.0996
184.02	0
184.185	15.752
184.349	0
184.513	0
184.677	21.0605
184.841	20.8643
185.005	5.20044
185.169	10.311
185.333	5.15723
185.497	10.353
185.661	5.19653
185.825	5.2168
185.989	15.561
186.153	5.12793
186.317	15.4639
186.481	0
186.645	10.291
186.809	20.6641
186.973	5.13916
187.137	20.8438
187.301	10.3218
187.465	5.19214
187.629	5.19824
187.793	15.4883
187.957	10.3823
188.121	10.5132
188.286	10.4746
188.45	10.5967
188.614	15.834
188.778	5.26343
188.942	10.5498
189.106	21.1641
189.27	21.002
189.434	10.4541
189.598	15.5547
189.762	20.6689
189.926	15.6133
190.09	0
190.254	5.17993
190.418	15.6841
190.582	20.5645
190.746	10.2295
190.91	5.15918
191.074	20.4434
191.238	5.18896
191.402	5.15063
191.566	5.21729
191.73	5.21411
191.894	0
192.058	5.22559
192.222	25.9268
192.387	10.2949
192.551	15.6421
192.715	5.28589
192.879	15.8145
193.043	5.28369
193.207	10.5698
193.371	21.0576
193.535	5.30371
193.699	0
193.863	10.4272
194.027	20.8867
194.191	25.7383
194.355	15.4604
194.519	25.9453
194.683	0
194.847	15.5703
195.011	15.5767
195.175	10.2861
195.339	20.5156
195.503	10.2432
195.667	5.13623
195.831	0
195.995	0
196.159	15.5483
196.324	5.18945
196.488	0
196.652	15.5986
196.816	20.6299
196.98	15.5371
197.144	26.2344
197.308	0
197.472	31.5313
197.636	0
197.8	0
197.964	10.5659
198.128	5.29395
198.292	15.7231
198.456	15.6714
198.62	15.5435
198.784	5.16235
198.948	10.2773
199.112	10.4165
199.276	5.19824
199.44	15.5483
199.604	5.18213
199.768	25.624
199.932	20.4805
200.096	10.2817
200.26	10.335
200.425	10.4111

200.589	10.3804
200.753	20.7881
200.917	0
201.081	5.18091
201.245	20.6924
201.409	10.3657
201.573	10.3813
201.737	0
201.901	15.731
202.065	26.2383
202.229	15.8062
202.393	21.1436
202.557	21.1729
202.721	10.5835
202.885	36.582
203.049	10.415
203.213	20.7236
203.377	25.8652
203.541	10.3315
203.705	10.4063
203.869	10.356
204.033	15.5435
204.197	0
204.361	25.582
204.526	15.52
204.69	10.293
204.854	15.5273
205.018	10.4307
205.182	10.353
205.346	10.4038
205.51	15.5854
205.674	10.3633
205.838	10.3906
206.002	25.79
206.166	5.22119
206.33	0
206.494	0
206.658	10.5991
206.822	5.323
206.986	0
207.15	15.9082
207.314	5.26807
207.478	5.20581
207.642	0
207.806	10.4165
207.97	15.4146
208.134	5.19336
208.298	10.3848
208.462	5.19116
208.627	5.15381
208.791	15.3545
208.955	10.3047
209.119	10.272
209.283	5.14258
209.447	10.3418
209.611	5.17114
209.775	5.17725
209.939	20.8174
210.103	15.543
210.267	10.3535
210.431	15.4326
210.595	10.3267
210.759	15.7114
210.923	10.4736
211.087	5.2771
211.251	15.9531
211.415	0
211.579	15.9131
211.743	10.5806
211.907	15.623
212.071	20.7949
212.235	10.4272
212.399	10.3247
212.563	20.6572
212.728	20.6973
212.892	20.5654
213.056	15.5591
213.22	25.6602
213.384	10.2573
213.548	5.13867
213.712	0
213.876	31.0352
214.04	10.3477
214.204	15.5581
214.368	15.6421
214.532	5.20435
214.696	10.3584
214.86	10.3003
215.024	5.14844
215.188	0
215.352	15.7617
215.516	0
215.68	5.31152
215.844	10.5923
216.008	10.6138
216.172	15.832
216.336	21.1289
216.5	10.5068
216.665	5.16553
216.829	31.043
216.993	10.2725
217.157	10.2617
217.321	0
217.485	15.5464

217.649	10.3657
217.813	30.9375
217.977	10.2349
218.141	20.5967
218.305	0
218.469	5.16333
218.633	15.5723
218.797	10.377
218.961	10.3066
219.125	15.5361
219.289	15.4492
219.453	10.3145
219.617	20.6963
219.781	5.22119
219.945	21.1045
220.109	0
220.273	5.28809
220.437	5.31104
220.601	10.5293
220.766	10.5322
220.93	10.5439
221.094	15.6221
221.258	0
221.422	15.4097
221.586	25.667
221.75	15.5669
221.914	10.3975
222.078	15.5967
222.242	0
222.406	25.6699
222.57	0
222.734	5.16235
222.898	15.5127
223.062	5.16504
223.226	15.6074
223.39	10.3623
223.554	5.14063
223.718	15.4614
223.882	0
224.046	0
224.21	20.7412
224.374	15.7017
224.538	21.041
224.702	10.5571
224.867	10.5405
225.031	5.30566
225.195	0
225.359	5.26196
225.523	5.20801
225.687	10.3579
225.851	5.16235
226.015	0
226.179	5.15161
226.343	15.5171
226.507	15.5415
226.671	15.5303
226.835	15.3984
226.999	20.5127
227.163	10.2876
227.327	0
227.491	25.8301
227.655	0
227.819	5.17456
227.983	5.13818
228.147	5.15723
228.311	5.15356
228.475	10.3584
228.639	15.4941
228.803	10.4565
228.968	26.2344
229.132	21.209
229.296	5.27026
229.46	10.6514
229.624	26.6191
229.788	10.5278
229.952	10.4678
230.116	0
230.28	25.8428
230.444	0
230.608	10.2554
230.772	20.7891
230.936	5.20215
231.1	15.6133
231.264	15.4683
231.428	15.3174
231.592	5.12671
231.756	10.2603
231.92	10.3423
232.084	15.2998
232.248	10.3281
232.412	0
232.576	15.4194
232.74	5.15405
232.905	5.16064
233.069	15.5029
233.233	5.2041
233.397	10.4941
233.561	5.25098
233.725	0
233.889	5.31592
234.053	5.27295
234.217	10.5938
234.381	5.23535
234.545	10.4263

234.709	20.7686
234.873	5.1438
235.037	25.8877
235.201	5.16919
235.365	10.3438
235.529	15.5913
235.693	20.6494
235.857	25.6924
236.021	10.2876
236.185	5.11914
236.349	10.293
236.513	5.14917
236.677	5.13135
236.841	20.7158
237.006	5.18848
237.17	15.4316
237.334	15.5654
237.498	5.16113
237.662	36.248
237.826	5.24414
237.99	0
238.154	10.5903
238.318	26.5527
238.482	15.834
238.646	10.5869
238.81	10.5454
238.974	15.6309
239.138	15.4868
239.302	10.3564
239.466	15.46
239.63	5.13647
239.794	15.541
239.958	5.17822
240.122	10.3662
240.286	10.2876
240.45	20.5303
240.614	0
240.778	0
240.942	5.14966
241.107	5.1521
241.271	20.4717
241.435	20.6299
241.599	30.9502
241.763	31.0898
241.927	10.3516
242.091	5.14746
242.255	0
242.419	10.5181
242.583	5.271
242.747	0
242.911	10.5786
243.075	5.2561
243.239	0
243.403	0
243.567	0
243.731	5.19873
243.895	31.0039
244.059	41.3691
244.223	10.3438
244.387	20.7412
244.551	5.19922
244.715	15.543
244.879	15.3535
245.043	10.249
245.208	15.4521
245.372	15.4209
245.536	10.2495
245.7	5.14551
245.864	10.3276
246.028	15.5483
246.192	10.3291
246.356	25.9785
246.52	10.334
246.684	10.2959
246.848	5.22046
247.012	0
247.176	10.5547
247.34	0
247.504	5.28955
247.668	15.772
247.832	10.5132
247.996	5.2229
248.16	15.689
248.324	10.4175
248.488	25.6807
248.652	0
248.816	15.4946
248.98	0
249.144	26.0176
249.309	25.7578
249.473	10.2676
249.637	20.4131
249.801	20.5693
249.965	10.2983
250.129	25.7412
250.293	5.15649
250.457	0
250.621	5.17773
250.785	5.15967
250.949	5.17578
251.113	15.4473
251.277	0
251.441	21.0068
251.605	10.5205

251.769	10.6421
251.933	21.2559
252.097	15.8413
252.261	5.25537
252.425	5.25195
252.589	5.24243
252.753	10.4175
252.917	15.5703
253.081	0
253.246	10.3223
253.41	5.19336
253.574	5.17651
253.738	20.7568
253.902	15.4346
254.066	15.3066
254.23	10.2388
254.394	10.2256
254.558	10.3071
254.722	15.4702
254.886	25.8906
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255.87	15.627
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256.854	10.5737
257.018	10.5508
257.182	10.415
257.347	0
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257.675	15.3516
257.839	15.4844
258.003	20.8135
258.167	15.5474
258.331	20.6768
258.495	5.11377
258.659	10.2285
258.823	20.5029
258.987	5.16772
259.151	5.15649
259.315	5.19775
259.479	10.4009
259.643	15.5068
259.807	0
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262.596	10.3687
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262.924	20.5547
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263.744	15.5508
263.908	5.16113
264.072	5.15552
264.236	10.3813
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264.564	15.5479
264.728	15.5508
264.892	5.23462
265.056	15.7295
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266.205	10.4297
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390.055	10.0806
390.219	10.062
390.383	20.0664
390.547	15.2554
390.711	10.1719
390.875	5.08472
391.039	40.6055
391.203	40.3828
391.367	20.1758
391.532	25.4238
391.696	10.1606
391.86	15.2036
392.024	20.4033
392.188	20.1914
392.352	25.333
392.516	15.3193
392.68	20.207
392.844	20.3818
393.008	15.3501
393.172	15.3628
393.336	15.5024
393.5	26.0313
393.664	5.17578
393.828	15.5317
393.992	10.3159
394.156	10.3491
394.32	15.3257
394.484	15.145
394.648	30.3008
394.812	5.0354
394.976	15.2378
395.14	40.6719
395.304	30.6035
395.468	20.2852
395.633	0
395.797	25.1709
395.961	10.1274
396.125	35.3477
396.289	25.3711
396.453	25.3301
396.617	25.4268
396.781	15.2285
396.945	5.09644
397.109	10.1621
397.273	15.2354
397.437	5.11426
397.601	46.3457
397.765	20.5645
397.929	26.0156
398.093	52.0684
398.257	25.8242
398.421	20.7695
398.585	15.5903
398.749	10.2803
398.913	25.3359
399.077	5.06885
399.241	50.623
399.405	15.3042
399.57	35.6445
399.734	25.5498
399.898	15.2993
400.062	20.2471
400.226	25.4072
400.39	25.2676
400.554	35.4141
400.718	15.2529
400.882	25.3711
401.046	15.2686
401.21	25.4238
401.374	25.3262
401.538	25.4893
401.702	25.3721
401.866	20.3613
402.03	20.5439
402.194	51.9453
402.358	5.18115
402.522	10.4282
402.686	25.7188
402.85	25.9111
403.014	5.18774
403.178	10.2207
403.342	20.3584
403.506	25.3457
403.671	20.1738
403.835	5.1145
403.999	20.3301
404.163	20.5547
404.327	5.10327
404.491	30.2979
404.655	30.417
404.819	15.1924
404.983	20.1709
405.147	15.2295

405.311	15.228
405.475	5.08228
405.639	15.395
405.803	20.3867
405.967	45.957
406.131	40.7813
406.295	30.7031
406.459	20.8145
406.623	5.16968
406.787	26.0635
406.951	31.1279
407.115	15.5703
407.279	20.7324
407.443	67.6602
407.607	20.4951
407.772	25.4238
407.936	30.623
408.1	20.3027
408.264	20.3984
408.428	25.7041
408.592	41.209
408.756	20.4248
408.92	25.4785
409.084	35.4141
409.248	20.2139
409.412	35.1738
409.576	25.3594
409.74	40.748
409.904	40.7363
410.068	46
410.232	30.6699
410.396	45.7168
410.56	15.2554
410.724	35.8379
410.888	41.0684
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411.216	26.1221
411.38	20.6533
411.544	26.0059
411.708	20.8145
411.873	31.0186
412.037	31.041
412.201	56.5605
412.365	56.3203
412.529	15.4492
412.693	36.3711
412.857	31.0859
413.021	73.0547
413.185	41.2285
413.349	46.5566
413.513	46.3242
413.677	35.6055
413.841	30.4531
414.005	35.3203
414.169	45.5957
414.333	30.8467
414.497	30.6768
414.661	30.7578
414.825	20.415
414.989	10.1304
415.153	35.8203
415.317	36.002
415.481	30.9248
415.645	41.8457
415.81	36.0762
415.974	46.6055
416.138	51.8086
416.302	15.5264
416.466	46.293
416.63	41.1602
416.794	25.6699
416.958	30.8662
417.122	15.7129
417.286	15.8096
417.45	31.9102
417.614	31.4365
417.778	25.9141
417.942	46.4414
418.106	41.002
418.27	15.3208
418.434	45.7227
418.598	15.3335
418.762	15.4668
418.926	51.5742
419.09	36.1465
419.254	25.543
419.418	25.4922
419.582	25.5127
419.746	25.5576
419.911	25.9434
420.075	41.6074
420.239	51.748
420.403	26.0186
420.567	26.0703
420.731	31.3711
420.895	47.4023
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421.223	26.333
421.387	15.7344
421.551	63.832
421.715	48.6484
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422.043	53.2617
422.207	21.293

