APPENDIX A
SUMMARY OF DRILLING FLUID AND ADDITIVE USE IN PHASE III BOREHOLES

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SUMMARY OF DRILLING FLUID AND ADDITIVE USE IN PHASE III BOREHOLES

This appendix is a detailed description and justification of the use of drilling fluids and drilling fluid additives in Phase III boreholes. Quantities of these materials (excluding compressed air and injection water) used over specific depth intervals are summarized in Tables A1 to A4. These tables also summarize quantities of materials used in the abandonment of the exploratory boreholes.

Exploratory Reverse-Circulation Boreholes

Exploratory boreholes were drilled using air-rotary dual-wall reverse-circulation (RC) drilling methods. The use of drilling fluids (other than compressed air) and additives was limited as much as possible to provide uncontaminated samples for further study. Conditioning of borehole walls was primarily needed in unconsolidated alluvium above the water table. Where practicable, drilling and sampling were conducted in the unsaturated zone using only air circulation over approximately 50- to 100-ft depth intervals. Borehole advancement was then stopped, and a small volume of bentonite slurry (approximately 50 lb. MAX GEL®, a polymer-coated bentonite, in approximately 100 gal. of water) was either pumped through the center tube of the drill string to the drill bit and up the annular space between the drill casing and the borehole wall or directly flooded down the annular space from the ground surface. The bentonite slurry was dried by circulating compressed air for about 1 hr. up the annular space. The borehole was then advanced and sampled using only air circulation for the next 50 to 100 ft. This method of borehole conditioning provided a stable borehole in unsaturated unconsolidated alluvium and minimized the potential for bentonite contamination of drill cuttings samples.

Use of injection water during RC drilling was restricted to the upper 20 to 50 ft of the saturated zone, where the drill hole would produce minimal water, and injection water was required to lift the moist or wet sample. Injection water was also used during the conventional circulation drilling from surface to 20 to 22.5 ft in the pilot holes used for setting a surface casing.

Drilling in the saturated zone presented very few borehole stability problems. Conditioning of borehole walls was accomplished as needed following methods similar to those used in the unsaturated zone, except for the drying-out phase. Bentonite was used sparingly to avoid sample contamination. Borehole NC-EWDP-19IM1A, where this conditioning technique was developed, had the greatest number of impacted samples. Samples from the interval from 557.5 to 605 ft. (10 samples) were not processed due to bentonite contamination. Borehole NC-EWDP-19IM2A had bentonite-contaminated samples in the interval from 370 to 380 ft (four samples), due to excessive use of bentonite when the borehole "tightened up" on the drill string. In this case, bentonite slurry was pumped down to the bit and up the annular space to loosen the drill string. Borehole NC-EWDP-22SA had a single bentonite-contaminated sample in the interval from 487.5 to 490 ft. No contaminated samples were noted in borehole NC-EWDP-10SA.

Flooded-Mud Monitoring Wells

Flooded-mud (FM) monitoring wells were drilled subsequent to exploratory RC boreholes at all four exploratory borehole locations. The FM boreholes were not sampled (except the lower portion of NC-EWDP-22S) because the RC exploratory holes provided good quality samples without contamination from drilling fluids. The FM drilling technique provides for large-

diameter, stable, and plumb boreholes ideally suited for open-hole geophysical logging and completion of multiple-screen monitor wells. FM wells were drilled using reverse FM circulation, whereby conventional single-wall drill pipe and collars are used in a borehole that is flooded with bentonite drilling fluid (mud) in the annular space. Mud is maintained and allowed to flood down the annular space from tanks or pits on the surface, and cuttings are returned through the center tube of the drill pipe. This flow direction is opposite to conventional mud drilling and is sometime called reverse drilling. Mud flow and return is initiated and controlled by injection of air into the center tube of the drill string, thereby "air-lifting" the drilling mud to the surface. The mud system provides a stable positive pressure on the borehole walls that maintains borehole integrity during borehole advancement, logging, and completion. The drilling fluid level in the annular space must be maintained to surface level to circulate the cuttings from the drill bit effectively. If lost circulation zones are encountered, usually additional additives and lost circulation materials (LCMs) are added to the drilling fluid to control the loss. In difficult lost circulation zones, the zone is usually grouted with cement grout to plug off fluid-loss zones. Drilling with FM methods develops a mud cake on the borehole walls that provides stability to the open borehole during logging and completion. After well completion, the mud cake is developed out of the sand pack and screen zones by a combination of airlift-swab and pump-swab development techniques.