422.371	42.2734
422.535	47.668
422.699	47.2598
422.863	47.0254
423.027	10.46
423.191	36.1523
423.355	30.6973
423.519	35.9238
423.683	35.5762
423.847	30.5596
424.012	35.5313
424.176	66.6172
424.34	31.3066
424.504	41.3691
424.668	36.2578
424.832	62.3652
424.996	36.5879
425.16	21.0879
425.324	31.5234
425.488	15.668
425.652	15.6958
425.816	52.0918
425.98	21.002
426.144	36.9883
426.308	31.7148
426.472	26.293
426.636	20.6953
426.8	45.7168
426.964	20.334
427.128	35.3164
427.292	25.0811
427.456	20.2979
427.62	45.3672
427.784	45.3145
427.949	20.1045
428.113	55.6191
428.277	25.332
428.441	15.481
428.605	30.8232
428.769	45.7637
428.933	25.3721
429.097	35.332
429.261	25.3828
429.425	20.458
429.589	25.7646
429.753	52.2383
429.917	36.709
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430.245	20.9854
430.409	5.2417
430.573	67.9531
430.737	5.18652
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431.065	25.4795
431.229	30.373
431.393	55.2207
431.557	19.8975
431.721	24.8438
431.885	40.166
432.05	30.249
432.214	20.1631
432.378	25.1582
432.542	30.3945
432.706	25.2314
432.87	15.3779
433.034	25.8721
433.198	36.6875
433.362	57.6992
433.526	31.3008
433.69	26.1279
433.854	52.7832
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434.182	10.6289
434.346	21.1035
434.51	57.5566
434.674	25.9551
434.838	46.3301
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435.33	46.2422
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435.822	25.1348
435.986	34.9844
436.151	5.06299
436.315	30.3779
436.479	35.0605
436.643	40.4609
436.807	40.4336
436.971	20.2852
437.135	40.6738
437.299	30.9404
437.463	10.4717
437.627	26.2266
437.791	25.9551
437.955	31.1826
438.119	15.6387
438.283	47.2852
438.447	21.1152
438.611	26.3291
438.775	73.5664
438.939	41.9434
439.103	31.3252
439.267	20.7822

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439.595	26.0479
439.759	26.0566
439.923	20.832
440.087	25.8369
440.252	15.3804
440.416	41.1719
440.58	35.5703
440.744	15.2197
440.908	34.877
441.072	30.1768
441.236	20.207
441.4	35.3789
441.564	25.4395
441.728	77.6836
441.892	26.1543
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442.22	46.9434
442.384	20.957
442.548	21.1387
442.712	31.9453
442.876	47.7676
443.04	42.2969
443.204	47.2129
443.368	31.5771
443.532	26.2539
443.696	41.8652
443.86	36.7207
444.024	37.1777
444.189	26.2744
444.353	41.998
444.517	41.998
444.681	20.8281
444.845	47.2246
445.009	20.6055
445.173	56.4102
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445.501	44.7773
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445.829	35.3887
445.993	25.4795
446.157	20.7432
446.321	31.3945
446.485	21.0059
446.649	5.20386
446.813	41.9844
446.977	31.7002
447.141	37.123
447.305	47.8691
447.469	21.1846
447.633	36.8418
447.797	36.916
447.961	21.0527
448.125	36.7656
448.29	15.8564
448.454	31.625
448.618	47.3242
448.782	36.7695
448.946	46.875
449.11	20.9316
449.274	30.8984
449.438	30.9561
449.602	10.2002
449.766	20.1914
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450.094	30.3115
450.258	25.5703
450.422	20.5234
450.586	36.3008
450.75	21.0186
450.914	26.2451
451.078	15.7637
451.242	31.6836
451.406	5.34082
451.57	15.9443
451.734	42.834
451.898	31.7451
452.062	21.1201
452.226	42.6973
452.391	15.7544
452.555	31.6182
452.719	10.5659
452.883	31.5088
453.047	21.0352
453.211	52.166
453.375	52.1836
453.539	31.6348
453.703	32.873
453.867	20.918
454.031	52.0215
454.195	20.4248
454.359	35.457
454.523	41.0605
454.687	0
454.851	20.8721
455.015	21.373
455.179	26.6787
455.343	21.3584
455.507	43.2109
455.671	59.7207
455.835	60.1523
455.999	32.625
456.163	21.3623
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456.492	26.4922
456.656	20.9717
456.82	36.8652
456.984	26.2295
457.148	57.8262
457.312	31.3887
457.476	36.7266
457.64	21.2227
457.804	20.9824
457.968	41.7754
458.132	36.7051
458.296	46.4863
458.46	25.8818
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458.788	36.0449
458.952	31.2744
459.116	25.9033
459.28	36.8809
459.444	37.3262
459.608	32.043
459.772	26.7764
459.936	43.1602
460.1	21.7676
460.264	27.2305
460.429	16.2422
460.593	48.5508
460.757	26.6611
460.921	31.877
461.085	47.1016
461.249	26.1865
461.413	26.0674
461.577	36.3242
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461.905	31.376
462.069	31.2559
462.233	20.8789
462.397	10.3481
462.561	36.0918
462.725	30.9209
462.889	15.2124
463.053	25.3135
463.217	45.3105
463.381	14.9536
463.545	40.0605
463.709	45.5508
463.873	25.4619
464.037	66.0352
464.201	30.501
464.365	35.7559
464.53	26.001
464.694	5.19995
464.858	21.0645
465.022	26.1973
465.186	25.7324
465.35	20.501
465.514	40.8867
465.678	15.2622
465.842	60.9824
466.006	20.4717
466.17	40.7324
466.334	30.7285
466.498	40.8496
466.662	40.6406
466.826	30.2725
466.99	34.9141
467.154	34.9121
467.318	34.6699
467.482	0
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467.81	15.1177
467.974	5.07617
468.138	15.481
468.302	46.3008
468.466	15.3569
468.631	10.436
468.795	15.8306
468.959	21.2637
469.123	36.7676
469.287	41.4141
469.451	25.7773
469.615	20.6436
469.779	10.2139
469.943	30.6572
470.107	50.9512
470.271	5.03369
470.435	25.4629
470.599	40.4375
470.763	25.543
470.927	10.2373
471.091	40.7188
471.255	30.9277
471.419	41.2305
471.583	10.269
471.747	15.4033
471.911	20.6709
472.075	25.7686
472.239	41.7188
472.403	15.7944
472.567	36.9277
472.732	15.8384
472.896	21.0117
473.06	10.6328
473.224	21.125
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473.552	31.1338
473.716	10.3403
473.88	10.2476
474.044	10.1821
474.208	15.2935
474.372	10.0864
474.536	20.2764
474.7	20.2725
474.864	10.1582
475.028	5.10254
475.192	10.2168
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475.848	25.7881
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476.176	10.27
476.34	0
476.504	10.4082
476.669	26.3164
476.833	31.8232
476.997	47.3301
477.161	21.1738
477.325	31.7129
477.489	52.5469
477.653	31.4102
477.817	20.7666
477.981	51.4492
478.145	25.8516
478.309	40.5
478.473	35.5879
478.637	35.5039
478.801	55.7148
478.965	25.3789
479.129	40.9004
479.293	25.5547
479.457	15.3433
479.621	30.8711
479.785	0
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480.277	25.7559
480.441	41.3691
480.605	41.2441
480.77	36.4785
480.934	10.5938
481.098	21.0137
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481.426	47.5762
481.59	52.6074
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482.246	30.999
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482.574	15.3418
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483.23	15.2148
483.394	20.3545
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485.199	15.7783
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486.511	25.7998
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487.167	25.3818
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487.823	30.7168
487.987	30.7158
488.151	35.584
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491.924	20.4473
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493.729	36.7285
493.893	25.8389
494.057	51.2891
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494.385	25.8096
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494.877	46.1699
495.041	15.3154
495.205	5.05469
495.369	35.6738
495.533	46.6992
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516.202	5.2207
516.366	46.1816
516.53	25.6279
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516.858	30.8877
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517.186	36.1914
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517.515	30.8027
517.679	35.7969
517.843	35.8555
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518.499	10.3652
518.663	51.8145
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518.991	15.3877
519.155	20.7285
519.319	26.1367
519.483	47
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519.811	36.8984
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520.303	15.8086
520.467	26.0771
520.631	20.5869
520.795	10.1855
520.959	46.332
521.123	30.9434
521.287	15.4199
521.451	30.9639
521.616	25.8066
521.78	35.8184
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522.108	35.9531
522.272	36.0508
522.436	31.0742
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524.076	26.2061
524.24	5.2771
524.404	26.4336
524.568	36.7988

524.732	31.375
524.896	35.9023
525.06	20.417
525.224	36.0879
525.388	20.4863
525.552	36.125
525.717	0
525.881	35.9785
526.045	30.7939
526.209	20.6133
526.373	20.6152
526.537	15.4111
526.701	5.19336
526.865	10.3364
527.029	36.293
527.193	25.8174
527.357	26.0146
527.521	30.8711
527.685	46.2598
527.849	36.4609
528.013	15.5884
528.177	31.5088
528.341	26.4463
528.505	31.7646
528.669	26.4238
528.833	21.2354
528.997	26.1338
529.161	46.2793
529.325	56.6895
529.489	15.3823
529.653	72.25
529.818	20.5703
529.982	82.4688
530.146	41.084
530.31	46.3887
530.474	46.2461
530.638	36.0625
530.802	30.8457
530.966	51.5039
531.13	51.4395
531.294	41.4355
531.458	41.4648
531.622	36.2773
531.786	20.5459
531.95	51.418
532.114	20.8154
532.278	41.5352
532.442	73.625
532.606	26.3848
532.77	26.3232
532.934	58.4492
533.098	68.2656
533.262	36.6016
533.426	51.543
533.59	61.6387
533.755	51.1992
533.919	36.082
534.083	46.1875
534.247	46.4297
534.411	30.749
534.575	76.7852
534.739	46.4043
534.903	30.8027
535.067	41.125
535.231	46.2402
535.395	25.8496
535.559	36.2734
535.723	36.334
535.887	46.5254
536.051	36.0195
536.215	67.1563
536.379	41.4609
536.543	15.6743
536.707	57.5215
536.871	31.709
537.035	52.9395
537.199	63.4316
537.363	42.2363
537.527	52.3359
537.691	41.1504
537.856	45.9473
538.02	56.3125
538.184	61.4004
538.348	76.9102
538.512	41.4531
538.676	56.3164
538.84	25.6318
539.004	41.1211
539.168	36.0723
539.332	25.709
539.496	61.6836
539.66	56.5859
539.824	25.7422
539.988	56.5195
540.152	31.0498
540.316	87.3086
540.48	51.4238
540.644	62.2188
540.808	31.3594
540.972	62.7051
541.136	74.168
541.3	68.3906
541.464	58.2402
541.628	31.668

541.792	36.3379
541.957	46.5
542.121	51.2246
542.285	66.1406
542.449	51.6152
542.613	25.8486
542.777	56.6777
542.941	41.4434
543.105	51.5234
543.269	30.8623
543.433	25.6533
543.597	41.248
543.761	36.0664
543.925	30.9727
544.089	51.6836
544.253	30.8457
544.417	46.5566
544.581	25.7324
544.745	72.3086
544.909	20.7949
545.073	20.7344
545.237	42.0859
545.401	15.7358
545.565	47.2344
545.729	52.9551
545.893	36.6992
546.058	41.9316
546.222	25.8037
546.386	56.0703
546.55	61.3359
546.714	61.6973
546.878	20.6055
547.042	36.4004
547.206	41.2637
547.37	46.0449
547.534	40.9902
547.698	61.6387
547.862	61.6855
548.026	46.3828
548.19	51.5313
548.354	36.0566
548.518	46.375
548.682	30.793
548.846	51.7188
549.01	41.291
549.174	62.3477
549.338	52.1797
549.502	57.6113
549.666	15.8086
549.83	73.6133
549.995	63.4902
550.159	21.1221
550.323	26.2412
550.487	46.4336
550.651	61.3945
550.815	46.1367
550.979	66.7852
551.143	51.7559
551.307	41.4785
551.471	36.2031
551.635	46.1484
551.799	45.9609
551.963	61.6016
552.127	25.5693
552.291	51.334
552.455	56.3789
552.619	56.4414
552.783	41.3613
552.947	51.3945
553.111	51.6016
553.275	46.2988
553.439	41.7188
553.603	57.2676
553.767	51.9063
553.931	52.8535
554.096	36.666
554.26	42.2051
554.424	37.0039
554.588	26.0215
554.752	57.084
554.916	46.2148
555.08	51.1934
555.244	30.8877
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555.572	41.3633
555.736	56.623
555.9	76.6953
556.064	56.2715
556.228	86.6992
556.392	41.0859
556.556	66.6289
556.72	41.1934
556.884	25.8594
557.048	46.4785
557.212	46.6953
557.376	46.4922
557.54	46.4141
557.704	36.1758
557.868	67.5586
558.032	52.332
558.197	68.3984
558.361	41.998
558.525	84.7617
558.689	31.6152

558.853	57.5703
559.017	52.0879
559.181	40.9609
559.345	25.541
559.509	51.1191
559.673	35.9004
559.837	46.6484
560.001	41.2129
560.165	71.6445
560.329	40.9395
560.493	45.709
560.657	40.8672
560.821	56.3828
560.985	36.041
561.149	72.1641
561.313	46.4863
561.477	25.8564
561.641	61.707
561.805	77.3516
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562.133	46.8438
562.298	62.5664
562.462	36.8379
562.626	31.7129
562.79	36.748
562.954	31.4629
563.118	36.748
563.282	46.6758
563.446	15.4541
563.61	92.2305
563.774	46.0371
563.938	41.3359
564.102	72.4922
564.266	41.2422
564.43	51.7871
564.594	96.8555
564.758	76.7578
564.922	25.54
565.086	51.2891
565.25	51.7559
565.414	72.3516
565.578	41.4102
565.742	56.9082
565.906	46.3789
566.07	56.4043
566.234	36.25
566.399	46.5664
566.563	41.8145
566.727	57.832
566.891	36.5859
567.055	58.0625
567.219	47.4082
567.383	31.4961
567.547	57.2129
567.711	77.3828
567.875	76.8242
568.039	56.2988
568.203	41.0918
568.367	41.2871
568.531	62.0957
568.695	66.5391
568.859	46.0469
569.023	46.0078
569.187	61.5957
569.351	45.9746
569.515	82.793
569.679	20.6113
569.843	30.9961
570.007	41.4063
570.171	76.8594
570.336	56.8105
570.5	46.4082
570.664	41.6309
570.828	78.1406
570.992	36.7383
571.156	31.6709
571.32	42.3574
571.484	37.1055
571.648	52.4492
571.812	41.8281
571.976	77.1992
572.14	61.7715
572.304	46.168
572.468	77.1797
572.632	46.6309
572.796	66.75
572.96	56.8008
573.124	30.6748
573.288	112.625
573.452	76.4688
573.616	102.574
573.78	66.4648
573.944	56.7266
574.108	46.4395
574.272	72.2227
574.437	56.9277
574.601	46.0586
574.765	67.1992
574.929	57.0254
575.093	46.9355
575.257	31.3457
575.421	42.3379
575.585	52.8359
575.749	47.4531

575.913	57.7715
576.077	57.1445
576.241	25.9268
576.405	51.1855
576.569	61.6465
576.733	25.707
576.897	30.7881
577.061	56.5059
577.225	56.4805
577.389	35.8086
577.553	46.0762
577.717	51.1484
577.881	46.1758
578.045	61.9434
578.209	41.0547
578.373	57.0273
578.538	15.5127
578.702	62.1465
578.866	46.041
579.03	36.1484
579.194	20.7168
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579.522	63.127
579.686	68.582
579.85	52.9238
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580.342	78.2969
580.506	81.9219
580.67	35.8809
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580.998	51.0938
581.162	41.2734
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581.818	71.8398
581.982	35.8105
582.146	82.1016
582.31	51.4082
582.474	56.3359
582.639	61.7441
582.803	51.5684
582.967	35.9063
583.131	36.1602
583.295	66.707
583.459	82.9141
583.623	36.4238
583.787	41.9707
583.951	47.4082
584.115	68.8633
584.279	42.1992
584.443	31.4766
584.607	83.6797
584.771	25.5986
584.935	61.6836
585.099	25.6191
585.263	25.6025
585.427	61.9316
585.591	51.709
585.755	15.3989
585.919	41.1055
586.083	61.5176
586.247	51.3418
586.411	56.5469
586.576	51.3164
586.74	62.0156
586.904	25.7021
587.068	66.6563
587.232	51.6992
587.396	41.0684
587.56	61.791
587.724	46.4746
587.888	51.834
588.052	31.2715
588.216	47.7344
588.38	58.2637
588.544	74.0742
588.708	47.3691
588.872	83.0234
589.036	46.4277
589.2	40.9238
589.364	30.6445
589.528	25.5469
589.692	51.3672
589.856	72.0703
590.02	56.5859
590.184	51.3457
590.348	35.8223
590.512	46.2871
590.677	36.1113
590.841	77.0156
591.005	41.2129
591.169	66.5039
591.333	46.3516
591.497	30.7578
591.661	41.252
591.825	51.6348
591.989	51.7832
592.153	20.7051
592.317	47.4102
592.481	63.2559
592.645	42.5957
592.809	69.2031

592.973	47.3887
593.137	57.2012
593.301	66.9219
593.465	71.457
593.629	46.0137
593.793	66.4219
593.957	82.7695
594.121	51.7188
594.285	25.7607
594.449	77.0781
594.613	51.0059
594.778	66.6094
594.942	66.7891
595.106	51.082
595.27	20.5039
595.434	97.6094
595.598	56.418
595.762	61.6387
595.926	30.8535
596.09	66.707
596.254	46.707
596.418	20.8672
596.582	62.625
596.746	37.1191
596.91	52.8145
597.074	47.4199
597.238	47.4453
597.402	46.916
597.566	61.8203
597.73	20.4473
597.894	55.8457
598.058	56.2656
598.222	25.7461
598.386	87.9258
598.55	82.2891
598.714	82.0508
598.879	25.4473
599.043	56.4336
599.207	56.3184
599.371	71.7617
599.535	77.1484
599.699	76.9336
599.863	72.0703
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600.519	129.656
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600.847	120.207
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601.339	110.539
601.503	78.8359
601.667	77.8945
601.831	113.238
601.995	111.492
602.159	86.5859
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602.651	139.141
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603.8	97.1445
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604.292	102.309
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604.62	113.691
604.784	98.2344
604.948	115.195
605.112	104.734
605.276	131.258
605.44	105.188
605.604	121.02
605.768	110.25
605.932	119.723
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606.588	101.711
606.752	139.445
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607.081	134.234
607.245	66.6328
607.409	111.727
607.573	107.086
607.737	133.359
607.901	107.07
608.065	97.5938
608.229	123.422
608.393	112.719
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609.213	139.75
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613.478	125.172
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614.134	73.6133
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614.462	130.461
614.626	102.984
614.79	138.594
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615.119	158.594
615.283	107.41
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615.775	102.309
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616.759	92.2695
616.923	118.895
617.087	123.652
617.251	97.1016
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617.579	149.133
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617.907	151.828
618.071	131.297
618.235	120.973
618.399	130.844
618.563	131.133
618.727	88.3164
618.891	118.57
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619.22	112.867
619.384	132.367
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619.712	138.68
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620.696	122.695
620.86	143.836
621.024	108.379
621.188	118.676
621.352	154.773
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621.68	108.039
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622.172	78.2148
622.336	148.07
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623.157	103.137
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623.485	127.152
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623.813	107.406
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626.109	82.3867
626.273	109.07
626.437	88.5469
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626.765	136.492
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631.359	115.039
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632.999	113.711
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634.639	70.4844
634.803	116.184
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635.296	123.809
635.46	92.6719
635.624	149.25
635.788	137.563
635.952	136.094
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638.248	111.34
638.412	65.7148
638.576	95.5977
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638.904	76.8906
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641.857	111.262
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644.318	147.18
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645.958	117.414
646.122	133.164
646.286	76.5898
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647.927	112.676
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648.419	120.32
648.583	140.852
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649.239	162.125
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649.567	140.453
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650.387	130.32
650.551	78.9219
650.715	132.055
650.879	156.586
651.043	110.547
651.207	116.262
651.371	68.9648
651.535	129.313
651.7	113.441
651.864	100.441
652.028	125.008
652.192	105.352
652.356	134.555
652.52	106.449
652.684	127.551
652.848	112.473
653.012	124.121
653.176	116.715
653.34	138.891
653.504	146.383
653.668	124.336
653.832	109.563
653.996	125.93
654.16	124.965
654.324	129.922
654.488	120.398
654.652	135.156
654.816	118.547
654.98	152.25
655.144	134.164
655.308	112.211
655.472	137.109
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658.261	130.953
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658.589	116.457
658.753	111.543
658.917	135.945
659.081	163.031
659.245	122.227
659.409	113.438
659.573	120.148
659.738	130.633
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660.066	119.566
660.23	130.883
660.394	111.43
660.558	101.836
660.722	145.5
660.886	111.367
661.05	131.164

661.214	127.008
661.378	114.57
661.542	120.797
661.706	124.809
661.87	128.727
662.034	147.469
662.198	111.402
662.362	121.207
662.526	118.539
662.69	128.859
662.854	137.859
663.018	113.938
663.182	119.051
663.346	124.824
663.51	122.035
663.674	112.055
663.839	148.719
664.003	120.473
664.167	124.93
664.331	101.73
664.495	110.746
664.659	130.406
664.823	144.195
664.987	123.203
665.151	111.305
665.315	134.336
665.479	126.602
665.643	106.98
665.807	119.617
665.971	129.703
666.135	121.008
666.299	148.633
666.463	140.867
666.627	108.305
666.791	126.008
666.955	143.406
667.119	122.309
667.283	135.414
667.447	166.211
667.611	116.055
667.775	119.227
667.94	137.789
668.104	109.055
668.268	109.637
668.432	136.445
668.596	138.336
668.76	137.906
668.924	116.727
669.088	133.422
669.252	129.617
669.416	125.824
669.58	143
669.744	130.406
669.908	112.363
670.072	122.984
670.236	126.066
670.4	91.6484
670.564	137.914
670.728	103.457
670.892	121.746
671.056	135.492
671.22	127.16
671.384	116.871
671.548	120.582
671.712	136.375
671.877	98.8555
672.041	116.488
672.205	135.289
672.369	122.516
672.533	107.922
672.697	120.156
672.861	131.844
673.025	115.43
673.189	135.344
673.353	128.266
673.517	134.68
673.681	127.676
673.845	113.949
674.009	133.633
674.173	142.766
674.337	133.852
674.501	123.383
674.665	131.039
674.829	118.074
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675.321	143.047
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675.649	99.1641
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676.634	125.461
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677.126	124.359
677.29	138.328
677.454	138.578
677.618	127.836
677.782	122.668
677.946	133.867
678.11	90.8594