Drilling fluids used for FM drilling included: AQUA GEL GOLD SEAL®, an untreated bentonite, and QUIK-GEL®, a treated (polymerized) bentonite together with soda ash (sodium carbonate) to control pH. Lesser amounts of drilling fluid additives, including DrisPac®, a polyanionic cellulose polymer, and EZ-MUD®, a liquid polyacrylamide, were used for viscosity and fluid loss control. Finally, Magma Fiber®, a mineral-based extruded "wool", BENSEAL®, granular 8-mesh untreated bentonite, and Portland cement were variously used either alone or in combination to control lost circulation.

The boreholes NC-EWDP-19IM1 and -19IM2 were drilled using drilling fluid containing only an untreated ground bentonite product, AQUA GEL GOLD SEAL®, because of concerns about adding any organic chemicals, such as polymers. A lost circulation zone encountered at total depth in -19IM1 (1,012.5 ft) required the use of 90 lb. of Magma Fiber® in an attempt to seal the rapid fluid loss in this zone. Circulation was never re-established, and the Magma Fiber® is not likely to have coated the borehole walls and was probably lost to the encountered fracture or pore void space. Borehole sounding prior to well completion indicated the hole caved above the fracture to about 980.3 ft. No lost circulation problems were encountered during drilling of -19IM2.

The boreholes NC-EWDP-10S and -22S were drilled using both AQUA GEL GOLD SEAL® and QUIK-GEL® drilling mud. In NC-EWDP-10S, AQUA GEL GOLD SEAL® was used together with QUIK-GEL® in approximately the upper 300 ft, and QUIK-GEL® was used in the remainder. In NC-EWDP-22S, QUIK-GEL® was used primarily in the unsaturated zone and AQUA GEL GOLD SEAL® in the saturated zone.

Lost circulation was encountered in the unsaturated alluvial sediments in both boreholes. At NC-EWDP-10S, several additives were used to control the fluid loss in the borehole. Drilling through the interval from 75 ft to approximately 440 ft, DrisPac®, EZ-MUD®, Magma Fiber®, and native soil were added to the drilling fluid. Approximately 90,000 gal. of drilling fluid were lost in the interval from 75 to 440 ft. Drilling beyond 440 ft and into the water table at

approximately 590 ft, the rate of drilling fluid loss decreased, and no additives were added to the drilling fluid.

Similar lost circulation zones were encountered drilling NC-EWDP-22S in the unsaturated alluvium as at -10S. Drilling in the interval from 120 to 176 ft, lost circulation zones required addition of Magma Fiber® to the drilling fluid and adding BENSEAL® (ground 8-mesh bentonite) directly down the borehole. Drilling was stopped at 176 ft and the borehole was grouted with cement from 176 ft up to approximately 70 ft. The grout was drilled out and lost circulation zones were again encountered beyond 181 ft. Drilling continued to 290 ft with the addition of Magma Fiber® and DrisPac® to the drilling fluid. Drilling was stopped at 290 ft and the borehole was again grouted with cement from 290 ft up to approximately 100 ft. A total of approximately 90,000 gal. of drilling fluid were lost in the unsaturated zone from 120 to 290 ft. Drilling beyond 290 ft and into the saturated zone at approximately 480 ft, the rate of drilling fluid loss decreased and 50 lb. of DrisPac® was added to the drilling fluid. Continued loss of drilling fluids for the remainder of the borehole indicates that approximately 200,000 gal. total of drilling fluid was lost, most likely to the unsaturated zone. The use of drilling fluid additives DrisPac®, EZ-MUD®, and Magma Fiber® were limited to the unsaturated zone and the uppermost portion of the saturated zone of -10S and -22S.

Following completion of the FM wells, extensive well development was conducted to remove excess drilling fluids and excess drilling fluid additives.

Casing Advance Piezometer Wells

Boreholes NC-EWDP-10P and -22PA were drilled using air circulation and did not require the use of drilling fluid additives. Water was injected during drilling of NC-EWDP-10P from 252.5 to 295 ft. Fugitive water from lost circulation zones in NC-EWDP-10S (120 to 290 ft) was encountered through this interval. Water production from this zone caused sample return problems. Injection water was required to flush the sample out of the drill string and sample return hoses.

No injection water was required during drilling of borehole NC-EWDP-22PA.