678.274	121.543
678.438	150.625
678.602	104.383
678.766	112.777
678.93	147.906
679.094	135.648
679.258	102.051
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679.586	112.184
679.75	138.164
679.914	103.555
680.079	117.242
680.243	130.844
680.407	109.492
680.571	122.512
680.735	136.984
680.899	111.383
681.063	129.805
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681.391	109.535
681.555	140.594
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681.883	98.5117
682.047	108.305
682.211	98.6211
682.375	120.273
682.539	134.625
682.703	122.293
682.867	109.883
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683.195	111.973
683.359	115.75
683.523	112.844
683.687	107.523
683.851	117.086
684.015	115.152
684.18	149.492
684.344	132.219
684.508	118.391
684.672	112.504
684.836	135.117
685	147
685.164	115.012
685.328	121.504
685.492	113.82
685.656	107.43
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685.984	133.117
686.148	154.023
686.312	136.508
686.476	125.305
686.64	151.055
686.804	116.273
686.968	123.477
687.132	133.359
687.296	113.16
687.46	112.313
687.624	147.141
687.788	129.797
687.952	117.336
688.117	120.883
688.281	131.547
688.445	131.68
688.609	116.527
688.773	141.539
688.937	140.008
689.101	131.859
689.265	124.121
689.429	106.473
689.593	135.617
689.757	131.484
689.921	127.758
690.085	124.738
690.249	126.617
690.413	128.938
690.577	115.57
690.741	101.668
690.905	121.461
691.069	120.512
691.233	136.695
691.397	126.59
691.561	105.664
691.725	138.438
691.889	128.453
692.053	129.313
692.218	123.895
692.382	126.188
692.546	103.504
692.71	132.727
692.874	126.41
693.038	130.641
693.202	122.23
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693.53	128.617
693.694	117.688
693.858	152.156
694.022	110.848
694.186	112.691
694.35	129.078
694.514	118.801
694.678	107.559
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695.99	136.406
696.154	118.855
696.319	125.113
696.483	126.418
696.647	130.531
696.811	129.516
696.975	126.84
697.139	129.648
697.303	145.688
697.467	118.141
697.631	116.594
697.795	121.395
697.959	104.293
698.123	118.152
698.287	132.141
698.451	115.141
698.615	108.637
698.779	138.672
698.943	107.59
699.107	151.57
699.271	148.18
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699.599	118.246
699.763	111.641
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700.091	112.602
700.255	141.711
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700.912	120.18
701.076	158.75
701.24	132.617
701.404	114.074
701.568	125.914
701.732	135.883
701.896	118.43
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702.552	136.102
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703.208	98.9922
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704.685	134.109
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705.013	133.664
705.177	126.824
705.341	122.445
705.505	137.648
705.669	119.734
705.833	135.758
705.997	131.875
706.161	121.98
706.325	113.691
706.489	123.914
706.653	134.828
706.817	93.2578
706.981	123.543
707.145	119.23
707.309	148.109
707.473	123.32
707.637	151.625
707.801	139.609
707.965	145.766
708.129	154.688
708.293	126.73
708.458	111.906
708.622	127.887
708.786	148.469
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709.114	104.93
709.278	117.371
709.442	131.844
709.606	125.543
709.77	122.969
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710.754	110.676
710.918	134.234
711.082	120.305
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711.574	119.762
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712.066	78.3633
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712.559	121.09
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713.051	104.746
713.215	100.031
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713.707	129.742
713.871	146.625
714.035	79.5508
714.199	80.375
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715.019	69.8867
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715.347	132
715.511	146.914
715.675	126.305
715.839	100.996
716.003	106.355
716.167	111.535
716.331	141.383
716.495	101.109
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716.988	122.66
717.152	91.7422
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717.48	142.461
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717.808	113.602
717.972	135.023
718.136	129.93
718.3	140.273
718.464	109.902
718.628	124.996
718.792	87.9414
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719.284	166.195
719.448	108.793
719.612	89.5352
719.776	103.84
719.94	122.746
720.104	138.164
720.268	127.434
720.432	128.109
720.597	64.5586
720.761	108.629
720.925	149.469
721.089	178.219
721.253	114.555
721.417	114.199
721.581	128.57
721.745	66.293
721.909	102.93
722.073	113.039
722.237	139.883
722.401	134.586
722.565	135.352
722.729	141.273
722.893	145.977
723.057	153.633
723.221	122.516
723.385	145.992
723.549	116.359
723.713	111.809
723.877	96.7148
724.041	148.43
724.205	128.156
724.369	134.43
724.533	150.508
724.698	151.031
724.862	125.418
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725.19	167.188
725.354	120.266
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726.174	121.375
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726.502	116.477
726.666	85.5781
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727.322	136.008
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727.65	134.547
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727.978	114
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728.47	150.078
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728.799	119.281
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729.127	140.984
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729.783	166.641
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730.111	135.148
730.275	136.781
730.439	158.797
730.603	106.422
730.767	148.883
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731.751	150.445
731.915	129.883
732.079	124.266
732.243	114.594
732.407	118.5
732.571	155.336
732.735	94.0898
732.9	129.82
733.064	104.746
733.228	109.418
733.392	166.375
733.556	104.605
733.72	94.0156
733.884	88.6719
734.048	98.8242
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734.376	100.121
734.54	146.938
734.704	116.609
734.868	138.039
735.032	150.234
735.196	180.969
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735.524	121.137
735.688	82.9844
735.852	113.758
736.016	123.887
736.18	124.449
736.344	182.305
736.508	139.383
736.672	155.563
736.837	114.414
737.001	118.957
737.165	125.289
737.329	114.762
737.493	171.336
737.657	94.1836
737.821	146.094
737.985	156.047
738.149	109.883
738.313	83.0547
738.477	115.934
738.641	142.578
738.805	121.93
738.969	121.879
739.133	160.398
739.297	96.3398
739.461	133.023
739.625	132.227
739.789	150.945
739.953	124.137
740.117	139.313
740.281	124.383
740.445	145.68
740.609	98.5508
740.773	82.6133
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741.102	155.789
741.266	108.871
741.43	104.406
741.594	73.0547
741.758	98.6758
741.922	130.617
742.086	93.5547
742.25	141.273
742.414	114.609
742.578	130.961
742.742	136.984
742.906	132.055
743.07	127.277
743.234	111.641
743.398	148.938
743.562	133.742
743.726	101.582
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744.054	133.945
744.218	108.625
744.382	153.508
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744.874	155.063
745.039	57.4531
745.203	135.297
745.367	145.242
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746.187	98.6836
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746.843	169.328
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747.335	100.973
747.499	116.664
747.663	138.523
747.827	132.75
747.991	140.93
748.155	156.906
748.319	87.5
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748.811	129.953
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749.14	133.602
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749.632	98.3906
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750.124	145.445
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750.616	177.484
750.78	119.824
750.944	131.805
751.108	84.457
751.272	105.59
751.436	133.063
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751.764	95.3359
751.928	127.852
752.092	136.844
752.256	130.734
752.42	151.031
752.584	108.301
752.748	103.906
752.912	67.9961
753.076	115
753.241	120.203
753.405	167.148
753.569	125.25
753.733	146.867
753.897	152.016
754.061	115.32
754.225	110.43
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754.717	167.164
754.881	99.4258
755.045	131.313
755.209	147.422
755.373	131.75
755.537	138.008
755.701	127.527
755.865	148.602
756.029	154.32
756.193	121.688
756.357	146.547
756.521	104.27
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756.849	109.098
757.013	104.055
757.178	109.961
757.342	145.445
757.506	156.18
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757.834	151.016
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758.162	126.145
758.326	99.0703
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758.982	141.156
759.146	89.7266
759.31	174.352
759.474	126.879
759.638	116.133
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760.458	185.172
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761.607	150.984
761.771	108.805
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762.099	88.1953
762.263	147.023
762.427	172.063
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762.755	105.02
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763.247	131.078
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763.575	126.98
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763.903	154.148
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765.051	112.91
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770.793	93.082
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771.121	119.816
771.285	155.289
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772.433	111.426
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772.925	101.84
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789.986	118.855
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791.298	77.1055
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794.087	149.563
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794.579	118.059
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794.907	156.891
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796.711	103.582
796.875	127.473
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800.648	117.027
800.812	133.414
800.976	92.7422
801.14	124.297
801.304	113.234
801.468	129.414
801.632	88.3672
801.796	92.3125
801.961	122.555
802.125	90.1523
802.289	95.0508
802.453	109.895
802.617	104.406
802.781	114.348
802.945	69.5117
803.109	98.7852
803.273	124.406
803.437	79.5039
803.601	84.8008
803.765	95.8125
803.929	100.5
804.093	55.0918
804.257	100.551
804.421	110.344
804.585	55.2695
804.749	96.7422
804.913	71.9375
805.077	92.957
805.241	98.1758
805.405	67.4531
805.569	92.8047
805.733	102.75
805.897	92
806.062	111.855
806.226	90.1992
806.39	105.152
806.554	89.8555
806.718	120.152
806.882	93.9258
807.046	74.8672
807.21	123.918
807.374	105.105
807.538	94.7031
807.702	75.1992
807.866	65.1328
808.03	90.9727
808.194	95.9492
808.358	115.93
808.522	85.6172
808.686	85.9492
808.85	66.7383
809.014	87.4297
809.178	92.4258
809.342	51.6445
809.506	113.418
809.67	102.914
809.834	102.645
809.998	91.3633
810.163	81.0664
810.327	90.5625
810.491	94.8164
810.655	69.9063
810.819	84.793
810.983	128.703
811.147	79.4844
811.311	49.5547
811.475	110.176
811.639	90.0078
811.803	75.5273
811.967	55.1973
812.131	75.8047
812.295	85.2578
812.459	75.1719
812.623	121.188
812.787	91.0625
812.951	71.9922
813.115	67.0703
813.279	92.2227
813.443	82.7578
813.607	82.75
813.771	93.1953
813.935	72.5664
814.099	50.9961
814.264	80.75
814.428	95.332
814.592	80.0352

814.756	79.9375
814.92	64.8125
815.084	94.0508
815.248	84.6953
815.412	59.5938
815.576	79.7227
815.74	90.5156
815.904	40.123
816.068	85.625
816.232	85.7109
816.396	60.0957
816.56	115.207
816.724	106.371
816.888	81.4219
817.052	92.1797
817.216	61.8281
817.38	56.8066
817.544	77.2461
817.708	98.9063
817.872	93.168
818.036	46.4004
818.2	60.9844
818.365	100.688
818.529	125.074
818.693	84.8867
818.857	74.4336
819.021	84.8125
819.185	89.1406
819.349	104.148
819.513	99.3047
819.677	74.9688
819.841	75.3281
820.005	75.8047
820.169	70.543
820.333	55.6582
820.497	55.3398
820.661	85.4961
820.825	96.7227
820.989	91.9336
821.153	87.5352
821.317	98.0586
821.481	61.9277
821.645	67.1953
821.809	57.3965
821.973	77.207
822.137	51.2188
822.301	76.1172
822.466	90.1719
822.63	70.0703
822.794	94.0117
822.958	34.623
823.122	94.0273
823.286	93.8164
823.45	64.75
823.614	74.9688
823.778	74.8555
823.942	136.516
824.106	95.3906
824.27	85.2852
824.434	60.6406
824.598	70.293
824.762	90.3555
824.926	61.1973
825.09	71.6289
825.254	61.5762
825.418	82.6836
825.582	108.559
825.746	72.75
825.91	98.4023
826.074	92.3164
826.238	71.1563
826.402	110.52
826.567	105.125
826.731	104.68
826.895	49.7832
827.059	133.375
827.223	103.867
827.387	99.4141
827.551	109.859
827.715	75.2148
827.879	85.3516
828.043	85.8125
828.207	120.758
828.371	75.5273
828.535	65.1055
828.699	74.8516
828.863	102.141
829.027	91.7695
829.191	50.9668
829.355	71.4414
829.519	87.9141
829.683	36.0566
829.847	25.9912
830.011	61.5801
830.175	71.3203
830.339	69.9258
830.504	65.1445
830.668	54.4883
830.832	35.3633
830.996	49.8418
831.16	101.633
831.324	35.166
831.488	76.0898
831.652	35.248

831.816	35.5684
831.98	40.5801
832.144	50.9961
832.308	50.6602
832.472	50.9004
832.636	70.8711
832.8	55.2207
832.964	40.4043
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833.292	81.4844
833.456	62.248
833.62	82.6484
833.784	46.9219
833.948	67.2266
834.112	46.0449
834.276	61.1914
834.44	65.2656
834.605	74.5586
834.769	45.1504
834.933	80.6875
835.097	50.3828
835.261	71.3203
835.425	50.543
835.589	71.5625
835.753	40.584
835.917	40.9004
836.081	65.6875
836.245	56.0254
836.409	50.4375
836.573	60.6133
836.737	25.292
836.901	60.5645
837.065	61.1582
837.229	102.566
837.393	46.3594
837.557	61.9277
837.721	41.5273
837.885	72.3047
838.049	83.0273
838.213	71.2305
838.377	70.2695
838.541	55.2949
838.706	60.0508
838.87	50.3301
839.034	41.9453
839.198	74.0547
839.362	58.1484
839.526	55.8594
839.69	72.2773
839.854	59.5566
840.018	64.7852
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840.674	66
840.838	88.3438
841.002	52.6387
841.166	59.0898
841.33	68.8789
841.494	79.2891
	Natural Gamma
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841.33	63.0918
841.166	57.8516
841.002	55.9434
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840.674	55.4023
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840.182	60.0586
840.018	51.625
839.854	59.7305
839.69	57.3105
839.526	57.8945
839.362	60.0625
839.198	62.5859
839.034	52.6777
838.87	51.3203
838.706	54.0234
838.541	59.5332
838.377	67.3555
838.213	55.0547
838.049	44.7363
837.885	74.1797
837.721	56.293
837.557	60.1367
837.393	41.5234
837.229	53.5801
837.065	71.3828
836.901	57.4688
836.737	90.6406
836.573	45.8574
836.409	77.0977
836.245	51.5625
836.081	79.375
835.917	54.6035
835.753	60.0547
835.589	60.0898
835.425	63.7754
835.261	72.5469
835.097	64.8867
834.933	51.7363
834.769	71.4453

834.605	53.7637
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834.112	66.5039
833.948	39.1289
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833.62	52.4688
833.456	66.25
833.292	61.2031
833.128	47.2266
832.964	62.3027
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832.636	59.834
832.472	61.6133
832.308	45.9824
832.144	67.3945
831.98	49.0234
831.816	77.918
831.652	66.1133
831.488	61.9766
831.324	58.8242
831.16	41.1406
830.996	63.3262
830.832	71.5273
830.668	51.2246
830.504	69.8281
830.339	44.2246
830.175	55.3848
830.011	53.1641
829.847	60.3809
829.683	35.7695
829.519	69.5547
829.355	53.377
829.191	53.4492
829.027	65.7891
828.863	55.9746
828.699	71.5547
828.535	82.5117
828.371	78.5938
828.207	70.7539
828.043	76.7539
827.879	83.1953
827.715	86.5313
827.551	93.0352
827.387	65.6836
827.223	107.379
827.059	82.3867
826.895	87.8203
826.731	80.4023
826.567	64.5195
826.402	77.4297
826.238	87.4492
826.074	107.613
825.91	86.0859
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825.582	86.0078
825.418	81.5938
825.254	79.7578
825.09	110.578
824.926	98.9531
824.762	99.3047
824.598	107.266
824.434	107.148
824.27	86.332
824.106	76.5586
823.942	82.1992
823.778	83.8242
823.614	93.9961
823.45	76.5039
823.286	91.8945
823.122	90.9063
822.958	98.8438
822.794	119.332
822.63	84.9102
822.466	82.5039
822.301	91.1992
822.137	62.4883
821.973	82.3008
821.809	84.2617
821.645	93.0117
821.481	94.4922
821.317	64.7148
821.153	70.9258
820.989	72.0625
820.825	77.1289
820.661	68.2227
820.497	90.9531
820.333	76.8125
820.169	71.7734
820.005	86.9297
819.841	66.3242
819.677	79.793
819.513	87.4727
819.349	79.6484
819.185	98.4766
819.021	84.3672
818.857	88.3398
818.693	70.7578
818.529	74.9063
818.365	98.2969
818.2	65.6875
818.036	70.8477
817.872	83.7344
817.708	79.5469

817.544	72.4844
817.38	90.0742
817.216	77.6719
817.052	92.4688
816.888	74.6758
816.724	93.5039
816.56	75.4883
816.396	71.9297
816.232	71.1836
816.068	82.9883
815.904	86.1133
815.74	92.3164
815.576	56.3047
815.412	75.9023
815.248	88.3555
815.084	72.0938
814.92	78.3945
814.756	84.2422
814.592	81.4297
814.428	81.6055
814.264	65.7266
814.099	71.9648
813.935	73.1094
813.771	80.7852
813.607	85.7188
813.443	73.4766
813.279	78.1875
813.115	85.1367
812.951	70.1328
812.787	80.8125
812.623	108.293
812.459	67.5781
812.295	79.3398
812.131	93.9492
811.967	91.3906
811.803	80.5625
811.639	80.7148
811.475	89.1133
811.311	87.2266
811.147	88.3242
810.983	55.9766
810.819	71.2383
810.655	69.7188
810.491	90.6602
810.327	80.9805
810.163	75.125
809.998	81.4141
809.834	73.3359
809.67	70.1055
809.506	93.582
809.342	89.1328
809.178	117.129
809.014	90.043
808.85	107.121
808.686	96.0078
808.522	79.3945
808.358	85.9414
808.194	74.6484
808.03	77.625
807.866	88.9336
807.702	81.2969
807.538	82.332
807.374	99.3477
807.21	105.746
807.046	118.895
806.882	101.918
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805.897	87.8438
805.733	74.8086
805.569	68.2773
805.405	79.0078
805.241	88.7305
805.077	93.168
804.913	102.344
804.749	87.375
804.585	78.6992
804.421	85.9531
804.257	89.7813
804.093	93.2188
803.929	74.8047
803.765	112.418
803.601	66.4688
803.437	122.371
803.273	93.1797
803.109	103.523
802.945	101.609
802.781	91.543
802.617	98.1523
802.453	102.328
802.289	88.457
802.125	104.422
801.961	106.289
801.796	87.6875
801.632	85.7188
801.468	138.523
801.304	128.852
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800.976	99.3984
800.812	94.8125
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799.992	101.984
799.828	108.977
799.664	86.1523
799.5	114.84
799.336	75.5859
799.172	110.688
799.008	87.2148
798.844	106.164
798.68	97.4023
798.516	89.4727
798.352	122.711
798.188	112.797
798.024	99.3594
797.86	113.84
797.695	95.125
797.531	147.305
797.367	120.113
797.203	106.086
797.039	124.082
796.875	99.4727
796.711	130.25
796.547	115.809
796.383	92.4141
796.219	148.578
796.055	131.766
795.891	116.496
795.727	108.039
795.563	106.449
795.399	110.066
795.235	126.031
795.071	123.594
794.907	113.441
794.743	119.48
794.579	106.277
794.415	113.926
794.251	100.441
794.087	134.313
793.923	123.355
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793.594	123.977
793.43	110.336
793.266	104.867
793.102	113.328
792.938	99.5195
792.774	117.18
792.61	123.344
792.446	104.035
792.282	118.184
792.118	104.797
791.954	104.215
791.79	124.332
791.626	101.75
791.462	128.555
791.298	116.676
791.134	93.8672
790.97	87.0195
790.806	104.203
790.642	134.805
790.478	101.852
790.314	129.93
790.15	108.121
789.986	124.32
789.822	124.551
789.658	108.953
789.493	96
789.329	125.992
789.165	116.359
789.001	128
788.837	104.418
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788.345	109.52
788.181	109.289
788.017	121.633
787.853	127.379
787.689	128.938
787.525	150.125
787.361	113.781
787.197	124.645
787.033	138.414
786.869	104.008
786.705	151.43
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786.377	104.555
786.213	159.234
786.049	103.484
785.885	137.961
785.721	136.344
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785.392	124.328
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785.064	140.648
784.9	107.418
784.736	123.785
784.572	140.813
784.408	127.84
784.244	121.215
784.08	117.453
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783.752	101.051
783.588	123.758

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783.096	114.621
782.932	127.652
782.768	119.711
782.604	119.227
782.44	130.133
782.276	130.055
782.112	139.313
781.948	114.199
781.784	143.609
781.62	104.551
781.455	136.398
781.291	118.125
781.127	116.297
780.963	139.852
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780.635	126.293
780.471	123.633
780.307	137.547
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779.979	117.754
779.815	136.211
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779.487	113.641
779.323	136.688
779.159	117.582
778.995	131.453
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778.667	110.027
778.503	159.344
778.339	137.039
778.175	126.082
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777.847	121.609
777.683	121.699
777.519	120.734
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777.19	128.586
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776.206	119.566
776.042	123.621
775.878	102.355
775.714	100.746
775.55	120.738
775.386	106.676
775.222	129.367
775.058	114.691
774.894	146.406
774.73	98.6172
774.566	113.91
774.402	121.879
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774.074	133.219
773.91	143.773
773.746	121.27
773.582	125.398
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773.253	91.582
773.089	148.398
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772.761	125.27
772.597	122.266
772.433	143.461
772.269	142.227
772.105	137.492
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771.121	132.453
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767.184	113.84
767.02	127.902
766.856	135.758
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765.215	130.414
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764.723	127.379
764.559	94.7773
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764.231	111.875
764.067	118.023
763.903	128.828
763.739	119.891
763.575	126.293
763.411	99.5938
763.247	114.281
763.083	99.5195
762.919	119.992
762.755	105.617
762.591	125.809
762.427	143.031
762.263	152.391
762.099	108.145
761.935	123.371
761.771	129.672
761.607	113.57
761.443	129.656
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760.95	97.0977
760.786	119.5
760.622	90.1289
760.458	149.156
760.294	128.977
760.13	146.305
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759.802	132.055
759.638	105.656
759.474	131.766
759.31	108.117
759.146	115.051
758.982	149.117
758.818	136.367
758.654	133.172
758.49	131.344
758.326	120.195
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757.998	136.758
757.834	147.523
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757.506	152.766
757.342	135.57
757.178	133.414
757.013	126.266
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756.521	122.227
756.357	112.207
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756.029	118.828
755.865	107.117
755.701	146.539
755.537	131.82
755.373	106.871
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755.045	117.531
754.881	138.93
754.717	110.738
754.553	120.258
754.389	113.211
754.225	124.008
754.061	108.008
753.897	124.551
753.733	124.602
753.569	122.281
753.405	116.414
753.241	126.105
753.076	128.586
752.912	131.594
752.748	117.465
752.584	130.258
752.42	145.719
752.256	134.961
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751.272	137.891
751.108	113.34
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750.288	144.805
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749.96	123.02
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748.975	107.586
748.811	121.98
748.647	101.27
748.483	123.695
748.319	135.805
748.155	151.438
747.991	160.352
747.827	138.516
747.663	99.2148
747.499	112.102
747.335	132.133
747.171	113.664
747.007	112.922
746.843	118.141
746.679	129.641
746.515	124.656
746.351	118.559
746.187	113.117
746.023	114.492
745.859	133.656
745.695	109.77
745.531	128.508
745.367	104.102
745.203	114.594
745.039	140.766
744.874	123.277
744.71	105.516
744.546	110.559
744.382	108.598
744.218	132.43
744.054	143.422
743.89	96.8125
743.726	124.484
743.562	121.5
743.398	111.219
743.234	99.6445
743.07	119.188
742.906	92.4922
742.742	108.914
742.578	133.023
742.414	116.793
742.25	118.41
742.086	148.328
741.922	146.508
741.758	120.27
741.594	117.43
741.43	102.043
741.266	127.211
741.102	116.82
740.938	107.484
740.773	100.621
740.609	131.586
740.445	125.191
740.281	129.688
740.117	121.953
739.953	124.355
739.789	130.977
739.625	116.504
739.461	138.891
739.297	121.805
739.133	117.125
738.969	150.992
738.805	134.375
738.641	114.313
738.477	96.3477
738.313	83.9805
738.149	142.398
737.985	119.293
737.821	122.449
737.657	110.105
737.493	126.578
737.329	112.613
737.165	105.289
737.001	135.742
736.837	103.941
736.672	139.5
736.508	134.391
736.344	106.445
736.18	115.598
736.016	112.523
735.852	118.086
735.688	106.664
735.524	113.102
735.36	121.242
735.196	109.703
735.032	104.449
734.868	103.098
734.704	128.172
734.54	144.68
734.376	118.074
734.212	127.949
734.048	111.016
733.884	135.797
733.72	130.469
733.556	119.078
733.392	139.586
733.228	135.492
733.064	117.203
732.9	119.598
732.735	149.43
732.571	115.441
732.407	110.988

732.243	109.953
732.079	119.098
731.915	110.727
731.751	123.211
731.587	128.023
731.423	148.422
731.259	149.844
731.095	134.414
730.931	117.078
730.767	138.773
730.603	151.43
730.439	128.898
730.275	132.813
730.111	116.414
729.947	113.039
729.783	100.707
729.619	129.781
729.455	124.77
729.291	112.922
729.127	144.094
728.963	115.168
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728.634	108.133
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727.322	114.609
727.158	145.133
726.994	140.945
726.83	109.668
726.666	128.117
726.502	121.66
726.338	124.898
726.174	131.898
726.01	140.023
725.846	132.742
725.682	136.328
725.518	118.293
725.354	148.758
725.19	123.926
725.026	143.563
724.862	126.418
724.698	122.258
724.533	127.016
724.369	143.367
724.205	133.141
724.041	127.098
723.877	126.719
723.713	147.086
723.549	122.168
723.385	122.281
723.221	123.711
723.057	117.754
722.893	133.531
722.729	112.973
722.565	140.359
722.401	127.801
722.237	133.07
722.073	136.258
721.909	126.25
721.745	115.961
721.581	154.242
721.417	135.68
721.253	117.449
721.089	108.379
720.925	129.789
720.761	121.074
720.597	133.609
720.432	122.727
720.268	137.727
720.104	124.41
719.94	136.688
719.776	113.285
719.612	131.969
719.448	129.547
719.284	123.992
719.12	126.227
718.956	107.25
718.792	135.484
718.628	144.625
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717.972	122.566
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717.316	135.438
717.152	117.949
716.988	128.359
716.824	125.109
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716.495	135.648
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716.003	140.359
715.839	104.109
715.675	94.8555
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715.183	111.563
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714.527	144.656
714.363	122.785
714.199	115.801
714.035	129.367
713.871	144.367
713.707	130.039
713.543	112.223
713.379	109.406
713.215	111.621
713.051	141.086
712.887	126.5
712.723	161.789
712.559	120.531
712.394	158.727
712.23	106.715
712.066	150.094
711.902	114.219
711.738	129.242
711.574	151.508
711.41	129.367
711.246	157.234
711.082	106.398
710.918	112.898
710.754	110.836
710.59	155.273
710.426	104.016
710.262	125.59
710.098	139.555
709.934	124.098
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709.606	120.973
709.442	156.445
709.278	134.43
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708.95	123.336
708.786	116.156
708.622	142.68
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708.293	110.668
708.129	121.098
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707.637	142.469
707.473	146.266
707.309	135.141
707.145	143.047
706.981	124.605
706.817	140.984
706.653	123.969
706.489	145.875
706.325	106.84
706.161	135.945
705.997	163.758
705.833	129.586
705.669	141.141
705.505	130.945
705.341	130.852
705.177	120.883
705.013	132.781
704.849	126.836
704.685	130.391
704.521	131.078
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703.536	130.359
703.372	139.219
703.208	122.906
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702.88	134.25
702.716	133.586
702.552	116.504
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700.42	133.836
700.255	106.574
700.091	132.484
699.927	101.836
699.763	131.414
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699.435	127.625
699.271	117.359
699.107	135.289
698.943	139.047
698.779	140.273
698.615	147.68
698.451	114.961
698.287	137.766

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697.303	154.555
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696.811	93.4141
696.647	135.719
696.483	134.945
696.319	130.203
696.154	125.926
695.99	109.055
695.826	138.375
695.662	133.023
695.498	126.457
695.334	143.68
695.17	131.898
695.006	137.211
694.842	118.441
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694.514	125.16
694.35	112.945
694.186	133.844
694.022	133.609
693.858	121.66
693.694	135.766
693.53	126.641
693.366	128.617
693.202	130.281
693.038	111.469
692.874	141.227
692.71	122.727
692.546	126.199
692.382	113.191
692.218	112.711
692.053	133.414
691.889	125.984
691.725	118.336
691.561	142.773
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689.921	133.5
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689.265	108.223
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688.937	120.051
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688.445	136.352
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688.117	125.438
687.952	117.254
687.788	121.605
687.624	127.641
687.46	105.781
687.296	134.602
687.132	138.211
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686.804	97.1133
686.64	106.656
686.476	157.953
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685.82	101.789
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685.164	148.281
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684.015	115.711
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683.687	125.379
683.523	122.824
683.359	119.125
683.195	110.938
683.031	95.0078
682.867	124.102
682.703	122.02
682.539	135.188
682.375	136.508
682.211	116.301
682.047	117.207
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681.227	87.7383

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680.899	138.734
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680.407	123.09
680.243	121.238
680.079	138.141
679.914	119.359
679.75	116.703
679.586	142.195
679.422	112.285
679.258	133.68
679.094	128.211
678.93	131.664
678.766	99.6367
678.602	125.773
678.438	142.344
678.274	115.805
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677.946	97.2539
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677.618	123.188
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674.665	162.516
674.501	140.453
674.337	113.238
674.173	115.18
674.009	132.211
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673.681	136.727
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673.353	120.867
673.189	117.699
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672.861	108.91
672.697	116.934
672.533	135.383
672.369	128.602
672.205	130.016
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671.877	120.426
671.712	121.355
671.548	120.895
671.384	110.965
671.22	119.824
671.056	137.383
670.892	130.266
670.728	110.5
670.564	123.902
670.4	124.762
670.236	134.594
670.072	130.977
669.908	124.242
669.744	126.762
669.58	122.375
669.416	138.383
669.252	115.066
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668.76	150.82
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667.94	147.945
667.775	127.992
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667.283	129.344
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666.955	130.898
666.791	135.383
666.627	109.227
666.463	129.555
666.299	156.102
666.135	150.211
665.971	129.93
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665.643	119.516
665.479	149.289
665.315	103.344
665.151	132.352
664.987	122.914
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664.495	139.672
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663.674	131.742
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661.214	137.578
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660.722	125.344
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658.753	133.203
658.589	109.973
658.425	144.797
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658.097	104.098
657.933	162.578
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657.441	93.8281
657.277	127.762
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656.949	130.813
656.785	127.086
656.621	125.902
656.457	114.727
656.293	115.844
656.129	133.945
655.965	139.906
655.801	124.25
655.637	124.008
655.472	119.086
655.308	133.789
655.144	114.469
654.98	111.699
654.816	119.293
654.652	125.379
654.488	99.9922
654.324	140.797
654.16	126.762
653.996	105.992
653.832	143.859
653.668	137.023
653.504	116.621
653.34	129.453
653.176	131.57
653.012	138.875
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652.684	124.367
652.52	134.711
652.356	134.336
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651.535	135.234
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650.879	137.586
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650.551	131.734
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650.223	123.75
650.059	136.344
649.895	128.625
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649.567	145.211
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649.239	111.301
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648.419	110.234
648.255	128.711
648.091	134.102
647.927	137.461
647.763	122.109
647.599	138.945
647.434	117.43
647.27	137.844
647.106	128.438