Open-Hole Sections of NC-EWDP-18P

Borehole NC-EWDP-18P was drilled with casing advance methods in alluvium to 45 ft. Beyond this depth, the borehole was advanced using open-hole conventional rotary methods with a 7.875-in. drill bit and compressed air as the primary drilling fluid in consolidated rock. Due to the high air permeability and/or instability of some formation intervals, it was necessary to use other drilling fluids and additives to restore circulation in several depth intervals. Small quantities of WYO-Foam®, an anionic detergent, were used to improve circulation at a depth of 135 ft. EZ-MUD® and QUIK-GEL® were used from about 140 to 145 ft. At about 145 ft, some water was injected. At about 490 ft, circulation was lost again and more EZ-MUD®, QUIK-GEL®, and WYO-Foam® were added. At 505 ft, lost circulation was encountered and some Magma Fiber® was added. At about 515 ft, more Magma Fiber® and Portland cement were added to condition the problem zone and plug the lost circulation zone up to about 480 ft depth. The plug was drilled out, and drilling proceeded while occasionally circulating QUIK-GEL® with EZ-MUD® to thinly cake the borehole walls and help prevent sloughing. At about 730 ft, there was another major loss of air circulation, the drill rods began sticking, and it was necessary to again add Magma Fiber®, EZ-MUD®, and BENSEAL®.

First water was observed at a depth of about 811 ft at NC-EWDP-18P, although the water table subsequently was measured at a shallower level (see Table 3.1-1). Drill cuttings return problems continued, and it was necessary to inject water to lift the 810 to 815 ft interval of drill cuttings to ground surface. Since there was still no (or very poor) cuttings return, WYO-Foam® was again added from about 815 ft to about 845 ft. The cuttings from 850 to 855 ft continued to show evidence of the detergent foam. Caving continued to be a problem from about 888 ft to a total depth of 890.4 ft.

After reaching total depth and prior to completion of NC-EWDP-18P, foam and other liquid and solid drilling fluids and additives, including LCMs, were flushed out of the hole by air lifting. As a result of this air lifting and because these substances were mostly used above the water table, these additives are unlikely to impact water production or water quality at this site.

Piezometer Boreholes Drilled by Reverse-Circulation Methods

Injection water was used in NC-EWDP-22PB and -23P during the conventional circulation drilling from surface to 22.5 ft in the pilot holes used for setting a surface casing. Following the cementing of surface casing with Portland cement and Cal Seal (cement hardening accelerator), the remaining portions of these boreholes were drilled similarly to the exploratory RC boreholes. Air was used as the primary drilling fluid in each borehole with the following exceptions: Water was injected in both boreholes in the upper 20 to 50 ft of the saturated zone, where the drill hole would produce minimal water, and injection water was required to lift the moist or wet sample. In addition, at NC-EWDP-22PB, injection water was needed to lift samples between 387.5 to 400 ft where moisture was encountered from fugitive water lost during the drilling of -22S.

In the unsaturated zone, small volumes of water and MAX GEL® were used to stabilize borehole walls in a manner similar to that used in exploratory RC boreholes. This method of borehole conditioning provided a stable borehole in unsaturated unconsolidated alluvium and minimized the potential for bentonite contamination of drill cuttings samples.

Drilling in the saturated zone presented more difficulties and required the use of significantly more MAX GEL® to condition borehole walls than in the smaller RC exploratory boreholes. A total of approximately 2,000 gal. of MAX GEL® slurry was intermittently added from the surface down the annular space while drilling the saturated zone of NC-EWDP-22PB. No drill cuttings samples were identified as being contaminated by bentonite.

Difficulties with borehole stability below approximately 490 ft in borehole NC-EWDP-23P required more aggressive use of drilling additives. Borehole conditioning from 490 to 1,340 ft (total depth) required the use of 130 bags (6,500 lb.) of MAX GEL® mixed with approximately 14,000 gal. of water to be flooded down the annular space during the advancement of the borehole. Alluvial drill cuttings samples from the interval from 945 to 990 ft (10 samples) were contaminated by drilling mud (MAX GEL®). Another six scattered samples below 900 ft were also identified as being contaminated.

Even with the aggressive use of bentonite to condition NC-EWDP-23P, after reaching total depth, loose sandy material collapsed below 700 ft and formed a sand collar at approximately 1,050 ft. The drill string became stuck in the hole and ultimately was separated with an explosive charge, and the bottom hole assembly was lost. Another approximately 5,000 gal. of MAX GEL® were flooded down the annular space in an effort to loosen the drill string.