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646.286	119.063
646.122	119.934
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645.794	149.273
645.63	114.598
645.466	133.539
645.302	140.188
645.138	141.211
644.974	135.609
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644.646	127.301
644.482	122.605
644.318	115.52
644.154	108.184
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643.826	127.605
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638.74	157.164
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638.412	116.242
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638.084	108.941
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637.756	131.859
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636.608	123.879
636.444	105.695
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636.116	132.859
635.952	114.438
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635.296	137.922
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634.967	135.578
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626.273	106.445
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625.781	119.246
625.617	90.7773
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625.289	95.6328
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623.157	134.961
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621.516	147.859
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617.087	102.707
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614.134	134.57
613.97	97.957
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613.314	92.7695
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610.689	127.82
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609.869	103.578
609.705	97.1758
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609.377	130.789
609.213	98.3203
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608.885	116.219
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608.229	110.809
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607.081	98.1406
606.917	103.387
606.752	116.832
606.588	102.855
606.424	111.949
606.26	98.4648
606.096	119.383
605.932	108.352
605.768	112.602
605.604	108.016
605.44	126.344
605.276	114.883
605.112	105.238
604.948	109.004
604.784	96.7227
604.62	124.59
604.456	100.516
604.292	109.656
604.128	87.6484
603.964	137.375
603.8	109.461
603.636	77.0938
603.472	107.156
603.308	82.4648
603.144	123.27
602.98	111.551
602.816	123.344
602.651	145.953
602.487	117.48
602.323	120.762
602.159	113.043
601.995	116
601.831	110.422
601.667	105.059
601.503	109.492
601.339	114.523
601.175	121.449
601.011	103.188
600.847	112.738
600.683	97.4102
600.519	106.313
600.355	105.418
600.191	98.2539
600.027	84.3047
599.863	87.8164
599.699	70.6836
599.535	61.834
599.371	48.4316
599.207	62.8418
599.043	47.4258
598.879	41.8848
598.714	55.2734
598.55	60.6973
598.386	56.2852
598.222	53.1406
598.058	62.7422
597.894	55.7129
597.73	52.5273
597.566	37.6758
597.402	72.6758
597.238	50.1348
597.074	46.5313
596.91	41.457
596.746	63.9375
596.582	35.8848
596.418	59.4395
596.254	60.3359
596.09	61.9512
595.926	70.9336

595.762	50.873
595.598	53.8477
595.434	51.8066
595.27	68.3711
595.106	38.7031
594.942	47.1895
594.778	58.916
594.613	53.627
594.449	73.7539
594.285	54.2949
594.121	56.6387
593.957	64.9102
593.793	48.9277
593.629	65.8984
593.465	51.0039
593.301	42.8438
593.137	43.0332
592.973	53.3672
592.809	57.3906
592.645	73.1953
592.481	57.3438
592.317	66.625
592.153	33.7949
591.989	40.293
591.825	60.5059
591.661	50.4668
591.497	53.8027
591.333	43.5449
591.169	60.2109
591.005	60.7383
590.841	52.2734
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590.512	46.9629
590.348	67.1563
590.184	62.625
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589.692	49.1094
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587.068	79.1563
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586.411	58.4727
586.247	38.6152
586.083	47.1836
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585.591	57.6699
585.427	47.7969
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585.099	43.9473
584.935	74.3203
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584.607	46.502
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584.279	41.7129
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583.951	51.5488
583.787	60.4609
583.623	54.7207
583.459	47.2578
583.295	53.4961
583.131	73.7109
582.967	69.0898
582.803	44.1777
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582.474	50.3984
582.31	61.9648
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537.527	36.6113
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473.552	21.373
473.388	24.8066
473.224	19.3164
473.06	28.9121
472.896	17.7803
472.732	14.6924
472.567	30.9688
472.403	35.6367
472.239	17.9131
472.075	20.9229
471.911	14.396
471.747	22.3408
471.583	20.9658
471.419	19.459
471.255	35.3984
471.091	16
470.927	31.9014
470.763	38.5293
470.599	25.6768
470.435	33.8027
470.271	24.0928
470.107	22.583
469.943	24.5322
469.779	21.4639
469.615	28.1436
469.451	29.7969
469.287	21.5537
469.123	33.4277
468.959	21.6406
468.795	23.1016
468.631	46.1563
468.466	31.2832
468.302	19.6904
468.138	29.2656
467.974	25.8369
467.81	25.1992
467.646	33.123
467.482	19.1436
467.318	28.9541
467.154	27.1172
466.99	23.9971
466.826	19.3066
466.662	16.2246
466.498	25.9717
466.334	25.793
466.17	30.3789
466.006	19.1787
465.842	32.2793
465.678	29.5635
465.514	35.8652
465.35	31.1836
465.186	39.6074
465.022	26.666
464.858	28.5098
464.694	21.5654
464.53	34.6504
464.365	26.4277
464.201	32.998
464.037	39.4082
463.873	29.0557
463.709	20.9844
463.545	38.4863
463.381	33.9883
463.217	29.2793
463.053	30.8066
462.889	29
462.725	16.2988
462.561	31.498
462.397	26.5947
462.233	28.0518
462.069	27.7305
461.905	26.0137
461.741	26.1211
461.577	35.9102
461.413	32.9063
461.249	38.4902
461.085	33.7949
460.921	47.8359
460.757	32.666
460.593	24.0635
460.429	30.6582
460.264	42.1895
460.1	28.9619
459.936	29.0098
459.772	28.627
459.608	41.4824
459.444	31.6143

459.28	23.3906
459.116	26.9492
458.952	21.7236
458.788	36.6211
458.624	26.6211
458.46	23.4668
458.296	18.6904
458.132	30.5342
457.968	28.6816
457.804	25.3008
457.64	42.0898
457.476	35.4629
457.312	25.3525
457.148	25.2227
456.984	10.187
456.82	17.3252
456.656	31.54
456.492	26.3164
456.327	12.2871
456.163	24.4971
455.999	36.8574
455.835	31.7383
455.671	19.332
455.507	27.9619
455.343	41.625
455.179	12.0859
455.015	25.9082
454.851	31.0664
454.687	18.9199
454.523	18.9063
454.359	32.5723
454.195	31.125
454.031	33.1113
453.867	41.9316
453.703	31.4795
453.539	29.5928
453.375	39.7539
453.211	33.2402
453.047	33.1426
452.883	41.4141
452.719	36.5176
452.555	27.1318
452.391	21.9785
452.226	39.1523
452.062	40.7754
451.898	32.5039
451.734	27.5654
451.57	34.207
451.406	44.375
451.242	29.1973
451.078	20.6553
450.914	29.3984
450.75	37.7129
450.586	31.875
450.422	29.8213
450.258	36.2402
450.094	33.3887
449.93	31.6924
449.766	41.2461
449.602	42.832
449.438	47.791
449.274	26.5508
449.11	21.6592
448.946	36.1641
448.782	31.3389
448.618	21.5264
448.454	26.8057
448.29	37.332
448.125	32.0215
447.961	25.2139
447.797	23.7695
447.633	36
447.469	27.4883
447.305	37.6152
447.141	25.4102
446.977	25.3887
446.813	30.5371
446.649	30.6406
446.485	35.2051
446.321	41.4375
446.157	29.7012
445.993	31.3262
445.829	31.5342
445.665	39.7324
445.501	18.1484
445.337	39.5781
445.173	28.1113
445.009	43.2773
444.845	50.0957
444.681	38.0254
444.517	36.0508
444.353	23.1494
444.189	35.0313
444.024	42.0625
443.86	21.9961
443.696	30.2598
443.532	22.127
443.368	32.6387
443.204	18.9629
443.04	39.3828
442.876	27.0928
442.712	16.9502
442.548	28.9863
442.384	33.9102

442.22	35.291
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441.892	33.1563
441.728	38.168
441.564	24.9473
441.4	44.7754
441.236	24.7549
441.072	27.9863
440.908	24.8525
440.744	34.8008
440.58	28.0938
440.416	29.541
440.252	39.3984
440.087	21.5859
439.923	31.5889
439.759	38.2891
439.595	28.6143
439.431	25.5156
439.267	38.8711
439.103	44.3438
438.939	25.6553
438.775	25.6504
438.611	22.1982
438.447	25.6924
438.283	25.6904
438.119	13.624
437.955	37.1484
437.791	38.5039
437.627	21.6367
437.463	29.9629
437.299	39.6777
437.135	36.3027
436.971	31.1934
436.807	34.6035
436.643	34.5977
436.479	37.7734
436.315	24.8086
436.151	44.6875
435.986	24.8115
435.822	36.4395
435.658	19.8164
435.494	29.6514
435.33	34.7461
435.166	30.3008
435.002	51.0859
434.838	32.1133
434.674	26.9385
434.51	23.8643
434.346	29.1289
434.182	41.7129
434.018	23.9082
433.854	38.9648
433.69	23.6006
433.526	23.627
433.362	28.5303
433.198	31.8037
433.034	28.1943
432.87	31.5039
432.706	26.6143
432.542	45.1973
432.378	31.6875
432.214	37.9453
432.05	31.2783
431.885	39.6953
431.721	41.6875
431.557	31.3496
431.393	24.415
431.229	37.7461
431.065	35.0781
430.901	20.1914
430.737	35.5469
430.573	30.042
430.409	33.3887
430.245	32.1445
430.081	29.1563
429.917	43.127
429.753	32.4453
429.589	28.9326
429.425	35.5293
429.261	33.8145
429.097	33.873
428.933	47.3066
428.769	19.9492
428.605	26.0557
428.441	31.4014
428.277	44.8008
428.113	43.1172
427.949	33.0488
427.784	36.2773
427.62	44.9434
427.456	16.7354
427.292	23.5137
427.128	30.0898
426.964	31.7061
426.8	44.248
426.636	27.7275
426.472	44.7051
426.308	34.3301
426.144	20.4746
425.98	41.3496
425.816	38.8105
425.652	33.5645
425.488	15.7998
425.324	34.9766

425.16	27.9092
424.996	42.002
424.832	20.7979
424.668	39.6602
424.504	28.9619
424.34	37.373
424.176	23.8037
424.012	28.9502
423.847	40.6719
423.683	42.6406
423.519	25.5693
423.355	22.1748
423.191	32.4844
423.027	30.6484
422.863	22.0879
422.699	33.7012
422.535	23.5557
422.371	25.4238
422.207	25.6318
422.043	42.1992
421.879	36.9785
421.715	40.4629
421.551	45.3691
421.387	33.7344
421.223	19.2334
421.059	24.5244
420.895	37.8066
420.731	37.4609
420.567	25.5029
420.403	36.4941
420.239	32.7715
420.075	27.1719
419.911	31.6055
419.746	35.5
419.582	36.8457
419.418	28.4766
419.254	28.4453
419.09	33.7109
418.926	35.6289
418.762	39.1309
418.598	39.3379
418.434	27.1084
418.27	35.9395
418.106	44.3438
417.942	28.835
417.778	32.2109
417.614	32.5527
417.45	27.873
417.286	46.7012
417.122	29.3828
416.958	36.6406
416.794	35.0547
416.63	33.4609
416.466	31.7803
416.302	29.8213
416.138	34.7109
415.974	25.9404
415.81	22.416
415.645	27.5029
415.481	39.5
415.317	15.2866
415.153	30.3145
414.989	35.6367
414.825	28.9668
414.661	35.8008
414.497	40.625
414.333	21.998
414.169	25.6709
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413.841	28.9893
413.677	37.248
413.513	23.752
413.349	40.793
413.185	39.4531
413.021	41.5762
412.857	33.1367
412.693	39.7266
412.529	33.1738
412.365	29.8604
412.201	35.4883
412.037	37.0176
411.873	33.2715
411.708	27.8633
411.544	36.7891
411.38	33.1719
411.216	32.9727
411.052	30.8516
410.888	37.4531
410.724	28.7275
410.56	23.8301
410.396	22.1416
410.232	38.957
410.068	47.2266
409.904	40.5352
409.74	22.4893
409.576	38.7031
409.412	33.2402
409.248	19.0508
409.084	27.6084
408.92	34.8145
408.756	29.7334
408.592	32.8965
408.428	24.1563
408.264	24.3115

408.1	30.4639
407.936	23.9258
407.772	27.4932
407.607	31.001
407.443	32.5391
407.279	32.2285
407.115	30.6582
406.951	40.7715
406.787	23.6318
406.623	18.3496
406.459	18.3174
406.295	23.5166
406.131	21.9189
405.967	20.167
405.803	36.791
405.639	16.7012
405.475	23.5068
405.311	23.4912
405.147	25.0703
404.983	19.9639
404.819	13.3281
404.655	21.8652
404.491	16.9785
404.327	16.9521
404.163	26.8867
403.999	25.0303
403.835	23.5605
403.671	22.0518
403.506	17.084
403.342	17.0693
403.178	11.9531
403.014	17.0713
402.85	13.7119
402.686	17.0352
402.522	11.8159
402.358	21.9238
402.194	23.4961
402.03	18.417
401.866	23.374
401.702	19.9707
401.538	24.9492
401.374	26.7813
401.21	35.3555
401.046	15.0972
400.882	28.2998
400.718	14.8149
400.554	24.7256
400.39	16.6162
400.226	26.6729
400.062	21.7129
399.898	23.3867
399.734	20.1514
399.57	18.4648
399.405	20.1201
399.241	11.7925
399.077	13.5835
398.913	13.7319
398.749	17.1914
398.585	10.2803
398.421	30.6191
398.257	16.8457
398.093	20.1182
397.929	16.8086
397.765	20.0625
397.601	16.7363
397.437	13.3237
397.273	18.293
397.109	26.9043
396.945	13.5835
396.781	28.4492
396.617	26.6211
396.453	14.833
396.289	13.2461
396.125	33.1934
395.961	29.7461
395.797	24.9463
395.633	20.2314
395.468	30.4307
395.304	25.4395
395.14	11.7012
394.976	16.6914
394.812	21.8975
394.648	23.9795
394.484	25.8369
394.32	17.1182
394.156	20.3555
393.992	18.5967
393.828	11.8477
393.664	30.707
393.5	16.8887
393.336	21.4521
393.172	18.2422
393.008	23.3057
392.844	23.4316
392.68	21.75
392.516	25.0605
392.352	19.9316
392.188	13.3218
392.024	13.3789
391.86	29.9346
391.696	20.0439
391.532	13.3442
391.367	18.3564
391.203	8.46973

391.039	25.3916
390.875	20.0547
390.711	24.9785
390.547	20.123
390.383	11.9834
390.219	20.6768
390.055	18.8496
389.891	22.1973
389.727	27.1719
389.563	20.3574
389.399	22.084
389.235	16.9268
389.071	23.3447
388.907	18.2363
388.743	16.6582
388.579	18.4297
388.415	21.8047
388.251	30.1484
388.087	18.3867
387.923	16.8018
387.759	26.8066
387.595	14.9199
387.431	23.1533
387.266	21.543
387.102	18.3936
386.938	23.7012
386.774	21.9414
386.61	15.1226
386.446	20.084
386.282	23.4893
386.118	25.3242
385.954	34.1035
385.79	29.0547
385.626	17.0684
385.462	22.1641
385.298	10.2998
385.134	20.4922
384.97	11.8638
384.806	21.9883
384.642	25.0518
384.478	28.4375
384.314	20.0889
384.15	14.9902
383.986	16.6465
383.822	21.6914
383.658	16.8213
383.494	25.1797
383.33	24.8594
383.165	39.7637
383.001	23.3105
382.837	20.1523
382.673	16.8057
382.509	25.2627
382.345	11.6953
382.181	21.8223
382.017	6.72168
381.853	18.458
381.689	20.2715
381.525	20.3242
381.361	30.6016
381.197	22.3496
381.033	26.0537
380.869	23.8135
380.705	27.0488
380.541	15.1846
380.377	25.4268
380.213	30.2744
380.049	21.6904
379.885	18.3018
379.721	18.3818
379.557	21.835
379.393	11.8135
379.228	18.4805
379.064	21.5684
378.9	19.7568
378.736	23.2178
378.572	9.99951
378.408	21.7031
378.244	11.6626
378.08	26.8154
377.916	15.2676
377.752	15.251
377.588	21.7363
377.424	23.3984
377.26	18.4854
377.096	18.7012
376.932	17.1797
376.768	27.3506
376.604	23.8887
376.44	15.292
376.276	13.5317
376.112	15.2627
375.948	27.1523
375.784	20.1318
375.62	21.5605
375.456	19.9521
375.292	30.1748
375.127	16.8213
374.963	11.7305
374.799	21.6709
374.635	14.8936
374.471	21.7031
374.307	20.1191
374.143	20.0576

373.979	21.5479
373.815	23.3203
373.651	21.9219
373.487	23.6885
373.323	13.4321
373.159	18.2979
372.995	16.666
372.831	16.9268
372.667	20.5332
372.503	15.4736
372.339	23.8916
372.175	23.749
372.011	30.709
371.847	18.7158
371.683	27.0332
371.519	16.7432
371.355	16.4092
371.191	13.3271
371.026	20.1553
370.862	31.7217
370.698	26.6982
370.534	18.5088
370.37	20.0723
370.206	21.666
370.042	23.2598
369.878	18.2256
369.714	21.5391
369.55	18.4063
369.386	13.4941
369.222	27.2314
369.058	18.5352
368.894	18.332
368.73	25.0205
368.566	15.1797
368.402	16.9541
368.238	15.3271
368.074	23.8633
367.91	25.5635
367.746	20.5479
367.582	22.1914
367.418	25.3828
367.254	18.5293
367.09	15.0518
366.925	18.3809
366.761	15.0303
366.597	33.4004
366.433	18.2881
366.269	19.9727
366.105	20.1924
365.941	20.0928
365.777	16.6621
365.613	9.90869
365.449	8.24756
365.285	26.8799
365.121	23.5879
364.957	25.1514
364.793	11.7676
364.629	20.1836
364.465	21.834
364.301	23.582
364.137	13.4272
363.973	13.564
363.809	6.80859
363.645	22.3047
363.481	18.9941
363.317	18.7666
363.153	18.6289
362.989	15.084
362.824	28.7168
362.66	21.8389
362.496	19.9531
362.332	6.63208
362.168	21.5732
362.004	23.4277
361.84	11.7778
361.676	21.8555
361.512	23.3438
361.348	13.2495
361.184	26.3789
361.02	18.3252
360.856	21.7031
360.692	25.0996
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360.364	15.1064
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360.036	23.6553
359.872	18.5234
359.708	13.3936
359.544	13.5459
359.38	12.0181
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359.052	13.6567
358.887	22.0957
358.723	22.0879
358.559	20.3691
358.395	20.3857
358.231	23.335
358.067	18.1992
357.903	16.5596
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357.575	18.5088
357.411	21.7715
357.247	16.6543
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356.755	25.0889
356.591	21.6592
356.427	28.3047
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356.099	20.3369
355.935	11.8618
355.771	21.8652
355.607	18.3184
355.443	18.3154
355.279	20.29
355.115	25.7842
354.951	15.3809
354.786	22.208
354.622	43.0625
354.458	15.3237
354.294	17.0625
354.13	15.27
353.966	18.5234
353.802	29.8301
353.638	14.9932
353.474	21.8145
353.31	16.8398
353.146	15.1035
352.982	28.4297
352.818	15.0171
352.654	19.9863
352.49	19.9541
352.326	19.8838
352.162	14.8955
351.998	23.2705
351.834	26.8643
351.67	25.3262
351.506	15.2007
351.342	28.5391
351.178	20.084
351.014	21.9492
350.85	11.9224
350.685	17.0244
350.521	18.7744
350.357	18.7158
350.193	20.5605
350.029	17.1875
349.865	18.6689
349.701	21.9092
349.537	18.3818
349.373	25.1504
349.209	25.168
349.045	19.998
348.881	26.6143
348.717	20.0791
348.553	20.2051
348.389	16.7832
348.225	18.3242
348.061	13.291
347.897	11.6313
347.733	25.1094
347.569	15.1597
347.405	23.5527
347.241	25.2217
347.077	20.1504
346.913	15.1328
346.749	26.8799
346.584	18.5117
346.42	32.0859
346.256	20.3418
346.092	20.5938
345.928	15.5669
345.764	13.752
345.6	22.1914
345.436	20.3271
345.272	23.5771
345.108	25.1807
344.944	18.1943
344.78	26.625
344.616	16.6934
344.452	25.0322
344.288	33.6484
344.124	10.1587
343.96	13.3984
343.796	16.5234
343.632	14.9448
343.468	11.687
343.304	21.8184
343.14	20.0684
342.976	21.7314
342.812	15.228
342.647	35.6641
342.483	20.3096
342.319	11.7368
342.155	15.0308
341.991	10.123
341.827	15.4414
341.663	24.0635
341.499	34.2344
341.335	17.0225
341.171	23.7344
341.007	13.5552
340.843	25.583
340.679	15.1328
340.515	19.7725
340.351	13.2246
340.187	31.8643
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206.33	9.94678
206.166	16.5117
206.002	15.0059
205.838	8.32129
205.674	13.2217
205.51	13.2603
205.346	14.8652
205.182	14.8516
205.018	9.98926
204.854	11.7954
204.69	3.35657
204.526	11.6831
204.361	13.335
204.197	15.0449
204.033	13.3564
203.869	13.4067
203.705	6.75513
203.541	6.80566

203.377	17.1475
203.213	13.645
203.049	22.0049
202.885	6.66919
202.721	24.9414
202.557	4.98608
202.393	11.625
202.229	9.94531
202.065	19.9053
201.901	13.2339
201.737	13.2021
201.573	13.3687
201.409	18.3477
201.245	4.96533
201.081	14.894
200.917	11.6245
200.753	6.61816
200.589	8.24121
200.425	11.5679
200.26	3.33569
200.096	5.0415
199.932	8.43506
199.768	14.938
199.604	8.28418
199.44	6.71509
199.276	3.38721
199.112	11.9214
198.948	6.80713
198.784	8.47852
198.62	10.1396
198.456	8.38867
198.292	10.0405
198.128	15.0771
197.964	11.6401
197.8	9.92285
197.636	13.2852
197.472	8.30273
197.308	8.33203
197.144	16.627
196.98	8.28955
196.816	0
196.652	3.33118
196.488	16.6582
196.324	16.4326
196.159	8.23291
195.995	9.93164
195.831	11.7114
195.667	11.8071
195.503	10.1304
195.339	14.9395
195.175	6.59302
195.011	16.6182
194.847	15.1953
194.683	11.9619
194.519	11.9136
194.355	11.854
194.191	5.05347
194.027	11.9121
193.863	11.9019
193.699	5.02954
193.535	14.9297
193.371	18.1641
193.207	11.6738
193.043	13.3608
192.879	11.6304
192.715	14.9302
192.551	8.32471
192.387	14.9717
192.222	11.7075
192.058	11.6201
191.894	11.5112
191.73	8.20605
191.566	11.5371
191.402	6.66504
191.238	13.4775
191.074	16.7227
190.91	13.2485
190.746	11.5752
190.582	16.7139
190.418	15.1704
190.254	15.2515
190.09	16.9238
189.926	8.46582
189.762	8.43506
189.598	13.5649
189.434	8.43945
189.27	8.33105
189.106	15.0381
188.942	6.61401
188.778	9.96875
188.614	6.6853
188.45	10.0239
188.286	9.88965
188.121	11.5845
187.957	5.00024
187.793	18.3984
187.629	8.29932
187.465	13.1602
187.301	3.28723
187.137	9.99121
186.973	11.6738
186.809	20.0381
186.645	10.0791
186.481	13.2891

186.317	6.61206
186.153	1.66663
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185.825	10.0879
185.661	21.917
185.497	11.8135
185.333	10.2637
185.169	15.3369
185.005	22.0234
184.841	20.0146
184.677	18.3447
184.513	8.36719
184.349	8.29492
184.185	13.2441
184.02	13.1738
183.856	11.5796
183.692	8.36914
183.528	6.69995
183.364	18.2266
183.2	11.5747
183.036	9.97266
182.872	6.6123
182.708	8.28516
182.544	14.9282
182.38	8.28613
182.216	11.6865
182.052	11.731
181.888	11.7373
181.724	10.0332
181.56	3.32434
181.396	16.7559
181.232	11.8599
181.068	18.7324
180.904	15.3311
180.74	18.5137
180.576	15.1406
180.412	6.70239
180.248	6.74292
180.084	8.37256
179.919	16.5537
179.755	9.97656
179.591	16.6162
179.427	16.6563
179.263	1.67139
179.099	8.33789
178.935	4.97046
178.771	11.5635
178.607	18.2559
178.443	18.2617
178.279	18.2979
178.115	16.5469
177.951	4.9458
177.787	16.7012
177.623	15.3047
177.459	15.123
177.295	14.9268
177.131	24.873
176.967	11.6821
176.803	10.1675
176.639	10.207
176.475	11.894
176.311	13.6123
176.147	13.5669
175.982	10.1558
175.818	13.5552
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175.326	11.5444
175.162	8.29004
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174.834	3.33423
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174.342	11.6602
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173.522	23.0752
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170.733	13.3882
170.569	16.6816
170.405	8.31738
170.241	4.94922
170.077	13.2407
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169.585	3.32556
169.421	9.87646