Table A1
Drilling Additives Used in Boreholes NC-EWDP- 19IM1A, -19IM2A, -10SA, and -22SA

Bore-hole ID	Borehole Activity	Date	Depth or Depth Interval (ft bgs)	Material	Quantity	Comments
19IM1A	Seal Surface/ Conductor Casing	7/10/01	0–22	KWIK PLUG®	<1 bag	Used in annular space of 22 ft - 8 5/8 in. hole and 6 5/8 in. surface casing.
	Borehole Advancement	7/12/01	22–470	MAX GEL®	3 bags (300 gal.)	Flooded down annular space of 5 3/8 in. borehole to control caving.
	Borehole Advancement	7/12/01	22–540	MAX GEL®	2 bags (300 gal.)	Flooded down annular space of 5 3/8 in. borehole to control caving.
	Abandonment	7/13/01	900–0	SUPER PLUG®	48 bags (<2400 gal.)	Used to plug-back borehole in stages from 900 ft to surface.
19IM2A	Seal Surface/ Conductor Casing	7/13/01	0–-22	KWIK PLUG®	<1 bag	Used in annular space of 22 ft - 8 5/8 in. hole and 6 5/8 in. surface casing.
	Borehole Advancement	7/15/02	22–370	MAX GEL®	1 2/3 bags (235 gal.)	Pumped down drill string through bit to condition caving hole. Hole drilled without additives through 370 ft.
	Borehole Advancement	7/16/02	370–720	MAX GEL®	4 bags (1,000 gal.)	Flooded down annular space of 5 3/8 in. borehole to control caving.
	Borehole Advancement	7/17/02	720–900	MAX GEL®	1 bag (100 gal.)	Flooded down annular space of 5 3/8 in. borehole to control caving.
	Abandonment	7/17/01	900–0	SUPER PLUG®	78 bags (<3,900 gal.)	Used to plug-back borehole in stages from 900 ft to surface.
10SA	Seal Surface/ Conductor Casing	7/18/02	0–22	KWIK PLUG®	12 bags	Used in annular space of 22 ft - 8 5/8 in. hole and 6 5/8 in. surface casing.
	Borehole Advancement	7/19/01	200–260	MAX GEL®	4 bags (400 gal.)	Flooded down annular space of 5 3/8 in. borehole and pumped down through bit to control caving.
	Borehole Advancement	7/24/01	260–590	MAX GEL®	2 bags (300 gal.)	Pumped down drill string through bit to condition caving hole.
	Borehole Advancement	7/25/01	590–665	MAX GEL®	2 bags (300 gal.)	Pumped down drill string through bit to condition caving hole.
	Borehole Advancement	7/26/01	665–1,150	MAX GEL®	6 bags (400 gal.)	Flooded down annular space of 5 3/8 in. borehole to control caving.
	Borehole Advancement	7/27/01	1,150–1,200	MAX GEL®	6 bags (400 gal.)	Flooded down annular space of 5 3/8 in. borehole to control caving.
	Abandonment	7/27/01	1,200–0	SUPER PLUG®	71 bags (<3,600 gal,)	Used to plug-back borehole in stages from 1,200 ft to surface.
	Abandonment	7/28/01	1,200–-0	SUPER PLUG®	70 bags (<3,600 gal.)	Used to plug-back hole in stages from 1,200 ft to surface.
22SA	Seal Surface/ Conductor Casing	7/28/01	0–22	KWIK PLUG®	10 bags	Used in annular space of 22 ft - 8 5/8 in. hole and 6 5/8 in. surface casing.

Bore-hole ID	Borehole Activity	Date	Depth or Depth Interval (ft bgs)	Material	Quantity	Comments
22SA	Borehole Advancement	7/29/01	100–360	MAX GEL®	2 bags (300 gal.)	Pumped down drill string through bit to condition caving hole.
	Borehole Advancement	7/30/01	360–705	MAX GEL®	4 bags (600 gal.)	Flooded down annular space of 5 3/8 in. borehole and pumped down to bit to control caving.
	Borehole Advancement	8/1/01	705–940	MAX GEL®	4 bags (600 gal.)	Flooded down annular space of 5 3/8 in. borehole to control caving.
	Abandonment	8/2/01	940–1,200	SUPER PLUG®	126 bags (<6,400 gal.)	Used to plug-back hole from 1200 ft to the surface in stages.

NOTES: Exploratory and sampling boreholes drilled with reverse-circulation air rotary.

KWIK PLUG® is untreated ground sodium bentonite chips used to seal between borehole walls and casings. It produces dense bentonite when hydrated.

MAX GEL® is a sodium bentonite coated with polymer used for circulation and hole conditioning.

SUPER PLUG® is a high solids bentonite grout (>30% solids) used to plug/abandon boreholes and seal annular space on wells.

Table A2
Drilling Additives Used in Boreholes NC-EWDP-19IM1, -19IM2, -10S, and -22S

Borehole ID	Borehole Activity	Date	Depth or Depth Interval (ft bgs)	Material	Quantity	Comments
19IM1	Seal Conductor Casing	8/13/01	0–78	Concrete	10 yards	Used to cement annular space between 30 in. auger hole and 18 in. conductor casing.
	Borehole Advancement	8/17/01	78–155	AQUA GEL GOLD SEAL®	12 bags (1,500 gal.)	Flooded down annular space of 14 3/4 in. borehole for circulation fluid and to control caving.
	Borehole Advancement	8/18/01	155–404	AQUA GEL GOLD SEAL®	128 bags (10,000 gal.)	Flooded down annular space of 14 3/4 in. borehole for circulation fluid and to control caving.
	Borehole Advancement	8/19/01	404–471	AQUA GEL GOLD SEAL®	110 bags (14,000 gal.)	Flooded down annular space of 14 3/4 in. borehole for circulation fluid and to control caving.
	Borehole Advancement	8/20/01	471–661	AQUA GEL GOLD SEAL®	144 bags (14,500 gal.)	Flooded down annular space of 14 3/4 in. borehole for circulation fluid and to control caving.
	Borehole Advancement	8/21/01	661–854	AQUA GEL GOLD SEAL®	139 bags (13,000 gal.)	Flooded down annular space of 14 3/4 in. borehole for circulation fluid and to control caving.
	Borehole Advancement	8/22/01	854–975	AQUA GEL GOLD SEAL®	50 bags (1,000 gal.)	Flooded down annular space of 14 3/4 in. borehole for circulation fluid and to control caving.
	Borehole Advancement	8/23/01	975–1,012.5	AQUA GEL GOLD SEAL®	70 bags (7,000 gal.)	Flooded down annular space of 14 3/4 in. borehole for circulation fluid and to control caving.
	Borehole Advancement	8/23/01	1,012.5	Magma Fiber®	3 bags	Lost circulation materials used in attempt to plug lost circulation zone at 1012.5 ft.
19IM2	Seal Conductor Casing	8/14/04	0–77	Concrete	17 yards	Used to cement annular space between 30 in. auger hole and 18 in. conductor casing.
	Borehole Advancement	9/4/01	77–105	AQUA GEL GOLD SEAL®	64 bags (4,000 gal.)	Flooded down annular space of 14 3/4 in. borehole for circulation fluid and to control caving.
	Borehole Advancement	9/5/01	105–409	AQUA GEL GOLD SEAL®	194 bags (10,000 gal.)	Flooded down annular space of 14 3/4 in. borehole for circulation fluid and to control caving.
	Borehole Advancement	9/6/01	409–580	AQUA GEL GOLD SEAL®	68 bags (4,000 gal.)	Flooded down annular space of 14 3/4 in. borehole for circulation fluid and to control caving.
	Borehole Advancement	9/7/01	580–835	AQUA GEL GOLD SEAL®	142 bags (14,500 gal.)	Flooded down annular space of 14 3/4 in. borehole for circulation fluid and to control caving.
	Borehole Advancement	9/8/01	835–965.6	AQUA GEL GOLD SEAL®	25 bags (2,000 gal.)	Flooded down annular space of 14 3/4 in. borehole for circulation fluid and to control caving.
10S	Seal Conductor Casing	9/20, 21/01	0–62	Concrete	25 yards	Used to cement annular space between 30 in. auger hole and 18 in. conductor casing.
	Borehole Advancement	9/24/01	62–156	QUIK-GEL®/ AQUA GEL GOLD SEAL®	74 bags (2,000 gal.)	Flooded down annular space of 14 3/4 in. borehole for circulation fluid and to control caving. Hauled 24,000 gal. water. pH adjusted with 3 bags soda ash.
	Borehole Advancement	9/24/01	125	DrisPac®	1 bag	Added to mud to increase viscosity and control loss.
	Borehole Advancement	9/24/01	62–156	Magma Fiber®	3 bags	Attempt to slow lost circulation.