169.257	9.86035
169.093	18.1953
168.929	10.0142
168.765	9.98242
168.601	15.0708
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168.273	16.6826
168.109	16.6865
167.945	4.99341
167.78	3.34766
167.616	11.7974
167.452	6.80518
167.288	11.9609
167.124	10.2144
166.96	10.1309
166.796	16.8506
166.632	10.0522
166.468	15.0029
166.304	8.32568
166.14	13.3071
165.976	9.93408
165.812	14.9189
165.648	8.31494
165.484	5.02612
165.32	21.6963
165.156	8.29541
164.992	9.94482
164.828	9.84766
164.664	11.5371
164.5	13.1367
164.336	11.5054
164.172	19.9238
164.008	13.3174
163.844	5.02148
163.679	11.6528
163.515	9.99268
163.351	15.0337
163.187	10.145
163.023	10.2651
162.859	13.689
162.695	8.48584
162.531	16.8457
162.367	10.064
162.203	11.7808
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161.547	6.61572
161.383	11.7256
161.219	11.7139
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160.891	16.5947
160.727	11.6187
160.563	9.96924
160.399	13.23
160.235	18.0957
160.071	19.6816
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159.578	13.481
159.414	10.083
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158.758	8.45654
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157.446	11.688
157.282	1.6543
157.118	14.9263
156.954	14.9619
156.79	16.6719
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156.462	13.3145
156.298	11.6006
156.134	16.7383
155.97	5.03052
155.806	16.4658
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155.477	12.9248
155.313	8.18604
155.149	10.0669
154.985	3.35352
154.821	8.34863
154.657	11.6475
154.493	16.7061
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154.165	11.8916
154.001	13.6362
153.837	6.77271
153.673	10.1587
153.509	17.0156
153.345	8.45117
153.181	13.4014
153.017	15.0142
152.853	8.2915
152.689	11.7129
152.525	15.0659
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151.869	11.6563
151.705	8.31738
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151.376	8.29688
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151.048	13.3677
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149.244	10.248
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148.916	16.9824
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148.588	11.7349
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145.307	13.3516
145.143	18.6563
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144.323	18.6143
144.159	13.4971
143.995	11.8354
143.831	10.0854
143.667	13.3701
143.503	10.0352
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143.174	18.5977
143.01	6.75684
142.846	10.0605
142.682	11.6445
142.518	13.5781
142.354	23.5967
142.19	11.8257
142.026	20.0088
141.862	22.0566
141.698	6.96899
141.534	15.1924
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141.042	11.6753
140.878	13.3076
140.714	14.9946
140.55	6.79492
140.386	20.5449
140.222	25.6123
140.058	8.47119
139.894	10.123
139.73	10.2012
139.566	5.11206
139.402	18.4727
139.237	13.3047
139.073	10.1187
138.909	6.76343
138.745	8.52051
138.581	10.2368
138.417	10.1729
138.253	13.5591
138.089	8.51514
137.925	11.9717
137.761	6.83325
137.597	10.2075
137.433	11.937
137.269	10.2739
137.105	15.5205
136.941	16.998
136.777	15.3311
136.613	6.8064
136.449	13.6152
136.285	13.7295
136.121	13.9365
135.957	14.0181
135.793	10.4082
135.629	12.1885
135.465	10.4531
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134.972	13.8076
134.808	17.1504
134.644	17.0742
134.48	10.2314
134.316	11.8809
134.152	16.8184
133.988	1.68414
133.824	13.3477
133.66	16.8174
133.496	6.75049
133.332	15.2305
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132.676	17.3271
132.512	15.2417
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132.02	23.9053
131.856	13.7773
131.692	12.0903
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131.364	15.5898
131.199	13.9419
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130.871	7.00073
130.707	15.7583
130.543	5.23438
130.379	13.8086
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129.723	8.48584
129.559	8.37354
129.395	10.0728
129.231	6.75537
129.067	13.5991
128.903	11.8159
128.739	6.7439
128.575	11.7617
128.411	13.9268
128.247	17.5693
128.083	12.1167
127.919	20.2803
127.755	13.5635
127.591	13.522
127.427	10.2813
127.263	13.877
127.098	17.4053
126.934	24.376
126.77	19.1689
126.606	19.9004
126.442	17.1035
126.278	15.2905
126.114	16.875
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125.786	10.1416
125.622	10.1904
125.458	18.3926
125.294	9.89063
125.13	11.5889
124.966	18.123
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75.4258	8.93506
75.2617	12.4185
75.0977	21.3008
74.9336	17.6709
74.7696	15.7964
74.6056	12.1284
74.4415	6.87183
74.2775	18.373
74.1134	6.91553
73.9494	12.1104
73.7854	12.083
73.6213	13.7407
73.4573	12.0664
73.2932	14.3574
73.1292	5.35596
72.9652	23.1406
72.8011	13.8105
72.6371	15.5513
72.473	17.4824
72.309	10.561
72.1449	14.2358
71.9809	24.4482
71.8169	12.3408
71.6528	10.6138
71.4888	12.4976
71.3247	16.2031
71.1607	14.3569
70.9967	19.54
70.8326	10.6567
70.6686	7.07959
70.5045	14.1836
70.3405	15.958
70.1765	8.36279
70.0124	8.62842
69.8484	24.1875
69.6843	15.6304
69.5203	15.686
69.3563	15.7139
69.1922	12.1279
69.0282	17.2998
68.8641	22.4316
68.7001	27.8877
68.5361	17.6201
68.372	35.1602
68.208	28.3604
68.0439	17.4004
67.8799	22.5566
67.7159	31.8428
67.5518	34.7539
67.3878	36.2441
67.2237	34.0918
67.0597	25.5791

66.8957	31.2451
66.7316	29.8857
66.5676	29.7969
66.4035	29.625
66.2395	24.3174
66.0755	22.7285
65.9114	34.9297
65.7474	34.6211
65.5833	37.7383
65.4193	30.9229
65.2553	34.2559
65.0912	34.4629
64.9272	38.1348
64.7631	44.7793
64.5991	38
64.4351	39.5215
64.271	29.4453
64.107	43.9199
63.9429	24.373
63.7789	32.5527
63.6149	46.5371
63.4508	47.3027
63.2868	31.8398
63.1227	50.7363
62.9587	48.3711
62.7946	39.4844
62.6306	37.4844
62.4666	51.4121
62.3025	43.3398
62.1385	36.5703
61.9745	26.377
61.8104	43.7402
61.6464	60.6973
61.4823	36.7246
61.3183	40.4551
61.1542	22.4961
60.9902	25.7559
60.8262	23.8916
60.6621	30.8223
60.4981	22.3691
60.334	34.166
60.17	22.1514
60.006	23.9063
59.8419	25.7021
59.6779	25.6602
59.5138	32.5234
59.3498	16.9932
59.1858	15.145
59.0217	18.2373
58.8577	25.6016
58.6936	17.2705
58.5296	13.8813
58.3656	12.1812
58.2015	18.9336
58.0375	12.1055
57.8734	18.9316
57.7094	24.0576
57.5454	22.415
57.3813	13.8999
57.2173	24.4434
57.0532	26.3984
56.8892	10.5151
56.7252	26.1777
56.5611	15.5786
56.3971	17.2432
56.233	12.1294
56.069	17.1816
55.905	23.918
55.7409	18.8223
55.5769	5.12549
55.4128	8.58203
55.2488	18.9141
55.0848	8.55029
54.9207	17.1152
54.7567	13.7295
54.5926	6.88574
54.4286	6.89038
54.2646	3.48547
54.1005	10.2886
53.9365	9.16992
53.7724	6.84668
53.6084	15.4023
53.4443	12.1445
53.2803	10.2559
53.1163	11.9575
52.9522	10.3608
52.7882	10.4971
52.6241	8.81738
52.4601	19.335
52.2961	10.4517
52.132	19.0928
51.968	17.3115
51.8039	17.3018
51.6399	12.0928
51.4759	15.4263
51.3118	8.55859
51.1478	15.3535
50.9837	20.5537
50.8197	24.1836
50.6557	6.91724
50.4916	18.7764
50.3276	10.3135
50.1635	18.7988
49.9995	10.2471

49.8355	13.6401
49.6714	16.957
49.5074	18.6152
49.3433	15.4258
49.1793	10.3867
49.0153	15.5806
48.8512	10.3745
48.6872	13.5864
48.5231	10.2407
48.3591	17.1904
48.1951	20.9551
48.031	15.8638
47.867	13.9697
47.7029	17.3467
47.5389	10.4512
47.3749	7.01074
47.2108	12.2124
47.0468	19.0391
46.8827	13.6997
46.7187	15.3472
46.5547	15.397
46.3906	8.58545
46.2266	13.6382
46.0625	11.957
45.8985	8.60352
45.7345	12.1001
45.5704	20.7412
45.4064	5.12207
45.2423	15.2773
45.0783	18.752
44.9142	8.46582
44.7502	8.58398
44.5862	24.0537
44.4221	20.6504
44.2581	10.252
44.094	10.2603
43.93	8.57031
43.766	12.1636
43.6019	19.2676
43.4379	13.9546
43.2738	13.9692
43.1098	15.6372
42.9458	8.75488
42.7817	8.77295
42.6177	24.3242
42.4536	15.4585
42.2896	8.58984
42.1256	5.11914
41.9615	8.51074
41.7975	8.56445
41.6334	11.9868
41.4694	17.1396
41.3054	17.1455
41.1413	12.1533
40.9773	25.9951
40.8132	10.249
40.6492	15.3545
40.4852	20.2559
40.3211	13.7197
40.1571	12.0806
39.993	10.3228
39.829	17.1895
39.665	22.4443
39.5009	13.9302
39.3369	18.9775
39.1728	17.2246
39.0088	13.8521
38.8448	19.1201
38.6807	6.98535
38.5167	14.0737
38.3526	14.042
38.1886	7.01123
38.0246	15.7666
37.8605	24.0938
37.6965	8.63379
37.5324	8.57813
37.3684	10.269
37.2044	15.3911
37.0403	11.9092
36.8763	20.5244
36.7122	29.2197
36.5482	22.4199
36.3842	29.1738
36.2201	17.1602
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35.892	10.2715
35.728	22.4199
35.564	13.6499
35.3999	15.4478
35.2359	23.9893
35.0718	29.2041
34.9078	24.2529
34.7437	24.0059
34.5797	30.9111
34.4157	24.0869
34.2516	22.5654
34.0876	12.2915
33.9235	28.5479
33.7595	13.9844
33.5955	19.0371
33.4314	17.3486
33.2674	22.4883
33.1033	19.0859
32.9393	13.8101

32.7753	11.9072
32.6112	18.8262
32.4472	15.397
32.2831	19.0391
32.1191	24.1523
31.9551	6.86377
31.791	22.2646
31.627	10.2563
31.4629	15.3599
31.2989	27.3584
31.1349	13.6387
30.9708	22.0342
30.8068	20.5527
30.6427	15.4858
30.4787	26.125
30.3147	10.3843
30.1506	32.5488
29.9866	27.2578
29.8225	17.1523
29.6585	10.4448
29.4945	22.8418
29.3304	19.2344
29.1664	24.4316
29.0023	15.668
28.8383	19.1865
28.6743	26.1182
28.5102	15.5581
28.3462	29.5068
28.1821	28.8721
28.0181	23.8438
27.8541	13.7192
27.69	15.4736
27.526	18.8086
27.3619	13.6563
27.1979	23.9863
27.0339	20.7842
26.8698	13.814
26.7058	23.9824
26.5417	6.77783
26.3777	20.4004
26.2136	25.7188
26.0496	20.7441
25.8856	24.415
25.7215	29.2275
25.5575	20.4619
25.3934	30.4443
25.2294	20.6289
25.0654	40.0645
24.9013	19.3223
24.7373	26.2617
24.5732	29.6191
24.4092	28.0195
24.2452	19.2842
24.0811	22.7217
23.9171	18.9131
23.753	22.3262
23.589	27.3555
23.425	42.7695
23.2609	18.9385
23.0969	23.9277
22.9328	18.7676
22.7688	18.999
22.6048	27.5469
22.4407	18.9082
22.2767	24.1162
22.1126	42.3477
21.9486	20.3232
21.7846	17.0684
21.6205	27.3779
21.4565	17.3613
21.2924	30.999
21.1284	24.252
20.9644	27.498
20.8003	39.3164
20.6363	32.7852
20.4722	34.5859
20.3082	34.6465
20.1442	29.5
19.9801	34.8203
19.8161	19.3633
19.652	42.0273
19.488	34.9141
19.324	27.8438
19.1599	20.6328
18.9959	20.6592
18.8318	32.5723
18.6678	23.9346
18.5038	23.8154
18.3397	28.9502
18.1757	20.5791
18.0116	18.9922
17.8476	17.2549
17.6836	17.168
17.5195	22.123
17.3555	13.645
17.1914	17.2559
17.0274	18.9697
16.8633	20.5088
16.6993	30.8623
16.5353	15.5752
16.3712	27.7236
16.2072	22.4326
16.0431	22.2256
15.8791	30.8418

15.7151	20.8008
15.551	19.2266
15.387	26.4336
15.2229	22.918
15.0589	27.8252
14.8949	20.9111
14.7308	22.5518
14.5668	27.5947
14.4027	20.7363
14.2387	23.8438
14.0747	18.6934
13.9106	27.2402
13.7466	20.6338
13.5825	17.2871
13.4185	20.5947
13.2545	15.499
13.0904	17.0986
12.9264	23.9902
12.7623	15.332
12.5983	20.4893
12.4343	15.3145
12.2702	17.1572
12.1062	25.9072
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11.7781	19.1689
11.6141	12.1152
11.45	17.0596
11.286	17.084
11.1219	15.5737
10.9579	12.2935
10.7939	22.8369
10.6298	17.4443
10.4658	13.8687
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10.1377	14.0845
9.97365	12.2217
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9.48153	20.3662
9.31749	22.1006
9.15345	17.1328
8.98941	15.3745
8.82537	22.2285
8.66133	22.2021
8.49729	17.1836
8.33325	24.1318
8.16921	12.022
8.00517	18.7939
7.84113	20.3936
7.67709	18.8037
7.51305	19.0947
7.34901	31.2881
7.18497	17.2471
7.02093	17.1035
6.85689	20.4414
6.69285	17.1328
6.52881	27.8877
6.36477	22.6875
6.20073	20.9063
6.03669	29.9209
5.87265	38.6895
5.7086	22.6924
5.54456	19.3916
5.38052	19.1406
5.21648	34.4004
5.05244	27.3965
4.8884	20.3975
4.72436	18.9248
4.56032	22.3711
4.39628	22.2705
4.23224	22.2822
4.0682	29.2129
3.90416	32.8379
3.74012	31.0527
3.57608	13.6548
3.41204	20.4248
3.248	32.2734
3.08396	18.8916
2.91992	15.5742
2.75588	25.8887
2.59184	12.1392
2.4278	18.9775
2.26376	12.0352
2.09972	22.4063
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1.77164	15.6245
1.6076	6.95898
1.44356	8.74414
1.27951	7.02686
1.11547	8.83887
0.951434	1.75677
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0.623353	8.60693
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-1.18109	10.3081

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-1.50917	5.16528
-1.67321	8.61328
-1.83725	13.7031
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-2.16533	13.8149
-2.32937	15.5825
-2.49341	15.4766