Borehole ID	Borehole Activity	Date	Depth or Depth Interval (ft bgs)	Material	Quantity	Comments
10S	Borehole Advancement	9/25/01	156–313	QUIK-GEL®/ AQUA GEL GOLD SEAL®	286 bags (28,000 gal.)	Flooded down annular space of 14 3/4 in. borehole for circulation fluid and to control caving. Two bags soda ash added to adjust pH.
	Borehole Advancement	9/25/01	156–313	DrisPac®	3 bags	Added to mud to increase viscosity and control loss.
	Borehole Advancement	9/25/01	156–313	Magma Fiber®	4 bags	Attempt to slow lost circulation.
	Borehole Advancement	9/25/01	156	EZ-MUD®	5 gal.	Added to mud to increase viscosity and control loss.
	Borehole Advancement	9/26/01	313–377	QUIK-GEL®	100 bags (32,000 gal.)	Flooded down annular space of 14 3/4 in. borehole for circulation fluid and to control caving. Two bags soda ash added to adjust pH.
	Borehole Advancement	9/26/01	377	BENSEAL®	6 bags	Added down open borehole in attempt to seal lost circulation zone.
	Borehole Advancement	9/26/01	377	DrisPac®	2 bags	Added to mud to increase viscosity and control loss.
	Borehole Advancement	9/26/01	377	Magma Fiber®	47 bags	Attempt to slow lost circulation.
	Borehole Advancement	9/26/01	377	EZ-MUD®	5 gal.	Added to mud to increase viscosity and control loss.
	Borehole Advancement	9/26/01	377	Native soil	125 gal.	Added to slow loss of drilling fluid.
	Borehole Advancement	9/27/01	377–440	QUIK-GEL®	85 bags (34,000 gal.)	Flooded down annular space of 14 3/4 in. borehole for circulation fluid and to control caving.
	Borehole Advancement	9/27/01	377–440	DrisPac®	1/4 bag	Added to mud to increase viscosity and control loss.
	Borehole Advancement	9/28/01	440–691	QUIK-GEL®	72 bags (12,000 gal.)	Flooded down annular space of 14 3/4 in. borehole for circulation fluid and to control caving. Loss under control.
	Borehole Advancement	9/29/01	691–900	QUIK-GEL®	20 bags (4,000 gal.)	Flooded down annular space of 14 3/4 in. borehole for circulation fluid and to control caving.
22S	Seal Conductor Casing	9/21/01, 9/22/01, and 10/4/01	0–66	Concrete	27 yards	Used to cement annular space between 30 in. auger hole and 18 in. conductor casing.
	Borehole Advancement	10/10/01	66–181	QUIK-GEL®	267 bags (20,000 gal.)	Flooded down annular space of 14 3/4 in. borehole for circulation fluid and to control caving.
	Borehole Advancement	10/10/01	120	Magma Fiber®	1 bag	Attempt to slow lost circulation.
	Borehole Advancement	10/11/01	181	QUIK-GEL®	131 bags (13,000 gal.)	Flooded down annular space of 14 3/4 in. borehole for circulation fluid and to control caving.
	Borehole Advancement	10/11/01	181	Magma Fiber®	49 bags	Attempt to plug lost circulation zones.

Borehole ID	Borehole Activity	Date	Depth or Depth Interval (ft bgs)	Material	Quantity	Comments
22S	Borehole Advancement	10/11/01	181	BENSEAL®	51 bags	Attempt to plug lost circulation zones.
	Borehole Advancement	10/12/01	176	Concrete	8 yards (3 sack mix)	Sealed lost circulation zone.
	Borehole Advancement	10/13/01	181–282	QUIK-GEL®	242 bags (24,000 gal.)	Flooded down annular space of 14 3/4 in. borehole for circulation fluid and to control caving.
	Borehole Advancement	10/13/01	181–282	Magma Fiber®	28 bags	Attempt to control lost circulation.
	Borehole Advancement	10/14/01	282–290	QUIK-GEL®	68 bags (34,000 gal.)	Attempt to regain circulation; refill baker tanks.
	Borehole Advancement	10/14/01	282–290	Magma Fiber®	5 bags	Attempt to control lost circulation.
	Borehole Advancement	10/14/01	282–290	DrisPac®	3 bags	Added to mud to increase viscosity and control loss.
	Borehole Advancement	10/15/01	236	Concrete	10 yards (3 sack mix)	Sealed lost circulation zone.
	Borehole Advancement	10/16/01	290–345	QUIK-GEL®	115 bags (12,500 gal.)	Flood hole start drilling plug; used one bag soda ash added to adjust pH.
	Borehole Advancement	10/16/01	290	DrisPac®	1 bag	Added to mud to increase viscosity and control loss.
	Borehole Advancement	10/17/01	345–624	QUIK-GEL® / AQUA GEL GOLD SEAL®	381 bags (42,500 gal.)	Flooded down annular space of 14 3/4 in. borehole for circulation fluid and to control caving. Began using AQUA GEL GOLD SEAL® below 528 ft.
	Borehole Advancement	10/18/01	624–912	QUIK-GEL® / AQUA GEL GOLD SEAL®	224 bags (71,000 gal.)	Flooded down annular space of 14 3/4 in. borehole for circulation fluid and to control caving.
	Borehole Advancement	10/19/01	912–1,198	QUIK-GEL® / AQUA GEL GOLD SEAL®	192 bags (57,000 gal.)	Flooded down annular space of 14 3/4 in. borehole for circulation fluid and to control caving.

NOTES: Flooded-mud reverse-circulation boreholes for installation of multiple screen wells.

AQUA GEL GOLD SEAL® is an untreated sodium bentonite used for circulation fluid.

QUIK-GEL® is a sodium bentonite coated with polymer used for circulation and hole conditioning.

Magma Fiber® is inert mineral wool used for sealing lost circulation zones.

DrisPac® is polyanionic cellulosic polymer used to increase mud viscosity and for fluid loss control.

EZ-MUD® is a water soluble polymer designed to prevent clay disintegration, stabilize boreholes, and lubricate drill tools.

BENSEAL® is 8-mesh untreated ground sodium bentonite used to seal zones in boreholes and wells.

Table A3
Drilling Additives Used in Boreholes NC-EWDP- 10P, -22PA, and -18P

Bore-hole ID	Borehole Advancement	Date	Depth or Depth Interval (ft bgs)	Material	Quantity	Comments
10P	Borehole Advancement	9/10/01 to 12/19/01	0–910.5	NA	NA	No additives were used during borehole advancement.
22PA	Borehole Advancement	1/15/01 to 1/27/02	0–779.8	NA	NA	No additives were used during borehole advancement.
18P	Borehole Advancement	9/21/01	85	QUIK-GEL®	2 bags (300 gal.)	Pumped down center of 3-1/2 in. drill pipe to control caving in 7-7/8 in. borehole.
	Borehole Advancement	9/22/01	135	Wyo-Foam®	2 cups foam (175 gal.)	Pumped down tube of 3-1/2 in. drill pipe to clean out borehole cuttings.
	Borehole Advancement	9/22/01	135	EZ-MUD®	1 cup	Pumped down tube of 3-1/2 in. drill pipe to stabilize borehole.
	Borehole Advancement	9/22/01	140	QUIK-GEL®	1/2 bag (175 gal.)	Used to lift cuttings and condition borehole.
	Borehole Advancement	9/24/01	490	QUIK-GEL®	2 bags (175 gal.)	Used to lift cuttings and condition borehole.
	Borehole Advancement	9/24/01	490	EZ-MUD®	1-quart (175 gal.)	Mixed with QUIK-GEL® to stabilize borehole.
	Borehole Advancement	9/26/01	515	Magma Fiber®	1 bag (380 gal.)	Tremmie down 7-7/8 in. hole to seal up lost circulation zone.
	Borehole Advancement	9/26/01	515–489	Portland Cement	35 bags (380 gal.)	Tremmie down 7-7/8 in. hole to seal up lost circulation zone.
	Borehole Advancement	10/4/01	515	Magma Fiber®	1 bag (380 gal.)	Tremmie down 7-7/8 in. hole to seal up lost circulation zone.
	Borehole Advancement	10/4/01	440	EZ-MUD®	1/2 cup (175 gal.)	Pumped down center of 3-1/2 in. drill pipe to stabilize borehole.
	Borehole Advancement	10/4/01	440	WYO-Foam®	2 cups foam (175 gal.)	Pumped down center of 3-1/2 in. drill pipe to clean out borehole cuttings. Subsequently flushed from hole by air lifting.
	Borehole Advancement	10/7/01	730	Magma Fiber®	1-1/2 bags (310 gal.)	Pumped down center of 3-1/2 in. drill pipe to clean out borehole cuttings. Subsequently flushed from hole by air lifting.
	Borehole Advancement	10/7/01	730	EZ-MUD®	1/4 cup (175 gal.)	Pumped down center of 3-1/2 in. drill pipe to stabilize borehole.
	Borehole Advancement	10/7/01	735	Enviro-Plug®	1 bag (135 gal.)	Pumped down center of 3-1/2 in. drill pipe to seal lost circulation zone.
	Borehole Advancement	10/8/01	820	WYO-Foam®	2 gal. (175 gal.)	Pumped down center of 3-1/2 in. drill pipe to clean out borehole cuttings. Subsequently flushed from hole by air lifting.

Bore-hole ID	Borehole Advancement	Date	Depth or Depth Interval (ft bgs)	Material	Quantity	Comments
18P	Borehole Advancement	10/9/01	845	WYO-Foam®	2 gal. (400 gal.)	Pumped down center of 3-1/2 in. drill pipe to clean out borehole cuttings. Subsequently flushed from hole by air lifting.

NOTES: Casing advance boreholes for sampling, drive-core sampling, and installation of piezometer wells.

QUIK-GEL® is sodium bentonite coated with polymer used for circulation and hole conditioning.

Enviro-Plug® is a high solids bentonite grout (>30% solids) used to plug/abandon boreholes and seal annular space on wells.

EZ-MUD® is a water soluble polymer designed to prevent clay disintegration, stabilize boreholes, and lubricate drill tools.

WYO-Foam® is an anionic detergent used to clean cuttings from borehole.

Magma Fiber® is inert mineral wool used for sealing lost circulation zones.

Table A4
Drilling Additives Used in Boreholes NC-EWDP-22PB and -23P

Bore-hole ID	Borehole Activity	Date	Depth or Depth Interval (ft bgs)	Material	Quantity	Comments
22PB	Seal Conductor Casing	2/21/02	0–22.5	Cal Seal / Portland Cement	8–50 lb. bags 12–94 lb. bags	Used to cement 10 3/4-in. conductor casing in 14 1/2-in. borehole.
	Borehole Advancement	2/22/02	60–180	MAX GEL®	2 bags (150 gal.)	Injected down center of 4 1/2 in. drill pipe to control caving in 8 1/2 in. hole.
	Borehole Advancement	2/23/02	180–320	MAX GEL®	2 bags (150 gal.)	Injected down center of 4 1/2 in. drill pipe to control caving in 8 1/2 in. hole.
	Borehole Advancement	2/24/02	320–420	MAX GEL®	2 bags (150 gal.)	Injected down center of 4 1/2 in. drill pipe to control caving in 8 1/2 in. hole.
	Borehole Advancement	2/25/02	420–520	MAX GEL®	2 bags (150 gal.)	Injected down center of 4 1/2 in. drill pipe to control caving in 8 1/2 in. hole.
	Borehole Advancement	2/26/02	520–840	MAX GEL®	6 bags (750 gal.)	Flooded down annular space of borehole to control caving in 8 1/2 in. hole.
	Borehole Advancement	2/27/02	840–1200	MAX GEL®	16 bags (1,200 gal.)	Flooded down annular space of borehole to control caving in 8 1/2 in. hole.
23P	Seal Conductor Casing	3/9/02	0–22.5	Cal Seal / Portland Cement	10–50 lb. bags 20–94 lb. bags	Used to cement 10 3/4-in. conductor casing in 14 1/2-in. borehole.
	Borehole Advancement	3/9/02	0–63	MAX GEL®	2 bags (150 gal.)	Injected down center of 5 1/2 in. drill pipe to control caving in 8 1/2 in. hole.
	Borehole Advancement	3/10/02	63–190	MAX GEL®	3 bags (200 gal.)	Injected down center of 5 1/2 in. drill pipe to control caving in 8 1/2 in. hole.
	Borehole Advancement	3/11/02	190–320	MAX GEL®	5 bags (200 gal.)	Injected down center of 5 1/2 in. drill pipe to control caving in 8 1/2 in. hole.
	Borehole Advancement	3/12/02	320–490	MAX GEL®	<1 bag (<200 gal.)	Injected down center of 5 1/2 in. drill pipe to control caving in 8 1/2 in. hole.
	Borehole Advancement	3/13/02	540–940	MAX GEL®	40 bags (6,000 gal.)	Flooded down annular space of borehole to control caving in 8 1/2 in. hole.
	Borehole Advancement	3/14/02	940–1,140	MAX GEL®	60 bags (6,000 gal.)	Flooded down annular space of borehole to control caving in 8 1/2 in. hole.
	Borehole Advancement	3/19/02	1,140–1,340	MAX GEL®	20 bags (4,000 gal.)	Flooded down annular space of borehole to control caving in 8 1/2 in. hole.
	Borehole Advancement	3/20/02	1,150	MAX GEL®	27 bags (4,500 gal.)	Pumped down annular space of borehole to stabilize top of hole while trying to loosen drill pipe from sand boot at 1,150 ft.
	Borehole Advancement	3/21/02	1,150	MAX GEL®	6 bags (600 gal.)	Pumped down annular space of borehole to stabilize top of hole while trying to loosen drill pipe from sand boot at 1,150 ft.

NOTES: Reverse-circulation air rotary boreholes for sampling and installation of piezometer wells.

MAX GEL® is a sodium bentonite coated with polymer used for circulation and hole conditioning.